Anthropogenic Water Use (CCI-AWU)

Deliverable 1:
User Requirement Document (URD) V.1

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The closure of the Earth's water cycle (as well as the energy balance and the carbon cycles) through satellite Earth Observation (EO) represents one of the outstanding scientific challenges highlighted by the Global Climate Observing System (GCOS). Required standards of accuracy are fixed to 5% and annual timescale. To this end, a suite of essential climate variables (ECvs) has been defined to understand the evolution of climate and to assess the potential derived risks. However, if targets at annual timescale can generally be reached, larger uncertainties are observed for sub-annual and sub-continental time and spatial scales, respectively (Dorigo et al., 2021; Rodell et al., 2015). In this context, the development of an ECV that includes the information on anthropogenic water use (AWU) can help in advancing the proper closure of the water cycle at higher spatial and temporal scales. In the ESA Climate Change Initiative Anthropogenic Water Use (CCI-AWU) precursor project, AWU is more specifically intended as agricultural water allocated for irrigation, which represents the largest anthropogenic water use, thus making irrigation being the most impactful human activity on the hydrological cycle. FAO (2016) estimated that irrigation, worldwide, accounts for more than 70% of water withdrawn from surface (i.e., rivers, lakes) and subsurface (i.e., groundwater) water sources and these estimates are expected to increase in the near future due to an increase in population and in food production, especially over arid and semi-arid regions (McDermid et al., 2023). In this context, the main data source identified by GCOS for tracking AWU is from FAO's AQUASTAT. However, AQUASTAT provides survey-based irrigation estimates which do not meet the GCOS requirements, i.e., data are provided on a 5-years interval instead of yearly and are available every 2-3 years.

The overarching objective of Climate Change Initiative – Anthropogenic Water Use (CCI-AWU) precursor project is to derive long-term (i.e., at least twenty years) AWU time series for selected regions using several approaches exploiting remote sensing observations, as a proof-of-concept of the feasibility towards a proper AWU ECV product.

The CCI-AWU project involves a consortium led by CNR-IRPI and comprises the following organisations:

1. Vienna University of Technology (TU Wien), hereinafter TUWIEN;
2. KULeuven, Department of Earth and Environmental Sciences, Division Soil and Water Management (KATHOLIEKE UNIVERSITEIT LEUVEN), hereinafter KULeuven;
3. University of Perugia (UNIVERSITY OF PERUGIA), hereinafter UNIPG
4. Politecnico di Milano (POLITECNICO DI MILANO), department of Civil and Environmental Engineering, hereinafter POLIMI

1.2 Scope of this report

This document aims at describing the efforts of the Consortium in order to create a strong network and connection with climate research and climate service user communities. In this context, a questionnaire was shared with climate scientists and the climate communities to gather their needs and feedback regarding a CCI AWU ECV. In this report (version 1 - V.1) results based on the first set of answers provided by scientists are reported: the report will be updated with a version 2 (V.2) version once a more consistent number of answers will allow more robust statistics.

1.3 Applicable Documents

- Proposal.

- Deliverable D2. Report explaining the criteria for selecting the test regions.

1.4 Document Organization

The document is organised as follows: first, the methodology applied to obtain information on user requirements, consisting of a questionnaire, is presented, then the results are discussed.

2. Methodology

To gain knowledge about the utility of a new ECV AWU and long-term AWU estimates among climate users we implemented a questionnaire which was distributed through the main social channels and to main companies/organisations focusing on climate research. The questionnaire has the following objectives:
1) understanding the background of the users, the scale of their applications as well as the target techniques used for their studies/services;
2) understanding to what extent users would be interested in the development of a new ECV AWU and in long-term AWU products developed within the CCI-AWU precursor project;
2) understanding the products, the users are mainly interested in as well as their associated requirements such as spatial and temporal resolution as well as the level of accuracy needed for the developed products;
4) relate their answers with the project activities to understand whether the scientific objectives of the project are in line with the climate user needs and whether the available instruments/techniques/algorithms are mature enough to reach the user requirements.
In **Sections 3** we report and discuss the questions and the users' answers, trying to find any relation with the activities foreseen in the project.
The climate users questionnaire is accessible via the following link:

https://docs.google.com/forms/d/e/1FAIpQLSd0Bo9tY9Q9hqAM6keT5cooBT4O3WYzlxIGGWxKxt3U8mY0bA/viewform?usp=sf_link

For now, we have only received 16 answers, but we are confident that additional contributions from the users will be provided in the next weeks-months.

3. Answers

3.1 Users' field and background

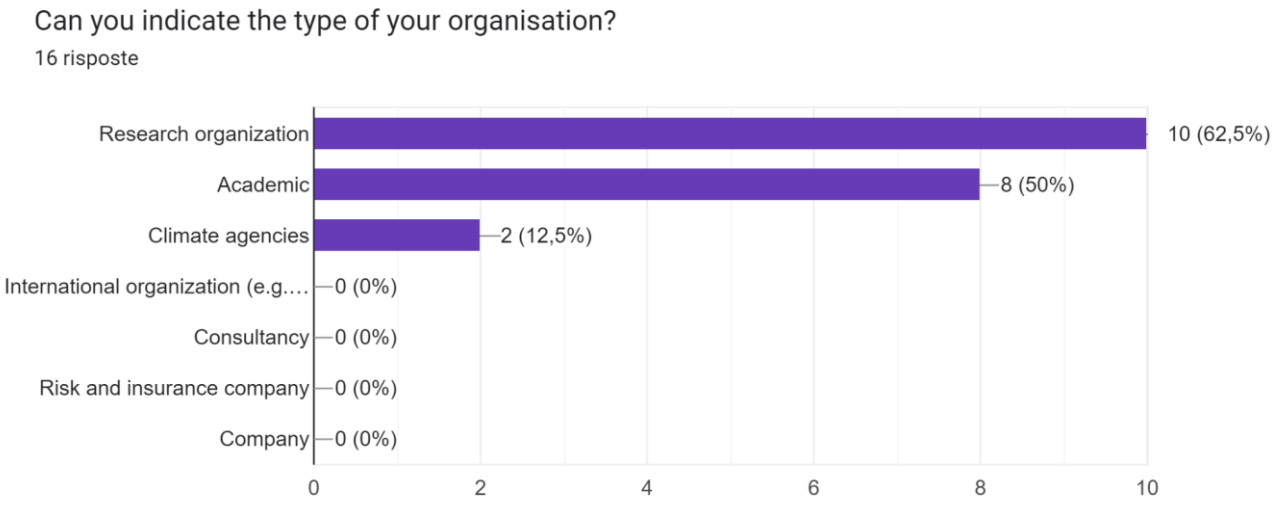


Figure 1. chart indicating the type of organisation of the contacted users

The chart in Figure 1 indicates that the majority of the reached organisations/users belong to research organisations (62.5%), while 50% consist of academic individuals, with only 12.5% connected to climate agencies. This highlights the need to strengthen our connections with climate agencies for V.2 of the D1 document. The largest group of respondents to the questionnaire are researchers (75%), followed by professors (18.8%), managers (12.5%), engineers, and product developers (both at 6.3%). Figure 2 provides an overview of the positions held by the users included in the statistics.

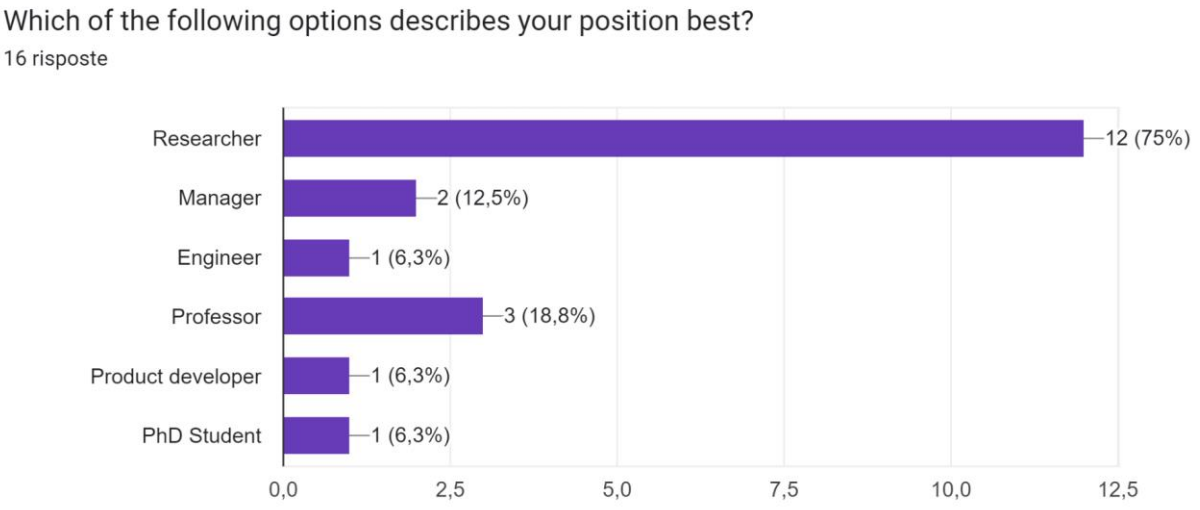


Figure 2. chart indicating the working position of the contacted users.

An additional question focused on the field describing the expertise of the contacted users. Figure 3 shows how the main expertise covers the field of drought and water resources (68.8 %), followed by agriculture (56.3%) and Land atmosphere interactions (43.8%). Climate modelling only covers the 25% of the users field followed by the carbon cycle (12.5%), food, extreme precipitation and irrigation/water conservation (all scored at 6.3%). For a more detailed description of the users' expertise the reader can refer to Figure 3.

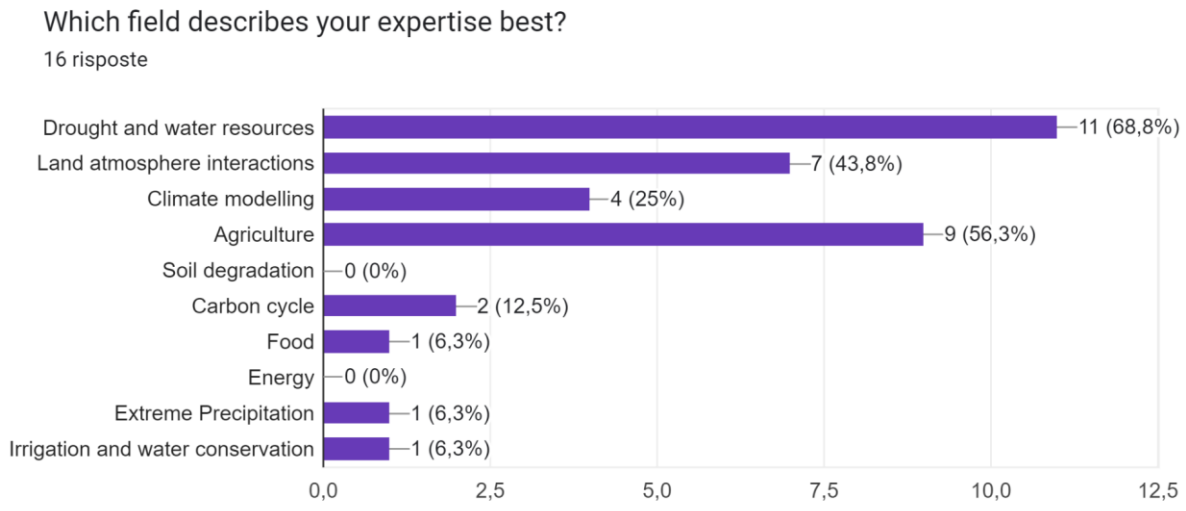


Figure 3. chart indicating the users expertise.

3.2 Scales and methodologies employed in users' applications

Based on the answers received on the scale of the applications carried out by the users we found that the highest percentage of the applications (56.3%) is on a regional scale (i.e., the Mediterranean basin). In contrast, 43.8% of users are engaged in applications on a broader continental or global scale which likely involve more complex and wide-ranging datasets and analyses. National/county scale studies account for 31.3% of applications. This finding suggests there is still significant interest and activity at the national level, albeit to a lesser extent. Based on Figure 4, it is interesting to note that the main part of the users utilises both modelling and remote sensing data in their application. This integrated approach aligns well with the project's objectives, which leverage satellite data alongside modelling methodologies and algorithm development to generate comprehensive and long-term datasets related to agricultural water use (AWU).

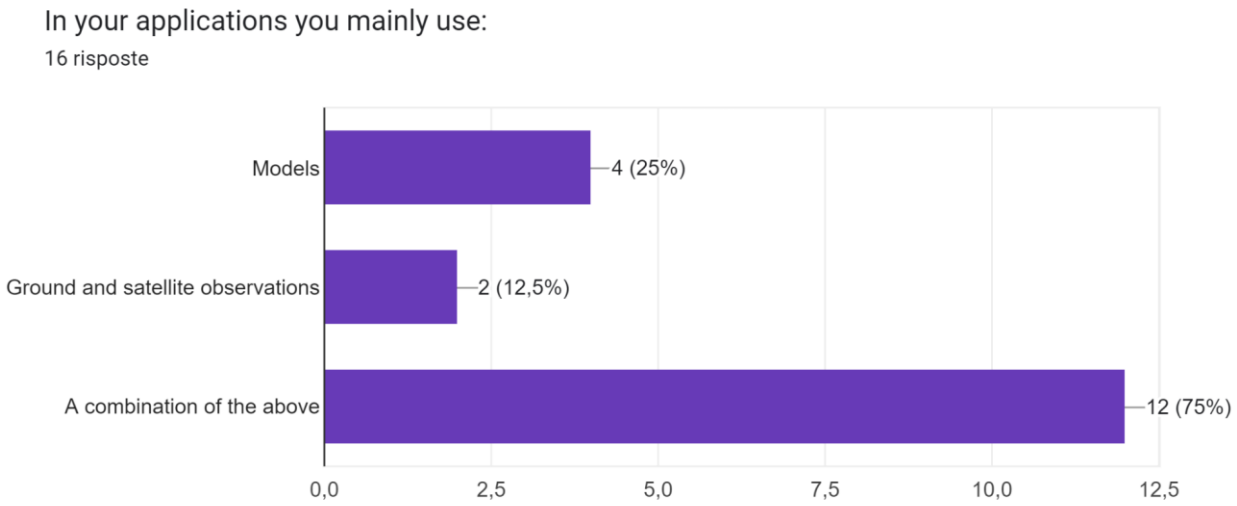


Figure 4. Main techniques used in user's applications.

3.3 Role of AWU in climate studies

There is a strong agreement between the users in considering AWU a crucial variable for climate studies. Figure 5 illustrates this consensus on a scale of 1 to 5, where a score of 1 represents the lowest importance and 5 the highest. Remarkably, **50% of users rated AWU at a level of 4, while the remaining 50% rated it at the highest level of 5**. This underscores the unanimous recognition of AWU's critical role within climate-related analysis.

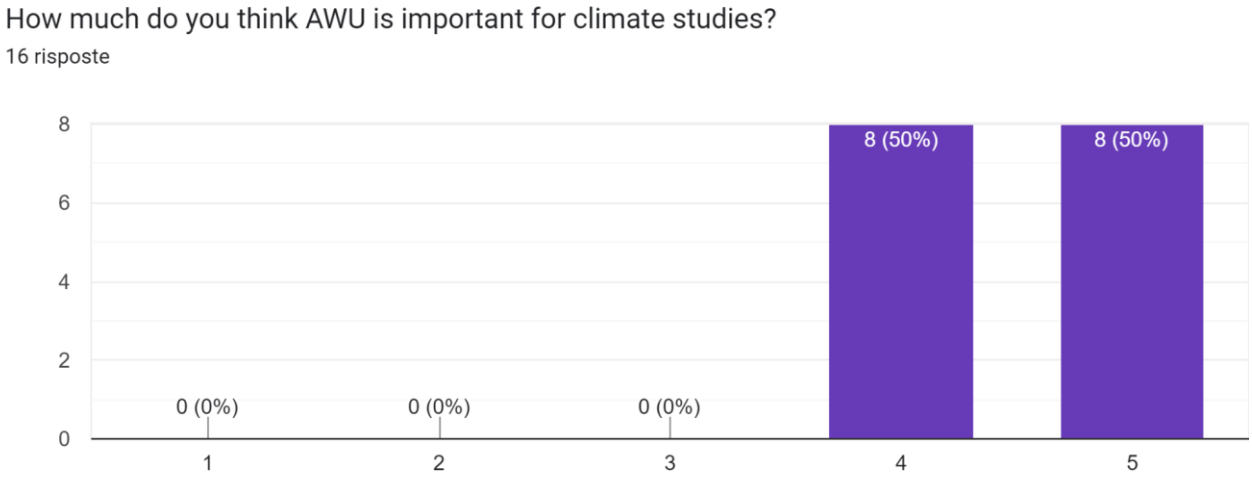


Figure 5. Importance of AWU for climate studies

On the other hand, there is also consensus among users regarding the perceived low importance currently attributed to AWU in climate studies. Figure 6 showcases the responses from users, utilising a rating scale from 1 to 5 similar to Figure 5. Notably, 50% of users express agreement that the level of AWU information

within current climate studies is low, giving it a rating of 2. In contrast, only 18.8% of users indicate that the degree of AWU information is high, assigning it a rating of 5. This highlights a general sentiment among users regarding the underrepresentation of AWU in current climate research.

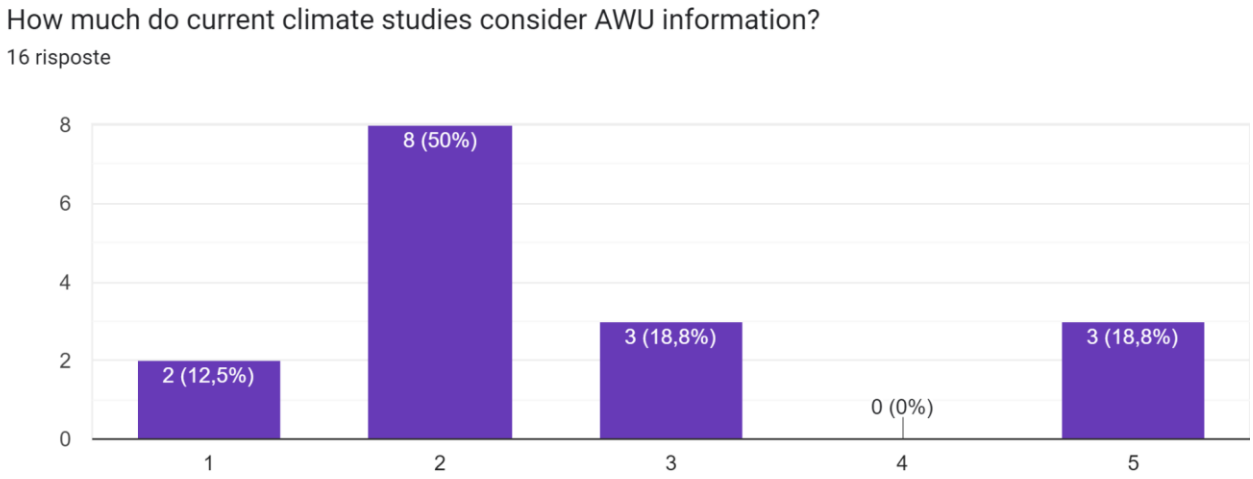


Figure 6. rating the amount of information of AWU included in current climate studies.

Previous results are further validated by the responses to the following question regarding the data source of AWU utilised by the users when incorporating AWU into climate studies**. It's notable that 25% of users do not integrate AWU into their climate analyses**. Meanwhile, 31.3% of users leverage a combination of satellite data, modelled datasets, and statistical surveys for their AWU analysis. Additionally, 18.8% of users rely solely on satellite-derived information, while statistical surveys and modelled data alone are utilised by 12.5% of users each. These outcomes are detailed in Figure 7, illustrating the diverse data sources employed by users for integrating AWU into climate research.

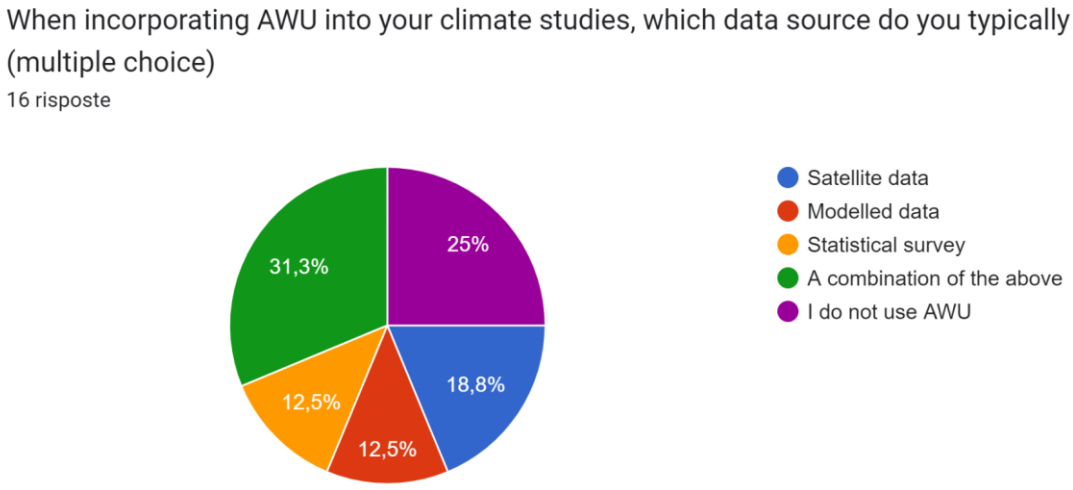


Figure 7. Data source of AWU for climate studies.

An additional question reveals the users' perspectives on the potential enhancement in representing crucial hydrological and atmospheric variables through a comprehensive understanding and consideration of AWU in climate studies. Figure 8 highlights a strong consensus among users regarding the primary variables affected by AWU. **Evaporation and soil moisture emerge as the most influenced variables when AWU is accurately accounted for in climate studies**. Surprisingly, biomass does not appear to be considered a major variable impacted by AWU according to the users' responses. Nonetheless, users recognize a notable impact on river discharge, water vapour, and land surface temperature due to AWU. These insights provide valuable considerations for advancing the representation of these variables within climate research frameworks. When directly asking the users to write out other possible relevant variables to be considered the groundwater and total water storage come up as the most important, followed by snowpack, photosynthesis, soil nutrient content and structure, soil texture, radiation use efficiency, extinction coefficient.

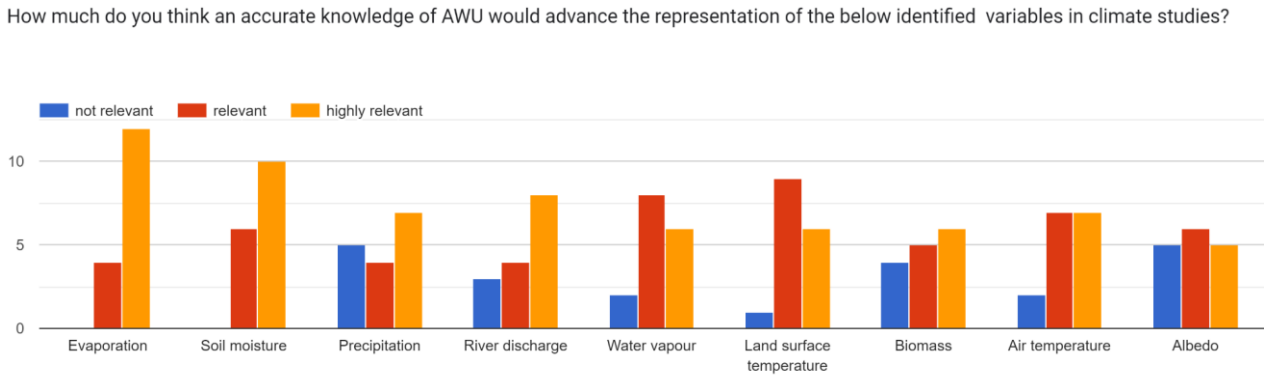


Figure 8. Influence of an accurate representation of AWU on relevant hydrological/atmospheric variables.

3.4 Users' needs on a ECV AWU

The first question on the users' preferences for the spatial resolution of a potential AWU dataset retrieved from satellite data reveals distinct trends among respondents. According to the responses detailed in Figure 9, **56.3% of users express a preference for a very high spatial resolution of <1 km, indicating a desire for fine-resolution spatial data**; 2) another 56.3% of users would find a spatial resolution ranging from 1 km to 10 km acceptable for their needs; 3) approximately 18.8% of users are open to utilising a coarser spatial resolution falling between 10 km and 100 km; and 4) a smaller subset of users (6.3%) indicates a willingness to work with any available information regardless of spatial resolution. When asking to justify their answers most of the users highlight the necessity of a very fine spatial resolution to allow to simulate hydrological processes as well as to improve precision irrigation and agriculture. Other answers focus on the high values that AWU data, although at coarser resolution, could have on climate studies.

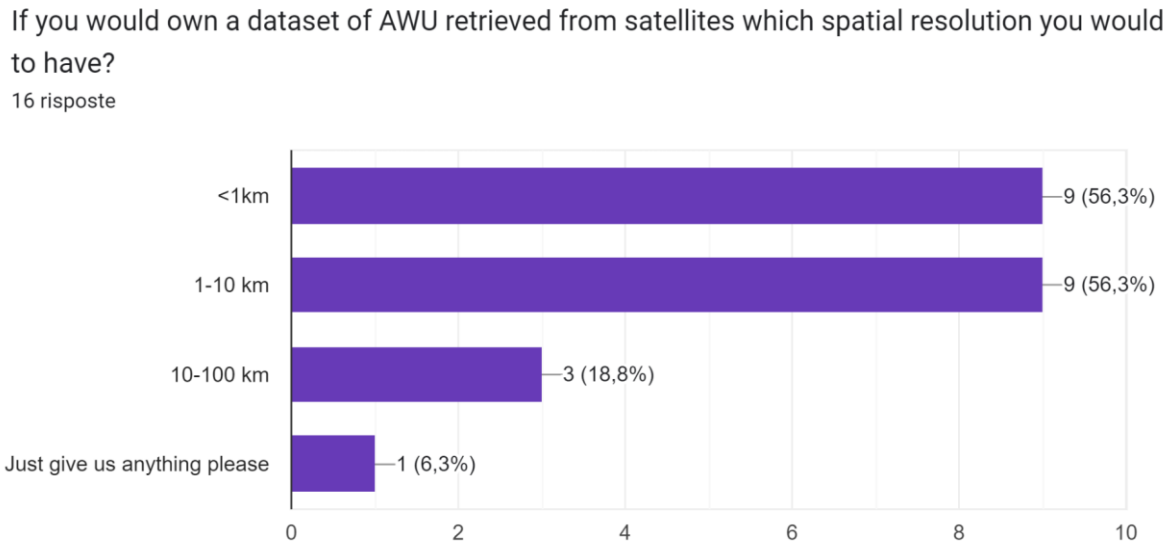


Figure 9. Users' spatial resolution requirements.

As a second question we asked the users which temporal resolution they would prefer for a possible AWU dataset retrieved from satellite data. We found very interesting results, summarised in Figure 10. Most users (56.3%) express a strong **preference for daily irrigation data**, indicating a need for fine-resolution temporal information to capture dynamic agricultural water use patterns. Additionally, 43.8% of users are open to utilising monthly data, suggesting a broader acceptance of slightly less frequent updates. Approximately 37.5% of users would ideally prefer weekly data, striking a balance between the previous two answers. A smaller subset (12.5%) of users expresses interest in hourly data, although this level of temporal resolution remains challenging due to current limitations in satellite data capabilities, where a trade-off exists between spatial and temporal resolution. On the other hand, both high spatio-temporal resolution could be reached using modelling frameworks integrated with satellite data (i.e., data assimilation techniques).

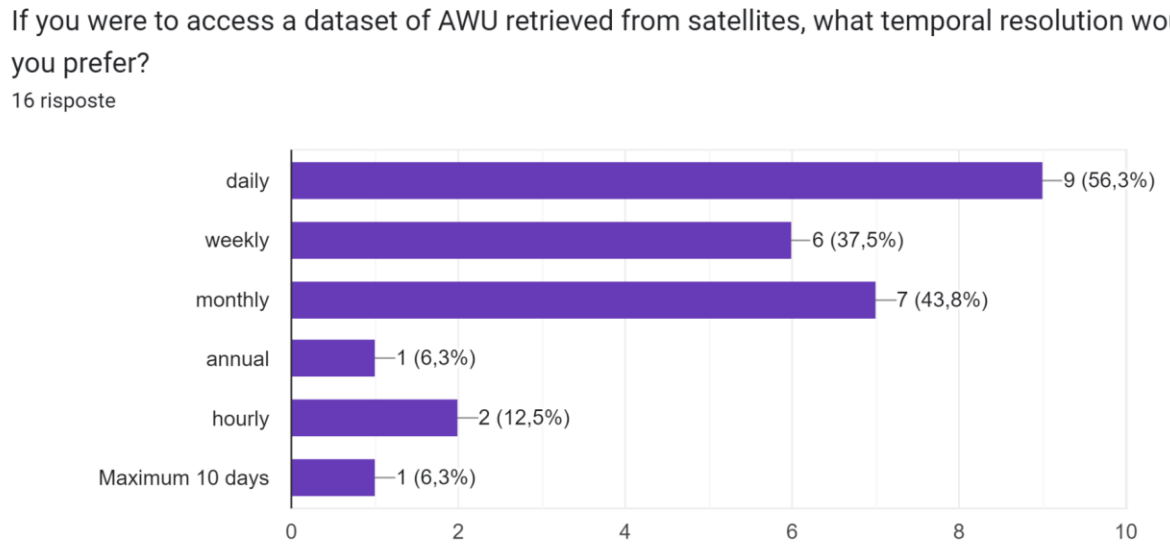


Figure 10. Users' temporal resolution requirements.

When asking users about their desired target areas for an AWU dataset, responses exhibited a wide range of interests. While some users expressed interest in global coverage, **the majority indicated preferences for regional studies focusing on specific areas such as Europe, the Mediterranean basin, South America, India, or the United States**. Notably, there is a consensus among users on the importance of focusing on irrigation and drought hotspots worldwide. This emphasis underscores the critical need for AWU data to address key agricultural challenges and water crises in regions prone to water scarcity and drought, where effective water management is vital for sustaining agricultural productivity.

We additionally asked users which could be the target temporal coverage that a AWU dataset should have to be relevant for climate studies (Figure 11). As expected, **56.3% of users expressed interest in a long-term dataset spanning over 20 years**, emphasising the importance of capturing extensive historical data for comprehensive climate research related to AWU. Interestingly, 50% of users indicated acceptance of AWU datasets covering a period of 10 to 20 years. This broader acceptance reflects the feeling that **a decade or more of data still provides valuable insights into long-term trends and variability in irrigation water use, supporting meaningful climate analyses**. These findings hold significant implications for evaluating the objectives of the precursor CCI-AWU project. Considering the current temporal coverage of satellite datasets, there is a feasible opportunity to provide AWU datasets spanning the preferred 10 to 20-year timeframe. This alignment with user expectations underscores the project's potential to provide valuable data for climate studies over a substantial historical period.

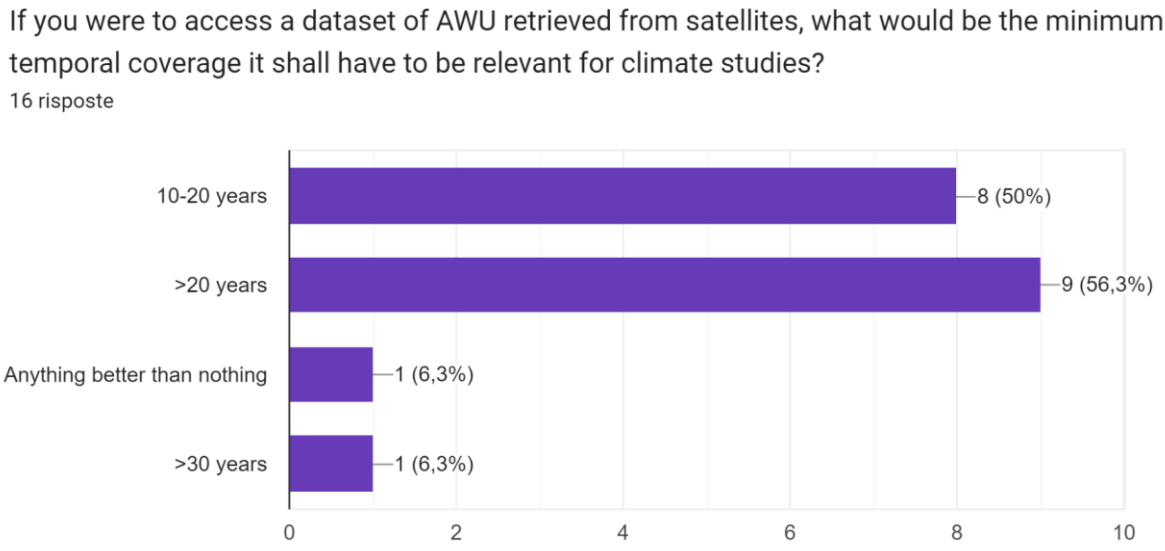


Figure 11. Temporal coverage requirements.

An additional critical aspect that was faced with the questionnaire is the required accuracy of satellite-derived AWU datasets. Our questionnaire assessed preferences on a scale from 0 to 8, where 0 means irrelevance and 8 indicates high relevance, with targeted accuracy ranging from 0% to 30-50%. **The highest percentage of users expressed acceptance of an accuracy level between 30% and 50%**, with

18.8% indicating willingness to accept even lower accuracy (0-10%). Only two respondents expressed interest in higher accuracy levels of 70-80%, highlighting the importance of aiming for a median accuracy value. One user emphasised that, considering the errors included in current datasets (statistical database, models), having an irrigation dataset with an error of 30 to 50% would be a great step forward. For more details the reader can refer to Figure 12.

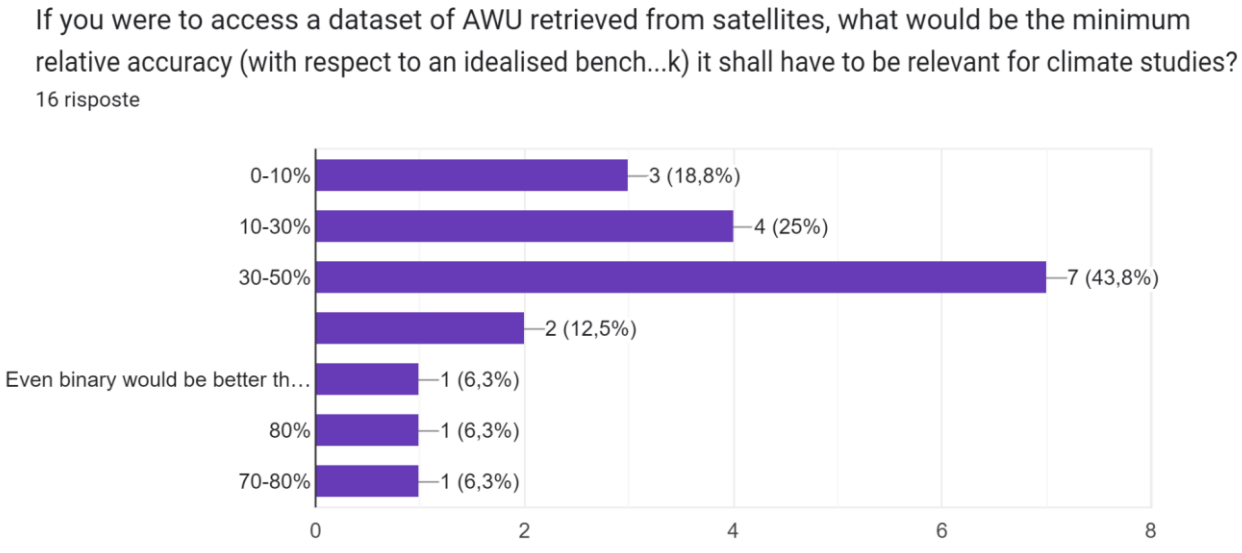


Figure 12. Required accuracy for a possible satellite-derived irrigation dataset

Finally, we asked users to provide a rank for the different characteristics that the product should have (i.e., spatial and temporal resolution, accuracy, ecc.) in terms of importance for climate studies, where 1 is the most important and 5 is the least important. The results, shown in Figure 13, indicate clear preferences among respondents. Most of the users seem to agree that **a high temporal resolution is the most important aspect, followed by the spatial resolution and accuracy.** Record length also received significant importance, being ranked with a score of 2 by most users. Additionally, latency was considered moderately important, with 10 out of 16 users ranking it as a medium importance aspect. These findings highlight the consensus among users regarding the prioritisation of key characteristics for an effective climate study product.

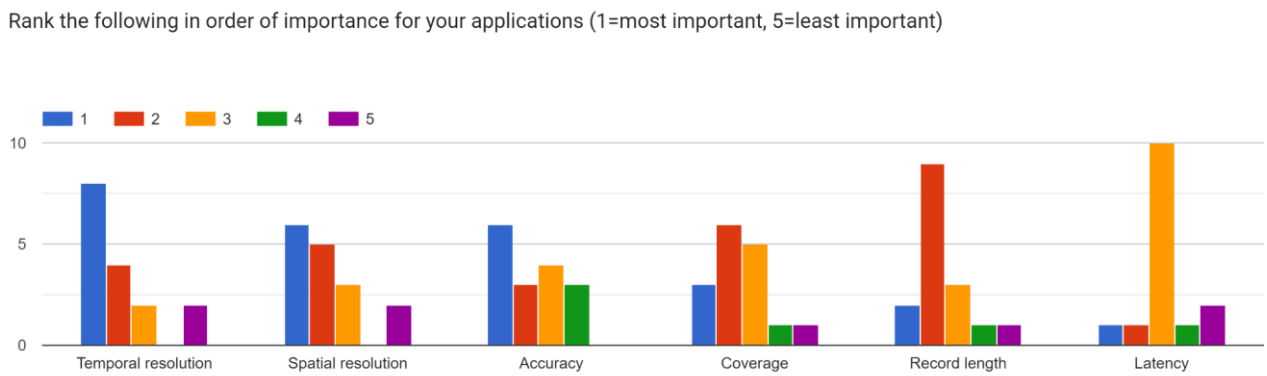
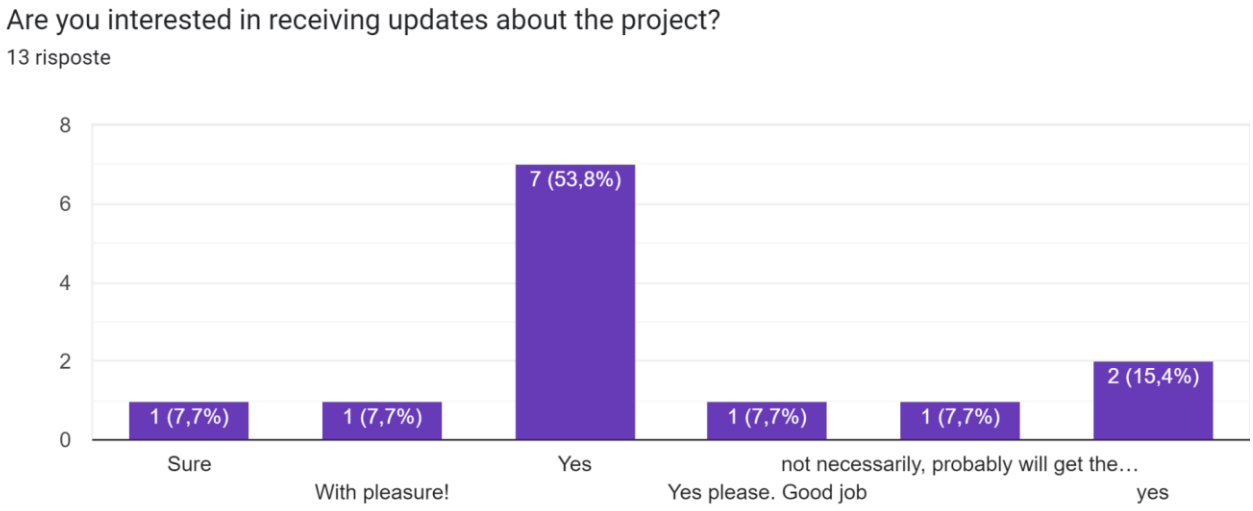


Figure 13. Rank of the characteristics that a satellite-derived AWU product should own.

3.5 Users' feedbacks on the CCI-AWU project

The CCI-AWU project obtained good feedback from the contacted users so far. There is widespread agreement that the project has the potential to contribute significantly to improve the water resource management for sustainable agriculture and development.

As displayed in Figure 14, nearly all users expressed interest in receiving updates on the project and its future developments. This feedback provides valuable input for disseminating the project's results within the climate and research community, fostering broader engagement with the project outcomes and collaborations with the climate community. We think that the positive response highlights the relevance and impact of the CCI-AWU project in addressing critical challenges related to water sustainability, agricultural development and climate studies gaps.



Conclusions

So far only 16 answers were collected. It's important to note that the report will be updated with a Version 2 (V.2) once a more substantial number of responses will be gathered, allowing for more robust statistical analysis. For this reason, the consortium is sharing the questionnaire through their social media channels. At the moment, respondents to the questionnaire predominantly come from research organisations with a focus on water resources, drought, land-atmosphere interactions, and climate modelling.

AWU was identified as crucial for climate studies, with 50% of users expressing that it's inadequately incorporated in current climate studies (e.g., 25% of the respondents reported the lack of integration of AWU in their studies). From the collected responses, it was found that evaporation and soil moisture are the most affected variables when AWV is accurately incorporated into climate studies, while there is a widespread perception that other variables, such as precipitation and biomass, are less affected. Users highlighted the critical need for high spatial resolution data (<10 km) and daily temporal resolution spanning at least 20 years. Regarding accuracy, users expressed a requirement ranging from 30% to 50%.

Furthermore, all users have shown keen interest in the project and expressed a desire to receive regular updates on its progress.

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