European Commission

Activity Report on Citizen Science – discoveries from a five year journey

Sven Schade
Chrysi Tsinaraki
Marina Manzoni
Anna Berti Suman
Fabiano Antonio Spinelli
Irena Mitton
Alex Kotsev
Blagoj Delipetrev
Karen Therese Fullerton

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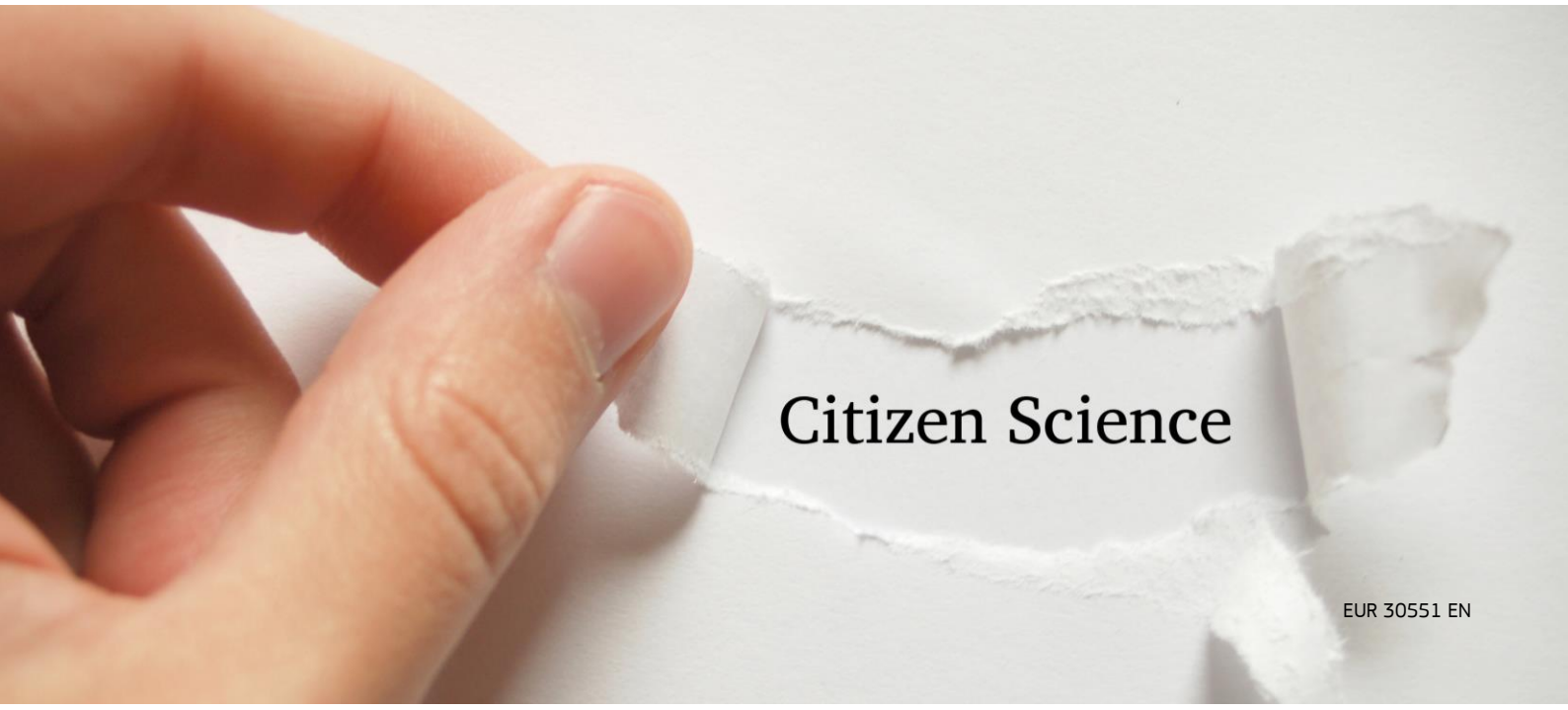

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Contact information
Name: Sven Schade
Address: Via E. Fermi 2749, 21027 Ispra (VA), Italy
Email: s.schade@ec.europa.eu

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Authors

Sven Schade, European Commission, Joint Research Center (JRC) Ispra, Italy

Chrysi Tsinaraki, European Commission, Joint Research Center (JRC) Ispra, Italy

Marina Manzoni, European Commission, Joint Research Center (JRC) Ispra, Italy

Anna Berti Suman, Tilburg Institute for Law, Technology, and Society (TILT), seconded as visiting scientist at the European Commission Joint Research Centre (JRC), Ispra, Italy

Fabiano Antonio Spinelli, European Commission, Joint Research Center (JRC) Ispra, Italy

Irena Mitton, European Commission, Joint Research Center (JRC) Ispra, Italy

Alex Kotsev, European Commission, Joint Research Center (JRC) Ispra, Italy

Blagoj Delipetrev, European Commission, Joint Research Center (JRC) Ispra, Italy

Karen Therese Fullerton, European Commission, Joint Research Center (JRC) Ispra, Italy

Abstract

Citizen Science evolved from a long tradition in fields, such as biodiversity and meteorology, into almost all scientific fields. Simultaneously, regional and global communities became well organised and interconnected, and we arrived at a situation in which Citizen Science is not only prominent in research and civil society, but also well recognised in political agendas. Over the past five years, we (the Citizen Science team of the European Commission's Joint Research Centre (JRC), Digital Economy Unit, B.6) explored and helped shaping the uptake of Citizen Science within Europe and world-wide. This report summarizes our main activities. It is organized in different areas of activities that our team was involved in and elaborates on our major work items under each of these clusters - including some selected highlights. These elaborations are synthetic while including illustrative material and refer the interested reader to more detailed explanations that have already been published elsewhere. We close by presenting some of our key lessons learned, and by providing pointers to future work.

1 Scope and introduction

Citizen Science, which can be characterised in many different ways[1], evolved from a long tradition in fields such as biodiversity and meteorology, into almost all scientific fields[2]. At the same time, regional and global communities became well organised and interconnected[3], and we arrived at a situation in which Citizen Science is not only prominent in research and civil society, but also well recognised in political agendas[4] and in approaches for evidence-based policy making[5].

Over the past five years, we (the Citizen Science team of the European Commission's Joint Research Centre (JRC), Digital Economy Unit, B.6) explored and helped shaping the uptake of Citizen Science within Europe and world-wide. This included work on Citizen Science and policy[6], environmental Citizen Science, technology[7], and data and metadata standards[8].

This report summarizes our main activities, presents lessons learned and provides some reflections for future work. It is organized in a set of different areas of activities that our team was involved in and elaborates on our major work items under each of these clusters, including some selected highlights.

In a nutshell, Section 2 presents our work supporting environmental Citizen Science, whereas Section 3 is dedicated to the interoperability of Citizen Science data and metadata. Activities to increase the uptake and wider use of Citizen Science are presented in Section 4, before we elaborate on the use of new technologies (in Section 5). Recent investigations of the legal and rights-based context are sketched in Section 6, and we present an excursion into related work on mobile apps related to COVID-19 in Section 7. After highlighting some of our recent dissemination and exploitation activities (Section 8), we conclude the report by listing selected lessons learned and providing some final remarks (Section 9).

The elaborations in this report remain synthetic while including illustrative material and refer the interested reader to more detailed explanations that have already been published elsewhere. Complementary material is also available from our official web presence[9].

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1 A very good overview has been recently published as Haklay M., et al. (2020). ECSA's Characteristics of Citizen Science. Zenodo, http://doi.org/10.5281/zenodo.3758668

2 See, for example, Schade S. and Tsinaraki C. (2016). Survey report: data management in Citizen Science projects, EUR 27920 EN, Luxembourg (Luxembourg): Publications Office of the European Union, https://ec.europa.eu/jrc/en/publication/survey-report-data-management-citizen-science-projects and Turbé A., et al. (2019). Understanding the Citizen Science Landscape for European Environmental Policy: An Assessment and Recommendations. Citizen Science: Theory and Practice, 4(1), http://doi.org/10.5334/cstp.239

3 See, for example, Manzoni M., et al. (2020). Workshop Report WG3: Recommendations for the development of (national) Citizen Science Strategies. COST Action 15212 Workshop Report, https://cs-eu.net/news/workshop-report-wg3-recommendations-development-national-citizen-science-strategies

4 See, for example, European Commission (2020). A new ERA for Research and Innovation, COM/2020/628 final, https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=COM:2020:628:FIN and European Commission (2020). Best Practices in Citizen Science for Environmental Monitoring, SWD(2020) 149 final, https://ec.europa.eu/environment/legal/reporting/pdf/best_practices_citizen_science_environmental_monitoring.pdf

5 Sucha V. and Sienkiewicz M. (Eds.) (2020). Science for policy handbook, Springer, https://ec.europa.eu/jrc/communities/sites/jrccties/files/science_for_policy_handbook_fin.pdf (especially Chapter 8: Engaging with Citizen)

6 See, for example, the web page of the COST Action 15212 Working Group 3 https://cs-eu.net/wgs/wg3, European Commission (2020). Citizen Science - Elevating research an innovation through societal engagement, brochure https://ec.europa.eu/info/files/citizen-science-elevating-research-and-innovation-through-societal-engagement_en and Schade et al. (forthcoming). Citizen Science and Policy, in the Science of Citizen Science, Springer, https://www.springer.com/gp/book/9783030582777

7 See, for example, Schade, S. et al. (2019). Aliens in Europe. An open approach to involve more people in invasive species detection. Computers, Environment and Urban Systems, 78, https://doi.org/10.1016/j.compenvurbsys.2019.101384 and Sturm U., et al. (2018) Defining principles for mobile apps and platforms development in citizen science. Research Ideas and Outcomes 4: e23394. https://doi.org/10.3897/rio.4.e23394

8 See, for example, Schade S., Tsinaraki C. and Roglia E. (2017). Scientific data from and for the citizen. First Monday, Volume 22, Number 8 - 7 August 2017 , http://dx.doi.org/10.5210/fm.v22i7.7842 and https://github.com/citizen-science-association/ppsr-core

9 Citizen Science page on the JRC Science Hub, https://ec.europa.eu/jrc/communities/en/community/citizensdata

2 Citizen Science in support of environmental policy

In January 2015, the Directors General of DG Environment (ENV), DG Climate Action (CLIMA), Joint Research Centre (JRC), DG Research and Innovation (RTD) and Eurostat, and the European Environment Agency (EEA) have established an informal group named **Environmental Knowledge Community (EKC)**, with the following objectives:

- To establish and regularly update a comprehensive overview of ongoing and planned work on environmental knowledge, to share it and to use it for integrated knowledge planning.
- To efficiently distribute the required knowledge co-creation and sharing among the main stakeholders.
- To better align knowledge support with relevant policy priorities and to facilitate better medium- to long-term definition and programming of knowledge support.

This process formed the basis for the EKC Roadmap adopted in May 2015. The Roadmap is directly linked to the 7th Environment Action Programme (7EAP)[10], focusing on several deliverables until 2020, while keeping an outlook driven by the 7EAP vision for 2050. The internal working of the EKC is ensured by close collaborations at desk officer level, regular meetings at senior expert ("Sherpa") level, bi-annual meetings of the relevant Directors, and annual discussions between the involved Director Generals (DGs) and the Executive Director of the EEA. As an instrument to explore and advance the joint work on new knowledge requirements, the EKC established a set of so-called **Knowledge Innovation Projects (KIPs).**

As part of its contribution to the EKC, the JRC leads the KIP on Citizen Science. Since 2016, the KIP on Citizen Science particularly addresses the relationship between people and data – not only to monitor the state and trends of the environment and relations to human health, but also to help assess the impact and effects of the implementation of environmental related policy across the EU. This joint work achieved many fruitful outcomes and a high level of visibility. This is especially because the EKC has a governance structure that spans across the entire hierarchy.

We provide a general overview of the Citizen Science KIP and its status reports on the internal wiki pages of the EKC. Our joint work is carried out by frequent interactions, regular coordination calls (usually on a three-weekly basis), inputs to relevant meetings at Director and at DG level, as well as a series of physical meetings. It was this work that also allowed us to contribute to the feedback of the Citizen Science community on the Aarhus convention on Access to Information, Public Participation in Decision-making and Access to Justice in Environmental Matters[11].

2.1 Citizen Science and environmental monitoring

The highest priority work item for the past two years was the Commission Staff Working Document (SWD) "Best practices on Citizen Science and environmental monitoring"[12]. This document implements Action 8 of the "Actions to Streamline Environmental Reporting" (SWD (2017) 230 final): Promote the wider use of Citizen Science to complement environmental reporting. The "Actions to Streamline Environmental Reporting" are the European Commission's response to the evaluations of environmental legislation under the regulatory fitness and performance programme (REFIT) looking at environmental reporting and monitoring issues systematically.

Following intense preparations in 2018 and 2019, the document was finally published in summer 2020, which gave us the time required to match closely the priorities of the new Commission.

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10 Environment Action Programme to 2020, https://ec.europa.eu/environment/action-programme

11 UNECE Consultation on the Recommendations on electronic information tools, http://www.unece.org/environmental-policy/conventions/public-participation/aarhus-convention/tfwg/task-force-on-access-to-information/consultation-on-the-recommendations-on-electronic-information-tools.html

12 European Commission (2020). Best Practices in Citizen Science for Environmental Monitoring, SWD(2020) 149 final, https://ec.europa.eu/environment/legal/reporting/pdf/best_practices_citizen_science_environmental_monitoring.pdf

The best practice document was jointly written under the lead of DG Environment (Environmental Knowledge, Eco-Innovation & SMEs Unit, ENV.A.3). Main contributions were made by the JRC (Digital Economy Unit, JRC.B.6), the EEA (Data and Information Services (DIS) Programme) and DG RTD (Climate and Planetary Boundaries and Open Science Units. RTD.C.3 and RTD.G.4) – based on our joint experiences in the Citizen Science KIP, a study (An inventory of Citizen Science activities for environmental policies)[13] that was conducted in 2018, and a series of stakeholder workshops. The workshops included an event at the premises of the JRC in Ispra (Italy) in November 2018[14], a round table in Brussels (April 2019), a co-writing session with Commission colleagues (September 2019) and a final stakeholder workshop in Brussels (October 2019). The network of Environmental Protection Agencies (EPA Network)[15] and the Eionet community[16] (coordinated by the EEA) have also been consulted in parallel, including the participation of EKC partners in their meetings, for example, on 23-24 May 2019 in Zurich. Feedbacks received were all positive with constructive suggestions for improvements.

The final document makes recommendations along four major areas:

1. Matchmaking between policy needs and Citizen Science activities
2. Promote awareness, recognition and trust
3. Provide standards for data quality and interoperability, and share tools
4. Support coordination, collaboration and resources for policy impact

Each recommendation is accompanied by a set of action points for different audiences. The action points address either public authorities (on different administrative levels), Citizen Science networks, practitioners, or a combination of the above.

These recommendations and actions set a baseline for future work items in the environmental domain throughout the European Commission and the Citizen Science community. After 2020, in order to ensure continuity and the necessary follow up, several tasks will remain to coordinate Citizen Science for environmental policy throughout the Commission different activities. The JRC is committed to lead a dedicated action that explores the use of Citizen Science data in the Green and the Smart Community Data Spaces[17], among others including inputs to the revision of the Directive on public access to environmental information[18], which is due next year. Beyond that, we will research the role of Citizen Science data in data spaces and ecosystems, as well as the contributions that Citizen Science might make to new forms of governance, including its relationship to the public sector.

2.2 Developing mobile applications for observing our environment

Our research includes and builds on a selected set of hands-on activities. These dedicated developments and engagements for providing Citizen Science solutions use diverse technologies, such as, mobile internet, smart phones and lower-cost sensor systems. The hands-on approach is essential for our work because these concrete practices provide us with real experiences, own illustrations, and help to form new collaborations for knowledge co-creating and sharing. The JRC was primarily involved in three core developments, whereas additional support is provided to a few underlying matters – mostly related to data interoperability and standards (see also Section 3).

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13 European Commission, Directorate-General for Environment; European Commission, Joint Research Centre; Bio Innovation Service (2018). An inventory of citizen science activities for environmental policies. European Commission, Joint Research Centre (JRC) [Dataset], https://data.europa.eu/euodp/en/data/dataset/jrc-citsci-10004

14 Manzoni M., et al. (2019). Citizens Science and Environmental Monitoring: Benefits and Challenges, Publications Office of the European Union, https://ec.europa.eu/jrc/en/publication/citizens-science-and-environmental-monitoring

15 Web page of EPA network, https://www.eea.europa.eu/about-us/who/epa-network

16 Web page of Eionet, https://www.eionet.europa.eu

17 See, for example, https://ec.europa.eu/digital-single-market/en/news/expert-workshop-common-european-smart-communities-data-space

18 Directive 2003/4/EC of the European Parliament and of the Council of 28 January 2003 on public access to environmental information and repealing Council Directive 90/313/EEC, https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A32003L0004

2.2.1 Collaboration on Invasive Alien Species in Europe

The Invasive Alien Species (IAS) in Europe mobile application (see also Figure 1) is being developed since 2015 with the involvement of DG Environment from the very beginning in order to allow users to report the presence of species listed as IAS of Union concern according to the EU Regulation no. 1143/2014 (IAS Regulation). It enables the general public (amateurs and professionals) to receive and share information about Invasive Alien Species (IAS) in Europe. It provides details about 66 different IAS that are considered to be of interest to the complete European Union. Users can record pictures of possible Invasive Alien Species together with complementary information about their observation. This app is developed in close collaboration with the relevant JRC thematic experts, i.e., the European Invasive Alien Species Network (EASIN) team of the Water & Marine Resources Unit (D.2).

Figure 1. *Screenshot of the Invasive Alien Species Europe App – main menu.*

The Invasive Alien Species in Europe app is our flagship in this area of work. During the past five years this activity developed into a full-fledged solution that connects Citizen Science to policy at different levels of administration. The app became available in 11 languages[19] with 6 different login options[20].

Apart from the high visibility and continuing demands, this app also provides us with a baseline for further experimentations. Whereas we keep updating our validation system in order to allow more users to participate in quality control, we also experimented with the use of Artificial Intelligence (AI) and chatbot technology in the form of an intense case study (more details are provided in Section 4). Here, the app bears high potential to showcase explainable AI and human-centred AI by elaborating on the possible interplays between humans and machines, as requested in the European Commission's White Paper on Artificial Intelligence[21]. In the future, this work will serve as a case study on the Green Data space under the European Strategy for Data[22], and to research new forms of

[19] English, French, Spanish, German, Greek, Hungarian, Italian, Portuguese, Romanian, Serbian, and Turkish.

[20] Facebook, Twitter, LinkedIn, Strava, Eu Login and a native EASIN option (to be phased out soon).

[21] European Commission (2020). White paper on Artificial Intelligence - A European approach to excellence and trust, COM(2020) 65 final, https://ec.europa.eu/info/sites/info/files/commission-white-paper-artificial-intelligence-feb2020_en.pdf

[22] European Commission (2020). A European strategy for data, COM(2020) 66 final, https://ec.europa.eu/info/sites/info/files/communication-european-strategy-data-19feb2020_en.pdf

governance. Apart from the functional improvements (such as the inclusion of local species lists in addition to the list of IAS of Union concern), highlights also include collaborations with Member State authorities and institutions for supporting the dedicated use of the IAS Europe App, including:

- The Institute of Biological Research, University of Belgrade, Serbia, in the role of coordinator for alien species monitoring of the Joint Danube Survey4 (JDS4), under the responsibility of the International Commission for the Protection of the Danube River (ICPDR).
- The IUCN, Centre for Mediterranean corporation, Spain, and University of Murcia, Spain as coordinators of the LIFE INVASAQUA "Especies exóticas acuáticas invasoras de agua dulce y sistemas estuarinos: Sensibilización y Prevención en la Península Ibérica".
- The Bulgarian Academy of Sciences, co-funding from the Bulgarian Science Fund for the Alien CSI project.
- The Environment and Resources Authority (ERA), the competent authority responsible for the implementation of the IAS Regulation in Malta.
- The Interreg Danube Project Sava TIES, involving partners from the EuroNatur Foundation, ISKRIVA Institute for Development of Local Potentials, and the Public Institution „Zeleni prsten" of the Zagreb County.

The increasing collaborations with Member States and research projects are also acknowledged as part of the branding inside the App (see also Figure 2).

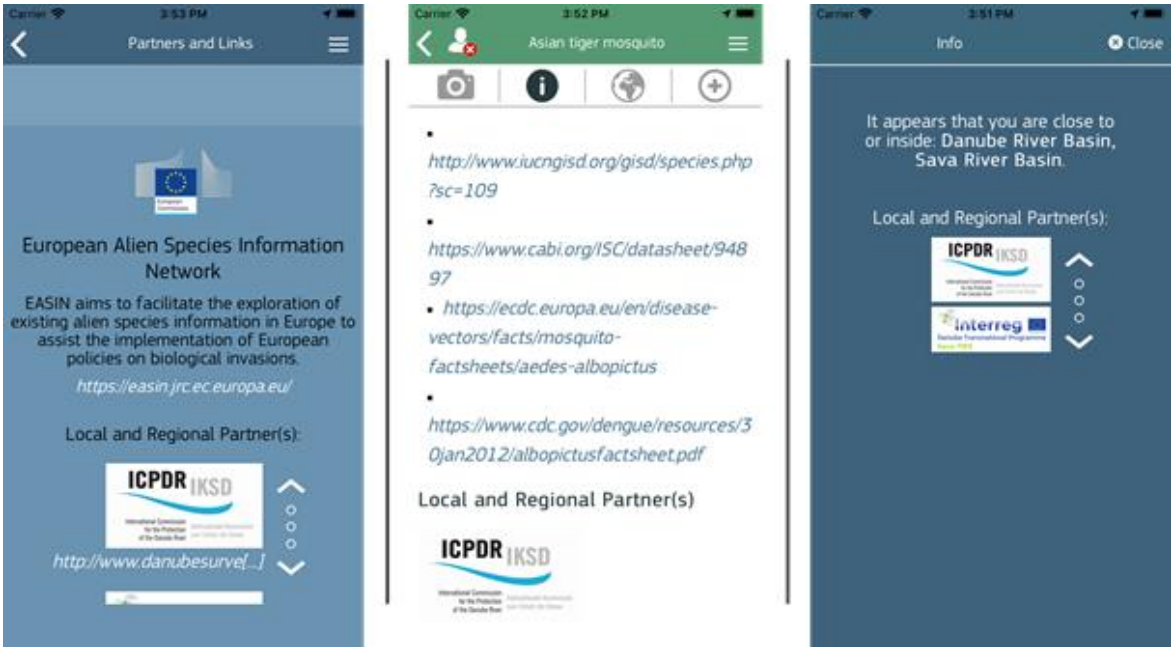

Figure 2. *Invasive Alien Species in Europe app – branding examples: page with partners' information (left), recognition related to local invasive species (middle), local recognition (right).*

Accompanying documentation and user guidance is available, together with the underlying source code (under an open license)[23]. Furthermore, we published the underlying scientific and technical work in the International Journal Computers, Environment and Urban Systems (CEUS)[24]. A complete report of our activities, especially also including the achievements of the supporting JRC Proof of Concept (PoC) Project "IAS Europe app: engaging Citizens in alien species surveillance" are summarized in separate documents. This work also contributes to the COST Action Alien CSI Increasing understanding of alien species through Citizen Science (COST Action CA17122)[25].

[23] Landing page for the Invasive Alien Species in Europe mobile app, https://digitalearthlab.jrc.ec.europa.eu/app/invasive-alien-species-europe

[24] Schade S., et al. (2019). Aliens in Europe. An open approach to involve more people in invasive species detection. Computers, Environment and Urban Systems, 78, https://doi.org/10.1016/j.compenvurbsys.2019.101384

[25] Web presence of the COST Action AlienCSI, https://alien-csi.eu

2.2.2 A mobile app in support of the Natura2000 network

We provided the myNatura2000 application for mobile phones (see also Figure 3) to help promoting and raising the awareness of Natura2000 network of protected sites[26]. It was developed, so people could locate, explore and learn about the protected species and habitats in Natura 2000 sites. This includes the rating of Natura2000 sites, as experiences during a visit.

The MyNatura2000 mobile application was developed since 2016, including the co-design with DG Environment and relevant JRC colleagues (of the Knowledge for Sustainable Development & Food Security Unit, D.6). As part of the suite of apps that were developed in our unit (JRC.B.6), the myNatura2000 one was our lead case for re-using and building on experiences with Invasive Alien Species (EASIN). We developed a fully operational app.

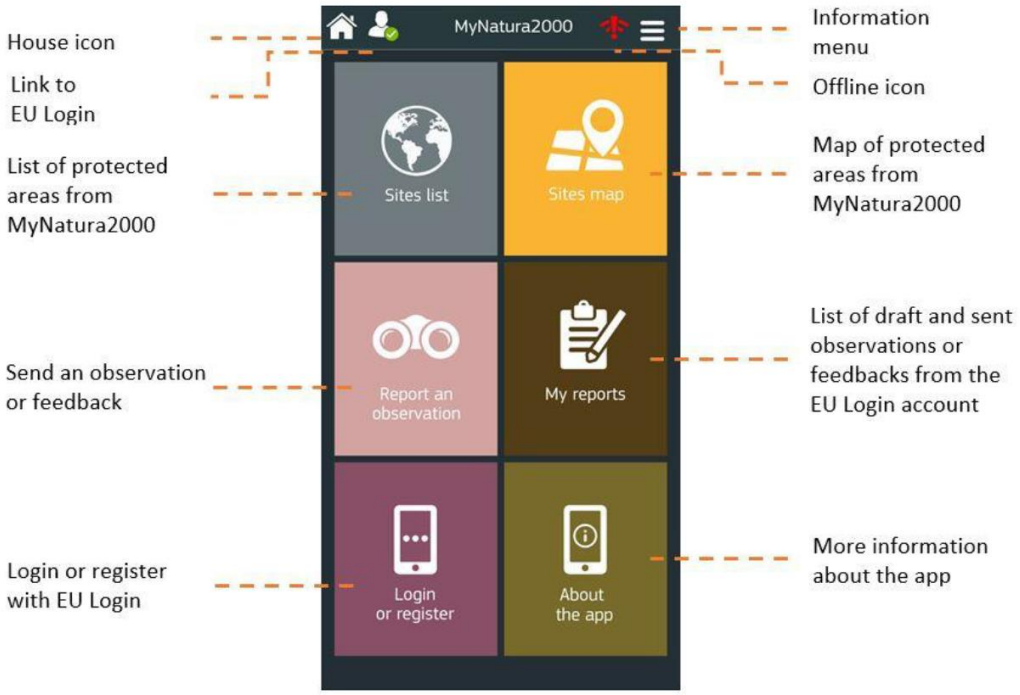

Figure 3. *Screenshot of the myNatura2000 app – main menu.*

In 2019 this work contributed to the successful closing of Action 14 of the action plan on nature, people and the economy. Under Action 14 "*Support recognition of good management of Natura 2000 sites and awareness-raising of the Nature Directives through relevant fora, availing of new technologies and outreach activities, and strengthen links between natural and cultural heritage, especially in the context of 2018 as European year of cultural heritage*".

At the time we also commissioned a test and validation campaign with the Social Technovations Lab Korlátolt that provided us with a final feedback report, including possible scenarios for future use and improvements (see also Table 1). Accompanying documentation and user guidance is available, together with the underlying source code (under an open license)[27]. The detailed results from the testing are provided in a separate document. These materials remain available for possible re-use.

[26] Web presence of Natuira2000, https://ec.europa.eu/environment/nature/natura2000/index_en.htm
[27] Landing page for the myNatura2000 Europe mobile app, https://digitalearthlab.jrc.ec.europa.eu/app/mynatura2000

Table 1. *Overview of usage scenarios for the myNatura2000 app.*

scenarios	Who is engaged?	Collected field data	Main study questions?
to identify threats of degradation	Monitoring experts, NGO experts	yes	Whether the App can be used for recording and collecting data on the pressures and threats of degradation? How can it be done? Who could be engaged?
to monitor the Natura 2000	Monitoring experts, NGO experts, CS practitioners, National park managers, and guards	yes	What data should be collected? How the App can be used for recording and collecting data for monitoring species and habitats?
to assess the implications of plans and projects	NGO experts, individual experts, University students	no	How the App could support the Identification activities that cause any disturbance likely significantly to affect the conservation objectives?
to support learning	University students, teachers, NGO experts	yes	How the App supports learning? What learning outcomes could be realized by students? At what education level?
to setting site-level conservation objectives	NGO experts, National park managers, and guards,	no	How the App could support the setting of site-level conservation objectives? Could it be any policy implication of MyNatura2000 app?
to empower NGOs and local people	NGO experts, individual experts	yes	How this app could support NGOs to strength their watchdog function: esp. monitor the activities of local governments, forest industry?
to improve the conservation measures	Individual experts	no	How could the app supporting the monitoring of statutory, administrative or contractual measures applied in the different areas of Natura 2000? ? Who could be engaged? What are the limitation of this approach?
to support research with non-expert data	Researchers from Nösztép, individual experts,	yes	How Nösztép (MAES-HU) can be supported by using My Natura 2000 App for field data collection? What data should be collected?
to support promotion of Natura 2000 sites	National park managers, and guards,	yes	Could the National Parks and NGOs use this app for promoting their activities? What would be the role of NPs? Could the values of protected sites be promoted by MyNatura2000 app?

2.2.3 A mobile app informing about air quality

We also developed a mobile phone application (together with colleagues of the Air & Climate Unit, C.5) that enables amateurs and professionals alike to receive information about the quality of ambient air and notifies them in case of an exceedance of pre-set pollution thresholds (see also Figure 4). It displays data from the air sensing networks that publish their data using Sensor Observation Services compliant with the INSPIRE Directive[28]. The source code of the mobile application (see also below) is already published openly for further reuse[29].

Figure 4. *Screenshot of the SenseEurAir app – main menu.*

[28] Directive 2007/2/EC of the European Parliament and of the Council of 14 March 2007 establishing an Infrastructure for Spatial Information in the European Community (INSPIRE), https://eur-lex.europa.eu/legal-content/EN/ALL/?uri=OJ%3AL%3A2007%3A108%3ATOC

[29] Web presence of SenseEurAir, https://digitalearthlab.jrc.ec.europa.eu/app/senseeurair

2.3 Exploring the use of lower-cost sensor systems

Findings from a long-term collaboration involving also colleagues of JRC Air & Climate Unit (C.5) as the thematic lead - also feed into the EKC demonstrators. This work particularly addresses the use of lower-cost sensors systems for measuring air pollution (Gerboles et al., 2016[30], see also Figure 5 for some impressions).

Figure 5. *AirSensEUR sensor boxes in action –a deployment of the first version in the Netherlands (on top) and the newest version as presented at the European Clean Air Day 2019 (at the bottom).*

[30] Gerboles M., et al. (2016). AirSensEUR: an open data/software /hardware multi-sensor platform for air quality monitoring - Part B: Host, influx datapush and assembling of AirSensEUR; EUR 28054 EN; doi:10.2790/214743, https://ec.europa.eu/jrc/en/publication/airsenseur-and-open-datasoftwarehardware-multi-sensor-platform-air-quality-monitoring-part-b-host

In 2019, we published the Joint Statement on new opportunities for air quality sensing - lower-cost sensors for public authorities and Citizen Science initiatives"[31]. This document is a major outcome of an expert meeting (24 October 2018 in Frankfurt, Germany) involving almost 40 organizations from government, public administration, academia and different parts of society. It suggests a way forward for critical areas such as data quality, interoperability, modelling, calibration, and data management. The details provided in the full statement centre around two key messages. First, co-operation between official monitoring networks (reference quality data) and lower-cost sensor operators is a key to make air quality data more usable. Second, to be able to combine forces and benefit from each other's expertise, the different perspectives of all stakeholders should be taken into account.

As a substantial activity, C.5 started a new arrangement with DG Environment (called AQSENS) about the integration of smart sensors and modelling for air quality monitoring in cities. Whereas the outcomes are documented separately, highlights of this work include the signatures of three major contracts in 2019 which will (i) provide and maintain sensing devices; (ii) deploy the devices in three cities in Europe; and (iii) host a data handling and processing platform, respectively.

We are supporting the AQSENS led by the Air & Climate Unit (us on the establishment of a dedicated data platform, interoperability and guidance for citizen scientists), and developed a mobile app to access official and complementary sensor data, especially leveraging of an open source lower-cost sensor system that we developed with our colleagues in the past.

The established data platform[32] is fully based on open standards (OGC SensorThings API[33], OGC Sensor Observation Service[34]) and open-source software. It provides functionalities for mashing up authoritative and low-cost sensor data, cleaning of time series and calibration of sensors through the application of different computational strategies. The figures below give some impressions.

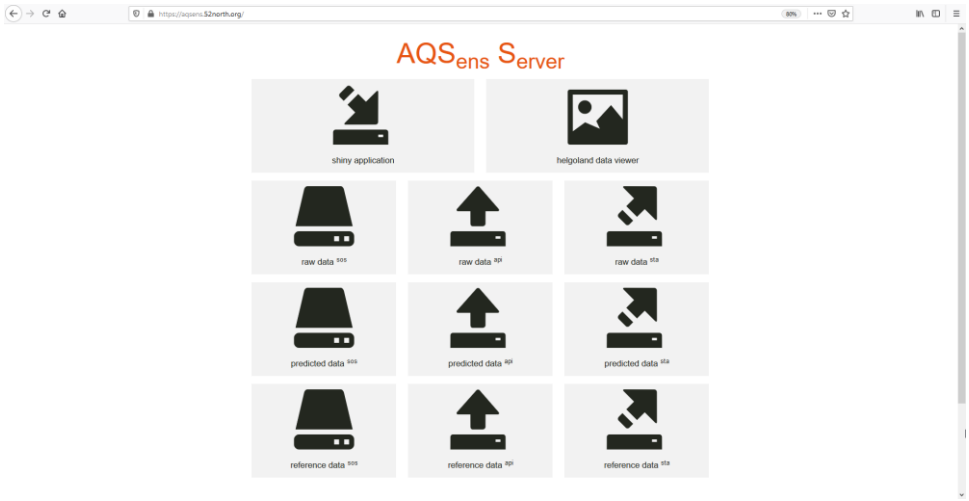

Figure 6. *Screenshot of the platform for air quality data – setup of the server infrastructure, providing access to raw, predicated and reference data.*

31 Schade S., Herding W., Fellermann A. and Kotsev A. (2019). Joint Statement on new opportunities for air quality sensing - lower-cost sensors for public authorities and citizen science initiatives. Research Ideas and Outcomes 5: e34059. https://doi.org/10.3897/rio.5.e34059

32 Web presence of the developed platform, https://aqsens.52north.org

33 Web page of the OGC standard SensorThingsAPI, https://www.ogc.org/standards/sensorthings

34 Web page of the OGC standard Sensor Observation Service (SOS), https://www.ogc.org/standards/sos

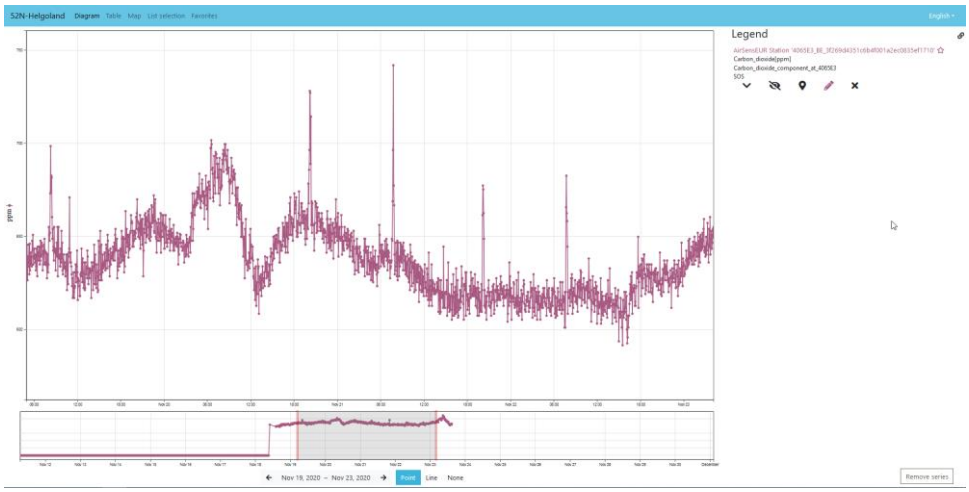

Figure 7. *Screenshot of the platform for air quality data – exploring measurements of a single station.*

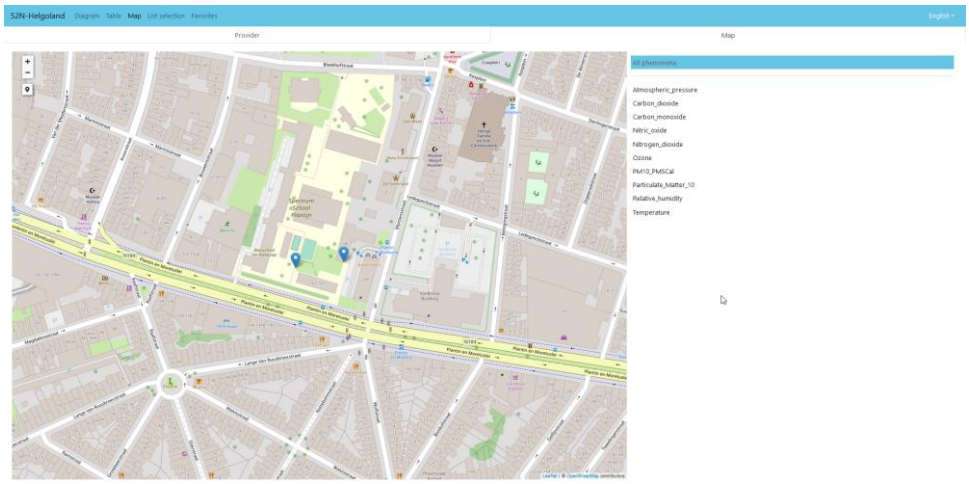

Figure 8. *Screenshot of the platform for air quality data – map overview of some stations.*

Support to the completion of AQSENSE (managing the technology platform contract and providing guidance to citizen scientists) is planned until late-2021, but likely to be extended because of COVID-19 complications. There is a clear relationship with the Internet of Things (IoT), as a case study and hands-on work with respect to data ecosystems and complementary use of data from various sources by local, national, and international authorities.

2.4 Investigating the interplay between humans and the natural environment

As part of our environmental Citizen Science work, we also support colleagues in the JRC Land Resources and Knowledge for Policy: Concepts and Methods Units (D.3 and H.1) on nature-based solutions and biodiversity in cities (BiodiverCities)[35]. Our contribution aims at those of the 12 participating cities that are interested in Citizen Science approaches (see also Figure 9). We see good connection to local governance and plans for digitalization, for example, e-government plans.

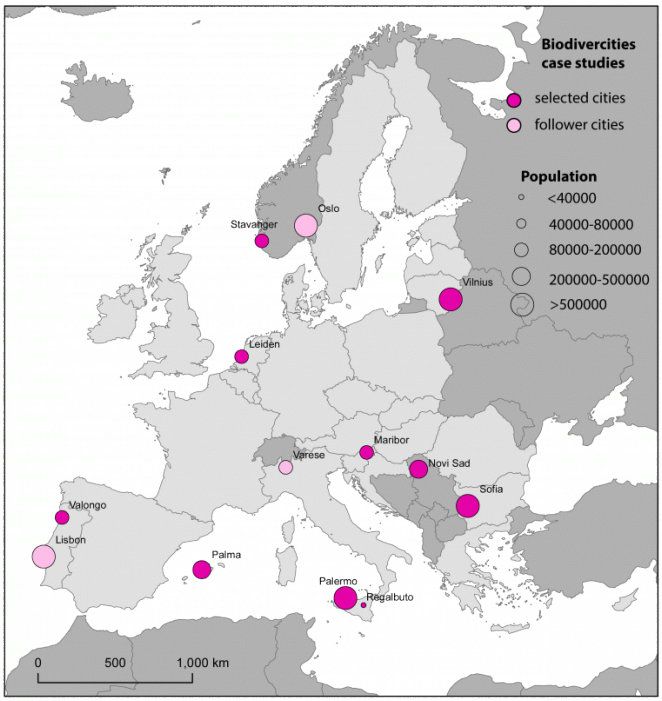

Figure 9. *Overview of the cities participating in BiodiverCities.*

[35] Web page of the BiodiverCities project, https://oppla.eu/groups/biodivercities

3 Improving interoperability in Citizen Science

From the origins we worked on the interoperability of Citizen Science metadata and data, including solid data management approaches[36]. Among other, this resulted in a more than 500 cases strong inventory of Citizen Science projects related to (environmental) policy - currently according to Altmetric the most prominent data set of the JRC Data Catalogue[37]. Based on our experiences, we also contributed to the development of European end international standards for knowledge exchange, i.e. we were highly active in relevant communities and standardization bodies.

Given the progress, we now move into a phase in which we apply these standards to maintain robust and interoperable data and knowledge about Citizen Science and related activities. The work on data and interoperability will now focus on Citizen Science as a part of data ecosystems, particularly, but not only, in connection to the smart community data space.

3.1 Standards for Citizen Science data and metadata

We contribute to the development of the interoperability of Citizen Science data, which we understand as a wide concept. Overall, we distinguish between (1) data about Citizen Science projects and activities; (2) data about Citizen Science data sets; and (3) observations and measurements from Citizen Science. In each of these three areas, we faced challenges when bringing already existing data (knowledge) sources together but helped to design re-usable and interoperable components. Since practical solutions can only be co-created with the existing communities, we established working relationships with a series of partners.

3.1.1 International working group on Citizen Science data and metadata models

Following our interactions since 2015, we contributed with the COST Action 15212 (Working Group 5 "Improve data standardization and interoperability")[38] on Citizen Science and the International Working Group in Citizen Science Data and Metadata[39] to a standardisation approach, underlying supporting infrastructure, and a proposal for a common way of describing of Citizen Science projects.

We decided to prioritise these interactions because of their potential to coordinate among other relevant standardisation activities (see below). We especially build on our Citizen Science inventory and catalogue (see also Section 3.2) in order to provide an advanced version of the so called "Public Participation in Scientific Research (PPSR) standards.

During the past years, we help in the establishment of a governance structure to define, update and maintain community standards[40]; contributed to conceptual improvement of the models; and supported the publication of a new web presence[41]. Most recently, we lead the development of an approach to implement the conceptual models of the PPSR standards using most recent technologies (JSON Schema and JSON-LD). We showcased the way ahead based on our own mobile apps, backend infrastructure, inventory and catalogue using the open-source tool Pentaho[42] (see also Figure 10 for an illustration).

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36 See, for example, Schade S. and Tsinaraki C. (2016). Survey report: data management in Citizen Science projects, EUR 27920 EN, Luxembourg (Luxembourg): Publications Office of the European Union, https://ec.europa.eu/jrc/en/publication/survey-report-data-management-citizen-science-projects and Schade S., Tsinaraki C. and Roglia E. (2017). Scientific data from and for the citizen. First Monday, Volume 22, Number 8 - 7 August 2017 , http://dx.doi.org/10.5210/fm.v22i7.7842

37 European Commission, Directorate-General for Environment; European Commission, Joint Research Centre; Bio Innovation Service (2018). An inventory of citizen science activities for environmental policies. European Commission, Joint Research Centre (JRC) [Dataset], https://data.jrc.ec.europa.eu/dataset/jrc-citsci-10004

38 COST Action 15212 (Working Group 5 "Improve data standardization and interoperability"), https://cs-eu.net/wgs/wg5

39 International Working Group in Citizen Science Data and Metadata, https://www.citizenscience.org/get-involved/working-groups/data-and-metadata-working-group

40 Geneva Declaration on citizen science data and metadata, https://www.cs-eu.net/sites/default/files/media/2018/06/COST-WG5-GenevaDeclaration-Report-2018.pdf

41 New web presence of the PPSR standards, https://core.citizenscience.org

42 Web page of Pentaho, https://sourceforge.net/projects/pentaho

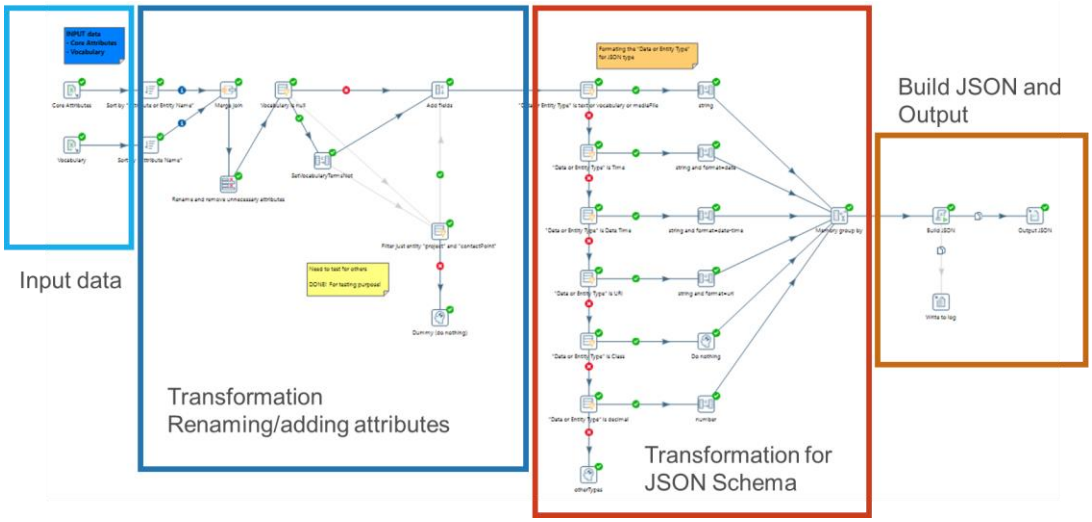

Figure 10. *Overview of the generation of a JSON-Schema based on PPSR using Pentaho.*

A final agreement on the next version of the standard model and encoding has yet to be reached. We expect this for early 2021. Once available, the connections for re-use by OGC and GEOSS (see below) have been established and should be a logical next step. We will continue using this standard, especially when it comes to the exchange of Citizen Science project information, and future impact assessments.

3.1.2 Open Geospatial Consortium (OGC)

Through the Open Geospatial Consortium (OGC)[43] and its Domain Working Group (DWG) on Citizen Science[44], we partnered in the first ever OGC Interoperability Experiment on Citizen Science[45], which published its final report in early 2020[46]. This offered data interoperability solutions and architectural settings (also relevant for GEO/GEOSS, below). We use the Earth Challenge 2020 (to date the world's largest ever coordinated Citizen Science campaign)[47] as an illustrative example (Figure 11).

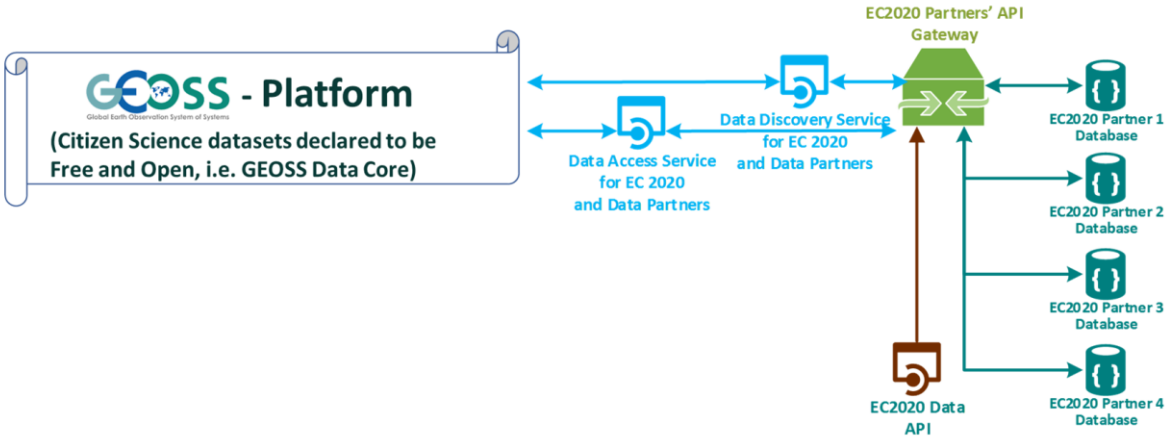

Figure 11. *Sketch of a possible connection between EC2020 and the GEOSS Platform, an example of a coordinated structure to make Citizen Science data discoverable and accessible via GEOSS.*

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43 Web page of the OGC, https://www.opengeospatial.org

44 Web page of the OGC Citizen Science group,https://www.opengeospatial.org/projects/groups/citizenscience

45 Web page of the first OGC Interoperability Experiment on Citizen Science https://www.opengeospatial.org/projects/initiatives/citsci-ie

46 Final report of the first OGC Interoperability Experiment on Citizen Science http://docs.opengeospatial.org /per/19-083.html

47 Web page of the Earth Challenge 2020, https://earthchallenge2020.earthday.org

We were also involved in shaping a follow-up experiment to particularly address Citizen Science data set descriptions. We also see a particular value in experimenting with the SensorThingsAPI standard[48] of the OGC, as it provides a flexible and up-to-date approach for sharing observations and measurements from Citizen Science activities.

3.1.3 Group on Earth Observation (GEO)

In the past, we had intense discussions in the context of the Group on Earth Observation (GEO)[49] and the Global Earth Observation System of Systems (GEOSS)[50] on how Citizen Science might best contribute to and benefit from GEOSS. These discussions were informed by the OGC experiments and took place as part of the GEO Community Activity (CA) on Earth Observation and Citizen Science[51]. On the conceptual level, we reached an agreement in the group how the OGC-based solutions could help to better integrate Citizen Science data (as in-situ or ex-situ measurements) into the data and knowledge infrastructure that GEOSS provides on a global scale. However, more work will be required by the community to provide implementations. Organisational issues might be most difficult to resolve.

We are still elaborating how to address the identified organisational issues, especially in relation to the provision of the new Research Topic and eventually a new Citizen Science Data Journal of Frontiers[52]. Furthermore, including the before mentioned SensorThingsAPI in the GEOSS Platform infrastructure is considered as a valuable way ahead. Here, it will be important to further elaborate on the connection between Citizen Science and in-situ data, the role of data cubes, and the potential use of GEOSS by citizen scientists.

3.1.4 Biodiversity Information Standards (TDWG)

Biodiversity Information Standards (TDWG)[53] is the major community developing and maintaining standards for biodiversity – an area that is leading in terms of Citizen Science for many decades. Accordingly, interactions with TDWG are considered very useful in learning good practices and identifying possible approaches for wider applications. We are in contact with this group via the COST Action 17122, and contributed with a session dedicated to Citizen Science and data quality during the Biodiversity Next conference in 2019[54]. This work provided new insights on how to approach and document quality assurance of biodiversity data – treating it equally, i.e. independent from its source (being Citizen Science or not). Further discussions on data management and possible improvements in validating species observation were taken up in the AlienCSI COST Action. They are topic of the current and future work plan of the action.

3.1.5 CODATA and the World Data System

Especially throughout 2019, we were involved in a series of discussions, especially with CODATA and the World Data System (SDG working group)[55], GEO/GEOSS, the ECSA Maximisation Group on SDGs, and the WeObserve project in order to stay informed and start shaping our own position in this rapidly emerging landscape. As an immediate action, we identified the Global Partnership for Sustainable Development Data[56] as a relevant actor, especially as they prepare guidelines on the use of Citizen Generated Data (CGD) for the SDGs (see also Section 4.2). We established the contact with them, also

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48 Web page of the OGC standard SensorThingsAPI, https://www.opengeospatial.org/standards/sensorthings

49 Web page of GEO, https://www.earthobservations.org/index.php

50 Web page of GEOSS, https://www.earthobservations.org/geoss.php

51 Overview of the GEO Work program, https://www.earthobservations.org/activity.php?id=142

52 Open call for the Frontiers research topic on "Open Citizen Science Data and Methods", https://www. frontiersin.org/research-topics/13843/open-citizen-science-data-and-methods

53 Web page of TDWG, https://www.tdwg.org

54 Web page of Biodiversity Next conferences, https://biodiversitynext.org

55 Web page on the citizen science group under the world data system, https://www.icsu-wds.org/community/working-groups/citizen-science

56 Web page of the Global Partnership for Sustainable Development Data, http://www.data4sdgs.org

to ensure knowledge exchange related to our work on Citizen Science and environmental reporting (see also Section 2.1).

3.2 Inventory of Citizen Science activities for environmental policies

In order to get an evidence-base of Citizen Science activities that can support environmental policies in the European Union (EU), the European Commission (DG Environment) contracted Bio Innovation Service (FR), in association with Fundacion Ibercivis (ES) and The Natural History Museum (UK), to perform a "Study on an inventory of Citizen Science activities for environmental policies"[57]. The Citizen Science team of the JRC provided scientific and technical support to this work, including the set-up of the scientific methodology and agreements on the kind of information that was collected by the contractors.

The first objective was to develop an inventory of Citizen Science projects relevant for environmental policy and assess how these projects contribute to the Sustainable Development Goals (SDGs) set by the United Nations (UN) General Assembly in 2015. To this end, a desk-research and an EU-wide survey were used to identify 503 Citizen Science projects of relevance to environmental policy.

The second objective was to assess the conditions under which Citizen Science can best support environmental policy, through the selection and analysis of a sample of Citizen Science projects. This was followed by an in-depth analysis of 45 projects along 94 project attributes. Subsequently, this analysis provided the foundation for making a series of recommendations to leverage the contribution of Citizen Science to environmental policy.

Since 2018, we maintain and eventually update the inventory of Citizen Science activities that relate to environmental policy that resulted from this work[58] (see also Figure 12). This inventory is updated on a regular basis, considering possible additions from the survey that is provided as a dedicated EUSurvey[59] (Figure 13). It became a primary source for Citizen Science research and practice worldwide. According to Altmetrics the inventory is the most popular data set of the JRC data catalogue (score of over 100, whereas the second most referred data set as a score of slightly over 50, status: 9 December 2020). A related scientific publication has been accepted for the international journal Citizen Science: Theory and Practice[60].

[57] Bio Innovation Service (2018). Citizen science for environmental policy: development of an EU-wide inventory and analysis of selected practices. Final report for the European Commission, DG Environment under the contract 070203/2017/768879/ETU/ENV.A.3, in collaboration with Fundacion Ibercivis and The Natural History Museum, https://op.europa.eu/en/publication-detail/-/publication/842b73e3-fc30-11e8-a96d-01aa75ed71a1

[58] European Commission, Directorate-General for Environment; European Commission, Joint Research Centre; Bio Innovation Service (2018). An inventory of citizen science activities for environmental policies. European Commission, Joint Research Centre (JRC) [Dataset], https://data.jrc.ec.europa.eu/dataset/jrc-citsci-10004

[59] EUSurvey to add entries to the JRC's Citizen Science inventory, https://ec.europa.eu/eusurvey/runner/CSProjectInventory

[60] Turbé, A., et al. (2019). Understanding the Citizen Science Landscape for European Environmental Policy: An Assessment and Recommendations. Citizen Science: Theory and Practice, 4(1), p.34. DOI: http://doi.org/10.5334/cstp.239

Figure 12. *Citizen Science inventory on the JRC Data Catalogue.*

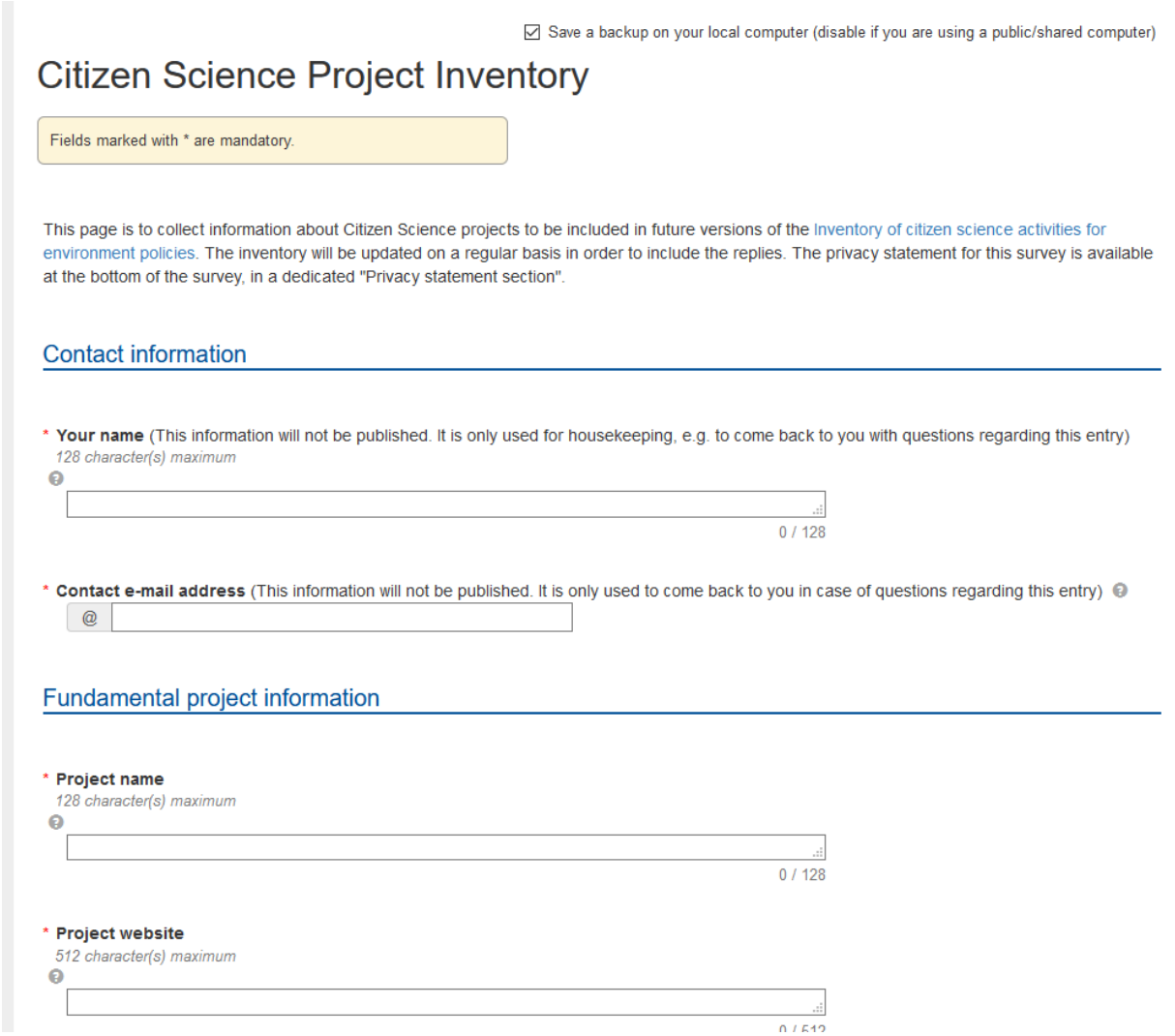

Figure 13. *EUSurvey for entering additional Citizen Science projects to the inventory.*

Following the publication of the study, the underlying data sets, and an offer to include additional projects in the inventory, we took actions in 2019 in order to make the content of the inventory more visible and used. This included a map-based visualisation and other graphical representations (see also Figure 14), as well as an online catalogue (Figure 15)[61]. The data set was also used in events such as the Vespucci Training School on "Digital Transformations in Citizen Science and Social Innovation"[62] and the iDiv Summer School "Citizen Science – Innovation in Open Science, Society and Policy"[63] for further data analysis.

61 The Citizen Science explorer online, https://ec-jrc.github.io/citsci-explorer

62 Event page of the "Vespucci Training School on Digital Transformations in Citizen Science and Social Innovation" 2019, https://cs-eu.net/events/internal/vespucci-training-school-digital-transformations-citizen-science-and-social

63 Event page of the iDiv Summer School 2019, "Citizen Science – Innovation in Open Science, Society and Policy", https://www.idiv.de/en/summerschool/summer-school-2019.html

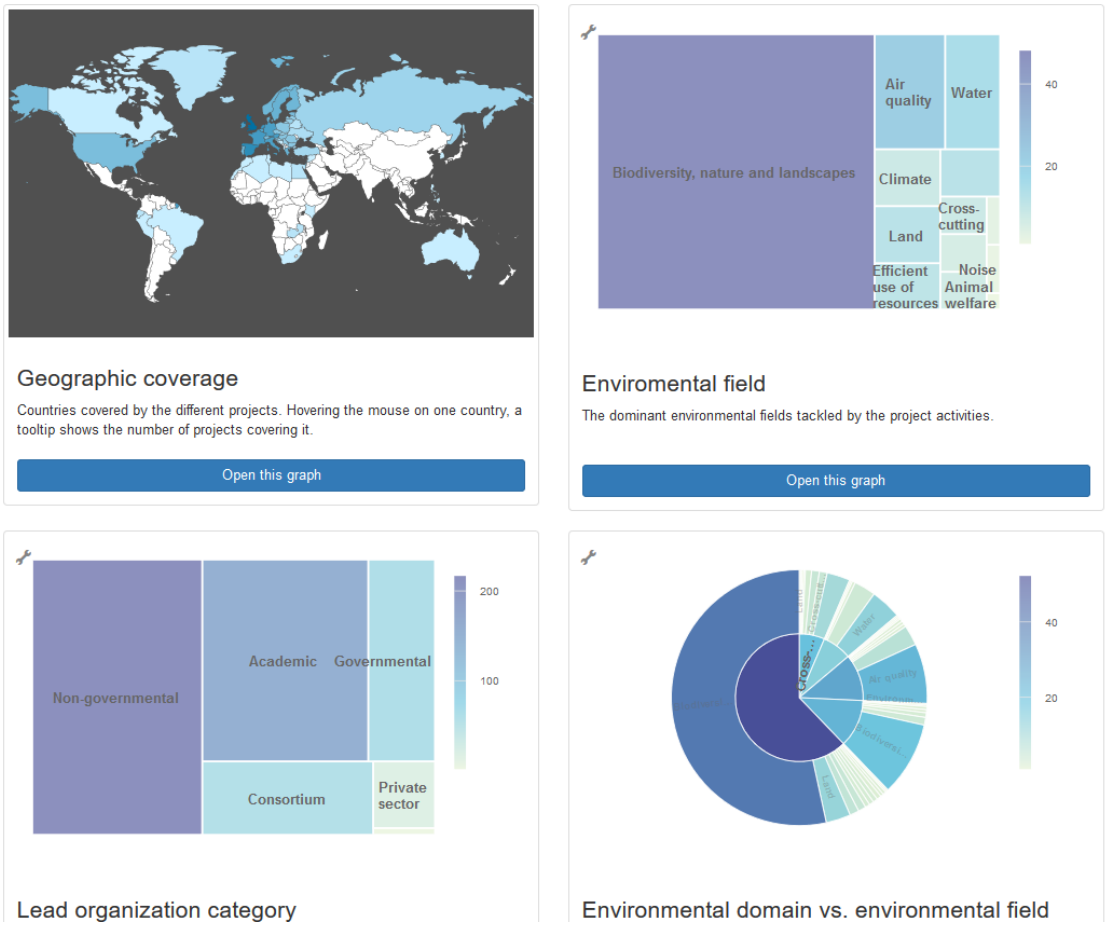

Figure 14. *CitSci-X (explorer) – Examples of the map and graph-based visualisations.*

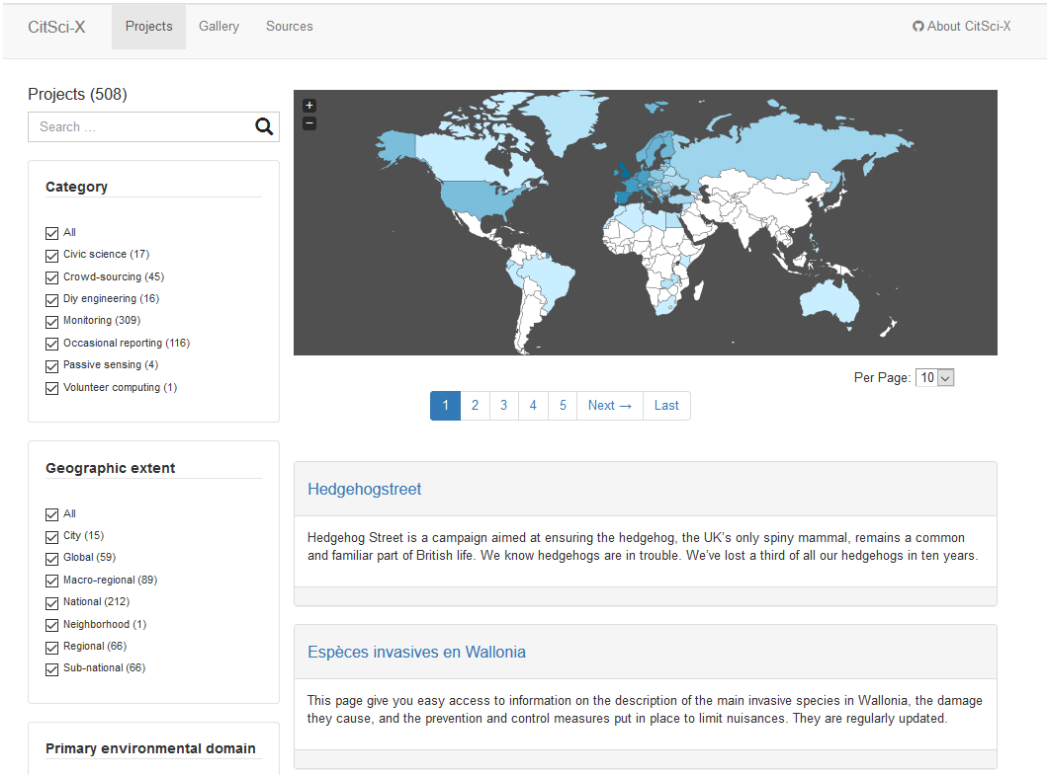

Figure 15. *CitSci-X (explorer) – Screenshot of the catalogue.*

In 2020 we reviewed some attribute definitions and provided a new distribution with explanation of shortcomings and suggestions for eventual improvements. We will also add a new distribution that will include an encoding of the data set following the latest version of the PPSR standard (see also Section 3.1.1). We envisage three ways of exploiting the inventory of Citizen Science projects:

(1) Re-using it as an approach to manage evidence bases – both, within our larger work environment and publicly (since the approach proved to work, and provides us with a sophisticated approach to stay up to date).

(2) Populating it more, at least to show a good practice on how to enhance interoperability with other existing data sources and thereby extend an existing evidence base with new entries (work is under preparation within the context of the COST Action AlienCSI). This activity could contribute to the development of a baseline for investigating digital governance.

(3) Exploring how to improve the assessment of policy impacts and of social impacts (i.e. how much does Citizen Science influence society and how to evaluate its role in the bigger picture). This is an essential element for the future Citizen Science aspects within the topic area of digital transformation. Impacts on the notion of public services are to be included.

4 Increasing the uptake of Citizen Science

The political support for scaling up Citizen Science keeps growing - with the Horizon Europe missions[64] and the European Research Area[65], but also, within Member States, and internationally[66].

4.1 Contribution to the COST Action 15212 on Citizen Science

We actively participated in the COST Action 15212 "Citizen Science to promote creativity, scientific literacy, and innovation throughout Europe"[67]. This COST Action had a leading role to understand and frame Citizen Science in Europe. We were involved in this Action, especially in the working groups on data and metadata[68], and the one to improve the science-policy-society interface[69].

We dedicated part of our work on analysing national and regional Citizen Science strategies in the EU[70]. This activity gave us access to the best available knowledge about Citizen Science related policies and stakeholder groups within different countries and regions. This is especially valuable for supporting research policy at EU level, but also, in reaching out to countries, for Citizen Science support to sectorial policies (see also Figure 16).

Under the working group to improve the science-policy-society interface, a pan-European survey on Citizen Science strategies and initiatives in Europe was launched in 2019 after an intense year of preparation. The ultimate objective of the survey was to understand the landscape of such initiatives, whether these have been developed as institutional, spontaneous, or commissioned by a given Community, identify the actors involved, the methodologies and tools applied, their underlying dynamics, the influencing factors, and avenues to promote and further develop Citizen Science approaches in support to Policy Making both, at country and European level.

This is the first such attempt in Europe, and the collaborative efforts of the representatives of COST Action 1512 and the Citizen Science team of the JRC, have offered through the survey a unique opportunity to achieve this objective through their knowledge of the European landscape, and their diversified expertise in the different countries. The results from the survey are being summarised, analysed, and presented in a report for publication by the end of this year.

The different reports summarising the conclusions and actions stemming from the Workshops co-organised with the members of the COST Action in preparation of the survey, are available on the COST website[71]. While developing the Survey on Citizen Science strategies and practices in Europe, it became clear that there is the need to investigate better how the policy and social impact of Citizen Science (and other forms of engagement in the management of public good) can be better assessed. This study confirmed the importance of such assessment for both, paving the way to an increased support to policy making, as well as advocating Citizen Science and its deployment in other policy areas. This is a curtail area to assess potential future governance models – in which Citizen Science, and citizen generated data at large, might play a key role.

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64 Landing page for the Missions in Horizon Europe, https://ec.europa.eu/info/horizon-europe/missions-horizon-europe_en

65 European Commission (2020). A new ERA for Research and Innovation, COM/2020/628 final, https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=COM:2020:628:FIN

66 See, for example, the current discussions on UNESCO Recommendations on Open Science, https://en.unesco.org/science-sustainable-future/open-science/recommendation and the consultation on the Recommendations on electronic information tools under the Aarhus Convention http://www.unece.org/environmental-policy/conventions/public-participation/aarhus-convention/tfwg/task-force-on-access-to-information/consultation-on-the-recommendations-on-electronic-information-tools.html

67 Official COST Office page about COST Action 15212, https://www.cost.eu/actions/CA15212/#tabs|Name:overview

68 Web page of the COST Action 15212 Working Group 5, https://cs-eu.net/wgs/wg5

69 Web page of the COST Action 15212 Working Group 3, https://cs-eu.net/wgs/wg3

70 Manzoni, M., Vohland K., Schade, S, Survey on Citizens Science Strategies and Initiatives: report on outcomes in Europe: Technical Report on Outcomes, European Commission, Ispra, 2020, JRC123471.

71 This includes a series of four workshop reports: https://cs-eu.net/news/workshop-report-wg-3-pan-european-comparison-development-and-implementation-cs-strategies, https://cs-eu.net/news/workshop-report-wg-3-citizen-science-strategies-europe, https://cs-eu.net/news/cs-strategies-europe-event-report-cesis-latvia-june-4th-2019 and https://cs-eu.net/news/workshop-report-wg3-recommendations-development-national-citizen-science-strategies

Figure 16 indicates those domains of applications, beyond those related to environment, where Citizen Science approaches are by nature deemed to reach the highest relevance and impact, namely, cultural heritage, agriculture, social science, astronomy and, finally, participation in local policymaking for the management of public good. The survey revealed also that new fields of applications are emerging in areas especially related to health and urban management, which is particularly important especially now in facing the unprecedented challenges brought about by the COVID-19 era (see also Section 7).

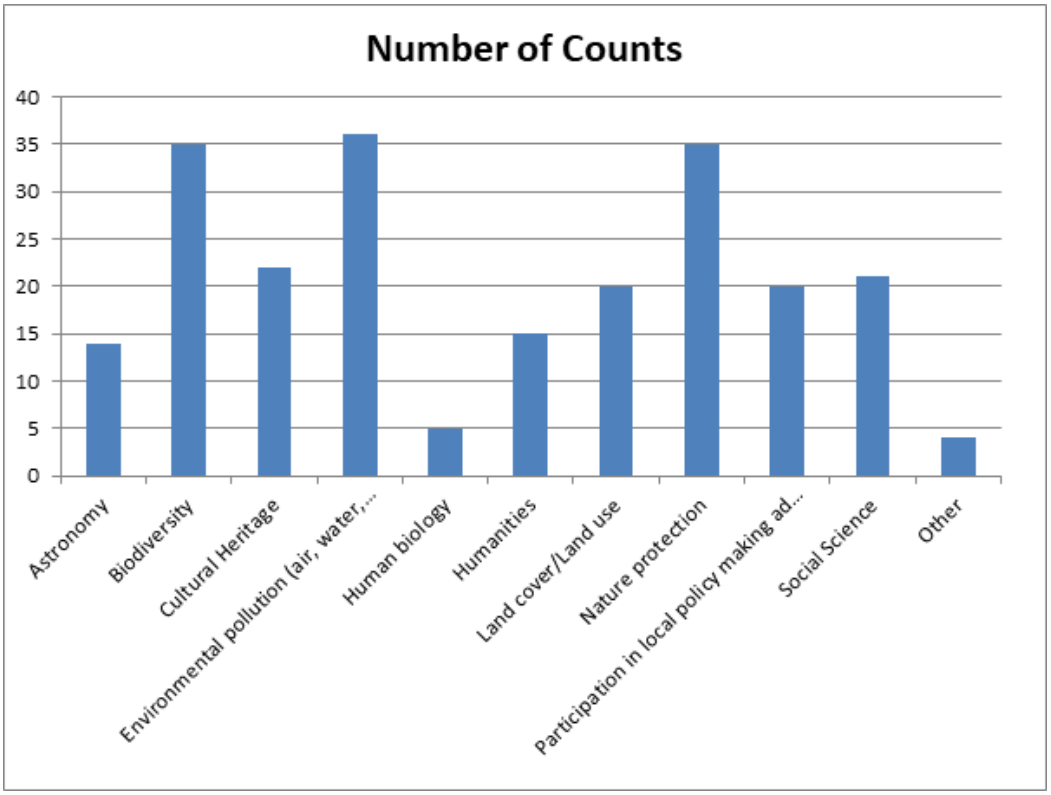

Figure 16. *Distribution of thematic areas addressed by Citizen Science as indicated in a survey across COST countries in 2019.*

The efforts for the preparation and the results from the pan-European survey provided evidence to a number of underlying principles and for paving the way of future direction in the context of Citizen Generated Data in support to Digital Transformation of Government and Public Sector Innovation applicable to several key areas in the management of public good, like energy, transport, health and urban management in general.

The analysis of this area also laid the ground for the development of several recommendations that provided important input for the Declaration on Citizen Science in Support to the SDGs that was presented at the German Presidency Event "Knowledge for Change: A decade of Citizen Science (2020-2030) in support of the SDGs" (see also Section 4.2). The conference presented, evaluated, and discussed the exciting contributions that Citizen Science makes in framing and achieving sustainable development, specifically the UN Sustainable Development Goals (SDGs) and brought together expertise from policy makers, institutional and citizen scientists, economists, NGOs.

The COST Action successfully completed its final grant period on 20 September 2020. We have contributed to several chapters in its final book the *Science of Citizen Science*[72] that is due for publication by the end of this year. One of the direct results from the discussions brought about by the book, is that the definition of Citizen Science is very much instrumental, it highly depends on different purposes and contexts of application, and on the different extents of citizen participation. In

[72] Vohland, K. et al. (Eds.) (in press). The Science of Citizen Science, Springer, https://www.springer.com/gp/book/9783030582777

this respect, beyond providing insights on the understanding of this area, the state of development at European level and the potential impact on policymaking processes, the book also offers a guidance to help practitioners identifying the best definition to address their objectives while, reflecting the corresponding level of participation by citizens in a given context. In doing this, the book intends to provide an overall picture of the current understanding of the area of Citizen Science, while preserving the inherent differences in its practice.

Some of the working groups of this COST Action intend to move to and continue their activities through the European Citizen Science Association (ECSA). This includes the data and metadata working group and parts of the policy working group. We will contribute to the transition of the activities towards ECSA with the tools and material developed under this action, keep helping the transition into the ECSA working groups and remain available for consultation. Citizen Science in support to policy remains an important topic, as one perspective to digital transformation in different areas other than environment, for example, urban management and Smart Cities, Transport, Energy, Agriculture, Health and Education. In this respect, the role of Citizen Science in digital governance can be best assessed and further developed with this connection to ECSA.

4.2 Citizen Science and the Sustainable Development Goals (SDGs)

Following an initial investigation about the relationship between Citizen Science activities and the SDG framework in 2018 (as part of the study on an inventory of Citizen Science activities for environmental policies, see also Sections 2.1 and 3.2), discussions intensified in 2019. A slightly wider setting of the general evolvement of the discussions at UN - primarily with the UN Environment Program, UNEP[73] emerged.

We contributed to messages delivered by the European Commission at the UN Science-Policy-Business Forum on the Environment[74] in 2019. This included a speech by DG Environment's Director for Sustainable Development, as well as a presentation of DG Research and Innovation on the European Perspective on Citizen Science. Contributions focused on the role of Citizen Science for the science-policy interface, for empowering citizens and for increasing science's credibility, in the context of SDGs, and passed the following key messages:

- We need to raise the importance of Citizen Science as a tool for (1) collecting environmental data, (2) empowering citizens in policy making, notably environmental, (3) increasing trust in science and public institutions.
- We need to explain better, how Citizen Science can contribute to SDGs, both for monitoring and for promoting societal transformation.

In addition, throughout the past years, the members of the Citizen Science team were involved in a series of discussions, especially with CODATA and the World Data System (SDG working group), GEO/GEOSS, the ECSA Maximisation Group on SDGs, and the WeObserve project in order to stay informed and start shaping our own position in this rapidly emerging landscape. As an immediate action, we identified the Global Partnership for Sustainable Development Data[75] as a relevant actor, especially as this is currently calling for meetings and guidelines on the use of Citizen Generated Data (CGD) for the SDGs. We will maintain this connection, also to ensure knowledge exchange related to our work on Citizen Science and environmental reporting (see also Section 3.1).

We also contributed to a major scientific article "Citizen Science and the United Nations Sustainable Development Goals"[76], which was published in Nature Sustainability and within one month already reached over 160.000 reads and almost 500 tweets (since its publication on 9 October 2019).

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73 Web page of UNEP, https://www.unep.org

74 Web page of the UN's Science-Policy-Business Forum, https://un-spbf.org

75 Web page of the Global Partnership for Sustainable Development Data, https://www.data4sdgs.org

76 Fritz S., et al. (2019). Citizen science and the United Nations Sustainable Development Goals. Nat Sustain 2, 922–930, https://doi.org/10.1038/s41893-019-0390-3

This work was complemented by dedicated investigations in the area of sustainable consumption, in which we supported the JRC Units Bio-economy (D.1), Land Resources (D.3) and Knowledge for Sustainable Development & Food Security (D.6) in the co-design of a possible mobile application or toolbox. As one highlight of this activity, we jointly organised a co-creation session at the Second Citizen Engagement Festival in December 2019. The participants were highly committed during the intense 90-minute work, and provided specific personas (representing potential target audiences, see Figure 17 for an example), sets of designs, details for the four favourite ideas, and a priority voting.

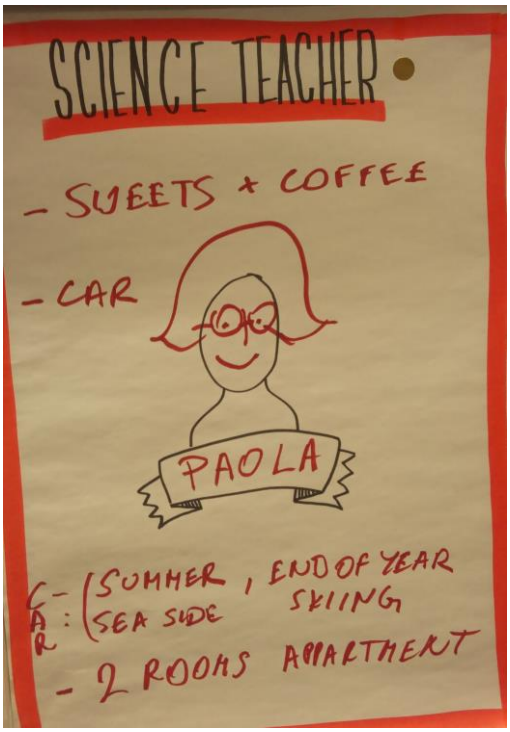

Figure 17. *Persona – science teacher, including breakfast habits, transport to work, preferred vacations and housing condition.*

Finally, the JRC played a major role in the drafting of the **Declaration[77] on Citizen Science in Support to the SDGs** that was presented at the German Presidency Event "Knowledge for Change: A decade of Citizen Science (2020-2030) in support of the SDGs"[78], and was involved in five interventions and as part of the official Programme. The Declaration, that was endorsed and finally signed by over 250 people, projects and organisations participating in the conference, is a living document standing as a reference point in setting directions for future actions to address the SDGs by all stakeholders animated by common intents.

In November 2020, we submitted a new COST Action proposal on the topic, under the lead of the International Institute for Applied Systems Analysis (IIASA), and with over one hundred supporters. Results are expected in May 2021.

4.3 Towards a theory for spreading and scaling Citizen Science

Complementing large questions (such as, the role of Citizen Science for governance, its contributions to human-centred and explainable AI, and relationships with data altruism) and building on leading examples (such as, participatory mapping, bird watching or water quality monitoring) there is an eminent need to develop a better and more structured understanding of the context dependency and growing potential of Citizen Science approaches. This is both, in terms of scaling and spreading. Here,

[77] Web page of the Declaration on Citizen Science and the SDGs, https://www.cs-sdg-conference.berlin/en/declaration.html

[78] Event page of the conference "Knowledge for Change: A decade of Citizen Science (2020-2030) in support of the SDGs", https://www.cs-sdg-conference.berlin/en

(up-)scaling can be considered as expanding a successful Citizen Science initiative in terms of both, the number of participants and the geographic extent. Spreading refers to portability and replication of existing solutions, without a change of the actual scale of the activity in itself.

Once we understand the context dependency and pathways for expansion of single initiatives, we will be able to thrive for a systemic integration of Citizen Science approaches into larger governance structures. This will not only allow us to support digital transitions, but also to offer opportunities for engagements in policy making and implementation. In this way, Citizen Science will become one important piece of the larger puzzle that will help us all to get fit for the new digital age and to contribute to a vibrant democracy.

Based on our previous research[79] we thus saw a need to more closely investigate impacts of (new) technologies and especially their potential role in the uptake of Citizen Science approaches at different geographic scales. Following the JRC's mandate as the European Commission's knowledge management and scientific services, we are particularly interested in the barriers and possibilities in the context of the EU.

We collaborated with Ideas for Change [80] to assess enablers and barriers for the up-scaling and the spreading of Citizen Science approaches. This work highlights possible roles – both, positive and negative – of technology, and includes illustrative examples. Possible implications related to the European Union (EU) context are considered where applicable. The final report[81] lays the grounds for a theory about the spreading and scaling of Citizen Science, based on an exploratory and solid research approach. Being challenged with a task to explore new horizons, the team at Ideas for Change dived deeply into existing scientific concepts, and identified and transferred ideas from related fields. They ultimately propose a novel framework that helps not only structuring the complex topic but can also serve as the basis for practical applications. A set of case studies is presented to illustrate and validate the proposal. The case studies also provide a starting point and possible inspirations for new activities that intend to engage large amounts of participants in Citizen Science. We hope this relevant work will open new pathways for research and for policy advice.

The study was presented at the conference *A decade of Citizen Science (2020-2030) in support of the SDGs,* organised under the German Council Presidency of this Semester, where it received a lot of attention.

4.4 Support to the upscaling of the Plastic Pirates project across the EU

A structured approach to proliferate and grow Citizen Science initiatives from one context to another remains a challenge. We started investigating options with Ideas for Change in 2019/2020 (see also Section 4.3) and now build on this expertise in order to support a more systemic evolution. Such an approach is, for example, requested by the Horizon 2020 Missions[82] (which are designed for citizen engagement and provide a strong framework for Citizen Science supporting their implementation) and the European Research Area (ERA, including the commitment of the European Commission to "*organise with Member States and stakeholders Europe-wide participatory Citizen Science campaigns to raise awareness and networking, crowdsourcing platforms and pan-European hackathons, in particular in the context of Horizon Europe Missions. The Commission will develop with Member States best practices to open up science and innovation to citizens and youth*")[83].

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79 The work presented in this report, but also Schade S., et al. (2017). Using new data sources for policymaking, EUR 28940 EN, Publications Office of the European Union, Luxembourg, ISBN 978-92-79-77078-4, doi:10.2760/739266, JRC109472, https://ec.europa.eu/jrc/en/publication/using-new-data-sources-policymaking

80 Web page of Ideas for Change, https://www.ideasforchange.com

81 Maccani G., et al. (2020). Scaling up Citizen Science, Publications Office of the European Union, Luxembourg, 2020, doi:10.2760/00926, JRC122219, https://ec.europa.eu/jrc/en/publication/scaling-citizen-science

82 Landing page for the Missions in Horizon Europe, https://ec.europa.eu/info/horizon-europe/missions-horizon-europe_en

83 European Commission (2020). A new ERA for Research and Innovation, COM/2020/628 final, https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=COM:2020:628:FIN

A lead pilot project (Plastic Pirates[84]) is greatly supported under the current Trio Presidency of the Council of Europe (by Germany, Portugal and Slovenia)[85]. There is an open invitation to all Member States to join, and we are discussing our joint support with DG RTD and DG Education, Youth, Sport and Culture (EAC). This work has been, for example, well acknowledged by the recent conclusions of the Council of the European Union (13567/20 of the 1st of December 2020). The Meeting conclusions include the following statements that the Council "*CALLS on the Commission and Member States to further develop and implement the "plastic pirates" Citizen Science campaign as the ERA pilot action to foster "interaction" within the ERA in order to raise awareness among citizens, in particular young citizens, on the impact and benefits of R&I in their daily lives. ENCOURAGES cooperation with the proposed Mission on Healthy Oceans, Seas, Coastal and Inland Waters*".

We became closely involved in interconnecting the required colleagues and communities with a joint vision to work on the up-scaling of Citizen Science initiatives in the coming years – learning from initial experiences with Plastic Pirates. We intend to build on the initial experiences to support the systemic use of Citizen Science in new forms of governance, especially using new technologies and managing the data collected. This is so far unprecedented work on the role of public institutions in the spreading and scaling of Citizen Science, including findings on the use of digital technology and managing data in appropriate ways. This work will also contribute to discussions on data spaces and digital governance across the EU.

84 Web page of the Plastic Pirates go Europe initiative, https://www.plastic-pirates.eu/en

85 Trio Programme of the Council of the European Union, https://www.eu2020.de/eu2020-en/news/article/trio-programme-germany-portugal-slovenia/2353560

5 Exploring the use of new technologies for Citizen Science

Over the past years, we carried out a series of activities considering the use of mobile phone applications and lower-cost sensor systems. Applications included nature protection, invasive alien species monitoring, air quality, and others (see also Sections 2.2 and 2.3). We used these works not only to explore the use of new technologies by the JRC and the European Commission as a whole, but also to build larger cross-European networks. Given the continuous evolution of technology, it is important to also investigate emerging solutions and explore approaches beyond what we introduced earlier in this report.

5.1 Applying automated image recognition to invasive species reports

In 2019 and 2020 we experimented with possibilities of AI in order to identify which images (e.g. delivered by mobile apps) contain species information (and not any inappropriate content), and under which conditions species can be automatically identified based on one or more images. This work provided us a first insight into the issues behind machine learning.

Among others, we applied the image recognition model of iNaturalist 2017[86] to the data that is submitted to us from the Invasive Alien Species in Europe app. A related paper was presented at the EnviroInfo Conference 2020[87]. It was entitled "Automated invasive alien species recognition: lessons learned from applying the iNaturalist 2017 computer vision model on citizen-science data" (see also Figure 18).

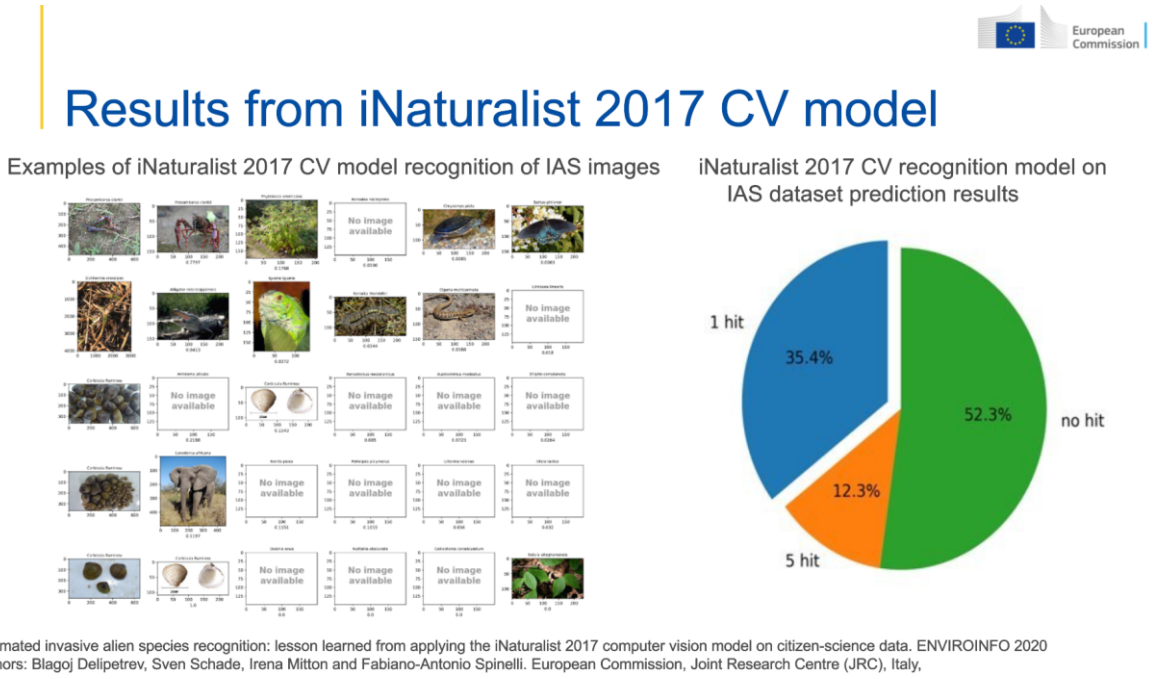

Figure 18. *Indication of the first results from applying the iNaturalist model on our data set. ("1 hit" means that a species is successfully recognised in an image; "5 hit" means that the correct species appears in the list of the five most probable species, but not on first place; "no hit" means that the correct species is not recognised at all).*

In 2021 we intend to modify an already available (REST-based) web service to receive and analyse species. This service currently encapsulates one image recognition model for testing purposes. This model is generic and needs improvement. We plan to include these improvements and to parametrize the service in a way that also other image recognition models can be selected. We will begin with the well-known model iNaturalist 2017, which was already tested internally.

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86 Dataset of the iNaturalist Challenge 2017, https://www.groundai.com/project/the-inaturalist-challenge-2017-dataset/1

87 Event page of EnviroInfo 2020, http://cyprusconferences.org/enviroinfo2020

In the coming year(s) we will test different models and data sets – first continuing in the area of species recognition and later carrying the work into other thematic areas. For the moment, we will seek for collaboration on thematic experts with the COST Action AlienCSI and JRC Water & Marine Resources Unit (D.2), as well as JRC Land Resources Unit (D.3). We also intend to combine chatbot and species recognition functionalities to explore more complex scenarios of hybrid intelligence.

The case will put us into the position to provide hand-on illustrations and lessons in the field of human-centred and explainable AI, as promoted in the European Commission's White Paper on Artificial Intelligence[88]. It will also allow us to gain insights about the relationship between AI and the data required to meaningfully apply it.

5.2 Exploiting the use of chatbots for interactions between humans and machines

In 2020 we began investigating viable options to use chatbots. We are investigating the basics but see a fantastic opportunity to extend this line of research, building on already elaborated application area to learn quick; and then deriving more general lessons and eventually re-applying what we learned to other fields.

To start working with chatbots, we decided to use Facebook as main platform, taking advantage of its diffused messaging system, (Facebook) Messenger. Trying to understand the potential offered by this type of technology, we decided to create a prototype connected to our Invasive Alien Species in Europe App (see also Section 2.2.1), with the purpose of reproducing some functionalities through the discursive interaction offered by chatbots.

First we did a series of analyses to understand which could be the best development tool, trying to find the best balance between features and costs. We have therefore restricted the choice to the two most used tools, "ManyChat"[89] and "ChatFuel"[90]. We decided for the latter precisely because, with zero cost, it already offered the possibility of creating chatbots that can be connected to external Web Services, which is especially useful in our case, because we could have reused the existing Web Services used by our app.

Following this choice, we decided to implement three key features provided by our app: consultation of the invasive alien species catalogue, possibility of sending species observations, providing the data directly to the chatbot, and viewing of observations created via a chatbot (see also Figure 19).

Wanting to go deeper into the subject, we also began to analyse the possibilities offered by alternative messaging systems, connected to the world of mobile telephony: our choice therefore fell on Telegram (see also Figure 20), one of the most popular instant messaging systems that offers advanced internal mechanisms for creating and managing chatbots. In this case, unlike Messenger for Facebook, we have not created a working complete prototype connected to our App, but we have only begun to create a Web Service that was used to interpret and respond to some messages received from the users. This system will certainly be deepened in the course of 2021, to try to understand its potential and usable functionalities.

In 2021 we will continue with our initial experiments and resolve central technical and administrative questions. We will also continue our brainstorming on opportunities and seek to involve more colleagues in the related discussions. We will also plan for a series of future experiments.

We foresee to continue and extend our chatbot experiments (using FB and integrations with mobile applications (EASIN)). We also intend to investigate the use of chatbots as an alternative to apps, especially in Citizen Science and engagement. We also seek to combine our works on chatbots and species recognition with a view to design and execute more complex experiments.

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88 European Commission (2020). White paper on Artificial Intelligence - A European approach to excellence and trust, COM(2020) 65 final, https://ec.europa.eu/info/sites/info/files/commission-white-paper-artificial-intelligence-feb2020_en.pdf

89 Web page of ManyChat, https://manychat.com

90 Web page of chatfuel, https://chatfuel.com

Also, this work will put us into the position to provide hand-on illustrations and lessons in the field of human-centred and explainable AI. It will also allow us to gain insights in relation to digital governance and the possible role(s) of machines.

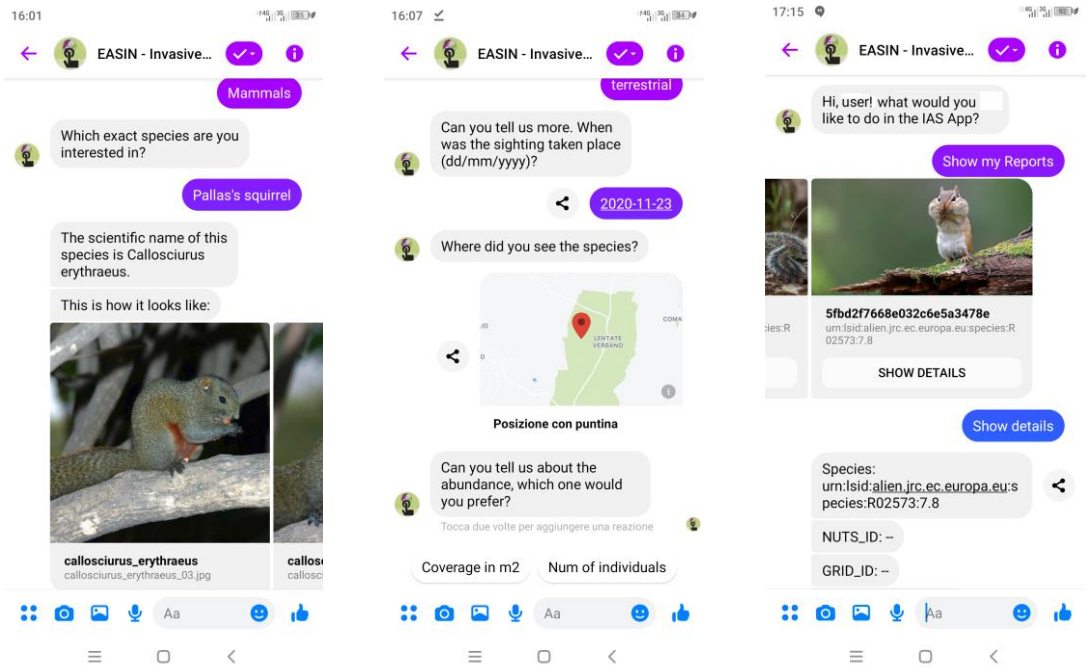

Figure 19. *First impressions of using a chatbot to replicate the functionalities of a mobile app.*

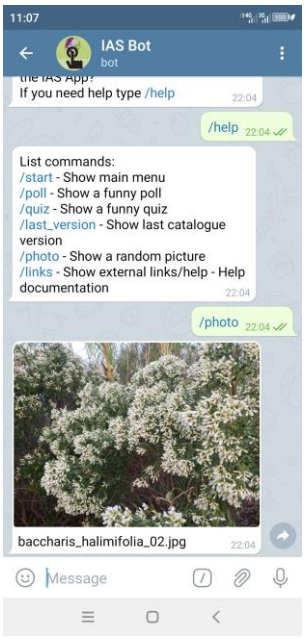

Figure 20. *Screenshot of using a chatbot on Telegram.*

6 Legitimizing the use of Citizen Generated Data

Figure 21. *'Civic sentinel in action', credit: Alice Toietta for SensJus.*

Citizen Sensing – as a particular branch of Citizen Science - is increasingly considered as a *source of evidence* in (environmental) litigation. This can be, for example, witnessed in the ground-breaking Formosa litigation decided in summer 2019 by a U.S. Court (*San Antonio Bay Estuarine Waterkeeper et al. vs. Formosa Plastics Corporation et al.* Case 6:17-cv-00047 Document 155 Filed on 06/27/19)[91]. Furthermore, Citizen Sensing has often been regarded as *a tool to mediate* the (environmental) conflict and restore broken or damaged trust relations (between citizens, the government and eventually the private actor)[92]. Related research is still in its infancy. The growing attention to the topic devoted by U.S.-based scholars[93] is not flanked by a parallel inquiry from the European perspective. Starting from these premises, the 'Sensing for Justice' project (in short 'SensJus') aims at filling a knowledge gap and provide newly required research capacity in the EU[94].

This year, SensJus was successfully kicked off (in June) and first scientific contributions could be achieved, a lively and well visited web page was set up[95] and a few blog posts launched, for example on the novel concept of a civic 'right to contribute to environmental information' when institutions

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91 Details on U.S. Court - San Antonio Bay Estuarine Waterkeeper et al. vs. Formosa Plastics Corporation et al. Case 6:17-cv-00047 Document 155 Filed on 06/27/19, https://static.texastribune.org/media/files/193f5484368b30dcdd2e6dd1b30a1eec/Formosa.pdf?_ga=2.193550381. 1213474106.1561991418-765179048.1533865077

92 Berti Suman and Van Geenhuizen (2019). https://www.tandfonline.com/doi/full/10.1080/09640568.2019.1598852

93 Among others Wyeth, G et al. (2019). The Impact of Citizen Environmental Science in the United States. *The Environmental Law Reporter* 3, 49: 10237-10263

94 Announcement of the Marie Curie Individual Fellowship awarded to Anna Berti Suman, researcher on 'Citizen Sensing', https://www.tilburguniversity.edu/magazine/marie-curie-individual-fellowship-awarded-anna-berti-suman

95 Web page of the SensJus project, https://sensingforjustice.webnode.it

struggle to fulfil their relative duties[96]. Related articles are in press[97] and under review[98]. A full-fledged vignette-based story of complex legal notions in simple and accessible terms is in the pipeline (along the lines of Figure 21).

The network of the project rapidly expanded, with supporters and advisors from the U.S. to Japan to Africa and a considerable media attention[99]. We contributed to international consultations and to other projects' work with our insights, such as to the United Nations Economic Commission for Europe consultation on "Recommendations on electronic information tools", which is part of the Aarhus Convention process[100], and to the U.S.-based Open Environmental Data Project[101]. A triggering fieldwork in Basilicata was conducted in October 2020 and novel insights on citizens gathering data in very conflictive scenarios were gathered[102]. Still in this year, more knowledge on case studies is being collected, for example through a structured cooperation with the very collaborative Observatory of the Brenta-Bacchiglione River Basin[103]. We recently also published a scientific article about legitimization strategies for contested uses of citizen-generated data for policy[104].

Also, in future, our work will be carried out at the interface of *data use and governance* – with a focus on peoples' rights and claims and also drawing on collaborations with JRC colleagues from other teams on the topic[105]. We will also zoom in on the overarching issue of civic trust in competent public authorities and in legal enforcement, both in the context of environmental challenges but also in that of the present pandemic times[106]. This work lays at the intersection between the use of data and technology, as well as governance, trust and ethics. SensJus is set up as a three-year post-doctoral research project, first funded under the NWO Rubicon Individual Grant (Dutch Research Council) then under a Marie Curie fellowship (Horizon2020 scheme).

This year, we could gather numerous inspiring lessons from the SensJus project. We expect that 2021 will be another year rich of discoveries in this rather new field of research!

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96 News item "Citizen Sensing: towards a right to contribute to environmental information", https://cs-eu.net/news/citizen-sensing-towards-right-contribute-environmental-information

97 Such as, a contribution to the Journal of Human Rights and the Environment, special issue on "New Protest Movements Shaping our Future", https://www.elgaronline.com/view/edcoll/9781800881082/9781800881082.xml

98 Such as, an analysis of the Formosa case that has been submitted to the Journal of Citizen Science Theory and Practice, https://theoryandpractice.citizenscienceassociation.org

99 For examples, see the SensJus project description of the European Citizen Science Platform, https://eu-citizen.science/project/165 and a podcast about the project, https://findoutwhy.info/blog/f/the-impact-of-citizen-science-on-environmental-change

100 Blog post about the contribution to the Aarhus convention, https://eu-citizen.science/blog/2020/10/06/supporting-environmental-democracy-and-aarhus-convention

101 Web page of the Open Environmental Data Project, https://www.openenvironmentaldata.org

102 Blog post about the field work in Basilicata https://sensingforjustice.webnode.it/l/on-the-footprints-of-the-civic-sentinels

103 Details about the Eastern Alps Hydrographic District (AAWA)from the page of the WeObserve project, https://www.weobserve.eu/autorita-di-bacino-dei-fiumi-isonzo-tagliamento-livenza-piave-brenta-bacchiglione-aawa

104 Berti Suman A. , Schade S. and Abe Y. (2020). Exploring legitimization strategies for contested uses of citizen-generated data for policy. Journal of Human Rights and the Environment, Vol. 11 Special Issue, December 2020, pp. 74–102, https://www.elgaronline.com/view/edcoll/9781800881082/9781800881082.00008.xml

105 Micheli M., Ponti M., Craglia M. and Berti Suman A. (2020). Emerging models of data governance in the age of datafication. Big Data & Society, doi:10.1177/2053951720948087, https://journals.sagepub.com/doi/full/10.1177/2053951720948087

106 Blog post "Sensing Covid-19 and Climate Change", https://blog.uvt.nl/environmentallaw/?p=430

7 Reactions to COVID-19 crisis

COVID-19 emerged as a pandemic and led to a multi-faceted global crisis, which included impacts on the understanding and perception of science, as well as trust in governmental institutions. It can be argued that Citizen Science thereby increased in importance as far as scientific literacy and education is concerned. In addition, COVID-19 also affected the way Citizen Science is carried out. Together with members of the peer community, we elaborated on some of these effects in an early blog post[107].

In addition to this direct connection to Citizen Science, the COVID-19 crisis triggered the collection and integration of data, not only about infections and their distribution, but also about human behaviour. At the same time, we witnessed the diverse and quickly emerging use of old and new digital tools[108]. The work presented here focuses on a subset of such tools: mobile applications (apps).

With the goal to improve our understanding about the emergence of COVID-19 related mobile applications, we follow, since April 2020, a multiple sources approach to monitor and analyse their evolution. Therefore, we decided to consider three prominent sources of information.

First, we started exploring the publication of apps in prominent app stores. This is to understand which apps are developed and made available to a large public. This was implemented following a hybrid approach, which combines the automatic scraping of Google Play and Apple App Store, the integration and harmonisation of the scraped information using Extract-Transform-Load (ETL) procedures, and the enrichment of the information from manual analysis. Manual analysis is performed by a team of six researchers, based on the app descriptions scraped from the stores.

Second, we are also interested to explore how people react to these developments and if some apps spark more discussions than others. Being fully aware of biases in social media data, we decided to focus related investigations on Twitter as one of the most used social media platforms of our times. We started harvesting tweets with keywords relevant to COVID-19 and mobile apps on 15 March 2020 and kept collecting them ever since. Notably, this is done using the publicly available Twitter API, i.e., we do not retrieve all tweets with the targeted keywords, but only a subset.

Third and last, to cover the media attention and thereby an important means of dissemination and opinion forming, we also investigated the mentioning of COVID-19-related apps in prominent news media. To this end, we prepared, in close collaboration with the JRC European Media Monitoring (EMM)[109] team, a dedicated category based on the same keywords that we use for Twitter that we are following.

In order to provide first results about the data gathered, we created a series of graphics that are collectively depicted in Figure 22. More details can be found in the technical report we have prepared together with several other colleagues[110].

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107 Blog post on Citizen Science in the times of COVID-10, https://www.citizenscience.org/covid-19

108 For an elaboration of COVID-19 digital transformation in Europe see https://ec.europa.eu/jrc/en/publication/eur-scientific-and-technical-research-reports/artificial-intelligence-and-digital-transformation-early-lessons-covid-19-crisis

109 Web page of the European Media Monitor (EMM), https://emm.newsbrief.eu/overview.html

110 Tsinaraki C., Mitton I., Dalla Benetta A., Micheli M., Kotsev A., Minghini M., Hernandez L., Spinelli F. and Schade S., *Analysing mobile apps that emerged to fight the COVID-19 crisis*, European Commission, Ispra, 2020, JRC123209, https://ec.europa.eu/jrc/communities/en/community/citizensdata/document/analysing-mobile-apps-emerged-fight-covid-19-crisis

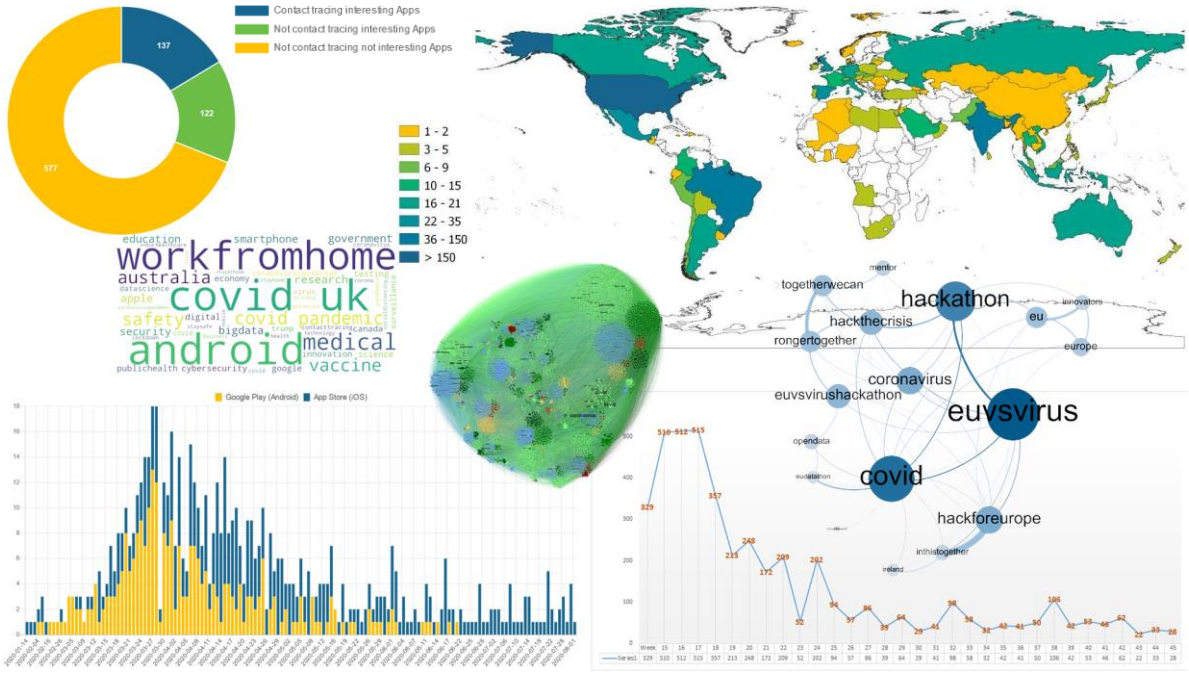

Figure 22. *"Collage" of graphs depicting the first results from our multiple sources approach.*

This work on COVID-19-related apps improves our understanding on this dynamic landscape and can provide us with a particular angle on how technology is used for governance in a crisis situation, which is implying even more the need to address legal and ethical considerations.

Our future activities include: (a) Documenting and publishing the scientific insights and lessons learned from this work increasingly directing from basic work to emerging deeper research questions; (b) Eventually look at the evolution of app functionality, i.e. from information provision to crisis management and recovery and identify where this work proves most useful; and (c) Reflecting on the multiple sources approach and its use for other topics than the Coronavirus.

8 Dissemination and exploitation

Given that our dedicated Citizen Science work was planned until 2020, we invested considerable efforts in the dissemination and exploitation of our work, especially this year. In terms of exploitation the feed into our future work program and integration with digital governance and data ecosystems was most important.

8.1 Highlights from selected events

The Citizen Science team was highly active throughout the year to present our results, discuss important findings, and define future work areas. The members of the team and our partners continued to connect more widely with different communities. In the context of environmental reporting those included, for example, the network of *Environmental Protection Agencies* and its Interest Group on Citizen Science, municipalities, Citizen Science NGOs, etc. In relation to data and metadata we contributed to numerous activities of the communities and organisations mentioned in Section 3.1. More generally, we also co-organised and participated in events related to the SDGs, and the further diffusion of Citizen Science in policy and in practice.

Among other, we contributed to the following events:

- RTD, the JRC, ENV and the EEA participated and hosted multiple sessions at the *Knowledge for Change: A decade of Citizen Science (2020-2030) in support of the SDGs* conference, on 4 November 2020 in Berlin (participation was online). Here, the JRC was also deeply involved in the preparation of the conference declaration.
- The JRC, ENV and the EEA participated and hosted multiple sessions at the *European Citizen Science Conference - ECSA 2020*, on 6-11 September 2020 in Trieste (participation was online).
- The JRC participated in *the Final Symposium and Management Committee Meeting 2020 of the COST-Action Citizen Science to promote creativity, scientific literacy, and innovation throughout Europe*, on 3 September 2020 in Antwerp (participation was online).
- The JRC participated in the panel "Citizen Science for the UN Sustainable Development Goals" during the *EuroScience Open Forum - ESOF2020*, on 2-4 November 2020 in Trieste (participation was online).
- As part of the COST Action 15212, the JRC co-organised *two workshops to discuss Citizen Science strategies and networks in Europe*, last one on 4 November 2019 in Vienna.
- JRC together with RTD, ENV and the EEA participated in the *Citizens Observatories joint (final) event*, on 9 October 2019 in Brussels.
- JRC contributed to the training school *"Citizen Science – Innovation in Open Science, Society and Policy"* on 21-28 August in Leipzig.
- EEA, ENV and the JRC discussed with the *Citizen Science Interest Group of the Network of European Environment Agencies*, on 23&24 May 2019 in Zurich.
- The JRC discussed with the German Museum for Natural History and the German Ministry for Education and Research on *legal frameworks for Citizen Science* (in Germany), on 21 May 2019 in Berlin.
- The JRC co-organised a *training school on the complementarity of human and machine intelligence*, on 11&12 April 2019 in Seville.
- DG ENV, JRC, RTD, EASME and REA participated and presented at *the Doing It Together Science (DITOS) final event*, on 3 April 2019 in Brussels.
- With the scientific support of the JRC, DG ENV and RTD participated in the *UN Science-Policy_Business Forum on the Environment*, 8-10 March 2019 in Nairobi.
- JRC co-organised a training school on *Digital Transformations in Citizen Science and Social Innovation*, 21-25 January in Fiesole.

In addition to the above events, members of the Citizen Science KIP attended a range of video conferences on topics such as: Data quality in Citizen Science, Citizen Science and the SDGs, Standards for Citizen Science, The role of Citizen Science in GEO, etc.

8.2 JRC and EC partnerships

In designing, developing and testing the different scientific systems and data bases outlined above, we rely on a series of collaborations within the JRC and the European Commission as a whole. At the same time, these experiences contribute to the scientific, technical and policy work of others. Most recently, this included primarily:

- The *thematic work* based on collaborations with the specific units already mentioned above.
- Contributions to the EKC, under our lead of the *Citizen Science KIP* already mentioned above.
- In 2020, we also started a collaboration with our DG Environment colleagues that are dealing with the *Aarhus Convention inside the EU*. This was particularly to coordinate our inputs to the revision of the recommendations on environmental information tools.
- Discussions with *DG RTD's Science with and for Society (SwafS) program*, for example, on impact assessments of Citizen Science activities, a 2020 Eurobarometer on Perceptions of Science, Research and Innovation, the Berlin conference on Citizen Science and the SDGs, coordinating feedback on the UNESCO recommendations on Open Science[111].
- Feedback to RTD on the *Horizon Europe Missions*, in respect to Citizen Science for implementing the missions.
- Close collaboration with DG RTD and EAC as regards the upscaling of *Plastic Pirates* already mentioned above.
- Especially our experiences in mobile app development resulted in the co-organisation of the workshop *Apps@JRC* with the JRC Advanced Computing & ICT Support Unit (I.5). This workshop took place on the 13th of June 2019 and gathered colleagues from every directorate of the JRC. We saw 19 different apps presented, but also got an overview of the many administrative and legal issues behind such developments. Discussions of the business and the technical level concluded that day. Details are provided as part of the European Commission internal MobileApps@JRC CONNECTED space, which we used to prepare and follow-up on the event.
- Contributions to the JRC Communities of Practice, including the ones on *Citizen Engagement, Cities, and SDGs*.

8.3 Collaborations beyond the European Commission

Over the past five years, as already indicated in the text above, we built most intense collaborations with several communities, initiatives, and projects. Most recently, those included (among other) the European Citizen Science Association ECSA[112] (Technology and Air Quality Working Groups), US-based Citizen Science Association (International Working Group on Citizen Science Data and Metadata), Australian Citizen Science Association, German Citizen Science Association, Austrian Citizen Science Association, OGC Domain Working Group on Citizen Science, GEO Community Activity on Earth Observation and Citizen Science, COST Action 15212, COST Action 17122, networks of national environment agencies, and many more - including many renown experts active in this area from all over the world.

These collaborations also include relevant H2020 projects (Doing It Together Science (DITOS)[113], WeObserve[114], COs4Cloud[115], EU-Citizen.Science[116] and others) to jointly contribute to the development of a European Citizen Science Platform.

Our work focusses now primarily on the provision of the material that we developed and feedback provision to EU-Citizen. Science, as well as an advisory role for ECSA.

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111 UNESCO web page on Recommendations on Open Science, https://en.unesco.org/science-sustainable-future/open-science/recommendation

112 Web page of the European Citizen Science Association (ECSA), https://ecsa.citizen-science.net

113 Web page of the Horizon 2020 project DITOS, http://www.togetherscience.eu

114 Web page of the Horizon 2020 project WeObserve, https://www.weobserve.eu

115 Web page of the Horizon 2020 project COs4Cloud, https://cos4cloud-eosc.eu

116 Web page of the Horizon 2020 project EU-Citizen.Science, https://eu-citizen.science

9 Conclusions

The activities described in this report illustrate a rich and fruitful journey that explored the use of Citizen Science in policy, and policy in support of Citizen Science – over the course of the past five years. We did cover multiple work areas including the environmental facet of Citizen Science, interoperability at various levels, diffusion of successful examples, opportunities offered by novel technologies, and some of the legal dimensions of Citizen Science and citizen sensing. Some of the implications of the COVID-19 crisis have been explored, and our knowledge about mobile apps helped us investigating the emerging landscape also in this respect. Carrying out these activities led to a rich set of fruitful collaborations – within and beyond the environmental domain - and put us in a position to shape our future steps.

In the closing section of this report, we summarize some of the main lessons that we learned along the way, but we also take the opportunity to reflect on the evolution of Citizen Science – especially within the EU. For our own work, we outline a pathway from focussing on Citizen Science until now to a broader approach in which Citizen Science is put into perspective to today's priorities of the European Commission – here especially a Europe fit for the digital age[117], a new push for European democracy[118] and the European Green Deal[119].

9.1 Lessons learned

In addition to the many results sketched above, and the numerous references provided for more detail, we consider the following general messages important to highlight:

1. Things are never as you imagine from your desk. It is thus not enough to investigate the landscape and case studies from a distance. Hand-on experiments and fieldwork (as, for example, presented in Sections 2.2, 2.3 and 6) are important to gain detailed knowledge and validate general findings in real situations. Only in such a way we can gain the best scientific and technical knowledge that is required to support European policy making.
2. Citizen Science involves above all people; therefore, it also implies subjective appreciations, it needs qualitative indicators and motivation. As such our research must go beyond the original settings (scientific communities), involve multiple stakeholders, and be based on multidisciplinary approaches. This applies to dedicated applications, but also more general when building new partnerships (see Section 8)
3. We should always acknowledge that participation is an offer (potentially even a legitimate right). It should not be the goal to have everybody become a citizen scientist, but to offer everybody the same opportunities to participate in science and in evidence-based policy making. This is particularly important to consider in relation to spreading and scaling of Citizen Science (see also Section 4) - in the sense that every (European) citizen should be offered equal opportunities to participate.
4. Constructive participation, acknowledgement of impact, trust and legitimation stand at the basis of its wider deployment. Without these Citizen Science will always be misunderstood, confined to a limited environment (mere academic discussion), a smaller role in society and gentle impact on policy. Among other, this became clear in the context of our research on environmental Citizen Science (Section 2).
5. Showing passion and understanding of viewpoints and respect of different perspectives is a win-win approach when working with practitioners. At the same time, initiatives must show

[117] European Commission priority 'A Europe fit for the digital age', https://ec.europa.eu/info/strategy/priorities-2019-2024/europe-fit-digital-age_en

[118] European Commission priority 'A new push for European democracy', https://ec.europa.eu/info/strategy/priorities-2019-2024/new-push-european-democracy_en

[119] European Commission priority 'A European Green Deal', https://ec.europa.eu/info/strategy/priorities-2019-2024/european-green-deal_en

practical applications and concrete results for all the participants involved. Especially the work on legitimisation and rights (Section 6) underlined this finding.

6. People who engage with Citizen Science practices wish to trigger a response from decision-makers or politicians. The gathering of data per se is of minor relevance compared to the desire to see an action from the competent authorities caused by their participation. When the response is not there then this augments the risk to decreasing (instead of increasing) trust. Again, this was particularly visible when dealing with environmental issues (Section 2) and legitimisation (Section 6).
7. The easier the data gathering methodology, the more likely is the policy uptake. Citizen Science evidence may be more likely to be accepted by authorities and in courts as evidence if they derive from simple data collection procedures, such as using own senses (e.g. smell) or just collecting physical samples (e.g. plastic in water). The more complex technologies (e.g. sensor systems) get, the more difficult it becomes that the results are used for policy. However, authorities and academia can help choosing technologies and measurement methodologies, as we, for example, found in our work related to air quality but also more widely by the inventory presented in Section 3.2.
8. In this area technology needs to be particularly people friendly, allow for easy feedback, and respect privacy. As technologies evolve and more possibilities arise, it is of vital importance to evaluate which technology is most appropriate for a given Citizen Science initiative. It does not always have to be the most innovative solution. Although the work on standardisation (Section 3) was often situated in technologically focussed communities, we could witeness a positive change of perspective from talking about 'users' to carrying about participants in Citizen Science activities.
9. Citizen Science, being highly people-centric and process oriented, provides unique opportunities to explore and challenge of digital governance. On the one hand, as indicated in Section 5, the interplay between human and machine intelligence (sometimes called collective intelligence) offers great potential to contribute to human-centred and explainable AI. On the other hand, activities such as those on interoperability presented in this Section 3 also address issues of data donation, data sovereignty, and the people-dimension of data ecosystems - including facets of citizen generated data and ownership.
10. Citizen Science is strongly mediated by culture and socio-economic factors. Hence, especially when looking into repeatability and replication (see also Section 4) contextualisation is always necessary. This included Citizen Science definitions, aims, tools, methodologies, etc. Therefore, in our work we can only provide guidance and support and be a point of reference, but cannot be prescriptive, as we are just a part of a bigger, more complex, and dynamic picture. It has also to be acknowledged that practices differ depending on the topic under consideration – and are at various stages of development.
11. Citizen Science theory and practice evolved strongly over the past half-decade. As indicated across the entire report but especially in Section 8, communities were newly built and became well organised - at the national, European, and global scale. Whereas this does not include all practices and especially bottom-up initiatives might never be fully connected, this evolution has also led to considerable changes and recognition in policy (e.g. in the context of the SDGs).
12. It is the time to take the next steps, and to systemically improve the embedding of Citizen Science into the larger context of citizen engagement and new forms of governance. Horizon Europe and ERA already set the scene for this further evolution. Particular attention should be put to the possibilities and limitations of replication of successful solutions, and the interoperability (in its widest sense) of methods and tools.

When it comes to our own work practices, whereas participating in events facilitates our visibility and the mainstreaming of our activities, we can confirm that the organisational set-up of the EKC was ideal to initiate and expand on collaborative work with multiple DGs and agencies. In on our practical experiences, we could benefit not only from the close interactions at desk officer level between all

the EKC members, but also of the overarching structures comprising frequent mid-management meetings, bi-annual meetings on the level of Directors, and the annual DG-level meetings. This governance structure covering all administrative levels of the organisation - but remaining reasonable light weight - allows to raise discussions to the most appropriate level, provide recognition, and take constructive decisions for the way ahead.

Now, that the best practices on *Citizen Science and environmental monitoring* were published as a Commission Staff Working Document (SWD) we successfully concluded Action 8 of the "Actions to Streamline Environmental Reporting", put also forward a set of recommendations and implementing actions for the years to come. The entailed recommendations will also shape most of our own work in 2020 and our future planning. This particularly includes the shaping of contributions to the priorities of the New Commission, such as the Green Deal and the Biodiversity Strategy, as well as close investigations of the wider relationships between Citizen Science and sustainable development, as well as Citizen Science in support to sectorial policies beyond the environment. The implications of digital transformation and emerging data ecosystems will require further attention. Our 2019 and 2020 activities will be evaluated in this new context to prioritise future work items.

9.2 Final remarks

Over the past five years, we succeeded to build on and extend our previous experiences, thereby progressing way beyond the state of the art, for example, by experimenting with and promoting the use of mobile applications for Citizen Science in support of European policies; or the use of existing standards. At the same time, we moved major parts of our scientific systems and data bases to a stable infrastructure – benefitting from systems that exist on the EC corporate level (such as the ScienceHub[120], the JRC's GitHub space[121], the JRC Data catalogue[122] and others). This streamlining of resources enabled us to transfer most of the operational parts of our infrastructure into established environments. The infrastructure for continuing experiments was successfully transferred to a new set-up, including all required administrative approvals. We continued these transitions in 2020, so that we can entirely reply on the corporate information and technology services and embed our scientific systems seamlessly in the unified web presence of the European Commission.

We also got first experiences in the application of AI and chatbots in Citizen Science. AI and other technologies can be used in multiple combinations with Citizen Science to combine the best aspects of human and machine learning – while identifying and respecting possible ethical concerns.

Our initial findings provide a fruitful ground for more in-depth research in the coming years. Here, especially the role of technology for the up-scaling and the spreading of Citizen Science approaches - and their contributions to governance - require more attention. Up-scaling refers to the extension of an existing approach form a smaller geographic area to a larger one (e.g. from a city to a region). Spreading describes a process in which an approach that was successfully applied in one location is carried over to another location - at the same geographic extent (e.g. from one city to another). Related scientific and technical work has the potential not only to inform research or environmental policy, but also to highly relevant aspects of AI, digital transformation, data spaces (data ecosystems) and better regulation.

A more articulated positioning of our Citizen Science related work in respect to the priorities of the European Commission, and the direction of the Digital Economy Unit are topic to another document that is currently in preparation. This especially addresses the priorities on a Europe fit for the digital age, a new push for European democracy and the European Green Deal.

Updates about our work, and complementary material are also available from our official web presence[123]

[120] Web page of the JRC, https://ec.europa.eu/jrc
[121] Git hub presence of the JRC, https://github.com/ec-jrc
[122] JRC Data Catalogue, https://data.jrc.ec.europa.eu
[123] Community page on the JRC Science Hub, https://ec.europa.eu/jrc/ communities/en/community/citizensdata

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