ROADMAP for the uptake of the Citizen Observatories' knowledge base

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AUTHORS: Gerid Hager, Raquel Ajates, Ane Bilbao, Andrew Cobley, Saskia Coulson, Dahlia Domian, Michele Ferri, Dilek Fraisl, Steffen Fritz, Margaret Gold, Nikoletta Karitsioti, Joan Masó, Ian McCallum, Giovanni Tomei, Martina Monego, Inian Moorthy, Ester Prat, Athanasia Tsertou, Valantis Tsiakos, Linda See, Uta Wehn, Mel Woods

WEOBSERVE ADVISORY BOARD: Barbara Anton, Alena Bartonova, Muki Haklay

WEOBSERVE COORDINATOR: Steffen Fritz and Gerid Hager, International Institute for Applied Systems Analysis, Laxenburg, Austria

WEOBSERVE PROJECT OFFICER: Izabela Freytag

LAYOUT: Adam Islaam

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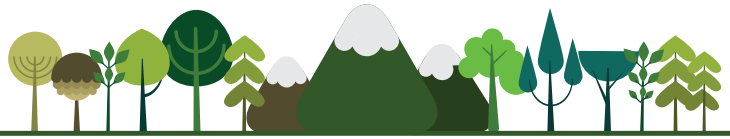
Contents



Executive Summary

The global community is challenged by an array of highly complex issues at an unprecedented scale and urgency, such as climate change, biodiversity loss, political radicalisation or the global coronavirus pandemic. Facing and addressing these issues humanely and in a timely manner calls for new forms of societal collaboration. With the European Green Deal and the new EU research and innovation framework programme Horizon Europe (2021-2027), the European Commission aims to develop and promote the uptake of innovative solutions to address these most pressing global challenges, including climate change and the achievement of the UN Sustainable Development Goals. As a result, there is increasing demand for new knowledge and action partnerships, engaging citizens and a range of other critical stakeholders in urgently needed social innovation processes. Citizen Observatories, a particular form of citizen science, focus on environmental monitoring and collective action and provide ample opportunities for citizen and stakeholder collaboration. They are well-positioned to address socio-ecological challenges and can complement official data streams in innovative ways. The European Union is now well-placed to strengthen the Citizen Observatory approach and to strategically employ Citizen Observatories to achieve the EU's aim of widening participation and better relating its research and innovation agenda to overarching societal needs as well as to citizens' needs in particular.

Fully tapping into the innovation and impact potential of Citizen Observatories requires continuous investments and targeted actions. WeObserve, an H2020 Coordination and Support Action, brought together several Citizen Observatory projects to share and consolidate knowledge and identify best practices. Many of the insights gained have been synthesised into this detailed research and innovation roadmap for future Citizen Observatories, outlining focus areas, dedicated pathways and proposed actions in each of them (Figure 1). The four main areas:

AREA 1 **Impactful alliances and communities**
AREA 2 **Robust data value chains**
AREA 3 **Sustainable market growth**
AREA 4 **Integration with official data frameworks and open data systems**

The aim of this roadmap is to outline a dynamic landscape and provide actionable pathways to further advance Citizen Observatories' capabilities and impacts in the future. It is targeted at Citizen Observatory practitioners (research institutions, civil society organisations, public authorities and others) for conceptualising and directing key aspects of future Citizen Observatories; at national funding agencies of EU member states to identify potential scenarios for funding Citizen Observatories nationally; as well as for the European Commission as a consultation document for shaping Horizon Europe programme funding calls. It allows different entry points and the actual route(s) through the roadmap will be largely determined by the context and perspective of those seeking input from it. The roadmap is concluded by a set of recommendations to funding bodies on how the next-generation of Citizen Observatories can be structurally supported and enabled to implement proposed actions as well as advance Citizen Observatories in service of Horizon Europe goals.

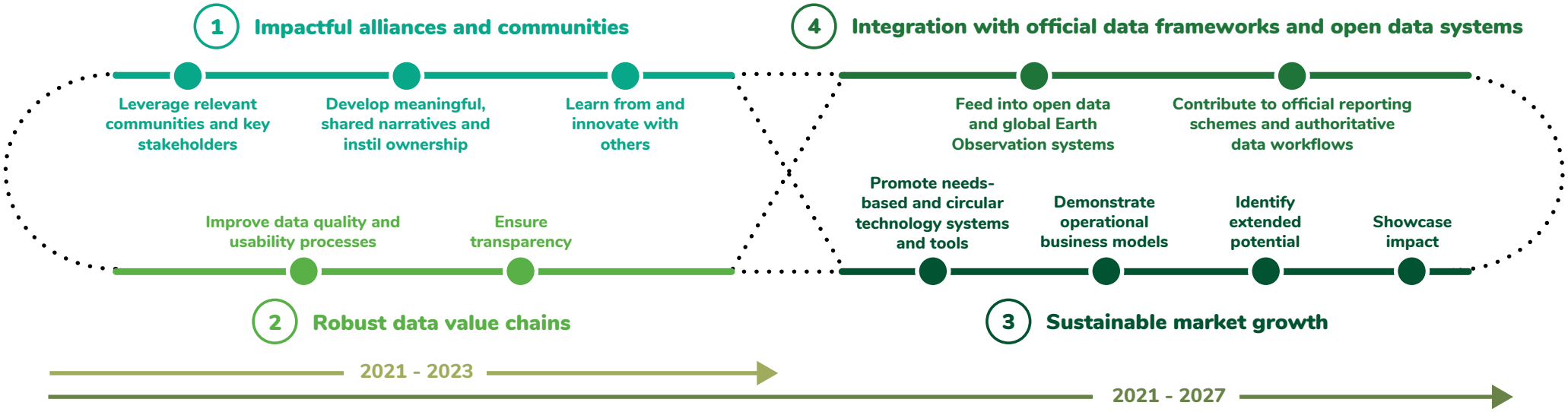


Figure 1: Main areas and pathways of the roadmap including interlinkages between areas.

1. Expanding horizons: A vision for Citizen Observatories in Europe and beyond

1.1 The potential and relevance of Citizen Observatories

In 2009, Prof. Jacqueline McGlade first spoke of a "global citizen observatory" and the valuable contributions individuals could make in observing and understanding the environment and informing actions in a changing world [1]. In 2021, at the time of writing this roadmap, Europe and the world are caught in a global pandemic and crisis, that underlines the importance and value of collective action, communal solidarity, knowledge sharing and timely and trustworthy data to underpin swift evidence-based decision-making and innovation, amongst others. Besides the pandemic, other highly complex issues challenge the global community at an unprecedented scale and urgency. Climate change, environmental destruction and pollution, biodiversity loss, inequity, political radicalisation and social alienation are the result of an accumulation of unfavourable practices across sectors and industries. Facing and addressing them humanely and in a timely manner calls for continuous efforts as well as new forms of societal collaboration. Effective decision-making and collective action are needed to minimise destructive behaviours and policies and increase social, environmental and economic co-benefits.

With the European Green Deal, the European Commission sets out "to make Europe the first climate neutral continent by 2050, with a sustainable economy that leaves no one behind"[1]. Horizon Europe – the new EU research and innovation framework programme (2021-2027) – aims at generating knowledge and promoting the uptake of innovative solutions to support this vision and to address these most pressing global challenges, including climate change and the achievement of the UN Sustainable Development Goals [2, 3]. This framework is embedded within a new, mission-oriented approach that should gear R&I funding and investments more directly towards achieving specific and targeted goals for tackling grand societal challenges [4,5]. Four out of the five mission areas of Horizon Europe directly support the ambitious Green Deal agenda[2]. In a recent staff working document "Best Practices in Citizen Science for Environmental Monitoring" [6], the European Commission also highlights how environmental knowledge generated by citizens via citizen science initiatives can help deliver on the European Green Deal and other EU and global priorities as well as outlining remaining challenges and barriers for its broader uptake for environmental monitoring. As a result, there is increasing demand for mechanisms that create or support new knowledge and action partnerships, engaging citizens and a range of other critical stakeholders in such urgently needed social innovation processes to aid environmental protection and sustainable development.

Citizen Observatories (briefly described in Box 1) offer opportunities for citizen and stakeholder involvement and participation and are well-positioned to address socio-ecological challenges in innovative ways. Citizen Observatories can also complement official data streams and compliance monitoring, especially where official data are sparse, contested or hard or expensive to obtain. As summarised by Hager et al. [7], Citizen Observatories, so far, have:

- Increased citizen participation in environmental monitoring, management and governance at local and regional scales as well as educated thousands of citizens in the theory and practice of citizen science;
- Played a pivotal role in addressing key socio-environmental issues by enabling individuals and communities to monitor and contribute observations, data and other 'in-situ' information, complementing authoritative and formal data sources for policy-making and environmental governance;
- Enabled and improved the dialogue between citizens and authorities and other key stakeholders through the formation of new partnerships;
- Led to behavioural and management changes on the individual level and citizen empowerment, such as considerably reducing water usage in farm management or starting to use and discuss collected data with local authorities, as well as changes to urban infrastructure;
- Contributed important scientific knowledge, e.g., by addressing data gaps, data validation and Earth Observation ground-truthing, and improved and standardised services and decision-making tools.

Box 1: Citizen Observatories in a nutshell

Citizen Observatories are a particular form of citizen science and collective action with the aim to create evidence and knowledge and to apply the evidence for advocacy and place-based decision-making to reach environmental and societal impact. They provide a mechanism for new partnerships between societal actors including citizens, scientists, decision and policy makers and others to tackle complex socio-environmental challenges. Citizen Observatories engage the public in scientific knowledge creation, employing citizen science methods, digital tools and sensors to gather data, share information, and motivate change. Typically, they intend to engage communities longer-term, or for a defined timeframe to address a specific issue or situation.

1 https://ec.europa.eu/commission/presscorner/detail/en/ip_20_1669, accessed Jan 21, 2021

2 Missions: Healthy oceans, seas, coastal and inland waters; Climate-neutral and smart cities; Soil health and food; Adaptation to climate change and societal transformation

Authorities who have employed Citizen Observatories for environmental risk management have seen improvements in the risk monitoring and management processes as well as potential lower overall expenditure costs of in-situ data collection [8]. Citizen Observatories also demonstrably contribute action towards achieving the SDG goals and targets and to SDG indicator monitoring with yet largely untapped potential [9, 10]. They have also emerged to address pressing social issues and as a means to hold authorities and governments accountable in times of crisis (see examples in section 2) and have proven to be fertile ground for bottom-up social innovation, that can disrupt current unsustainable practices as well as inspire and accelerate formalised processes of innovation [11]. However, the scrutiny with which Citizen Observatories are judged and evaluated – regarding their treatment of data quality, data management and standardisation, their ways of stakeholder engagement, communication and the demonstration of impacts, amongst others - poses a continuous need to improve. It also provides a unique opportunity for Citizen Observatories to become role-models for innovation at the interface of society, science and policy and opens up discussion around wider issues of data quality, standards and democratisation of knowledge in conventional science contexts.

The European Union is now well-placed to strengthen its leadership role in advancing and promoting the Citizen Observatory approach and to strategically employ Citizen Observatories to achieve the EU's aim of widening participation and better relating its research and innovation agenda to society and citizens' needs. A wide range of thematic clusters in the Horizon Europe programme under *Pillar 2: Global Challenges and European Industrial Competitiveness* could greatly benefit from employing the Citizen Observatory concept as well as help to improve it, from, e.g., operationalising air quality observatories for pollution monitoring (Cluster 1: Health); coupling Earth Observation from space with citizen-powered ground-truthing (Cluster 4: Digital, Industry and Space); to providing solutions for natural capital conservation, and fostering climate neutral and resilient societies (Cluster 5: Climate, Energy and Mobility; and Cluster 6: Food, Bioeconomy, Natural Resources, Agriculture and Environment). Furthermore, Horizon Europe's focus on providing and commissioning permanent research and data infrastructures as well as spurring innovation and new markets *(Pillar 1: Open Science and Pillar 3: Innovative Europe)* can not only help improve Citizen Observatory technologies and data infrastructures, but also support them in developing new business models and further expanding their value chains.

1.2 Future scenarios

Future Citizen Observatories, developed with Horizon Europe and via other funding streams, will differ regarding the topics addressed, the temporal and spatial scales of operations, the functions of monitoring, the initiators and the type of contributing actors, the nature of change triggered, and many more. Despite this inherent diversity, certain core principles and aims will guide them, such as building on the premises of citizen and community empowerment and participation, awareness raising, cooperation and new partnerships as well as the collection and use of data and evidence to address both locally and globally relevant social and environmental challenges. Importantly, Citizen Observatories will provide opportunities to overcome simplistic dichotomies such as bottom-up versus top-down action or local versus global efforts, by creating iterative processes, up-scaling opportunities and collaboration across many stakeholders. In doing so, Citizen Observatories can become integral to facilitating powerful alliances across all actors of society, striving for policy and legal impacts and changes to individual behaviours. Box 2 provides examples of possible scenarios for Citizen Observatories stemming from a vision(s) workshop, attended by Citizen Observatory practitioners, providing a glimpse into such possible futures.

Photo by Ingrid Vasconcelos on Unsplash

Box 2: A kaleidoscope of Citizen Observatories in 2025

Thousands of citizens are regularly monitoring water levels and providing information through mobile apps as part of a **Citizen Observatory for flood risk monitoring and management**. Data are assimilated with other sensor data in hydrological–hydraulic models. The multi-way communication between authorities, the citizens and flood managers significantly increases the effectiveness of early warning, civil protection operations during flood emergencies and has led to reduced damage from floods with a 45% reduction of damage costs to people, buildings and economic activities, compared to floods occurring before the implementation of the Citizen Observatory. The collective system of self-protection from flood events has demonstrated the value of non-structural prevention measures at a regional level and is now elevated to the national scale. *(Inspired by the citizen observatory in the Brenta-Bacchiglione catchment in northern Italy)*

The **LandMapping Citizen Observatory** brings together the global giants in data processing, natural sciences, and volunteer communities to gather data on the uses of land around the globe to make this elusive characterisation of the land finally possible. Tapping into the leisure activities of many outdoor enthusiasts has resulted in an unprecedented documentation of the Earth's surface. Anyone can take part in an adventure-oriented game to answer questions about the landscape. Using AI and the millions of photographs captured outdoors has resulted in new, automated methods for recognition of land use types as part of a collective global effort to better understand how the Earth is being used by mankind and to inform local policy and communities to protect, manage and restore their environment. *(Inspired by Geo-Wiki and Adventure Scientists)*

A citizen observatory focused on monitoring plant phenology reveals drastic effects of climate change on natural habitats and turns **naturalists into climate change activists**. The observatory started with a handful of people collecting data about nature but now has influenced thousands to demonstrate for climate action and to put pressure on governments to pass laws to drastically accelerate the process to reduce carbon emissions and move to renewable energies. Participants also take individual measures to reduce their personal carbon footprints following recommendations provided by the Citizen Observatory. *(Inspired by RitmeNatura)*

Back in 2020, residents of Murcia in Spain started a campaign to protect the polluted Mar Menor, Europe's largest saltwater lagoon, to grant it legal rights by recognising it as a legal "person". After four years of coordinated efforts, a legal entity status was awarded to Mar Menor in 2024, and a **Citizen Observatory to restore the lagoon was** set up with different groups in the community, including farmers, residents, schools, an association of volunteer biologists and the local authority. The observatory establishes a tripartite effort of monitoring water quality at the Mar Menor and inland, monitoring pesticide and fertiliser runoff from agricultural fields to inform regenerative land management practices, and monitoring biodiversity in the lagoon, to improve water quality and to restore ocean biodiversity and the local fish, seahorse and bird populations. *(Inspired by SOS Mar Menor)*

The establishment of the **first permanent citizen-powered European Research Infrastructure** supports a radical new form of societal partnership. It enables civic society to contribute data and information on an ongoing basis and with the highest ethical and technical standards. In an unprecedented effort, a diverse group of experts from community initiatives, DIY groups, data science, national statistics, environmental monitoring, Earth Observation, citizen science and open science has joined to develop a functional infrastructure and system that supports citizen sensing through Citizen Observatories on a continental scale. In addition to a technical infrastructure and data integration system, the ERI also provides ongoing support, capacity building and training in member countries, supported by the "A Citizen Observatory Alliance in Every Town" Programme. The data gathered are used for local decision and policy making as well as official EU-level compliance monitoring and reporting. *(Inspired by Cos4Cloud)*

The European Commission launches the "**A Citizen Observatory Alliance in Every Town**" Programme to support Citizen Observatories across Europe at the local level. The alliances are formed by representatives from the community, local school, universities or colleges and work closely with a specifically allocated and dedicated team of local authorities to propose, design, deliver and act on local Citizen Observatory projects. *(Inspired by Town Twinning Programmes and the Green Leaf Network)*

1.3 Scope and aim of the roadmap

This document outlines a dynamic landscape and provides actionable pathways via the roadmap in chapter 4 to further advance Citizen Observatories' capabilities and impacts in the future, especially in service of European and global societies to enable them to collectively address some of these most pressing global challenges. Furthermore, the roadmap can help establish tangible opportunities for Citizen Observatories in Horizon Europe under the Green Deal agenda. The roadmap is targeted primarily at the following stakeholder groups:

- Practitioners (research institutions, civil society organisations, public authorities and others) for conceptualising and directing key aspects and R&I plans for future Citizen Observatories and related projects;
- National funding agencies of EU member states to gain insights from existing Citizen Observatories and identify suitable scenarios for funding Citizen Observatories nationally;
- The European Commission as a consultation document for shaping Horizon Europe programme funding calls in support of the implementation of the European Green Deal.

1.4 Development of the roadmap

The roadmap represents the synthesis of research, workshops, and other forms of discussions and conversations amongst Citizen Observatory and citizen science practitioners, researchers, public authorities, engaged citizens, and representatives from the European Commission, under the umbrella of the WeObserve project (Box 3). Amongst the core activities and publications that provide the basis for the roadmap are:

- The WeObserve Landscape Reports on Citizen Observatories in Europe [12, 13];
- Observing the Environment: Challenges and Opportunities in Citizen Science, a knowledge exchange event at the European Commission in Brussels in 2019 [14];

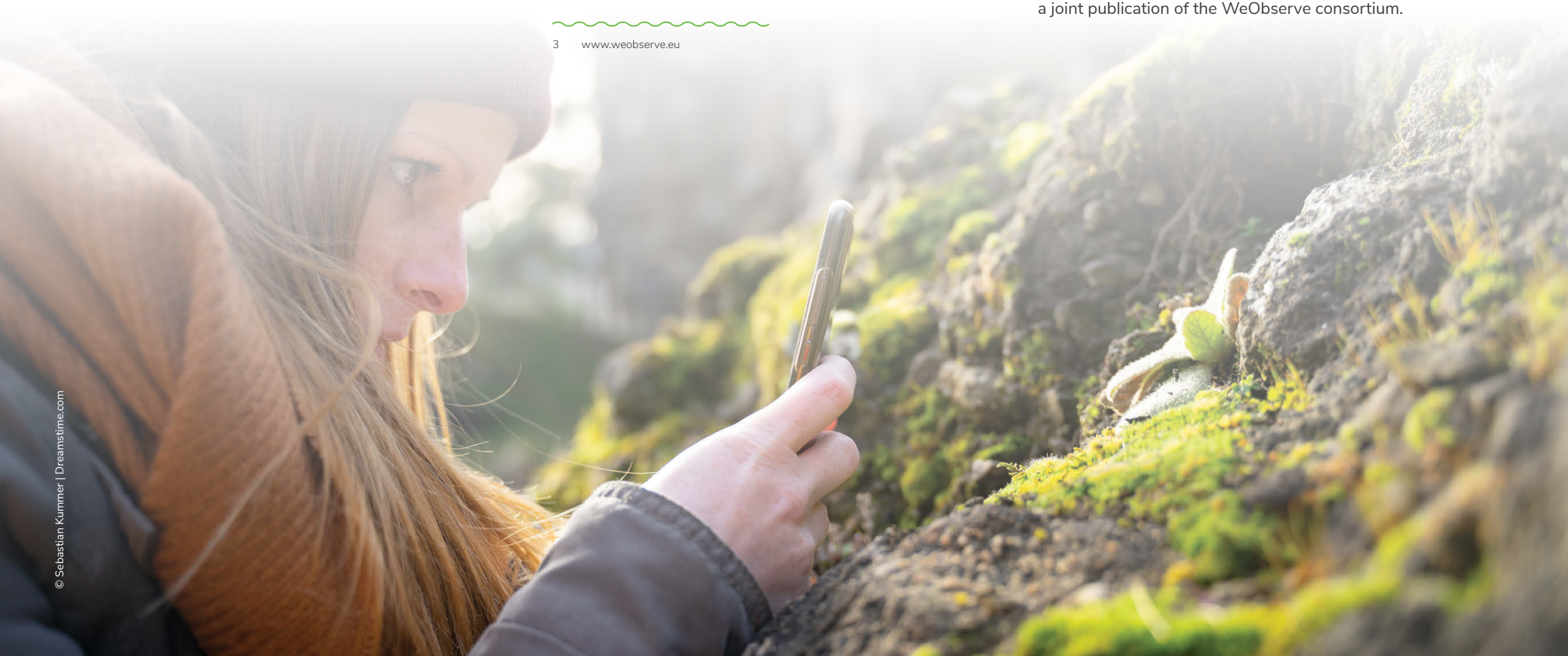
- Work from the WeObserve Communities of Practice that supported the citizen science working session in the EuroGEO Workshop 2019, leading to the formulation of the Lisbon Declaration on the current state of citizen science in GEO and GEOSS [15];
- The WeObserve policy briefs [16, 17];
- A workshop on citizen science and the SDGs in October 2018, followed by collaborations that led to several journal papers on the potential of Citizen Observatories and citizen science for SDG monitoring and implementation [9, 10, 18]; as well as
- Other efforts across the WeObserve consortium and WeObserve Communities of Practice to synthesise relevant lessons learnt [7, 8].

Box 3: What is WeObserve?

WeObserve[3], an H2020 Coordination and Support Action (Dec 2017-March 2021), brought together four H2020 Citizen Observatory projects (LandSense, Ground Truth 2.0, GROW Observatory, and Scent) (Box 4) and the Citizen Observatory for flood risk management of the Brenta-Bacchiglione river basin in Italy. It delivered the first European-wide Citizen Observatory knowledge platform and enabled the sharing and consolidation of experiences and best practices to inform practitioners, policy makers and funders of Citizen Observatories.

3 www.weobserve.eu

Initial scoping of this document was done by Project Advisors from the European Commission (EASME, DG R&I) together with the WeObserve project coordinator (IIASA). The scope of the document was then discussed amongst WeObserve partners and with the WeObserve Expert Advisory Board. A draft outline was set up and reviewed by WeObserve partners who also met in January 2021 for a “Citizen Observatory vision(s) workshop”, when they shared and discussed visions for Citizen Observatories in Europe. Additionally, insights on the impacts of specific WeObserve activities were gathered. A draft version of the roadmap was discussed with members of the WeObserve Communities of Practice (CoPs) during CoP Forum 6 in March 2021, the WeObserve Expert Advisory Board and Project Officers at the EC to gain feedback and inputs. The roadmap is a joint publication of the WeObserve consortium.



2. The Citizen Observatory landscape

Since the emergence of the Citizen Observatory concept in 2009, the European Commission (EC) has widely embraced it, providing leadership in the advancement of Citizen Observatories for environmental monitoring in particular. Two distinct goals and characteristics were to combine Earth Observation technologies with tech-enabled and community-based environmental monitoring for delivering new data and information systems as well as empowering communities and providing them with understandable information for decision-making [19]. Multiple Citizen Observatories and Citizen Observatory projects as well as the coordination across Citizen Observatories have been supported via the European Union's (EU) Seventh Framework (FP7) and Horizon 2020 (H2020) research and innovation programmes, covering a diverse range of topics – from soil health, odour and air pollution, or flood and drought monitoring to the integration and interoperability of Citizen Observatory services or the consolidation of Citizen Observatory knowledge gained (Table 1). These projects have developed innovative technologies and applications that enable citizens to effectively participate in environmental monitoring and stewardship as well as express the policy priorities of their community. Most recently, the first European Green Deal call under the H2020 programme offered further opportunities for Citizen Observatory funding, highlighting the continuous support and interest in the concept's potential.

FP7-funded	Focus	Timeline
COBWEB	Biosphere monitoring	2012-2016
OMNISCIENTIS	Odour monitoring	2012-2014
CITI-SENSE	Air pollution monitoring	2012-2016
WeSenseIt	Flood and drought monitoring	2012-2016
Citclops	Coastal and marine water quality monitoring	2012-2015
H2020-funded	**Focus**	**Timeline**
Making Sense	Open design and digital maker practices, DIY environmental monitoring, air, water, soil and sound pollution	2015-2017
CAPTOR	Combining citizen science, collaborative networks and environmental grassroots social activism to raise awareness and find solutions to the air pollution problem	2016-2018
hackAIR	Development of an open technology toolkit for citizens' observatories on air quality	2016-2018
Ground Truth 2.0	Flood risk management, environmental quality of life, land and natural resources management, sustainable livelihoods, climate change adaptation	2016-2019
GROW Observatory	Soil, land use, crop planting, and water resources	2016-2019
LandSense	Land use and land cover monitoring	2016-2020
Scent	Water supply and quality, flood risks	2016-2019
SMURBS	Integration of EO and citizen observations for a common approach to enhance urban environmental and societal resilience	2017-2021
WeObserve	Knowledge consolidation and mainstreaming of Citizen Observatories	2017-2021
DNoses	Odour monitoring	2018-2021
Monocle	Water quality monitoring	2018-2022
CitieS-Health	Assessing urban air and noise pollution and the link to health impacts	2019-2021
MICS	Measuring impacts of citizen science, nature-based solutions, water quality and biodiversity	2019-2021
WeCount	Urban road transport monitoring	2019-2021
TeRRIFICA	Adaptation processes to climate change through living labs, crowd-mapping and co-design	2019-2022
Cos4CLOUD	Interoperability and integration of Citizen Observatory technology and data with European Open Science Cloud	2019-2023
DIONE	Complementing EO data with farmer-based monitoring to inform CAP regulations and decision-making at farm level	2020-2022
FRAMEwork	Citizen Observatory for monitoring biodiversity in farmland landscapes	2020-2025

Table 1: Citizen Observatories and Citizen Observatory type projects funded by the EU via FP7 and Horizon 2020 programmes (extended from [12])

Citizen Observatories have also been explored in the academic literature within the European context, highlighting the interplay of citizen participation, data gathering and knowledge exchange via the use of mobile and web technologies and sensing devices, evidence-based decision-making, local action and policy change (cf. [20-23]). Citizen Observatories have facilitated decisions and actions across a wide network of stakeholders including citizens, citizen organisations, policy makers, scientists and data aggregators by building on multi-directional flows of data, information and knowledge. Furthermore, Citizen Observatories have shown to manifest in many different ways, building on top-down and bottom-up models, including contributory, collegial, collaborative, or co-designed actions (cf. [25]), some building exclusively on one or the other, sometimes employing both side by side. Citizen Observatories have also transitioned from one such model, to another during their lifetime [7, 26]. Taking these elements together uncovers the complex nature of Citizen Observatories from a socio-technical perspective and hints at the types of challenges that they may face in practice.

Outside the European funding context and the focus on community-based and technology enabled environmental monitoring, other initiatives have emerged that identify as "Citizen Observatories", such as the the Obywatelskie Obserwatorium Demokracji (Citizens Observatory of Democracy)[4], a platform that brings together civil society reactions to changes in legislation, the Observatorio Ciudadano Nacional del Feminicidio México (National Citizen Observatory on Femicide in Mexico)[5], a citizen participation initiative for monitoring and systematising information on the lack of prosecution of femicidal violence, or the Observatorio Ciudadano COVID-19 Nicaragua (Citizen Observatory for COVID-19 in Nicaragua)[6], a network of doctors and volunteers in Nicaragua, established to report suspect cases of COVID-19 infections after official data streams had been criticised for inaccurate and insufficient case reporting. While addressing these initiatives in more depth is out of the scope of this report, it is important to highlight that these cases exemplify core values found in Citizen Observatories and project these in domains other than environmental monitoring and management. Stemming from different societal needs, they also strive for citizen empowerment and build on the organisation and exchange of data, evidence and information, to inform decision and policy making as well as to support or question public authority and accountability. These similarities underline common strengths and also illustrate where some of the untapped potential of the Citizen Observatory concept lies.

Box 4: The four Citizen Observatory projects joining forces under WeObserve

LandSense (2016-2020) built a Citizen Observatory for Land Use and Land Cover monitoring, by connecting citizens with EO data to transform current approaches to environmental decision-making.

The GROW Observatory (2016-2019) created a citizen science community of food growers and small-scale farmers across Europe to generate, share and use information on land, soil and water resources at high-resolution through the use of low-cost sensing technology.

Ground Truth 2.0 (2016-2019) developed a co-design methodology for setting up locally relevant and sustainable citizen observatories. It demonstrated and validated this approach in real conditions by setting up seven Citizen Observatories in four European and two African countries.

Scent (2016-2019) created a toolbox of smart technologies and applications that aims to enable citizens to monitor Land Cover and Land Use changes, soil conditions and river parameters and how these affect flood phenomena in their urban or rural areas.

4 http://citizensobservatory.pl/, accessed on Jan 20, 2021

5 https://www.observatoriofeminicidiomexico.org/, accessed on Jan 20, 2021

6 https://observatorioni.org/, accessed on Jan 20, 2021

3. From Citizen Observatory challenges to action

The diversity and evolution of the Citizen Observatory landscape within and outside the European funding context also highlights the importance of and need for coordination and consolidation actions – such as WeObserve – to be able to learn from experiences and develop expertise, strengthen and form new partnerships, continue contact with participating communities and establish networks across funding and domain boundaries to foster joint innovation.

3.1 Challenges faced by Citizen Observatories and strategies to address them

Initially, WeObserve focused on three topics that proved to be challenging for mainstreaming Citizen Observatories, based on experiences gained in LandSense, Ground Truth 2.0, GROW Observatory, and Scent respectively:

- **AWARENESS:** Improving awareness of and engagement in Citizen Observatory and citizen science activities
- **ACCEPTABILITY:** Increasing the quality and acceptability of Citizen Observatory data and methods, showcasing the added value for improved uptake in communities and policy making
- **SUSTAINABILITY:** Creating stable communities, infrastructures and transition processes that facilitate the sustainability of the Citizen Observatory itself and help scale up Citizen Observatory activities.

These three challenge areas provided a framework to kick-start the reflection on Citizen Observatory experiences in greater depth and informed the design of activities under WeObserve more specifically. In seeking to understand more deeply the underlying factors that may hold them back from becoming more sustainable over the long term and achieving their intended impacts, WeObserve gathered the experience of Citizen Observatory projects through a series of workshop events, interviews, desktop research and collaborations. The most in-depth insights have come from interactions with Ground Truth 2.0, the GROW Observatory, LandSense and Scent, but to extend our understanding of Citizen Observatories in different contexts, we also reached out to other projects.

The range of challenges that Citizen Observatories face in practice primarily stems from their unique characteristics in terms of their reliance on an underlying technology platform or mobile application, the need to engage closely with policy and public authority stakeholders, and the significant time and effort required to build an engaged community of participants. Tensions can sometimes arise within Citizen Observatories (for example, regarding the acceptability or ownership of the data, or regarding the approach to gathering data) due to different mindsets and perspectives, and the different needs and motivations of the various stakeholders engaged. This can be visualised as a 'triangle of trust' that must stay in balance between citizen participants, the decision makers who can address the issue, and the scientists leading or supporting the initiative and, in many cases, the needs of the scientific method itself. Additionally, the ambition of many Citizen Observatories to contribute to environmental governance and policy change requires an operational period that will necessarily extend beyond the end of typical project funding timelines, as longer-term impacts only become evident or achievable over these longer time scales. A detailed account of how the challenges manifested in different projects and how they were specifically addressed can be found in the WeObserve EU Citizen Observatories Landscape Report II [13].

3.2 WeObserve actions and lessons learnt

In addition, WeObserve implemented a range of umbrella activities to jointly address the common challenges across Citizen Observatories. Table 2 in Appendix 1 presents the respective activities and the key lessons learnt. They include, amongst others, the implementation of hackathons and an Open Data Challenge to promote and demonstrate the uptake of Citizen Observatory data for the development of downstream applications and to spur solution prototyping for Citizen Observatory and citizen science data integration, cataloguing and authentication; Roadshows and massive open online courses (MOOCs) to showcase the added value of Citizen Observatories for environmental risk and disaster management and to engage with an international community of learners new to citizen science, experienced citizen scientists and practitioners; or Communities of Practice (CoPs) to demonstrate the value of citizen-generated data and impact for SDG monitoring, to adopt data quality, curation and preservation of data and address privacy and licensing issues, to inventorise methods for capturing the impacts of Citizen Observatories on governance, and to share knowledge on co-designing Citizen Observatories and engaging stakeholders.

However, the outlined challenges as well as the strategies to address them are, like the Citizen Observatory concept, not fixed but continuously evolving and manifesting in different ways, depending on the specific Citizen Observatory and its context. For example, the sustainability challenge identified in WeObserve was originally focused on the financial and community sustainability of Citizen Observatories that had a mandate to establish long-term activities (see Box 5 for actions that have continued from recent H2020 Citizen Observatory projects). However, Citizen Observatories may not necessarily

need to run in the long-term and invest in establishing systems and networks to ensure continuation. They may also be set up for a defined timeframe to address a specific issue or situation. Similarly, sustainability in terms of environmental concerns for digital waste have been growing and future Citizen Observatories will need to consider and specifically address these. Hence, mapping emerging concerns should become a key activity of future Citizen Observatories to ensure previously unrecorded challenges are identified and acted on as and when required.

Box 5: Continued action

LandSense: The NaturaAlert app and biodiversity threat monitoring is further used by BirdLife volunteers in Spain, Indonesia and Greece. Further expansions to other BirdLife partner countries are envisioned [27]. The French National Mapping Agency (IGN) has implemented new methods in the updating of their authoritative land use land cover map, inspired by LandSense.

GROW Observatory: Many participants of the soil sensing network established in GROW have continued soil sensing. For example, after the end of the H2020 funded period, farmers in El Hierro, Spain, worked with the local government to place soils sensors in the different climate regions of the island. A superuser in GROW Place Portugal uploaded his own data to Github and used them in novel ways. GROW Place Greece started exploring combining soil sensor data with migratory bird data to inform land and biodiversity conservation policies [28].

Ground Truth 2.0: The Meet Mee Mechelen Citizen Observatory in Belgium continued its activities related to air quality monitoring as part of the larger Klimaan initiative. RitmeNatura in Spain is up and running as part of the Phenotandem pilot project of CSEOL, with citizens collecting phenological data to monitor the impacts of climate change. Grip op Water Altena (NL) is still actively working on climate-proof water management and the diverse stakeholders of the Maasai Mara Citizen Observatory in Kenya continue their activities to strive for a balance between biodiversity management and sustainable livelihoods.

Scent: Registered users to SCENT applications have increased by 15% since the end of the project. Gamification and engagement activities during the project campaigns have created a community that has remained active beyond the end of the project activities. In addition, relevant organisations and associations (i.e., NGOs, hikers, walking groups, climbers, local municipalities, environmental associations etc.) are using the data collection tools for opportunistic collection of environmental information even without active campaigns running.

3.3 Gaps and emerging issues

Aside from the above-mentioned areas, gaps became evident, and several topics remained underexplored or fell outside the scope of WeObserve. They provide additional and ample opportunities for future Citizen Observatories to improve and develop solutions. While outlined here, these topics have also been considered in the proposed roadmap in section 4.

- **Citizen Observatory business model development and implementation:** All four Citizen Observatory projects under WeObserve have proposed business models during their lifetime (confidential reports to the EC), identifying a diverse set of value propositions as well as outlining the financial value and cost-saving potential of Citizen Observatories. In addition, WeObserve has addressed the wider definition of sustainability and business modelling of Citizen Observatories and developed several activities (WeObserve Open Data Challenge, Hackathons, MOOC, Toolkit) to explore market opportunities and the potential for further impact and uptake. Other areas were not or only partly addressed, e.g., around the cost-effective provision of emergency services, policy consultation or other public services, or developments of community-based data ownership and profit-making models such as data cooperatives. The topic of up-scaling has also gained importance in the field of citizen science more generally and factors that can promote scaling ambitions have been identified recently [29]. Nevertheless, the consideration of such up-scaling factors in the design, implementation and business modelling of Citizen Observatories as well as their respective emerging markets remain underexplored.

- **Capturing emergent Citizen Observatory innovations:** Citizen Observatory projects have managed to transition and sustain activities as well as spur innovations beyond the initial project lifetimes, giving way to new methods, interactions amongst stakeholder groups, changes on the ground (Box 5), or “softer” innovations, such as replicated methodologies, adapted tools, or improved materials. They have only just started to capture social and digital innovations emerging in participating communities. Nonetheless, such spin-off innovations are important for the real impacts and highlight the function of Citizen Observatories as drivers of innovation. Ways to capture and communicate these impacts are elusive, especially when roles and responsibilities around the Citizen Observatories evolve and change.

- **Citizen Observatories and the media:** During the lifetime of the four Citizen Observatory projects, other comparable activities with impressive community success and policy impact have taken a different approach to community and stakeholder engagement by pioneering new forms of media partnerships and engagement (cf. CurieuzeNeuzen project[7]). While the GROW Observatory, for example, also leveraged design and media intelligence for innovative audience development by deliberately including media experts in the project consortium, the topic remains underexplored in the realm of Citizen Observatories and citizen science, despite its tremendous potential.

- **Citizen Observatories and participation patterns:** There is a lack of understanding of the long-term community participation patterns (from levels of participation, data

7 https://2018.curieuzeneuzen.be/

generation, to connections with and involvement in policy) that might occur in well-established Citizen Observatories with more stable and long-term funding, e.g., with a length of community involvement over three years. Furthermore, ensuring inclusive participation across age groups, social backgrounds and gender has remained under-addressed by large-scale Citizen Observatory projects.

- **"Bottom-up" and citizen-led Citizen Observatories:** Insights from the four Citizen Observatory projects suggest that Citizen Observatory activities built together with established communities, such as bird monitoring groups of the BirdLife network or other (local) environmental NGOs and succeeding to address their distinct needs and requirements by providing enabling technologies are successful regarding their uptake and potential continuation (cf. [LandSense]). While the DITOs project together with WeObserve comes to a similar conclusion in a policy brief on innovation management for citizen science [30] and certain successful community driven initiatives such as OpenStreetMap have been explored in particular, a detailed account of the unique strengths and challenges across bottom-up Citizen Observatories, that are community driven, or backed by CSO/NGOs, is still missing.

- **Citizen Observatories and open data management:** WeObserve has deliberately addressed data issues with the Interoperability Community of Practice and reported on interoperability experiments and efforts to standardise data across citizen science initiatives. Nonetheless, the management of large datasets, data and information feedback to data contributors, the protection of sensitive data, as well as proper data attribution, amongst others, need further attention and improved integration with the Open Science movement as well as their open data and open access principles, mechanisms and infrastructures.

- **Citizen Observatories and security issues:** Particular security issues potentially evoked by Citizen Observatory activities can be related to land access, monitoring and subsequent visualisation and open accessibility of the resulting data or information that can put observers or the observed in dangerous situations, such as recording illegal logging, poaching, or threatened species. A deliberate and consolidated reflection on these issues across Citizen Observatories and guiding principles to address them would be beneficial.

- **Citizen Observatories in new domains:** The Citizen Observatory concept originated from the domain of Earth Observation and environmental monitoring and, so far, has been largely funded under this umbrella. At the same time, other types of Citizen Observatories have emerged as outlined in chapter 2, as a means to respond to societal issues, health-related challenges, or a lack of transparency or access to data in situations of crisis. Exploring the application of and developing Citizen Observatories to address new challenges and issues outside the immediate scope of environmental monitoring has been beyond the scope of WeObserve but opens up exciting new pathways and opportunities for citizen engagement and empowerment and the identification of data needs.

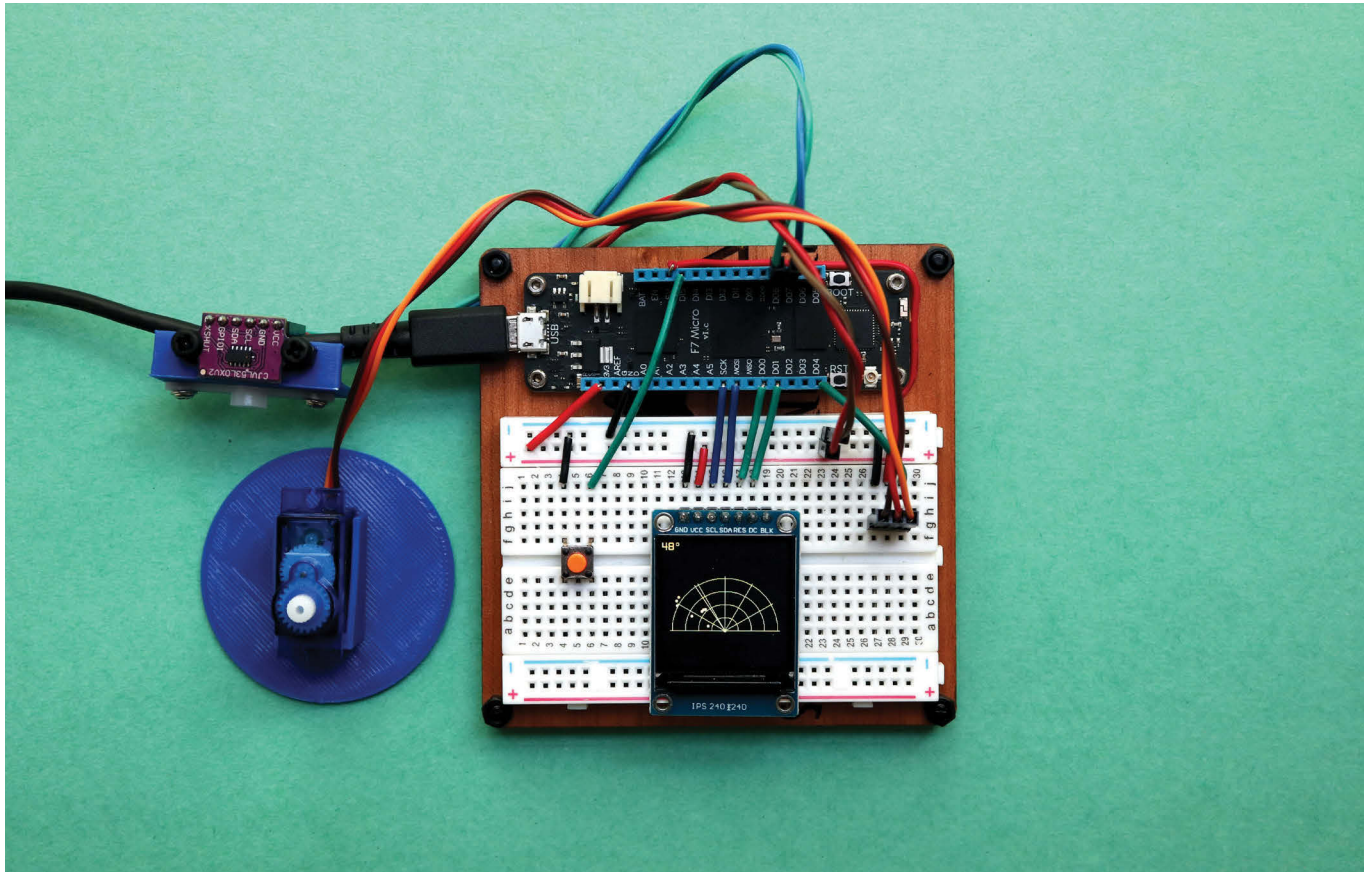


Photo by Jorge Ramirez on Unsplash

4. A research and innovation roadmap for Citizen Observatories

The roadmap proposes four main research and innovation areas as well as specific pathways and actions for future Citizen Observatories to further develop and advance the uptake and mainstreaming of the concept and related practices. Each action item includes a more nuanced direction of travel, outlines the potential for research and innovation and provides a basic, and inevitably incomplete, collection of resources to build on. It allows different entry points and the actual route(s) through the roadmap will be largely determined by the context and perspective of those seeking input from it. The overarching areas, as well as the pathways and actions were identified by and are based on the experience of past projects and guided by the WeObserve consortium's vision for future Citizen Observatories. The implementation and applicability of the roadmap can be adapted to the specific goals, context, initiators and core actors of new Citizen Observatories and the specific challenges they aim to address. For certain Citizen Observatories, some proposed actions and activities may be more relevant than others, while other Citizen Observatories will find that several suggested approaches are mutually beneficial, e.g., engaging both large media outlets and established, place-based communities. We hope funders of future Citizen Observatories will find inspiration and direction from the roadmap when formulating the scope and requirements for future funding calls and programmes. After presenting the roadmap, we offer specific recommendations for funders on how the implementation of proposed actions and new Citizen Observatories can be structurally supported.

The four roadmap areas for future research and innovation concerning Citizen Observatories have a proposed short-term focus for 2021-2023 (Area 1 and 2) as well as a medium-term focus for 2021-2027 (Areas 3 and 4):

AREA 1: IMPACTFUL ALLIANCES AND COMMUNITIES – Citizen Observatories build on multi-stakeholder collaboration, including citizens, scientists, policy makers, and other key societal actors and experts. Forming impactful alliances, capitalising on existing invested networks, sharing visions, working towards shared goals and acknowledging contributions is key to successful Citizen Observatories. Exchanging and sharing knowledge across Citizen Observatory practitioner networks helps find local solutions to common problems as well as develop joint innovations for shared challenges.

AREA 2: ROBUST DATA VALUE CHAINS – Citizen Observatories revolve around the collection and provision of trustful data and evidence to inform and empower citizens, communities as well as policy and decision-making. Establishing trustworthy and suitable data collection and description pathways, ensuring alignment with existing standards, as well as providing transparent and suitable accreditation and IPR approaches enhances the acceptability and uptake potential of Citizen Observatories.

AREA 3: SUSTAINABLE MARKET GROWTH – The market for Citizen Observatories has been explored in the past but it requires more effort for it to become established and recognised as such. Positioning Citizen Observatories as value-adding, cost-effective, responsible and impactful mechanisms to address some of communities' and society's greatest challenges will grow the market potential of Citizen Observatories.

AREA 4: INTEGRATION WITH OFFICIAL DATA FRAMEWORKS AND OPEN DATA SYSTEMS – Citizen Observatories and citizen science projects successfully contribute to official flood monitoring and management, to SDG indicator monitoring and to the validation, or "ground-truthing" of remote sensing and EO data through providing in-situ observations. They also fill data gaps and expand scattered official monitoring systems with spatial and temporal high-density data. Integrating Citizen Observatory data and processes with official data streams and systems for risk monitoring and management, national reporting, EU reporting, or indicator monitoring for the UN Sustainable Development Goals, requires efforts across large stakeholder groups and structures, including (sub-)national, GEO and SDG delivery pipelines.

Area 1. Impactful alliances and communities

PATHWAY: LEVERAGE RELEVANT COMMUNITIES AND KEY STAKEHOLDERS

ACTION 1.1. Engage with active, place-based communities, community organisations and citizen-driven initiatives

DIRECTION: Citizen Observatories revolve around the collection and provision of trustful data and evidence to inform and empower citizens, communities as well as policy and decision-making. Establishing trustworthy and suitable data collection and description pathways, ensuring alignment with existing standards, as well as providing transparent and suitable accreditation and IPR approaches enhances the acceptability and uptake potential of Citizen Observatories.

R&I POTENTIAL: The market for Citizen Observatories has been explored in the past but it requires more effort for it to become established and recognised as such. Positioning Citizen Observatories as value-adding, cost-effective, responsible and impactful mechanisms to address some of communities' and society's greatest challenges will grow the market potential of Citizen Observatories.

RESOURCES TO BUILD ON: GROW community champions report [31]; GROW MOOC programme for training communities [32]; GROW Places communities[8]; GT2.0 communities[9].

8 https://knowledge.growobservatory.org/article-categories/grow-places/index.html
9 https://gt20.eu/citizen-observatories/

ACTION 1.2. Engage with decision makers, policy and government agencies

DIRECTION: Sensitisation of policy and decision makers on the benefits of collaborating with citizens and embedding citizen generated data into the decision-making cycle (from local to national planning and management) are essential to reach policy acceptance and wider uptake of Citizen Observatories. Include relevant authorities already in the project design and proposal phase, such as environmental protection agencies, city councils, regional government agencies etc.

R&I POTENTIAL: Identify value propositions for policy stakeholders, understand key pain and gain points and barriers for collaboration with policy stakeholders and develop strategies to address them; Co-develop new data pipeline models and monitoring processes, based on Citizen Observatory approach; Better understand requirements for policy engagement; Identify relevant (national, EU, UN) agencies and programs that could benefit from citizen science.

RESOURCES TO BUILD ON: WeObserve Cookbook[10]; Making Sense Framework & Assessment of Participatory Strategies [33]; GT2.0 Stakeholder engagement strategy [34]; GT2.0 Guidelines for Citizen Observatories [35]; SCENT Toolbox impact assessment [36].

10 https://www.weobserve.eu/cookbook

ACTION 1.3. Secure support from gatekeepers and community champions

DIRECTION: Nurturing community champions and local ambassadors and employing community managers to ensure local communities are empowered via a spokesperson and addressed adequately. This will help build, engage and keep communities active. Employ community managers with social and emotional skills to link communities to decisions makers, policy and government agencies and overcome any language barriers. Provide training to these managers to actively listen to and act as amplifiers of their communities' concerns, interests and ambitions.

R&I POTENTIAL: Evaluate the role of gatekeepers and community champions in the success of Citizen Observatories, develop best practices to build and secure such roles, especially for short-term mobilisation and long-term maintenance of local communities. Better understand the role of champions and gatekeepers, who are key in governance transition phases for establishing Citizen Observatories long-term.

RESOURCES TO BUILD ON: GT2.0 engagement strategy [34]; GROW community champions report [31]; UCL's introductory course in Citizen Science[11]; Making Sense community champions and transformation design [37].

11 https://www.ucl.ac.uk/short-courses/search-courses/citizen-science-and-scientific-crowdsourcing-introduction

ACTION 1.4. Develop operational relationships with the media and business/industry

DIRECTION: New modes of collaboration with media and business/industry based on shared goals and interests can maximise joint value creation and impact (e.g., shared interests and goals of Citizen Observatories and investigative, or evidence-based journalism, as well as businesses that build on entrepreneurship and innovation for sustainability, or eco-innovation).

R&I POTENTIAL: Uncover impact potential of relationships with yet underexplored, but key socio-economic actors, such as partners from media, industry and business; Explore incentive structures and value-added for such actors in becoming operational parts of Citizen Observatories; Learn from success stories and develop media collaborations to mainstream citizen science.

RESOURCES TO BUILD ON: GROW Engagement report [38]; CurieuzeNeuzen approach and campaigns[12].

12 https://curieuzeneuzen.be/

PATHWAY: DEVELOP MEANINGFUL, SHARED NARRATIVES AND INSTIL OWNERSHIP

ACTION 1.5. Tap into media intelligence and media R&D for audience development and innovative participation models

DIRECTION: Citizen Observatories can benefit from expertise in storytelling, digital onboarding and audience behaviours and hence, leverage media partnerships to conceptualise and deliver intelligent, professional media strategies; Capitalise on media R&D and data-driven knowledge of trends and trajectories in building audience communities rather than pursuing conventional communication approaches and patterns of engagement.

R&I POTENTIAL: Analyse of success stories where media intelligence supports Citizen Observatory outreach, community onboarding and audience development; Develop media strategy guidelines and respective tools for Citizen Observatories.

RESOURCES TO BUILD ON: GROW Engagement report [38]; Storythings steps[13], applied in GROW.

13 https://storythings.com/work/our-approach/

ACTION 1.6. Ensure strong and suitable communication and facilitation across stakeholders

DIRECTION: Deliberate communication and facilitation through well-trained and experienced facilitators allows for efficient multi-directional collaboration, translates information across stakeholders and helps to build trust and alignment.

R&I POTENTIAL: Invest in capacity building of facilitators and community managers in the context of Citizen Observatories in particular and elaborate synergies with other related areas such as design capabilities for facilitating design thinking and service design processes; Enhance the development of adaptable stakeholders mapping and engagement tools.

RESOURCES TO BUILD ON: Making Sense Recommendations & Guidelines for Powerful Deliberate Practices [39]; SCENT Research Report on citizen attitudes and behaviours [40]; GT2.0 Guidelines for co-design of Citizen Observatories [34, 35].

ACTION 1.7. Employ co-design approaches to democratise processes and foster ownership and buy-in

DIRECTION: Facilitating all-stakeholder design as multi-lateral consultation or collaborative development helps to understand individual stakeholder needs as well as to address potentially contradictory goals. Multiple iterations can increase transparency, facilitate cooperation and create robust outcomes that address stakeholder needs. Co-define what empowerment looks like for participating stakeholders and actors.

R&I POTENTIAL: Expand applicability of co-design approaches in different contexts; Understand and identify conditions for employing a co-design approach; Better understand how co-design can trigger and lead to social innovation and transformation processes and how it facilitates the democratisation of science and collective decision-making.

RESOURCES TO BUILD ON: Climate Innovation Card Game [41]; GT2.0 co-design approach [35]; Making Sense co-creation process and tools in Citizen Sensing: A Toolkit [42]; WeObserve Toolkit[14]; WeObserve Cookbook; Making Sense: Empowering participatory sensing with transformation design [43]; SCENT Game design and engagement strategy [44]; SCENT End-user needs and requirements analysis for sustainable Citizen Observatories [45].

14 https://www.weobserve.eu/toolkit/

ACTION 1.8. Acknowledge and reward voluntary participation

DIRECTION: Implementing suitable reward and recognition systems for voluntary participation as a standard and core practice of Citizen Observatories will enhance trust, ownership and help establish new roles and responsibilities of participants within the community.

R&I POTENTIAL: Develop new recognition and reward models with high acceptability and understand how they aid the functioning and success of Citizen Observatories (these can range from gamification and awards, to certification models, monetary compensation, public recognition and accreditation in scientific publications, and any other value creating efforts).

RESOURCES TO BUILD ON: Motivating and sustaining participation in VGI [46]; Crowdsourcing in-situ data Gamification and mobile technology for crowdsourcing [47, 48]; GROW community champions report [31]; Incentives and barriers for participation in community-based environmental monitoring [49]; SCENT – Best practices in serious gaming [50].

PATHWAY: LEARN FROM AND INNOVATE WITH OTHERS

ACTION 1.9. Ensure transdisciplinary anchoring and responsible research practice

DIRECTION: Citizen Observatories require new forms of transdisciplinary action research, putting science into practice and maximising scientific, data-driven and practice-based expertise across disciplines. Following transparent accreditation principles, respecting and acknowledging local knowledge and reflecting on power asymmetries and dynamics of knowledge and technology production helps to assure responsible research practices.

R&I POTENTIAL: Spur responsible science innovation by developing action-based, ethical approaches to transdisciplinary research, integrating practitioners' experience with natural and social science disciplines, technology and cultural studies and media R&I; Develop guidelines for mapping and addressing power imbalances across actors and project activities and develop use cases for existing tools, such as the RRI focused Societal Readiness Thinking Tool or from Value-Sensitive Design practice[15].

RESOURCES TO BUILD ON: Societal Readiness Thinking Tool[16], Envisioning Cards from VSD Lab[17].

15 https://vsdesign.org/

16 https://www.thinkingtool.eu/

17 http://www.envisioningcards.com/

ACTION 1.10. Join/start groups for knowledge and experience exchange on relevant topics

DIRECTION: Seeking exposure in peer-groups to share knowledge and experience, test assumptions and uncover blind spots, support others and vice versa, learning from others; Seek to find specific action tasks with tangible goals to ensure momentum of collaboration as well as tangible outcomes; Time and resources required should not be underestimated and need to be accounted for; Aim to reduce barriers to group accessibility and participation.

R&I POTENTIAL: Leverage national and international networks to improve recognition of Citizen Observatory capabilities and practices across scales; Encourage excellence in the field and promote peer-to-peer learning, capacity building and succession of young researchers and practitioners.

RESOURCES TO BUILD ON: WeObserve CoPs[18]; CS&OS CoP[19]; ECSA working groups[20]; CSEOL innovation community[21]; Citizen Science Global Partnership[22]; GEO CitSci Community Activity[23].

18 https://www.weobserve.eu/cops/

19 http://citizenscienceglobal.org/projects.html#csos

20 https://ecsa.citizen-science.net/working-groups/

21 https://cseol.eu/

22 http://citizenscienceglobal.org/

23 https://twitter.com/geocitsci

Area 2. Robust data value chains

PATHWAY: IMPROVE DATA QUALITY AND USABILITY PROCESSES

ACTION 2.1. Describe and define the purpose and value of gathered data across stakeholders

DIRECTION: This helps to address barriers and balance trade-offs between rigid scientific methodologies and quality controls and the actual contexts and diverse goals of stakeholders the data are collected by and intended for. Furthermore, it can help clarify what type of information and data feedback is needed (decision support, visualisations, etc).

R&I POTENTIAL: Explore and uncover the meaning of data quality and different dimensions of trust in and value from data from the perspective of a wide range of stakeholders; Develop protocols and tools for purpose and value scoping, identify metadata requirements to capture projects' goals and values and to document various value contributions of data; Develop nuanced data profiles.

RESOURCES TO BUILD ON: Climate Innovation Card Game [41]; Making Sense Toolkit [42]; Community-level indicators [51-53]; SCENT End-user needs and requirements analysis for sustainable Citizen Observatories [45].

ACTION 2.2. Provide high-quality training to participants and data providers

DIRECTION: Training participants in the steps of data collection, while acknowledging their needs, interests and motivations, is an important mechanism to ensure data quality, and increase trust and buy-in. This can be achieved, amongst others, through DIY toolboxes, embedded and social learning platforms, gamification, information feedback, or advice services.

R&I POTENTIAL: Investigate the link between different training and capacity building methods and gains in data quality; Further explore characteristics and affordances of successful monitoring protocols and data capture tools.

RESOURCES TO BUILD ON: GROW MOOCs [32], WeObserve Cookbook; SCENT Training workshops prior to citizen science campaigns in Greece & Romania [54, 55].

ACTION 2.3. Document data quality and strive towards achieving existing data standards

DIRECTION: Implementing quality standards will help Citizen Observatories gain acceptance and standard services will increase the uptake of data as well as improve interoperability in larger systems, such as integration with GEOSS or the European Open Science Cloud (EOSC).

R&I POTENTIAL: Provide trustworthy and robust datasets by implementing data quality documentation mechanisms, linked to the data capture or post-validation processes, and the adoption of relevant data standards in the field; Increase reusability of data by the global community through integration into wider networks.

RESOURCES TO BUILD ON: WeObserve Cookbook; WeObserve Interop CoP[24]; CitSciIE experiment[25] and Interoperability Experiment report [56]; LandSense Quality Assurance Service [57, 58]; GT2.0 data quality module [59]; SCENT Harmonisation platform data quality [60].

24 https://www.weobserve.eu/weobserve-cop3-interoperability-and-standards-for-citizen-observatories/

25 https://external.ogc.org/twiki_public/CitSciIE/WebHome

ACTION 2.4. Further develop semantics and tools for data collection, annotation and review

DIRECTION: Approaches to describe the human dimension as part of data standards and metadata descriptions (contributor/user descriptions and requirements/needs, etc.) can help provide a more comprehensive picture of data, its potential value and use, as well as establishing open data review and feedback procedures to evaluate data value and usage once data are available.

R&I POTENTIAL: Provide the capacity to merge project and campaign data that share the same semantics and increase impact; Improve data quality, by means of reputation, data validation, user feedback, and completeness of the data; Develop and improve usability of existing tools for annotating and providing feedback on citizen science and authoritative data, promoting data review processes in citizen science.

RESOURCES TO BUILD ON: WeObserve Interop CoP; OGC SensorThings API[26] and Geospatial User Feedback[27];SCENT Harmonisation Platform OGC compliance [60].

26 https://www.ogc.org/standards/sensorthings
27 https://www.ogc.org/standards/guf

PATHWAY: ENSURE TRANSPARENCY

ACTION 2.5. Establish transparent data policy models that balance data ownership, privacy and data protection requirements with the mandate for open access data and transparent data governance

DIRECTION: Investing in processes to create robust and specific Citizen Observatory data policies helps establish clear agreements on data ownership, what data can be shared, and when and how it can be used by others. It helps address data 'sovereignty' of local communities, privacy and traceability issues of citizen-based contributions, as well as develop relevant data protection measures. Strive towards open data access and FAIR data principles, so a broader audience can create insight from the data.

R&I POTENTIAL: Gain deep insight into data requirements in terms of sensitive data collected and open access so that mechanisms can be put in place from the beginning; establish clear and reusable procedures for addressing FAIR principles, data ownership, sharing and "as open as possible, as closed as necessary" policies, communicated transparently to avoid data protection and ownership issues. Improve processes for the usability of data in other projects by a correct specification of a licence that contemplates it while protecting data from misuse.

RESOURCES TO BUILD ON: LandSense examples and models related to data protection and privacy [58, 61-63].

ACTION 2.6. Deploy a transparent and integrated ethics framework

DIRECTION: Citizen Observatories need to ensure respect for people and for human dignity, fair distribution of the benefits and burden of research and participation following the general principle of maximising benefits and minimising risks/harm, the protection of the values, rights and interests of all participants as well as addressing questions of inclusivity and vulnerabilities around socio-economic status, language, ethnicity, identity etc.

R&I POTENTIAL: Provide Citizen Observatory use cases or operational tools for the consideration of ethical questions on a project design and data collection level and guidelines for practical implementation; Build and expand on existing tools and communities, such as promoted by the Open Data Institute, the EthicalGEO Initiative and others.

RESOURCES TO BUILD ON: Locus Charter[28]; Open Data Ethics canvas[29]; Panelfit MOOC[30]; Outputs from CSI-COP project[31].

28 https://ethicalgeo.org/locus-charter/
29 https://theodi.org/article/data-ethics-canvas/
30 https://www.panelfit.eu/ethical-and-legal-issues-regarding-ict-data-protection/
31 https://csi-cop.eu/

Area 3. Sustainable market growth

PATHWAY: PROMOTE NEEDS-BASED AND CIRCULAR TECHNOLOGY SYSTEMS AND TOOLS

ACTION 3.1. Address communities and/or local authorities with existing data needs as key, demand-side market players and provide enabling technologies that help maximise community and/or policy impact

DIRECTION: Building technology solutions with and for communities and/or local authorities that can become enablers for reaching their goals, e.g., where piecemeal data are already collected, and basic workflows exist. Turn existing workflows into digital workflows to enable concerted data collection, local policy making or fast response action, where needed. However, rely on existing, well established, and robust technologies where possible and don't assume 'digital first' in every case.

R&I POTENTIAL: Identify and elevate existing communities and local authorities with clear information and data needs, as well as existing workflows; Explore enabling function and uptake of co-developed technologies that build on shared and existing needs of a local authority or community of interest/practice.

RESOURCES TO BUILD ON: Experience from NaturaAlert [27]; SCENT experiences from civil protection agencies and policy makers [36].

ACTION 3.2. Build on and reuse existing, open access technologies and tools

DIRECTION: Development efforts can build on open code and implementation experiences and focus on user feedback, and iteratively improve supportive technologies, e.g., for sensing, data gathering, data sharing and visualisation, in order to improve technology effectiveness and usability. Available toolkits should be capitalised on and used.

R&I POTENTIAL: Adapt tools to account for latest insights from user research and for improved data capture; Explore development and usage journey of effective and successful open-source data and tools related to Citizen Observatories; Understand barriers for uptake of open-source tech; Develop use cases for existing toolkits to improve them as well as expand their applicability.

RESOURCES TO BUILD ON: WeObserve Github[32]; Citizen Observatory datasets[33]; GROW GitHub[34]; LandSense GitHub[35]; CitSci Manager Tool[36]; WeObserve Toolkit; EU-Citizen.Science resources[37].

32 https://github.com/WeObserve
33 https://www.weobserve.eu/marketplace/#datasets
34 https://github.com/growobservatory
35 https://github.com/LandSense
36 https://www.citsci.earth/
37 https://eu-citizen.science/

ACTION 3.3. Strive for zero emission/zero waste approaches and actively tackle waste issues

DIRECTION: Waste and emissions produced by Citizen Observatories (e.g., the packaging, distribution, and disposal of sensors, long distance travel) must be dealt with, and should be planned for from the outset. Grassroots communities need to be supported especially where country regulations are inconsistent. Where possible, Citizen Observatories should support or integrate opportunities for waste upgrading and negative emission activities.

R&I POTENTIAL: Develop best-practices, tools and guidelines for tackling waste issues and how to work towards zero emission/zero waste processes in project design and implementation.

RESOURCES TO BUILD ON: No supporting resources identified.

PATHWAY: DEMONSTRATE OPERATIONAL BUSINESS MODELS

ACTION 3.4. Include business partners to maximise the uptake potential of Citizen Observatories

DIRECTION: Collaboration with SMEs and other commercial partners can illuminate value creation and market uptake beyond science and policy making and help build Citizen Observatory communities and technologies with specific continuation requirements in mind.

R&I POTENTIAL: Better understand the potential function and role of SMEs in Citizen Observatories; Further explore and consolidate the overall market potential of Citizen Observatory data, services and tools for downstream applications.

RESOURCES TO BUILD ON: GT2.0 Report on market analysis and market uptake [64].

ACTION 3.5. Explore service-based business models and other commercialisation or long-term sponsorship models

DIRECTION: Service-based business models can serve as a potential approach for Citizen Observatories in the future. Furthermore, coordinated actions across Citizen Observatories, such as Open Data Challenges, Citizen Observatory Toolkits, or online courses can serve as indicators for the market potential of Citizen Observatories and help maximise broader impact and uptake.

R&I POTENTIAL: Explore, amongst others, how Citizen Observatories can (co-)develop service solutions for different actors and audiences, support larger service providers (e.g., Copernicus services), or sustain technical platforms using open-source tech models with a service platform (business model) on top.

RESOURCES TO BUILD ON: WeObserve Copernicus Pilots [65]; WeObserve MOOC[38]; WeObserve Open Data Challenge[39]; WeObserve Toolkit; Climate Innovation Card Game [41].

38 https://www.futurelearn.com/courses/weobserve-the-earth
39 https://www.weobserve.eu/marketplace/opendatachallenge/

ACTION 3.6. Prepare implementation and handover of Citizen Observatory business models

DIRECTION: Turning Citizen Observatory efforts into tangible products or services, aligned with a sustainable business model, can support the transition of a proof of concept into a launchable business concept.

R&I POTENTIAL: Work towards actual implementation and testing of business models via launch of spin-off initiatives, funded by start-up, seed, or VC funding; Explore links and handovers to the follow-up support mechanism and develop best-practice guidelines.

RESOURCES TO BUILD ON: SCENT exploitation strategy [66].

PATHWAY: IDENTIFY EXTENDED POTENTIAL

ACTION 3.7. Embed Citizen Observatories' ambitions within a global change context

DIRECTION: Citizen Observatories can fully tap into their demonstrated potential to provide opportunities to citizens to contribute actions and tangible outcomes to the global sustainable development agenda, aligning ambitions and actions with high-level strategies (SDGs, EU Green Deal etc) and defining scaling aims and anticipated outcomes that are responsible and promote sustainable development and climate action.

R&I POTENTIAL: Explore and design tools to align Citizen Observatory contributions to continental or global frameworks such as the EU Green Deal or SDGs, and to assess and document the extent to which Citizen Observatory contributions can support these strategies; Improve translation and communication of the relevance of global agendas at the local level to achieve sustained engagement and impact and advance collaborative design methodologies to prioritise participants' motivations and ambitions towards global goals.

RESOURCES TO BUILD ON: Toolkit for scaling Citizen Science projects [67]; Publications on citizen science and Citizen Observatories with a focus on SDGs [9, 10, 18]; WeObserve Policy Brief #2 [17]; Climate Innovation Card Game [41]; WeObserve CO4EO workshops[40].

40 https://www.weobserve.eu/marketplace/citizen-observatories-for-earth-observation/

ACTION 3.8. Strengthen links to Citizen Observatories outside Europe as well as to global initiatives

DIRECTION: Although the concept of funding 'Citizen Observatories' is largely of European origin, Citizen Observatories should be developed and supported internationally to increase the collection of community-driven evidence for decision-making and policy. Links to existing Citizen Observatories outside of Europe (that may be known by other names) and other globally reaching citizen-driven efforts (e.g., Sensor. Community) should be identified and strengthened to expand the network of Citizen Observatories globally.

R&I POTENTIAL: Understand the landscape of Citizen Observatories globally and identify common areas of interest; Link initiatives in a global network, thereby contributing to the scaling up of otherwise locally dispersed or disconnected initiatives; Identify relevant initiatives and activities to understand synergies and mutual learning potential.

RESOURCES TO BUILD ON: WeObserve Cookbook; Citizen Observatory online map[41]; Citizen Science Global Partnership; European Citizen Science Association[42]; Citizen Science Association[43]; Australian Citizen Science Association[44].

41 https://www.weobserve.eu/about/cos-landscape-map/
42 https://ecsa.citizen-science.net/
43 https://www.citizenscience.org/
44 https://citizenscience.org.au/

ACTION 3.9. Leverage use of Citizen Observatories in new domains

DIRECTION: In the past, Citizen Observatories have mainly emerged to support environmental monitoring, yet they have the potential to be developed in domains such as health, equality, climate change, waste reduction, the circular economy, etc.

R&I POTENTIAL: Explore other areas where Citizen Observatories can provide evidence to support policy and decision-making beyond environmental monitoring, e.g., domains covered by the SDGs.

RESOURCES TO BUILD ON: WeObserve Cookbook; Publications on citizen science and Citizen Observatories with a focus on SDGs [9, 10, 18].

PATHWAY: SHOWCASE IMPACT

ACTION 3.10. Publicise Citizen Observatory costs and benefits

DIRECTION: A robust and comprehensive cost-benefit analysis has wide implications for both the acceptability and sustainability of Citizen Observatories, also trying to document non-commercial value. It can create a basis for decision-making and a good case for incurring uptake and maintenance costs, e.g., by public authorities. Maintenance costs after a Citizen Observatory has been set up and the technologies and methodologies have been created, should be considered separately from the development costs. Value estimates of potential Citizen Observatory products and services should also be considered, even though these can be hard to quantify in advance.

R&I POTENTIAL: Develop cost-benefit models and demonstration and evaluation tools that can be used by Citizen Observatories to transparently disclose costs and benefits.

RESOURCES TO BUILD ON: Cost-benefit analysis of Citizen Observatories [8, 68]; CPI framework to analyse context of community-based monitoring initiatives [69].

ACTION 3.11. Showcase Citizen Observatory capabilities, success and impact stories

DIRECTION: Highlighting capabilities of Citizen Observatories, their impacts and outcomes, e.g., in policy making and environmental management, creates opportunities for collaboration and the reuse of data and platforms. Telling Citizen Observatory's success stories can build trust by further clarifying Citizen Observatory objectives and relating the potential benefits to communities and other stakeholders. This can strengthen knowledge and awareness of the value of citizen generated data as well as reduce barriers or lingering concerns for citizens themselves, the community, authorities and society at large.

R&I POTENTIAL: Apply and evolve existing impact assessment approaches for Citizen Observatories, in order to collect robust medium- and longer-term evidence, and guidelines for turning evidence into communicable stories; Expand collaborations to showcase capabilities to other communities (GEO, open science...).

RESOURCES TO BUILD ON: Capturing impact stories in citizen science [70, 71]; Impact assessment of citizen science [72]; WeObserve Insights paper [7]; WeObserve Citizen Observatory landscape reports [12, 13]; GROW actions for SDGs [9]; WeObserve MOOC; LandSense impact and sustainability assessment [73]; GROW report on mission outcomes [74].

Time horizon: 2021-2027

Area 4. Integration with official data frameworks and open data systems

PATHWAY: FEED INTO OPEN DATA AND GLOBAL EARTH OBSERVATION SYSTEMS

ACTION 4.1. Integrate with large open data and open research infrastructures

DIRECTION: Citizen-generated open datasets and knowledge can increase reach via integration to the EOSC or linkage with the EduGain Community of universities and research centre users. Evidence-based local data and its reusability for research can be better promoted and engagement in wider networks sharing similar interests and data can be enhanced.

R&I POTENTIAL: Expand experience and best-practices for employing single sign on systems to contribute to several projects and services; Invest in capacity building on open data platform integration within the Citizen Observatory practitioner community; Provide services based on open data integration to future citizen science projects and better understand operational barriers to open data sharing that are not linked to ethical, privacy or security issues.

RESOURCES TO BUILD ON: Outputs of the COS4Cloud project[45]; LandSense federated authentication for tools and services [75]; Scent integration with GEOSS portal; CitSci Interoperability Experiment report [56].

45 https://cos4cloud-eosc.eu/

ACTION 4.2. Share interoperable resources and data through standardised platforms and services

DIRECTION: Seeking interoperability of project data, creating common vocabularies and procedures that aggregate Citizen Observatory data into bigger datasets and sharing data quality tools will amplify the uptake and usability of Citizen Observatories and improve value delivery across domains and beyond the individual Citizen Observatories.

R&I POTENTIAL: Create a federation of technical resources of citizen science and Citizen Observatories to host and share services; Develop centralised and trusted infrastructure, authorisation and tools to deploy and maintain Citizen Observatory campaigns.

RESOURCES TO BUILD ON: CitSci Interoperability Experiment report [56]; Lisbon Declaration [15]; WeObserve policy brief #1 [16]; LandSense Quality Assurance Service [57, 58]; SCENT Harmonisation Platform [60]; GT2.0 data visualization platform (using SOS standard)[46].

46 http://www.ogc3.uab.cat/gt20/

ACTION 4.3. Improve uptake of Citizen Observatory data in GEOSS and the usability of GEO services for Citizen Observatories

DIRECTION: Enhancing collaboration between Citizen Observatory practitioners and formalised GEO member groups and participant organisations, in coordination with the GEO Secretariat, can mainstream Citizen Observatory data to complement remote sensing and traditional in-situ data. Simplified mechanism to include such data in GEOSS by connecting citizen science and Citizen Observatory federations directly to the GEOSS platform are needed as well as services that are appealing to citizens and citizen scientists and better opportunities for citizen scientists to exploit GEOSS data.

R&I POTENTIAL: Identify and showcase the value proposition of Citizen Observatories for the GEO community and vice versa; Explore value, service appeal and usability of GEO services for citizens and citizen scientists as end-users; Engage with GEO Engagement Priorities Coordination to develop a citizen science strategy for the GEO Engagement Priorities to capitalise on demonstrated benefits of the integration of Earth Observation and citizen science.

RESOURCES TO BUILD ON: Lisbon Declaration [15]; WeObserve policy brief #1 [16]; GEO CitSci Community Activity[47]; SCENT resources offered to GEOSS[48].

47 https://www.earthobservations.org/documents/gwp20_22/GEO-CITSCI.pdf
48 https://www.geoportal.org/?f:sources=wfsscentID%2CwmsSCENTID

PATHWAY: CONTRIBUTE TO OFFICIAL REPORTING SCHEMES AND AUTHORITATIVE DATA WORKFLOWS

ACTION 4.4. Enable the uptake of Citizen Observatory data

DIRECTION: Building relationships and collaboration with local authorities, national agencies, statistical offices (NSOs), EU-level (EEA) and relevant UN custodian agencies is key to create a network that enables the uptake of Citizen Observatory data for local to global level monitoring efforts, including building and maintaining infrastructures, capacities and other key partnerships.

R&I POTENTIAL: Explore options and develop pathways to integrate Citizen Observatory data streams into official reporting practices and governmental open data platforms (e.g., built on CKAN system[49]); Deliberately address and increase understanding of potential misalignment between Citizen Observatories' and official statistic's underlying goals and assumptions for data production; Create brokerage and match-making opportunities where projects can link with authorities to scope and address existing data needs.

RESOURCES TO BUILD ON: WeObserve SDG-CoP[50] activity; Publications on citizen science and Citizen Observatories with a focus on SDGs [9, 10, 18]; SDSN Trends policy roadmap for modern data systems for sustainable development [76]; WeObserve Cookbook.

49 https://ckan.org/

50 https://www.weobserve.eu/weobserve-cop4-sdgs/

ACTION 4.5. Align data protocols

DIRECTION: Alignment of data protocols with requirements from NSOs and other national government agencies is important as well as the international implementation of comparable methods and data for EU-level or global level SDG reporting.

R&I POTENTIAL: Investigate the feasibility of aligning data collection methods across different projects with international or global definitions; Identify and further develop suitable data quality criteria or data quality assurance procedures across projects and initiatives; Provide interoperability training.

RESOURCES TO BUILD ON: CitSci Interoperability Experiment report [56]; SCENT Harmonisation platform – adoption of relevant quality assurance protocols and use of OGC SensorThings API [60].

ACTION 4.6. Elevate Citizen Observatory initiatives' capabilities

DIRECTION: Many citizen science activities and Citizen Observatories, at the local level, can benefit from support to modify and improve data collection and analytical tools, data validation and interoperability measures and to improve their capabilities for long time data storage and availability to feed official data streams.

R&I POTENTIAL: Develop strategies to ensure a balance between the quality requirements for scientific rigour and standardised monitoring with citizens' needs, skills and motivations; Improve the availability of suitable and well-described protocols and tools for citizen-led monitoring; Develop operational processes and infrastructures and train practitioners to ensure long-term data availability.

RESOURCES TO BUILD ON: LandSense Quality Assurance Service [57, 58]; SCENT Harmonisation platform [60]; SCENT Collaborate platform[51].

51 https://scent-project.eu/scent-toolbox

ACTION 4.7. Disseminate and support best-practices

DIRECTION: Build on case studies where Citizen Observatory data are used in innovative ways by public authorities and NSOs and disseminate these examples through appropriate channels. Collect best practices as a result and share success stories.

R&I POTENTIAL: Maximise experience from tested roadshow formats and similar communication approaches to share success stories amongst public authorities; Build a network of interested and invested authorities; Better understand information needs and motivators of NSOs or UN custodian agencies and what 'best-practice' means to them; Identify factors of success as well as failures regarding best-practices to feed the learning cycle.

RESOURCES TO BUILD ON: WeObserve SDG-CoP[52] activity; Publications on citizen science and Citizen Observatories with a focus on SDGs [9, 10]; Citizen Observatory for flood risk reduction[53] [8].

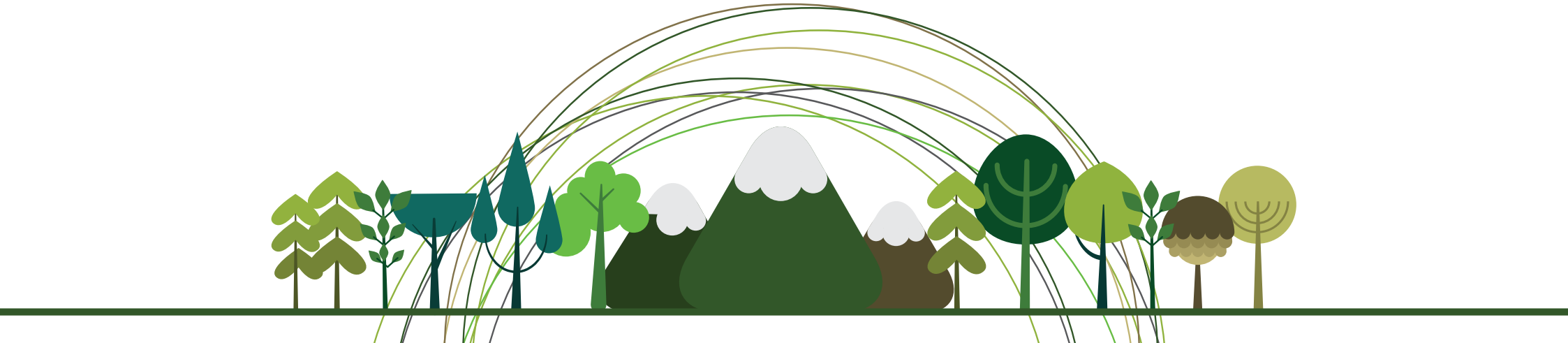
52 https://www.weobserve.eu/weobserve-cop4-sdgs/
53 https://www.weobserve.eu/roadshows/

ACTION 4.8. Secure investment and engagement

DIRECTION: Secure investment for the development of business cases linked to the sustainability of the Citizen Observatory initiatives to maintain essential technical infrastructures and the engagement of citizens for official monitoring longer-term.

R&I POTENTIAL: Explore and understand pressures as well as incentive structures of public authorities and agencies to invest in Citizen Observatories long-term; Develop operational processes that fit with and complement existing workflows and maximise benefits.

RESOURCES TO BUILD ON: Cost-benefit analysis of Citizen Observatories [8, 68]; CPI framework to analyse context of community-based monitoring initiatives [69].



5. Recommendations to future funders of Citizen Observatories

Suitable funding schemes as well as legal and policy frameworks are essential to foster an environment for Citizen Observatories that enables them to start, thrive and continue their activities to deliver value and impact across multiple stakeholder groups. Concluding the roadmap, we offer several recommendations to funders on conditions that can support the pursuit of proposed pathways, largely improve the opportunities for Citizen Observatories in Horizon Europe as well as advance Citizen Observatories in service of Horizon Europe goals.

- **Offer innovative funding schemes and funding support functions** – Often, it takes many years for a Citizen Observatory to become operational and productive and subsequently to lead to scientific and decision-making results. Appropriate funding for such longer-term development and innovation has been difficult to secure. Future Citizen Observatories will benefit from funding schemes that are flexible, involve cascading funds and employ agile evaluation approaches to allow for iteration, co-design and open outcomes. To fully maximise this potential for societal and environmental impact, make follow-up or alternative sources of funding available to projects that meet specific targets, support the link and transition into national funding schemes for local continuation or offer tender prospects as follow-up opportunities to develop proof-of-concept applications into reliable open-source tools when uptake potential can be demonstrated. A concrete example would be dedicated Citizen Observatory funding through an instrument such as ERANET. Furthermore, the strategy report for the implementation of a mission-oriented process towards the new EU R&I vision [5] outlines concrete new pathways for innovative finance and funding instruments. Citizen Observatory practitioners and prospective project consortia will need dedicated information and support to be able to fully exploit such a new funding landscape for their benefit and to deliver maximum impacts. Other funding options through Erasmus+ streams or school networks should allow and expand to fund bottom-up community initiatives wishing to explore more localised Citizen Observatories that could evolve into networks such as the long-established Town Twinning programme.
- **Support diverse and ambitious communication and media plans** – Deliberate strategies informed by innovative media intelligence and professional services, prioritised over conventional communication and dissemination approaches, will help Citizen Observatories gain momentum, reach large audience engagement as well as achieve impact, from individual citizens to policy making.
- **Enable impact alliances** – To secure the engagement of public authorities, policy stakeholders, place-based communities and community organisations from the start, carefully composed consortia will be required, that can rally viable support and buy-in across these groups as well as to ensure suitable adaptation of the Citizen Observatory concept to respective local or national contexts. Deliberate consideration of partner profiles as well as consortium composition will be needed for call design and during the funding evaluation phases.
- **Strengthen cross-cutting networks** – To drive excellence in the field and to continue to share and consolidate knowledge, more support will be needed to strengthen the participation of Citizen Observatory experts and practitioners in established networks, working groups and Communities of Practice (e.g., ECSA, GEO, OGC, UNESCO, etc.).
- **Build and support sustainable infrastructures and technologies** – such as a permanent e-infrastructure to federate citizen science and Citizen Observatory projects, integrate citizen-generated data, host and share services,

as well as connecting the federation to the EOSC and to the GEOSS platform, and promoting open-source software, shared code bases, and sustainable open-source hardware.

- **Strengthen funding for dedicated coordination and support actions** – Support is needed across Citizen Observatories for the joint creation and maximisation of market and business opportunities, knowledge consolidation and capacity building, the development of integrated data and tech infrastructures and standards, the elevation and recognition of local, bottom-up projects and place-based activities, as well as coordinated efforts to advance the uptake and integration of Citizen Observatory data into official data streams, reporting and monitoring efforts.
- **Mainstream Citizen Observatories across all areas of Horizon Europe** – Citizen Observatories will be able to unfold their full potential as cross-cutting, operational mechanisms only when taken out of specific funding corners. Widespread application, normalisation and mainstreaming across different funding calls, topics and programmes will provide new opportunities to address socio-environmental challenges and to increase citizen participation in governance processes across Europe.
- **Enable the uptake of the Citizen Observatory concept outside Europe and in other domains** – Europe can extend its leadership role in support of participatory monitoring and governance and democratisation of science by scaling Citizen Observatories beyond Europe and in new domains. Deliberately supporting Citizen Observatories in funding calls with a focus on international cooperation can provide citizen empowerment to developing and least developed countries.
- **Encourage the formulation of a European Policy Directive on the use of citizen-generated data** – To support the valorisation and uptake of Citizen Observatory and citizen science practices and data as an official data source, legislative acts are needed to set specific goals for individual member countries to achieve as well as align their processes to. The "Crowdsourcing and Citizen Science Act of 2016"[54], issued by the Congress of the USA, has provided such legal conditions to grant Federal agencies the explicit authority to use crowdsourcing and citizen science practices and data and encouraging its appropriate use. In Europe, niche legal regulations exist, such as the COMMISSION DELEGATED REGULATION (EU) 2018/968, supplementing Regulation (EU) No 1143/2014 with regard to risk assessments in relation to invasive alien species [77]. It invites the use of citizen science data for risk assessment purposes as supplementary information and in cases where conventional, peer reviewed scientific evidence is insufficient. However, a general and overarching directive, such as the Crowdsourcing and Citizen Science Act in the USA, is still missing.

54 https://www.congress.gov/bill/114th-congress/house-bill/6414/text

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Appendix 1. WeObserve actions to address challenges

Table 2: Key lessons learnt on how specific WeObserve actions helped address the challenge of awareness, acceptability and sustainability of Citizen Observatories (abbreviations used in the table: CO – Citizen Observatory, CS – citizen science)

WeObserve activity	Aim of activity	Awareness of COs	Acceptability of COs	Sustainability of COs
Communities of practice (CoPs)	*To consolidate and disseminate practice-based knowledge of COs, sharing information and resources, and working to further develop best practice guidelines and toolkits for COs.*	The existence of the CoPs and the thematic breadths covered by the four CoPs provided awareness raising mechanisms among wide communities of stakeholders who heard about CS and COs for the first time at events, online (e.g., Twitter, WeObserve website) and in other contexts.	The WeObserve CoPs have consolidated the CO knowledge base via delivered knowledge products and insights on issues that have hampered the acceptability of COs (e.g., data quality, stakeholder engagement, relevance for SDG monitoring). The close links that the CoPs have formed with relevant networks, stakeholders and communities (e.g., GEO, UN system, other H2020 projects) for disseminating their results and insights have served to strengthen the acceptability of COs among these audiences.	The open atmosphere created within all four CoPs in terms of their members sharing not only successes but also struggles with various aspects of CO realities, processes and technical difficulties has served to foster and accelerate the exchange of experiences and solutions and their application in respective COs, contributing to their sustainability.
SDGs-CoP	*To connect CS practitioners and researchers, National Statistics Offices (NSOs), UN and international agencies and data/stats communities to exchange knowledge and resources to demonstrate the value of CS data and impact for SDG monitoring and achievement.*	The SDGs CoP joined the CS community with NSOs, UN agencies, as well as the broader data and stats communities, organizing a range of events, giving presentations at UN conferences, such as the UN World Data Forum, UN International Conference on Big Data, UN Environment Assembly, UNEP Science Policy Business Forum or the UN Inter-Agency Expert Group on SDG Indicators meetings.	The SDGs CoP has been working with the UN, NSOs and other key stakeholders to increase the acceptability of CS as an official source of data that could be leveraged for SDG monitoring and reporting. For example, a pilot in Ghana has been set up by IIASA, the Ghana Statistical Service, UNEP, UN SDSN, the Earth Challenge 2020 and the Wilson Center to promote CS as an official data source globally.	The SDGs CoP also works towards the use of CS in monitoring the SDG indicator 14.1.1b on marine litter, so it can become a stable source of data to produce official statistics on marine litter, as well as an approach mobilizing citizens to take action to address the marine litter/plastics problem on a global scale.
Interop-CoP	*To adopt data quality, curation and preservation of CO data, address privacy and licensing issues as well as to conduct an interoperability experiment within the Open Geospatial Consortium (OGC).*	In reporting its findings to the Open Geospatial Consortium (OGC) members meeting, the interop CoP contributes to the awareness COs to governmental, academic and industry communities represented in the OGC. The OGC membership understands that the CO community is another field of application of international open standards.	The Interop-CoP demonstrates that COs can provide data with high quality and in recognised international standards, such as the Sensor Things API.	The Interop-CoP contributes to the sustainability of the COs advancing technologies and approaches that improve CO data description, availability and use and hence, to increase its overall value which is a prerequisite for the sustainability of the observatories.

Impact-CoP	*To inventorise methods for capturing the impacts of COs on governance, to capture CO impact stories as well as provide guidance on CO impact assessment for the CoP-impact members and beyond*	-	The Impact CoP provides methods for capturing the impacts of CS/COs. Moreover, the application of some of those methods by CoP members serves to provide examples of tangible impacts which in turn provide the basis to convince various stakeholders of the relevance of CS/COs, hence increasing their acceptability.	The creation of impact and the longer-term sustainability of COs are intricately linked. By providing methods and evidence of COs impacts, this CoP strengthens the case for maintaining COs and provides concrete means by which CO members can argue the case for longer term CO activity to funders, CO members and new CO recruits.
Co-design and engagement-CoP	*To share knowledge on co-designing COs and engaging stakeholders to learn about common successes and challenges across projects.*	The CoP shared and presented its findings on diverse engagement practices and methods for CO co-design at conference sessions and in sister projects. Its contribution to the joint CoPs glossary has helped create common terminology and language and reduce confusions regarding some of the key terms and concepts related to COs that newcomers face.	The discussions and knowledge products of this CoP serve to highlight that there is not 'one size fits all' when it comes to setting up COs and engaging stakeholders, but that different contexts and situations require careful attention and tailoring of approaches. This helps COs to better connect with the needs of specific, local stakeholders, resulting in COs that are more relevant and hence contributing to greater acceptance of COs.	-
CO landscape mapping and reports	*To advance the understanding of the CO concept and related practices in Europe*	The Landscape Reports highlight the range and types of COs, the topics that they have been addressing, and the types of stakeholders that they have been engaging with, thus raising awareness and making a significant contribution to the overall knowledge base.	The Landscape Reports explore types of challenges that COs face in practice, within the context of their particular topics and stakeholders and share CO actions taken to successfully address these challenges. The reports also offer recommendations that are more broadly applicable to other COs in order to reduce those challenges and improve their acceptability pre-emptively.	The Landscape Reports offer insights about how CO initiatives can best be sustained over the long term, to better enable them to achieve their aims, sharing the experiences and recommendations from the range of COs.
Massive open online course (MOOC)	*To share knowledge, promote learning and engage with an international community of learners, from people new to CS, to experienced citizen scientists and practitioners.*	MOOCs are very effective in raising awareness of COs. Being free to access, the MOOCs attracted thousands of learners. By running the MOOCs on an international platform, the awareness raising took place not only within EU borders, but at the global level. The learning experience enabled many participants to delve deeper into the concept of COs and understand the mechanics and resources required to form new observatories.	MOOCs provide free training and information to large numbers of people, e.g., about the scientific underpinning and quality controls for data collection and analysis. The academically robust character of a MOOC paired with its informal and social atmosphere provides a safe and expert space to ask questions and discuss particular areas of concern that might be causing distrust or a lack of acceptability.	MOOCs can run recurrently and can be used to engage and train many participants of COs over a long period of time. They can also be a component of a financially sustainable CO model, e.g., developing tailored courses for companies, NGOs, UN or governmental institutions. MOOCs offer learning opportunities for a high number of people spread out across the world, with learning activities taking place online and practical activities to be carried out in local areas.

Roadshows	*To connect with authorities and environmental managers and showcase the added value of COs for environmental risk and disaster management, as well as allow authorities to learn about the operational challenges of implementation of COs in the context of flood risk management.*	They raised awareness of COs among several authorities (local authorities from municipalities, emergency managers, civil protection representatives, Land Reclamation Consortia, regional and national policy makers, civil protection volunteers, water authorities, environmental agencies and ministries) in different geographical and social contexts in Europe (Italy, Spain, Slovenia, Scotland).	Roadshows provided policymakers, disaster managers and local authorities an expert space to discuss their needs and doubts of COs as an approach for flood risk and disaster management (e.g., quality of information, social dimension and design of COs) as well as to explore the potential of COs and understand if they can be applied in their socio-geographical context.	Thanks to the Roadshows, authorities became aware that the economic benefits deriving from a CO approach outweigh the costs of implementing it, reducing the annual expected damage, in the case of flooding, to a large degree. This vision, shared with water related authorities over Europe, supports the sustainability of CO solution.
WeObserve challenges at the INSPIRE hackathon	*To spur solution prototyping for CO and CS data integration, cataloguing and authentication*	WeObserve organised three challenges in the context of the INSPIRE Hackathon, opening to the wider geospatial community an ample amount of citizen-generated resources for environmental monitoring. Participants in the consolidated teams learnt more about the potential of CO data to be utilised in the context of their existing applications as well as about the different parameters that can be monitored through CO approaches.	To improve the acceptability of citizen generated data, three use cases were tested: 1) enabling accessibility to protected CO resources while also allowing their direct consumption and utilisation by third party applications 2) the integration of datasets provided from COs with EO based catalogues and 3) developing and testing interoperable tools toward the provision of combined access to environmental observations from citizens and in-situ sensors.	The WeObserve hackathons demonstrated how to maximise the value of CO data by improving the discoverability and usability related to environmental applications and the GEOSS data management principles. This also counteracts the creation silos of resources, while promoting the use of open solutions and common standards for data sharing.
Interoperability experiment	*To identify best practices for CO data interoperability and the application of data standards*	-	The interoperability experiment increases acceptability of the COs data by 1) identifying mechanisms to integrate different COs data in a single view, 2) promoting the use of the same standards than official data (Sensor Web Enablement), 3) describing data quality to increase credibility, 4) promoting the use of clear definitions for the variables captured and 5) federating applications and services in distributed infrastructures.	The interoperability experiment tested technologies that can lower the maintenance of CO services. By using one of the tested open-source software products (e.g., 52 North Helgoland) the infrastructure set up can be kept up to date easily. The use of standard components prevents technological vendor lock-in, as components can be easily replaced by equivalent interoperable ones.
Copernicus pilot & COs for Earth Observation workshops	*To demonstrate the value of CO data for the field of EO and remote sensing*	The Copernicus pilot and CO4EO workshops engaged with the Copernicus in-situ and the Copernicus land monitoring services promoting CO data and capacities to complement other sources of in-situ data, providing information and jointly developing pilots that account for what the COs can offer.	The Copernicus pilot and CO4EO workshops helped clearly specify the dataset offerings and provided examples on how CO data can be used in practice in combination with remote sensing. The CO4EO workshops showcased that CO data and information can complement official, traditional, in-situ and remote sensing data sources, allowing relevant authorities to improve and fill gaps in the environmental monitoring process.	The EEA and subcontracted companies that support the in-situ component for land are aware of the COs datasets and the cost associated with keeping the observatory up and running. In the near future, they could consider these costs as part of new procurements.

Open data challenge (ODC)	*To promote and demonstrate the uptake of CO data for the development of downstream applications*	ODCs are particularly effective for raising awareness of COs and CO data with data and technological audiences, SMEs and start-ups that might not be familiar at all with COs and other CS concepts and developments.	ODCs encourage COs to get their data "camera ready" and make it open access. By making more CO data open access, its increased ubiquity can contribute to increased familiarity and applications, resulting in higher levels of acceptability. Organising an open call for the ODC also increases the visibility and normalisation of COs for people reached by the call, whether they decide to take part or not.	ODCs foster the uptake of CO data in the business sector as well as the development of innovative applications of CO data, increasing the chance of finding income generating streams for the CO longer-term.
Policy briefs	*To translate and highlight relevant findings and insights for policy makers and funders*	The Policy Briefs make results and insights easier to access and digest for policy makers and funders, and hence can improve awareness of the existence and relevance of COs for environmental management and disaster management.	-	The Policy Briefs are a key mechanism for issuing concrete Calls to Action to funders and policy makers regarding what is required to ensure the sustainability of COs: from a technical perspective in terms of their integration into GEOSS and from a financial perspective in terms of improving the enabling conditions that allow COs to thrive and sustain their activities.
WeObserve conference	*To increase the visibility of COs in Europe and showcase their added value on multiple levels and across stakeholders*	The WeObserve conference took place in the context of the Citizen Science and SDGs Conference in 2020 and promoted the vision of making COs integral to environmental monitoring at a European and international level. The sessions were targeted at COs and community-based initiatives, researchers, policy and decision makers, government officials, NSOs, and European Commission officers, UN agencies and data communities and attended by more than 200 participants.	The WeObserve sessions, amongst others, demonstrated the value of CO and CS data for tracking progress of the SDGs, drawing upon concrete examples of the use of citizen-generated data by NSOs and UN agencies. Additionally, examples of downstream applications and value creation of CO outputs and data for business, policy and EO stakeholder were presented.	-
Toolkit	*To gather best practice tools and methods from CO projects and make them accessible to other CS/CO projects*	By offering open access resources, the WeObserve Toolkit lowers barriers to use and increases discovery. Practitioners new to COs can explore the Toolkit in an easy way, e.g., by doing a general search on participatory tools.	The toolkit offers insights on the methods and tools used by COs and can thus increase trust in CO processes.	Tailored toolkits and open tools can become part of a broader sustainability and up-scaling plan for COs as they can be reused and repurposed.
Cookbook	*To provide guidelines for creating successful and sustainable COs*	The cookbook guides newcomers to the field of COs to relevant resources that allow them to understand what COs are in terms of the characteristics of COs as well as the history of COs.	The cookbook captures best practice lessons as well as insights on the barriers for COs and how these can be addressed. In this way, it helps to overcome prevalent concerns that hold back the uptake and spread of COs.	The cookbook guides users through available resources that provide insights and guidelines for creating purposeful and sustainable COs. It presents a 'one-stop-shop' for many issues that can affect the sustainability of COs, whether at their inception, implementation or long-term operation.

WeObserve

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