CITIZEN SCIENCE TO SUPPORT PROGRESS OF THE SDGS AND COS4CLOUD'S CONTRIBUTION THROUGH ITS SERVICES AND TOOLS

Policy Brief

Cos4Cloud

Executive Summary

Achievement of or progress towards achieving the UN Sustainable Development Goals (SDGs) will increase critical climate change resilience for global communities. **However, impacts of climate change threaten and may even reverse recent progress towards the SDGs**. Under this increased pressure, utilising additional non-traditional approaches to support continued progress of the SDGs is crucial. The use of non-traditional data sources, such as citizen science, can be key in filling in gaps in statistical data coverage (Fritz et al. 2019).

Citizen science has the potential to support both progress towards and monitoring of the SDGs. Citizen science actively involves citizens and members of the general public in scientific research that generates new knowledge (ECSA 2015). Citizen science projects frequently involve low-cost interventions which can increase geographical reach, timeliness and volume of data collection and analysis. Data generated through citizen science can help fill in data gaps for monitoring SDG indicators by increasing the availability of ground-level observations (Gold & Wehn 2020; Proden et al. 2022).

This document describes some of the capabilities and benefits of citizen science which can support progress towards the SDGs. These include **increasing availability, analysis and exchange of data**, and provision of opportunities for **science education, increasing public engagement, and collaboration across society**. It also explains how the EU-funded Horizon 2020 project Cos4Cloud has contributed to improving citizen science data quantity and quality. The document also highlights some case studies and recommends actions to promote and utilise citizen science as well as the integration of citizen science data in this context.

Introduction to citizen science and citizen observatories

Citizen science (CS) encompasses a wide range of activities and practices in many different scientific disciplines from biodiversity monitoring to the social sciences (Haklay et al. 2020). Many definitions of this concept can be found. For the purpose of this policy brief, citizen science is understood **as actively involving citizens and members of the general public in scientific research that generates new knowledge** (ECSA 2015). Citizen science has the potential to bring together science, policymakers, and society as a whole in an impactful way: it aims to contribute to science, promotes participation and public engagement, fosters scientific knowledge and understanding, can impact policies and governance, and provides opportunities for societal transformation.

Citizen observatories (COs) are community-based environmental monitoring and information systems that allow individuals to collect and share observations – mainly related to biodiversity and the environment (WeObserve consortium 2018; Woods et al. 2022). **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).

The **Cos4Cloud project** ('Co-designed citizen observatories for the EOS-Cloud') has developed thirteen **services to improve citizen science technologies**, among other things: facilitate the integration of automatic species recognition into COs; a repository of tools to view and analyse citizen science data; acknowledging systems, etc.

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 to monitor the SDGs. **Cos4Cloud's services are openly available on the European Open Science Cloud (EOSC)**, for any citizen observatory to use them and will ultimately contribute to ensuring the long-term viability of COs and help them reach a global scope.

Citizen science can increase available data across multiple SDG targets

The UN Sustainable Development Goals (SDGs) are a set of goals, targets and indicators at the heart of the 2030 Agenda for Sustainable Development by the United Nations (UN 2015). They **address current global issues** such as poverty and hunger, climate change, need for sustainable cities or responsible consumption. At the halfway point to the target date of 2030, it is crucial to increase efforts towards achieving the SDGs and robust data is needed to report and monitor progress.

Several **issues with data** currently used to track progress towards the SDGs are pointed out in the literature: SDG monitoring mostly relies on traditional data, primarily collected by national statistical offices (NSOs) and, due to its associated high costs and lengthy collection processes, it can be scarce, inaccurate, incomplete, irregularly collected, quickly outdated, not always representative due to limited spatial coverage and variations, etc. (Ballerini & Bergh 2021; Fraisl & See 2020; Fritz et al. 2019). In 2019, this resulted in many countries not regularly collecting data for over half of the indicators and 68% of the environmental SDG indicators lacking data (Fraisl et al. 2020).

Additionally, many SDG targets within Goal 2 'End Hunger', Goal 6 'Clean Water and Sanitation', and Goal 13 'Climate Action' rely on ecosystem services provided by healthy and resilient ecosystems. In the same way that the climate crisis is deeply intertwined with

Co-design activity during ECSA's Conference 2022.
Credit: Cos4Cloud's co-design team.

the biodiversity crisis – ecosystem loss is also a direct consequence of climate change –, there are significant opportunities to tackle and monitor both issues simultaneously (The institute of environmental sciences 2021). Resilient ecosystems are supported by Goal 14 'Life below Water' and Goal 15 'Life on Land', and related protective and regenerative policy informed by data as evidence. **Without sufficient monitoring and reporting, particularly of environmental data, SDG targets may not be achieved.**

Non-traditional data sources such as citizen science and citizen observatories are a **cost-effective means** to address this challenge by greatly increasing the quantity and geographic spread of data collection, and improving the granularity of data and sometimes timeliness (Proden et al. 2022). Citizen science data is usually collected more frequently and at finer spatial resolution than traditional data feeding into SDG monitoring (Fraisl et al. 2020). All of these are particularly useful for environmental data collection. Therefore, **data collected through citizen science and citizen observatories can supplement traditional data sources and bridge spatial and temporal data gaps for SDG reporting**.

The first article to quantitatively assess the potential of citizen science for monitoring SDG indicators (Fraisl et al. 2020), demonstrated that citizen science is "already contributing" to the monitoring of 5 SDG indicators and "could contribute" to 76 indicators – totalling around 33% of SDG indicators – (potentially) providing the greatest inputs to SDG 15 'Life on Land', SDG 11 'Sustainable Cities and Communities', SDG 3 'Good Health and Wellbeing', and SDG 6 'Clean Water and Sanitation'. This indicates that citizen science data has the most potential to contribute to the monitoring of environmental SDG indicators – 37 out of 93 environmental indicators, around 40% (Fraisl et al. 2020). With **68% of the environmental SDG indicators lacking data** as of 2019, **the potential of citizen science and citizen observatory data for SDG monitoring becomes even more evident** (Fraisl & See 2020).

Two of the COs involved in Cos4Cloud, FreshWater Watch and OdourCollect, feed the monitoring of the SDGs. The former feeds directly into indicator 6.3.2 'Proportion of bodies of water with good ambient water quality' and the latter indirectly into SDG indicator 3.9.1 'Mortality rate attributed to household and ambient air pollution' (Woods et al. 2022).

It should be highlighted that there are still some reservations from public authorities and NSOs to accept citizen science data as a complement to official data, as many still believe that this data does not meet the necessary quality standards for informed decision-making and could introduce bias (Fritz et al. 2019; LandSense CDB Project Group 2020; Woods et al. 2022). However, growing literature demonstrates that, when employing quality assurance methods in citizen science projects (such as iterative project design and implementation), **data produced can be reliable, trustworthy and comparable to data produced by professional scientists** (Fraisl et al. 2022; LandSense CDB Project Group 2020). Moreover, new technologies and tools such as the ones developed in Cos4Cloud are contributing to improve the quality, quantity and interoperability of citizen science and citizen observatory data.

NSOs' views towards non-traditional data sources have evolved over the last years as pressure placed on them to produce data for SDG reporting and monitoring has grown (Proden et al. 2022). The usefulness of **citizen science data to fill in the data gaps** mentioned will probably become more apparent as NSOs acquire more expertise and familiarity with utilising citizen science data (Proden et al. 2022). After all, its advantages are numerous: it can not only provide valuable data across space and time, but reach remote locations and better represent local communities, who may have a deeper understanding of local (environmental) conditions (Ballerini & Bergh 2021; Piera & Justamante 2022).

Case Study: BioBlitz

A BioBlitz (or biodiversity blitz) is a participatory event where participants (usually the general society) have to find, photograph and identify as many species as possible in a set location, within a certain timeframe. Due to their short time frame, BioBlitzes are able to provide timely datasets of a defined area that can complement long-term inventories, contribute to monitor national and international targets and inform decision-making in areas such as biodiversity monitoring and invasive alien species (DITOs consortium 2017).

For example, the Cos4Cloud project has organised a yearly BioBlitz under the name 'BioMARató', a citizen science marine observation event held in Catalonia over the summer. The 2022 edition was also celebrated in the Island of Tremiti in Italy. Citizen scientists photographed marine organisms, identified the species and uploaded their observations to the COs Natusfera (in 2021) and MINKA (in 2022). Around 200 participants uploaded over 25.000 marine species photographs in the 2022 edition (Cos4Cloud consortium 2023d).

Researchers use the thousands of observations collected to assess coastal biodiversity in the region. Based on the photos of the 2021 edition, a community of experts in marine taxonomy were able to locate 24 exotic species and register two new records of species never before sighted on the Catalan coast (Cos4Cloud consortium 2023d). The data collected in and around Barcelona will feed into the Barcelona City Council's Biodiversity Atlas to update the information on marine biodiversity.

BioMARAtó 2021.
Photo credit: Anèl·lides, serveis ambientals marins.

Citizen science promotes societal collaboration & engagement

Citizen science can not only produce valuable data, but it can have a **positive impact on society** and the localities where citizen science projects are carried out by providing opportunities for informal and accessible science education, bringing a sense of community and ownership of the scientific process, engaging the public and raising awareness of local issues, empowering people and communities to debate about and take action to address local and global challenges, encouraging engagement and participation in decision-making processes, etc. (Woods et al. 2022). Most of these are due to the **collaborative nature of citizen science** as it can be highly collaborative at multiple stages of the project design and research process, for example by building on co-design approaches. Research and problem-solving builds on experiences and knowledge of volunteers, professional scientists, schools and community groups, research organisations, NGOs, and other stakeholders.

Citizen science as an approach diversifies and strengthens research and practical solutions. **Collaboration and engagement by multiple stakeholders is necessary to address SDGs and associated targets**, particularly challenges exacerbated by climate change impacts. Workable solutions and willingness to act can also depend on **science education.** It is **highly valuable that citizens can contribute to SDG monitoring through citizen science but it is crucial that they can help to implement the SDGs** (Fritz et al. 2019). Citizen science is well-suited to accomplish this by supporting education and learning, fostering partnerships and co-creating solutions to global challenges (Woods et al. 2022).

Case Study: Co-design

Co-design activity during ECSA's Conference 2022.
Credit: Cos4Cloud's co-design team.

Cos4Cloud technologies and services are developed using the co-design methodology. 'Co-design' or collaborative design is a practice that often involves different types of actors in meaningfully contributing to developing innovative solutions to a problem, a challenge or a need (Cos4Cloud consortium 2022). Co-design can be used to improve ideas, products, services and policies among others. Cos4Cloud has implemented the co-design methodology to develop its services. To do this, the project organised several co-design and testing workshops with the services' end users, including **stakeholders from government, academia, industry, and the general public, most of them part of the citizen science community (COs users or workers, naturalists, BioBlitz participants, etc.).** The aim of these activities was to improve the services by meeting the needs and expectations of the end users, better understand the multifaceted nature of the technological setup of citizen observatories and improve the functionality of the technological services designed to enhance COs (Guasch et al. 2022; Woods et al. 2022).

Citizen science technologies increase data analysis and exchange

Citizen observatories as well as research can generate large volumes of data, which are often shared between multiple research and reporting bodies. **With limited resources, there are often difficulties in analysing and sharing large data sets.** Some COs share their data with international platforms such as GBIF (Global Biodiversity Information Facility) 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 new technologies such as big data or artificial intelligence (Woods et al. 2022). These can hinder take-up of citizen science and citizen observatory data. Moreover, most scientific fields other than biodiversity lack a globally recognised platform as the central data repository (Woods et al. 2022).

Citizen science and COs have identified common issues with data analysis and exchange. Citizen science groups and initiatives have **developed technologies for citizen science and citizen observatories which allow for increased data collection, analysis, and interoperability**, as is the case with the technological services and tools developed in Cos4Cloud to address these issues. These new developments can contribute to the **integration of citizen science data with traditional data sources**, applicable to increased SDG monitoring and reporting.

Technological advances, and accessible tools such as mobile apps and platforms to record citizen science data, increase the exchange rate of data allowing real-time or rapid validation and verification by experts, such as in the BioBlitz case study. The delivery of rapid datasets can allow for reduced action time in cases of invasive alien species, for example (DITOs consortium 2017).

Case Study: Artificial intelligence integrated within camera traps

Cos4Cloud has developed FASTCAT-Edge and FASTCAT-Cloud, camera trap technologies which enable users to assemble a camera trap, which **can automatically filter camera trap data and identifies and counts species**. This reduces time spent on manual filtering and analysis for researchers, and assists novices with identification, additionally **improving quality of data.** Filtered data can be **uploaded to open access citizen science platforms**, enabling access and exchange of data for researchers.

Testing activity with the FELIS group in Catalonia.
Credit: Ángela Justamante.

Case Study: An online tools repository to facilitate the analysis and visualisation of citizen science data

Cos4Cloud has developed MECODA (ModulE for Citizen Observatory Data Analysis), an online repository to **provide tools to analyse all sorts of data – biodiversity, environmental, social, etc. – coming from COs and other data sources or users' own sets**. MECODA is based on Orange Data Mining, a visual programming toolbox made to simplify analysis and data visualisation workflows (develop geospatial analysis, statistical approaches or image analysis processes, etc.). The result is a workflow that can be saved and reproduced by others, and modified when necessary. The images and data can also be saved locally for further exploration. **Users do not need a technical background to use MECODA. MECODA** has developed specific widgets to access data from COs and, currently, it allows access data from MINKA, OdourCollect, CanAirIO or Ictio, but it can be expanded easily to other observatories and different citizen science data types. MECODA is a service developed by the ICM-CSIC.

Master's students during a testing activity with MECODA.
Credit: Karen Soacha.

Policy Implications and Recommendations

1 Create and strengthen networks of citizen observatories

As put forth, citizen observatories and the data they generate can play a crucial role in SDG 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, inform about the SDGs and co-create solutions to global challenges (Woods et al. 2022). Supporting networks of COs through the development of new services and tools, the main aim of Cos4Cloud, can improve the quality, quantity and interoperability of citizen science data available for SDG monitoring and reporting (Woods et al. 2022).

2 Advocate for citizen science as an approach for decision-making and SDG monitoring

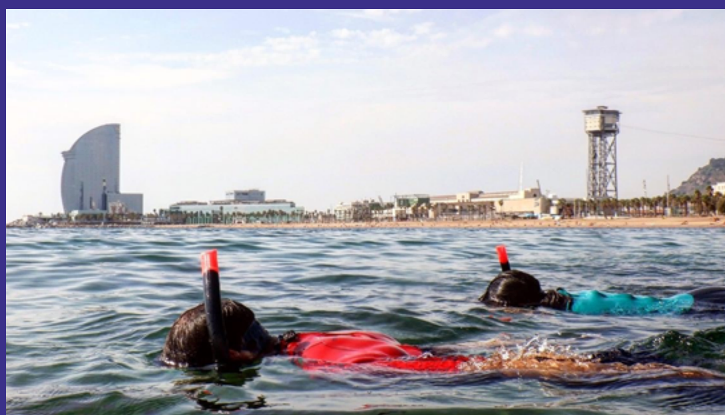
Citizen science can improve acceptance and transparency of the policy process. The participation of citizens in environmental decision-making and governance increases the mutual trust between citizens, policy makers and public authorities (LandSense CDB Project Group 2020). Based on existing policy frameworks that encourage and support citizen science for decision-making, new policies and guidelines should be put into place to allow and promote take-up of citizen science data for SDG monitoring (Fritz et al. 2019).

3 Increase integration of citizen science data with existing SDG monitoring and reporting[1]

a. Address concerns of policymakers and NSOs and issues related to data quality through criteria or standard identification to ensure data quality, or through data quality assurance procedures or protocols, to make data fit for purpose.

b. Follow the FAIR[2] and open data principles, harmonising data collection and sharing, and building robust data value chains aligned with existing standards.

c. Share best practices and lessons learned in using citizen science for SDG monitoring, and promote dialogue and effective collaborations between NSOs and citizen science projects.



BioMARAtó 2021.
Photo credit: Anèl·lides, serveis ambientals marins.

d. Further develop new open access and open source services and tools to overcome technological limitations related to data quality, quantity and interoperability.

1. More detailed recommendations related to the take-up of citizen science data for SDG monitoring are included in Fraisl et al. (2020 and 2022), Fritz et al. (2019) and Proden et al. (2022).

2. Findable, accessible, interoperable and reusable.

4 Foster multi-stakeholder partnerships and alliances

Partnerships and alliances between governments, NSOs, citizen science and citizen observatory managers, researchers and practitioners as well as setting up communities of practice are key to learn with and from each other building on each other's experiences, needs and expertise (Fraisl & See 2020; Fraisl et al. 2022). Closer interaction between citizen science networks and communities and thematic or SDG-related research communities as well as the coordinated exchange of SDG-relevant citizen science best practices and tools across countries and thematic areas could also be beneficial (Knobloch & Fabó Cartas 2021).

5 Support education and learning through citizen science

Citizen science coupled with new technologies creates a connection between science and education that promotes public engagement in science, boosts science learning in schools and other educational contexts, and fosters engaged and active citizens that can contribute to sustainable development and the implementation and achievement of the SDGs. Examples could be the incorporation of citizen science linked to the SDGs in school curricula and higher education, and training support related to these topics (Knobloch & Fabó Cartas 2021). In this sense, Cos4Cloud has organised several activities to integrate citizen science into environmental educational curricula, activity led by the National and Kapodistrian University of Athens (NKUA).

6 Increase funding of citizen science projects

The sustainability of citizen science initiatives and COs through bespoke and innovative funding schemes is key for the potential of citizen science data as a source of data for SDG monitoring to unfold, and be able to provide valuable data both across space and time (Fraisl et al. 2020). Increased funding is necessary if citizen science projects are to meet the high expectations placed on them (e.g. meaningfully engaging citizens, collecting and analysing high quality data, sharing and disseminating results, etc.) while maintaining their autonomy and potential for social innovation (Moczek et al. 2021).

Further recommendations to create an enabling environment for the take-up of citizen science and citizen observatory data (for the SDGs) can be found in Fraisl et al. (2020), Fritz et al. (2019), Knobloch & Fabó Cartas (2021) and WeObserve consortium (2021).

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. Moreover, the Cos4Cloud Toolbox and Evidence Hub will serve as a 'one-stop-shop' of guidelines and educational materials produced in the project, contributing to its legacy.

Conclusion

Citizen science innovative approaches such as engaging participants in BioBlitzes and **technology improvements** for data collection, data interoperability, and data access, can benefit monitoring and reporting across multiple SDG targets. Considering **citizen science** approaches, including collaboration and societal engagement, when addressing SDG challenges, may mitigate additional pressures of climate change impacts on SDG success. **Non-traditional data sources**, such as citizen science, can be **key in filling in both spatial and temporal gaps in statistical data coverage for SDG reporting and monitoring**. Networks of citizen observatories are key in helping to achieve this potential.

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