Supplementary Materials

Table S1. GROW contributions to Sustainable Development Goals and Targets.

SDG	Target	Most relevant GROW events and resources
1.End poverty in all its forms everywhere	Target 1.5: By 2030, build the resilience of the poor and those in vulnerable situations and reduce their exposure and vulnerability to climate-related extreme events and other economic, social and environmental shocks and disasters	GROW's datasets have demonstrated the potential of citizen science data for the validation of soil moisture satellite data, used for the refinement of climate models and the prediction of extreme weather events such as wildfires, droughts and floods. GROW Edible Plant Database [27] with locally specific and crowd validated planting and harvesting dates and "Share my planting calendars" Facebook group: provide information for local adaptation for food growing and a mechanism to share and discuss changes in real-time. GROW Dynamic Soil Moisture Maps [72]: a showcase of a service prototype that can help vulnerable communities monitor land conditions over time and adapt land management to mitigate effects of climate events and help take preventive action (e.g. heat wave mitigation, wildfire prevention, flood erosion etc). Free MOOCs with content on regenerative food growing and soil management techniques.
2. End hunger, achieve food security and improved nutrition and promote sustainable agriculture	Target 2.3: By 2030, double the agricultural productivity and incomes of small-scale food producers, in particular women, indigenous peoples, family farmers, pastoralists and fishers, including through secure and equal access to land, other productive resources and inputs, knowledge, financial services, markets and opportunities for value addition and non-farm employment	Free MOOCs with content on regenerative food growing and soil management techniques. Free GROW Observatory app with Edible Plant Database [27] and content on regenerative food growing and soil management techniques to support information access and capacity building for small-scale food growers. Continuous soil moisture data at farm level to enable farmers to enhance land management (e.g. improve water usage).
	Target 2.4: By 2030, ensure sustainable food production systems and implement resilient agricultural practices that increase productivity and production, that help maintain ecosystems, that strengthen capacity for adaptation to climate change, extreme	Public engagement, free extensive training and resources on regenerative food growing and soil management techniques (GROW MOOCs, GROW Observatory app, online resources).

	weather, drought, flooding and other disasters and that progressively improve land and soil quality	Increased knowledge on the effectiveness of regenerative food growing techniques (polycultures vs. monocultures) through citizen science experiments, increased capacity of small-scale growers to conduct research-based experiments to improve their own growing. Generation of new data on land and soil that contributed to validation of satellites as well as other applications that strengthen capacity for adaptation to climate change and extreme weather events (e.g. dynamic soil moisture map).
	Target 2.5: By 2020, maintain the genetic diversity of seeds, cultivated plants and farmed and domesticated animals and their related wild species, including through soundly managed and diversified seed and plant banks at the national, regional and international levels, and promote access to and fair and equitable sharing of benefits arising from the utilisation of genetic resources and associated traditional knowledge, as internationally agreed	Promotion of polycultures and diverse growing systems through MOOCs and GROW Knowledge Base resources, incl. promotion of plant diversity through locally specific Edible Plant Database [27] and knowledge sharing activities ("Share my planting calendars" Facebook group), and sharing of regenerative growing practices that promote biodiversity.
3. Ensure healthy lives and promote well-being for all at all ages	Target 3.d: Strengthen the capacity of all countries, in particular developing countries, for early warning, risk reduction and management of national and global health risks	GROW's datasets demonstrate the potential of citizen science data for the validation of soil moisture satellite data, used for the refinement of climate models and the prediction of extreme weather events such as wildfires, droughts and floods. Free MOOCs with content on regenerative food growing and soil management techniques that promote environmentally friendly and healthy diets, and the mitigation of climate change effects. GROW Dynamic Soil Moisture Maps [72]: a showcase of a service prototype that can help communities monitor land conditions over time and adapt land management to mitigate effects of climate events and help take preventive action (e.g. heat wave mitigation, wildfire prevention, flood erosion, etc).
4. Ensure inclusive and equitable quality education and promote lifelong learning opportunities	Target 4.7: By 2030, ensure that all learners acquire the knowledge and skills needed to promote sustainable development, including, among others, through education for sustainable development and sustainable lifestyles, human rights, gender equality, promotion of a culture of peace and non-violence, global citizenship and	Provision of skills-based learning for food production and consumption, SDGs and creating positive change with open data through several iterations of four free MOOCs and Knowledge Base resources.

for all	appreciation of cultural diversity and of culture's contribution to sustainable development	
6. Ensure availability and sustainable management of water and sanitation for all	Target 6.4: By 2030, substantially increase water-use efficiency across all sectors and ensure sustainable withdrawals and supply of freshwater to address water scarcity and substantially reduce the number of people suffering from water scarcity	Providing a variety of stakeholders from small and medium scale farmers, to Forestry Commissions with a low cost option to monitor soil moisture. Some farmers from El Hierro (Spain) participating in GROW were able to reduce irrigation by c. 30 percent just after a month of taking part in soil monitoring activities.
	Target 6.5: By 2030, implement integrated water resources management at all levels, including through transboundary cooperation as appropriate	At local level participants in several GROW Places used soil sensors to a) better understand moisture distribution across their land and to b) adjust land/water management accordingly. Additionally, the dynamic soil moisture maps, as a demonstrator, highlight how low cost sensors distributed in a community can provide information for different decision making levels.
	Target 6.6: By 2020, protect and restore water-related ecosystems, including mountains, forests, wetlands, rivers, aquifers and lakes	Working with Forestry Commissions (Croatia, Luxembourg and Greece), Water Authorities (Netherlands) and local Department of Agriculture (Canary Islands) in different GROW Places to provide them with soil moisture data across a variety of locations with sensors, as well as estimated values for a wider geographical area. These datasets can contribute to better informed policy decisions for water conservation. The GROW datasets were also explored in conjunction with other datasets for wildlife conservation purposes (monitoring how changes in soil moisture affect migratory birds feeding patterns in protected catchment areas).
	Target 6.b: Support and strengthen the participation of local communities in improving water and sanitation management	Hundreds of people from 24 communities in 13 EU member states took people in sensing activities. 20.5k people actively participated in citizen science or data collection, and more than 23k were engaged through GROW events. 17,400 people in 165 countries took part in a GROW online course. Eight GROW communities decided to carry on post project funding. In total, GROW reached 7.8 million people through social media and project activities.

8. Promote sustained, inclusive and sustainable economic growth, full and productive employment and decent work for all	Target 8.2: Achieve higher levels of economic productivity through diversification, technological upgrading and innovation, including through a focus on high-value added and labour-intensive sectors	Promotion of diversification strategies in a) growing (training and promotion of sustainable polycultures and agroforestry) and b) land livelihoods (e.g. complementary income through coordination of citizen science activities for Community Champions). Introduction to new sensing technology and innovative open data to a wide range of growers from diverse backgrounds, contributing to technology literacy.
	Target 8.4: Improve progressively, through 2030, global resource efficiency in consumption and production and endeavour to decouple economic growth from environmental degradation, in accordance with the 10-Year Framework of Programmes on Sustainable Consumption and Production, with developed countries taking the lead	Promotion of and offer of free training and location-sensitive advice on regenerative soil management and food growing methods that reduce environmental degradation (e.g. GROW MOOCS, regenerative growing techniques via GROW Observatory app). GROW Edible Plant Database [27] with locally specific and crowd validated planting and harvesting dates and "Share My Planting Calendars" Facebook group: provide information for local adaptation for food growing and a mechanism to share and discuss changes in real time. Dynamic soil moisture maps: a showcase of a service prototype that can help vulnerable communities monitor land conditions over time and adapt land management to mitigate effects of climate events and help take preventive action (e.g. heat wave mitigation, wildfire prevention, flood erosion, etc).
9. Build resilient infrastructure, promote sustainable industrialisation and foster innovation	Target 9.5: Enhance scientific research, upgrade the technological capabilities of industrial sectors in all countries, in particular developing countries, including, by 2030, encouraging innovation and substantially increasing the number of research and development workers per 1 million people and public and private research and development spending	GROW's engagement and MOOC programme engaged thousands of people in scientific training. The online courses and downloadable resources included detailed steps on designing a research experiment, from problem identification, study design, data collection and analysis and application of findings. By demonstrating the feasibility of creating an international community of citizen scientists, GROW highlighted citizen science's potential for innovating and increasing the capacity of public research approaches.
11. Make cities and human settlements	Target 11.3: By 2030, enhance inclusive and sustainable urbanisation and capacity for participatory, integrated and sustainable human settlement planning and management in all countries	Some GROW places were based in urban areas, i.e. supporting food growing as a sustainable practice in cities, from private gardens, to community allotments. Several the GROW Places involved allotment groups.

inclusive, safe, resilient and sustainable	Target 11.4: Strengthen efforts to protect and safeguard the world's cultural and natural heritage	Collecting and sharing regenerative agriculture techniques and knowledge about planting/harvesting plants under local conditions can be considered an act of safeguarding applied knowledge as part of cultural/natural heritage
	Target 11.b: By 2020, substantially increase the number of cities and human settlements adopting and implementing integrated policies and plans towards inclusion, resource efficiency, mitigation and adaptation to climate change, resilience to disasters, and develop and implement, in line with the Sendai Framework for Disaster Risk Reduction 2015–2030, holistic disaster risk management at all levels	Active involvement of policy makers in the Observatory through the Observatory Policy Interface led by the FAO Soil Global Partnership. Interviews and surveys with policy makers were carried out to understand their views and wants for citizen science data. Celebration of policy focus events, including: a) GROW Policy Workshop in Brussels (September 2019). This event was organised in collaboration with the Global Soil Partnership of the UN Food and Agriculture Organisation. It featured keynote presentations by European Commission policy officers from the Directorate-General for the Environment (DG-Environment) and the Executive Agency for Small-Medium Enterprises (EASME); the Director of the FAO Liaison Office in Brussels, Mr. Rodrigo de Lapuerta; and Greek Member of the European Parliament, Mr. Petros Kokkalis who is an active advocate of the SDGs at EU and UN level and regularly uses GROW as an example demonstrating the potential of COs in the relevant Committees on the Environment, Public Health and Food Safety, and Agriculture and Rural Development. b) SDG event in Athens "Citizens and Open Data for Sustainability" (Athens, February 2019) supported by the British Council, SciCo, CulturePolis, the British Permaculture Association and the Irish non-profit organisation Cultivate. This event hosted keynote presentations by distinguished speakers from Greece and Britain, including the Hellenic Platform for Development, the National Observatory of Athens and the General Secretariat of the Greek Ministry of Environment and Energy, the Edinburgh Futures Institute, and the University of Dundee. It was attended by 130 participants while reaching out to a further 135 viewers through a live stream. Wide press coverage, a dedicated blog post and video recordings of the event were made available for wider reach. c) Citizens' Forum in Scotland (September 2018). This event brought together citizens and civil society representatives active on climate action, resilience, self-sufficiency, sustainable land use and food production in Scotland. to identify local issues related to land management, food production and soil stewardship. The event featured presentations of GROW's citizen sensing mission and an interactive session for participants to identify solutions and effective local action to

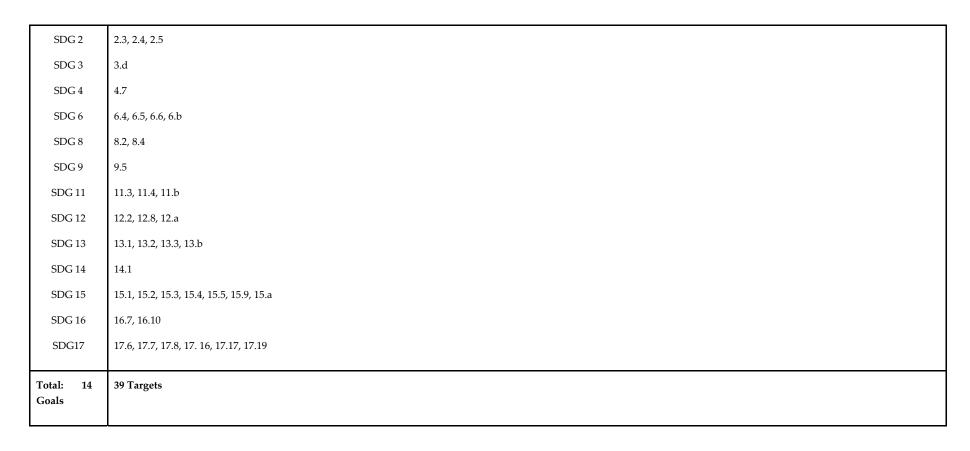|		promote regenerative growing practices and ways to influence policy on land and soil management. d) World Soil Day Event in GROW Place Ireland (December 2018). This event was attended by senior officials from the Central Statistics Office and the Cork Food Policy Council.
12. Ensure sustainable consumption and production patterns	Target 12.2: By 2030, achieve the sustainable management and efficient use of natural resources	Creation of free water information advice based on soil moisture data. Continuous soil moisture data at farm level to enable farmers to enhance land management (e.g. improve water usage). Dissemination of regenerative growing techniques that promote sustainable management and use of resources.
	Target 12.8: By 2030, ensure that people everywhere have the relevant information and awareness for sustainable development and lifestyles in harmony with nature	Hundreds of people from 24 communities in 13 EU member states took people in sensing activities. 20.5k people actively participated in citizen science or data collection, and more than 23k were engaged through GROW events. 17,400 people in 165 countries took part in a GROW online course. 8 GROW communities decided to carry on post project funding. In total, GROW reached 7.8 Million people through social media and project activities. Negative externalities: by using a relatively short lived sensor with plastic packaging and materials, GROW's sensing technology generated plastic and electronic waste.
	Target 12.a: Support developing countries to strengthen their scientific and technological capacity to move towards more sustainable patterns of consumption and production	GROW Report "Replicability of the GROW Citizen Observatory outside EU Borders" led by FAO partner analysed challenges and opportunities for COs in lower income countries. GROW's MOOCs were run in the open access and internationally accessible FutureLearn platform. Any learners from any part of the world with an internet connection could join all the GROW courses and access the GROW Knowledge Base resources for free. Sustainable food production and consumption topics were covered, as well as scientific and technological approaches for citizen science projects.

13. Take urgent action to combat climate change and its impacts	Target 13.1: Strengthen resilience and adaptive capacity to climate-related hazards and natural disasters in all countries	Global contribution: GROW has contributed to the validation of soil moisture data from remote sensing sources. This parameter is a strong indicator in helping the international community to extreme weather events. Local contribution: training thousands of people from all over the world on regenerative and climate friendly food growing and soil management methods.
	Target 13.2: Integrate climate change measures into national policies, strategies and planning	GROW carried out research with policy makers to gain a better understanding of their level of awareness and attitudes towards COs and citizen generated environmental data. Promotion of soil moisture as a crucial variable for climate related policy planning.
	Target 13.3: Improve education, awareness-raising and human and institutional capacity on climate change mitigation, adaptation, impact reduction and early warning	GROW ran several iterations of four MOOCs and international events to improve education and awareness of climate change mitigation, adaptation, impact reduction. The observatory also highlighted the potential of citizen science to improve institutional capacity to adapt to climate change and to provide data for early warning systems.
	Target 13.b: Promote mechanisms for raising capacity for effective climate change-related planning and management in the least developed countries and small island developing States, including focusing on women, youth and local and marginalised communities	Through its international MOOC programme reaching learners in 182 countries, GROW demonstrated the potential of observatories for training people in harder to reach locations. The role of Community Champion demonstrated a recruitment and community engagement mechanism that could be adapted to focus on specific population groups, e.g. women, youth and local and marginalised communities.
14. Conserve and sustainably use the oceans, seas and marine resources for sustainable	Target 14.1: By 2025, prevent and significantly reduce marine pollution of all kinds, in particular from land-based activities, including marine debris and nutrient pollution	Through a wide set of freely accessible and downloadable resources, the GROW App and the MOOC programme, GROW provided information and supported training on organic growing and soil management practices that avoid nutrient pollution of local waterways and associated marine areas.

development		Negative externalities: by using a relatively short lived sensor with plastic packaging and materials, GROW's sensing technology generated plastic and electronic waste. Some of this waste could end up in water bodies.
15. Protect, restore and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, and halt and reverse land degradation and halt biodiversity loss	Target 15.1: By 2020, ensure the conservation, restoration and sustainable use of terrestrial and inland freshwater ecosystems and their services, in particular forests, wetlands, mountains and drylands, in line with obligations under international agreements	The GROW Dynamic Soil Moisture Maps [72] developed from citizen generated data visualise the variability of water content over a terrain, demonstrating a tool that could be made available to farmers, scientists and policy makers to improve water management. The GROW Water Planner is a tool that allows small scale growers to find out how much water their plants will need over the coming months, based on their location [23]. It is intended to support water planning and management activities. The version developed was a prototype that could be developed further with a more complete data set. Citizen generated data can lead to exploring innovative conservation approaches, e.g. by analysing soil moisture data in conjunction with wildlife data as it happened in GROW Place Greece.
	Target 15.2: By 2020, promote the implementation of sustainable management of all types of forests, halt deforestation, restore degraded forests, and substantially increase afforestation and reforestation globally	GROW promoted agroforestry through its training and resources. The validation of soil moisture remote data also contributed to the refinement of climate models, and thus improved predictions of droughts and wildfires, enabling governments to put policies in place to reduce the risk of losing forested areas.
	Target 15.3: By 2030, combat desertification, restore degraded land and soil, including land affected by desertification, drought and floods, and strive to achieve a land degradation-neutral world	GROW promoted agroforestry through its training and resources. The validation of soil moisture remote data also contributed to the refinement of climate models, and thus improved predictions of droughts and wildfires, enabling governments to put policies in place to reduce the risk of losing forested areas.
	Target 15.4: By 2030, ensure the conservation of mountain ecosystems, including their biodiversity, in order to enhance their	The validation of soil moisture remote data contributed to the refinement of climate models, and thus improved predictions of droughts and wildfires, enabling governments to put policies in place to reduce the risk of losing forested areas.

	capacity to provide benefits that are essential for sustainable development	
	Target 15.5: Take urgent and significant action to reduce the degradation of natural habitats, halt the loss of biodiversity and, by 2020, protect and prevent the extinction of threatened species	GROW courses included content on the raise and threats posed by fast rates of biodiversity loss. With a focus on moving beyond sustainable practices into regenerative approaches, the Observatory promoted agroforestry, polycultures and other techniques for increasing biodiversity and wildlife in growing sites through its training and resources.
	Target 15.9: By 2020, integrate ecosystem and biodiversity values into national and local planning, development processes, poverty reduction strategies and accounts	By raising awareness, up-skilling citizens and creating connections between communities and policy makers in GROW Places, GROW paved the way for future collaborations and citizen engagement in national and local policy making and planning.
	Target 15.a: Mobilise and significantly increase financial resources from all sources to conserve and sustainably use biodiversity and ecosystems	At the end of the project, MOOC learners were provided with a list of resources and funding sources to continue their training and community activities, e.g. Erasmus schemes. Some of the GROW Places have continued their soil sensing activities. The GROW Observatory as a project is the result of financial resources from the EC being spent on efforts to sustainably manage ecosystems and hence promotes progress towards this target.
16. Promote peaceful and inclusive societies for sustainable development, provide access to justice for all and build effective, accountable and inclusive institutions at	Target 16.7: Ensure responsive, inclusive, participatory and representative decision-making at all levels	GROW's online courses covered participatory governance methods at the local level as well as channels to take part in online consultations at the European level. At the end of the project, MOOC learners were provided with a list of resources and funding sources to continue their training and community activities, e.g. Erasmus schemes.
	Target 16.10: Ensure public access to information and protect fundamental freedoms, in accordance with national legislation and international agreements	GROW followed FAIR (findability, accessibility, interoperability, and reusability) principles. The Observatory made all its citizen generated datasets publicly available in accordance with GDPR legislation.

all levels		
17. Strengthen the means of implementation and revitalise the Global Partnership for Sustainable Development	Target 17.6: Enhance North-South, South-South and triangular regional and international cooperation on and access to science, technology and innovation and enhance knowledge-sharing on mutually agreed terms, including through improved coordination among existing mechanisms, in particular at the United Nations level, and through a global technology facilitation mechanism	GROW Report "Replicability of the GROW Citizen Observatory outside EU Borders" led by FAO partner analysed challenges and opportunities for COs in developing countries. GROW is a partner in the WeObserve project, a consortium of four H2020 COs. WeObserve is a Support and Coordination Action to amplify the outcomes and impacts of COs and to share insights with researchers from all over the world. GROW's MOOCs were run in the open access and internationally accessible FutureLearn platform. Any learners from any part of the world with an internet connection could join all the GROW courses and access the GROW Knowledge Base resources for free.
	Target 17.7: Promote the development, transfer, dissemination and diffusion of environmentally sound technologies to developing countries on favourable terms, including on concessional and preferential terms, as mutually agreed	GROW's MOOCs were run in the open access and internationally accessible FutureLearn platform. Any learners from any part of the world with an internet connection could join all the GROW courses and access the GROW Knowledge Base resources for free. These courses included content on DIY sensors and the pros and cons of other sensing technology.
	Target 17.8: Fully operationalise the technology bank and science, technology and innovation capacity-building mechanism for least developed countries by 2017 and enhance the use of enabling technology, in particular information and communications technology	GROW's MOOCs were run in the open access and internationally accessible FutureLearn platform. Any learners from any part of the world with an internet connection could join all the GROW courses and access the GROW Knowledge Base resources for free. These courses included content on DIY sensors and the pros and cons of other sensing technology. GROW Report "Replicability of the GROW Citizen Observatory outside EU Borders" led by FAO partner analysed challenges and opportunities for COs in developing countries.
	Target 17.16: Enhance the Global Partnership for Sustainable Development, complemented by multi-stakeholder partnerships that mobilise and share knowledge, expertise, technology and financial resources, to support the achievement of the Sustainable	GROW was a successful demonstration of a public funded international consortium of 18 partners, including academic institutions, small business, NGOs and a workers' cooperative with a very diverse range of skills and expertise.

	Development Goals in all countries, in particular developing countries	
	Target 17.17: Encourage and promote effective public, public-private and civil society partnerships, building on the experience and resourcing strategies of partnerships	GROW was a successful demonstration of a public funded international consortium of 18 partners, including academic institutions, small business, NGOs and a workers' cooperative with a very diverse range of skills and expertise. GROW designed and tested a co-design methodology and card set, i.e. Co-Design Climate Innovations Tool, to guide the co-creation and co-ideation of CO propositions and innovation prototypes aligned to the SDG framework [56]. They were tested with diverse audiences in Brussels, London, Lisbon and Santiago de Chile.
	Target 17.19: By 2030, build on existing initiatives to develop measurements of progress on sustainable development that complement gross domestic product, and support statistical capacity-building in developing countries	GROW has already made data contributions to SDG monitoring. Additionally, other potential data contributions are presented in this paper. GROW Report "Replicability of the GROW Citizen Observatory outside EU Borders" led by FAO partner analysed challenges and opportunities for COs in developing countries. This deliverable reflected on the potential of citizen science to increase statistical capacity-building in developing countries. GROW's focus on bringing together citizens and policy makers demonstrated a model for creating partnerships with National Statistical Offices, which could be pursued in other countries, both higher and lower income countries.
Summary		
SDG Goals addressed by GROW activities	**SDGs Indicators addressed by GROW activities**	
SDG 1	1.5	

SDG 2	2.3, 2.4, 2.5
SDG 3	3.d
SDG 4	4.7
SDG 6	6.4, 6.5, 6.6, 6.b
SDG 8	8.2, 8.4
SDG 9	9.5
SDG 11	11.3, 11.4, 11.b
SDG 12	12.2, 12.8, 12.a
SDG 13	13.1, 13.2, 13.3, 13.b
SDG 14	14.1
SDG 15	15.1, 15.2, 15.3, 15.4, 15.5, 15.9, 15.a
SDG 16	16.7, 16.10
SDG17	17.6, 17.7, 17.8, 17. 16, 17.17, 17.19
Total: 14 Goals	**39 Targets**

Supplementary materials

Table S2. Description of GROW project activities

Activity category	**Activity description**

Training at-a-scale, awareness raising & capacity building through Massive Open Online Courses (MOOCs)	MOOCs are online courses openly accessible to an unlimited number of learners via the web. Through the use of MOOCs, GROW was able to scale up participation, while still maintaining scientific rigour for complex scientific protocols. MOOCs allowed the project to engage with and train thousands of participants in the use of low-cost and DIY sensors, nutrient testing kits; land and soil surveys; methodological design; data collection and data awareness and regenerative agricultural practices. Learners outside of Europe who were not directly involved in sensing activities in GROW Places, were able to join the MOOCs, thus raising awareness of the potential of citizen observatories beyond European borders. Four MOOCs were created and were iterated between May 2017 and May 2019. In total, the courses attracted 17,400 enrolments from learners based in 165 countries [20]. Two iterations of the courses included specific content on using citizen-generated data for creating positive change at the growing plot, community and global level. Several learning steps also deliberately addressed the SDGs as a topic, from definitions to introduction to the SDG framework as well as specific contributions made by GROW.
Engagement & innovation through co-design & participatory methods	GROW developed an award winning Co-Design Climate Innovations Tool[1] for the ideation of new COs with multi-stakeholder groups (designers, policy makers, citizen scientists and Community Champions, environmental ministers and scientists) in London, Brussels, Lisbon and Santiago de Chile. The tool, through the use of persona cards, role play tasks and placing players in a crisis situation, was able to encourage an empathetic response in different scenarios with diverse stakeholders' concerns and motivations. The game also includes a set of SDG cards, that participants can use to consider the SDG framework and map it to their ideated observatories. GROW provided comprehensive community training, enabling participants to design and collect data for their own environmentally aware growing experiments [73]. The Great GROW Experiment allowed growers to practise their research skills and engage in participatory knowledge creation. The experiment compared productivity from a polyculture planting to a monoculture planting of the same three crops. This topic was chosen based on citizen feedback from surveys conducted in the first MOOC. A full experiment handbook including recording sheets for use on the plots was available on the GROW website.
Relationship building through new connections between	GROW organised multiple community events, generating specific and direct examples of civic participation into policy engagement, creating different connections between citizen science communities and policy makers at the subnational, national and EU levels, that were established due to GROW's activities at different policy levels: **GROW and policy advocacy for the SDGs at the subnational level**

---

[1] 2019 Academy for Design Innovation Management Conference Award

communities and policy actors	GROW generated and maintained place-based communities in 24 GROW Places. Most of these communities were led by individuals and organisations who have already been championing sustainability locally, providing useful anchors between the international CO and regional environmental and societal challenges. The project offered several opportunities for local meetings and multi-stakeholder consultations, where citizen scientists were invited to discuss and scope local sustainability solutions.
	The local community in Greece raised funds to expand the discourse on soil and land resources, through the organisation of "Rural Dialogues" in the region. Participating farmers, land managers, key stakeholders and local decision makers were engaged into community mapping of soil and land resources, followed by awareness campaigns and educational programmes [74]. Members of the community also led the creation of a new independent political group in the City of Alexandroupolis, which has participated in the local municipal elections (May 2019), achieving a 26.1 percent of the votes with a campaign centred on the local implementation of the SDGs. A Citizen Workshop at GROW Place Scotland (Dundee, September 2018) brought together civil society, researchers and local authority representatives, in order to discuss the contribution of the project's citizen sensing activities in the implementation of Scotland's Good Food Nation policy, with specific reference to the SDGs.
	GROW and policy advocacy for the SDGs at the national level
	The role of COs in shaping SDG agendas at the national level was also emphasised through public events and multi-stakeholder consultations organised by GROW and its local communities. A public event titled "Citizens and Open Data for Sustainability" (Athens, February 2020) brought together policy makers, academic researchers, civil society representatives, startup entrepreneurs, technologists and the wider public. With a specific focus on SDGs, this meeting was supported by the British Council, SciCo, the British Permaculture Association and the Irish non-profit organisation Cultivate. It was an example of GROW's potential to generate international connections and policy advocacy opportunities proactively, without having to wait for project data or final results.
	Another case with relevance to the SDGs at the national level was developed in GROW Place Ireland. Representatives of the Irish Central Statistics Office attended a Citizen Workshop organised by GROW (Carlow, 2018), sharing their vision for open data and their willingness to incorporate citizen science data in their official data streams. The event focused on how citizen science and open data could be used to empower citizens to play an active role in climate action and the transition to sustainable land use practices in Ireland. In Luxembourg, the forestry and nature administration distributed a batch of over 300 sensors to foresters over the whole country. Their aim was to have a good coverage of soil data humidity and temperature in forests, and to obtain a good dataset from GROW sensors which they could integrate into an ongoing study of other forest parameters.
	GROW and policy advocacy for the SDGs at the EU level
	Aiming to showcase the role and potential of COs in participatory governance at the EU level, GROW organised a Policy Workshop in Brussels that brought together policy makers, scientists, civil society stakeholders and growers working in the areas of soil and land

	conservation to address policy and governance challenges for agricultural policy, environmental management, citizen science, the SDGs and Earth Observation. Besides raising awareness on the potential contribution of COs to policy design, the event featured participatory sessions to better understand policy makers' data needs and priorities and to identify the barriers to collaborating with COs. The interaction between the different stakeholders provided insights for overcoming the identified barriers and key actions for increasing the uptake of CO data for agriculture, environmental management and other critical policy design. Participants were able to work together in interdisciplinary teams, using the Co-Design Climate Services Tool card game discussed above.
From data to action through enabling activities and innovations	Activities to enable citizens to move from mere contribution of data to actionable insights included: GROW Dynamic Soil Moisture Maps [72]. The GROW Dynamic Soil Moisture Maps visualise the variability of water content over a terrain, demonstrating a tool that could be made available to farmers, scientists and policy makers. A data artist was commissioned to create a visualisation of GROW's grid of citizen-managed soils sensors. These dynamic maps enabled farmers of any scale to manage their irrigation and land with more accuracy. GROW's crowdsourced Edible Plant Database [27]. Embedded into a free mobile app, the database equipped experienced and novice growers with information on plant requirements and location-specific planting and harvesting dates for 12 European climate zones. A "Share my planting calendars" Facebook group with more than 570 members allowed growers to share local planting and harvesting dates to improve the level of accuracy of the advice provided by the app. Efforts supporting citizens to move from data to action, resulted in the emergence of several open data-led innovations. For example, Forestry Departments and National Park Management Authorities started using soil sensors for the first time thanks to GROW activities. In the Canary Islands, after just one month of collecting and accessing GROW soil moisture data, two banana farmers in El Hierro realised they were over-irrigating their crop, an observation that led them to reduce the use of water for irrigation by between 30 to 50 percent. In GROW Place Netherlands, farmers participating in GROW started taking their own soil moisture data to regular meetings with the Official Water Boards for the first time. In this way, they were able to better support their concerns and proposals for sustainable water management. The usability of the sensor data was demonstrated not just as a stand-alone database, but also in conjunction with other datasets for innovative applications. At GROW Place Greece, the Evros Delta National Park Management Authority installed sensors in this wetland as a pilot to combine sensor data with data on migratory birds behaviour to see how variability on soil moisture affects feeding and migration patterns. In the Canary Islands, some participants connected vineyard yield data with sensor data. A team in GROW Place Austria tested the effectiveness of different mulching techniques with tea-bag index data [75].

Table S3: Potential contributions of GROW data to SDG 2.4.1 monitoring

SDG 2.4.1 indicator variable, sub-indicators (italic)	GROW datasets and parameters
Agricultural land area	Land data: land use and land cover, area size
Prevalence of soil degradation	Soil data: soil moisture, above ground temperature, above ground light levels – as supplementary information Polyculture experiment data: soil texture, stone content – as supplementary information
Variation in water availability	Soil data: soil moisture (percent), date/time with high temporal resolution (15mins)
Management of fertilizers	Land management data: type, date and area size of fertiliser use Polyculture experiment data: management interventions, type and date
Management of pesticides	Land management data: type, date and area size of pesticide use Polyculture experiment data: management interventions, type and date

Table S4: Potential contributions of GROW data to SDG 11.3.1 monitoring

SDG 11.3.1 sub-indicators	GROW datasets and parameters
Expansion of built-up area	Land data: land use and land cover, area size Polyculture experiment data: location, determining allotments and growing spaces, canopy cover
Absolute extent of land that is subject to exploitation by agriculture, forestry or other economic activities	Land data: land use and land cover, area size Polyculture experiment data: location, determining allotments and growing spaces
Over-intensive exploitation of land that is used for agriculture and forestry	Land data: land use and land cover, area size

Table S5: Potential contributions of GROW data to SDG 15.1.1 monitoring

SDG 15.1.1 indicator variable	GROW datasets and parameters
Forest area	Land data: land use, land cover and canopy coverage, area size Polyculture experiment data: location, determining allotments and growing spaces, canopy cover

Table S6: Potential contributions of GROW data to SDG 15.3.1 monitoring

SDG sub-indicator (italic) and supplementary info	GROW datasets and parameters
Land cover	Land data: land use, land cover and canopy coverage, area size Polyculture experiment data: location, determining allotments and growing spaces, canopy cover
Topography, farming practices, or soil properties	Land data: slope, landscape type and position, slope orientation Land management data: mulching, irrigation, fertilizer use, pesticide use, tillage, and other interventions, with area size, date Soil data: soil moisture, above ground temperature, above ground light levels, date/time Polyculture experiment data: soil texture, stone content, topography and canopy cover, other observational data and management interventions