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Article

Local Action with Global Impact: The Case of the GROW Observatory and the Sustainable Development Goals

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Abstract: This article reports on Citizen Observatories' (COs) potential to contribute to the Sustainable Development Goals (SDGs), reflecting on the experience of the GROW Observatory (GROW). The research aims to take the first steps in closing the gap in the literature on COs' potential contributions to the SDG framework, beyond quantitative data contributions for indicator monitoring. Following an analysis of project activities and outcomes mapped against the SDG framework, the findings reveal GROW's potential contributions across two dimensions: (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. While earlier research has focused mostly on the latter (dimension ii), CO activities can impact numerous goals and targets, highlighting their potential to relate global SDGs to local level action, and vice versa. These findings align with the growing literature on COs' ability to bring together policy makers, scientists and citizens, and support changes to environmental policy and practice. Furthermore, this research suggests groundwork activities that address the goal and target level can also enhance sustained data collection to contribute to indicator level monitoring. We conclude with future trends and recommendations for COs wishing to contribute to the SDGs.

Keywords: Citizen Observatory; Sustainable Development Goals; participatory policy making; co-design; citizen science; SDG indicators; open data

1. Introduction

1.1. The United Nations Sustainable Development Goals (SDGs)

The United Nations Sustainable Development Goals (SDGs) are seen as “a global blueprint for dignity, peace and prosperity for people and the planet, now and in the future” [1]. The 17 SDGs address global challenges related to poverty, inequality, climate change, environmental degradation, prosperity, peace and justice. The Goals are interconnected, and global ambition is to achieve all of them by 2030. They include 169 targets and 244 indicators established by the UN General Assembly [2] to monitor progress. The UN classified each of the 244 indicators across three tiers that reflect the existence or lack of an agreed methodology to track progress [3].

While the high level goals and targets offer a generic ambition and allow for a great diversity of actions to achieve them, indicators provide specific, better defined measures and clearer interpretation for monitoring progress. While monitoring efforts occur at different levels, from local to global, the main responsibility for SDG indicator monitoring lies with national governments. Official statistics are normally based on data officially collected by state authorities e.g., through surveys, censuses and official sensors [4–6].

1.2. Citizen Observatories: The Case of the GROW Observatory

Citizen Observatories (COs) build on citizen science methodologies to engage citizens in community-based environmental monitoring [7]. Four COs were funded by the European Commission in the framework of the Horizon 2020 research and innovation programme [8], building on existing technology-enabled mechanisms to promote participatory environmental governance, such as Europe for Citizens, eGovernment Action Plan 2016–2020, Debating Europe and The Futurium Platform [9]. COs are participatory initiatives led by transdisciplinary teams, train citizen scientists on data collection and analysis, often through sensors and other widely available technology. COs address major societal and environmental challenges such as soil health, air quality, biodiversity decline, and natural disasters by providing valuable data for sustainable environmental management and policy making, that are often not available from conventional sources [10,11].

This research focuses on GROW Observatory, a CO for soil health and climate action implemented between November 2016 and October 2019, with some participating communities still continuing to collect data today. GROW embraced digital technology to address three key global challenges: (i) scaling up citizen science from local to globally coordinated efforts; (ii) improving data literacy by providing robust and open access education on citizen science to thousands of learners worldwide; and (iii) performing in-situ measurements to validate soil moisture data from remote sensing, specifically, Sentinel-1 satellites (“ground-truthing”). This work gave rise to a central database with hundreds of millions of soil measurements and land observations, delivering Europe’s largest citizen-led soil moisture survey and an invaluable source of open data for Earth Observation.

Twenty four GROW Places in thirteen EU countries formed a community management framework through a network of Community Champions [12]. Besides contributing soil moisture data to the CO through sensors connected to their personal mobile devices, citizens also had opportunities for peer-peer learning, sensing and citizen science. At the global level, GROW linked people from all corners of the world interested in food growing, open data, citizen science and citizen sensing, digital art and environmental policy.

Approximately 70 out of the 169 targets are related to food systems [13]. Although it was not initially mapped against the SDG framework, the GROW project focused on mainstreaming climate action, promoting sustainable farming and soil conservation practices, and protecting against extreme weather events linked to climate change. Thus, the assumption was that GROW and other COs working on environmental topics were particularly well positioned to make contributions to several of these food and environment related targets. At the time of the adoption of the SDGs as a policy framework at the subnational, national and global level in September 2015, GROW was already defined as a proposition. Since November 2016, GROW evolved from proposition to implementation and delivery, identifying and realising concrete connections with the SDGs. With this paper, we aim to contribute to the growing literature on how COs can contribute to SDG monitoring and SDG implementation.

1.3. The Rise of Citizen-Generated Datasets and Their Contribution to the SDGs

COs, by definition, can enhance environmental monitoring capacity by largely increasing the data collection and validation points for all kinds of variables. The inclusion of citizen-led approaches into SDG monitoring has the potential to provide data at larger and finer spatial and temporal scales that would otherwise be impossible to obtain through due to lack of resources and conventional data collection approaches, thanks to the engagement of place-based communities across different

geographies [6,14]. By making citizens the core element of observatories, COs can contribute to more timely and effective implementation of the SDGs by engaging large numbers of citizens and communities into scoping, monitoring and solving some of the most urgent and pressing challenges they seek to address. Nevertheless, citizen science methodologies and data are not yet accepted as standard sources for SDG monitoring and reporting, although reasons to use them are increasingly being presented [14–17]. Despite the expanding number of available datasets, 68 percent of the 93 environmental SDG indicators cannot yet be measured due to a lack of relevant data [18].

Recently published research provides systematic evidence on areas where citizen science is currently contributing, or where it could potentially contribute to SDG indicator monitoring [6,14]. Fraisl and colleagues [6] found that citizen science is “already contributing” to the monitoring of five SDG indicators and that it “could contribute” to 76 of them, collectively equating to around 33 percent of the total number of SDG indicators. The greatest opportunities identified relate to SDG 15-Life on Land (64 percent), SDG 11-Sustainable Cities and Communities (60 percent), SDG 3-Good Health and Wellbeing (56 percent), and SDG 6-Clean Water and Sanitation (55 percent).

Despite this new evidence on current and potential contributions of citizen science and COs to SDG indicator monitoring, there are no systematic assessments of their application in actions for implementing and achieving the SDGs at goal and target level. This paper provides the first empirical evidence in this area, by examining and illustrating the potential range of contributions of COs and citizen science to the entire SDG framework. First, we describe the methods and data used. Then, we present evidence from a case study across two dimensions: (A) Actions that can facilitate the implementation and achievement of SDG goals and targets and (B) Data contributions to SDG monitoring at indicator level. After presenting the results of the analysis, we discuss how the findings relate to the wider field of COs and citizen science, presenting the guiding principles that can support current and future citizen science projects contributing or wishing to contribute to the SDGs. We conclude by acknowledging the limitations of this research, with recommendations for future research for existing and new CO concepts willing to contribute to global efforts towards the SDGs.

2. Methods and Data

To gain insights on GROW’s contributions to the SDG framework, goals and targets, a selection of project data sources were examined. We analysed project deliverables, citizen-generated datasets, multimedia resources (videos, training handbooks, etc.), GROW Massive Open Online Courses (MOOCs) statistics and the final report to the European Commission to create a list of project activities, outcomes, citizen science datasets and resources that were then mapped against the SDG framework. Additionally, we reflected on our direct participation in project planning meetings, work packages, general assembly and public project events and activities from November 2016 to October 2019. Below we describe the data sources for each of the two analytical lenses applied.

2.1. Actions that Can Facilitate the Implementation and Achievement of SDG Goals and Targets

Building on Fraisl et al. [6], we have adapted their generic approach for mapping citizen-generated datasets against SDG indicators. Furthermore, we extend its application to also map project activities and outcomes against SDG targets, in a novel attempt to identify their impact potential at the target level. For this mapping exercise, we reviewed the following project deliverables:

- Deliverable 1.4-GROW Observatory: Mission Outcomes [19]
- Deliverable 2.4-GROW Community Champions Programme [12]
- Deliverable 3.2-Replicability of the GROW Citizen Observatory outside EU Borders (Confidential)
- Deliverable 4.3-Report on science experiments and protocols and the collective creation of knowledge in GROW Missions [20]
- GROW Observatory Summary Report [21]
- GROW promotional, reporting and training videos [22]

- GROW MOOC statistics-provided by FutureLearn (GROW online course provider)
- GROW Knowledge Base resources [23–25]

The analysed data included detailed descriptions of project activities that were held during the preparatory and implementation phases of GROW as well as project outcomes and outputs. The activities and outcomes that were identified as part of this exercise were then examined further and clustered into several activity categories to distil common characteristics amongst them.

2.2. Data Contributions to SDG Monitoring at Indicator Level

We further built on the approach reported by Fraisl et al. [6] for evaluating the potential suitability of specific GROW datasets for SDG indicator monitoring, considering three possible outcomes: (i) providing data for monitoring indicators and sub-indicators; (ii) providing relevant supplementary data, or (iii) no alignment with SDG indicators. Where alignment was possible, we extended the baseline analysis and added fine-grained detail by mapping each relevant dataset against specific indicators, sub-indicators, or supplementary indicator information. Table 1 outlines the citizen-generated datasets considered for this analysis (see [26] for more details).

Table 1. GROW datasets used for analysis.

Dataset	Description
Soil data	A time series dataset, stemming from 6500 validated consumer sensors [27] and containing 516 M rows of soil data with the following parameters: soil moisture (percent, 5–10 cm depth), above ground temperature (degrees Celsius, 10 cm) and above ground light level (lumens, 10 cm), and metadata: latitude and longitude of the sensor, name of the sensor and date of observation. The data were collected by community groups, land managers, small scale and family farmers, and others across 24 GROW Places, in 13 EU countries from November 2017 to October 2019 using mobile phones [12]. GROW's citizen-generated Soil Moisture Data [28] have been used in satellite validation and the evaluation of Sentinel-1 products [29].
Land and land management data	This dataset, collected using the GROW Observatory mobile app, accompanied the soil data (see above). It contains data on land use, land cover and topography, as well as specific documentation of land management practices, such as irrigation, fertilizer use or tillage (dataset not published).
Edible plant data	The Edible Plant Database [30] provides location-specific plant information of 146 edible plant species across 12 European climate zones, consisting of plant specific fields, such as botanical name, common name, water requirements, soil requirements etc.; location information as well as location-specific growing information, such as planting and harvesting dates for indoors/undercover or outdoors cultivation. Some planting and harvesting dates were crowd-validated, or crowd-updated through a dedicated "Share my planting Calendars" Facebook group activity and incorporated as such in the database.
Polyculture experiment data	The polyculture dataset contains location and time-based yield data for three different crops growing in two plots, additional data on soil texture, stone content, topography and canopy cover, plus other observational data as well as crop management interventions (dataset not published). The data were collected by hobby growers as part of a hypothesis-driven citizen science experiment to investigate yield differences of small monoculture versus polyculture growing plots for three crops.

3. Findings

In this section, we present the findings of the qualitative and quantitative analysis of the project activities and outcomes in relation to the SDG framework. First, we cover the qualitative findings at the SDG goal and target level, followed by the results on GROW's quantitative data contributions to SDG indicator monitoring.

Sections 3.1 and 3.2 outline two main types of potential contributions of COs to the SDG framework in detail. Section 3.1 presents an analysis across five kinds of activities that took place during the entire cycle of setting up and running the CO, aiming -amongst others- to support the generation of locally meaningful, globally relevant datasets: From-data-to-action activities; new connections between communities and policy actors; design and application of participatory methods; awareness raising activities; and empowering citizens to take positive climate action. Section 3.2 reports on the findings of mapping specific GROW citizen-generated datasets against SDG indicators and sub-indicators.

While GROW data for indicator monitoring could potentially support four out of 169 (2.4 percent) targets across three goals, GROW activities could potentially support 39 targets out of 169 (23.1 percent) across 14 goals (Table S1). Furthermore, it became apparent that GROW datasets could serve in two ways: both for SDG monitoring and goal/target implementation, or for goal/target implementation only. Table 2 below summarises these results, highlighting where GROW activities contribute to targets, as well as which targets could also be supported by GROW data for indicator monitoring.

Table 2. Potential contributions of GROW activities and data to Sustainable Development Goals (SDG) framework (green: activity contributions at target level; blue: activity contribution at target level and data contributions at indicator level; left of black bar: “outcome” targets, i.e., circumstances to be attained, left of black bar: “means of implementation” targets).

Goals	Targets																		
1	1.1	1.2	1.3	1.4	1.5	1.a	1.b												
2	2.1	2.2	2.3	2.4	2.5	2.a	2.b	2.c											
3	3.1	3.2	3.3	3.4	3.5	3.6	3.7	3.8	3.9	3.a	3.b	3.c	3.d						
4	4.1	4.2	4.3	4.4	4.5	4.6	4.7	4.a	4.b	4.c									
5	5.1	5.2	5.3	5.4	5.5	5.6	5.a	5.b	5.c	5.d									
6	6.1	6.2	6.3	6.4	6.5	6.6	6.a	6.b											
7	7.1	7.2	7.3	7.a	7.b														
8	8.1	8.2	8.3	8.4	8.5	8.6	8.7	8.8	8.9	8.10	8.a	8.b							
9	9.1	9.2	9.3	9.4	9.5	9.a	9.b	9.c											
10	10.1	10.2	10.3	10.4	10.5	10.6	10.7	10.a	10.b	10.c									
11	11.1	11.2	11.3	11.4	11.5	11.6	11.7	11.a	11.b	11.c									
12	12.1	12.2	12.3	12.4	12.5	12.6	12.7	12.8	12.a	12.b	12.c								
13	13.1	13.2	13.3	13.a	13.b														
14	14.1	14.2	14.3	14.4	14.5	14.6	14.7	14.a	14.b	14.c									
15	15.1	15.2	15.3	15.4	15.5	15.6	15.7	15.8	15.9	15.a	15.b	15.c							
16	16.1	16.2	16.3	16.4	16.5	16.6	16.7	16.8	16.9	16.10	16.a	16.b							
17	17.1	17.2	17.3	17.4	17.5	17.6	17.7	17.8	17.9	17.10	17.11	17.12	17.13	17.14	17.15	17.16	17.17	17.18	17.19

3.1. Actions to Advance SDGs Goals and Targets

An alignment between many of the project’s activities and outcomes with several SDG goals and targets was identified. GROW’s citizen science missions (periods of coordinated citizen science activities), learning resources and public events were relevant to 14 SDG goals and 39 targets. This covers a considerable number of goals and targets, namely 82.4 percent of total goals and 23.1 percent of total targets. Table S1 offers a detailed mapping of the contributions of GROW Observatory activities that help to advance towards specific SDGs, at goal and target level.

Furthermore, the following activity categories emerged from the set of individual actions and outputs and highlight common characteristics of activities that hold contribution potential for SDG implementation:

- From-data-to-action activities: Project activities designed (a) to train citizens to use sensors and collect other land and growing data, and (b) to move beyond quantitative data collection, such as Insights Workshops and MOOCs, to support participants in gaining new skills and to identifying trends and actionable insights from collected soil and growing data.

- Activities to generate new connections between communities and policy actors, including GROW multi-stakeholder policy events in several countries, the involvement of policy institutions in soil sensing activities, and new links with Departments of Agriculture and National Statistics Offices.
- Participatory design methods: These included GROW's citizen science experiments and data visualisations designed with citizens' input, as well as a novel methodology and card set tool created by GROW to support the co-design of future COs in the context of SDGs.
- Awareness raising activities: project actions (see the mapping of specific activities against SDG goals and targets in Table S1) and online activity allowed GROW to reach 7.8 Million people, including through public events, social media posts and videos and free MOOCs.
- Empowering citizens to be involved in climate action in a positive and constructive manner: offering a sliding scale of participation in the CO from shorter one-off activities, to more time demanding citizen science opportunities, including enrolling on free courses, joining GROW Places, attending webinars or face to face events, etc.

A detailed description of CO activities relevant to the SDGs to support the above categories can be found in Table S2.

3.2. Data Contributions to SDG Indicator Monitoring

In this section, we provide more detail to current efforts to assess the contribution of COs' datasets to the monitoring of specific SDG indicators [6]. The analysis of GROW datasets against SDG indicators [3] revealed that three of them (soil data, land and land management data, polyculture experiment data) could, in principle, directly contribute to the monitoring of four SDG indicators, namely indicator 2.4.1 (Tier II), 11.3.1 (Tier II), 15.1.1 (Tier I) and 15.3.1 (Tier I), and especially to a number of their sub-indicators. This observation also evolves insights reported by Fraisl et al. [6], who had identified the potential contribution of GROW Observatory data to only two indicators (2.4.1 and 15.3.1). This also suggests that their assessment of potential citizen science data contributions may lie at the lower end of the actual contribution potential of citizen science towards SDG monitoring.

The remaining GROW dataset (Edible Plant Database) does not show potential for contributing to SDG monitoring, although it can aid the implementation of the SDGs at the goal and target level (see Table S1). A description of the datasets mapped to the most relevant SDG indicators the data could contribute to can be found in Tables S3–S6. Below we offer a summary of these identified links between GROW's datasets and different indicators:

3.2.1. SDG 2: Zero Hunger—Indicator 2.4.1: Proportion of Agricultural Area under Productive and Sustainable Agriculture

Two citizen-generated datasets collected as part of GROW could directly feed into the monitoring of Tier II Indicator 2.4.1 (Tier II): Proportion of agricultural area under productive and sustainable agriculture [31]. These are the soil moisture dataset as well as the land and land management dataset. The area under productive and sustainable agriculture is further composed of 11 sub-indicators capturing environmental, economic and social dimensions of sustainable production. In detail, GROW data could directly contribute to the denominator of the indicator through land use and land cover data, as well as to four of the sub-indicators that correspond to the indicator's nominator (see Table S3).

3.2.2. SDG 11: Sustainable Cities and Communities—Indicator 11.3.1 Ratio of Land Consumption Rate to Population Growth Rate

This land dataset could potentially contribute to monitoring Indicator 11.3.1 (Tier II): Ratio of land consumption rate to population growth rate, which is also referred to as "land use efficiency" [32]. GROW data could contribute to monitoring land consumption via the three linked sub-indicators (see Table S4).

3.2.3. SDG 15: Life on Land Monitoring—Indicator 15.1.1: Forest area as a Proportion of Total Land area

The land dataset of GROW could potentially contribute to monitoring the Indicator 15.1.1 (Tier I): Forest area as a proportion of total land area (see Table S5). This indicator consists of two variables (forest area and total land area) with no relevant sub-indicators [33].

3.2.4. SDG 15: Life on Land—Indicator 15.3.1: Proportion of Land that is Degraded over Total Land Area

The soil moisture and the land datasets could potentially contribute to monitoring Indicator 15.3.1 (Tier I): Proportion of land that is degraded over total land area [34]. While total land area is considered to be a relatively simple variable, the complexity of land degradation and its conceptualisation poses challenges for monitoring. GROW could contribute to monitoring one of the three sub-indicators outlined for this part of the indicator (land cover, land productivity, carbon stock) (see Table S6).

To determine the extent of land degradation, national government authorities are invited to consult other information sources, such as Earth Observation and additional ground-based data. This should enable them to monitor a broader and more integrated set of variables linked to land degradation, including topography variables such as landscape, slope, orientation, farming practices, or soil properties [34]. GROW data on topography, soil moisture and land management at ground-level are also well positioned and suitable to provide such supplementary information for indicator monitoring.

4. Discussion

In this section, we discuss the above findings in relation to the existing literature and the wider implications for current and future COs wishing to contribute to global efforts to achieve the SDGs and how the SDG framework can be addressed more deliberately in the design and implementation of COs. The findings suggest that COs can contribute data not only for indicator monitoring but there is even greater potential—in terms of framework coverage, i.e. higher number of targets reached vs. lower number of contributions at indicator level—to aid action and implementation towards reaching the SDGs on the ground. Based on the activity categories identified in the Findings section, we discuss five guiding principles to a) reflect on GROW's contributions to the SDGs, and b) with the view to support current and future citizen science projects contributing or wishing to contribute to the SDGs: Working towards the SDGs as a coherent integrated framework; fostering multilevel governance connections; co-designing for meaningful long term engagement; maintaining COs as spaces to facilitate relevant debates; and offering opportunities for proactive, enjoyable and measurable climate action.

4.1. Considering the Multilevel Contribution of Citizen Science to the SDG Framework beyond Indicator Monitoring

The mapping exercise revealed that several CO activities potentially contributed to more than one goal/target, highlighting cross-cutting benefits with multilevel impacts, such as the MOOCs and Insights Workshops (see discussion below and Table S1 for more details). This finding reveals the importance of considering the entire SDG framework, from indicators and sub-indicators, to goals and targets level. Data-related activities in COs (e.g. GROW's Insight Workshops to support citizens in becoming more confident with collecting and handling environmental open data) can support goal and target level action, beyond specific monitoring purposes by raising awareness and data literacy.

Furthermore, some GROW datasets (i.e. GROW Edible Plant Database) have great potential to aid the implementation of the SDGs at the goal and target level though they could not contribute to SDG monitoring directly. The crowdsourced character of the Edible Plant Database, along with other activities such as the MOOCs and multi-stakeholder local events, contributed applied knowledge for climate change adaptation via locally relevant and up-to-date planting/harvesting dates as well as to community building and empowerment. These are essential steps to support collective efforts for climate adaptation and mitigation as well as enabling more sustainable and adaptive behaviours.

CO datasets can also play a significant role in the validation of conventional SDG monitoring data sources by providing complementary high-resolution data. A better understanding of SDG indicator and sub-indicator structures can enhance the impact of COs in attempts to support SDG progress and monitoring. Despite efforts to advance all indicators to Tier I, data validation remains a crucial bottleneck as discussed in GROW's contributions to specific indicators above [1,31–33]. The combination of different data sources is emerging as a more effective method to combine the strengths of citizen-generated data with traditional data sources such as single data sources (e.g. using farm survey data or remote sensing data only) [14,35,36]. Besides providing data at farm level, GROW demonstrated that citizen science can contribute to the validation of satellites, resulting in enhanced Earth Observation and remote sensing data for global climate monitoring [21] and validation of SDG monitoring sources.

4.2. Fostering Multi-Level and Multi-Stakeholder Policy Connections

The multi-faceted nature of a large-scale, international CO, such as GROW, can provide valuable inputs to policy frameworks [37]. For example, by seeking solutions to local challenges and advocating for more effective sustainability policies, GROW's communities explored the SDGs and environmental governance beyond their local or national realities. This integrated local-global outlook of COs provides an effective framework for policy improvements in the context of EU environmental, agricultural and climate policies. In this context, COs can potentially play a crucial and multi-functional role in shaping, disseminating and implementing a number of new EU policies, namely the EU Green Deal [38], the Farm to Fork Strategy [39], the EU Biodiversity Strategy [40] or the EU Climate Law [41].

Establishing new partnerships between COs and National Statistics Offices during the project design stage can help realise concrete CO contributions to participatory policy making, beyond the adoption of CO data for indicator monitoring. Creating such multi-stakeholder connections early in the project and prior to data collection—as described in the activities in Table S2 for GROW Place Ireland—fills a gap which can greatly enhance the impact of COs. However, challenges and barriers to the uptake of citizen-generated data for SDG monitoring, as outlined in Fraisl et al. [6], or other types of policy up-take, also apply to the case of GROW and likely to other COs' data. Very few citizen science and no CO projects have well established links with National Statistical Offices and government official observatories, nor formed partnerships to co-develop approaches that could meet the needs of both participating citizens and public institutions. There are no established organisational processes or robust infrastructures in place that could aid such a joint approach. Issues around data quality, data sparsity, incomplete data or a lack of suitable baseline data still pose considerable challenges. The harmonisation and/or successful integration of different data streams is a challenge in itself, but it becomes even more challenging when citizen-generated data are concerned. However, many promising activities are currently underway to standardise citizen science data [42] and to make it interoperable with more traditional data systems (e.g. GEOSS).

GROW and COs in general, are well positioned to establish links between citizen-generated environmental data and the underpinning socio-political transformations required for achieving the SDGs. Enabling citizen scientists to monitor and make sense of their own environment provides two advantages: the generation of locally relevant data to improve informed decision making for that area, as well as more engaged citizens through the training and data collection process. GROW activities, events and communities are a good illustration of a CO's potential to build local capacity in data literacy, while offering a space for citizens to participate in environmental governance and policy making. Policy events with a focus on the SDGs took place in Greece, Ireland, Belgium and Scotland (2018 and 2019), bringing together a broad range of actors from civil society to Members of the European Parliament and policy officers at the European Commission. These events provided a platform for initiating wider discussions, reconnecting citizens to science, and science to policy, as well as fostering mutual understanding. However, these opportunities also highlight the need for COs to be inclusive, ensuring that a wide range of stakeholders are engaged and represented in the process [43].

4.3. Collaborative Approaches for Meaningful Long Term Engagement and Impact

Citizen-led environmental monitoring with ambitions to contribute to the SDGs requires a degree of translation to highlight its relevance at the local level in order to achieve sustained engagement and impact. Those impacted most by the challenge at hand should be at the centre of shaping and delivering the monitoring initiative. Thus, planning the resources for, and adopting collaborative design methodologies reflects a commitment to prioritising participants' motivations and ambitions, making sure these are taken into consideration early in the project. Furthermore, by acknowledging and accommodating communities' needs and visions, projects can avoid using citizen scientists as unpaid assistants for low-cost SDG monitoring with no rights or access to the data they have collected [43,44].

The benefits of using deeper forms of participatory design in the field of environmental monitoring have been discussed in the literature [45–47]). However, toolkits and methodologies for activities in this area are still elusive [48], as recognised by many coordination initiatives and platforms providing space for shared tools and toolkits [49–53]. Gradually toolkits which develop and advocate for collaborative methodologies, and methods for environmental monitoring derived from participatory and empathy design [54,55] are becoming increasingly available [56–58]. GROW's co-design methodology and card set tool [59] are a contribution to this body of work, and serve to guide the co-creation and co-ideation of CO propositions and innovation prototypes aligned to the SDG framework. They were tested with diverse audiences in Brussels, London, Lisbon and Santiago de Chile.

In order to move away from satellite validation using citizen-generated sensor data as a mere contributory activity [60], the project introduced design-led activities and resources created to train and empower participants to produce and make sense of their own soil sensor and food growing data. This focus on "making sense" of data [56] to identify actionable insights that can improve practice and policy, led to the emergence of collegial citizen science activities across a number of communities [20,61].

Citizen scientists' continuing participation in soil moisture and edible plant data generation beyond the end of the project's funded period emphasises the importance of establishing a shared understanding and meaning of the community's purpose and contribution. Based on the GROW experience, a citizen-centred design approach for COs seems to translate into sustained participation. If citizens and other stakeholders feel ownership and recognition at desired levels, they are more likely to commit to a CO for the long term, creating win-win collaborations. This highlights how the groundwork activities at goal and target level can also potentially enhance sustained levels of data contributions and better data quality at indicator level.

4.4. Maintaining Citizen Observatories as Spaces for Debate

Due to its multifaceted nature, COs can also serve as a platform for overarching societal debates that relate to several aspects of the COs.

In 2019, a study identified that 68 percent of the 93 environmental SDG indicators cannot yet be measured due to a lack of relevant datasets [18]. Covering this large gap would require data collection at very wide spatial and temporal scales, which currently cannot be met by traditional science and current levels of investment in science [18]. The required scale of data collection and sharing can be achieved through citizen science and the use of technologies, such as hand-held devices and low-cost sensors. However, these opportunities also come with concerns. Vohland et al. [43] have analysed how citizen science may add to the neoliberalisation of science by using volunteers for data collection as a cheap way of filling gaps in conventional institutionalised science. Calls for revising the SDGs framework, decoupling them entirely from ideas of endless economic growth and adapting their relevance to current global crises, are already starting to emerge [62]. Therefore this debate needs to also consider inequalities linked with the exploitation of big open data [63,64] and particularly of big open citizen science datasets that perpetuate unsustainable visions of incessant economic growth [65].

The SDGs offer a coherent pathway for making progress towards social justice and the protection of human rights [66]. Though from an agrarian perspective, which was highly relevant to GROW

specifically, it is important to highlight the aspects and targets of the framework that might present food as a commodity and farming as a mere economic activity. Biocultural diversity, traditional practices, landscapes (rural and urban) and the aesthetic value of nature are often labelled as “development assets” in an attempt to monetise them. Thus, COs can potentially promote human-centered and commons-based approaches to current trends of digitisation of Europe’s agricultural sector [67], by fostering appropriate technology for different farming scales, open source sensors and technologies and peer-to-peer knowledge transfer (e.g. see Carlon, 2018 for an analysis of Farm Hacks, a worldwide community of farmers that builds and modifies their own tools). In this context, COs can also enhance the ongoing public debate on the use of open technologies and citizen-led innovation for democratising food systems [68].

COs are also well positioned to address some of the main risks to digital ecosystems for environmental resource management and the SDGs, identified by UNEP: monopolies of global datasets and “digital colonialism”; quality, transparency and openness of data and algorithms; protecting individual privacy, data security and intellectual property; and the direct environmental impacts of maintaining such huge combined data centres [18]. Data ownership and recognition of citizen scientist contributors are particularly important aspects in COs’ data collection, making COs an appropriate platform for addressing these risks and for testing alternative solutions, such as open data policies and outputs with creative commons licensing. Co-design approaches can help to find agreed solutions, and to explore what kind of rewards would be most appreciated by different types of contributors (e.g. attribution, training opportunities, promotion of own citizen science projects, etc).

In the context of GROW, it was also important to acknowledge the issue of negative externalities of digitising farming systems with sensing hardware and illustrates the challenges that COs face in relation to the use of technology. COs have to balance several key variables: sustainability, cost, reliability, complexity of use, average product life and waste. For example, the lower the cost, the more likely COs are to encounter and deal with technical problems, which require more resources for technical support and logistics (e.g., replacement of faulty sensors). The use of complex and more expensive sensors requires more training and reduces the number of sensors that can be afforded by a CO, thus reducing the number of citizens and communities who can be provided with free sensing technologies. The commercial soil sensor used in GROW, although chosen after a thorough evaluation of soil sensors available at the time, came with a significant amount of plastic packaging and parts, generating plastic and electronic waste and hence being counterproductive to sustainable development. Alternative and more sustainable DIY options were explored together with Community Champions at an Insight Workshop (Lisbon, 2019) and in one of the MOOCs. In this context, COs play an important role to ensure and discuss the use of sustainable sensing technologies.

4.5. Offering Opportunities for Addressing Environmental Crises with Positive Climate Action

The high numbers of citizens participating in GROW’s activities and events reflect people’s interest in taking part in citizen science and community-led climate action. The action-based character of COs contrasts with many environmental campaigns focusing on the dire consequences of climate change. COs can present themselves as potential climate solutions and antidotal mechanisms to reduce levels of eco-anxiety (i.e. the fear of environmental damage or ecological disaster) caused by the growing realisation of the urgency for action to combat climate change and its impacts [69,70]. COs offer a valuable opportunity to accelerate and amplify civic engagement and to reduce the feeling of powerlessness. Well-designed environmental monitoring and sensing, training and networking activities combined with social interaction can help citizens relate closely to measurable climate action, either individually, or as part of their local community and as members of an international community of practice. This is particularly relevant to the roadmap for action defined by the SDGs, connecting social progress and well-being with the preservation of environmental resources.

Over the last two years, younger generations have been demanding urgent and concrete political action for the transformation of entire economic sectors and industries. Sustainable land

use management and soil health emerge as key climate mitigation solutions, calling for massive civic engagement and filling the existing data gaps. As an important component of Responsible Research and Innovation programmes [71], COs successfully demonstrate how citizens can directly support science while raising awareness and generating evidence for the necessary improvements in policy. In this context, they offer a clear pathway for science-driven policy, by combining citizen observations, scientific research and iterative assessment for improved decision making.

By increasing access to information on regenerative growing practices and techniques which help to preserve and improve soil health and biodiversity, GROW supported positive steps to empower people in growing their own food sustainably and increasing their access to fresh healthy food while protecting the environment. This is of particular importance to ensure food security and community resilience in the context of economic recessions and unexpected and widespread crises, such as the COVID-19 pandemic [72].

GROW built sensing communities around soil moisture as its measurable variable. In comparison to other environmental challenges that require immediate actions (e.g. earthquakes, fires and floods), soil degradation has longer term impacts. Therefore, it is also harder to attract urgent civic action around it. Nevertheless, by linking environmental challenges with positive narratives such as sustainable food growing and large-scale climate action, COs can offer a platform that enables communities to link a single identified variable such as soil moisture, to locally relevant and tangible information. For some of the GROW Places, e.g. GROW Place Netherlands, monitoring soil moisture meant gaining a sense of preparedness to deal with flood risk; for other communities such as GROW Place Greece and Portugal, soil moisture, or lack thereof, was an indicator of potential droughts and wildfires. Thus, COs can help communities generate and respond to locally relevant data with global importance.

4.6. Limitations of This Research

The human-centered and community-based nature of COs makes them a dynamic forum for environmental and social action. Currently, COs are characterised by a relatively short-term and project-based implementation which creates inherent complexities for reporting their longer-term impacts. New developments that might originate from novel partnerships, or changes in practice and policies which are realised in longer cycles or even after the end of the project, are difficult to be addressed adequately. While it is possible to align CO activities and their tangible outcomes to the SDG framework (as presented in this paper), assessing and documenting the extent to which these contributions translate into progress at the SDG goal and target level is challenging, particularly within the life of such a project. Hence, there is a need for a more comprehensive impact assessment approach for citizen science contributions to the SDGs, in order to collect robust medium and longer term evidence that goes beyond indicator monitoring.

The reported outcomes of GROW activities—particularly those related to data innovation that required citizen-generated datasets—could only be evaluated towards the end of the project, after participants were recruited and trained and had contributed data, through interviews and co-assessment methodologies with Community Champions. Conducting interviews or a survey with more sensor users and across different GROW Places could have provided a more exhaustive list of local impacts and other insights (e.g. cross-cutting issues such as innovation being hindered by technical issues with sensor application, as occurred in the Evros River Delta at GROW Place Greece).

In terms of data contributions to specific indicators, our analysis shows that GROW data could potentially be applied to monitoring four indicators, but only partially. This partial applicability poses a first limitation to the actual potential uptake. Data harmonisation, interoperability and avoiding piecemeal data collection is what is desired by organisations responsible for monitoring and reporting progress towards the SDGs [33]. The analysis presented in this paper, comparing specific variables of data in the SDG framework with data variables generated in GROW, did not consider data quality, representativity, accessibility, ownership and privacy restrictions, which poses another limitation to the actual contribution potential. Furthermore, citizens are guided by their own interests

and motivations and the context within which they operate is different from the context of official monitoring systems. This creates an inherent tension between scientific standards, common reference structures or land classification systems and citizens' understanding of ecosystem features, and their ability to classify and monitor them; as well as accessing appropriate tools and methods that can help bridge the two domains. Training of citizens and the application of user-friendly, scientifically suitable tools can enhance citizens' abilities and skills in monitoring, documenting and making sense of their environment [20,73]. Nonetheless, appropriate, affordable and easy to use tools are not always available. Including citizen-led data in SDGs monitoring will need to account for these differences and attempt to find a balance between the quality requirements for scientific rigour and standardised monitoring with citizens' needs, skills and motivations as well as the availability of suitable protocols and tools for citizen-led monitoring.

5. Conclusions

Although global datasets are growing exponentially, 68 percent of the 93 environmental SDG indicators cannot yet be monitored due to a lack of suitable data [74]. COs emerge as promising mechanisms for closing data gaps and helping to validate monitoring data from other sources. Recent studies have started to analyse citizen science contributions to specific SDG indicators [6]. However, while citizen science data for indicator monitoring can be an important contribution of COs to the SDGs, a narrow perception of COs as mere large-scale data contributors might undermine the wider potential and benefits of COs.

In this paper, we have moved beyond a focus on data collection for indicator monitoring to considering the wider contributions of COs to action for the SDGs. Building on the experience and insights from the GROW Observatory, we have mapped project activities from this case study to the SDG framework at two levels: (A) concrete actions to facilitate the implementation and advancement towards SDG goals and targets and (B) potential data contributions to SDG indicator monitoring. The findings reveal that GROW data for indicator monitoring could potentially support four out of 169 (2.4 percent) targets across three goals. GROW activities could potentially support 39 targets out of 169 (23.1 percent) across 14 goals (see Table S5).

Beyond contributing citizen-generated datasets to cover current data gaps—such as soil moisture data in the case of GROW—efforts to align COs to the entire SDG framework can bring more relevance to the remit of citizen science projects. An integrated CO approach to the SDG framework can build a common language to communicate impacts and contribute to engagement strategies as participants realise how their local action can connect and contribute to global change. It is also important to be aware of and plan in advance to avoid negative externalities from project activities, for example, the generation of electronic and plastic waste from sensors, which can be counterproductive to sustainable development.

We have presented evidence of how COs can facilitate multi-stakeholder connections, skills and trust-building, service provision and data gathering. Building on the findings, we have shared five guiding principles to support current and future citizen sensing projects wishing to contribute to the SDGs: working towards SDGs as a coherent integrated framework; fostering multilevel governance connections; co-designing for meaningful long term engagement; maintaining COs as spaces to facilitate relevant debates (such as big open data ownership and the need to decouple SDGs from economic growth); and offering opportunities for positive climate action. Citizen science projects are encouraged to consider the SDG framework as a whole, rather than focus on generating data for specific isolated indicators, without providing and empowering participants with knowledge of the wider context of the overall SDGs framework, how it relates to them and their communities, and offering them the skills to create meaningful progress towards the 17 goals.

Thanks to the multifaceted nature of COs, their potentially wide geographical reach and diverse group of stakeholders involved, they not only provide pathways for large scale and adaptive data collection approaches, but they also offer avenues for massive awareness raising and public

engagement around solving specific societal and environmental challenges. These attributes of COs offer opportunities for alignment with goal and target-oriented policy frameworks, such as the SDGs. COs are well-positioned to empower communities to provide local meaning to environmental variables of global significance and make the SDGs locally relevant.

A key factor for long term data supply is engagement through a shared understanding of the usefulness and relevance of citizens' contribution. This finding highlights how the groundwork activities at goal and target level of the SDGs framework can significantly enhance sustained levels of potential data contributions at the indicator level. Placing citizens at the centre of COs to achieve locally meaningful and globally relevant datasets opens interesting questions and inquiries for further research in citizen-led innovation for environmental conservation and societal well-being, as framed by the SDGs.

Supplementary Materials: The following are available online at <http://www.mdpi.com/2071-1050/12/24/10518/s1>, Table S1: GROW contributions to Sustainable Development Goals and Targets, Table S2: Description of GROW project activities, Table S3: Potential contributions of GROW data to SDG 2.4.1 monitoring, Table S4: Potential contributions of GROW data to SDG 11.3.1 monitoring, Table S5: Potential contributions of GROW data to SDG 15.1.1 monitoring, Table S6: Potential contributions of GROW data to SDG 15.3.1 monitoring.

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