Available online at www.sciencedirect.com

ScienceDirect

Current Opinion in
Environmental Science & Health

Recent contributions of citizen science on sustainability policies: A critical review

Laura Criscuolo[1], Alba L'Astorina[2], René van der Wal[3] and Laura Colucci Gray[4]

Abstract

Citizen science (CS) is often used to describe collaborations between researchers and non-professional volunteers who help with data collection and other research tasks, such as species identification, data annotation, and classification. Other definitions refer to citizens producing their own evidence to influence policy and raise community awareness, including participatory projects where citizen scientists contribute to defining the focus, co-design, or run an entire research project. This integrative review provides a critical appraisal of both empirical studies and theoretical perspectives on CS in emerging research related to environment and health policies, with a particular emphasis on sustainability. The analysis points to the need for greater awareness of CS methodology in order to redress the relations between scientific research and policy-making, considering local communities' knowledge and values as pivotal to shaping future sustainability policy agendas, in ways that are both more comprehensive and sensitive to changing contexts and specific needs.

Addresses

[1] Institute of Geosciences and Earth Resources - National Research Council (IGG-CNR), Via G. Moruzzi 1, Pisa, Italy

[2] Institute for Electromagnetic Sensing of the Environment - National Research Council (IREA-CNR), Via Corti 12, Milano, Italy

[3] Swedish University of Agricultural Sciences, Dept. of Ecology, Ulls Väg 16, 75651, Uppsala, Sweden

[4] Moray House School of Education and Sport, University of Edinburgh, Scotland

Corresponding author: L'Astorina, Alba (lastorina.a@irea.cnr.it)

Current Opinion in Environmental Science & Health 2023, **31:**100423

This review comes from a themed issue on **Environmental Impact Assessment 2022: Sustainability in the agro-food ecosystem: policies, measure and measurement**

Edited by **Ettore Capri**

For complete overview of the section, please refer to the article collection - Environmental Impact Assessment 2022: Sustainability in the agro-food ecosystem: policies, measure and measurement

https://doi.org/10.1016/j.coesh.2022.100423

2468-5844/

Keywords

Citizen science, Sustainability, Policy-making, SDGs, Participatory research, Top-down/bottom-up approach.

Introduction

Citizen science (CS) is not an entirely new concept (see Box 1); it has been around for long enough to develop a diversity of approaches, modes of operation, and communities of interest [1].

Recent decades have seen a growth of interest in CS due to its interfacing role between public policies and citizens' experiences [17–20], particularly in relation to promoting a deeper engagement of society with sustainability policies.

On September 25, 2015, the General Assembly of the United Nations' Resolution 'Transforming our world: the 2030 Agenda for Sustainable Development' [21] and the associated Sustainable Development Goals (SDGs) framework set out a global agenda for sustainable development (see Box 2).

Referred to as comprehensive, far-reaching, people-centered, and universal, the SDGs have been described as the "transformative agenda" for global policy on matters of society, economics, and the environment [24]. Signatories are committed to "respecting national policies and priorities" with each Government setting its own national targets yet with a shared and collective responsibility from all parties – private sector, non-governmental organizations, private agencies, and civil society actors – for the outcomes. Such an ambitious plan brings up a number of challenges and critiques with respect to data collection and monitoring of progress toward the goals. For example, one of the factors concerns the ability of citizens to engage with CS activities, both in terms of dispositions/personal capacities and resources; but there are also questions about the need for different countries to interpret key priorities in order to enable informed action and participation from all citizens [25].

In this context, recent developments in CS interface more closely than ever before with processes of change in knowledge (co-)production, at both local and global levels [*26]. This is currently an open terrain for research and debate, which is evidenced by the rise of working groups, conferences, and editorial contributions

Box 1. The concepts behind Citizen Science

CS is generally understood as "scientific work undertaken by members of the general public, often in collaboration with or under the direction of professional scientists and scientific institutions", as first defined in the Oxford English Dictionary in 2014 [2]. However, since its origins, CS has shown itself to be rich in facets and implications and to be a sufficiently loose concept to facilitate communication and cooperation among different disciplines and research communities [3–5]. Some authors have linked CS with the democratization of science [4], while others highlighted how it can help scientists in obtaining more data for their activities [5–7]. However, issues of data quality [8–10] and different levels of volunteer motivation and involvement [11,12] affect the potential of CS to be seen as a reliable tool for scientific research [13]. Turrini et al. [14] suggested a multi-level framework for CS, from enabling learning at the individual level, to generating new scientific knowledge and promoting transformation at the societal level. However, there remain limitations and challenges with CS as a methodology for scientific research. Strasser et al. [15] identified five epistemic practices to describe the diversity of participatory research and discuss a number of historical, political, and social questions for future research in CS. Recent debates and developments are centered on CS as a process for reinventing the way knowledge is produced, distributed, and acted upon [16].

Box 2. The UN 2030 Agenda and the SDGs framework

The United Nations 2030 Agenda "Transforming our world: the 2030 Agenda for Sustainable Development" was adopted in 2015 and ratified by 193 countries as a roadmap to "end all forms of poverty, fight inequalities, and tackle climate change" and to reach sustainable development by 2030 [22,23]. The Agenda implementation relies on a layered framework: 17 SDGs, articulated in 169 targets, which are themselves monitored by means of a set of 231 indicators. The indicators are classified into three levels based on their level of methodological development and the availability of data at the global level [IAEG-SDGs]. The indicator framework has been modified comprehensively in 2020 by the United Nations Statistical Division (UNSD) and will be last revised in 2025. Each signatory country contributes to the framework by monitoring indicators at national level. Custodian agencies (United Nations bodies and other international organizations) are responsible for compiling, verifying, and submitting country data to the UNSD. The UNSD provides periodic updates, reports, and access to the collected data [https://unstats.un.org/sdgs/].

The 17 SDGs are as follows: (1) No Poverty, (2) Zero Hunger, (3) Good Health and Well-being, (4) Quality Education, (5) Gender Equality, (6) Clean Water and Sanitation, (7) Affordable and Clean Energy, (8) Decent Work and Economic Growth, (9) Industry, Innovation and Infrastructure, (10) Reduced Inequality, (11) Sustainable Cities and Communities, (12) Responsible Consumption and Production, (13) Climate Action, (14) Life Below Water, (15) Life On Land, (16) Peace, Justice, and Strong Institutions, and (17) Partnerships for the Goals.

The Agenda also proposes the "5Ps" of sustainable development as a holistic tool to monitor progress in SDGs. It highlights five dimensions of sustainable development – People, Planet, Prosperity, Peace, and Partnerships – useful for looking at SDGs as interconnected objectives [https://www.unsdglearn.org/microlearning/understanding-the-dimensions-of-sustainable-development/].

focused on the possible convergence between CS and SDGs (see Box 3).

Two main strands within the recent literature provide the background to current discussions. First, CS is seen as a means to enhance scientific knowledge production ("productivity view"), for example, by extending the capacity to collect data at a large scale or providing data that may not be accessible via more conventional means [31]. Second, CS is seen as bridging the gap between science and broader society ("democratization view"), thus considering not only data but also the plurality of local knowledge and experience that are necessary for extended and active public participation [32,33,34]. Integrative views are also proposed in order to support just transitions, including agenda setting, mobilizing resources, and facilitating the co-evolution of socio-technical aspects of transitions [35].

This integrative review provides a critical appraisal of empirical studies and theoretical perspectives on CS in emerging research related to sustainability. Literature searches were conducted through multi-disciplinary digital databases to identify purposes and practices. Papers published since 2019 were included alongside a small selection of earlier background studies with a view to provide a snapshot of current research directions and priorities.

Interactions between CS and local and global sustainability policies

CS data for monitoring progress within the SDGs framework

In 2017, a briefing produced by the Stockholm Environment Institute [36] identified a potential contribution of CS to the definition, monitoring, and/or implementation of 42 SDGs targets out of 169. A year

Box 3. Recent initiatives to strengthen interactions between CS and SDGs

Among the numerous recent initiatives, the *Task Group on Data from Participatory Mapping for the SDGs*, set up in 2020 by the *Committee on Data of the International Science Council* (CODATA), is producing relevant contributions in the direction of aligning CS products with SDG indicators [27], including a series of "how to" guides aimed at providing guidance to CS groups on what measurements are necessary in order to contribute to SDG indicators in a number of different issue areas (https://codata.org/initiatives/task-groups/citizen-science-for-the-sustainable-development-goals/how-to-guides-for-citizen-science-groups-on-sdg-indicators/). The *Working Group on Citizen Science for the SDGs* by the *Thematic Research Network on Data and Statistics* (SDSN TReNDS) is focused on assessing the potential of CS to inform SDG decision-making and combine Earth observation and CS data [**28]. The CROWD4SDG Innovation Action supported by the *European Commission's Science with and for Society* (SwafS) program promotes the development of CS projects aimed at tackling the SDGs, with a focus on climate action [29]. The ECSA Conference 2018 and the United Nations World Forum 2020 dedicated sessions on the relationship between CS and SDG; the hybrid conference *Knowledge for Change: A Decade of Citizen Science (2020–2030) in* Support *of the SDGs*, held in 2020, as an official event of Germany's 2020 EU Council presidency, resulted in a conclusive CS SDG Declaration [30].

Among the editorial contributions, the scientific journal *Sustainability* (ISSN 2071-1050) hosted the special issues *Citizen Science and the Role in Sustainable Development* (https://www.mdpi.com/journal/sustainability/special_issues/citizen_sci_sus, closed October 31, 2020), and *Citizen Science Projects for Environmental Challenges and Sustainable Development Goals* (https://www.mdpi.com/journal/sustainability/special_issues/citizen_science_sdg, closed December 31, 2021). They collected a wide range of research, analysis, and perspective contributions, exploring how CS can contribute to the achievement of the SDGs at local, regional, and international levels. Lastly, the journal *Citizen Science: Theory and Practice* is preparing for a spring 2023 Special Collection on the subject *Contributions of Citizen Science to the SDGs and International Development Frameworks* (https://citizenscience.org/2022/03/17/special-collection-sdgs-and-international-development-frameworks/).

later, the inventory produced by the European Commission revealed the contributions of environmental CS projects to SDGs, largely to health and well-being (SDG 3), climate mitigation and adaptation (SDG 13), terrestrial nature conservation (SDG 15), and global partnership for sustainable development (SDG 17). It highlighted the potential for CS to be a cost-effective way to contribute to policy [16]. Notably, CS provides non-traditional data sources to fill data gaps in the SDG framework; thus, a roadmap for integrating CS data into the formal SDGs' reporting mechanisms has been proposed [31]. A similar interest in CS was also expressed by UN Environment – the custodian agency for 26 of the environment-related SDG indicators – which is exploring CS among new data sources, because of its potential to contribute to global and local level SDG monitoring [37]. A systematic analysis of current and potential contribution of CS to the monitoring of SDGs indicators shows how CS is currently contributing to five indicators and could contribute to 76 others. This means that around 33% of SDG indicators could receive inputs from CS data [**28]. Ajates et al. built on this approach, evaluating the suitability of citizen observatories for SDGs monitoring at goal, target, and indicator levels [*38]. Many contributions from the literature discuss the potential of CS to produce relevant inputs particularly for goal 15 (Life on land) [*38,39,40,41,**28], goal 11 (Sustainable cities and communities) [*38,42,**28], goal 3 (Good health and well-being) [43,44], goal 6 (Clean water and sanitation) [45–47, **28], goal 4 (Quality education) [39, 48], goal 13 (Climate action) [49,50], goal 7 (Affordable and Clean Energy) [51], and goal 2 (Zero Hunger) [52]. Other authors highlight mismatches between SDG monitoring needs and datasets produced through CS activity, suggesting measures to maximize the potential of CS data to contribute – quantitatively and qualitatively – to the SDG framework [53–58].

Although the SDG framework provides for official reporting at the national level, there are also "pushes" to analyze the SDGs at a more local level [58,59], in order not to smooth out the differences within nations and take account of particular local conditions. CS activities are often local and therefore lend themselves well to contributing to this effort [57]. Nevertheless, it is necessary to be aware that CS is spread unevenly across geographical, socio-economic, and disciplinary levels [60], and for this reason, its potential contribution to the monitoring of SDGs is equally uneven.

In addition, the requirement to report progress on set agendas, such as the 2030 Agenda for Sustainable Development, stretching over long periods of time is resource-intensive. Sustaining basic statistical operations may be given priority over measuring progress toward SDGs, thus pointing to the need to seize innovations in data collection and build stronger partnerships with new data producers to fill data gaps [61].

CS used to design indicators and policies

While the role of CS for the SDGs has been long acknowledged by the United Nations institutions through, for example, the "Citizen Science Global Partnership" (CSGP), an implementation gap remains. Research practice, funding agencies, and global science organizations point to co-production as a means to address the complexity of sustainability challenges instead of traditional, disciplinary approaches [62].

While in contributory projects, scientists may be able to align data collection with official research protocols, co-created and collegial projects might promote greater ownership of key SDGs indicators linked to local policies. Seeking to address this gap, International Programs, such as the Programme on Ecosystem Change and Society (pecs-science.org), the Global Land Programme (glp.earth), and Future Earth (https://futureearth.org/), give practical examples of projects involving scientists working closely with local community groups to address socio-ecological challenges (e.g. land management, water-climate nexus, and biodiversity), forging interdisciplinary teams at the interface between science and practice. One such example from the Global Land Programme includes the production of aerial images by remote sensing to engage citizens in Zambia in interpreting data about their landscape and using the data to address practical problems in the community (e.g. where to grow crops or how to resolve boundary issues with neighbors).

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). Yet, while such commitments can achieve substantial results in practice, they often outpace the development of guiding definitions of what knowledge co-production is and the frameworks to assess its quality or success [63,54]. Promising results are offered by recent initiatives involving Citizen Observatories (COs), such as the experience of the GROW Observatory project. Findings point to (i) actions to advance the implementation of goals and targets through awareness raising and training, participatory methods, multi-stakeholder connections, and supporting citizens to move from data to action; (ii) data contributions to SDG indicator monitoring through citizen-generated datasets, thus enhancing sustained data collection for ongoing indicator level monitoring [38].

A number of CS projects are thus focused on data to inform public governance [20] as well as scientific research [64,65]. On the basis of the literature and these findings, two general observations can be made that are of relevance for the CS-SDG link. First, many CS projects, particularly those that provide data contributing to scientific research, may not be locally relevant. Second, those that are co-created are largely interested in generating local impacts—whether on communities, governments, or both. While contributory projects enhance global accountability, the local focus can also be purposefully exploited to improve the SDG monitoring framework, by compensating for the current lack of granular and spatially disaggregated data [66], as well as helping to meet the promise of inclusive development [31]. Crucially, this entails that CS projects may not only ameliorate the current SDG data apparatus but also make significant, tangible contributions toward the broader idea of the SDGs. However, only a minority of initiatives currently produce data with the intention of filling gaps in existing datasets, and only a couple include the monitoring of SDG indicators among their primary aims. This suggests that there is still a significant lack of alignment between SDG data demand, on the one hand, and CS projects purposes, on the other [67]. Discrepancies between objective measurements versus subjective judgments in the analysis of impacts and long-term contributions to the SDGs point to divergent interests and different needs [68,53] but also to issues of language and translation, as terminologies in the field of SDGs and CS need to be understood by different communities of actors, within and outside academia [*69]. Recognition of key cultural issues is particularly relevant to the analysis of the implementation of SDGs in rural settings, such as SDG 15 Life on Land, where conflict may arise over the differential uses of limited resources [70], thus requiring a more rigorous assessment of issues of inclusion in CS projects involving local communities [71].

CS actions as a direct contribution to sustainability objectives

A third wave of recent CS projects, largely stemming from European research networks, highlights two significant "pulls" toward extended participation. First, the growth of citizens' environmental sensing [72] with its focus on wearable sensing technologies and data processing techniques for decentralized data collection by non-experts – described by a variety of terms including human sensing, participatory sensing, crowdsourcing or "just" CS – has the potential to collect continuous, highly granular data over extended time periods. However, sensing can also relate to senses defined as a faculty of the body to perceive an external stimulus via the traditional senses of sight, hearing, taste, smell, and touch. The combination of "objective" sensor measurements and subjective impressions, as proposed by participatory projects involving the arts and sciences, may lead to new insights into current environmental issues as experienced by people in their everyday life [73]. In this frame, CS is viewed as a vehicle for mobilizing tacit knowledge and contributes to greater community cohesion, whereby human and environmental health are not solely measured according to universal parameters but include the ability of people to use data to learn about their own communities, adapt, and self-manage vis-à-vis significant change [74,75]. Yet, this raises challenges for the interpretation of data among different disciplinary experts and between experts and members of the public, calling for greater attention to the quality and design of methods for participation in CS [16]. The emerging literature points to the inclusion of under-represented voices in public debates, including those of youth in non-western countries [76] and marginalized groups with low levels of data literacy [57]. Participatory practices of CS, such as those involving the arts, are attentive to the quality of inclusive spaces, for instance, harnessing cultural heritage in museums [*77] and across community science in the digital space [78] to forge hybrid social networks [79] and achieve more equitable outcomes toward the SDGs [80]. A more significant shift at this level is that of recognizing how knowledge and cultures are produced "*in and through the material body*" and that "*regulations are not just reproduced in the body but are also manipulated and subverted through its acts*" [81]. Recognizing knowledge as embodied, contextual, and discursive opens up new avenues for transformative [82,83] multi-level governance in CS for SDGs [84]. The emerging literature points to the hybridity of methods and plurality of languages and ways of knowing, witnessed by the emergence of "collectives" pushing for greater flexibility of terminology to understand and implement CS practices across the Global North and the Global South [*82,85].

The potential of CS to act both at a social and cultural level and create connections between science, politics, and society goes hand in hand with the transversal, integrative intentions of the 5Ps (see Box 2). CS is particularly relevant and attuned to the people and partnership dimensions. Specifically, CS can help address problems affecting the application of the agenda, such as the fragmentation of goals, the top-down approach, and the long-standing difficulty of integrating subjective, cultural, and historical components into the SDGs framework of [86].

Conclusions

This review highlights the existing contributions of CS to SDGs. While extensive studies have been conducted to assess the potential of CS for large-scale data collection and monitoring of progress on SDGs, questions arise as to whether the SDGs are meaningful and relevant at the local level. If the former focuses on the importance of localized approaches to data collection to increase capillarity and granularity, the latter emphasizes the need for co-production, inclusion, and participation of citizens to enable new priorities and agendas to emerge and be addressed collectively within the relevant local contexts. Further research is required at the methodological level to understand approaches and practices that facilitate the integration of qualitative and personal experiences in CS data, thus taking account of a plurality of research practices and cultural traditions. This opens up exciting new avenues of CS to bridge environmental, social, and economic dimensions in sustainability policy.

Formatting of funding sources

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

No data was used for the research described in the article.

Acknowledgements

This review has not received funding. The work was stimulated by the experience gained within the project BRIDGES – building reflexivity and response-ability involving different narratives of knowledge and science – supported by the Cariplo Foundation. We wish to thank the project team, with which we have experimented CS activities for local sustainable goals.

References

Papers of particular interest, published within the period of review, have been highlighted as:

* of special interest
** of outstanding interest

1. Kesperowski D, Kullenberg C: **The many modes of citizen science**. *Sci Technol Stud* 2019, **32**:2–7. 2019.
2. Eitzel MV, Cappadonna JL, Santos-Lang C, Duerr RE, Virapongse A, West SE, Kyba C, Bowser A, Cooper CB, Sforzi A, Metcalfe AN, Harris ES, Thiel M, Haklay M, Ponciano L, Roche J, Ceccaroni L, Shilling FM, Dörler D, Heigl F, Kiessling T, Davis BY, Jiang Q: **Citizen science terminology matters: exploring key terms**. *Citiz Sci Theory Pract* 2017, **2**.
3. Star SL, Griesemer J: **Institutional ecology, `Translations' and boundary objects: amateurs and professionals in Berkeley's museum of vertebrate zoology**. *Soc Stud Sci* 1989:1907–1939.
4. Irwin A: *Citizen science: a study of people, expertise and sustainable development*. London: Routledge; 2002.
5. Bonney R: **Citizen science: a lab tradition**. *Living Bird* 1996, **15**: 7–15.
6. Bonney R, Cooper CB, Dickinson J, Kelling S, Phillips T, Rosenberg KV, Shirk J: **Citizen science: a developing tool for expanding science knowledge and scientific literacy**. *Bioscience* 2009, **59**:977–984.
7. Silvertown J: **A new dawn for citizen science**. *Trends Ecol Evol* 2009, **24**:467–471.
8. Kosmala M, Wiggins A, Swanson A, Simmons B: **Assessing data quality in citizen science**. *Front Ecol Environ* 2016, **14**:551–560.
9. Balázs B, Mooney P, Nováková E, Bastin L, Arsanjani JJ: **Data quality in citizen science**. In *The science of citizen science*. Edited by Vohland K, Land-zandstra A, Ceccaroni L, Lemmens R, Perelló J, Ponti M, Samson R, Wagenknecht K, Springer Nature; 2021:139–155.
10. Lukyanenko R, Wiggins A, Rosser HK: **Citizen science: an information quality research frontier**. *Inf Syst Front* 2020, **22**: 961–983.
11. Lotfian M, Ingensand J, Brovelli MA: **A framework for classifying participant motivation that considers the typology of citizen science projects**. *ISPRS Int J Geo-Inf* 2020, **9**:704.
12. Coleman D, Georgiadou Y, Labonte J: **Volunteered geographic information: the nature and motivation of producers**. *Int J Spatial Data Infrastruct Res* 2009, **4**:332–358.
13. Haklay M: **Citizen science and volunteered geographic information: overview and typology of participation**. In *Crowdsourcing geographic knowledge*. Edited by Sui D, Elwood S,

Goodchild M, Springer Science & Business Media; 2013: 105–122, https://doi.org/10.1007/978-94-007-4587-2_7.

14. Turrini T, Dörler D, Richter A, Heigl F, Bonn A: **The threefold potential of environmental citizen science-Generating knowledge, creating learning opportunities and enabling civic participation**. *Biol Conserv* 2018, **225**:176–186.

15. Strasser B, Baudry J, Mahr D, Sanchez G, Tancoigne E: **"Citizen science"? Rethinking science and public participation**. *Sci Technol Stud* 2019, **32**:52–76.

16. Vohland K, Land-Zandstra A, Ceccaroni L, Lemmens R, Perelló J, Ponti M, Samson R, Wagenknecht K. *The science of citizen science*. Springer Nature; 2021.

17. European Commission, Directorate-General for Environment: *Citizen science for environmental policy: development of an EU-wide inventory and analysis of selected practices*. Publications Office; 2018. https://data.europa.eu/doi/10.2779/961304.

18. European Commission, Joint Research Centre (JRC): *An inventory of citizen science activities for environmental policies*. European Commission, Joint Research Centre (JRC); 2018. PID, http://data.europa.eu/89h/jrc-citsci-10004.

19. Hecker S, Haklay M, Bowser A, Makuch Z, Vogel J, Bonn A. *Citizen science: innovation in open science, society and policy*. UCL Press; 2018.

20. Ponti M, Craglia M. *Citizen-generated data for public policy*. Ispra: European Commission; 2020. JRC120231.

21. United Nations DESA: *Resolution adopted by the general assembly on 25 September 2015, transforming our world: the 2030 agenda for sustainable development*. 2015 (A/RES/70/1).

22. United Nations: *Resolution adopted by the general assembly on 6 July 2017, work of the statistical commission pertaining to the 2030 agenda for sustainable development*. 2017 (A/RES/71/313).

23. United Nations DESA: ***IAEG-SDGs - tier classification for global SDG indicators. United Nations, Department of Economic and Social Affairs, Statistics Division***. https://unstats.un.org/sdgs/iaeg-sdgs/tier-classification/.

24. Swain RB: **A critical analysis of the sustainable development goals**. In *Handbook of sustainability science and research*. Edited by Leal Filho W, Springer, World Sustainability Series; 2018, https://doi.org/10.1007/978-3-319-63007-6_20.

25. Roche J, *et al.*: **Citizen science, education, and learning: challenges and opportunities**. *Front Sociol* 2020, **5**.

26. * Shulla K, Leal Filho W, Sommer JH, Salvia AL, Borgemeister C: **Channels of collaboration for citizen science and the sustainable development goals**. *J Clean Prod* 2020, **264**, 121735.
This study explores and provides a framework for five collaboration channels of interaction between CS and SDGs. The model is based on different approaches (top-down and bottom-up) and involves specific actions, main actors, and potential collaborations.

27. de Sherbinin A, Bowser A, Chuang TR, Cooper C, Danielsen F, Edmunds R, Elias P, Faustman E, Hultquist C, Mondardini R, Popescu I, Shonowo A, Sivakumar K: **The critical importance of citizen science data**. *Front Clim* 2021, **3**:20.

28. ** Fraisl D, Campbell J, See L, Wehn U, Wardlaw J, Gold M, Moorthy I, Arias R, Piera J, Oliver JL, Masó J, Penker M, Fritz S: **Mapping citizen science contributions to the UN sustainable development goals**. *Sustain Sci* 2020, **15**:1735–1751.
The paper is currently the most complete analysis on the contribution of citizen science to SDG monitoring at the indicator level. It offers the results of a systematic review of the complete set of 244 SDG indicators, mapping and documenting where CS projects are already providing data for the monitoring (5 SDG indicators) and where they could potentially do so (76 SDG indicators).

29. Pernici B: **CROWD4SDG: Crowdsourcing for sustainable developments goals**. In *Book of short papers SIS 2020.* Edited by Pollice A, Salvati N, Schirripa Spagnolo F, Pearson; 2020: 248–252.

30. **Our world – our goals: citizen science for the sustainable development goals", CS SDG declaration, from the conference: knowledge for change: a decade of citizen science (2020-2030)**. In *Support of the SDGs*; 2020. https://survey.naturkundemuseum-berlin.de/sites/default/files/uploads/Citizen%20Science%20SDG%20Declaration.pdf; 2020.

31. Fritz S, See L, Carlson T, Haklay MM, Oliver JL, Fraisl D, … West S: **Citizen science and the United Nations sustainable development goals**. *Nat Sustain* 2019, **2**:922–930.

32. Leal Filho W, Tripathi SK, Andrade Guerra JBSOD, Giné-Garriga R, Orlovic Lovren V, Willats J: **Using the sustainable development goals towards a better understanding of sustainability challenges**. *Int J Sustain Dev World Ecol* 2019, **26**: 179–190.

33. Mensah J: **Sustainable development: meaning, history, principles, pillars, and implications for human action: literature review**. *Cogent Soc Sci* 2019, **5**, 1653531.

34. ** Ballerini L, Bergh SI: **Using citizen science data to monitor the Sustainable Development Goals: a bottom-up analysis**. *Sustain Sci* 2021, **16**, https://doi.org/10.1007/s11625-021-01001-1. 1945–1962.
This article discusses the potential and difficulties for linking CS data with the SDGs by including the voices of key stakeholders involved in a set of 30, CS case-study projects. The article shows that CS has powerful local impacts in educating and engaging communities, thus providing a much-needed local and contextual dimension to SDG global monitoring.

35. * Sauermann H, Vohland K, Antoniou V, Balázs B, … Winter S: **Citizen science and sustainability transitions**. *Res Pol* 2020, **49**, 103978.
The paper evaluates the potential of CS to support complex sustainability transitions in areas such as renewable energy, public health, or environmental conservation, by integrating the "productivity view" and the "democratization view" of CS.

36. West S, Pateman R: *How could citizen science support the sustainable development goals? Policy brief.* York, UK: Stockholm Environment Institute; 2017. Available online: https://www.sei.org/publications/citizen-science-sustainable-development-goals/.

37. Campbell J, Neuner J, See L, Fritz S, Fraisl D, Espey J, Kim A: **The role of combining national official statistics with global monitoring to close the data gaps in the environmental SDGs**. *Stat J IAOS* 2020, **36**:443–453.

38. * Ajates R, Hager G, Georgiadis P, Coulson S, Woods M, Hemment D: **Local action with global impact: the case of the grow observatory and the sustainable development goals**. *Sustainability* 2020, **12**, 10518.
This article reports on Citizen Observatories' (COs) potential to contribute to the SDGs framework, providing evidence not only at the indicator level but also at goal and target ones, moving thus beyond quantitative data.

39. Schleicher K, Schmidt C: **Citizen science in Germany as research and sustainability education: analysis of the main forms and foci and its relation to the sustainable development goals**. *Sustainability* 2020, **12**:6044.

40. Koffler S, Barbiéri C, Ghilardi-Lopes NP, Leocadio JN, Albertini B, Francoy TM, Saraiva AM: **A buzz for sustainability and conservation: the growing potential of citizen science studies on bees**. *Sustainability* 2021, **13**:959, https://doi.org/10.3390/su13020959.

41. Head JS, Crockatt ME, Didarali Z, Woodward MJ, Emmett BA: **The role of citizen science in meeting sdg targets around soil health**. *Sustainability* 2020, **12**, 10254, https://doi.org/10.3390/su122410254.

42. Lepenies R, Zakari I: **Citizen science for transformative air quality policy in Germany and Niger**. *Sustainability* 2021, **13**: 3973, https://doi.org/10.3390/su13073973.

43. Calyx C: **Sustaining citizen science beyond an emergency**. *Sustainability* 2020, **12**:4522, https://doi.org/10.3390/su12114522.

44. Asingizwe D, Murindahabi MM, Koenraadt CJM, Poortvliet PM, van Vliet AJH, Ingabire CM, Hakizimana E, Mutesa L, Takken W, Leeuwis C: **Co-designing a citizen science program for malaria control in Rwanda**. *Sustainability* 2019, **11**:7012, https://doi.org/10.3390/su11247012.

45. Bishop IJ, Warner S, van Noordwijk TCGE, Nyoni FC, Loiselle S: **Citizen science monitoring for sustainable development indicator 6.3.2 in England and Zambia**. *Sustainability* 2020, **12**: 1–15.

46. Quinlivan L, Chapman DV, Sullivan T: **Applying citizen science to monitor for the sustainable development goal indicator 6.3.2: a review**. *Environ Monit Assess* 2020, **192**:1–11.

47. Hegarty S, Hayes A, Regan F, Bishop I, Clinton R: **Using citizen science to understand river water quality while filling data gaps to meet United Nations Sustainable Development Goal 6 objectives**. *Sci Total Environ* 2021, **783**, 146953.

48. Queiruga-Dios MÁ, López-Iñesta E, Diez-Ojeda M, Sáiz-Manzanares MC, Vázquez Dorrío JB: **Citizen science for scientific literacy and the attainment of sustainable development goals in formal education**. *Sustainability* 2020, **12**:4283.

49. Kythreotis AP, Mantyka-Pringle C, Mercer TG, Whitmarsh LE, Corner A, Paavola J, Chambers C, Miller BA, Castree N: **Citizen social science for more integrative and effective climate action: a science-policy perspective**. *Front Environ Sci* 2019, **7**: 10.

50. Batsaikhan A, Hachinger S, Kurtz W, Heller H, Frank A: **Application of modern web technologies to the citizen science project BAYSICS on climate research and science communication**. *Sustainability* 2020:12, https://doi.org/10.3390/SU12187748.

51. Wuebben D, Romero-Luis J, Gertrudix M: **Citizen science and citizen energy communities: a systematic review and potential alliances for SDGs**. *Sustainability* 2020, **12**, 10096.

52. Kral RM, Maftukhah R, Mentler A, Murtiningrum M, Ngadisih N, Keiblinger KM: **Citizen science in the field: Co-experimentation at pilot scale for sustainable use of natural resources**. *Sustainability* 2020, **12**, https://doi.org/10.3390/su12187700.

53. Woods S, Daskolia M, Joly A, Bonnet P, Soacha K, Liñan S, Woods T, Piera J, Ceccaroni L: **How networks of citizen observatories can increase the quality and quantity of citizen-science-generated data used to monitor SDG indicators**. *Sustainability* 2022, **14**:4078, https://doi.org/10.3390/su14074078.

54. Moczek N, Voigt-Heucke SL, Mortega KG, Fabó Cartas C, Knobloch J: **A self-assessment of European citizen science projects on their contribution to the UN sustainable development goals (SDGs)**. *Sustainability* 2021, **13**:1774.

55. Rigler G, Dokou Z, Khadim F, Sinshaw B, Eshete D, Aseres M, Amera W, Zhou W, Wang X, Moges M, Azage M, Li B, Holzer E, Tilahun S, Bagtzoglou A, Anagnostou E: **Citizen science and the sustainable development goals: building social and technical capacity through data collection in the upper blue Nile basin, Ethiopia**. *Sustainability* 2022, **14**:3647, https://doi.org/10.3390/su14063647.

56. Parkinson S, Woods S, Sprinks J, Ceccaroni LA: **Practical approach to assessing the impact of citizen science towards the sustainable development goals**. *Sustainability* 2022, **14**: 4676, https://doi.org/10.3390/su14084676.

57. Pateman R, Tuhkanen H, Cinderby S: **Citizen science and the sustainable development goals in low and middle income country cities**. *Sustainability* 2021, **13**:9534, https://doi.org/10.3390/su13179534.

58. *Global taskforce of local and regional governments, united nations development programme and UN-habitat: roadmap for localizing the SDGs: implementation and monitoring at a subnational level*. 2016. https://unhabitat.org/roadmap-for-localizing-the-sdgs-implementation-and-monitoring-at-subnational-level.

59. Salvia AL, Leal Filho W, Brandli LL, Griebeler JS: **Assessing research trends related to Sustainable Development Goals: local and global issues**. *J Clean Prod* 2019, **208**:841–849.

60. Mačiulienė M, Butkevičienė E: **The ecosystem approach in addressing sustainable development goals through citizen science in Lithuania**. *Sustainability* 2022, **14**:2155, https://doi.org/10.3390/su14042155.

61. Cázarez-Grageda K, Schmidt J, Ranjan R: **Reusing citizen-generated data for official reporting: a quality framework for national statistical office–civil society organization engagement**. In *PARIS21 Working Paper, PARIS21 Consortium*; 2020. Paris, https://paris21.org/sites/default/files/inline-files/CGD_FINAL.pdf; 2020.

62. Gunnell JL, Golumbic YN, Hayes T, Cooper M: **Co-created citizen science: challenging cultures and practice in scientific researchCo-created citizen science: challenging cultures and practice in scientific research**. *J Clin Outcome Manag* 2021, **20**: Y01, https://doi.org/10.22323/2.20050401. 05.

63. Norström AV, Cvitanovic C, Löf MF, West S, Wyborn C, Balvanera P, Bednarek AT, Bennett EM, Biggs R, de Bremond A, Österblom H: **Principles for knowledge co-production in sustainability research**. *Nat Sustain* 2020, **3**:182–190.

64. Turbé A, Barba J, Pelacho M, Mugdal S, Robinson LD, Serrano-Sanz F, Sanz F, Tsinaraki C, Rubio JM, Schade S: **Understanding the citizen science landscape for European environmental policy: an assessment and recommendations**. *Citiz Sci Theory Pract* 2019, **4**:34, https://doi.org/10.5334/cstp.239.

65. Harris C: **Looking to the future? Including children, young people and future generations in deliberations on climate action: Ireland's Citizens' Assembly 2016–2018**. *Innov Eur J Soc Sci Res* 2021, **34**:677–693.

66. Yamin P, Fei M, Lahlou S, Levy S: **Using social norms to change behavior and increase sustainability in the real world: a systematic review of the literature**. *Sustainability* 2019, **11**: 5847.

67. Schade S, Pelacho M, van Noordwijk T: **Citizen science and policy**. In *The science of citizen science*. Edited by Vohland K, Land-Zandstra A, Ceccaroni L, Lemmens R, Perelló J, Ponti M, Samson R, Wagenknecht K, Cham: Springer; 2021, https://doi.org/10.1007/978-3-030-58278-4_18.

68. Sprinks J, Woods SM, Parkinson S, et al: Coordinator perceptions when assessing the impact of citizen science towards sustainable development goals. Sustainability, Volume 13, Issue , February 2021, Article number 2377

69. * Heinisch B: **Knowledge translation and its interrelation with usability and accessibility. Biocultural diversity translated by means of technology and language—the case of citizen science contributing to the sustainable development goals**. *Sustainability* 2020, **13**:54.

This paper applies the concept of knowledge translation to frame citizen science as a mediator between the public and policymakers. Exemplified by biocultural diversity, the analysis points to the need for CS guided by the SDGs to adopt forms of knowledge ((and) translation) that are useable, accessible, and meaningful.

70. Ferrari CA, Jönsson M, Gebrehiwot SG, Chiwona-Karltun L, Mark-Herbert C, Manuschevich D, Powell N, Do T, Bishop K, Hilding-Rydevik T: **Citizen science as democratic innovation that renews environmental monitoring and assessment for the sustainable development goals in rural areas**. *Sustainability* 2021, **13**:2762, https://doi.org/10.3390/su13052762.

71. Montanari M, Jacobs L, Haklay M, Donkor FK, Mondardini MR: **Agenda 2030's, "Leave no one behind," in citizen science?** *J Sci Commun* 2021, **20**, https://doi.org/10.22323/2.20060207 (06) A07-A07.

72. Loreto V, Haklay M, Hotho A, Servedio VDP, Stumme G, Theunis J, Tria F. *Participatory sensing, opinions and collective awareness*. Cham Springer International Publishing; 2017, https://doi.org/10.1007/978-3-319-25658-0.

73. Bartar P: **Artistic knowledge production for another planet? Participation as cultural practice and scientific approach for quality enhancement in citizen science**. *Front Environ Sci* 2016, **4**.

74. Grootjans S, Stijnen M, Kroese M, Ruwaard D, Jansen M: **Citizen Science in Blue Care: a partnership between research, practice, policy and the community**. *Int J Integrated Care* 2019, **19**:1–8, https://doi.org/10.5334/ijic.s3432. A432.

75. King AC, Odunitan-Wayas FA, Chaudhury M, Rubio MA, Baiocchi M, Kolbe-Alexander T, Montes F, Banchoff A, Sarmiento OL, Bälter K, Gardiner PA: **On behalf of the our voice global citizen science research network. Community-based**

approaches to reducing health inequities and fostering environmental Justice through global youth-engaged citizen science. *Int J Environ Res Publ Health* 2021, **18**:892, https://doi.org/10.3390/ijerph18030892. Jan 21.

76. Ostermann-Miyashita EF, Pernat N, König HJ: **Citizen science as a bottom-up approach to address human−wildlife conflicts: from theories and methods to practical implications**. *Conserv Sci Prac* 2021, **3**:e385, https://doi.org/10.1111/csp2.385.

77. * Hetland P, Pierroux P, Esborg L: *A history of participation in museums and archives: traversing citizen science and citizen humanities*. London: Routledge; 2020.

This book provides a framework and a collection of essays for understanding how participatory modes in natural, cultural, and scientific heritage institutions intersect with practices in citizen science and citizen humanities.

78. Bailo F: *Online communities and crowds in the rise of the five star movement*. London: Palgrave Macmillan; 2020.

79. Dosemagen S, Parker A: **Citizen science across a spectrum: building partnerships to broaden the impact of citizen science**. *Sci Technol Stud* 2019, **32**:24−33.

80. Butcher S: **Urban equality and the SDG's. Three provocations for a relational agenda**. *Int Dev Plann Rev* 2021:14−32.

81. Roberts R: *Unbearable sensualities*. New York: Wesleyan University Press; 2021.

82. * Liebenberg LA, Lombard M, Shermer M, Uase Xhukwe, Biesele M, Xao D, Carruthers P, ≠Oma Kxao, Hansson SO, Langwane H, Karoha, … Voysey M: **Tracking science: an alternative for those excluded by citizen science**. *Citiz Sci Theory Pract* 2021, **6**:6, https://doi.org/10.5334/cstp.284.

Exploring and queering the boundaries of participation, this paper proposes the new term “tracking science” to take account of issues of postcoloniality and inclusion of alternative ways of knowing in citizen science practices.

83. Collazo Expósito LM, Granados Sánchez J: **Implementation of SDGs in university teaching: a course for professional development of teachers in education for sustainability for a transformative action**. *Sustainability* 2020, **12**:8267.

84. Bilsky E, Calvete Moreno A, Fernández Tortosa A: **Local governments and SDG localisation: reshaping multilevel governance from the bottom up**. *J Human Develop Capab* 2021, **22**:713−724.

85. Latulippe N, Klenk N: **Making room and moving over: knowledge co-production, Indigenous knowledge sovereignty and the politics of global environmental change decision-making**. *Curr Opin Environ Sustain* 2020, **42**:7−14.

86. Gobbato Leichtweis M, Schirmer Soares R: **Designing the 5P lens - a tool for critical reflection on the cultural dimensions of Agenda 2030**. In *28th International Sustainable Development Research Society Conference, Stockholm*; 2022. 15-17 June.