Channels of collaboration for Citizen Science and the Sustainable Development Goals

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Abstract

Citizen Science, known as the participation of individuals and groups in scientific processes, is an increasingly growing discipline, which can contribute for the achievement of the Sustainable Development Goals. The UN Agenda 2030 for Sustainable Development is all-inclusive, where every contribution is valid. Participation, partnerships, education, sustainable living and global citizenship, all of which can build on Citizen Science activities, are crucial for the Sustainable Development Goals. In this context, this study aims at exploring several collaboration channels for Citizen Science-related activities and the Agenda 2030. Challenges and critical aspects are discussed based on the opinions of practitioners collected through a comprehensive online survey. Furthermore, recommendations for future involvement are given on a framework of interactions at different levels for Citizen Science and the Agenda 2030.

1. Introducing Citizen Science

Citizen Science (CS) works alongside science, education, and civic engagement and is increasingly being a discipline in its own right (Science Europe, 2018). There are several definitions, but CS is often considered as the participation of lay people, individuals, or groups in scientific processes (Kullenberg and Kasperowski, 2016). These contributions differ from

informal learning due to engagement in science-related processes (Jordan 2002), such as modelling, new discoveries, observations, data collections and analyses, technological processes, and evidence-based policies (Raddick et al., 2009).

Citizen Science has existed for a long time, but it has especially expanded in recent years due to more collaborations between volunteers and researchers, emerging technologies and new ways of data collection such as crowdsourcing, digital sharing, online projects and social networks (Socientize, 2013). Common synonyms for CS are "amateur science," "crowd sourced science," "volunteer monitoring," and "public participation in scientific research" (https://scistarter.org/citizen-science). A citizen scientist, without necessarily a scientific background, volunteers to collect or process data for scientific research (Silvertown 2009). CS has changed the professional-amateur relationship because of an increased accessibility to the internet and tolerance of the web (Dowthwaite and Sprinks, 2019). The field of CS is growing towards scientific literature and policy making, but there is a need to foster trust in CS results, so to increase their use and consequently strengthen the field (Rasmussen, 2019). Barriers to the implementation of CS projects, either practical (lack of funding or training) or theoretical (whether the projects live up to the standards of scientific practice) are context dependent without necessary reducing results quality (Elliott and Rosenberg, 2019). CS is more successful in some fields than in others. For instance, in soil science or ecosystem ecology, although it facilitates conservation, technical expertise and samples quality are perceived as obstacles (Reed et al. 2018). Capacity building processes for CS can be important for future policies, but necessitate the involvement of wide range of people and institutions (Richter et al., 2018). Citizen Science is implemented mainly in industrialized countries such as the US, European nations and Australia (Guerrini 2019), and it is increasingly witnessed in China as well as in the Global South. CS is less visible in developing countries (Pocock 2018), challenged by accountability, data accuracy, lack of trust, and specific cultural issues among others. Despite

that, CS has potential for developing countries, as it facilitates long-term datasets and monitoring (Gouraguine et al., 2019).

2. Citizen Science and the Sustainable Development Goals

Several features of the UN Agenda 2030 for Sustainable Development can build on Citizen Science, such as encouraging participation, partnerships and collaborations, education, sustainable living and global citizenship. CS related activities can address sustainability challenges and contribute to the implementation of Sustainable Development Goals (SDGs). Citizen Science encourages social cohesion, a crucial element for the moral dimension of the Agenda 2030, which aspires to benefit all people and leave no one behind through global citizenship and shared responsibility (UN 2015). The Agenda 2030 document assigns the principal obligation to the member states, depending on their capacity and political will. The role of non-state actors and individuals during the SDGs implementation process is ambiguous, affected by national actions (Bexell and Jönsson, 2017).

Sustainable development does not require a top-down approach, but rather a networked, problem-solving attitude, where all actors, and especially young people, are engaged (Sachs, 2012). It is widely accepted that the implementation of the SDGs requires a full integration across sectors, disciplines, countries, and actors. Explicitly in Goal 17, “Partnerships for the Goals,” the role of non-state actors in multi-stakeholder partnerships is emphasized as a way to engage with and enhance cooperation (UN, 2015). Furthermore, in order to use the SDGs as a “common language,” it is necessary to scale them down to all levels of society such as individuals, communities, organization, networks etc. For sustainable development, public participation is crucial (Leal Filho, 2019). As a consequence, CS actions performed by individuals, teams, or networks of volunteers with a significant contribution to the societal

changes cannot be neglected. Citizen Science can contribute to attaining the SDGs by pressuring governments and businesses to take action, through defining national priorities, monitoring, and implementing processes (West and Pateman, 2017). The role of CS for the SDGs is acknowledged by the United Nations institutions through the "Citizen Science Global Partnership" (CSGP), launched in December, 2017. This network seeks to promote CS for a sustainable world and to support existing CS associations such as the European Citizen Science Association (ECSA), the US Citizen Science Association (CSA), the Australian Citizen Science Association (ACSA) and other emerging networks. Its purpose is to coordinate NGOs, governments and businesses that work with the global CS community and to track the contributions of CS towards the SDGs implementation (http://citizenscienceglobal.org). Furthermore, a task group "Citizen Science for the SDGs - Aligning Citizen Science outcomes to the UN Sustainable Development Goals" was established in order to facilitate and encourage the inclusion of data generated by Citizen Science projects in the official framework to monitor the SDGs (http://www.codata.org/task-groups/citizen-science-for-the-sustainable-development-goals).

Citizen Science actions or processes can drive society transformations (Chari, 2017). To achieve a sustainable transition of societies, it is mandatory to prioritize the citizens' concerns and to appreciate their knowledge (Wildschut, 2017). Citizen Science can advance a better understanding of science as a whole (NACSEM, 2018). The movement is driving the necessity for transparent processes and access to science (Irwin, 2018). The benefits of researchers are related mainly to research quality, dissemination and science appreciation in the future (Knack et al. 2017). Citizen Science actions reduce mistrust through collaborations and orient science to react according to the necessities of the society (Smith et al. 2017).

Citizen Science can also advance a better understanding of the Agenda 2030. The engagement of scientists in the SDGs' by fostering evidence based policymaking by the UN Institutions

98 would result in a stronger process of policy design and implementation (Elliott et al., 2019).
99 Furthermore, the SDGs are an opportunity to revive the sustainability research agenda, due to
100 the importance of sustainable development principles for policies and quality of life (Leal Filho
101 et al, 2018). In order to contribute to sustainable development, individuals must understand the
102 ambiguous and complex issues of sustainability and become "sustainability citizens"
103 (UNESCO, 2018). Some elements that influence CS as it is related to sustainability are
104 innovation, citizenship, ethics, education and knowledge. The Agenda 2030 debate on the goals
105 can be informal for a wider non-specialist public, thus raising the world population's awareness
106 about the urgency for sustainability challenges (Josephsen, 2017).

107 This study considers theories of governance and partnerships for sustainable development.
108 Governance facilitates the political dimensions of CS, showing its impact outside the
109 government and policy aspects *(Gobel at al. 2019).* For progress towards sustainability,
110 governance structures should enable coordination in uncertain and complex environments with
111 multiple actors at all levels (Kemp et al., 2005). Complementary, to empower citizens to inform
112 decision making a combination of social and technological innovation is needed (Groom et al
113 2019). Governance of a CS project is also important to explain how much it contributes to the
114 SDGs. Unlike social enterprises, CS projects are based on operational rather than business
115 models (Bio Innovation Service, 2018). Citizen Science processes can take place on a global
116 level, as virtual, huge interactions, or on a local level as more continuous, hands-on
117 interventions (Socientize, 2014). Social or governance frameworks usually define the position
118 of CS at governance level, in the process of linking institutions with citizens (DITOS 2019b).
119 CS challenges in policy are related to issues of data quality and management, governance and
120 policy implementation (Hecker et al, 2019)

121 There are many visible and invisible ways in which individuals, groups, or organizations can
122 influence the SDGs. This study considers five collaboration channels of CS, as presented in
123 Table 1. These channels will be useful throughout the paper.

124 Table 1. Collaboration channels of Citizen Science

a) Influence through the representation of organized Citizen Science networks in the multi-stakeholder partnerships and engagement mechanisms created for the SDGs, at the national and international level	Goal 17 explicitly stresses the importance of alliances for the SDGs and encourages non-state actors' involvement in the multi-stakeholder platforms. The communities engaged in CS are getting better organized, but the contribution to the SDGs through the multi-stakeholder platforms depends on many factors such as the degree of institutionalization in each country, the infrastructure of involvement, and the willingness of national institutions to collaborate with CS organized groups or networks.
b) Influence through contribution to each of the SDGs individually, by actions that contribute to addressing sustainability issues and themes, i.e. nature conservation, climate change, health, etc.	Although environmental contribution is considered a strong point for CS, tackling sustainability can depend on outreach to society through project structure and governance. Usually, CS projects, even small, cannot reach all layers of society for instance citizens with a tertiary education (Hecker et al. 2018).
c) Influence through involvement in the policy cycle	Citizen Science contribution in policy processes enhances science, society interactions and evidence-based policies. Yet, its impact is difficult to track due to the policy cyclic features and the space of scientific evidence for decision making (Bio Innovation Service, 2018). The Agenda 2030 addresses public participation in many targets, i.e. *Target 11.3, by 2030, enhance inclusive and sustainable organization and capacity for participatory, integrated and sustainable human settlements planning and management in all countries.* The integration of Citizen Science into policy remains challenging, because CS projects achieve multiple outcomes and contribute to different fields (Haklay et al., 2018).
d) Influence through education	Citizen Science contributes to the citizens' empowerment by subject competency and education. It complements Education for Sustainable Development (Pettibone et al., 2016), and Global Citizenship, embraced in the Agenda 2030 in Targets 4.7, 12.8, 13.3. Citizen Science can address Goal 4 in quality education by being included in the curricula, as an educational tool that combines non-traditional and traditional learning (DITOS, 2019a). While in relation to civic education, it fosters a broad

	scientific mentality, encouraging democratic engagement and addressing complex modern problems (Ceccaroni, 2017).
e) Influence through the SDGs' monitoring and reporting, as a source for data provision	The complicated process of the SDGs' data management and monitoring requires additional sources of data provision. Data provided by CS-related activities can be valuable for the national statistical offices or the UN Statistical Office, i.e. as a non-traditional data source. Citizen Science is also acknowledged as a complementary source by policymakers for environmental policies, environmental monitoring and reporting, especially valuable for early warnings of environmental issues (European Commission, 2017).

The objective of the study is to explore several "collaboration channels" for Citizen Science and the Agenda 2030 for Sustainable Development, by analysing challenges and critical aspects, and by providing a framework of interaction from the top-down and bottom-up prospective in order to encourage a broader and more effective engagement. The analyses are based on information from the current practices and opinions of practitioners, researchers, scientists, policy makers, citizen scientists, and organizations that involve citizens in scientific projects, and representatives of CS networks.

3. Methodology

In order to provide a better understanding of the contribution of CS to the implementation of the SDGs, an international survey was performed. At first, a list of topics of interest was developed and reviewed by the authors, aiming to ensure that all pertinent questions were considered and to remove potential overlaps among them. The survey was then disseminated using the online application Google Forms, and responses were collected between March and July 2019. The survey was composed of 11 questions encompassing the "collaboration channels" (a), (b), (c), (d), and (e), as displayed in Appendix 1, including the respondents' role in CS, forms of engagement in CS-related activities, forms of participation in the SDGs'

processes, and, in particular, the involvement with each Goal. Furthermore, questions about the motivation for CS to contribute to the SDGs, critical points, challenges and opportunities were also assessed.

The survey was designed to collect data from a wide audience, including practitioners from diverse disciplines, citizen scientists, policy makers and researchers. The authors disseminated the survey by email to the network of the Citizen Science COST Action and to other networks or CS national or international platforms and projects, as presented in Appendix 2. Furthermore, the office of Inter-University Sustainable Development Research Programme (IUSDRP), (https://www.haw-hamburg.de/en/ftz-nk/programmes/iusdrp.html), disseminated the survey by email to the researchers connected to IUSDRP. As stated in the introductory note about the survey, knowledge about Citizen Science was fundamental for participation, as respondents were to express their opinions based on their personal experience. The survey was also applied (and disseminated to the participants) during two workshops organized by the COST Action CA15212: 1) Workshop of WG4 and EU-Citizen Science: co-creating the European Citizen Science platform of the future and the 2) Workshop of WG5, on citizen-science ontology, standards and data.

The survey results were analysed through simple descriptive statistics in order to summarize and combine the collected information. Quotes from open spaces were used to support the results, presenting real and practical experiences/concerns from the respondents. These responses were investigated through content analyses and its inductive approach – in which the organisation of responses includes open coding, creation of categories, and abstraction (Elo & Kyngäs, 2008).

4. Results

This section presents an overview of the survey findings, related to the respondents' countries and role to CS, their contribution to the SDGs, the processes of implementation, motivation and challenges.

The survey received 84 responses in total and the respondents were based mainly in Europe (73%, n=61). The demographic distribution of the participants is detailed in Figure 1. It can be observed that approximately 21% of the respondents are from other continents and some of them (presented as "Others") opted for not stating their countries.

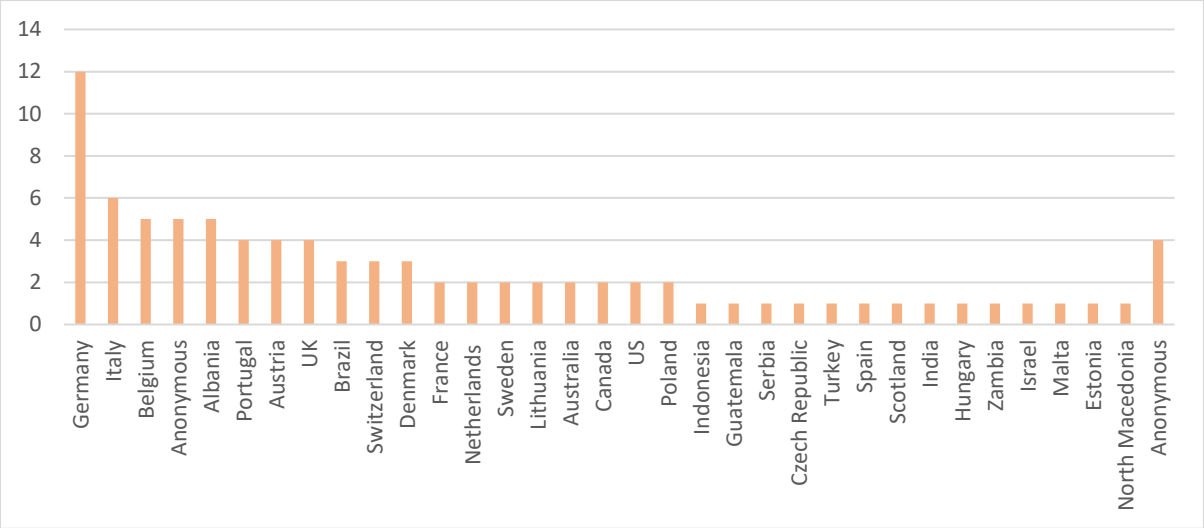

Figure 1. Location of the 84 respondents and number of responses per country

The majority of the respondents are part of organisations that involve citizens in scientific projects/initiatives or belong to the CS national/international networks. The percentages of respondents according to their role in CS are shown in Figure 2. Some participants who selected the option "Other" belong to organizations that coordinate CS projects, or are game creators or providers of data collection infrastructure for Citizen Science.

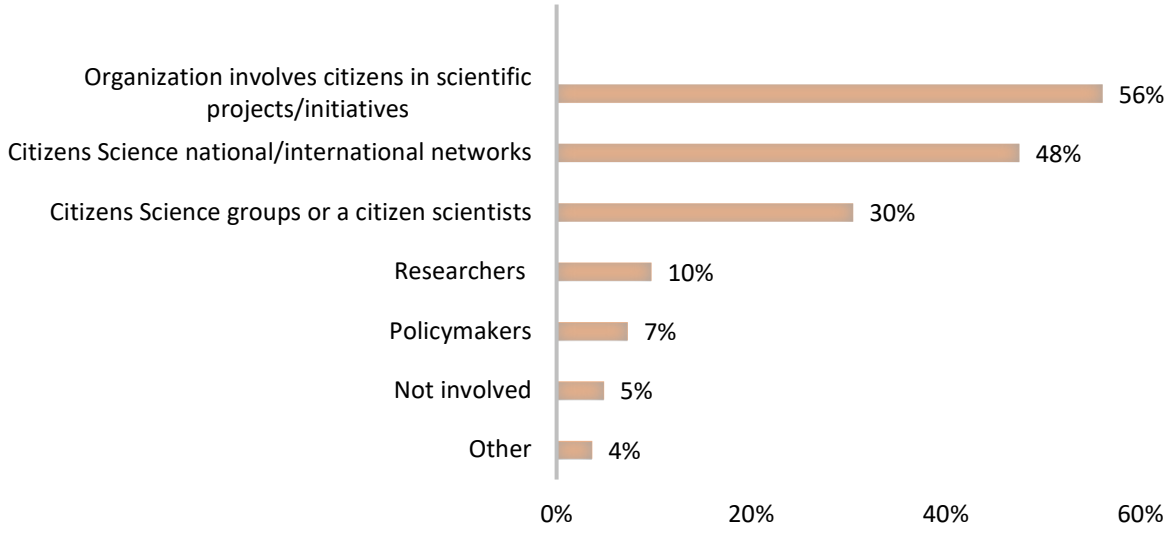

Figure 2. Group of respondents according to their role in CS (%, n = 84)

The gathered responses show that some efforts are already in motion to align the CS-related activities with the Agenda 2030 for Sustainable Development. While 31% of respondents stated that they are integrating the SDGs in existing CS projects or research and 25% are in the process of aligning policies with the goals, 12% indicated not having started this process. Most of the participants (60%), on the other hand, declared that they are working broadly on SDGs themes (i.e. health, water, biodiversity, education), which contributes indirectly to achieving the goals. The participants mentioned additional specific information about their involvement, as illustrated in the quotes in Table 2. In some cases, respondents also mentioned to be working with specific targets of some SDGs.

Table 2. Quotes presenting additional information on the alignment between CS and the SDGs

Main aspect	**Quotes**
SDGs and CS integration	*"A section for SDGs is being included in work for the preparation of the Ontology of CS, by Working Group 5, of COST Action CA15212".*
Align policies with SDGs	*"Our infrastructure implements standards-based data and metadata capture which should allow for citizen science data to be more readily used in data analysis for SDGs".* *"ECSA is part of CSGP which is working to link CS with SDGs".*

Work with specific Targets	*"Including citizens to record data to map invasive alien species, it aligns with target 15.8 "By 2020, introduce measures to prevent the introduction and significantly reduce the impact of invasive alien species" and indirectly with other SDGs in terms of increasing awareness on environmental issues, and increasing scientific literacy".*
Research	*"In my PhD research I linked CS with the notion of the "commons" that is with the idea of sustainability and accessibility"* *"I research if and how policy making guidelines such as Agenda 2030 are "done"/practiced during CS activities connected to museum public engagement".*

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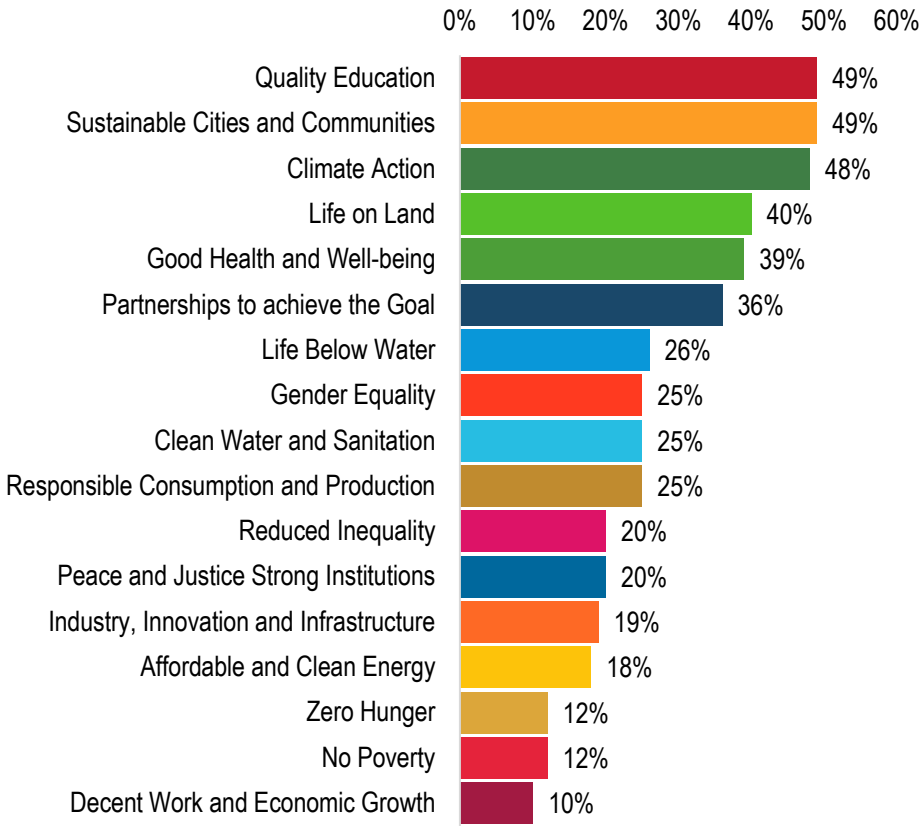
197 Regarding respondents' work with specific Sustainable Development Goals, Figure 3 presents
198 a ranking from the most to the less used SDG. Goals 4 (Quality Education), 11 (Sustainable
199 Cities and Communities) and 13 (Climate Action) were the most selected ones, following the
200 same trend presented by Salvia et al. (2019).



201

202 Figure 3. Ranking of the most used SDGs by the survey respondents

203

204 When it comes to the goals prioritised by countries with higher number of respondents, there
205 are some interesting differences. For Germany, the goals are 4, 5, 11, 12, and 13; Italy has
206 SDGs 13, 15, and 17; Belgium has the goals 2, 7, 11, and 12; and finally but not least: Albania,

with SDGs 10, 11. These topics tend to be related to the strengths and weaknesses of each region (Salvia et al., 2019), therefore being more researched by CS as well.

The respondents of this survey participate in the SDGs implementation processes through creation of partnerships or collaborating with existing networks (32%), and through actions organized by national/local entities or by international organizations (29%). Furthermore, 30% of them invite CS groups or networks in national/local initiatives, i.e. to participate in public consultations and expert workshops. 23% of the respondents are not participating in SDGs related processes. Other forms of participation, mentioned by 13% of the respondents, mainly related to dissemination and engagement, are shown in the quotes in Table 3:

Table 3. Quotes presenting additional forms of participation in SDGs processes

Main aspect	Quotes
Support in implementing actions related to the SDGs	*"We support scholars to implement projects that feature SDGs, including teachers and students".* *"We shape the projects we implement and some of these are actively engaging with SDGs".* *"By considering SDGs in the new EU Common Agricultural Policy indicators".*
Promoting awareness and local actions	*"By letting citizens address their own concern, with small action all around the globe for fixing local issues can help fixing global issues".* *"Awareness raising, simulation of local action".* *"By empowering citizens so they can address SDGs".*
International efforts	*"Contributing to international efforts on data and metadata standardisation and data mobilisation to data aggregators".* *"Integration into curriculum (K-12 and Higher Education) and weave into community science, including the global City Nature Challenge".*

Providing general data to fill the gaps of information for the 17 Goals is considered very important by 69% of the respondents, while 45% of them find it more useful to concentrate on the data for the environmental indicators. 48% consider it important to channel the data through national reporting and monitoring platforms and 30% though UN statistical offices. Other forms of data provision, selected by 13% of respondents are explained in the quotes in Table 4:

Table 4. Quotes presenting additional forms of data provision

Main aspect	Quotes
National reporting	*"I find it important, through the national reporting and monitoring platforms because I think the data could certainly contribute to that, although I have no knowledge of those platforms in my country; however, CS data are already widely in use for meeting environmental reporting obligations".* *"Provide insight into the actual perception and penetration of SDGs in various sectors".*
Disaggregation	*"By establishing new indicators for those SDGs that don't have a specific indicator yet".* *"CS data serve not only for filling gaps but also adding complementary views".* *"There is scope for CS to not just provide data, but also raise awareness of the challenges".*
Non official channels	*"Through community non official data that can be contrasted with national environmental data".* *"By involving communities in their own implementation of SDGs, creating models for development of SDGs and understanding current bottle necks in some developments from a social perspective so that they can be efficiently tackled".*

Regarding the elements of the Agenda 2030 which can engage the cooperation of Citizen Science, the expressed opinions were also balanced: 61% of the responses pointed out the Educational element (including sustainable living and global citizenship); 56% highlighted the importance of Collaboration and partnerships; and 54% of the responses identified the participatory character of the Agenda 2030 as significant for CS efforts. Additional elements mentioned by the respondents are explained in the aspects and quotes of Table 5:

Table 5. Quotes presenting additional opinions about the important elements of the Agenda 2030 for CS

Main aspect	Quotes
Institutionalization	*"Specific clarity and guidance around where gaps in SDG knowledge/data exist and clear project ideas, methods and protocols for community participation. It is critical that participatory projects be driven/promoted with a strong and simple goal focus and be well supported".* *"There is no actual enforcement"* *"I think that CS and SDGs are very close, regardless of the recent label SDGs".* *"CS and policymakers need to work in partnership or else the citizens will just do their own thing. They are not just a cheap labour force without their own agenda. Much can be achieved with CS, but it is not a panacea for the world's problems".*
Specific Goals	*"Promoting gender equality and social inequalities".* *"Specific Goals, such as SDG4, SDG5, and SDG17".*
Education and values	*"CS is a great way to teach science with plenty of added value. It should be integrated into schools' curricula".* *"Linking to the SDGs is essential for CS. It will support efforts to achieve the SDGs, but more importantly it will raise CS awareness for SDGs, and progress toward them".*

Regarding some of the challenges or obstacles that prevent CS from engaging with the SDGs, the lack of awareness for SDGs is the most considered by 64% of the respondents. Other problems are related to the lack of infrastructure of involvement (55%), data reliability, accuracy and ownership (38%), exclusiveness of CS related activities by institutions (36%), and the voluntary character of CS contributions by 33% of respondents. Other problems stated by 16% of participants include the information explained in the quotes in Table 6:

Table 6. Quotes presenting additional challenges that prevent CS in engaging with SDGs

Main aspect	Quotes
Political and institutional aspect	*"SDGs are a political tool, not sure if the citizens need to work with it".* *"To achieve something they believe in, politics make a link and 'box' it into SDGs Square".* *"The Goals are for policymakers, they are not for citizens".* *"CS projects could not be interested in policy making activity and prefer to focus on the local/community level without scaling up to global/institutional level".* *"Low credibility of official entities which promote SDGs, often hypocrite and/or using double standard"* *"Lack of capacity of National Statistical Offices to handle non-traditional data, their resistance to new data sources, data quality issues, etc.".*
Resources	*"Lack of funding from the National Statistics Offices and related public bodies".* *"For statistical offices, CS data is perceived to lack representativeness, too much bias".* *"Financing opportunities for long-term CS projects".*
SDGs aspects	*"Intrinsic contradictions/ target conflicts".* *"For indicators at global level, CS data has not the right coverage".* *"The lack of guaranteed delivery in the future".* *"Should be transparent the communication of SDGs".*
Educational institutions challenges	*"Academic reward schemes, deficit models in public engagement".* *"Pressure on school curricula, they may not feel they have space on SDGs".* *"Institutional mechanisms at higher education institutions supporting CS"*
CS limits	*"The term CS is very confusing, it's very broad and covers many definitions, and maybe it could be good to fix that first".*

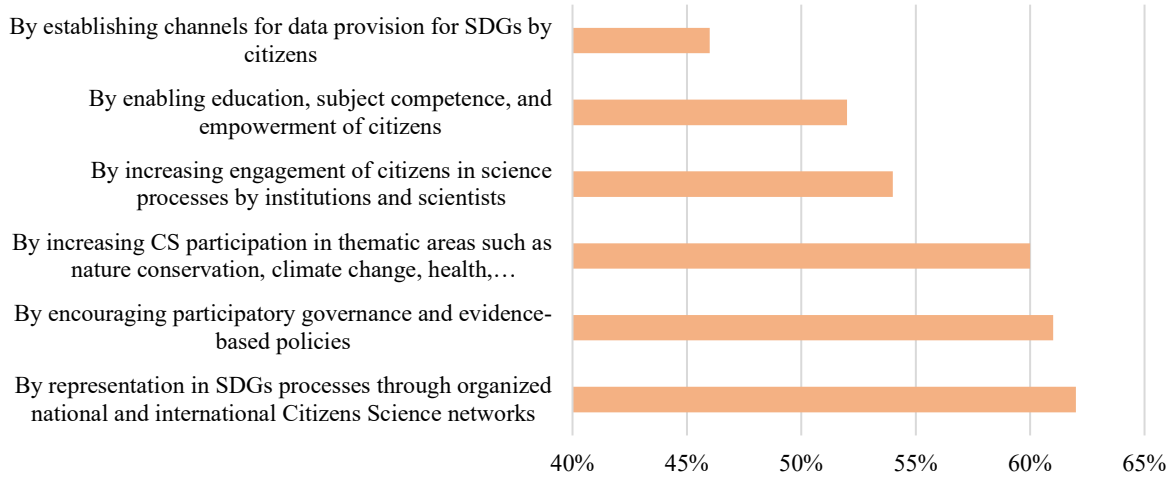
Reasons for the motivation of individuals, groups or organizations involved in CS activities to contribute to the SDGs are very diverse. "Recognition" is the most selected reason (54%), followed by "possibilities for new partnerships" (48%), and "financing opportunities" (38%). Additional reasons stated by 29% of respondents include added value, peer pressure, ideology and responsibility, as shown in this sample of quotes in Table 7:

Table 7. Quotes presenting additional reasons of motivation of CS to SDGs

Main aspect	Quotes
Added value	*"Transformer role of Science in Society".* *"A good context for work on Education for Sustainable Development".* *"Impacts on participant's life such as health effects of air pollution".* *"Relevance and impact of CS if aligned with SDGs"* *"Creates new types of data, added value, and opportunities for financing, especially from big conservation NGOs".*
Peer pressure	*"The others do it, so you have to do to".* *"Local communities and local experts should be involved in the implementation of SDG using a bottom-up approach".*
Ideology and responsibility	*"I think that CS is intrinsically linked with SDGs, explicitly or not".* *"Contribute to big issues affecting humanity and the planet".* *"Explicitly doing CS to reach SGDs".* *"The opportunity to make an impact on society and environment"* *"Overarching societal goals, linked with projects and 'co-benefits'".*

While there is a general understanding that CS can contribute to reaching the SDGs and feed into the 2030 framework, the responses show balanced opinions on how this contribution can be increased, as presented in Figure 4.

Figure 4. Initiatives to increase the contribution of CS towards the SDGs



More opinions were expressed in the option "Others" and are explained in the quotes in Table 8:

Table 8. Quotes presenting additional opinions how CS contribution to the SDGs can be increased

Main aspect	Quotes

International aspect	*"By supporting the already existing CSGP in their work with the UN (hopefully beyond environmental issues)".* *"By complementing and following up global efforts on national, regional and local scale, in a coordinated manner and in collaboration with Citizen Science associations (where they already exist)".*
CS standard	*"Through developing standards for CS data, working closely with NSOs and UN custodian agencies, etc".* *"By placing this work in the context of citizen generated data".* *"Through making finance available for CS projects that adhere to SDG"*
Research and education	*"Through education of professional scientists".* *"Researcher-driven partnerships and projects with citizen participants"* *"Through research on the potential of CS to implement the SDGs and in particular on the transformational learning aspects within CS projects to implement the SDGs".*

5. Discussion

5.1 Critical aspects for Citizen Science and the Agenda 2030 for Sustainable Development according to the 5 "collaboration channels"

While similar critical elements in respect of the concept of citizen science in relation to sustainable development exist, this paper specifically focuses on the differences amongst tthose. Therefore, Table 9 presents the two perspectives considered: 1) The Agenda 2030 political perspective and 2) the Citizen Science perspective, with the purpose to point out to possible problems and challenges.

Table 9. Critical aspects for each of the 5 channels of collaboration from the Citizens Science perspective and the Agenda 2030 for Sustainable Development perspective

Collaboration Channels	**1. Critical aspects from Citizen Science perspective**	**2. Critical aspects from the Agenda 2030 perspective**
a) Influence through representation of organized CS networks, in the multi-stakeholder partnerships and engagement mechanism created for the SDGs, on the national and international level.	Not all countries have organized CS communities or networks. CS is more widespread in developed regions (US, Europe, Australia). Not all countries have strategies of CS in place at national or local levels. No infrastructure of involvement in national or local levels. (55% of respondents)	Not all countries have created multi-stakeholder partnerships for SDGs. Not all the countries have extended participation of non-state actors to the national platforms or committees for SDGs. Differences in the country's political will and commitment toward SDGs

	The CS international networks and organizations do not have enough resources to be very active in the national or international platforms for SDGs	Difficulties in coordination and securing a fair representation of all stakeholders in multi-stakeholder platforms.
b) Influence through contribution to each of the SDGs individually, by actions that contribute to solving sustainability issues i.e. nature conservation, climate change, health, etc.	Citizen Science contribution is mainly for the environmental issues and environmental Indicators. CS contribution is very low in some fields, i.e. agriculture. Participation of Citizen Scientists in projects for specific SDGs depends on the degree of involvement of the organizations or scientists. Organizations do not explain the project connection with SDGs to the Citizen Scientists. The participation doesn't extend to all level of citizens. Lack of the tools of technologies that allow CS to contribute, i.e., air quality, water quality.	Difficulties to connect local sustainability challenges with SDGs. Trade-offs and negative effects between some of the Goals. Organizations need extra work and resources to identify the links to SDGs. The ambiguity of organizations for SDGs can keep the projects contributing to the sustainability challenges, without feeding to the SDGs reporting framework. (Shulla et al, 2019). Lack of awareness for the Agenda 2030.
c) Influence through involvement in the policy cycle.	Exclusion of CS by institutions Insufficient coordination No official rules are in place by Public Institutions to include CS. Lack of participatory approach in governance. Resistance from decision-makers and difficult to identify policy linkages.(Turbe et al. 2019)	Difficulties in aligning national and local agendas to the SDGs Targets and Indicators. Lack of coordination at different levels and sectors. No commitment to the SDGs from local governments of some countries.
d) Influence through education	Confusion in CS of what is really learned by the participants. Not always CS projects contribute to the empowerment or education of the citizens or increase their subject competency. Lack of CS in the curricula. CS harvests only the knowledge of educated people. Organizations or scientists that include citizens neglect to give the required training when necessary. Environmental ethics of companies drive environmental training and performance (Singh et al, 2019)	SDG 4, on "Quality Education" influence all the Goals but there is no clear understanding of how (Shulla et.al 2020. Long term process to receive the results of education. Does not reach all levels of society. Lack of awareness about the SDGs and lack of their communication
e) Influence through the SDGs' monitoring and reporting, as a	No recognition of data provided by CS. Problems with data accountability, ownership, validity.	Slow process of data monitoring and reporting.

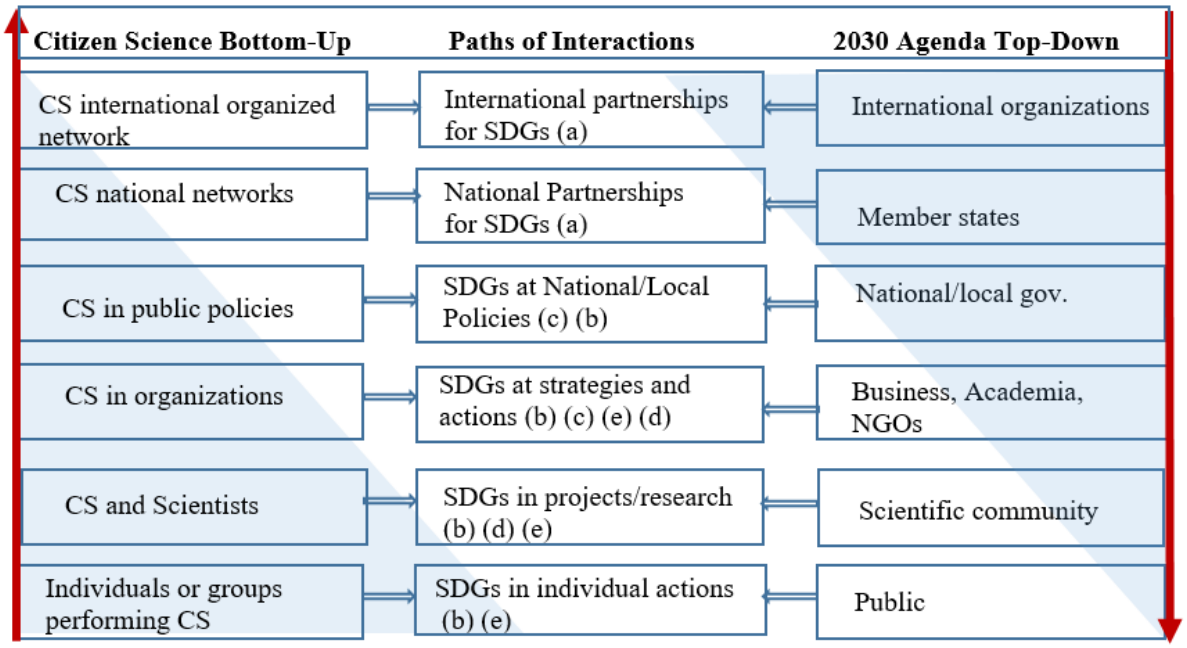
	source for data provision.	No infrastructure for data provision. Limitations in data portability, central to citizen science, for transferring the data to other sources (Quinn, 2018) No continuity after the project is closed. There is a major CS contribution on the virtual level and provision of data on line, which make it difficult to feed to the SDGs monitoring framework.	For some of the SDGs indicators, classified in Tier III, no internationally established methodology or standards are yet available (UNDESA 2019). No infrastructure capacities for harvesting unofficial and non-traditional data.

This table is based on the survey results, takes into account the available literature, and the authors' reflections on this combination of resources.

5.2 Framework of interactions for CS and SDGs on different levels

A framework for the potential interactions between CS and the SDGs is developed in order to explain a broader and more effective engagement. This model is based on different approaches (top-down and bottom-up) and involves specific actions, main actors, and potential collaborations. This framework is presented in Figure 6. It illustrates the paths of contributions between actors, identifying their connection with the collaboration channels (a) the representation of organized networks in the multi-stakeholder partnerships; (b) the contribution to each of the SDGs; (c) the involvement in the policy cycles; (d) education and (e) data provision, on different levels.

Figure 6. Framework of interaction for Citizen Science and the Agenda 2030 for Sustainable Development



The framework of interaction considers the paths of contribution by starting bottom-up for CS, in the sense that input coming from the citizens can influence more the Goals than other forms of engagement. Bottom-up examples, such as civic and DIY (Do It Yourself) projects have more potential for contributing to diversity in the SDGs (European Commission, 2017). The citizen's involvement in science can be either top-down, to generate data for scientists, or bottom-up, i.e. students or teachers raising new research questions (Mueller et al., 2012), but the level of engagement or position in the top-down and bottom-up spectrum can change during time. To support the growing movement of CS in Europe and beyond through communities and international players, both top-down and bottom-up approaches are necessary (Socientize, 2013).

On the other hand, the influence of the Agenda 2030 for CS starts from the top-down, given the national commitments role. Paragraph 47 of the Agenda 2030 states that governments have the primary responsibility for follow-up and review of the progress, at the national, regional and global level, in relation to the progress made in implementing the Goals and Targets until 2030 (UN 2015). Despite the encouragement, the bottom-up initiatives have not yet reached

all levels of society. For example, the German Federal Government, in order to implement the SDGs, is committed to the "top-down" approach, but also supports the individual federal states, and a wide range of actors to accelerate the "bottom-up" approach (Scholz et al., 2016). The enforcement of the links between CS and the Agenda 2030 (as shown in Figure 6) implies mutual benefits and bigger contribution to the 17 SDGs, as focus areas for the achievement of sustainable development and the well-being of the people (UNSSC, 2019).

5.3 Implications for each "collaboration channel"

The results of this paper contribute to generate the following discussions, organised by "collaboration channels":

a) Channel (a): Influence through the representation of organized Citizen Science networks in the multi-stakeholder partnerships and engagement mechanisms created for the SDGs, at the national and international level

A certain degree of institutionalization is needed to participate in partnership processes for the Goals, both on the national and international level. Organized CS groups or networks can be more present in multi-stakeholder settings that national governments are organizing in order to fulfil their SDGs commitments, for instance in national councils, inter-ministerial groups, and multi-stakeholder committees for consultation processes (UNDP, 2017). Thus, an increase of CS organized groups, where is not yet widely practiced, can facilitate their representation and can diversify the engagement of non-state actors to the whole SDG processes. While the coordination of European Citizen Science networks across Germany, Austria, Switzerland, and Spain have resulted in active national online platforms (Strasser and Haklay, 2018), more governmental support from other countries is needed to include CS in national strategies. Furthermore, an agreement of citizen Science understanding and criteria must be established to ensure consistency and data consideration by policymakers (Heigl et al., 2019). On the other

hand, the lack of a generally accepted definition of CS allows for methodical innovation and considerable heterogeneity (Eitzel et al., 2017).

b) Channel (b): Influence through contribution to each of the SDGs individually, by actions that contribute to addressing sustainability issues and themes, i.e. nature conservation, climate change, health, etc.

Citizen Science has the potential to make a major contribution at the local level, as SDGs will be delivered locally. Progress could be reached by including contribution and data from citizens for Goal 11, "Sustainable Cities and Communities" (Klopp 2017), for example. Exploring funding sources for this purpose would increase the resources for participation, as highlighted by the quote of a respondent: "*Encouraging CS projects to incorporate SDGs into their funding and reporting".* Despite the voluntary character of CS, local governments can provide funding programs for citizens with specific focus to the SDGs. Often voluntary commitments compromise the success of practices (e.g. failures in the Corporate Social Responsibility on a case study presented by Patnaik et al. (2017)). Investing in CS can help local governments to facilitate the SDGs because participatory approaches and citizen involvement in policy making are required to reach the several targets. CS can also help localize the SDGs, such as Goals 3, 4, 11, 13, 15, which were also among the Goals mostly chosen by the participants of this study (see Figure 3). Community's role for climate change adaptation is very important and can be dependent on gender, values, individual point of views and places (Brink and Wamsler, 2019). The contribution of CS projects in agriculture is low, but they can be useful for addressing food safety and nutrition, which contribute to Goal 3 on health and well-being (Ryan et al., 2018).

c) Channel (c): Influence through involvement in the policy cycle

Stronger involvement of CS in the policy cycle could result in a better implementation of the Agenda 2030, especially for achieving the Targets and Indicators that depend on participatory

practices. Governments can benefit from Citizen Science as a tool for public participation or as a source to close information gaps (Hadj-Hammou et al., 2017). Successful participation can also depend on how the participatory practices are designed. For instance, when designed as research, apart from the learning, they can feed to data gathering and a better outreach of science-policy in society (Damon, et al., 2016). Ineffective participation can increase decision-making costs, but participation of the public and enterprises in the government processes can increase the efficiency, e.g., air emissions control, and contribute to reaching the SDGs (Li et al., 2018). The influence of Citizen Science and community engagement in public health policies is increasing, mainly through contributing to health literacy, cohesion and rationality (Den Broeder et al., 2018).

d) Channel (d): Influence through education

An increase of CS-oriented projects from organizations or individuals can also contribute to the educational element of the Agenda 2030, by increasing the competence of the participants. The selected quotes below were added as additional information from the respondents.

> *Quote: "SDGs are more a vision of politics. When somebody takes part in the project, they do not realize the dimension of the project. If SDGs are clearly mentioned people would know what they do. Scientists must explain to the participants of the project the link to SDGs. It is the task of organizations to make the alignment".*

> *Quote: "CS projects often arise from a scientific problem which doesn't naturally relate to the SDGs. However, finding the connections and highlighting them would increase the success of both CS projects and SDGs".*

Increasing the presence of CS in the private sector, civil society and academia is needed, but it has to be based on equal terms of partnerships**.** Many companies and organizations are under a

lot of pressure to implement sustainability (Caiado et al., 2019). It can be achieved through alignment with the Agenda 2030, integration of the SDGs into existing projects, and by involving more citizen scientists and communicating the SDGs to them. It can require innovation, which is important for technology, economy and social development, (Oliva et al, 2018) and organizational changes towards more sustainable policies and practices (Jabbour et al, 2019). Furthermore, transformative leadership plays a role in green innovation and environmental performance of organizations (Singh, 2019).

e) Channel (e): Influence through the SDGs' monitoring and reporting, as a source for data provision

Citizen Science data are important for the Agenda 2030, if integrated in the SDGs' reporting and monitoring frameworks. The five dimensions of CS data- spatial, temporal, thematic, process, and management, based on their various features appear to be valuable for the SDGs (Fritz et al., 2019). They are particularly useful, if distinguished from traditional science data, for instance in recording species in diverse areas where other methods are not possible (Klemann Junior et al., 2017). Managing big data, from a variety of sources, can help companies overcome technological challenges (El-Kassar and Singh 2017), and facilitate the development of their sustainable capabilities (Singh and El-Kassar, 2018). Citizen-generated data can improve monitoring practices by offering alternative measurement methods (Lämmerhirt 2018). The e-infrastructure of data provision is an important aspect of CS, because CS often happens on the virtual level. "Online citizen science" can reinforce scientific research infrastructure with very few resources (Nov, 2014). In order to foster specific policies, CS programs should keep their internal sustainability through internal evaluations, publishing studies and leadership diversity (McGreavy et al., 2016). Effective tools for integrating CS data to the SDGs framework should be established, (for instance e-infrastructure of SDGs data reporting and monitoring) and open access to CS research should be encouraged.

Conclusions

Citizen Science and the SDGs share the same values for global sustainability challenges and empowering people. The partnership character of the Agenda 2030 allows for collaboration at different levels of society, and envisions the voluntary contributions that are often overlooked. Citizen Science has multiple outcomes, and every single commitment is essential for the SDGs. Citizen Science commitments to sustainability can comprise not only sensitive environmental issues but address all three dimensions of sustainability.

The results of this study indicate a big potential of interactions through the five "collaboration channels". The results point out to the involvement of Citizen Science activities mainly with SDG 4 "Quality Education", SDG 11 "Sustainable Cities and Communities", SDG 13 "Climate Action" and SDG15 "Life on Land"; to the need for institutionalization of CS representation in the national and international SDGS processes; to the importance of CS data infrastructure for the SDGs monitoring framework; to the mutual benefits of CS and SDGs from strengthening education and competencies; to the increase of presence of Citizen Science in companies through fair partnerships; and to the importance of Citizen Science in the policy cycles which helps the governments in fulfilling their commitments to the SDGs. Enforcement of CS links and paths of interaction with the SDGs can increase CS recognition and acknowledgment as a valuable source of contribution for sustainable societies. It can also help citizens and organizations to develop a better awareness of the value of the Agenda 2030 for the Sustainable Development.

Implication for Theory and Practise

The study contributes to the literature on Citizen Science. It explores the role of the CS discipline in achieving the global objectives toward a sustainable society. Regarding practical contributions, it supports the CS community, practitioners and policy makers by providing

424 better insights and hints for synergizing their work and raising awareness about the potential
425 of CS contributions for the Agenda 2030. Furthermore, the study contributes to the research on
426 the Agenda 2030 and the SDGs, and the necessary collaborations needed between disciplines
427 and actors. It points out critical aspects of these contributions and gives practical
428 recommendations for increasing CS involvement with the SDGs.

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431 **Limitations of the study and suggestions for future work**

432 Reaching a greater number of participants in the online survey would have certainly
433 strengthened the results of this study, as it would have assured a wider and more diverse
434 representation of participants, since a major part of them belong to national or international CS
435 networks or organizations. The aim was not to narrow the results by focusing only on network
436 administrators, but instead to welcome responses and insights from a wide range of CS
437 practitioners with various disciplinary backgrounds. The majority of the participants are from
438 Europe, so the relatively small sample size of participants from the other continents does not
439 allow for representation of a larger population. The sample represents the overall group
440 surveyed, and despite being a small sample, the data reliability is assured since the sample is
441 composed of researchers who are really engaged with Citizen Science and familiar with its
442 concept and practice.

443 The optimal sample size was not calculated in advance, as it was expected to reach the largest
444 possible number of participants, considering their availability and degree of involvement. The
445 Cost Action on Citizen Science community network is composed of about 275 practitioners.
446 Thus, the response rate is approximately 25%, which includes also the participants from other
447 domains as described in the methodology.

More participation from citizen scientists and policymakers would have provided a better and more representative understanding of their points of view. For this purpose, dissemination to a broader audience outside the above groups would have obtained more diverse results. Another limitation of this study is the lack of information on examples or case studies of current actions of CS and the SDGs related activities.

Future research should focus on the different channels of CS contributions for the implementation of the Agenda 2030 for Sustainable Development and in identifying new forms of cooperation. More specifically, future research can consider the following:

- Governance aspects of Citizen Science organized networks and institutionalization of CS actions for SDGs
- Financial aspects of Citizen Science and SDGs
- Citizen Science and SDGs in developing countries
- Citizen Science's role for thematic issues of the SDGs related to, for instance, climate change, agriculture, sustainable cities, education etc.
- Role of Citizen Science for localizing the SDGs, by contributing to the attainment of the SDGs Targets related to participatory planning and public involvement
- Citizen Science's contribution to sustainable development in different sectors, such as the private sector, civil society, the public sector and academia
- Citizen science, Global Citizenship and Education for Sustainable Development
- Exploring tools to integrate CS data in the SDGs framework

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Appendix 1. Summary of the survey instrument

Survey: The role of Citizen Science for the Sustainable Development Goals	
1. Where are you located?	
2. What is your role in Citizen Science?	My organization involves citizens in scientific projects/initiatives; Part of CS national/international networks; Part of CS groups or a citizen's scientist; Policymaker; Not involved; Other
3. How do you align your CS work with the Agenda 2030 for Sustainable Development? (multiple answers possible)	Integrating SDGs to the CS existing projects; Working broadly on SDGs themes (i.e. health, water, biodiversity, education etc.); Align policies with SDGs; Not aligned with SDGs; Other
4. Do you identify your CS work with any specific Goals? (multiple answers possible)	List of the 17 SDGs and their descriptions
5. How do you participate in the SDGs processes? (multiple answers possible)	Through creating partnerships or collaborating with existing partnerships for SDGs; By participating in SDGs implementation processes, national local or international; By inviting CS groups or networks in national/local initiatives; Do not participate; Other
6. How can CS provide data for the SDG? (multiple answers possible)	Providing general data to fill the gaps of information; Mainly provide data for environmental indicators; Through UN statistical offices as 'non-official' data providers for the SDGs; Though national SDGs reporting and monitoring platforms; Other
7. What motivates CS to align with SDGs? (multiple answers possible)	Recognition; New partnerships; Financing opportunities; Other

8. What are the barriers and challenges for CS toward the SDGs? (multiple answers possible)	Lack of awareness toward SDGs; No infrastructure of involvement; Exclusiveness by institutions; Problems with data reliability, accuracy and ownership; Voluntary character of contributions; Other
9. According to your opinion, how can CS contribution toward the SDGs be increased? (multiple answers possible)	By representation in SDGs processes through organized national and international Citizen Science networks; By increasing engagement of citizens in science processes by institution and scientists; By increasing CS participation in thematic areas, as nature conservation, climate change, health, education etc.; By encouraging participatory governance and evidence-based policies; By establishing channels for data provision for SDGs by citizens; By enabling education, subject competence and empowerment of citizens; Other
10. Citizen Science cooperate between science, education and civic engagement, what elements of Agenda 2030 enforce that?	Educational element, including sustainable living and global citizenship; Participatory character; Collaboration and partnerships; Other
11. Please let us know if you have any comments or wish to add/highlight anything.	

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754 Appendix 2. Citizen Science networks, platforms and projects which received the survey

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Citizen Science Cost Action CA15212	https://www.cs-eu.net
European Citizen Science Association (ECSA)	https://ecsa.citizen-science.net/
WeObserve Project	https://www.weobserve.eu/
International Institute for Applied Systems Analysis (IIASA)	https://www.iiasa.ac.at/
EU-Citizen.Science project	http://eu-citizen.science/
Doing it Together Science	http://www.togetherscience.eu/
Australian Citizen Science Association (ACSA)	https://citizenscience.org.au/
Atlas of Living Australia	https://www.ala.org.au/
Stifterverband	https://www.stifterverband.org/veranstaltungen/2016_06_23_citizen_science
OpenAIRE	https://www.openaire.eu/

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