# SUSTAINABILITY OF COS4CLOUD SERVICES FOR CITIZEN OBSERVATORIES

## Policy Brief

Cos4Cloud

# Executive Summary

The increase in popularity of citizen observatories (COs) over the last decade has come with increased participation and large amounts of collected data. This has **evidenced the challenges faced by COs associated with low interoperability, low levels of data validation and low technological capacity**. COs need to ensure that data of various formats and in large amounts is efficiently collected, identified, validated, analysed and stored. Moreover, interoperability must be ensured if data is to be shared across COs, organisations or reporting bodies.

The overarching vision of the Cos4Cloud project ('Co-designed citizen observatories for the EOS-Cloud') is to integrate citizen science infrastructures into the European Open Science Cloud (EOSC) **through the co-design of innovative services and tools to solve challenges faced by COs**, while bringing citizen science closer to the scientific community and society and providing new data sources.

This document describes some of the challenges faced by COs mentioned above and how the services developed by Cos4Cloud have responded to this need while integrating citizen science infrastructures into the EOSC in a groundbreaking manner and contributing to the ambitions of the EU's open science policy. The document also argues in favour of sustaining the services for COs and recommends actions for doing so.

# Citizen observatories and the challenges they face

**COs are the research infrastructures** (e.g. the technological platforms where a diverse range of tools are developed such as web portals, smartphone apps, electronic devices) **that allow the development of citizen science projects, particularly those with the main objective of large scale participation of the people, covering large geographical areas and long periods of time.** These new observatories integrate the latest information and communication technologies (ICT) to connect the citizens digitally, improve their observational capabilities and provide information flows (Mominó, Piera & Jurado 2017). Common characteristics of most COs are: citizen participation in environmental monitoring and governance, a bi-directional flow of data and information, and the use of mobile and web technologies to generate 'in situ' observations (WeObserve consortium 2018; Woods et al. 2022).

COs have been growing in popularity in Europe and have been supported in dedicated funding calls from the European Commission in the 7th Framework Programme (FP7), Horizon 2020 (H2020) and currently in Horizon Europe (HORIZON) (Gold & Wehn 2020). Some initiatives have received support from different funding schemes to consolidate COs and tools beyond the usual lifespan of conventional programmes as is the case with the following biodiversity monitoring platforms: Artportalen (exists since 2000), iSpot (since 2009), Pl@ntNet (since 2011), and Natusfera (since 2016).

The **community of COs and of citizen science more generally is rapidly expanding** – also beyond Europe. This expansion comes with **increased participation and large amounts of collected data.** To illustrate: According to a case study analysis by Chandler et al. (2016), from the 640 million species occurrence data available through the Global Biodiversity Information Facility (GBIF) more than 50% came from citizen science projects. Data in environmental monitoring is expanding too.

This leaves **COs facing large-scale challenges associated with low interoperability, low levels of data validation and low technological capacity.** COs need to ensure that data of various formats and in large amounts is efficiently collected, identified, validated, analysed and stored. Moreover, **data collected by COs is often shared** – or it aims to be – between multiple research and reporting bodies at different levels (local, regional, global) **for monitoring purposes or to integrate citizen science or CO data with traditional data sources.** For that, **interoperability must be ensured** as it allows scaling the impact of the data. Most scientific fields lack a globally recognised platform as their central data repository (Woods et al. 2022). When there is one, as is the case of GBIF for biodiversity, some COs share their data through them while others experience technical, financial and administrative difficulties that prevent them from doing so: e.g. lacking pathways to make data available, lacking connections between COs which can lead to overlapping data sets and difficulty in identifying data gaps, and insufficient expertise or resources to implement cutting-edge technologies such as big data or artificial intelligence (AI) (Woods et al. 2022). These can hinder take-up of citizen science and CO data and limit its potential. Other challenges and concerns arise such as the need to address privacy

and security issues regarding personal data or the significance of tracking contributions from citizens to ensure that they are correctly credited and their effort is valued (Hager et al. 2021).

**An associated issue is the sustainability of COs.** Citizen observatories, as research infrastructure for citizen science, are fairly inexpensive compared to major research infrastructures (Piera & Justamante 2022). A variety of stakeholders such as **the scientific community, the wider society, and policy-makers stand to benefit from funding COs in the long term.** Citizen science and COs can provide valuable data and information as evidence for informed policy- and decision-making to tackle growing environmental challenges (Fabó Cartas & Davies 2023; Piera & Justamante 2022).

# Cos4Cloud responds to the need for innovative services for COs

The overarching vision of the Cos4Cloud project ('Co-designed citizen observatories for the EOS-Cloud') is to integrate citizen science infrastructures into the European Open Science Cloud (EOSC) through the **co-design of innovative services and tools to solve challenges faced by COs, while bringing citizen science closer to the scientific community and society and providing new data sources.** In this way, citizen science and CO data can gain robustness and trust in the eyes of both academia and politics (Piera & Justamante 2022).

Therefore, Cos4Cloud has developed thirteen services that boost citizen science technologies through the improvement of: **data quality**, by simplifying expert verification, or using AI to improve identification; **CO and data interoperability**, by facilitating integration between data sets; and **data accessibility**, by processing data so they can be more easily uploaded to the EOSC – also ensuring open access (Woods et al. 2022). The services and tools developed also contribute to the sustainability and maintenance of COs, e.g. through Do-It-Yourself (DIY) tools that can be used, adapted and replicated (Woods et al. 2022). See more detail on the services developed in **Box 1**. Cos4Cloud has also been working to improve interoperability among COs to allow data exchange among different platforms and have more standardised and useful data sets for monitoring, for example, the UN Sustainable Development Goals (SDGs).

Some of Cos4Cloud's services are already available on the EOSC, connecting them with a wider, pan-European infrastructure. By being part of the EOSC, **Cos4Cloud has consolidated and clearly positioned the role of citizen science in the EOSC ecosystem** (Piera & Justamante 2022). The services have been co-designed taking into account user needs and considering interoperability and FAIR data principles. They can be used by anyone (COs, researchers, the public sector, industry…) some of them as modules – selected and installed as needed to improve functionalities – and others as complete online services. The services will contribute to **widespread the use of citizen science and CO data among traditional scientists and ultimately to ensuring the long-term viability of COs and helping them reach a global scope.** Through the development of the services and their associated measures, Cos4Cloud has created and is supporting a network of COs helping them face many of the challenges mentioned before (Woods et al. 2022).

# Box 1. Cos4Cloud services

- AI-GeoSpecies to integrate Artificial Intelligence (AI) into an already existing citizen science app to predict which plant species users will find in a particular area.
- AI-taxonomist to integrate automatic identification tools customisable to a citizen science project needs: helps users identify the species from a picture.
- Authenix to facilitate GDPR compliance and provide access to citizen science platforms and services via Single-Sign-On.
- Cos4Bio to integrate biodiversity data and Cos4Env to integrate environmental data from multiple COs in one place.
- DUNS: A service to help reward citizens' contributions by appropriately valuing and acknowledging them.
- FASTCAT-Cloud to filter and identify recordings and photos coming from camera traps with AI.
- FASTCAT-Edge: A Do-It-Yourseful (DIY) smart camera trap to record only videos and pictures of wildlife activity.
- GBIF-DL to train an AI model to identify a particular group of species very easily.
- MECODA: A tools repository for analysis and visualisation of all sorts of citizen science data.
- MOBIS: A service to create integrative citizen science apps to report environmental and biodiversity observations.
- Pl@ntNet-API to integrate Pl@ntNet's visual identification engine into an app.
- STAplus: An extended data model for the SensorThingsAPI to standardise citizen science data and make it accessible, interoperable and reusable among COs and services.

# The EOSC and the Cos4Cloud ecosystem

The aim of the **European Open Science Cloud** (EOSC) is to provide European researchers, innovators, companies and citizens with a **federated and open multi-disciplinary environment to host and process research data as well as find data, tools and services to support research, innovation and education** (EOSC Future n.d.). The core elements for this environment to be able to operate in an heterogeneous landscape of e-infrastructures and service providers – the smallest common denominator – has been called the "Minimum Viable Ecosystem (MVE)" of the EOSC (European Commission DG R&I 2018). The concept of the MVE has been developed and expanded over the last years in different publications (European Commission DG R&I 2018 and 2020; European Commission DG R&I et al. 2021). Overall, the elements it contains are the set of services for the EOSC to technically operate, federated data, a marketplace of resources and services coming from research infrastructures or other EOSC projects and that are integrated into EOSC core functionalities, and an interoperability framework (ibid.). A coordinated effort and the right incentives to use and contribute to the EOSC are needed for it to flourish.

Cos4Cloud is based on a solid framework for integrating and federating citizen science infrastructure, and making it available on the EOSC. **Cos4Cloud is the first use case and pioneer in integrating citizen science services in the EOSC**. One of the project's goals has been to create a Minimum Viable Ecosystem of Citizen Observatories (COs-MVE) and **demonstrate that the MVE proposed by Cos4Cloud for COs can be scaled and the services developed extended to other domains** – meeting the requirements of new EOSC users such as the public sector or the industry. Cos4Cloud has co-designed and prototyped a range of services that address the challenges faced by COs. The services and tools work individually but have been developed as part of a system; they complement each other and their interactions have a mutually reinforcing effect. This is possible because the services are interoperable and the COs involved in the COs-MVE have followed best practices and selected standards. Moreover, **co-designing the services has ensured that a variety of actors have been involved in the process and contribute to exploiting the system:** citizens, researchers, software developers, SMEs, etc.

Citizen science as well as the EOSC and open data are three out of the eight ambitions of the EU's open science policy (European Commission DG R&I n.d.). The network of federated COs in Cos4Cloud and the innovative Cos4Cloud services developed and integrated into the EOSC provide infrastructure for citizen science to increase the interoperability and openness of data, and amplify the capacity of citizen science and COs. **Cos4Cloud's endeavour directly contributes to the objectives for the development of the EOSC** put forward in the Roadmap as part of the Strategic Research and Innovation Agenda (SRIA) by the EOSC Association, the three ambitions of the EU's open science policy mentioned above, and aligns with the overall goals of the EOSC, including open access to scientific data, collaboration and sharing of data, and engaging the public in scientific research (EOSC Association Board 2022). Therefore, **continuing to fund and or sustain Cos4Cloud's services as well as citizen science projects related to the EOSC, aligns with the overall goals of the EOSC and should be strived towards**.

# Why sustain the services for COs?

## Experiences from the Cos4Cloud consortium[1]

The benefits of citizen science, COs, and the data and information produced for these initiatives are manifold and exceed the scope of this document. They include increased public engagement and awareness, cost-effective data collection, improved research quality, building trust in science, fostering innovation, etc. The previous section has scaled up the thinking and linked to the EOSC highlighting some of the benefits of the Cos4Cloud ecosystem and services at that level. In this section, **reasons for sustaining or further funding the services for COs developed by Cos4Cloud** are put forward. These are based on firsthand experiences gathered by the Cos4Cloud consortium while developing the services, implementing them and observing their impact so far.

- The services have made **participants involved in co-designing, testing and validating** them feel that their efforts have been valuable and attributed.
- The services and cutting-edge technology used (e.g. AI) have **brought in new CO participants and observers** (e.g. in biodiversity and environmental monitoring), and at the same time have helped to bring older participants into new technology.
- The services have **eased the validation and verification of data** so data curators can focus on validating more difficult observations, and they have facilitated the analysis of data without the need of having technical skills.
- Because technological advances such as the services developed, and accessible tools such as mobile apps and platforms to record citizen science data, **increase the exchange rate of data** allowing improved or rapid validation and verification by experts, which can allow for reduced action time in cases of invasive alien species.

1. This section is based on inputs provided by the Cos4Cloud consortium.

- Because after having built in and integrated the services into the COs, so much would be lost in terms of enhancing the quantity and quality of data if they were to be removed. The **enhanced quantity and quality of data** has given credibility to COs as official data providers.
- By wanting COs to make use of the services and the services being used, a need has been created that needs to be sustained. Also, even more could be done with the services in terms of integration and development if more time and resources were available.
- Because supported by these services, as a community we can contribute to **increasing the amount of scientific data** that is openly available, and to Open Science more generally.

The integration of the services in the COs bring benefits to the infrastructure itself and their functioning. Those benefits are reflected in an improvement of the experience by their end-users, some of these particular impacts are described below:

- The services contribute to environmental and biodiversity conservation, for example by increasing data quantity and quality. They also contribute to locating citizen observatories as a research infrastructure that provides useful data for research and decision-making in the environmental and biodiversity fields.
- The services provide an added value to mainstream **educational practices** and curricula by offering a range of learning opportunities that enrich current practices, e.g. participating in real-world data collection and analysis.
- The use of the services integrated in the COs by formal educators has allowed them to engage and become part of the citizen science community.
- The services will **serve multiple pedagogical and scientific purposes** that will enhance the students' competence in problem solving, as critical thinkers and citizens of the modern world.
- The research performed under Cos4Cloud has evidenced the learning gains from integrating these technologies and services in terms of environmental and scientific knowledge, and citizenship for sustainability.
- Because citizens can benefit from including **citizen science services in the EOSC** by contributing to environmental management and research projects, being involved in decision making, understanding the scientific method together with its strengths and limitations, and gaining environmental awareness.

# Policy Implications and Recommendations[2]

## 1 Financially support and strengthen networks of COs.

COs and the data they generate have a wide range of benefits and can play a crucial role in environmental and biodiversity monitoring. Networks of COs that learn from each other and collaborate can aid in achieving this potential, contribute to improving data interoperability and accessibility, foster science education and Open Science, among others (Woods et al. 2022). However, because communities around COs require a considerable amount of time to establish funding schemes should consider the longer operation time of COs (Gold & Wehn 2020). Secured financial support enables the continuity of COs as it can ensure ongoing infrastructure, as well as address other issues (Hager et al. 2021).

## 2 Support innovation for COs by prioritising and encouraging the use of open source technologies and open code

so that developed code, services and tools can be used by all COs and in other contexts by the communities beyond COs. Moreover, facilitating the connection between COs and the services can help sustain the services developed. After all, access to the services by the general public is largely achieved through the COs.

2. This section is based on inputs provided by the Cos4Cloud consortium.

## 3 Continue building and supporting developed services, technologies and infrastructure for COs.

Support and continue developing the endeavour started by Cos4Cloud – a network of federated COs and the innovative services developed and integrated into the EOSC, which provide infrastructure for citizen science to increase the interoperability and openness of data, and amplify the capacity of citizen science and COs, ultimately contributing to Open Science and facilitating the participation of citizens in scientific research. A permanent, federated CO-network infrastructure integrated into the EOSC can significantly benefit COs, the EOSC and the broader scientific community. Federating the services allows all those interested to profit from everything and the benefits outweigh the costs. The MVE proposed by Cos4Cloud for COs can be scaled and the services developed extended to other domains.

## 4 Expand the range of thematic clusters

and communities in the EOSC including citizen science as a science cluster supported by Cos4Cloud services that can improve the quality of citizen science data for decision making.

## 5 Increase the promotion of citizen science

among the EOSC community by emphasising the benefits and potential of citizen science for advancing scientific research and innovation. Supporting multilingualism in the EOSC could contribute to that.

## 6 Fund the production, adaptation and promotion

of appropriate educational material focusing on the pedagogical integration of the use of the services and linked COs into standard educational practices. This should be accompanied by more opportunities for pre-service and in-service teacher training on the use of the COs and their services.

## 7 Recognise and support citizen science research infrastructures,

**also known as COs, at national, regional and European level for their contribution in providing data and information for decision and policymaking.**

Since environmental monitoring by government authorities and administrations is required by law, the demand for Cos4Cloud's services is likely to increase if the services allow the reduction of costs and improve the forecasting capabilities. Citizen science and CO data can feed into reporting and monitoring, for example of the SDGs.

## 8 Foster multi-stakeholder partnerships and alliances

**between citizen science initiatives and other actors.** By working with universities, research institutions, SMEs and other organisations and actors, policy makers can help build a stronger network of support for citizen science initiatives, COs and the Cos4Cloud services for COs.

COs need the services to face the challenges mentioned and SMEs and companies might be interested in services related to continuous monitoring, early warning, evaluation of exploitation for the management of natural resources, among others, as well as data gathered by COs. Symbiotic collaborations could be found where the CO community helps to develop and improve the services and products and they get support from SMEs in return.

## 9 Advance the attribution of citizens' contributions

**associated to GDPR and ethics compliance by further studying this issue at European level.**

The voluntary nature of the work carried out by participants in citizen science initiatives and COs needs recognition. It is crucial to appropriately value, trace, and correctly credit citizens' contributions. Citizen science and CO participants are mostly not aware of the use made with the data they contributed. Before Cos4Cloud developed DUNS, no CO had a service to track this and report data use to contributors. Exploring the creation of ethics guides and a new Creative Commons licence to ensure ethics and GDPR compliance when attributing the use of CO data is suggested.

# Sustainability and Legacy

Cos4Cloud directly addresses some of the most critical challenges faced by citizen observatories by strengthening networking through service and tool development, interoperability, co-design and education. Some of the services developed are already available on the European Open Science Cloud (EOSC). The methodological guide "Co-design as a service" (Guasch et al. 2022) results from the experience and lessons learned in co-designing technological services and implementing co-design as a service within the Cos4Cloud project and consortium. The Cos4Cloud Toolbox and Evidence Hub will serve as a 'one-stop-shop' of guidelines, best practice examples and educational materials produced in the project, contributing to its legacy.

# Conclusion

The need for improved data quality, quantity, interoperability and technological capacity in general stemming from the expansion of citizen science and COs has been directly addressed by the technological services and tools developed within the Cos4Cloud project. This document has provided arguments for sustaining and or further funding these services not only because of their direct benefit and impact, but also in light of the network of federated COs to which they are linked and with which they create a Minimum Viable Ecosystem for COs to be integrated into the EOSC. This gives reason to continue this endeavour expanding and scaling Cos4Cloud's idea to other domains, ultimately contributing to the objectives of the EOSC and Open Science.

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