Eiffel
GEOSS APPLICATIONS
FOR CLIMATE CHANGE

REVEALING THE ROLE OF GEOSS AS THE DEFAULT DIGITAL PORTAL FOR BUILDING CLIMATE CHANGE ADAPTATION & MITIGATION APPLICATIONS

D4.3 *Best practices on climate resources quality documenting using QualityML*

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Executive Summary

This document corresponds to deliverable 4.3 entitled "Best practices on climate resources quality documenting using “QualityML" and is based on the outcomes of the Task 4.3 "Data quality assessment and feedback mechanism for GEOSS datasets". The work starts from the results of the Data Quality Co-design Workshop (DQ Cd W, which completion correspond to MS7), since it was the starting point to know the use cases of each Pilot, with the purpose of advising on the correct documentation of the quality of their data.

The main objective of this work is to generate a set of best practices and recommendations for data quality documentation. This objective is achieved through the information extracted from different meetings designed to:

- Collect information on the level of experience in using and producing metadata records (with especial emphasis on quality metadata indicators) of the different partners involved in the Pilot cases, as well as their knowledge on Geospatial User Feedback systems.
- Collect information on the processes involved in the different data product generation and validation in order to detect possible quality indicators to be recorded on metadata files.

Five meetings with the different producers involved in each Pilot were scheduled between July and October 2022. All meetings followed the same script designed to understand the processes involved on data creation and validation in order to detect and/or propose different types of quality indicators to be considered in metadata record generation.

These meetings showed up that in most cases producers are still developing the specific methodology to be used in their work. This situation derives in some difficulties to specify a processing and validation chain.

Even so, it was determined that most of the attendees at meetings have previous experience on metadata managing, that the quality of the products is mainly obtained at execution level and also a list of common quality indicators was obtained:

- Root Mean Square Error (RMSE)
- Correlation coefficient - r
- Nash-Sutcliffe model efficiency coefficient (NSE)
- Mean Absolute Error (MAE)
- Mean Squared Error (MSE)
- Mean Absolute Percentage Error (MAPE)
- Coefficient of Determination - R^2
- Spatialized quality estimators

As a result, the collected information in these meetings together with the previous work done in the DQ Co-design Workshop allowed us to generate a set of quality documentation examples (section 5.1.3) and general metadata templates (cited in section 5.1.1) that will help producers to improve their metadata records, according to the specified in the objective 5 of this project:

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"O5: EIFFEL will develop, using co-creation (O4), a set of CC adaptation and mitigation applications in different and quite diverse GEO SBAs, in order to demonstrate the project innovations."

All templates and examples provided here are based on ISO standards and use links to QualityML, an online registry to give semantics to the quality measures.

Moreover, even so at this stage of the producing phase Geospatial User Feedback (GUF) can't be included in any Pilot case portal, the NiMMbus system has been improved with new additional functionalities:

- More and better documentation of the system
- New Single-Sign-On systems
- Feedback Spatial Extent extension

And for future use of the pilots, this document also provides recommendations on the NiMMbus widget integration.

As future work it is expected to set additional meetings with the different partners in order to explain the best practices included in this document, as well as to help colleagues on metadata documentation and GUF integration in a more advanced state of their workplan.

Finally, it has been detected a need of a communication effort about the importance of metadata documentation. In this sense, it is also expected to keep developing tools such as GeM+ and NiMMbus to improve metadata users and producers experience.

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List of Acronyms and Abbreviations

Acronym	Meaning
GUF	Geospatial User Feedback
QualityML	Quality Markup Language
OGC	Open Geospatial Consortium
MS7	Milestone 7
GeM+	Universal Geospatial Metadata Manager
DQ Cd W	Data Quality Co-design Workshop

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List of Definitions

Concept	Meaning	URL
GUF	*Geospatial User Feedback*, "is metadata that is predominantly produced by the consumers of geospatial data products as they use and gain experience with those products".	https://www.ogc.org/standards/guf
QualityML	*Quality Markup Language*, is a "dictionary that contains hierarchically structured concepts to precisely define and relate quality levels: from quality classes to quality measurements. These levels are used to encode quality semantics for geospatial data by mapping them to the corresponding metadata schemas".	https://www.qualityml.org/
GeM+	*Universal Geospatial Metadata Manager,* is a "free application for Windows that allows to create, manage and edit metadata from very diverse sets of geographic information, whether is have access to the data or not".	https://www.miramon.cat/USA/Prod-GeMPlus.htm
GeoNetwork	*GeoNetwork*, is a catalogue application to manage spatially referenced resources. It provides powerful metadata editing and search functions as well as an interactive web map viewer.	https://www.geonetwork-opensource.org/
NiMMbus	*NiMMbus*, is a "solution for storing geospatial resources on the MiraMon cloud. Several resources can be stored in NiMMbus: points of interest, hyperlinks to a geospatial databases, citations of geospatial resources, publications and feedback items".	https://www.nimmbus.cat

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1 Introduction

Deliverable 4.3 contains the best practices on climate resource quality documenting using QualityML and is based on the elements identified in the MS7[1] and the continuity of activities carried out subsequently. This report mentions the MS7 in a summarized version and elaborates on it, when necessary, as the focus is on new activities and their results. These activities are the *Data Quality (DQ) bilateral meetings,* held between July and October 2022, and *DQ Best Practices* recommendations made based on the latter.

Five DQ bilateral meetings were held with the pilots in a 1:1 context between DQ scientists (UAB) and Pilot developers. The objective was to learn about the processes and methodologies they apply in the pilot, as well as the quality of the produced data/results, until the moment the meeting was realized. After certain knowledge of the pilot is gained, the accurate DQ metadata for each model and product can be identified and recommended, including support on how to describe best them in metadata documents in each case. This subject will be explained and exposed on section 4 and 5 of this document, respectively.

Last part of this document includes the best practices on climate resources quality documenting using QualityML. The section includes a compilation of the best way of documenting the quality elements needed, up to today, in the context of the EiFFEL climate pilots. This deliverable can be useful for those in the need of documenting quality metadata for geospatial datasets or of gathering geospatial user feedback for their products or services.

1.1 Context

1.1.1 Objectives

This deliverable report **D4.3** contributes mainly to project objective O2 and also to O5:

1. (**O2**) *EIFFEL will leverage techniques of Explainable AI to develop tangible indicators for CC impacts; it will also make use of super resolution, data fusion and stochastic modelling techniques to generate spatially and temporally explicit information from the untapped pool of GEOSS).*
2. (**O5**) *EIFFEL will develop, using co-creation (O4), a set of CC adaptation and mitigation applications in different and quite diverse GEO SBAs, in order to demonstrate the project innovations.*

1.1.2 Work plan

This report, Deliverable **D4.3** corresponds to **T4.3 Data quality assessment and feedback mechanism for GEOSS datasets (M3-M18)**, and it is part of **WP4 Improving temporal, spatial resolution and data quality of CC related datasets**.

The results presented in **D4.3** are focused on documenting the data quality of the pilots' results in a common way as well as in promoting the creating of user feedback about these pilots' results. The proper documentation of data quality in the pilots' results allows the improvement achieved by the augmentation methodologies to be explicit. Moreover, the

[1] MS7 is an EIFFEL Publication called **Co-design Workshop completion**, done by UAB partner. Main results and its methodology will be explained in a summarized version in section 2, *MS7: Summary.*

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knowledge created by the users included in the user feedback items about these results, can contribute to a better use of the pilots' results.

Results will then be used mainly in **WP7** (EIFFEL Pilot demonstrations and impact assessment) and WP3 (Augmenting GEOSS data exploration).

1.1.3 Milestones

D4.3 is linked to MS7:

- **MS7: Co-design virtual workshop completion**. *Means of verification: compendium of the co-design session*

1.1.4 Deliverables

D4.3 is based on the input of **T4.3** (lead beneficiary: **UAB**) and is correlated to **D7.3** Final Report on pilot impact assessments and recommendations (WP7) and all the **D3.4** Report on metadata augmentation methodologies for GEOSS datasets and the final version of the EIFFEL augmented metadata database (WP3).

1.2 Intended Readership and Document Structure

The dissemination level of this report is public; however, the target audience is someone with a basic geospatial knowledge and/or a person who is familiar with the generation of quality measures and metadata.

The document is organised as follows:

- Section 2 is a *Summary* of MS7, as this document is the continuity and development of work done in there.
- Section 3 presents the *Data Quality Co-design Workshop* based on the *DQ survey* results.
- Section 4 presents the *Data Quality Bilateral meetings,* results and considerations.
- Section 5 presents the *Best Practices and recommendations* in DQ for Pilots and teams.
- Section 6 presents Conclusions & Future Work.

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2 MS7: Summary

The MS7 focused on the results obtained during the DQ Cd W sessions, and was based on a part of DQ survey, answered by the EIFFEL project members. This section is a summary of the main results of the MS7, to contextualize the continuity of the activities carried out.

The *DQ Co-design Workshop (DQ Cd W)* was initially planned as a two-part event. The first part, DQ Cd W pre-event, was on May 10. It was designed as an informative session to lay the basis for a fruitful interactive co-design session later on. To this end, some basic DQ concepts were exposed to attendees[2], and there was also an interactive demonstration on the *Miro tool*[3], which would be the main tool for the next event. Finally, a DQ survey was sent to EIFFEL members to properly prepare the second part of the co-design event.

The DQ survey results were the basis for the second part of the DQ Cd W, held on May 20th, as the activities that were created related to the survey results. On next section, results and considerations about these survey results will be exposed and discussed.

Both events (and the survey) allowed us to evaluate and understand the attendee's knowledge about producer metadata and user feedback, their needs on both metadata approaches and their thoughts about the current situation of the *GEOSS Portal* platform based on their experience. Finally, some discussions were also carried out about how to improve GEOSS portal usage and how to motivate users to create feedback (both points will be briefly explained next).

MS7 provided attendees information and knowledge, also an open discussion space for asking and solving doubts related to data quality, at the time that it has given us ideas about the current situation at EIFFEL team and their/our necessities related to missing knowledge on quality measures.

Next section will expose the Data Quality Co-design Workshop in a short version, mostly to expose the survey results and their link to the event.

[2] See the outline of the first part of the DQ Cd W, i.e. the pre-event, on Appendix A.

[3] *Miro* is a platform to carry out collective dynamics while online meetings, making easier the experience, since it facilitates the process of "design thinking" in a participative way, allowing the interaction of different users at the same time and on the same board, as if they were physically working together.

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3 DQ Co-design Workshop and survey results.

A survey[4] was sent to every Eiffel participant through the mailing list. We were receiving answers from May 10th (after the pre-event) and until Monday 16th noon, and in total we got 17 answers.

Table 1. Pilots' representation on survey

Pilot number	%
1	24 %
1 & 5	12 %
2	18 %
3	24 %
4	6 %
5	12 %

Table 2. Pilots' declaration about modelling tools

Pilot number	%
1	24 %
1 & 5	12 %
2	12 %
3	12 %
4	6 %
5	6 %
All Pilots	6 %

As shown, pilot 4 was the least represented, however, they were active participants as one of them volunteered to expose their work.

About the work done by the consultants, main subjects were:

1. River discharge, evapotranspiration
2. Fire danger reanalysis and river discharge predictions
3. Spatial suitability of sustainable agricultural practices
4. Pollution predictions
5. Atmospheric predictions
6. Subsurface parameters of soils and deeper aquifers
7. Geospatial products/maps
8. Air quality
9. Soil Moisture
10. Predictions of forest pest phenology
11. Land cover regarding nature-based solutions

[4] See the survey questions on Appendix B

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3.1.1 Data Quality Co-design Workshop: Ice breaker activity

First activity on the Data Quality Co-design Workshop was an ice breaker, and the purpose was to write a concept related to data quality on a digital sticky note. Once that was done, we grouped the related concepts and asked the audience about their choice. The result is shown in Figure 1.

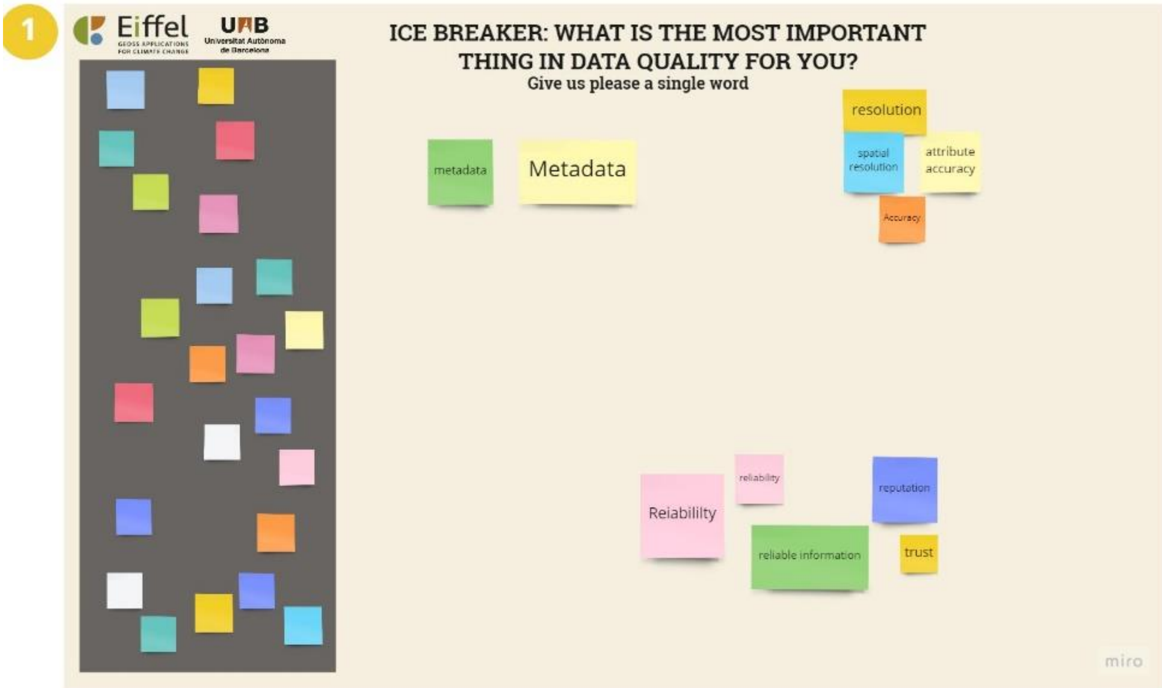

Figure 1. First board on the co-design event: Ice Breaker

There were three concepts' groups about most important things in DQ for attendees: first one with concepts related to the certainty of data, other with resolution characteristics and finally one about metadata as the most important thing in DQ.

3.1.2 Data Quality from producer's point of view

Second activity was related to quality measures. The purpose was to identify some quality measures (given by the organizers), that were written in different coloured sticky notes (even with the link to each one's description), so that the attendees could select them, ask about it if needed (or review the description on the link), and move the sticky note with the quality measure to the pilot area where they think it could be useful or/and necessary.

We presented five categories of quality measures, from ISO 19157:2013, namely *Positional accuracy*, *Thematic accuracy*, *Temporal quality*, *Completeness* and *Logical Consistency* [4]. All of them were described in a few words and had two sub-categories (also explained) with quality indicators written on sticky notes (and with their link to QualityML, where an extended explanation could be found), so attendees could take each of them and move to their pilots, if they consider it could be a useful quality indicator for their products/models.

Below, on table 3, the initial information given to develop the activity is show. There are also explained the five quality measures used, with the descriptions of each one, and two examples for them, also described in the table.

Table 3. Quality measures used on the Miro board exercise.

Quality Measure	Description	Examples used on exercise
Positional Accuracy	Accuracy of the position of features within a spatial reference system.	- *Absolute external positional accuracy*: Closeness of reported coordinate values to values accepted as or being true.
		- *Gridded data positional accuracy*: Closeness of gridded data position values to values accepted as or being true.
Thematic Accuracy	Accuracy of quantitative attributes and the correctness of non-quantitative attributes and of the classifications of features and their relationships.	- *Quantitative attribute accuracy*: Accuracy of quantitative attributes.
		- *Non quantitative attribute accuracy*: Accuracy of non-quantitative attributes.
Temporal Quality	Accuracy of the temporal attributes and temporal relationships of features.	- *Accuracy of a time measurement*: Correctness of the temporal references of an item (reporting of error in time measurement).
		- *Temporal consistency*: Correctness of ordered events or sequences, if reported.
Completeness	Presence and absence of features, their attributes and their relationships.	- *Completeness Comission*: Excess data present in the dataset, as described by the scope.
		- *Completeness Omission*: Data absent from the dataset, as described by the scope.
Logical Consistency	Degree of adherence to logical rules of data structure, attribution and relationships (data structure can be conceptual, logical or physical).	- *Domain consistency*: Adherence of values to the value domains.
		- *Topological consistency*: Correctness of the explicitly encoded topological characteristics of the dataset

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As an analysis of the final result of this activity (Figure 2, next), and about the distribution of indicators per Pilot, attendees from both Pilot 1 and Pilot 4 used indicators from all categories, from Pilot 5 and Pilot 3 used indicators from all too, excepting from *Logical Consistency*. Pilot 2 attendees only selected indicators from *Thematic Accuracy.*

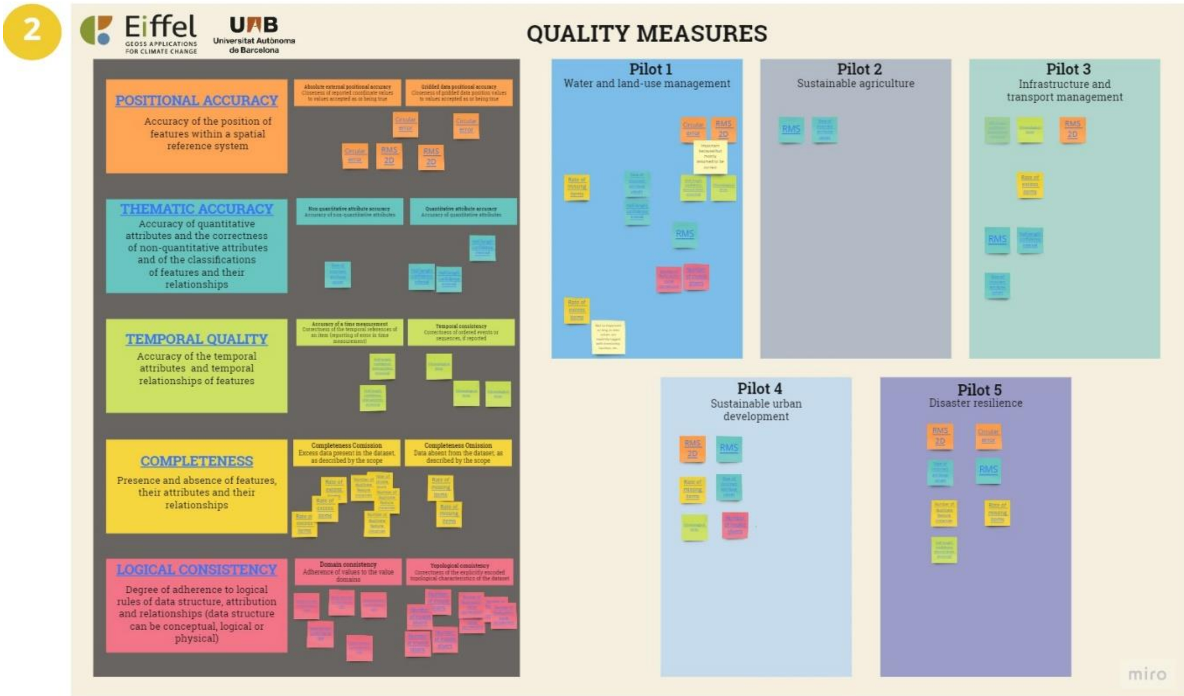

Figure 2. Final result of the second board on the co-design event: Quality measures for each pilot.

Regarding the use of the indicators, it is possible to identify that Positional Accuracy and Thematic Accuracy were much more used than the others, which can be easily explained by topic familiarity, since those are more common concepts. On the other hand, the following three (Temporal Accuracy, Completeness and Logical Consistency), are less known or less common elements, which probably meant more time and dedication to be understood by the attendees.

Another explanation is just about timing, as they were the last three indicator on the list, and probably attendees did not arrive to check what each one was about, as the activity timing was about 12 to 15 minutes. Probably, for this kind of activities that requires more agility from attendees, there should be more time for doing it properly.

This activity came from the survey results about having experience on making a quality report for their data and/or products, as we found that a 59% have never done it, while only a 35% have done, and a 6% didn't answer. These statistics were not as expected, as a 65% declare to not have experience in the subject or did not answer.

Also, when we asked for the URL of the quality reports we received five URLs, however none of them were DQ reports: three were scientific articles describing products and the other two

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were generic metadata, without quality measures. This indicated us that there was uncertainty about what is understood as a DQ report.

In the same line, when we asked about main problems with data quality (a multi-selection question, max. 3 per answer), results shown that principal problems are related on *finding or selecting an appropriate list of data quality indicators*, with 23% of the answers, also related to *document quality in metadata* (13% of the answers) and *to understand data quality indicators* (11% of the answers). Therefore, considering the results, we decided to work on quality elements definitions that could be familiar with attendees.

Next, on Figure 3, is the graph with the complete answers about main problem with data quality:

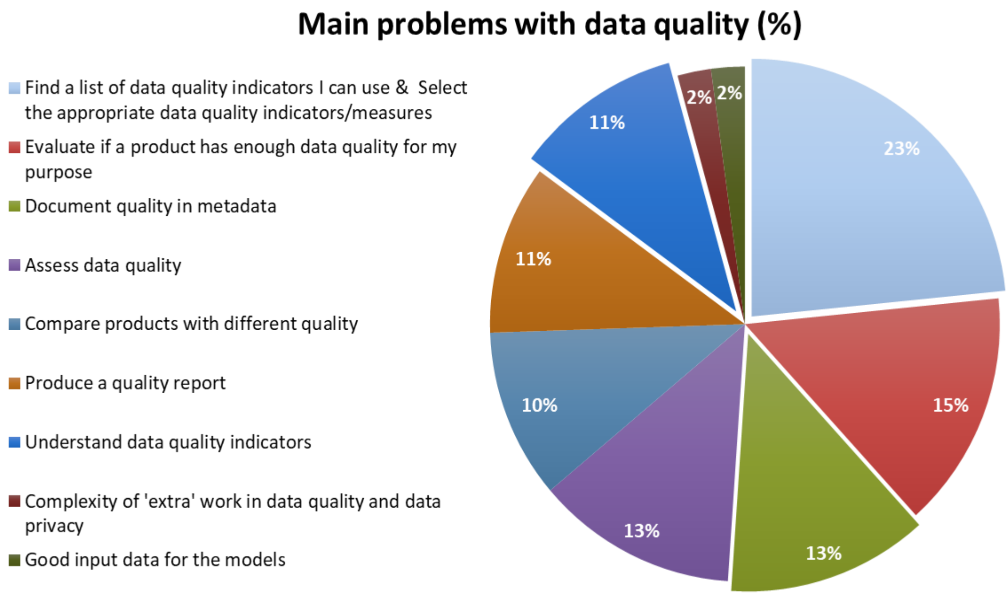

Figure 3. Main problems with data quality

3.1.3 About GEOSS Platform

Second section on the survey was about GEOSS Portal experience for consultants. There were three questions, two of them with alternatives (including an alternative "other", to write a different answer from the given ones) and another one with free space for writing a short answer. From the organizers' point of view, this section did not satisfy the expected responses.

First question sought to find out whether participants had used GEOSS Portal to discover and search for data, as well as their experience with it. Of the responses received, 10 out of 17[5] were aware of GEOSS Portal, however none had had a fully successful experience, one did not even know what GEOSS Portal was and 6 out of 17 had not used the platform.

[5] In absolute numbers.

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Figure 4 shows a bar graph of this question, with the given answers and some that were added by the consultants.

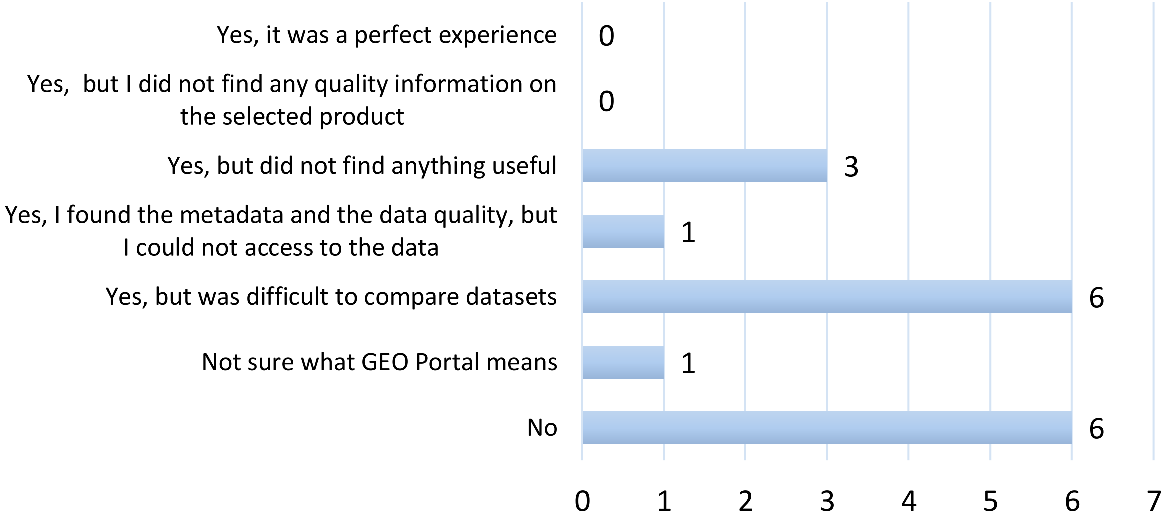

Figure 4. Experience on GEOSS Portal, in absolute numbers

Answers about second question of this section are in the same line, it was a free answer space to communicate if you have used the Geo Knowledge Hub and how was your experience.

It was a surprise when we realized that 14 out of 17 respondents declared that they had not used the platform (Figure 5), and of the remaining three, one had learned of its existence on the day of the Data Quality Co-design Workshop pre-event, another knew about it but had not used it, and the last one had no response.

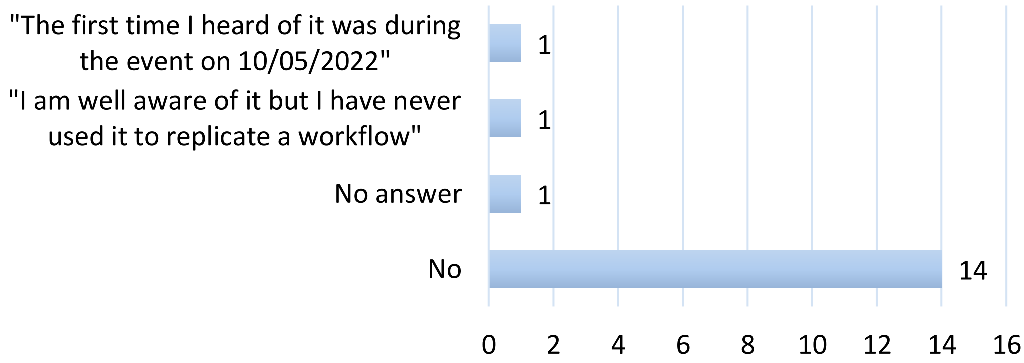

Figure 5. Experience using GEOSS Portal, in absolute numbers

This indicates that either there has been a serious problem of misinformation about the platforms and their contributions, or the respondents have not needed or been interested in using them. This has come to our attention, since *"project EIFFEL is a game changer in the domain of climate change adaptation and mitigation by harvesting the benefits of the GEOSS data"*, as is written on the website.

These results were the basis for the third interactive board on the Data Quality Co-design Workshop, which was design as a Brainstorm about the GEOSS Portal situation. As can be

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seen on Figure 6, on one side of the board we were asking about how to evaluate the current situation of the portal, on the other side we asked the reasons of that situation, in attendees' opinion.

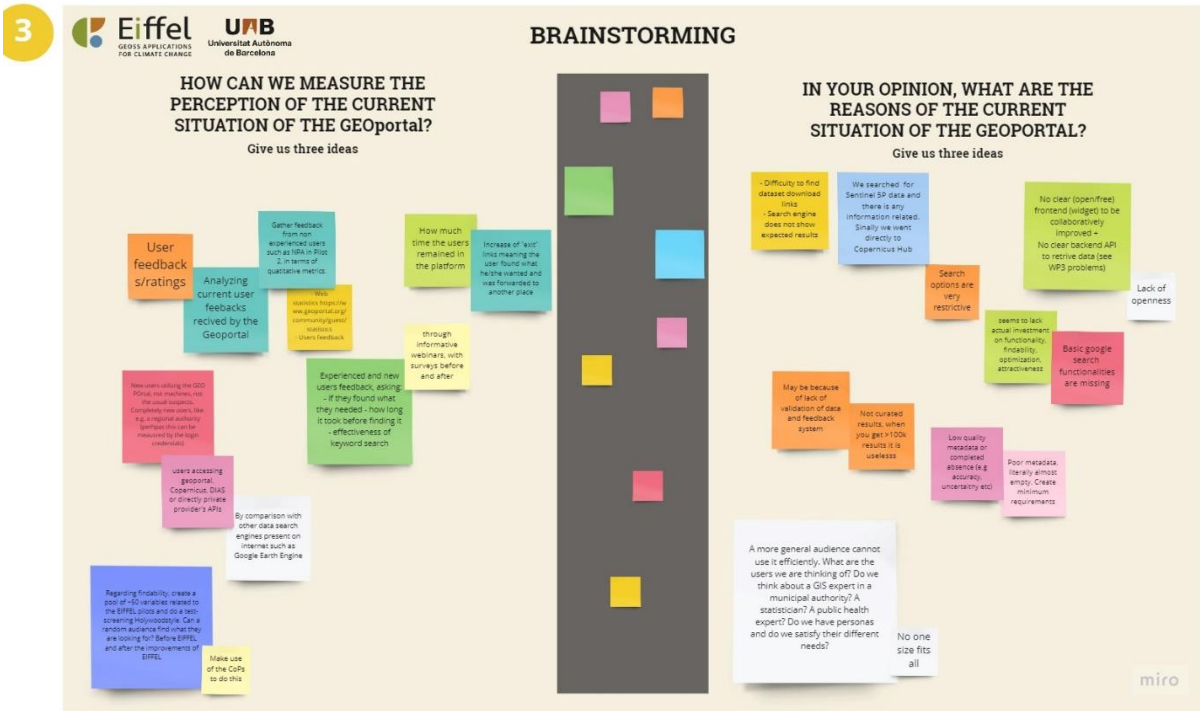

Figure 6. Third board on the co-design event: About the GEOSS Portal situation

3.1.4 User feedback: Survey results

Last section of the survey was about the experience of attendees generating Geospatial User Feedback (GUF) as users and their opinion about it.

In first place, we were looking for the wishes of consultants of giving comments or having considerations about the data that they were using. Most of the answers did not know or did not answer (47%), while 41% declare that they do have commentaries. Only 12% declare that they don't have comments about the data they were using.

Next question was about the willing of giving feedback if the data portal provides the interface for it. Most of the answers were positive, with a 59%, followed by a 29% of dubitative answers (I don't know / I have no answer), and finally the same 12% answered negatively to the question.

The third question in the GUF section asked who would be benefit from feedback, in a multichoice question. Most of the answers were for producers (13 of them), while 11 of them were for other users (consultants could mark as much as needed). Another one mention that was not expecting to give feedback.

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In a multichoice question about what kind of feedback consultants could provide, most of the answers said they would give comments and only one said that could provide a quality report (see Figure 7).

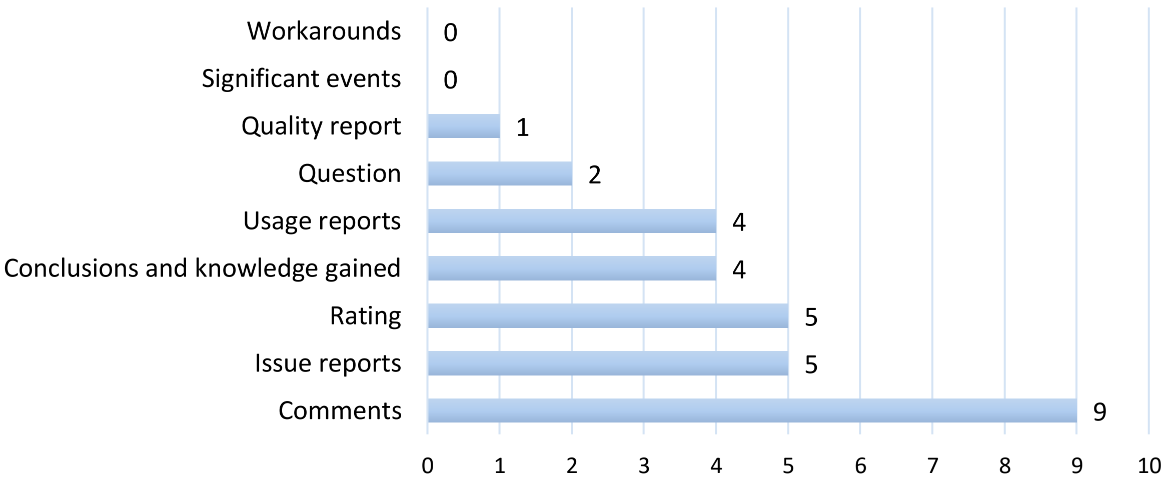

Figure 7. Types of feedbacks surveyed could provide, in absolute numbers

Asked about providing an example of the feedback they could produce to an exemplary dataset, 16 responses were retrieved, among which 3 of them were completely invalid while 6 were confusing and the remaining 7, fit the purpose of the question (Table 1). These answers are shown in Table 4, next.

Table 4. Feedback examples provided from survey.

CORRECT
Validation against other datasets (reanalysis)
Good coverage, good availability, similar with model produced results, etc
e.g. results of comparison of Copernicus HR-VPP with local datasets
if the dataset was useful for the purpose I used it
Missing data, inconsistency obvious bugs
While using the Copernicus Urban Atlas product, I found several inconsistencies with respect to the population which is an attribute to each shapefile of a city ()
short review
CONFUSING
Eg. how the dataset was used (in which application)
key information provided is typically not clear to new users
Interpretation of results/data based on expert/domain knowledge
Interpretation of results / data based on expert / domain knowledge
The dataset was produced by XXX. The measures were provided by in-situ sensors.
How to use a model using some particular set of data
NOT VALID
No
Not at this stage
Not sure yet

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About the availability of receiving feedback on data from their own, an 82% said yes, while a 18% did know or did not answer. And about replying to feedback, a 59% said that they were willing for it, a 29% did not answer o didn't know and a 12% would not be available to reply feedback.

Finally, about motivation for users of data on giving feedback, most of the answers were aligned to get responses to the comments or contributions, followed by recognition as an expert and finally altruism. On Figure 8 is the graph with all the answers.

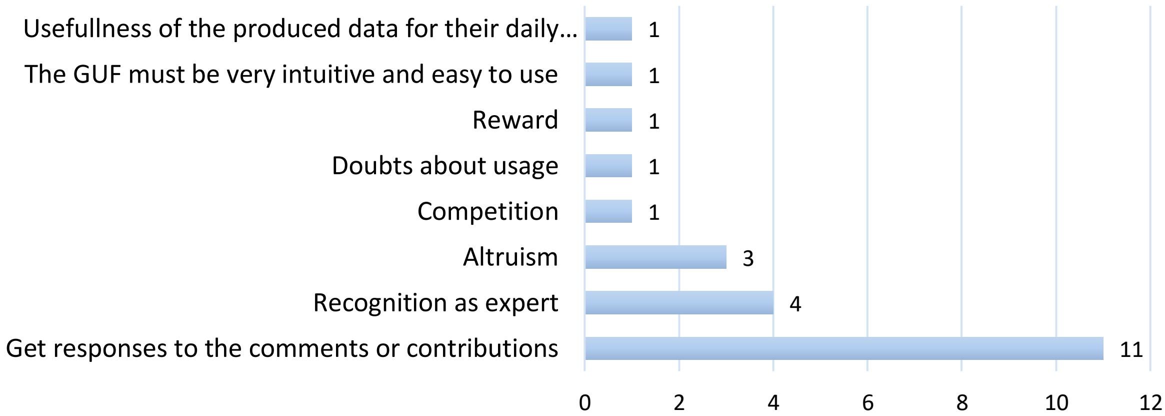

Figure 8. Motivations to provide feedback from users of data, in absolute numbers

Most of the answers on user feedback section show that most of the attendees have a positive disposition to generate and to respond to feedback, also that they usually have comments on the datasets they are working on and that they would like to have the possibility to give feedback about them.

As this is a section with a majority of positive responses, we wanted to reinforce and explore it, so we did an activity divided into two parts. The first to identify the ideal users of our datasets (by Pilot), the second to discuss about how to stimulate the creation of GUF items. Finally, and to close the activity, the idea was to "move" the stimulus ideas towards the selection of ideal users per pilot, so that each Pilot could identify different ways to stimulate the creation of GUF associated with their datasets. Figure 9 shows the final board of the activity.

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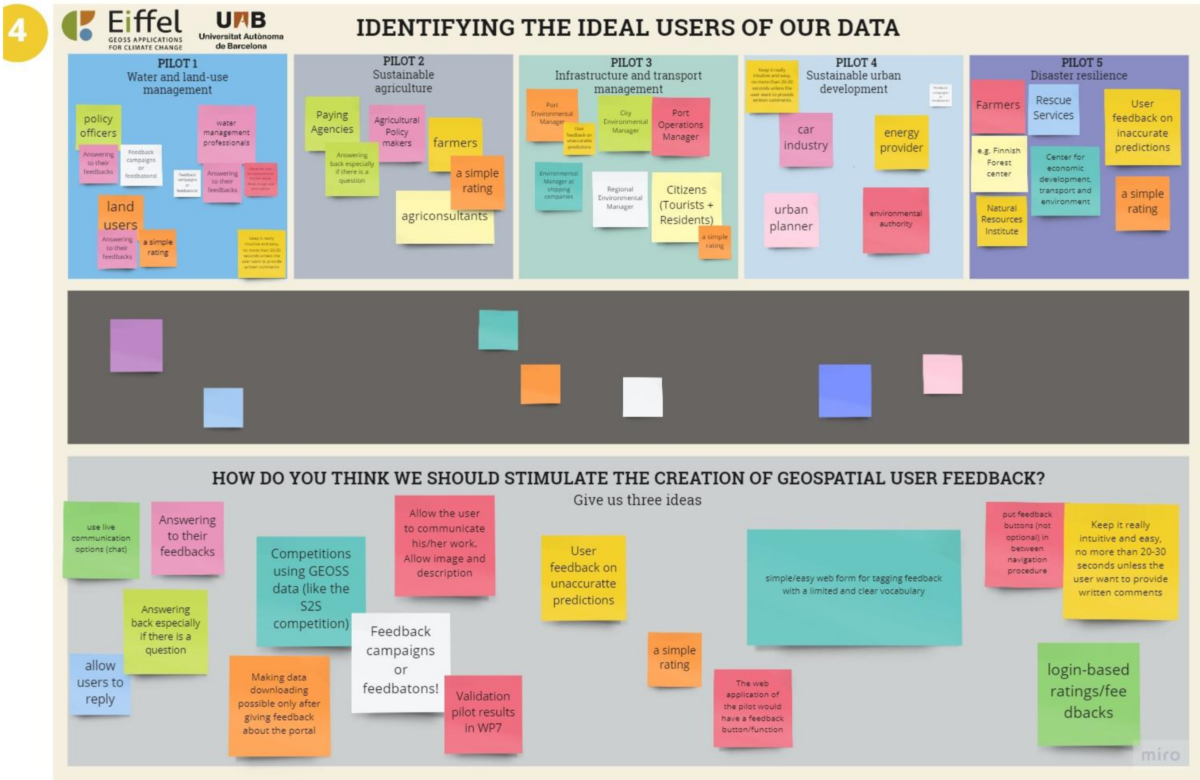

Figure 9. Forth board on the co-design event: Data's ideal users and proposals to stimulate the creation of GUF items

Each Pilot identified their ideal users of data, i. e. policy officers, land users, urban planners, farmers, agri-consultants, tourists and residents, among others. About the stimulation of giving feedback, most of the answers were some recommendations about the users' experience (making easier the experience on the platform), and other linked to general conditions, like being able to download the data only after giving feedback about it, for example.

3.2 Data Quality Co-design Workshop: Feedback and approaches

As we were working on feedback subject, we considered necessary to send a final satisfaction survey[6] to the attendees to the Data Quality Co-design Workshop. It was open since May 20th to November 11th, and we only received one answer, so this section will only be based on it.

The main idea of this survey was to identify the strengths and weaknesses of the Data Quality Co-design Workshop, with the purpose of improving on future co-design events.

As can be seen on Figure 10, feedback about the event shows that probably this person was expecting other type of workshop, as it did not satisfy his/her expectations (grade 2 from

[6] See the satisfaction survey questions on Appendix C.

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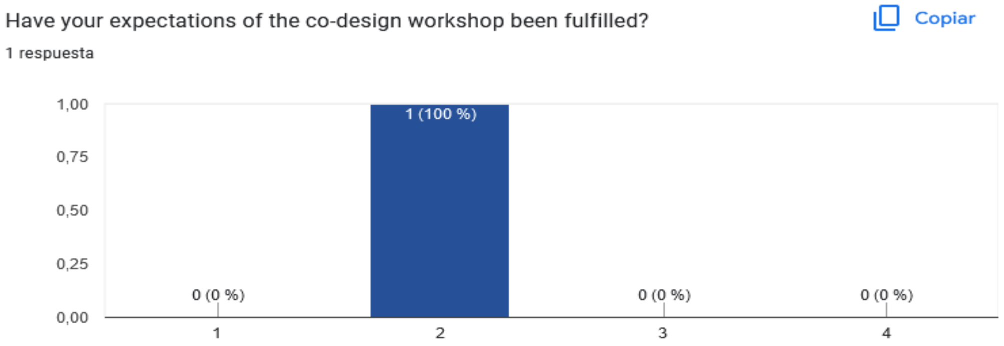
a 1 to 4 ranking). Also, this consultant considered that some knowledge about DQ was given but didn't understand what the path is to give feedback nor quality measures.



What did you like most about the co-design workshop?

1 respuesta

Some knowledge about quality tagging in datasets was obtained, as the presenters tried to do their best

What did you like least about the co-design workshop?

1 respuesta

Not clear what the main result should be, and what is the path to be followed by pilots to provide feedback and quality measures

Figure 10. Feedback answers about Data Quality Co-design Workshop [Opinion].

Do you have any comments or recommendations for future events?

1 respuesta

1) In general there was few knowledge about quality(ML) to make great adances in one single workshop. Probably more hints and trainig will be needed.
2) The results about the previous survey could have been provided in advance to save some time and focus more on the expected output of task T4.3
3) Pilots will probably act as prosumers (consumers and producers) of datasets (and applications). It is also not clear the potential correlation between input datasets and outputs datasets in terms of quality(ML) measurements. For example, if I take X datasets with variable QualityML values, how does it impact the output dataset generated by the pilots?
4) Different users (stakeholders) might have different expectations about the data, which probably will affect the priority given to some QuailtyML measures in front of others. Are we going to establish some priorization? Will it be by pilot application, or a more common approach for the Climate change field?
5) WP3 actors didn't participate, just pilots. Maybe a parallel session with WP3 partners will be required for the integration in the EIFFEL platform of user feedback, unless the approach is standalone/independent. WP3 include also tagging and including metadata, thus it should be clarified how to homogenize the whole process. You might also link T4.3 with T3.2 (ontology) to define a subset of QualityML entities to be included for Climate Change tagging, for example.
6) Integration with GKH still to be clarified to pilots; maybe there is already an strategy, but it seemed that pilot leaders ar emostly unware/unfamiliar with GKH

Figure 11. Feedback answers about Data Quality Co-design Workshop [Recommendations].

This satisfaction survey answer has made us considered that probably metadata and DQ information on attendees was not how we were expecting, nor what we considered necessary

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for making the event, at the time that this person was expecting for something closer to a lesson about DQ and how to give feedback than to an interactive session as it was.

However, on final commentaries, we found several reflexions that confirm our perception of the DQ level or interest among attendees and consultants, as well as some ideas and recommendations that will help us to evaluate next steps. One that is specially aligned to our perception, is a recommendation of meeting WP3 partners, as they are also working on metadata. So, a meeting looking for homogenising processes could benefit our work.

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4 Data Quality Bilateral meetings with Pilots

Bilateral meetings for consultant instances have been organized as an effort for improving DQ documentation in Pilot's products. The aim of these meetings was to understand the needs of each Pilot (mainly from the producer's perspective) and define in a coordinate way the quality documentation to be used.

To this end, the meetings were held under the following script:

- Objectives currently working on
- Model purpose
- Methodology for obtaining resulting product
- Data output descriptions (variable, units, resolution, frequency,...)
- Do we know the data quality of the inputs? Do we have metadata or quality reports?
- How do you asses data quality (e.g. uncertainty propagations, validation with reference datasets, etc.)?
- Do we have quality estimations at the model level or at the execution level?
- Types of developed metadata
- Comments or observations
- Geospatial User Feedback

The next subsections describe the course of the meetings held.

4.1 Bilateral Meetings

4.1.1 Pilot 1: Water and Land-Use Management.

Pilot 1 is divided in two subtasks led by different partners. The first subtask is focused on obtaining a hydrological model from a catchment between Netherlands and Belgium, while the second subtask plans to model soil carbon. Thus, a meeting for each one was arranged. The details of these meeting are transcribed below:

a) Hydrological modelling team

- **Meeting date**: 19/07/2022
- **Attenders**:
  Javiera Crisóstomo López (UAB)
  Alaitz Zabala Torres (UAB)
  Joan Masó Pau (CREAF)
  Claudia Bertini (IHE)
  Charalampos (Haris) Kontoes (NOA)
  Schalk Jan van Andel (IHE)
- **Duration**: 26 min

- **Objectives currently working on**:

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At the moment of the meeting, Pilot 1 hydrological modelling team members are focused on the hydrological model from Weerijs Brook catchment, between Netherlands and Belgium.

- **Model purpose**:
  The model reproduces hydrological processes to simulate, mainly, discharges, evapotranspiration, soil moisture and ground water level.

- **Methodology for obtaining resulting product**:
  Not answered

- **Data output descriptions (variable, units, resolution, frequency, …)**:
  They are producing a time series. For now, they have been running the model for one and a half years in different time periods for the existing data. They are also planning to make future projections. Depending on the obtained results, they will propose the better resolutions for the model.
  Generating maps is not the principal goal, but it can be done once Key Performance Indicators (KPI) are determined.

- **Do we know the data quality of the inputs? Do we have metadata or quality reports?**
  Despite they can provide a list of inputs for the model, they are still working on which of them can be more useful. They have problems because of the lack of data from the Belgium side.
  Once the inputs are decided they will be able to tell if there is some quality information to be preserved.

- **How do you asses data quality (e.g. uncertainty propagations, validation with reference datasets, etc.)?**
  They are calculating Root Mean Square Error (RMS), Correlation coefficient (r) and the Nash-Sutcliffe model efficiency coefficient (NSE) for the different calculated variables. They also have field data to evaluate ground water levels with the same statistical parameters.
  The evaluation is done only for the Netherland part of the catchment because of the lack of data for the rest of the study area. This evaluation is not spatialized, the quality is determined for all the area as a whole, using the validations points. For the rest of the area some quality assumptions will have to be made based on the result of the Netherlands part or quality will have to be referenced to other existing sources.

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- **Do we have quality estimations at the model level or at the execution level?**
  They probably can provide some metadata at the model level such as the kind of model used, the version, the kind of input data used but also de KPI achieved for a specific execution.

- **Types of developed metadata**
  They have no experience in metadata documentation.

- **Comments or observations**
  UAB will provide templates and guidance for generating metadata files.
  As Pilot 1 is generating projections, it seems possible to generate quality measures that comes from the climate adapt documentation, such as confidence of the result, in addition to those mentioned above.

- **Geospatial User Feedback**
  No comments for now

b) Carbon soil team

- **Meeting date**: 19/10/2022
- **Attenders**:
  Javiera Crisóstomo López (UAB)
  Alaitz Zabala Torres (UAB)
  Oscar González (UAB)
  Borjana Bogatinoska (OUNL)
  External Guest
- **Duration**: 27 min

- **Objectives currently working on**:
  The idea is to generate a carbon model to estimate carbon stock for the same Netherlands/Belgium catchment, based on some of the outputs of the hydrological model generated by IHE partners. They will study how land uses and its changes will affect the carbon stock. As carbon stock variation change infiltration and hydrological capacities, iterations between the carbon model results and the hydrological modelling are planned.
  They are in the first steps of their work, although a preliminary study has been published in 2022 (MSc thesis on carbon modelling Netherlands part of catchment; Timmer, van Wijnen, Lansu).

- **Model purpose**:
  Better understanding on the behaviour of both carbon and hydrological model and the effect of changing input variables in the context of climate change.

- **Methodology for obtaining resulting product**:
  Not answered

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- **Data output descriptions (variable, units, resolution, frequency, …)**:

- **Do we know the data quality of the inputs? Do we have metadata or quality reports?**
  For data inputs such as the DEM, Climate and Land Use bases, the quality parameters are really stablished. All of them are validated products. For the soil hydrological characteristics of the Netherlands is also validated and there are publications that can be referenced. The carbon data initially used is validated too, so the producer's accuracy is stablished.

- **How do you asses data quality (e.g. uncertainty propagations, validation with reference datasets, etc.)?**
  Some error propagation study could be done but it isn't the most informative way to show data accuracy. There are some nature-based cases with known inputs and outputs that can be used to validate the model in those specific situations and stablish some general quality parameters.

- **Do we have quality estimations at the model level or at the execution level?**
  Not answered.

- **Types of developed metadata**
  They have some experience both on standard and non-standard metadata documentation.
  For the outputs of the model, the metadata format has not been discussed yet. Collaborating with UAB in this aspect will be beneficial for both partners.

- **Comments or observations**
  As the subtask is still in a very first state of development, a new meeting could be arranged in the future to discuss with better criteria the best way to work on the metadata files.
  For the moment, UAB will provide some examples and OUNL will share some references for a better understanding of the modelling process.

- **Geospatial User Feedback**
  No comments for now

4.1.2 Pilot 2: Sustainable Agriculture.

- **Meeting date**: 18/07/2022
- **Attenders**:
  Javiera Crisóstomo López (UAB)
  Alaitz Zabala Torres (UAB)
  Joan Masó Pau (CREAF)
  Roxanne S. Lorilla (NOA)
  Stylianos Kokkas (IBEC)
  Samarinas Nikkiforos (IBEC)

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- **Duration**: 27 min

- **Objectives currently working on**:
  On the one side, they are generating information about the soil organic carbon content, the clay content. These two products will be used as inputs in the physical process-based model to produce the soil organic carbon sequestration product.

  All products are provided at national scale for the whole Lithuania but also at parcel level.

  On the other side, they are generating a spatial explicit indicator of how specific agricultural management practices (related mainly to agricultural landscape diversity, but also the maintenance of permanent grasslands or crop rotation with legumes) contribute to (or have an impact on) specific indicators on agricultural resilience.

- **Model purpose**:
  As there are different products, they use different models. On the one hand, there is a physical process-based model to produce a soil organic carbon sequestration model and the other hand there are causal discovering methods, geographical models and machine learning algorithms (random forest) to assess the impact of the different agricultural practices.

- **Methodology for obtaining resulting product**:
  The methodology for the obtention of the soil organic carbon sequestration was detailed during the co-design sessions.

  In order to obtain the impact of agricultural practices on productivity, as inputs they are using some ready products from satellite missions (MODIS, Sentinel or Landsat) but also information provided by the Lithuanian Paying Agency (NPAS) such as the land parcel identification system which contains the specific crop type for each parcel or if a parcel have been organically farmed or not. This information is a farmer's declaration, so it is not sure its level of accuracy. The model also uses climate variables and environmental conditions parameters.

- **Data output descriptions (variable, units, resolution, frequency, …)**:
  For the soil organic carbon sequestration, there's a period of considered observations but the result is a single value based on the median for the observations on that period. The results are at regional scale but also at parcel level.

  The productivity model generates a single result for each execution, also at regional and parcel level.

- **Do we know the data quality of the inputs? Do we have metadata or quality reports?**
  Some quality information may be found about the satellite products, for example, but there is no quality information about farmer's declaration in the land parcel identification system.

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- **How do you asses data quality (e.g. uncertainty propagations, validation with reference datasets, etc.)?**
  Uncertainty maps based on the prediction's interval ratio will be the main quality product for the produced soil organic carbon sequestration product. They will also use Root Mean Square Error (RMS) values for quality documentation.

  For the productivity impact product, they are still working on the modelling. They will send more details about it to the UAB team in order to find ways to assess quality estimators.

- **Do we have quality estimations at the model level or at the execution level?**
  Quality estimators will be provided at execution level.

- **Types of developed metadata**
  Generating XML metadata files with GeoNetwork with basic metadata such as resolution, coordinate systems, etc.

- **Comments or observations**
  As they have experience on metadata documentation using GeoNetwork, they will produce a first draft and then UAB will try to give advice on how to document those more specific quality aspects.

- **Geospatial User Feedback**
  They are planning to produce a web portal to distribute the generated products and they are interested in implementing Geospatial User Feedback. When the time comes UAB can help in this part of the implementation.

4.1.3 Pilot 3: Infrastructure and Transport Management.

- **Meeting date**: 18/07/2022
- **Attenders**:
  Javiera Crisóstomo López (UAB)
  Alaitz Zabala Torres (UAB)
  Joan Masó Pau (CREAF)
  Sebastian González (BPA)
  Victor Centella Fuster (PRO)
  Benjamín Molina Moreno (UPV)
  Amelia del Rey Pérez (PRO)
  José Antonio Clemente Pérez (PRO)
- **Duration**: 56 min

- **Objectives currently working on**:
  The aim is to help the Balearic Islands Port Authority (APB) mitigating the carbon footprint.

They are using in-situ sensors to obtain air quality data as well as climatic data in combination with port activity data (loading and unloading of ships, ship traffic, ship positioning, etc.), meteorological stations data and satellite data (Sentinel-5P).

There are three use cases:

1. Pollutant atmospheric analysis in Palma: correlation between port activity and pollutant sources (NO_2 and SO_2, city/port, wind, port traffic, etc). Currently there's no quality measures for this case. Is possible to have a beginning start point with in situ data.

2. Atmospheric emissions in Los Freus (Formentera): monitoring the pollutant emissions (NO_2 and SO_2) at regular ships connection between Eivissa – La Savina ports.

3. Berth optimization: Prediction of pollution episodes to support decision making in the optimization of ships traffic routes to/from the port area, so as to affect the least number of people.

At this moment they are in a first state of the pilot case, working on the correlation between the port activity and the main sources of contamination in terms of NO_2 and SO_2.

- **Model purpose**:
  The model purpose is to predict contamination pulses in order to improve the port management to minimize them.

- **Methodology for obtaining resulting product**:
  The output data is obtained using Tensorflow and Prophet modelling tools.

- **Data output descriptions (variable, units, resolution, frequency, …)**:
  At this moment the output specifications are still unknown and will depend on the model performance.

- **Do we know the data quality of the inputs? Do we have metadata or quality reports?**
  There are some quality bands that may be used from the Sentinel-5P input data.
  The in-situ sensors have a quality flag indicating if a register can be trust.

- **How do you asses data quality (e.g. uncertainty propagations, validation with reference datasets, etc.)?**
  The in-situ data can be split in a training set and a test set. At this moment, the quality estimators are calculated for each in-situ sensor, despite a single quality value could be estimated if a single model for the whole in-situ sensors is finally created.

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- **Do we have quality estimations at the model level or at the execution level?**
  For each model execution Mean Absolute Error (MAE), Mean Squared Error (MSE), Mean Absolute Percentage Error (MAPE), coefficient of determination (R^2) and accuracy calculated as (1-MAPE)*100 will be determined.

- **Types of developed metadata**
  No metadata has been developed yet.

- **Comments or observations**
  UAB recommendation is to generate a spatialized quality indicator, associated with point stations and in situ field data, from which predictions and adjustments are made. The idea is to identify areas where the adjustment is more complicated and others where it is easier, making it possible to obtain a spatial and/or global quality indicators for the entire layer.

  After the meeting, they sent us three JSON documents: one with validated data, other with the metrics and graphs with representation of both.

- **Geospatial User Feedback**
  No comments for now

4.1.4 Pilot 4: Sustainable Urban Development

It was finally not possible to arrange a meeting with Pilot 4 partners but, as far as we know from previous meetings, they are used to document standard metadata files by using the GeM+ tool. Moreover, we know that some of the outputs they are generating are spatialized quality indicators, which must be treated properly. A specific example will be generated.

4.1.5 Pilot 5: Disaster Resilience: Drought, forest fire and pest risk assessment Regional/National Scale

- **Meeting date**: 31/08/2022
- **Attenders**:
  Alaitz Zabala Torres (UAB)
  Fronzek Stefan (SYKE)
  Menberu Meseret (SYKE)
  Böttcher Kristin (SYKE)
  Jakkila Juho (SYKE)
  External guest
- **Duration**: 49 min

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- **Objectives currently working on**:
  The main objective is to generate drought, forest fire and pest outbreak risk to forest species related products and develop new tools for existing national Finnish web portals.

  At this moment they are working on the drought forest fire and pest outbreak risk modelling in the specific case of the risk assessment of independent impacts.

  This is achieved by combination of satellite and model data, conventional scenario analysis and impact response surface analysis. There is also a qualitative analysis of risk interpretation, risk management options and adaptation pathways.

- **Model purpose**:
  The purpose of the different models used is to improve forecast for drought, fires and pest risk.

- **Methodology for obtaining resulting product**:
  For the forecasting on drought simulation, they use the Watershed Simulation and Forecasting System (WSFS) in SYKE. It is a semi-distributed hydrological model covering the entire Finland and transboundary watersheds typically used for operational flood and drought forecasting that now is planned to be used for estimations of climate change impact in discharge, groundwater, etc.

  They are now trying to improve the WSFS model and using satellite soil moisture products (SMOS) to validate the results.

  For the forest fire modelling, they are using Canadian Fire Weather Index (FWI) and other forest fire indices calculated from climate variables. Some test calculations for a single site in Finland were conducted to prepare initial fire risk response surfaces and now they are planning how to include forest fuel load to the analysis.

  In the case of pest risk, a statistical relationship between phenology (derived from MODIS satellite images), climate and other environmental variables with the peak flying period of seven moth species has been detected. The modelling is done using a mixed effect regression model (R-code), but it is still in a development phase, and the aim is to generate national maps for each species peak flying period and maybe, in the future, generating climate scenario analysis and seasonal forecasting.

- **Data output descriptions (variable, units, resolution, frequency, …)**:
  At this moment it is still not decided which kind of data will be published.

- **Do we know the data quality of the inputs? Do we have metadata or quality reports?**
  There are some scientific papers that describes the methodology for forest fire and pest risk modelling.

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- **How do you asses data quality (e.g. uncertainty propagations, validation with reference datasets, etc.)?**
  Nash-Sutcliffe model efficiency coefficient (NSE), Root Mean Square Error (RMSE) for drought products and some statistical records can be extracted for the pest risk products.

- **Do we have quality estimations at the model level or at the execution level?**
  Execution level.

- **Types of developed metadata**
  They have experience in INSPIRE compliant metadata documentation but for the moment they are not producing full metadata records for all these products.

- **Comments or observations**
  They have several portals where data and metadata can be searched. The plan is to use these portals for the new data generated but hey will need some help to generate quality metadata standard compliant records. An XML template with a specific quality measure section will be generated by the UAB.

- **Geospatial User Feedback**
  No comments for now

4.2 Lessons learned

As mentioned before, the aim of the co-design and the bilateral meetings was to discuss the needs and understand the products that each pilot group is generating to define, in a coordinate way, a set of best practices or recommendations to improve their metadata documentation especially from the producer's quality perspective.

The bilateral meetings have shown that in most cases the work of the Pilots it is still in a preliminary phase: some of them are still defining the products to be generated and others are defining the best way to produce them. This means that, although a lot of work have been done, in some cases it is still not clear the inputs and outputs of the models and the best way to test the obtained results.

However, these meetings allowed us to identify that:

- Most of the producers have previous experience documenting metadata with different tools (GeM+, GeoNetwork, etc.) and at different levels of completeness.
- Quality of the Pilots' products will be assessed mainly at execution level.
- Non-spatialized quality estimators will be the most common indicators to be documented. The following list of quality indicators has been identified:
  - Root Mean Square Error (RMSE)
  - Correlation coefficient - r
  - Nash-Sutcliffe model efficiency coefficient (NSE)
  - Mean Absolute Error (MAE)
  - Mean Squared Error (MSE)

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    - Mean Absolute Percentage Error (MAPE)
    - R-squared or coefficient of Determination - R^2
- Spatialized quality estimators will also be generated, although it is not a common situation.
- The implementation of Geospatial User Feedback is not possible in any case at this moment because the server part for the different data products have not been established yet.

Examples on how to document these quality indicators are provided in the best practices section of this document.

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5 Best Practices and recommendations

5.1 Producer's metadata

5.1.1 Preliminary considerations

Data quality can be documented using different strategies depending on the level of previous knowledge of the data producers.

For the examples on this document, the combination of the ISO 19115:2003 [1] and ISO 19115-2:2009 [2] with links to the QualityML registry has been chosen. This decision has been made because during the different meetings held, it has been detected that the tools used by the majority of interviewed users to generate metadata records are still based on these standards. It must be said that, although currently withdrawn, in many cases they are considered the *de facto* standards and also are the base of the INSPIRE initiative.

However, the most direct and complete option to document quality on metadata records will be the use of the QualityML standard in combination with the ISO 19115-1:2014 [5]. This strategy requires the use of the 19115-3:2016 [6] XML schema implementation and a very advanced knowledge of both tools and standards. If any of the producers would like to use this strategy, detailed examples of how to encode quality elements linked to QualityML registry so can be found at www.QualityML.org.

On the other hand, since some of the users have little experience regarding the use of standards in metadata documentation, not only specific examples of the quality sections, but also two examples of complete metadata records based on the 19139-2:2012 schema implementation [3] are provided at https://www.qualityml.org/examples/index.htm and can be used as templates.

5.1.2 Encoding Quality Indicators using XML

Extensible Markup Language (XML) is a language created for storing, sharing and reconstructing structured information based on a set of rules to encode the information.

In the specific case of metadata storage, the root element in the XML file will be MD_Metadata (or MI_Metadata when using ISO 19115-2 for gridded data). This element represents the main class of the metadata records and contain different attributes such as the file identifier, the language used, the date stamp, etc (Figure 11).

Inside this root element several sections can be documented such as the reference system, the distribution information, the content information, etc. These sections are represented as aggregations of the MD_Metadata class and have different cardinalities. Quality Indicators will be described within the "report" element in the Data Quality section (DQ_DataQuality) and its cardinality (attribute dataQualityInfo) indicates that it is not a mandatory element, and it can exist as many times (for several quality classes) as the users need (Figure 11).

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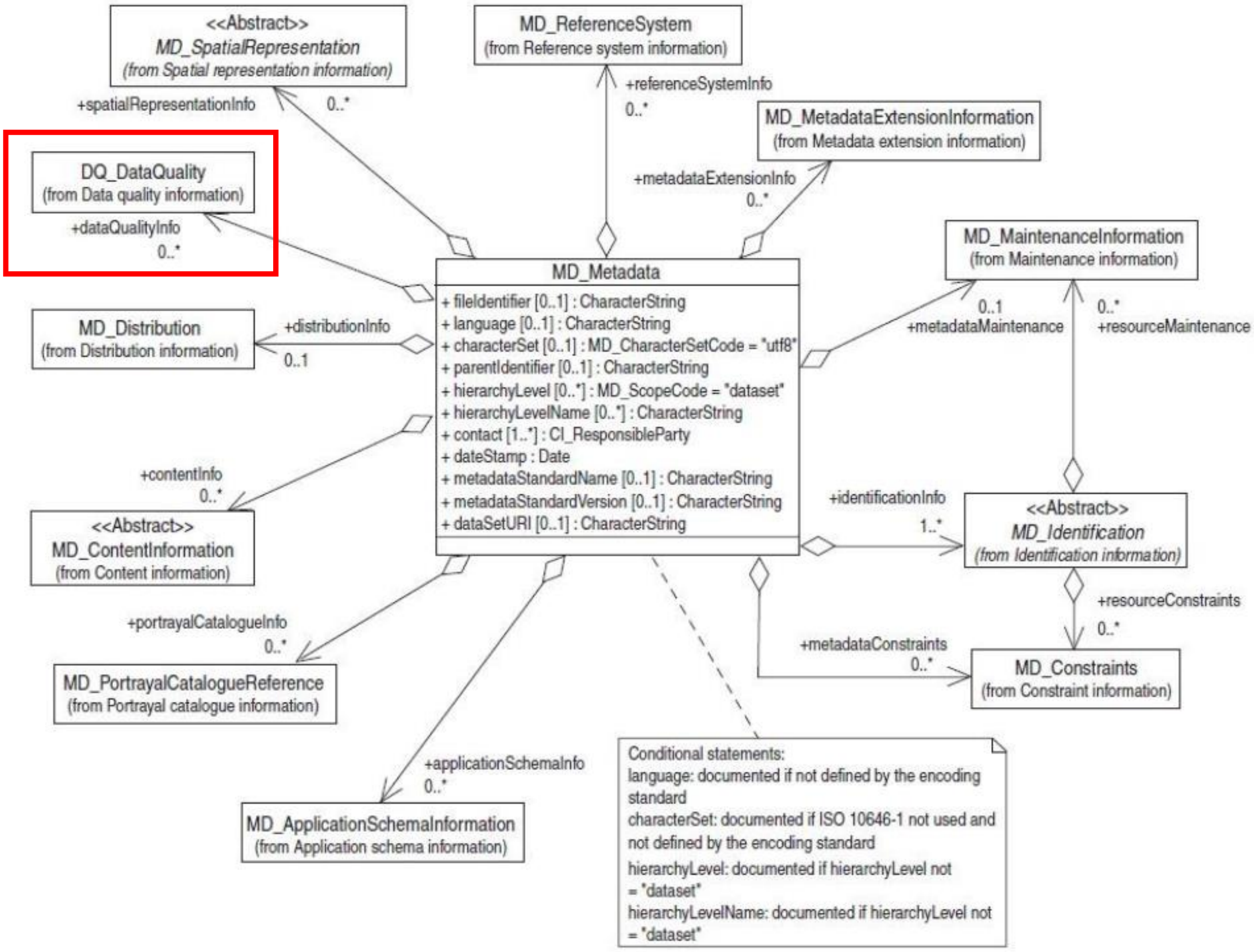

Figure 12. General UML metadata schema in ISO 19115:2003

Following a similar schema, the aggregation of quality elements conforms the "report" element within DQ_DataQuality. The cardinality of this relation indicates, again, that it is not a mandatory element, and that it can exist as many times as needed for several quality elements (Figure 12).

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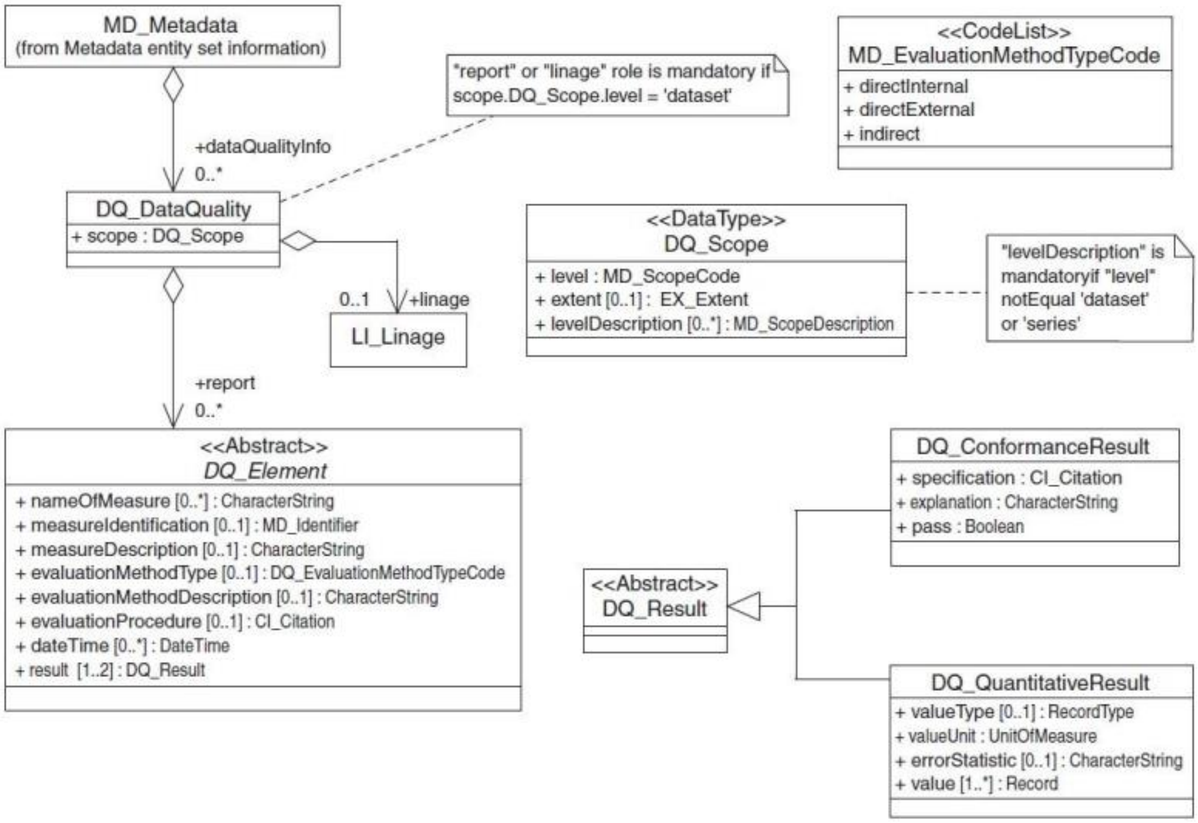

Figure 13. General UML Data Quality schema in ISO 19115:2003

DQ_Element is an *abstract* class, and this means this section will not be directly used in the metadata files, but it will be substituted by one of the several classes which are derived from it. These "derived" classes describe different types of quality measures, each of them covering a specific quality facet:

- DQ_AbsoluteExternalPositionalAccuracy: closeness of reported coordinate values to values accepted as true in a standard coordinate reference system.
- DQ_AccuracyOfATimeMeasurement: closeness of reported time measurements to values accepted as true.
- DQ_CompletenessCommission: excess data present in a dataset.
- DQ_CompletenessOmission: data absent from a dataset.
- DQ_ConceptualConsistency: adherence to rules of the conceptual schema.
- DQ_DomainConsistency: adherence of values to the value domains.
- DQ_FormatConsistency: degree to which data are stored in accordance with the physical structure of the dataset.

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- DQ_GriddedDataPositionalAccuracy: closeness of gridded data spatial position values to values accepted as true.

- DQ_NonQuantitativeAttributeAccuracy: measure of whether a non-quantitative attribute is correct or incorrect.

- DQ_QuantitativeAttributeAccuracy: closeness of the value of a quantitative attribute to a value accepted as or known to be true.

- DQ_RelativeInternalPositionalAccuracy: closeness of the relative positions of features in a related dataset to their respective relative positions accepted as true in a local coordinate reference system.

- DQ_TemporalConsistency: correctness of the order of events.

- DQ_TemporalValidity: validity of data with respect to time.

- DQ_ThematicClassificationCorrectness: comparison of the classes assigned to features or their attributes to a universe of discourse (e.g. ground truth or reference data).

- DQ_TopologicalConsistency: correctness of the explicitly encoded topological characteristics of a dataset.

So, the general XML structure for quality metadata documentation is as follows:

```
<gmd:MD_Metadata>
   <gmd:dataQualityInfo>
        <gmd:DQ_DataQuality>

        </gmd:DQ_DataQuality>
   </gmd:dataQualityInfo>
</gmd:MD_Metadata>
```

And inside the DQ_DataQuality element is where a specific quality facet (for example DQ_AbsoluteExternalPositionalAccuracy or DQ_QuantitativeAttributeAccuracy) will be documented.

Examples for each one of the quality indicators needed, identified in the bilateral meetings, are documented in section 5.1.3. As above mentioned, the XML code parts must be placed inside de DQ_DataQuality tag.

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5.1.3 Examples

This section contains specific examples for the XML encoding of the quality indicators list detected during the bilateral meetings. When possible, for each metric it also contains a link to its QualityML definition and coding example.

As explained in previous sections, this information is codified within the <gmd:DQ_DataQuality> in the metadata XML file. All the measures exemplified in this section are describing the ones needed by the pilots, according to bilateral meetings. All of them include a quality report (<gmd:report>) describing quality measures for the Accuracy of a Quantitative Attribute (<gmd:DQ_QuantitativeAttributeAccuracy>), for example the soil organic carbon sequestration predictions in pilot 2, the atmospheric pollutant concentration in pilot 3 or the drought severity for pilot 5.

For each quality report, the elements that need to be defined are:

- Name of the measure: for example "*Root Mean Square Error*" (in <gmd:nameOfMeasure>)
- Measure identification: using an identifier, and when possible linking to a quality measures registry such as QualityML (<gmd:measureIdentification> <gmd:MD_Identifier>), for example "*https://www.qualityml.org/pp1.0/measure/ QuantitativeAttributeCorrectness?domain=DifferentialErrors1D*"
- Result of the of report: usually using a quantitative result (<gmd:result>), for which several elements need to be defined:
    - Value type: describing the type of value for the quantitative result (in <gmd:valueType>), and including related information such as the range, for example *"Double precision real (range=[-1,1])"*
    - Value units (optional): describing the units for the specific measure (<gmd:valueUnit>) when needed. In the examples, different types of units have been used to show the particularities of the XML encoding in each case. See Appendix E for more information about documenting units.
    - Error Statistic: the name of the specific metric used for the measure, if possible a reference to the QualityML (<gmd:errorStatistic>), for example "*https://www.qualityml.org/1.0/metrics/RootMeanSquareError*".
    - Value: the calculated value of the specific measure.

The tables below describe these main elements for the different quality measures extracted from the bilateral meetings in a summarized way. The complete XML codification for each of the quality measures (combining the specific content in the table with the XML elements cited below) can be found in Appendix D.

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5.1.3.1 **Root Mean Square Error (RMSE):**

Table 5. XML main elements documenting Root Mean Square Error.

Root Mean Square Error (RMSE)		
Name of the measure		Root Mean Square Error
Measure identification	Identifier	https://www.qualityml.org/1.0/measure/RootMeanSquare?domain=DifferentialErrors1D
	Description	RootMeanSquare,DifferentialErrors1D
Result of the report	Value type (e.g)	Double precision real
	Units (e.g)	ppm
	Error Statistic	https://www.qualityml.org/1.0/metrics/RootMeanSquareError
	Value (e.g)	51.2

5.1.3.2 **Correlation Coefficient (r):**

Table 6. XML main elements documenting Correlation Coefficient.

Correlation Coefficient (r)		
Name of the measure		Quantitative Attribute Correctness (Correlation coefficient)
Measure identification	Identifier	https://www.qualityml.org/1.0/measure/QuantitativeAttributeCorrectness?domain=DifferentialErrors1D
	Description	QuantitativeAttributeCorrectness,DifferentialErrors1D
Result of the report	Value type (e.g)	Double precision real (range = [-1, 1])
	Units (e.g)	-
	Error Statistic	https://www.qualityml.org/1.0/metrics/Correlation
	Value (e.g)	0.32

5.1.3.3 **Nash-Sutcliffe model efficiency coefficient (NSE):**

Table 7. XML main elements documenting Nash-Sutcliffe model efficiency coefficient.

Nash-Sutcliffe model efficiency coefficient (NSE)		
Name of the measure		Quantitative Attribute Correctness (Nash–Sutcliffe model efficiency coefficient)
Measure identification	Identifier	https://www.qualityml.org/1.0/measure/QuantitativeAttributeCorrectness?domain=PredictedValues, ActualValues
	Description	QuantitativeAttributeCorrectness,PredictedValues,ActualValues
Result of the report	Value type (e.g)	Double precision real (max=1)
	Units (e.g)	-
	Error Statistic	https://www.qualityml.org/1.0/metrics/CoefficientOfDetermination
	Value (e.g)	0.9

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5.1.3.4 **Mean Absolute Error (MAE):**

Table 8. XML main elements documenting Mean Absolute Error.

Mean Absolute Error (MAE)		
Name of the measure		Mean Absolute Error (MAE)
Measure identification	Identifier	https://www.qualityml.org/1.0/measure/MeanAbsoluteError?domain=DifferentialErrors1D
	Description	MeanAbsoluteError,DifferentialErrors1D
Result of the report	Value type (e.g)	Double precision real
	Units (e.g)	kg/m^2
	Error Statistic	https://www.qualityml.org/1.0/metrics/MeanAbsolute
	Value (e.g)	0.25

5.1.3.5 **Mean Squared Error (MSE):**

Table 9. XML main elements documenting Mean Squared Error.

Mean Squared Error (MSE)		
Name of the measure		Mean Squared Error (MSE)
Measure identification	Identifier	https://www.qualityml.org/1.0/measure/RootMeanSquare?domain=DifferentialErrors1D
	Description	MeanSquaredError,DifferentialErrors1D
Result of the report	Value type (e.g)	Double precision real
	Units (e.g)	m^2
	Error Statistic	https://www.qualityml.org/1.0/metrics/MeanSquaredError
	Value (e.g)	3.2

5.1.3.6 **Mean Absolute Percentage Error (MAPE):**

Table 10. XML main elements documenting Mean Absolute Percentage Error.

Mean Absolute Percentage Error (MAPE)		
Name of the measure		Mean absolute error (Mean Absolute Percentage Error, MAPE)
Measure identification	Identifier	https://www.qualityml.org/1.0/measure/MeanAbsoluteError?domain=DifferentialErrors1D,ActualValues
	Description	Quantitative attribute accuracy,DifferentialErrors1D,ActualValues
Result of the report	Value type (e.g)	Double precision real (max=100)
	Units (e.g)	-
	Error Statistic	https://www.qualityml.org/1.0/metrics/MeanAbsolutePercentageError
	Value (e.g)	2.12

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5.1.3.7 Coefficient of Determination – R^2:

Table 11. XML main elements documenting Coefficient of Determination.

Coefficient of Determination – R^2		
Name of the measure		Quantitative Attribute Correctness (Coefficient of Determination)
Measure identification	Identifier	https://www.qualityml.org/1.0/measure/QuantitativeAttributeCorrectness?domain=DifferentialErrors1D
	Description	QuantitativeAttributeCorrectness,DifferentialErrors1D
Result of the report	Value type (e.g)	Double precision real (max=1)
	Units (e.g)	-
	Error Statistic	https://www.qualityml.org/1.0/metrics/CoefficientOfDetermination
	Value (e.g)	0.85

5.1.3.8 Spatialized uncertainty:

Table 12. XML main elements documenting Spatialized Uncertainty.

Spatialized uncertainty		
Name of the measure		Spatialized RMS
Measure identification	Identifier	-
	Description	-
Result of the report	Value type (e.g)	link
	Units (e.g)	m
	Error Statistic	-
	Value (e.g)	Path\To\File\RMS.TIFF

5.2 Geospatial User Feedback

During task 4.3, improvement have been to NiMMbus Geospatial User Feedback system. This section briefly describes these changes in the first place, and then describes the recommendations on how to connect NiMMbus system to any catalogue or portal, for the pilots to be able to integrate it.

5.2.1 Additional functionalities in NiMMbus system

Several additional functionalities have been added to the NiMMbus system, and they are briefly described in this section.

a) Improvement on the documentation: first version of the NiMMbus help, mainly describing user-feedback elements has been produced. Besides the general button to open the help, several direct links to specific content have been added

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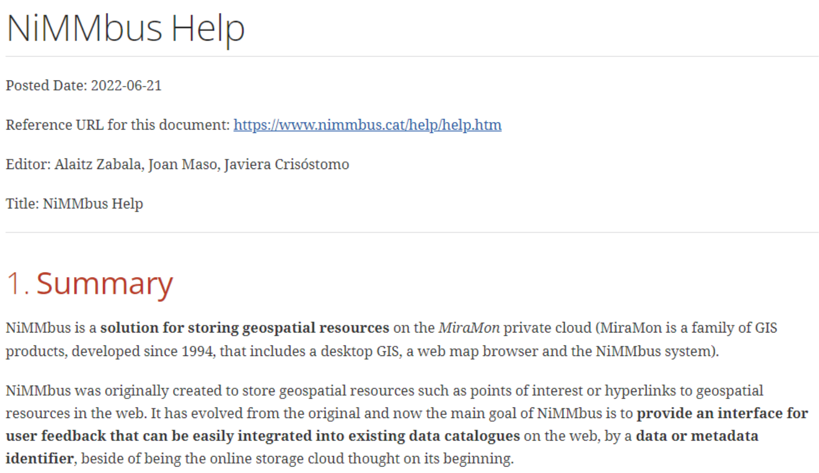
NiMMbus Help

Posted Date: 2022-06-21

Reference URL for this document: https://www.nimmbus.cat/help/help.htm

Editor: Alaitz Zabala, Joan Maso, Javiera Crisóstomo

Title: NiMMbus Help

1. Summary

NiMMbus is a **solution for storing geospatial resources** on the *MiraMon* private cloud (MiraMon is a family of GIS products, developed since 1994, that includes a desktop GIS, a web map browser and the NiMMbus system).

NiMMbus was originally created to store geospatial resources such as points of interest or hyperlinks to geospatial resources in the web. It has evolved from the original and now the main goal of NiMMbus is to **provide an interface for user feedback that can be easily integrated into existing data catalogues** on the web, by a **data or metadata identifier**, beside of being the online storage cloud thought on its beginning.

Figure 14. Updated NiMMbus help

b) Connection to new Single-Sign-On systems (SSO): to make NiMMbus interoperable with EIFFEL tools, the same SSO needs to be implemented. First of all, the NextGEOSS catalogue, also part of EIFFEL environment now, has changed its SSO system, so NiMMbus has been updated to properly connect to it. Moreover, Authenix SSO system has also been added, as it is a widely-use SSO system connected to eduGain and thus with many identity providers.

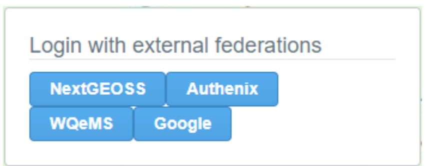

Figure 15. Single-Sign-on systems connected to NiMMbus

c) Extension to define spatial extent of a feedback item: sometimes, a user wants to provide feedback for a specific spatial subset in a dataset, for example to indicate in which area the problem of a dataset exists. The spatial extent for each target has been included in the NiMMbus system implementation. Moreover, the widget functionality is going to be extended to allow creation of a feedback item for a spatial subset of a dataset.

5.2.2 Recommendations to integrate NiMMbus system

This section summarizes the widget integration options for the NiMMbus system. There are other integration options (using Javascript and the NiMMbus Web API) which provide full control on how the content is shown in the screen, but require considerable more knowledge on JavaScript programming, including XML parsing and AJAX calls. This is Way the widget option is the recommended for most of the cases in general and for the EIFFEL pilots. Detailed information on all integration options can be found in https://github.com/grumets/nimmbus/tree/master/GUF_integration.

This section provides a general overview for the GUF integration with a pilot and its resources. They can be part of a catalogue or can be individual web pages. A "resource" can

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be anything that has an identifier in the web. Nevertheless, it is expected that your resources have some spatial component.

To be able to start working with the integration, each resources need to be uniquely identified in the system using a "code" (a.k.a. an identifier). Only identified resources can be associated to feedback items. This "code" needs to be unique in a "codespace". The combination of "code" and "codespace" should provide an identifier that can be considered unique and global. If you do not use the concept of "codespace" or "namespace", we recommend that you use the URL of your web service as the "codespace". Generally, the "codespace" is common to all your resources and can be hardcoded in your application.

There are three steps to integrate the widget. The first one is to include the JavaScript library in the HTML page, the second one to create a division or a window to contain the feedback, and finally to fill in the division (or window) with the widget. There are several options depending on the type of feedback that wants to be provided:

- Option 1: Feedback about a single primary target: is the easiest function to be integrated and allows to create feedback related to a single primary target, using the function *GUFShowFeedbackInHTMLDiv()*. This option can be tested in https://www.nimmbus.cat/test_widget.htm.
- Option 2: Feedback about multiple targets: in this case the function allows to define more than one target (at least one of them with a “primary” role), for example with a dataset as primary target and the dataset collection to which it belongs as secondary target. The function in this case is *GUFShowFeedbackMultipleTargetsInHTMLDiv()* and can be tested in https://www.nimmbus.cat/test_widget_multitarget.htm.
- Option 3: Feedback including reproducible usage: this option is the more advanced one. In this case, typically a portal uses user feedback to store and retrieve user feedback items including reproducible usage in a two steps process: creating the feedback items that include reproducible usage and retrieving those feedback items, for another user to apply them. For example, a portal can allow users to create new styles for the dataset, and thus another user can retrieve and apply a style defined by someone else.

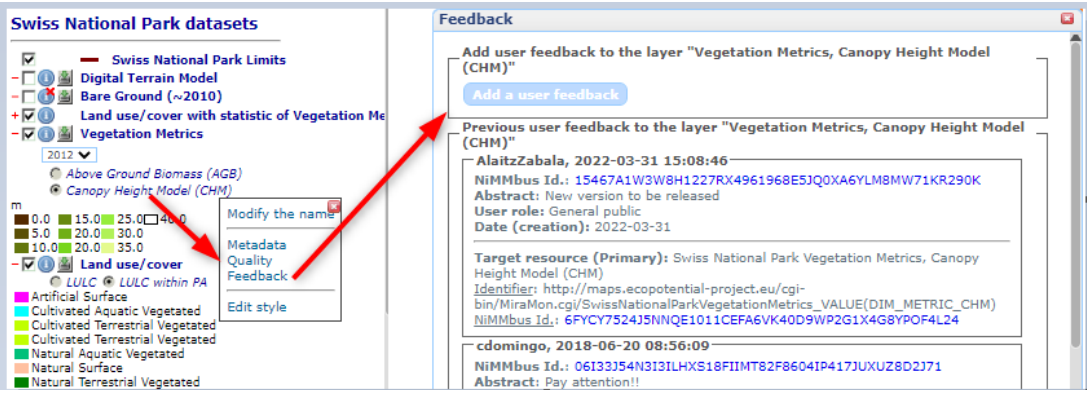

Figure 16. Example of widget integration for a single target (option 1)

Most of the pilots may create a single integration on their portals, and some of them may allow for reproducible usage as well.

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6 Conclusions and Future Work

The co-design workshop, the surveys and the bilateral meetings showed up that it is necessary to make a communicative effort to make the community understand the importance of metadata documentation. Currently, the general vision on this topic seems to be that metadata requires a great effort and does not report many benefits for producers. It must be understood that metadata documentation not only may help data producers to make their data more visible but the general scientific community to reproduce processes, take better decisions when using third party data, etc.

On the other hand, due to the early state of much of the Pilot's, the recommendations given in section 4 may be revisited in a near future: as the discrepancies between the co-design workshop and the bilateral meetings show (in terms of quality indicators to be used), it is still possible that changes in the products specifications vary their quality validation processes and some new metrics will be needed.

Moreover, although the responses to the surveys showed that there is a producer's interest on implementing Geospatial User Feedback systems, at this moment in most cases there is no information as how these products will be distributed (web map server, direct download, etc.).

For these reasons, it is intended to plan follow-up meetings with the different Pilot managers in order improve the quality metadata implementation when more specific information for each pilot case is available and apply GUF systems (based on NiMMbus) when possible.

Furthermore, as the only feedback we have received said, it seems necessary that at some point of the project execution a meeting with WP3 leaders will be necessary to exchange information about what we all have learned along our tasks.

Finally, an effort for updating tools to make metadata documentation and GUF more accessible for the public may be done as well as trying to use the lasts versions of the ISO standards whenever it is possible. In these sense, UAB team will continue developing the GeM+ tools and NiMMbus GUF platform.

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7 Normative references

[1] ISO. (2003). ISO 19115:2003: Geographic information — Metadata. Retrieved from https://www.iso.org/standard/26020.html

[2] ISO. (2009). ISO 19115-2:2009: Geographic information — Metadata — Part 2: Extensions for imagery and gridded data. Retrieved from https://www.iso.org/standard/39229.html

[3] ISO. (2012). ISO/TS 19139-2:2012: Geographic information — Metadata — XML schema implementation — Part 2: Extensions for imagery and gridded data. Retrieved from https://www.iso.org/standard/57104.html

[4] ISO. (2013). ISO 19157:2013 Geographic information — Data quality. Retrieved from https://www.iso.org/standard/32575.html

[5] ISO. (2014). ISO 19115-1:2014: Geographic information — Metadata — Part 1: Fundamentals. Retrieved from https://www.iso.org/standard/53798.html

[6] ISO. (2016). ISO/TS 19115-3:2016: Geographic information — Metadata — Part 3: XML schema implementation for fundamental concepts. Retrieved from https://www.iso.org/standard/32579.html

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Appendix A. Main concepts about Data Quality, on Data Quality Co-design Workshop pre-event.

Introduction: approaches for data quality

Producers' metadata

a. Data quality dimensions and definition
b. Data quality elements and estimation
c. Quality measures and QualityML
d. Strategy to produce data quality metadata
e. How to encode data quality?
f. How to know whether data is fit for purpose in the frontend?
g. Metadata in workflows
h. What we need to discover together in the co-design session?

Users' metadata

i. Geospatial user feedback (GUF) overview
j. How to know whether data has user feedback in the frontend?
k. How NiMMbus (GUF system) works?
l. Relation to GEOSS Knowledge Hub
m. Reproducible usage
n. What we need to discover together in the co-design session?

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Appendix B. Data Quality Survey, sent to EIFFEL members

Registration and questionnaire to prepare properly the data quality co- design event

You are providing personal information for the sole purpose of registering for the Data Quality Co-Design Event. Your personal data will not be used for other purposes.
The results of this survey will only be presented to others as general and anonymous tables.

To prepare for the meeting, consider adopting active participation, as it needs to be run as a co-design meeting, which requires more participation from attendees than organizers. Answering this survey takes 5 minutes of your time. Thank you very much in advance.

Personal data

1. Name and surname

___

2. Institution

___

3. Email

___

Data Quality from producer's point of view

This section is looking to collect information about your experience as a data producer and the quality data measures

1. I work directly in the following pilot cases (select all needed):

   - ☐ Pilot 1: Water and Land-Use Management
   - ☐ Pilot 2: Sustainable Agriculture
   - ☐ Pilot 3: Infrastructure and Transport Management
   - ☐ Pilot 4: Sustainable Urban Development
   - ☐ Pilot 5: Disaster Resilience: Drought, forest fire and pest risk assessment

2. I provide modeling tools for the following pilot cases (select all needed):

   - ☐ Pilot 1: Water and Land-Use Management
   - ☐ Pilot 2: Sustainable Agriculture
   - ☐ Pilot 3: Infrastructure and Transport Management
   - ☐ Pilot 4: Sustainable Urban Development
   - ☐ Pilot 5: Disaster Resilience: Drought, forest fire and pest risk assessment Regional/National Scale

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3. Describe the data that you or your model is producing:

4. Have you ever elaborated a quality report of your data and/or product? In that case, can you provide us the URL to it?

5. What are your main problems with data quality (select a maximum of 3):

- ☐ Assess data quality Produce a quality report
- ☐ Document quality in metadata Compare products with different quality
- ☐ Evaluate if a product has enough data quality for my purpose Understand data quality indicators
- ☐ Find a list of data quality indicators I can use
- ☐ Select the appropriate data quality indicators/measures
- ☐ Other: ______

6. Would you like to present a product and the data quality procedure used to elaborate it? Would you like to present any other data quality related topic? Please write a brief description of your presentation and the time you will need for presenting it (maximum 12 minutes). Your participation is IMPORTANT for the success of the co-design event.

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About GEOSS platform

This part of the survey seeks to collect information about your experienceas a user of the GEOSS platform and the GEOSS Knowledge Hub

1. Have you ever used the GEO Portal to discover and use data? What is your experience about it? Choose one option.

   - No
   - Yes, but did not find anything useful
   - Yes, but was difficult to compare datasets
   - Yes, but I did not find any quality information on the selected product
   - Yes, I found the metadata and the data quality, but I could not access to the data Yes, it was a perfect experience
   - Other: ______

2. Have you ever used the GEOSS Knowledge Hub? What do you think about it?

3. In your opinion, what is missing in the GEOSS Knowledge Hub? Choose one option.

   - A connection to scientific publications
   - A connection to policy briefs
   - A collaborative and incremental system related to the original data
   - Other: ______

GUF and Data Quality: users' point of view

The next questions are focused on your experience as auser generating GUF and your opinion about it

1. About the data you use, do you normally have comments or considerations that could be provided as feedback? Choose one option.

   - Yes
   - No
   - I don't know / I have no answer

2. Would you like to give feedback if the data portal provides the necessary interface? Choose one option.

   - Yes
   - No
   - I don't know / I have no answer

3. Do you believe feedback could be useful for: (select all needed)

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- ☐ Producers
- ☐ Other users
- ☐ None of them
- ☐ I'm not willing to spend time in giving feedback

4. What kind of feedback could you provide? (select all needed)

- ☐ Rating
- ☐ Comments
- ☐ Question
- ☐ Issue reports
- ☐ Workarounds
- ☐ Quality report
- ☐ Usage reports
- ☐ Significant events
- ☐ Conclusions and knowledge gained

5. Can you provide an example of the feedback you could produce to an exemplary dataset?

---

6. Are you open to receive feedback on your data? Choose one option.

- ◯ Yes
- ◯ No
- ◯ I don't know / I have no answer

7. Are you willing to reply to feedback provided by your users? Choose one option.

- ◯ Yes
- ◯ No
- ◯ I don't know / I have no answer

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8. What do you think that could motivate the users of your data/product to provide feedback? (Select all needed)

- [ ] Get responses to the comments or contributions
- [ ] Altruism
- [ ] Recognition as expert
- [ ] Reward
- [ ] Competition
- [ ] Other: ______

Thank you very much for your answers and your time!
See you again on May 20th at 10:00 CEST.Have a nice day!

Formularies Google

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Appendix C. Data Quality Co-design Workshop - Satisfaction Survey

This is an anonymous questionary to obtain your feedback about the Data Quality Co-Design Event. Your personal data will not be saved.

The results of this survey will only be for the knowledge of the organizing team and will not be shared with others.

Answering this survey takes less than 5 minutes of your time. We ask you to answer this survey as soon as possible, so that you remember more details that could be good inputs for future events organized by the UAB team.

Thank you very much in advance.

Your opinion about the Co-Design Workshop on May 20th

1. Have your expectations of the co-design workshop been fulfilled? Choose only one.

	1	2	3	4	
No, not at all	◯	◯	◯	◯	Yes, completely

2. What did you like most about the co-design workshop?

3. What did you like least about the co-design workshop?

4. Do you have any comments or recommendations for future events?

Thank you very much for attending to the co-design workshop

and for giving us your feedback about it

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Appendix D. Complete XML Quality encoding examples

This section contains specific examples for the XML encoding of the quality indicators list detected during the bilateral meetings. When possible, for each metric it also contains a link to its QualityML specification and coding example.

- **Root Mean Square Error (RMSE):**
  QualityML: https://www.qualityml.org/1.0/metrics/RootMeanSquareError

```
<gmd:report>
   <gmd:DQ_QuantitativeAttributeAccuracy>
        <gmd:nameOfMeasure>
             <gco:CharacterString>Root Mean Square Error</gco:CharacterString>
        </gmd:nameOfMeasure>
        <gmd:measureIdentification>
             <gmd:MD_Identifier>
                  <gmd:code>
                       <gmx:Anchor
xlink:href="https://www.qualityml.org/1.0/measure/RootMeanSquare?domain=DifferentialErrors1D">
   RootMeanSquare,DifferentialErrors1D
                       </gmx:Anchor>
                  </gmd:code>
             </gmd:MD_Identifier>
        </gmd:measureIdentification>
        <gmd:result>
             <gmd:DQ_QuantitativeResult>
                  <gmd:valueType>
                       <gco:RecordType>Double precision real</gco:RecordType>
                  </gmd:valueType>
                  <gmd:valueUnit>
                       <gml:DerivedUnit gml:id="DerivedUnit_1">
                            <gml:identifier codeSpace="urn:ogc:def:uom:UCUM">ppm</gml:identifier>
                            <gml:derivationUnitTerm uom="1">10*-6
                            </gml:derivationUnitTerm>
```


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```xml
                    </gml:DerivedUnit>
                </gmd:valueUnit>
                <gmd:errorStatistic>
                    <gco:CharacterString>
                        https://www.qualityml.org/1.0/metrics/RootMeanSquareError
                    </gco:CharacterString>
                </gmd:errorStatistic>
                <gmd:value>
                    <gco:Record>51.2</gco:Record>
                </gmd:value>
            </gmd:DQ_QuantitativeResult>
        </gmd:result>
    </gmd:DQ_QuantitativeAttributeAccuracy>
</gmd:report>
```

- **Correlation coefficient (r):**
  QualityML: https://www.qualityml.org/1.0/metrics/Correlation

```xml
<gmd:report>
    <gmd:DQ_QuantitativeAttributeAccuracy>
        <gmd:nameOfMeasure>
            <gco:CharacterString>Quantitative Attribute Correctness (Correlation coefficient)
            </gco:CharacterString>
        </gmd:nameOfMeasure>
        <gmd:measureIdentification>
            <gmd:MD_Identifier>
                <gmd:code>
                    <gmx:Anchor
                xlink:href="https://www.qualityml.org/1.0/measure/QuantitativeAttributeCorrectness?domain=Diff
                erentialErrors1D">
                        QuantitativeAttributeCorrectness,DifferentialErrors1D
                    </gmx:Anchor>
                </gmd:code>
            </gmd:MD_Identifier>
```


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```
        </gmd:measureIdentification>
        <gmd:result>
              <gmd:DQ_QuantitativeResult>
                    <gmd:valueType>
                          <gco:RecordType>Double precision real (range=[-1,1])</gco:RecordType>
                    </gmd:valueType>
                    <gmd:valueUnit/>
                    <gmd:errorStatistic>
                          <gco:CharacterString>
                                https://www.qualityml.org/1.0/metrics/Correlation
                          </gco:CharacterString>
                    </gmd:errorStatistic>
                    <gmd:value>
                          <gco:Record>0.32</gco:Record>
                    </gmd:value>
              </gmd:DQ_QuantitativeResult>
        </gmd:result>
  </gmd:DQ_QuantitativeAttributeAccuracy>
</gmd:report>
```

- **Nash-Sutcliffe model efficiency coefficient (NSE):**
  QualityML: https://www.qualityml.org/1.0/metrics/CoefficientOfDetermination

```
<gmd:report>
  <gmd:DQ_QuantitativeAttributeAccuracy>
        <gmd:nameOfMeasure>
              <gco:CharacterString>Quantitative Attribute Correctness (Nash-Sutcliffe model efficiency coefficient)
              </gco:CharacterString>
        </gmd:nameOfMeasure>
        <gmd:measureIdentification>
              <gmd:MD_Identifier>
                    <gmd:code>
```


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```
                        <gmx:Anchor
xlink:href="https://www.qualityml.org/1.0/measure/QuantitativeAttributeCorrectness?domain=PredictedValues,
ActualValues">
                            QuantitativeAttributeCorrectness,PredictedValues,ActualValues
                        </gmx:Anchor>
                    </gmd:code>
                </gmd:MD_Identifier>
            </gmd:measureIdentification>
            <gmd:result>
                <gmd:DQ_QuantitativeResult>
                    <gmd:valueType>
                        <gco:RecordType>Double precision real (max=1)</gco:RecordType>
                    </gmd:valueType>
                    <gmd:valueUnit/>
                    <gmd:errorStatistic>
                        <gco:CharacterString>
                            https://www.qualityml.org/1.0/metrics/CoefficientOfDetermination
                        </gco:CharacterString>
                    </gmd:errorStatistic>
                    <gmd:value>
                        <gco:Record>0.9</gco:Record>
                    </gmd:value>
                </gmd:DQ_QuantitativeResult>
            </gmd:result>
        </gmd:DQ_QuantitativeAttributeAccuracy>
    </gmd:report>
```

- **Mean Absolute Error (MAE):**
  QualityML: https://www.qualityml.org/1.0/metrics/MeanAbsolute

```
    <gmd:report>
        <gmd:DQ_QuantitativeAttributeAccuracy>
            <gmd:nameOfMeasure>
                <gco:CharacterString>Mean Absolute Error (MAE)</gco:CharacterString>
```

```xml
        </gmd:nameOfMeasure>
        <gmd:measureIdentification>
            <gmd:MD_Identifier>
                <gmd:code>
                    <gmx:Anchor
xlink:href="https://www.qualityml.org/1.0/measure/MeanAbsoluteError?domain=DifferentialErrors1D">
                        MeanAbsoluteError,DifferentialErrors1D
                    </gmx:Anchor>
                </gmd:code>
            </gmd:MD_Identifier>
        </gmd:measureIdentification>
        <gmd:result>
            <gmd:DQ_QuantitativeResult>
                <gmd:valueType>
                    <gco:RecordType>Double precision real</gco:RecordType>
                </gmd:valueType>
                <gmd:valueUnit>
                    <gml:ConventionalUnit gml:id="ConventionalUnit1">
                        <gml:identifier codeSpace="urn:ogc:def:uom:UCUM">kg/m2</gml:identifier>
                        <gml:conversionToPreferredUnit uom="m-3*g">
                            <gml:factor>1000000</gml:factor>
                        </gml:conversionToPreferredUnit>
                    </gml:ConventionalUnit>
                </gmd:valueUnit>
                <gmd:errorStatistic>
                    <gco:CharacterString>
                        https://www.qualityml.org/1.0/metrics/MeanAbsolute
                    </gco:CharacterString>
                </gmd:errorStatistic>
                <gmd:value>
                    <gco:Record>0.25</gco:Record>
                </gmd:value>
            </gmd:DQ_QuantitativeResult>
        </gmd:result>
```


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```
    </gmd:DQ_QuantitativeAttributeAccuracy>
  </gmd:report>
```

- **Mean Squared Error (MSE):**
  QualityML: https://www.qualityml.org/1.0/metrics/MeanSquaredError

```
  <gmd:report>
    <gmd:DQ_QuantitativeAttributeAccuracy>
        <gmd:nameOfMeasure>
            <gco:CharacterString>MSE</gco:CharacterString>
        </gmd:nameOfMeasure>
        <gmd:measureIdentification>
            <gmd:MD_Identifier>
                <gmd:code>
                    <gmx:Anchor
xlink:href="https://www.qualityml.org/1.0/measure/RootMeanSquare?domain=DifferentialErrors1D">
                        MeanSquaredError,DifferentialErrors1D
                    </gmx:Anchor>
                </gmd:code>
            </gmd:MD_Identifier>
        </gmd:measureIdentification>
        <gmd:result>
            <gmd:DQ_QuantitativeResult>
                <gmd:valueType>
                    <gco:RecordType>Double precision real</gco:RecordType>
                </gmd:valueType>
                <gmd:valueUnit>
                    <gml:ConventionalUnit gml:id="ConventionalUnit5">
                        <gml:identifier codeSpace="urn:ogc:def:uom:UCUM">m2</gml:identifier>
                            <gml:conversionToPreferredUnit uom="m2">
                                <gml:factor>1</gml:factor>
                            </gml:conversionToPreferredUnit>
                        </gml:ConventionalUnit>
                    </gmd:valueUnit>
```


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```
                <gmd:errorStatistic>
                        <gco:CharacterString>
                            https://www.qualityml.org/1.0/metrics/MeanSquaredError
                        </gco:CharacterString>
                </gmd:errorStatistic>
                <gmd:value>
                    <gco:Record>3.2</gco:Record>
                </gmd:value>
        </gmd:DQ_QuantitativeResult>
    </gmd:result>
  </gmd:DQ_QuantitativeAttributeAccuracy>
</gmd:report>
```

- **Mean Absolute Percentage Error (MAPE):**
  QualityML: https://www.qualityml.org/1.0/metrics/MeanAbsolutePercentageError

```
<gmd:report>
  <gmd:DQ_QuantitativeAttributeAccuracy>
      <gmd:nameOfMeasure>
          <gco:CharacterString>Mean absolute error (Mean Absolute Percentage Error, MAPE)</gco:CharacterString>
      </gmd:nameOfMeasure>
      <gmd:measureIdentification>
          <gmd:MD_Identifier>
              <gmd:code>
                  <gmx:Anchor
xlink:href="https://www.qualityml.org/1.0/measure/MeanAbsoluteError?domain=DifferentialErrors1D,ActualValues">
                      Quantitative attribute accuracy,DifferentialErrors1D,ActualValues
                  </gmx:Anchor>
              </gmd:code>
          </gmd:MD_Identifier>
      </gmd:measureIdentification>
      <gmd:result>
          <gmd:DQ_QuantitativeResult>
              <gmd:valueType>
```


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```xml
                <gco:RecordType>Double precision real (max=100)</gco:RecordType>
            </gmd:valueType>
            <gmd:valueUnit/>
            <gmd:errorStatistic>
                <gco:CharacterString>
                    https://www.qualityml.org/1.0/metrics/MeanAbsolutePercentageError
                </gco:CharacterString>
            </gmd:errorStatistic>
            <gmd:value>
                <gco:Record>2.12</gco:Record>
            </gmd:value>
        </gmd:DQ_QuantitativeResult>
    </gmd:result>
  </gmd:DQ_QuantitativeAttributeAccuracy>
</gmd:report>
```

- **Coefficient of Determination - R^2:**
  QualityML: https://www.qualityml.org/1.0/metrics/CoefficientOfDetermination

```xml
<gmd:report>
  <gmd:DQ_QuantitativeAttributeAccuracy>
    <gmd:nameOfMeasure>
        <gco:CharacterString>
                Quantitative Attribute Correctness (Coefficient of Determination)
        </gco:CharacterString>
    </gmd:nameOfMeasure>
    <gmd:measureIdentification>
        <gmd:MD_Identifier>
            <gmd:code>
                <gmx:Anchor
            xlink:href="https://www.qualityml.org/1.0/measure/QuantitativeAttributeCorrectness?domain=Diff
            erentialErrors1D">
                QuantitativeAttributeCorrectness,DifferentialErrors1D
                </gmx:Anchor>
```


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```
                </gmd:code>
            </gmd:MD_Identifier>
        </gmd:measureIdentification>
        <gmd:result>
            <gmd:DQ_QuantitativeResult>
                <gmd:valueType>
                    <gco:RecordType>Double precision real (max=1)</gco:RecordType>
                </gmd:valueType>
                <gmd:valueUnit/>
                <gmd:errorStatistic>
                    <gco:CharacterString>
                        https://www.qualityml.org/1.0/metrics/CoefficientOfDetermination
                    </gco:CharacterString>
                </gmd:errorStatistic>
                <gmd:value>
                    <gco:Record>0.85</gco:Record>
                </gmd:value>
            </gmd:DQ_QuantitativeResult>
        </gmd:result>
    </gmd:DQ_QuantitativeAttributeAccuracy>
</gmd:report>
```

- **Spatialized uncertainty:**

```
<gmd:report>
    <gmd:DQ_QuantitativeAttributeAccuracy>
        <gmd:nameOfMeasure>
            <gco:CharacterString>Spatialized RMS</gco:CharacterString>
        </gmd:nameOfMeasure>
        <gmd:result>
            <gmd:DQ_QuantitativeResult>
                <gmd:valueType>
                    <gco:RecordType>link</gco:RecordType>
                </gmd:valueType>
```


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```
                <gmd:valueUnit xlink:href="https://www.isotc211.org/2005/resources/uom/ML_gmxUom.xml#m"/>
            <gmd:value>
                <gco:Record>Path\To\File\RMS.TIFF</gco:Record>
            </gmd:value>
        </gmd:DQ_QuantitativeResult>
    </gmd:result>
  </gmd:DQ_QuantitativeAttributeAccuracy>
</gmd:report>
```


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Appendix E. Documenting Units in XML

Following ISO standards structure, three basic types of units can be documented in an XM file:

a) Base units: unit of measure that cannot be derived by combination of other base units within a particular system of units. For example, metre, gram, second, Kelvin, radian, coulomb and candela.

Below, an example of XML section documenting a base unit:

```
<gml:BaseUnit gml:id="BaseUnit1">
      <gml:identifier codeSpace=
                  "urn:ogc:def:uom:UCUM">
                  s
            </gml:identifier>
      <gml:unitsSystem>
                  SI
            </gml:unitsSystem>
</gml:BaseUnit>
```

b) Conventional units: units used in many application domains that are neither base units nor defined by direct combination of base units. For example, electronVolt for energy, feet and nautical miles for length or any measure derived from an SI base unit such as kg, mg or Celsius degrees. In most cases there is a known, usually linear, conversion to a preferred unit which is either a base unit or derived by direct combination of base units.

The gml:ConventionalUnit extends gml:UnitDefinition with a property that describes a conversion to a preferred unit for this physical quantity. When the conversion is exact, the element gml:conversionToPreferredUnit should be used, or when the conversion is not exact the element gml:roughConversionToPreferredUnit is available. Both of these elements have the same content model. The gml:derivationUnitTerm property defined above is included to allow a user to optionally record how this unit may be derived from other ("more primitive") units.

Below, an example of XML section documenting a conventional unit:

```
<gml:ConventionalUnit gml:id="ConventionalUnit_1">
      <gml:identifier codeSpace="urn:ogc:def:uom:UCUM">
            kg
      </gml:identifier>
      <gml:conversionToPreferredUnit uom="g">
                  <gml:factor>
                        1000
                  </gml:factor>
```


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```
        </gml:conversionToPreferredUnit>
    </gml:ConventionalUnit>
```

Derived units: defined by combination of other units. Derived units are used for quantities other than those corresponding to the base units, such as Hertz (s^{-1}) for frequency, Newton ($kg*m/s^2$) for force. Derived units directly based on base units are usually preferred for quantities within a system. If a derived unit is not based on the preferred unit, the gml:ConventionalUnit element should be used instead.

The gml:DerivedUnit extends gml:UnitDefinition with the property gml:derivationUnitTerms.

Next, an example of XML section documenting a derived unit:

```
<gml:DerivedUnit gml:id="DerivedUnit1">
    <gml:identifier codeSpace="urn:ogc:def:uom:UCUM">
        s-1
    </gml:identifier>
    <gml:derivationUnitTerm uom="s">
        1
    </gml:derivationUnitTerm>
</gml:DerivedUnit>
```

An exhaustive list of typical units and its classification can be found here: https://ucum.org/ucum

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