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Recent contributions of Citizen Science on sustainability policies: a critical review

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Abstract (100-120 words)
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.

keywords (max 6)
citizen science, sustainability, policy-making, SDGs, participatory research, top-down/bottom-up approach

Declaration of interest: none

Highlights

- Literature reveals a wide range of intersections between CS and sustainability policies
- Here we present a critical review of the most recent approaches on the subject
- CS constitutes a new possible data source for SDGs monitoring and reporting
- CS activities contribute to the design and implementation of sustainability policies
- Numerous efforts are underway to integrate CS in policymaking for sustainability

1. 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].

Box1: **The concepts behind citizen science**
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 amongst different disciplines and research communities [3, 4, 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, 6, 7]. However, issues of data quality [8, 9, 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 centred on CS as a process for reinventing the way knowledge is produced, distributed and acted upon [16].

Recent decades have seen a growth of interest in CS due to its interfacing role between public policies and citizens' experiences [17, 18, 19, 20], particularly in relation to promoting a deeper engagement of society with sustainability policies.

On 25 September 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).

Box2: **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 Sustainable Development Goals (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: (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, (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 5 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/].

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 towards 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 level [*26]. This is currently an open terrain for research and debate, which is evidenced by the rise of working groups, conferences and editorial contributions focussed on the possible convergence between CS and SDGs (see Box 3).

Box3: **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 focussed on assessing the potential of citizen science to inform SDG decision-making, and to combine Earth Observation and citizen science data [**28]. The *CROWD4SDG* Innovation Action supported by the *European Commission's Science with and for Society* (SwafS) programme promotes the development of CS projects aimed at tackling the SDG's, 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; and 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 31 October 2020), and *Citizen Science Projects for Environmental Challenges and Sustainable Development Goals* (https://www.mdpi.com/journal/sustainability/special_issues/citizen_science_sdg, closed 31 December 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/)

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 which 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.

2. Interactions between CS and local and global sustainability policies

2.1 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 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 5 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]. The literature discusses and documents the potential of CS to produce relevant inputs particularly for goal 15 (Life on land) [*38, 39, 40, 41, **28 Fraisl et al. 2020], 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, 46, 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, 54, 55, 56, 57, 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 towards 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].

2.2 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 e.g. 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 Programmes 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, 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 neighbours).

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; and (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 focussed 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 towards 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 judgements 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].

2.3 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' towards 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' citizen science - 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 amongst 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]. Emerging literature points to the inclusion of under-represented voices in public debates, including those of youth in non-western countries [76] and marginalised 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 towards the SDGs [80]. A more significant shift at this level is that of recognising 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]. Recognising knowledge as embodied, contextual and discursive opens up new avenues for transformative [*82, 83] multi-level governance in CS for SDG's [84]. Emerging literature points to 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 to 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].

3. CONCLUSIONS

This review highlights 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.

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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).

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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.

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Recent contributions of Citizen Science in sustainability policies: a critical review

Laura Criscuolo, Alba L'Astorina (corresponding author), René van der Wal, Laura Colucci Gray

Highlights (3 to 5 bullet points, max 85 characters, including spaces, per bullet point)

- Literature reveals a wide range of intersections between CS and sustainability policies
- Here we present a critical review of the most recent approaches on the subject
- CS constitutes a new possible data source for SDGs monitoring and reporting
- CS activities contribute to the design and implementation of sustainability policies
- Numerous efforts are underway to integrate CS in policymaking for sustainability

Conflict of interests

☒ The authors declare that they have no conflict of interests or personal relationships that could have appeared to influence the work reported in this paper.

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