Information services for growers

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DELIVERABLE 3.3

Information service for growers

Report

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Table of Contents

1 Scope of D3.3: Information Service for Growers

This deliverable outlines the main components of the information service developed by the GROW Observatory (GROW) for growers and other GROW audiences and users.

The GROW information service is made up of a range of **specific user-facing information services**, such as growing advice, planting/harvesting advice, watering advice and soil services. These include data design and data art commissions. Each has been developed integrating user insights and needs as well as data from different sources (sensors and other).

The deliverable describes the services, how they are embedded in the project, and how they were specified and developed through user research. The deliverable further describes the way the services are implemented in GROW Missions, and via curated data environments and digital platforms, for broad spectrum dissemination and communication. The latter include a number of online environments and tools collectively referred to as the GROW Collaboration Hub, as well as GROW social media channels, and the GROW Observatory mobile application.[1]

The following user-facing information services and products have been developed as a part of the GROW information service:

- **Data visualisations**:
  - Dynamic soil moisture maps
  - Soil water content visualisation
  - Individual soil moisture and sensor visualisations (“My Sensors”)
  - Public sensor overview map and information
- **Information modules**:
  - Location specific information service on edible plants
  - Information on regenerative growing practices
- **Responsive information service** on various topics via social media
- **Information innovation through art**: Data art commission and STARTS residency

Many other activities in GROW can be considered “information services” more broadly. They are not described in this deliverable. This concerns information services specific to GROW Mission participation, e.g. FAQs, discussion forums, webinars, information materials on how to participate, how to install sensors, how to troubleshoot, etc. This deliverable also excludes the GROW Observatory Massive Open Online Courses (MOOCs), and how GROW social media is used alongside the GROW website to facilitate the overall citizen science and user journeys.

[1] Related GROW project deliverables (not publicly available) are listed in the appendix for reference.

2 Introduction

The GROW Observatory is a European-wide project that engages thousands of growers, scientists and others passionate about their land and the soil they grow crops in. Using simple tools, GROW has not only empowered growers to better manage their soil/land, it is also helping growers to contribute to vital scientific environmental monitoring.

Why is there a GROW Observatory?
There are many human and environmental challenges facing us today. Two challenges that GROW focuses on are saving our soils and adapting to climate change. By helping people understand and improve both soil and food growing practices, by contributing soil moisture data over a large geographical scale and by empowering people to work on these topics collaboratively we can aid climate science, impact on policy, and make a difference in our own actions. This means we can help respond to the crucial sustainability challenges the planet faces.

What is GROW doing?
GROW takes action in growing spaces around Europe and providing learning experiences and information services online. Across Europe, thousands of growers are learning together: they try exciting new ways to improve their soil and food production methods. Participants do simple, coordinated soil experiments to capture and make sense of data on their local environment. This helps validate good local growing practices and international environmental monitoring.

Purpose of the GROW information service
The GROW information service (GROW IS), with its various components, is instrumental to the delivery of GROW as a Citizen’s Observatory (CO) and to building a CO community. It supports the design, delivery and impact of the observatory throughout seven phases, aligned in an iterative cycle (see Figure 1): SCOPING (SC), COMMUNITY BUILDING (CB), DISCOVERY (DI), SENSING (SN), AWARENESS (AW), INNOVATION (IN) and ADVOCACY (AD). Furthermore, the various information services are linked with specific, concerted CO activities, such as the Changing Climate Mission and the Living Soils Mission. Their purpose is to provide valuable information and operational tools to various GROW audiences, addressing their needs and interests, and to facilitate exchange amongst them. Hence, it acts as a centrepiece for stakeholder interaction and inclusive and collaborative development of the CO.

Most notably, the GROW IS does not solely provide one-way information to users and participants of GROW, but iteratively and responsively integrates citizen data, feedback and input to information service development and service delivery. The information services are, therefore, themselves iteratively developed through the implementation of the GROW seven stage process.

Fig. 1: Phases of the GROW Citizens' Observatory process model

This way, **we close and re-enter the loop of the process model**, from jointly identifying issues and needs to citizen-based data collection, user-centred development of innovative services, and the provision of services back to citizens, experts and policy makers. For example, GROW participants have generated interview and survey data, participated in group sessions and are collecting sensor data, thus continuously providing essential data, information and requirements for the GROW IS, which then further improves the service for all.

3 Embedding the GROW information service

3.1 Link with the seven phases of the GROW Observatory

The GROW Observatory unfolds in seven iterative phases. The GROW IS with its various components supports and helps to implement each phase in a distinct way.

SCOPING (SC)
Initial scoping was conducted to identify knowledge and service gaps, scope issues of concern, and to determine which information would be of the greatest value to growers and which formats information should be best presented. This initial scoping exercise was conducted using a user-centred, iterative design approach influenced by design thinking and service design models (cf. Dorst, 2011, Stickdorn and Schneider, 2010). The overall process is characterised by iterative and consecutive cycles of scoping, development, testing, evaluation and adaptation (Figure 2).

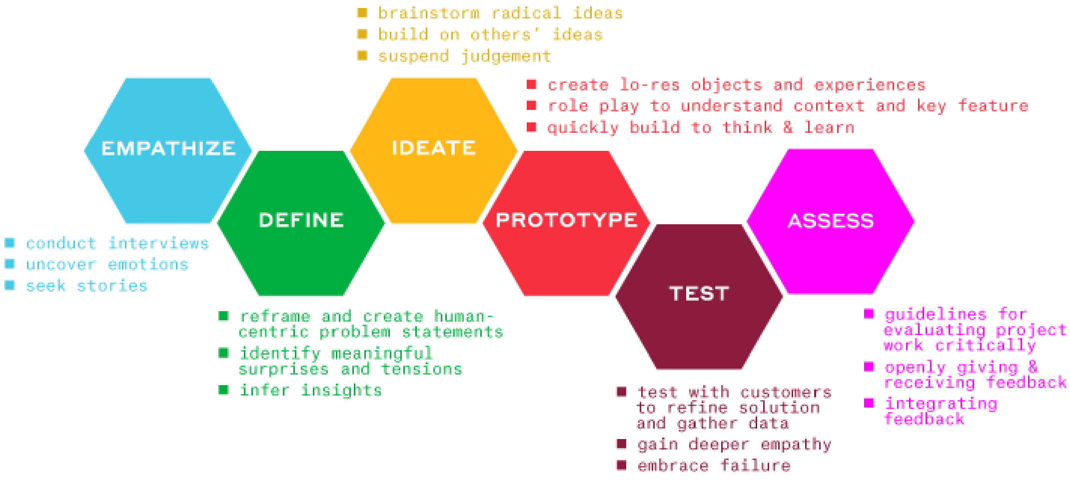

Fig. 2: Design Thinking Process (cf. Stanford d.school[2])

This initial stage, involving GROW consortium partners and from various GROW audiences using GROW Missions, Mass Online Open Courses (MOOCs), and social media channels, identified a series of opportunities to develop a portfolio of information services, which included Dynamic Soil Moisture Maps, soil Water content Visualisations, information on edible plants, etc. See Table 1 for full list of GROW IS provision. This initial stage was followed by a post service provision review, which identified that growers across GROW Places, were becoming more aware of the functionality and potential of citizen-generated data, with new localised data insights emerging. Characteristically, the insights captured during the post service provision review, began the next cycle of development, identifying specific issues, concerns and insights specific to each geographic location. It seemed that as grow communities increased their awareness for the value of data, there was a corresponding increase in new questions relative to the local context being generated

[2] https://dschool.stanford.edu/executive-education/dbootcamp

COMMUNITY BUILDING (CB)

The different information services of the GROW IS are built to encourage interaction amongst participants around information as well as reinforce a sense of place-based community for participants in both GROW Missions as well as the general public. Responsive information services via social media add an additional layer to the observatory as they:

- Connect the place-based communities across GROW places, and allow participants to sense they are part of something bigger than their local project activities;
- Provide an online community for people interested in growing food, sensing, soil, citizen science, but not necessarily participating in the GROW Missions;
- Encourage interactions between the two.

DISCOVERY (DI)

The services of the GROW IS support discovery and learning in every way, offering accessible and intuitive information on growing food, data and data collection, soil issues and many more topics in multiple formats. Investigating data visualisations enable, for example, first encounters with dynamic spatial data and to understanding their added value. Responsive information services based on user input or a critical interest (e.g. extreme weather events) facilitate the discovery of shared needs and create community bonding. Thus, the information services support potential users and GROW audiences in exploring a range of topics and data. This can spur curiosity and lead to deeper engagement and participation in the long run. The GROW IS provides self-paced learning opportunities as well as contextual information to support participants' onboarding and training processes in both GROW Missions. Entering a second cycle in the GROW process model (Figure 1), those services have then supported the creation of new services. As an example, sensor data submitted by Mission participants to the GROW Observatory has been the basis for the development of dynamic soil moisture maps, which in turn are now used to provide further training and contextual information to new citizen scientists. Grower's contributions of local planting/harvesting dates improve existing plant data and help encourage other growers to share their knowledge and benefit from wider local experience to improve their growing.

SENSING (SN)

The GROW IS is an important tool to ensure participants and users receive continuous feedback on their actions as participants in GROW and access to, and reward for, the data they collect. Seeing one's own sensor data or being able to follow how many sensors come online in one's region or neighbourhood increases not only ownership of the sensing and data collection process, but also encourages participants to continue and understand their part in the bigger picture.

AWARENESS (AW)

The GROW IS helps translate a selection of complex large datasets (e.g. sensor data, or climate data) and scientifically sound but scattered information (about plants and growing practices) into relevant formats for use at the local level. This translation process builds awareness and empowers participants to better understand the meaning of the data collection efforts, and findings. The various information services are key tools to sustain participation and maintain long term engagement, as they enable learning and feedback loops. They demonstrate that participants' data and knowledge needs are taken seriously to generate and provide knowledge and insights in a two-way fashion.

INNOVATION (IN)
The development of the GROW IS as an integral ecosystem of services, and the provision of individual information services themselves, are core activities of the innovation phase and action in GROW. New services, such as data visualisations, responsive services or artistic data explorations are created to help validate the CO concept and highlight its innovation and sustainability potential.

ADVOCACY (AD)
The combination of IS provides participants with evidence needed to identify and support advocacy processes in their local areas and regions.

GROW Phases **Information service**	SC	CB	DI	SN	AW	IN	AD
Dynamic Soil Moisture Maps	(X)	X	X	(X)	X	X	X
Soil Water Content visualisation	(X)		X		X	X	X
“My sensors” visualisations	(X)		X	X	X		X
Sensor overview map	(X)	X	X	X	X		
Info service on edible plants		X	X		X	X	
Info on regenerative growing			X		X		X
Responsive information service	X	X	X	(X)	X		X
Information innovation (data art)	(X)		X	(X)	X	X	X

Table 1: Link between information services and GROW phases, X-service has primary function, (X)-service has secondary function, e.g., in new iterative cycle of process model, or in support of other services.

Table 1 highlights which component of the GROW IS supports which GROW Phase.

3.2 Link with GROW Missions

Besides feeding into the different GROW Phases, the components of the GROW IS play a central role in the delivery of GROW Missions on the ground, such as the Changing Climate Mission and the Living Soils Mission. This section introduces each Mission shortly, while the function of each information service component in the Missions is described directly with each service (see section 5).

Changing Climate Mission
The Changing Climate Mission has the aim to improve society’s ability to mitigate and adapt to climate change by building our understanding of it through soil moisture, and its impact on soils and food growing. As part of this Mission, participants in several European locations (GROW Places), are using Flower Power sensors to collect continuous data for scientists to validate Sentinel-1 satellite soil moisture data. The validated datasets contribute to better climate models and more accurate predictions of extreme weather

events. The Mission follows citizen science methodology and enables citizens to contribute and share data at the same time as empowering growers to monitor and improve land and soil management practices.

Living Soils Mission
The purpose of this Mission is to develop and support an active network of small-scale growers and gardeners who grow food by using, and collaboratively investigating, practices that regenerate soils and create resilient ecosystems. Participation is open to anyone anywhere and data collection is focused on Europe. The objectives are to:

1. Help growers to access information and advice tailored to their location and growing conditions.
2. Increase the number of people growing in ways that regenerate soils and support diverse and resilient ecosystems
3. Investigate regenerative practice(s) at the smaller (i.e. not routinely mechanised) scale of growing and disseminate findings.

Through the provision of information services, based on rigorous academic evidence wherever possible, it is intended outcome is more people growing more food whilst improving soil, water and nutrient cycles, habitats and ecosystems, and developing local and international resilience to global issues of hunger, biodiversity loss and climate change.

3.3 Complementary information service delivery

The GROW IS is delivered through different complementary channels and environments to maximise uptake and to ensure optimal reach of the various target audiences. The GROW website[3] (also known as the GROW Collaboration Hub, or the user portal) includes the GROW discussion forum[4] and GROW knowledge base[5] as well as static information pages and dynamic data visualisations.[6] Social media channels include Medium, Facebook, YouTube, Twitter, Padlet and Instagram, using the same ID grow observatory for a coherent user experience. The GROW Observatory mobile application is available from Google Play (Android) and App Store (iOS). Table 2 provides an overview of the different information services and their respective delivery channel(s).

Information service	**Delivery channels**
Dynamic Soil Moisture Maps	GROW website
Soil Water Content visualisation	GROW website
“My sensors” visualisations	GROW website
Sensor overview map	GROW website
Info service on edible plants	GROW Observatory app and GROW social media (Facebook)

[3] https://growobservatory.org/
[4] https://hub.growobservatory.org/
[5] https://knowledge.growobservatory.org/
[6] https://growobservatory.org/data

Info on regenerative growing	GROW Observatory app and GROW website
Responsive information service	GROW website and GROW social media (Medium, Facebook, YouTube, Twitter)
Information innovation (data art)	GROW website and arts venues/events

Table 2: Link between information services and GROW delivery channels

3.4 Target audiences

Main audiences

The GROW IS as described in this deliverable addresses a range of stakeholders and audiences, including growers, specialist audiences and policy makers. Table 3 gives an overview of which information services support which main GROW audiences.

- **"Growers"** include gardeners (<1 ha of managed land), commercial small growers smallholders (1-10ha of managed land), urban food growers, established permaculturalists, agroforesters, community gardeners, allotmenteers, potential and new growers, school gardens, niche gardeners and care gardens.
- **"Specialist users"** include ecologists, agronomists, soil scientists, space scientists, environmental agencies, soil stewards, citizen science enthusiasts, botanic gardens, open source advocates, DIY sensing and maker communities, Satellite application companies, agri consultants, artists, media/bloggers (e.g., YouTube gardeners).
- **"Policy makers and advocacy"** includes, e.g., EU and national policy makers, food councils, media, NGOs, local councils and authorities.

Table 3 highlights links between information services and some main audience groups based on their primary functional interests.

Audience / **Information service**	Growers	Citizen Scientists	Scientists/ Researchers	Policy Makers
Dynamic Soil Moisture Maps	X	X	X	X
Soil Water Content visualisation	X		X	X
"My sensors" visualisations	X	X		
Sensor overview map		X	X	X
Info on edible plants	X	X	X	
Info on regenerative growing	X			X
Responsive information service	X	X		
Information innovation (data art)		X	X	

Table 3: Link between information services and GROW audiences

Personas

More specific audience development for the GROW Observatory and the GROW IS started with a personas approach (cf. Stickdorn and Schneider, 2010, Mulder and Yaar, 2007). Personas are characters envisioned to represent a specific and potential user type for a service or product. Personas that were considered as a basis for further investigating grower's needs and challenges are described in Table 4.

Nickname	**Background/Motivation**
Florian The Urban Millennial	Florian is 28 and lives in Freiburg, Germany. He has become increasingly concerned about climate change in recent years and is attempting to shift his lifestyle to be more sustainable. He cycles as much as possible and uses the tram when he can't. He has been involved in some activism through the Green party. Although he lives in an apartment, he grows what food he can on his balcony and also has access to a communal allotment in his neighbourhood.
Tim The Land Manager	Tim lives in the UK and manages a municipal park that has an active award winning community garden. He is helping other towns and cities with similar schemes that need help with site selection and design, as well as basic growing skills.
Martine The Educator	Martine is a 49 year old educator in France. His school has an Eco Schools award and Code Club. Their local council wants to bring eco and science together and set up a GROW sensor campaign for all schools across the region.
Miroslav The Commercial Grower	Miroslav is a small farm operator in Slovakia. His farm is part of a cooperative of other farms across the region. His farm is family-owned, and it's important to him that it stays that way. He is passionate about soil quality, but is typically farming all year round and has little time to gather data and plan better methods.
Sofía The Sustainability Activist	Sofía is 34 years old, and a member of the Barcelona chapter of a global sustainability movement. She has recently left her job to focus on the group full time. One of her major initiatives is attempting to convince the city government to set aside space for communal gardens. She doesn't grow herself yet due to a lack of appropriate places, although she would like to. She has taken part in a lot of citizen science experiments around wildlife and plantlife.

Table 4: Personas of specific GROW audiences

4 User research

Following the GROW approach of user research and user-centred design, one important goal was to develop the information services in an iterative fashion. Personas, user surveys, and in-depth interviews were developed and conducted to inform the GROW Observatory overall, and front-end services (including the GROW Observatory website and app) in particular. Results were considered for the user requirements and ensured that the design and functionality of the information services would serve real needs of the GROW user community. User testing of service prototypes was done to gain users' perceptions on the various service concepts and to understand what might drive or inhibit them to make use of them, uncovering potential usability issues. Identifying these drivers, inhibitors and usability issues allowed us to iteratively improve the services (cf. Rowley 1994). The following sections describe basic user research done to inform the GROW Observatory from the outset. Specific user testing is described, where applicable, directly with the information service in section 5.

Initial user research was conducted with a group of growers, mobilised through the wide network of growers jointly linked by project consortium partner organisations from December 2016 to May 2017 to test assumptions on user needs and respective advice/support services. The results informed adaptations to assumptions and to gather more nuanced insights into the needs and challenges of growers. These then served as the basis for the development of the various information services.

4.1 The Grower’s Online Survey

The Grower’s Online Survey was an exploratory survey. It used a non-probability sampling method, employing a combined sampling method, which is suitable for exploratory surveys (cf. Fowler, 1984). This descriptive survey aimed to

- Understand growers’ challenges and opportunities with respect to soil and land use.
- Understand attitudes, awareness, behaviour, knowledge and skills for growing practices and technology use.
- Gather insights to define requirements for the GROW information services development and identifying actions for future research.

The survey was completed by 172 participants. Almost 1/3 of the 172 participants (52) had no more than four years growing experience. Based on the survey, the most pressing challenges for responding growers overall (172) are:

- Improving soil fertility (58.40%)
- Dealing with pests (54.40%)
- Selecting best crops for my growing space (52.80%)
- Timing of planting season (knowing when is best to plant) (51.20%)

In comparison, the most pressing challenges for responding growers with less than four years growing experience are:

- Improving soil fertility (73.1%)
- Selecting the best plants for growing space (67.3%)
- Timing of planting season (knowing when is best to plant) (65.4%)
- Dealing with pests (59.6%)
- Understanding their soil (55.8%)

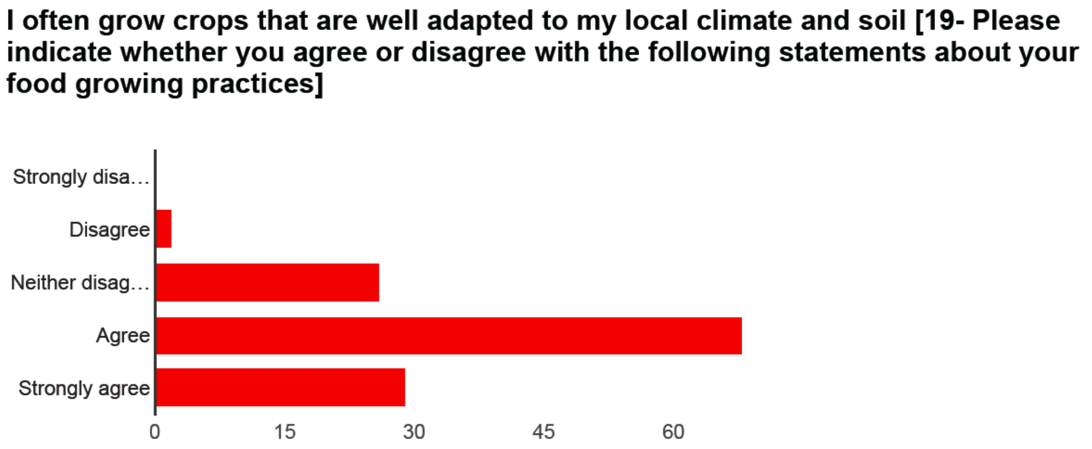

Fig. 3: Grower's plant adaptation to local climates

Less pressing challenges (all respondents) seem to be dealing with plant diseases, entrepreneurship/accessing new markets or making connections with other growers. Still, one third of the less experienced growers found timing of watering a challenge. Even though selecting the best plants and timing of growing seasons are perceived as a challenge by many, participants are more confident about their understanding of what can be grown in their region (Figure 3).

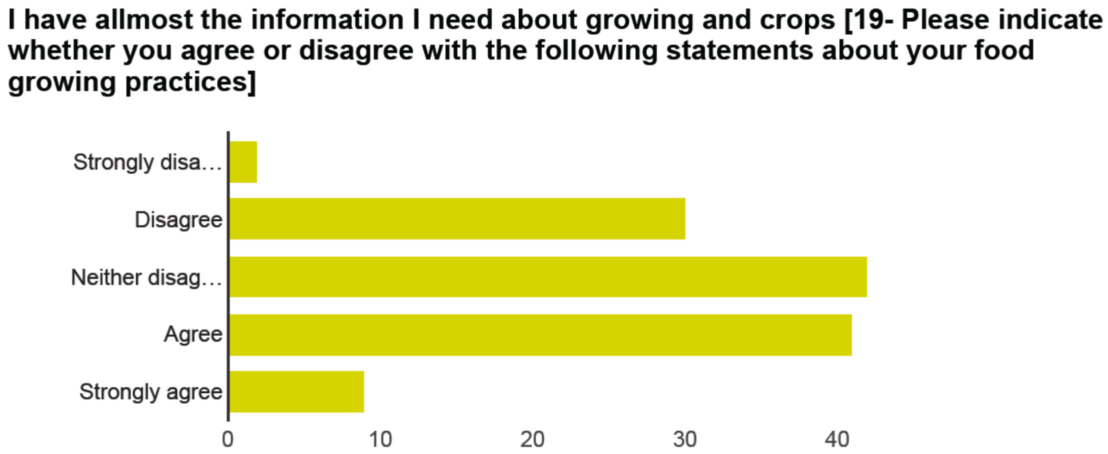

Fig. 4: Grower's perception on overall knowledge and information access

A comparatively lower proportion of growers say they have almost all the information they need or have a good understanding of their soil (Figures 4 and 5). This suggests a gap and scope for improving grower's knowledge with targeted and specific information services on growing techniques as well more nuanced plant information.

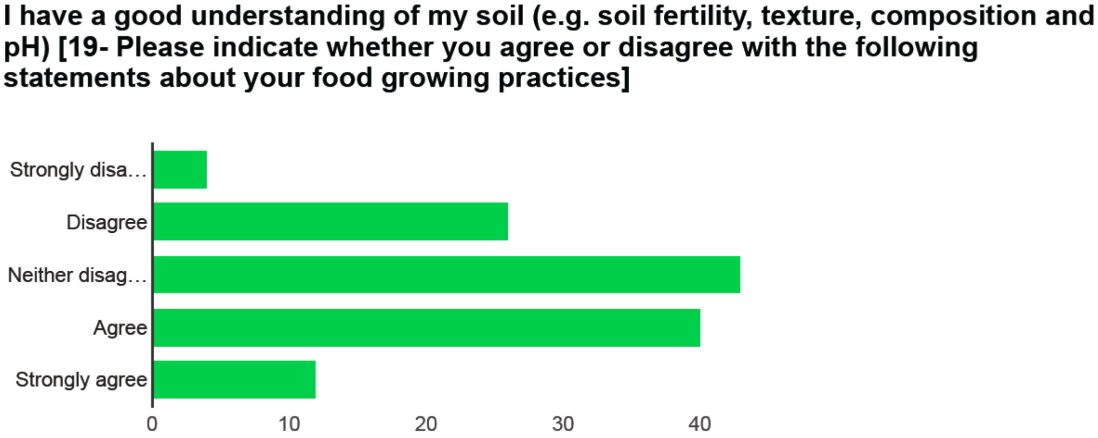

Fig. 5: Grower's perception on soil knowledge

Books and face-to-face communication are the most preferred sources for accessing information on food growing, closely followed by events and Internet websites. Facebook, Twitter, or mobile apps in general are least preferred. At the same time, more than half (56%) of survey respondents said they are curious about testing new devices and apps and are often connected to the Internet through using smartphones, tablets or computers.

4.2 User Stories

The online survey was followed by in-depth interviews and resulted in 60 user stories (Figure 6). Generating user stories is also a common technique in user-centred design (cf. Patton, 2014). User stories are informal but nuanced descriptions of user needs and challenges to be addressed by a service or product. They are often written from the perspective of an end user or user of a service or product and help guide development and further validate assumptions about audiences.

The elicited needs of growers were put into the following clusters:

- I need to access knowledge (34)
- I want to participate & influence soil policy (8)
- I need access to bilateral communication (8)
- I need to meet other growers (6)
- My growing context changed (4)

Fig. 6: Examples of user story cards in GROW based on in-depth interviews

From overarching needs, more nuanced user stories were derived. The overwhelming number of user stories (34) focused on accessing knowledge. Within this overarching need, the following specific topics could be identified:

- Help me learn about soil (15)
- Help me learn how to grow (9)
- Help me find trusted and relevant information (6)
- Collect and store relevant information (3)
- Help me share my experiences (2)

4.3 Summary of initial user research

The results of the user research provided support for several assumptions but helped refine understanding of specific aspects and motivated adaptations of some initial ideas and plans for the information services.

Assumption	**Target users have limited experience choosing suitable plants for specific location and soil and/or are interested in information regarding suitable plants.**
Results from survey and interviews	More than half of all respondents and about two thirds of less experienced growers find plant related aspects challenging, e.g., to select the best

	plants/crops for their growing space, or to know when it is best to plant. At the same time, many say to have a good understanding of what plants can be grown locally.
Implications for services	Plant advice based on location and time of year, with additional, more nuanced information on planting and harvesting dates, sunlight, water, soil requirements etc. Potential to validate and improve available planting/harvesting data with tacit knowledge from experienced growers.

Assumption	**Target users find dealing with pests a challenge and would welcome information on management strategies**
Results from survey and interviews	54% of all respondents find dealing with pests a challenge.
Implications for services	Treat pests in responsive services as they are not a core topic of GROW, but still an important issue to growers.

Assumption	**Target users need watering and irrigation advice**
Results from survey and interviews	Survey results indicate that actual time of irrigation seems comparably less of a comprehensive need and challenge than anticipated. When asked about it, one third of newer growers find it challenging.
Implications for services	Focus on giving more detailed information (how much water, not only when to water) and more descriptive information on watering and irrigation, included in plant information (e.g. plant water requirements, sensitivities) as well as considered in multiple regenerative practices (e.g. how to improve soil moisture, water infiltration, avoid erosion etc.).

Assumption	**Target users have limited experience in assessing and improving soil health/quality and/or are interested in information regarding soil health and quality and want to do something about it.**
Results from survey and interviews	Both the online survey and the interviews indicate a perceived lack of understanding around soils, as well as a clearly formulated need to improve knowledge and skills on soil specific growing practices.
Implications for services	Focus 1: on well-balanced information and how-to-descriptions on regenerative growing techniques and practices (e.g. plant rotation, mulching, composting, green manure, reduced digging etc.) to support growers in assessing and improving soil quality. Focus 2: provide information services that support local soil monitoring (soil moisture data, soil texture testing etc.) and in-depth information on soils

5 GROW information service components

5.1 Data visualisations

All visualisations are web-based and can be viewed on the GROW Observatory website.

5.1.1 Dynamic Soil Moisture Maps

GROW has developed the Dynamic Soil Moisture Maps[7] as a demonstration of an information service that can be used by growers, scientists and policy makers for applications in agriculture, climate forecasting and regional planning. These maps use GROW sensor data to generate a continuous estimation of soil water content over a terrain. There are currently dynamic soil moisture maps for three sites (two in Hungary, one in Portugal), with a plan to produce maps for 6 more sites (Figure 7). Maps have been created for clusters of up to 100 sensors within GROW Places as a demonstration of concept.

How are soil moisture maps useful?
The maps are aimed at farmers, scientists and policy makers to interrogate spatial patterns of soil moisture for applications in agriculture and climate forecasting. The initial version is intended as a demonstration of the type of service that could be produced for any farmer who collects point data from sensors placed in their land in a gridded distribution. Soil moisture is a changing property that needs to be mapped over time in order to respond to the needs of crops.

The maps are designed to enable farmers to answer questions such as:
- How variable is my land?
- Are there drier and wetter areas?
- Which areas can retain more water for a longer period?
- Where should I plant varieties/cultivars with low or high water requirements?
- Where do I need to plant water saturation tolerant varieties/cultivars?
- How large is the area within my land that needs to be irrigated?

How can farmers use the soil moisture maps?
High tech farmers invest in precision agriculture equipment but this equipment often requires knowledge of spatial variability of the soil across their farmland provided by expensive access to satellite data services, and lab analyses of soil. Small scale growers tend not to have access to precision farming services, which are often linked to the industrial supply of fertilisers and pesticides. The information provided by the Dynamic Soil Moisture Map is developed as part of an open and collaborative project, and can enable farmers large or small to manage their crops with great precision.

[7] soilmoisturemaps.growobservatory.org

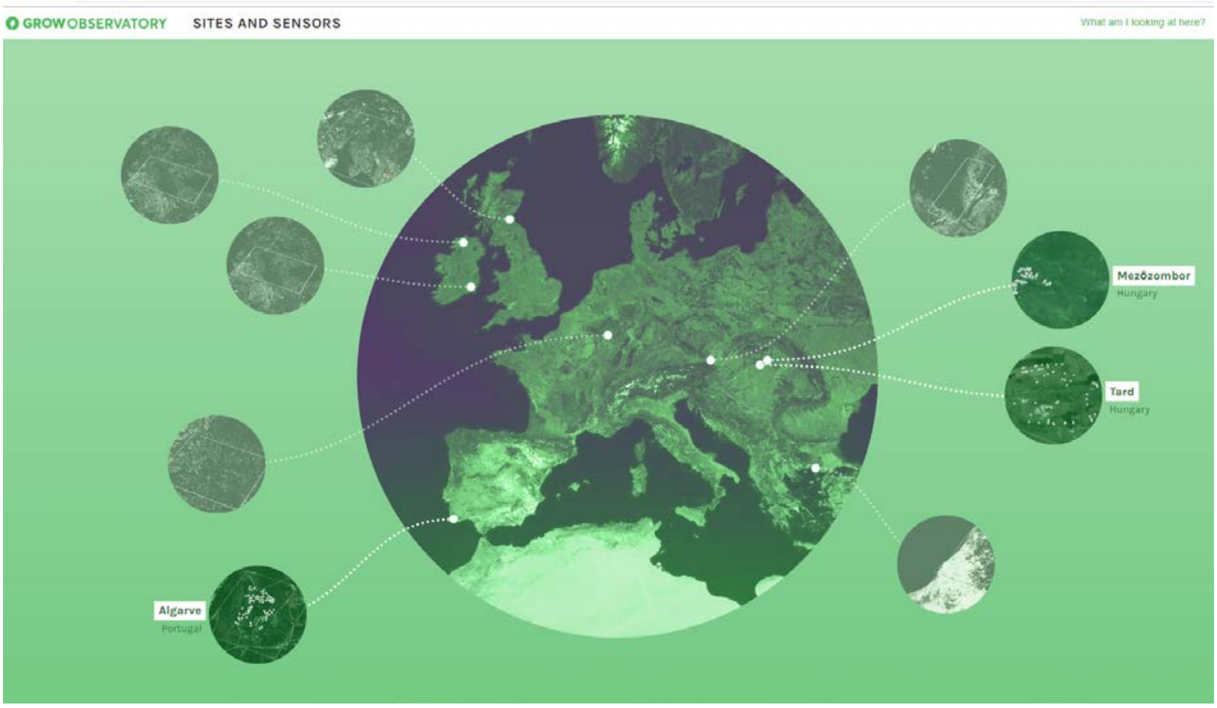

Fig. 7: Sites across Europe (GROW Places) with existing and potential dynamic soil moisture maps

What functionality does the visualisation offer?
The example (Figure 8) shows a cluster of sensors at a site in Hungary.

The map consists of

- A base map with background satellite image of the terrain with the delineated area where sensors are placed, with every sensor marked individually.
- A 3D “moisture model”, that displays in a large circle the continuous, interpolated soil moisture values between sensors on a site both in terms of colour saturation (the more saturated > the more moisture) and height (the higher > the more moisture). The values used for the interpolation model are single soil moisture values from one point in time per week (e.g., every Friday, 2pm). Hence, the visualisation offers one moisture model per week.
- Spatially represented single values for moisture, light and temperature, displayed in smaller circles as bars (the higher > the more moisture), and colour (the more saturated > the more moisture). The values used are average daily data for each sensor for moisture, light and temperature (Figure 9, left).
- Over time graphs for moisture, light and temperature, combining all sensor values in one graph respectively (Figure 9, right) using average daily values.

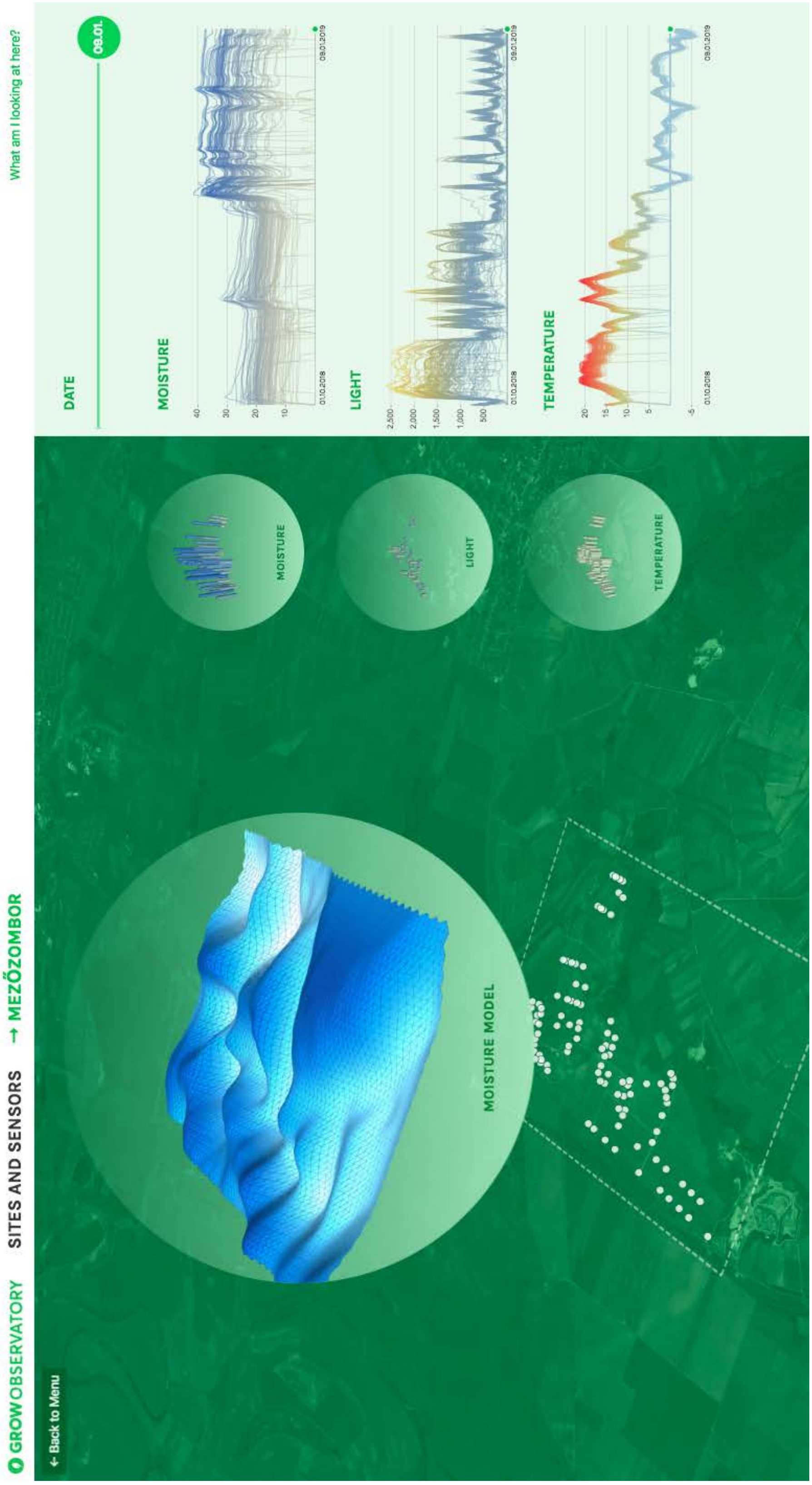

Fig. 8: Dynamic soil moisture map visualisation interface for Mezözombor, Hungary

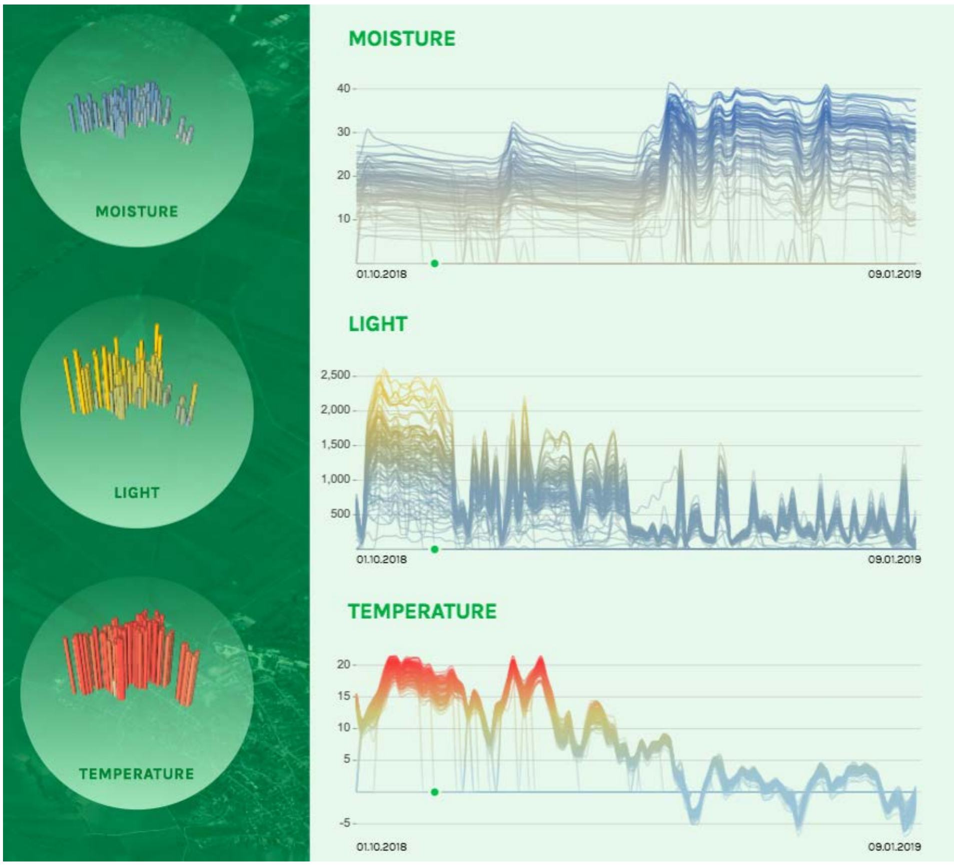

Fig. 9: Spatially represented single values (left) and over time graphs (right) for daily average moisture, light and temperature values

The online map allows the user to scroll along a timeline (green button in the upper right corner in Figure 8) and thus animate change in the moisture model and the moisture/light/temperature single values over time. Figure 10 shows the moisture model at different selected times. Sensors can be selected from the base map to highlight individual sensor values in the over time graphs (Figure 11). The map can also be rotated and viewed from different angles, so a user can more easily explore their landscape.

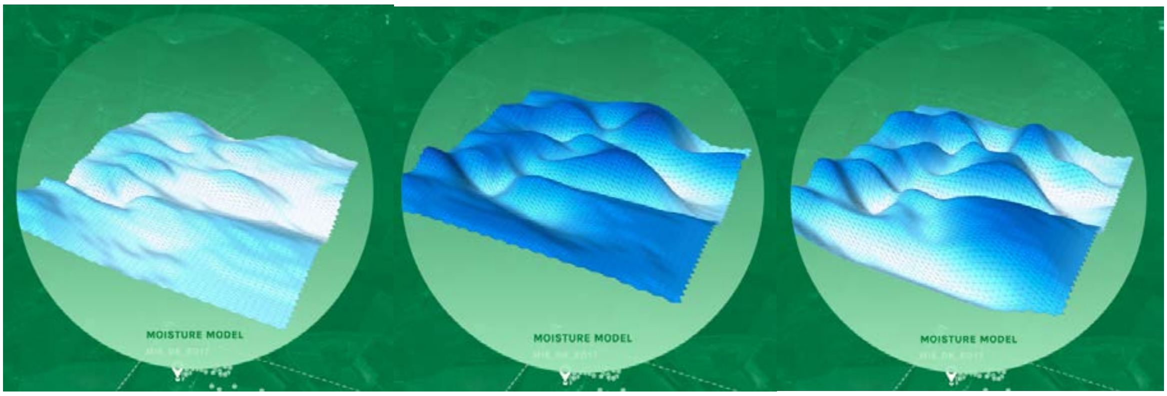

Fig. 10: Moisture model for 3 different timeframes

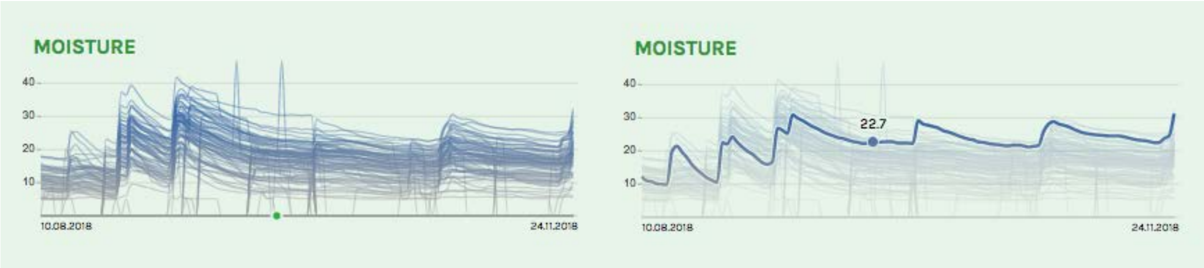

Fig. 11: Moisture over time graphs displaying all sensors (left) and highlighting one sensor (right)

Data used

The following data and services are used to produce the soil moisture maps:

- Sensor name
- Sensor location data
- Average daily sensor data from individual Flower Power sensors: soil moisture, temperature, light
- Interpolated soil moisture data for gridded moisture model
- Third party: OpenStreetMap satellite imagery, custom map styling via Mapbox (map design tools and mapping libraries)

Future development of the Dynamic Soil Moisture Maps

The more sensors deployed within a certain area on a site, the more detailed and accurate the soil moisture map is. The existing visualisation accommodates a maximum of 100 sensors but future versions could be expanded to accommodate more than 100 sensors. Since the GROW Observatory is not an automated soil moisture monitoring system, it relies on participants for collecting the data. Any future site visualised in a soil moisture map ideally distribute sensors in a way that can support an accurate soil moisture map and focuses on regular, timely intervals of data collection to improve temporal resolution. The more frequently data is provided by participants, the more up-to-date the database will be. In the current version, a static data set is uploaded manually. In a future version, data could be continuously updated to display a soil moisture map near real time.

Function in GROW Missions

Changing Climate Mission	● Reward for Mission participants ● Encouragement to continue contributing consistent sensor data uploads ● Alternative format for gaining insights from sensor data (complemented with a resource) ● Highlighting to other citizens, grower, farmer associations, scientists and other policy makers the value of the CS sensing activity ● Training tool for new Mission participants ● Soil moisture data visualisations are based on data collected by local communities in GROW Places. Being able to access soil moisture for their local area can help them see connections and become more aware of the joint challenges and options they face. ● Maps provide robust longitudinal data to raise awareness about specific place-based issues, and increase the likelihood of going up

	the local policy agenda, for example, fire risk in Greece and Portugal or flood prevention in the Netherlands. ● Soil moisture maps act as a) a method to present complex longitudinal data in a more visual way b) a reward for GPs c) provide another format for participants to explain what they are part of and communicate findings to different audiences (e.g. relatives, colleagues, local policy makers, etc.). ● For growers in the CC Mission with sufficient knowledge, they can interpret their mapped soil moisture data with a view to considering which interventions suit their moisture patterns e.g. soil moisture-conserving growing practices, or selection/placement of appropriate crops based on EPD information.
Living Soils Mission	Maps are focused on specific GROW Places in the Changing Climate Mission and not extrapolated beyond these. This limits direct evidence for participants outside GROW Places, but provides the following opportunities: ● Appreciation of the spatial and temporal dynamics of soil moisture across a small area (i.e. within one map). A particular point of interest might be changes following a watering event like precipitation or irrigation. ● Visual comparison of differences between regions (i.e. comparing maps e.g. Portugal, Hungary and Ireland) which can highlight wider scale variations in moisture availability across Europe.

5.1.1.1 User feedback and prototype testing

It was important to ensure that the visualisation could be understood outside of the scientific community. A user testing phase was incorporated into the development of this visualisation in early March 2019. After a prototype version was developed, it was tested with growers and non-growers.

A set of tasks and questions were developed to test the visualisation overall and also specific aspects that were potentially difficult to understand, or difficult to use. For example, users were asked to explain what certain elements (such as graphs) showed and whether they had noticed certain features (such as being able to rotate the map to view from different angles). Feedback from each tester was gathered and grouped according to predetermined topics, relating to specific visualisation features. This information was fed back to the data visualiser who incorporated it into the final version.

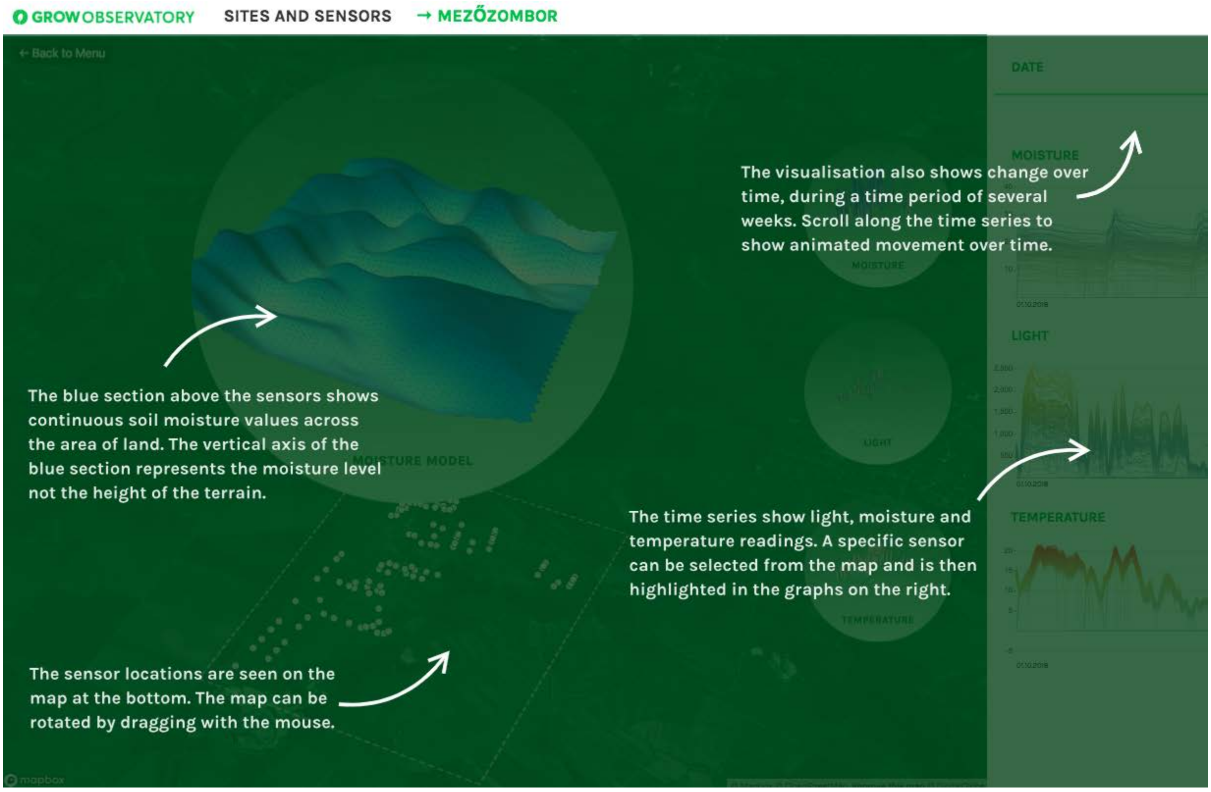

Fig. 12: Information layer added after user testing to better explain core parts of the visualisations

The topics covered by the feedback were:

- Screen resolution
- Moisture distribution graph
- Movement of bar graphs
- List of sensor IDs
- The moisture 'blanket'
- Date range
- Text to explain graphs
- Location coordinates
- Other labelling
- Rotation
- Other feedback out of scope for this version

Examples of changes made as a result of the feedback are:

- Removing a ‘moisture graph’ that no one could understand
- The date range was moved to a new position on the screen
- Addition of help text to indicate what is depicted by each element of the visualisation, e.g., what the points on the map show (Figure 12)

5.1.2 Soil Water Content

This visualisation and accompanying information benefits growers with more location-specific information on average water availability per month for crops. It can indicate when crops can grow without irrigation. Where additional water is needed for optimum crop growth, the average quantities needed each month are indicated. It is especially useful for growers who want to plan the quantities of water they will need throughout a month or year.

What functionality does the visualisation offer?
Users start by entering the location and the size of their growing space.
They provide their location by entering an address, postcode or GPS coordinates. They then give their plot size in metres (Figure 13).

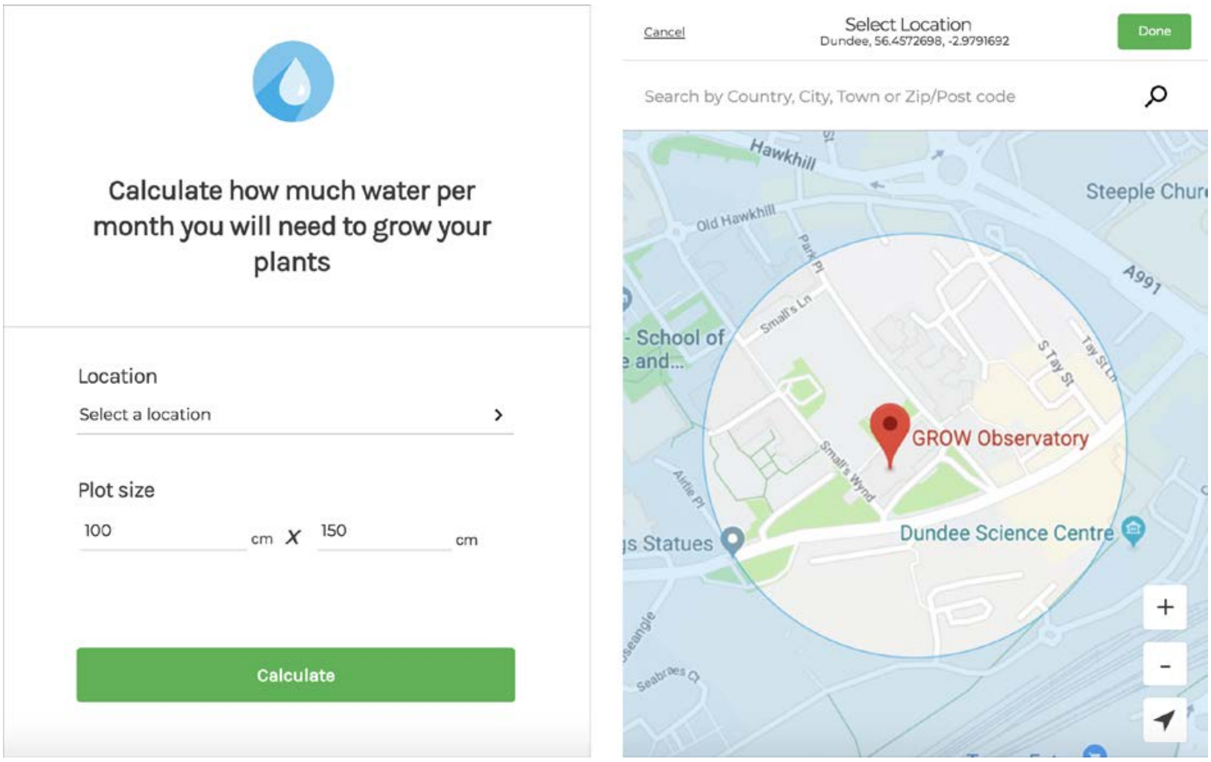

Fig. 13: Prototype screens showing plot size and location input

Using this information the tool calculates the amount of water they will need to give their plants, in addition to water from rainfall, an estimated amount which will vary depending on the amount and type of plants grown (Figure 14). This variability is explained to the user in an ‘About’ section.

Users can view water quantities per month and per day and also view data for an average dry year and an average wet year.

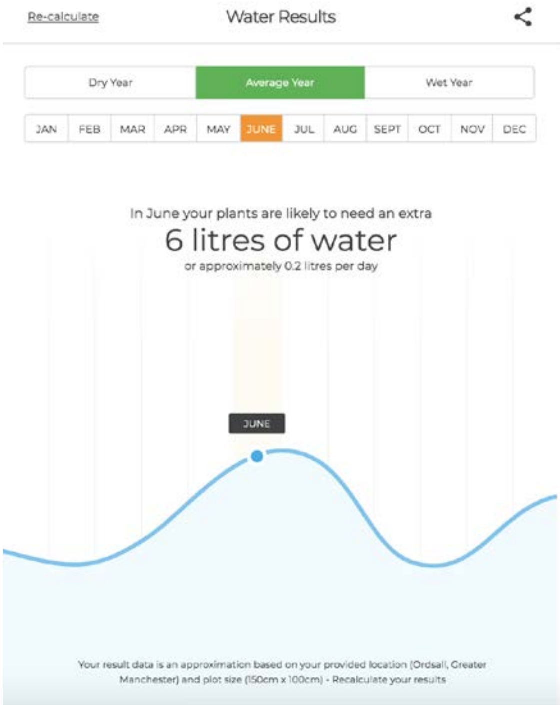

Fig. 14: Prototype screen showing water requirements results

The user can also share results for a specific location and plot size. They are able to copy a link that they can send to others which will open the tool on those specific results.

Data used

This tool is based on available climate data (temperature, precipitation from Agri4cast data) combined with synthesised plant water demands (based on 10 vegetable crops) for an average per month water availability (climate), water need (crops) and calculated water surplus/deficit for growing (the difference between climate and crop needs). It is location specific according to the original 25 km^2 grid of Agri4cast data. In the first instance, results are calculated for the area of the original 9 GROW Places. Additions are then being made for full countries, e.g., the UK. Upon finalisation, this will provide an indicative information service on water availability and irrigation needs for growers across Europe.

Function in GROW Missions

Changing Climate Mission	Being able to access plant available water content visualisations for their local area can help participants see connections and become more aware of the local challenges and options they face together. Water content information acts as a) a method to present complex longitudinal data in a more visual way b) a reward for GPs c) provide another format for participants to explain what they are part of and communicate findings to different audiences (e.g. relatives, colleagues, local policy makers, etc.).
Living Soils Mission	• For areas with visualisations, it can help new growers to make informed decisions about growing crops in their local region. They can see whether they are likely to have to irrigate and by how much. • For people in areas where crops may need irrigation in some months for optimal growth, regenerative growing practices that can help with soil water retention (e.g. mulching, cover crops) could be used to gain, or increase, yields.

5.1.2.1 User feedback and concept testing

The visualisation represents a tool for people who grow as a hobby or on a small scale commercial basis. Importance was placed on user-friendliness and simplicity in communicating the underlying scientific concept and combination of datasets for arriving at plant water availability, that is how much natural water (not irrigation) is in the soil and can be extracted by plants.

User survey

The initial concept was tested with users, to see if it would have practical value for them outside of a scientific context. This was done by way of a survey in January 2019, which was completed by 86 growers. The survey presented a set of questions that growers would be able to answer by using the service. These questions were:

- During which months will typically be a shortage or excess of water in my soil?
- How much extra water would I typically need to cover the water requirements of my plants?
- Does the water requirement pattern change with different years?
- Is it possible to grow a specific plant without irrigation?
- When is the best part of the year to plant and grow a specific plant?

For each question, respondents were asked to state:

- I feel I already know the answer to the question
- I don’t know the answer but don’t need to know it
- I want to know the answer to this question

The purpose was to determine whether the service would be valuable and to identify which aspects would be of greatest value. Respondents were also asked where they grow and what scale they grow at. The results (below) confirmed the service would be useful and informed which feature of the service should be built first in the initial version.

In summary, the results showed:

- The question that most people (59%) wanted to know the answer to was **‘How much extra water would I typically need to cover the water requirements of my plants?’**
- The question that fewest people (27%) needed to know the answer to was **’During which months will typically be a shortage or excess of water in my soil?’**
- All the other questions had at least 45% of people wanting to know the answer.

Based on those user needs we have developed a tool that tells growers the amount of water (on average, in litres per square metre of land) that they will need to give their plants on a monthly basis throughout the year. This builds on growers’ existing ‘common sense’ knowledge that there will be a shortage of water during summer months by giving them more precise information about the exact amounts of water they need to add.

User testing

User testing was carried out between the prototype stage and development stage. A clickable prototype was tested with 5 experienced growers of different ages (from early 20s to 60s).

The testing highlighted some things that need to be changed or added in order to make the tool easy to understand and use. For example, the following two aspects were not clear to all testers:

- whether the amount of water they were shown was per plant or for the whole growing space
- whether the amount of water shown was additional to the rainfall.

Both these issues were addressed by changing the wording.

Overall the testing also provided useful insights around the types of users who would most benefit from the tool and the best way to position it in terms of what it offered. It was concluded that new inexperienced growers would find it especially useful for getting a general idea about water requirements. In addition, rather than it being a tool about the water that is required 'right now today' it has more value for planning water requirements in advance across a whole month or year. This type of planning is especially useful even for experienced growers who want to collect rain water or who have limited access to water.

Another key finding from the user testing was that growers wanted further information from the tool about water requirements *specific to plants or broad families of plants*. Providing this information would give the tool a very solid value proposition for growers.

5.1.3 "My sensors" visualisations

"My sensors" visualisations can be seen by Changing Climate Mission participants with sensors once they are logged in to their profile on the GROW website. It enables them to view data from all their sensors and see their sensors located on a map.

The visualisation (Figure 15) consists of:

- A list of all sensors of one user (up to 100)
- Time-series graphs of above ground temperature, soil moisture and light for each individual sensor
- A map indicating the locations of all sensors
- The option to change and update the location of a sensor

A participant with a sensor will already be able to access a list of sensors and graphs of data in their Flower Power app. In this visualisation, the map overview of sensor locations provides additional information to what is available in the Flower Power app. This map allows growers to check that their sensors' locations have been recorded correctly and, if not, enables them to correct the location. Being able to see all the sensors on a map enables growers to compare data from closely located sensors and to see how readings correlate or differ.

By being able to see the overall distribution of their sensors and the data from each sensor, a grower can relate this to their own knowledge of their site and conditions to better understand hyper-local variation in light, temperature and moisture. With thoughtful reflection, this could lead to adjustment of growing practices including crop selection and use of practices to improve soils or modify moisture regimes.

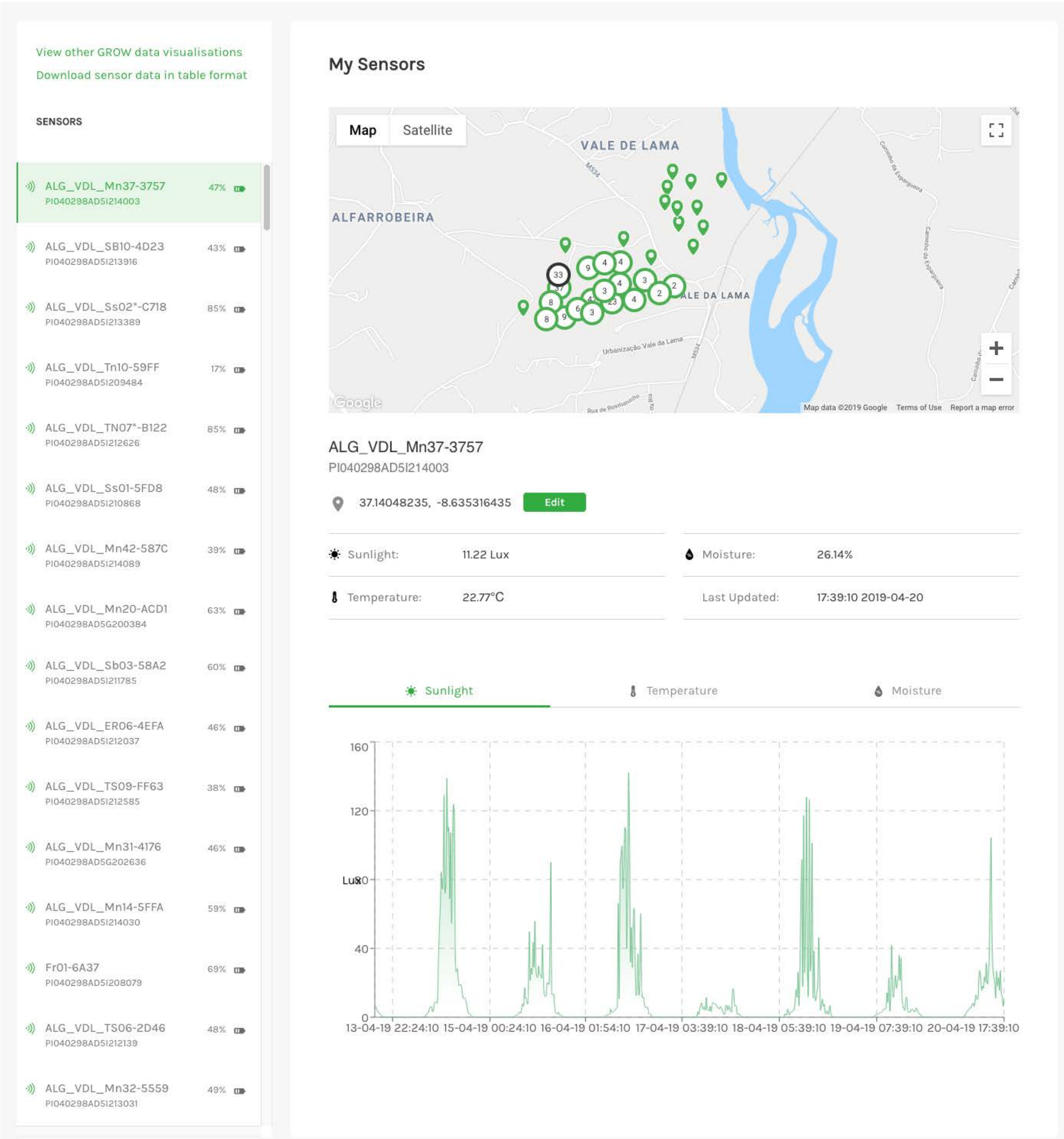

Fig. 15: "My Sensors" visualisation on the user portal on the GROW website, displaying available information and data on particular sensors.

Function in GROW Missions

Changing Climate Mission	● Reward for Mission participants ● Encouragement to continue contributing consistent sensor data uploads ● Alternative format for gaining insights from sensor data (complemented with a resource) ● Provide data to identify trends in the user's growing plot, allowing them to answer new questions about their soil and land management practices (e.g. comparing data overtime or from closely located sensors and to see how readings correlate or differ)
Living Soils Mission	N/A

5.1.4 Sensor overview map

This map shows the locations of all active GROW sensors across Europe (Fig 16). This is a live map showing a real-time view of current sensors and is available on the GROW website[8].

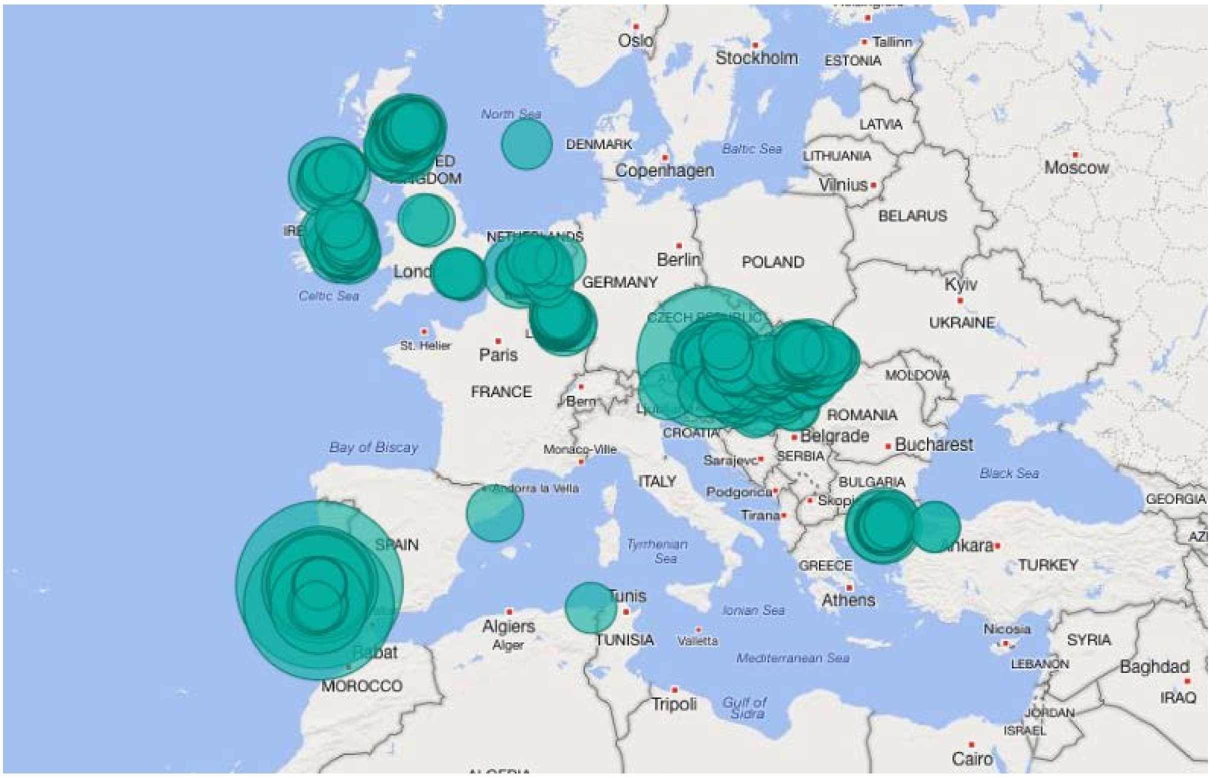

Fig. 16: Rough sensor placements and clusters across Europe

Visualisation features

The user can zoom in to the map using the scroll on their mouse or trackpad. As they zoom, the circles break into smaller circles, to indicate smaller clusters of sensors and then individual sensors (Figure 17 and 18). By hovering over a circle, the user can see information about the number of sensors, the geographic coordinates and the date when a sensor was last read (Figure 18). To ensure privacy, the map's zoom level is kept low enough to conceal the precise locations of each sensor.

[8] https://growobservatory.org/data/sensor-locations

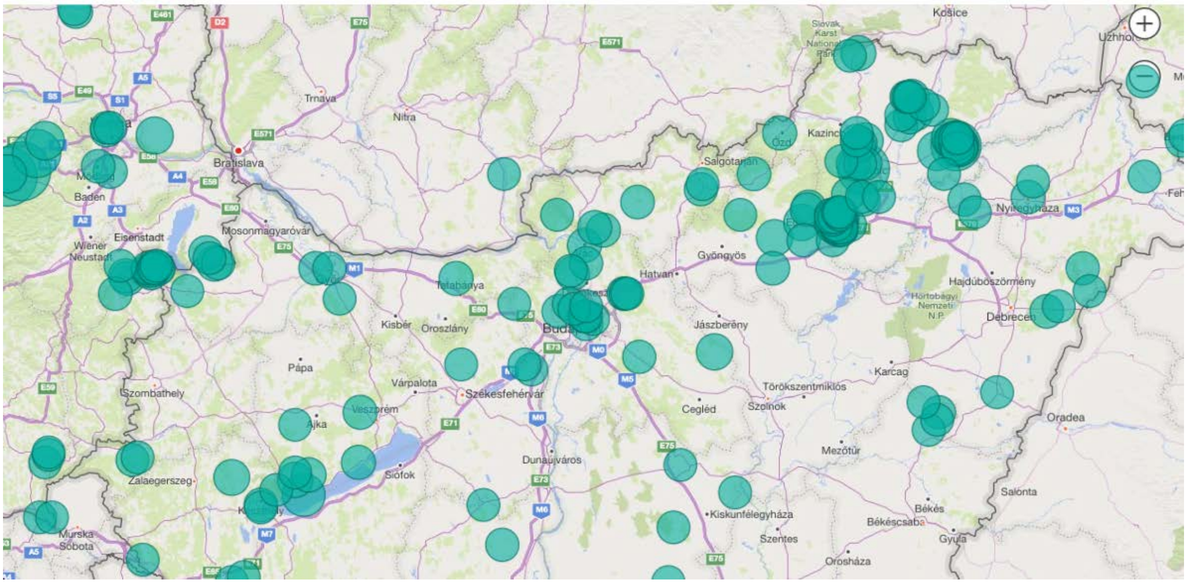

Fig. 17: Map with increased zoom level.

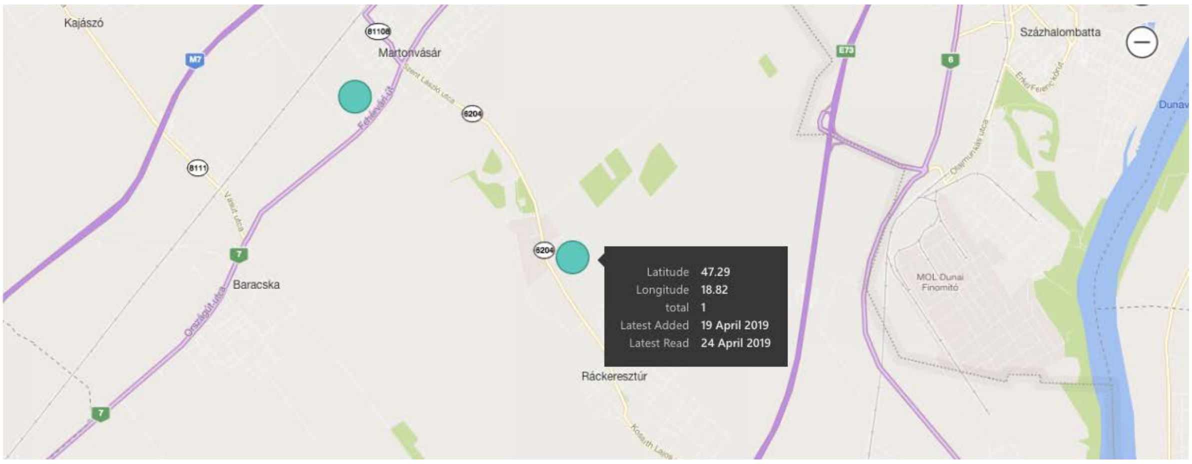

Fig. 18: Displaying detailed sensor information

In addition, two time series graphs accompany the sensor overview map (Figure 19), i.e. an overview of how many sensors are installed and added when and how many sensors were "read" (data actively collected from sensors by participants) and when.

Fig. 19: Number of sensors added by date (left) and number of sensors read by date (right)

Function in GROW Missions

Changing Climate Mission	• Valuable for participants who have a GROW sensor in their land as it enables them to view their sensors in the context of neighbouring GROW participants and the wider GROW community across Europe. • It is also beneficial to community champions in the Changing Climate Mission who have responsibility for sensor distribution. They can more easily see where sensors are and are not located in their region and when they were last read, and thus discuss with sensor users to ensure optimum data return.
Living Soils Mission	N/A

5.2 Information modules

5.2.1 Information on edible plants

Edible Plant Database via GROW Observatory app

The Edible Plant Database (EPD) offers a list of plants which users can grow in their respective locations in Europe. App users outside Europe can choose from 12 European countries (representative of 12 climate zones). From the location based plant list (Figure 20, left) they can further select plants to grow at the respective, current time of year ("to plant right now") (Figure 20, right). The selection for the "plant right now" function is based on location specific planting/harvesting dates.

Users can further select a plant from the list and explore detailed information about each plant (Figure 21), including:

- Plant images
- Common plant name
- Taxonomic name and cultivation group
- Short description of the plant
- Temperature class (e.g., hardy, half hardy, tender)
- Specifics for optimal growing
- Sunlight requirements (e.g., full sun, partial shade)
- Nutrient requirements (e.g., low, medium, high)
- Water requirements (e.g., low, medium, high)
- Preferred soil (e.g., loamy, sandy)
- Preferred pH
- Sensitivities (if applicable)
- Optimum germination temperature, which is the temperature at which seeds will sprout best.
- Information on sowing/planting (indoors, outdoors) and harvesting dates, specific to user's location that often differ significantly across Europe.

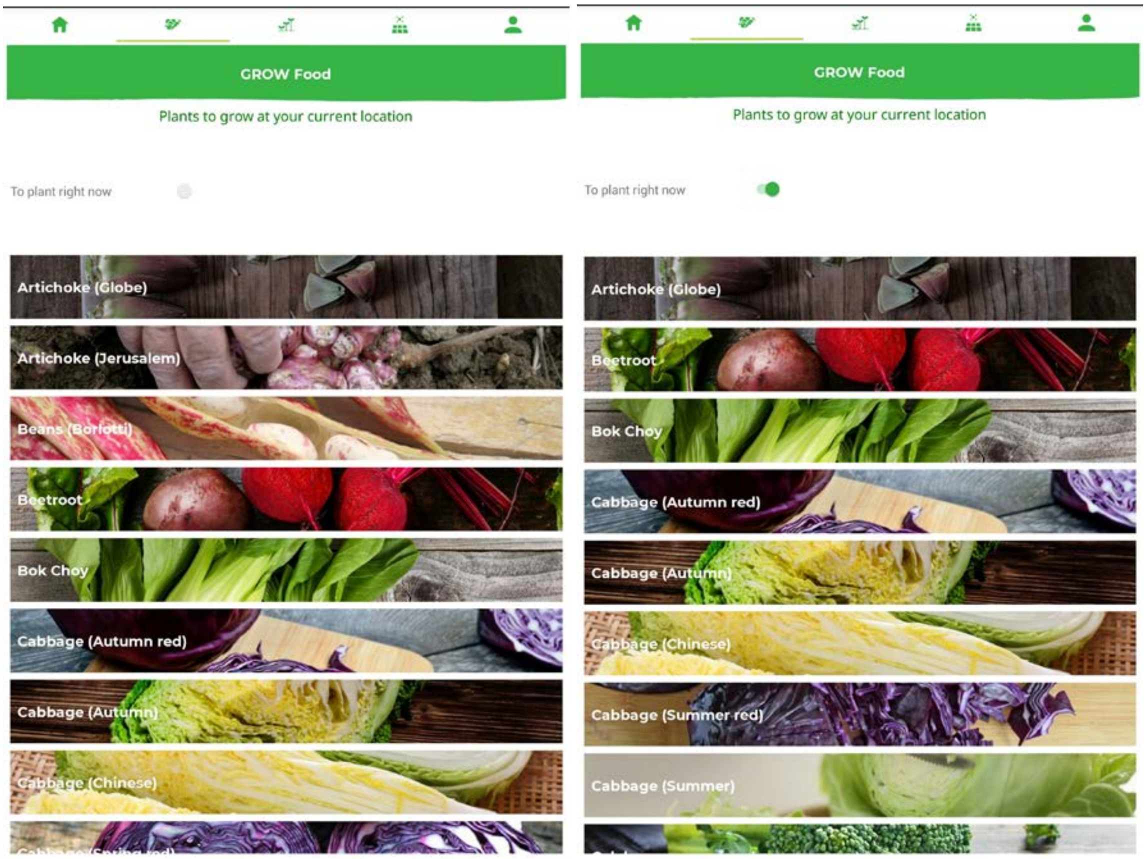

Fig. 20: Location specific plant list (left) and location and time specific plant list: "to plant right now" (right)

The EPD gives experienced and novice growers important information on plant requirements and provides location specific planting and harvesting dates for 12 European climate zones in one application.

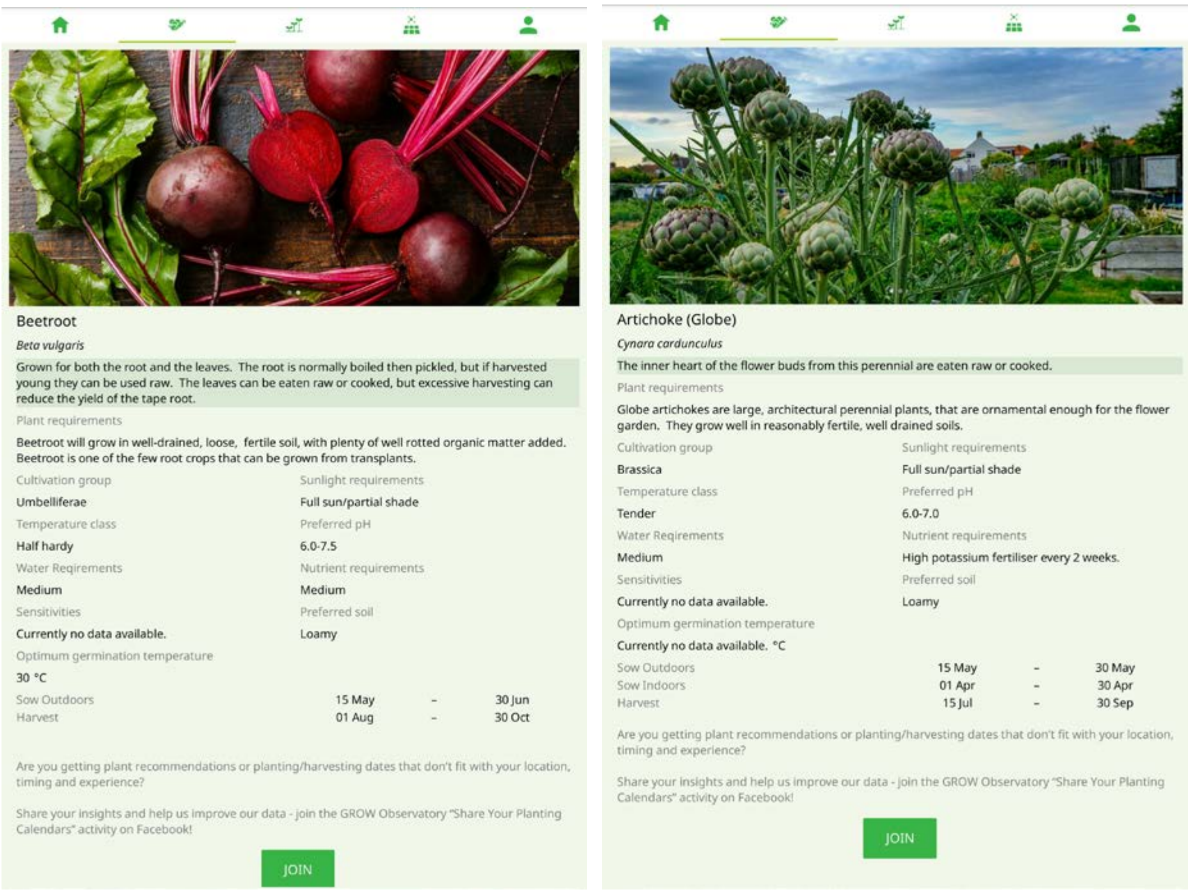

Fig. 21: Detailed plant information for Beetroot (left) and Globe Artichoke (right).

Share My Planting Calendar - Facebook group

In compiling the EPD, it became apparent that available data on planting and harvesting times was often not accurate or complete for many regions. This allowed for an innovative and responsive approach for the GROW project to crowd-source local planting and harvesting times for a number of edible plants. The "Share my planting calendars" Facebook page[9] is a group which encourages growers to share their planting and harvesting information and discuss their growing practices. By also sharing their general geographic location and growing knowledge, experienced growers can share and educate less experienced members of the group.

The focus of this page is to collect planting and harvesting data from citizen growers to improve the database – used by the GROW app – with localised, crowd-sourced planting and harvesting dates. Initially posts discussing a single plant species generated a minimal level of discussion, and no real data which could be used to populate tables for validation purposes. Following an iterative, adaptive approach, different options were envisioned and then implemented.

Polls were generated where page members are encouraged to vote on which plant species they are currently sowing or planting (Figure 22). Administrators of the page set up polls every 2 weeks with an initial list of 10 widely-grown plant species (Broad beans, Onions, Potatoes, Spinach, Radish, Runner beans, Carrots, Cabbage, Courgettes, and Peas). Group members can also add other crops to each poll to show what else they are planting. These polls have been running from the beginning of March and have generated in excess

[9] https://www.facebook.com/groups/sharemyplantingcalendars/

of 600 data points over the 6 two-week planting windows to date. These 600 data points include 51 different plants, and 8 climate zones. Location data, if available, is recorded by European environmental zone and sub zone (cf. Metzger et al., 2005) summarising the planting and harvesting data for each edible plant species for each European climate zone for each 2 week period highlighted in the calendars.

Fig. 22: Screenshot of the first Facebook poll.

The polls can improve the current data, e.g., in the UK the current planting calendars suggest a planting window for potatoes from mid-April to the end of May, however, the polls strongly suggest that these dates are later than growers are actually planting.

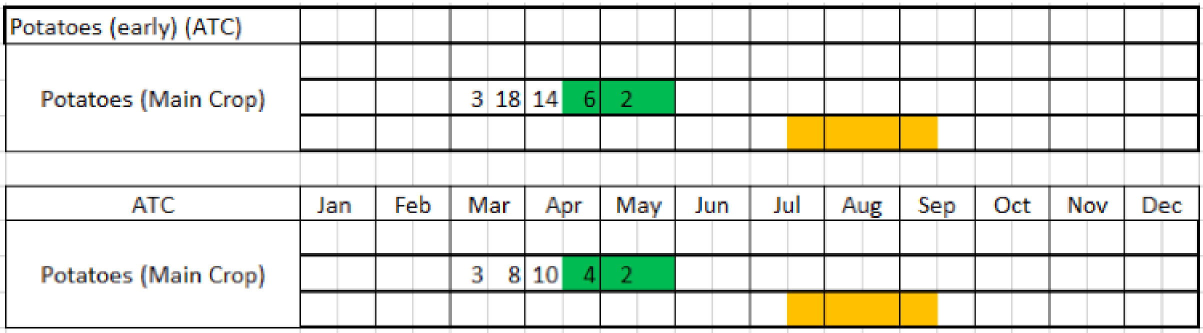

Fig. 23: Potato planting calendars for ATC with crowd-sourced data.

Figure 23 shows that to date, from 46 entries for potatoes we have validated planting data (3 or more growers voting for a date) suggesting that growers in the climate zone Atlantic Central (ATC) start planting at the beginning of March, and not mid-April, as our original data indicated. Figure 24 shows the planting and harvesting calendars for peas. Peas have been the most popular plant species, with 54 votes over 5 weeks in the polls. Growers in the Atlantic North (ATN) region have validated our dates, and growers in the ATC region actually plant peas 2 weeks earlier than our original indicative planting dates.

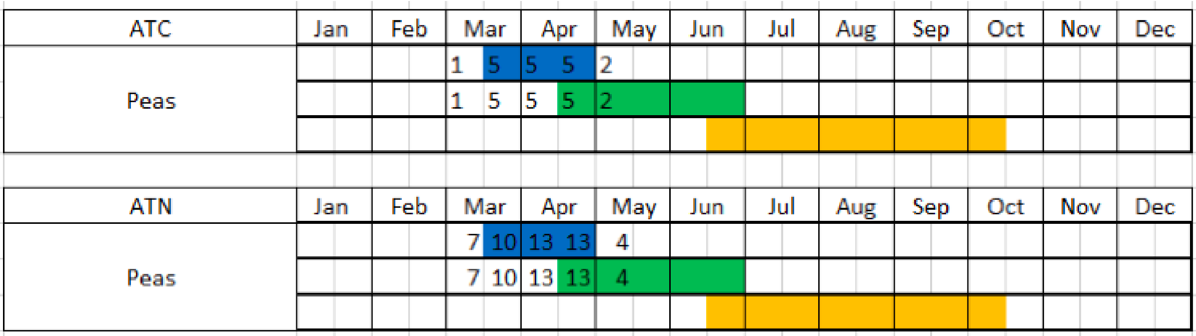

Fig. 24: Peas planting calendars for ATN and ATC with crowd-sourced data.

This crowd-sourced information will be used to inform the EPD info in the GROW Observatory app either confirming the dates we are already using, or that local growers have provided and validated alternate planting dates. Taking potatoes as an example, GROW Observatory app users will be informed that growers in ATC are planting much earlier than the calendars currently suggest (the first 2 weeks of March).

Crowd-sourcing data is not the only function of the Facebook page. It has become a community of practice, where growers from around the world are discussing their growing practices, sharing their experiences and posting images of their plots.

Function of information services on edible plants in GROW Missions

Changing Climate Mission	• Providing growing information on range of edible plants • Providing a complementary dataset participants can combine with sensor data to identify more complex insights.
Living Soils Mission	• Providing growing information on range of edible plants • Offering activity through the Share My Planting Calendar Facebook group, allowing the refinement of the advice provided through the edible plants information (GROW Observatory app). The popular Facebook group that brings together many growers from all over the world to exchange knowledge. This group underlines important feedback processes in the CO. It serves as a crowdsourced platform to gather growers' planting and harvesting dates, and it also acts as an information service itself, e.g. triggering responding to questions from growers on special conditions (e.g. weather events) and discussing implications for growing.

5.2.2 Information on regenerative growing practices

In addition to the information on edible plant cultivation described above, the GROW Observatory app gives information on "GROW Practices." These are specific techniques growers can use to a) Improve soil and/or b) Support ecosystems (Figure 25) and reflect audience specific information and knowledge gaps/needs (see section 4 - User research). Eight techniques were covered in the first publication of content (Table 5). Information is written for a target audience of new and inexperienced growers yet is accessible to more experienced growers looking to improve the environmental impact(s) of their growing.

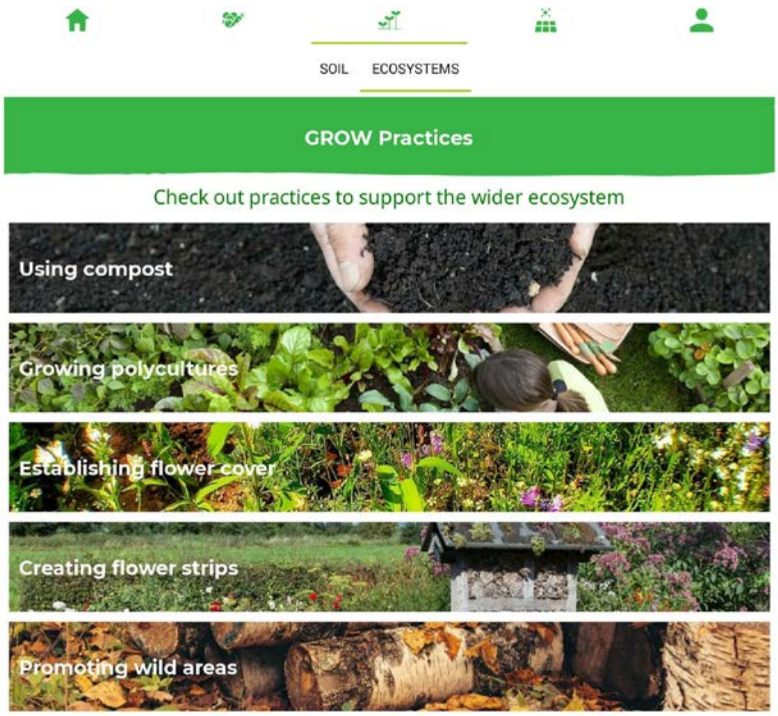

Fig. 25: List of practices to benefit the wider ecosystem. Users can easily switch to practices improving soil using the upper tabs "Soil"

Regenerative practices were identified and prioritised based on robust scientific underpinning for inclusion in the GROW Observatory app.

Practice \ Outcome	**Improve soil**	**Support ecosystems**
Using compost	x	x
Growing polycultures	x	x
Mulching	x	
Using cover crops	x	
Planting legumes	x	
Establishing flower cover		x
Creating flower strips		x
Promoting wild areas		x

Table 5: GROW Practices and their main, high-level function

The information provided is based on reviews of academic literature relating to each practice, and represents a summary of the best current evidence.

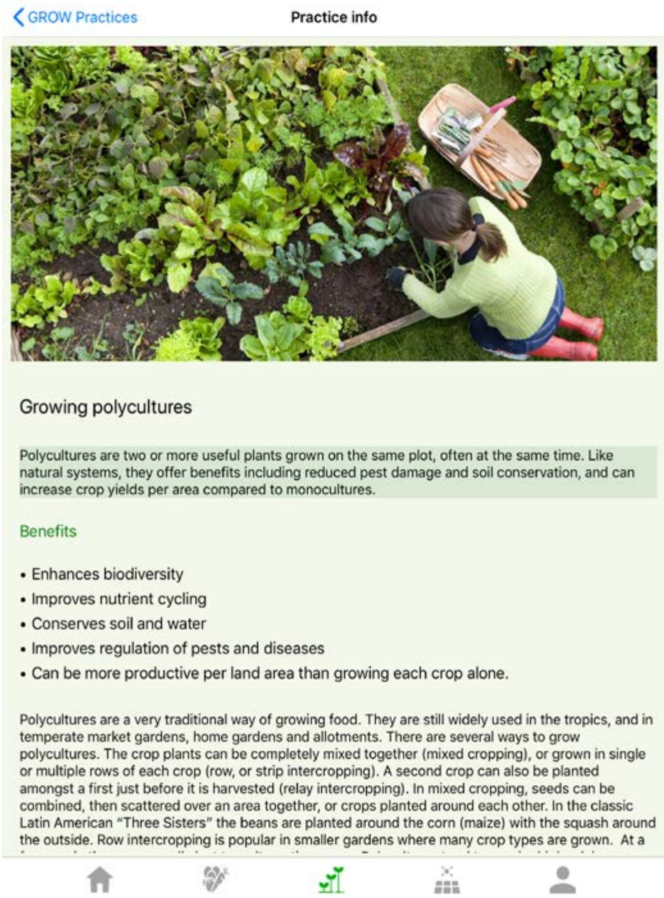

Fig. 26: Regenerative practice description (growing polycultures) in the GROW Observatory app

Since many practices have not been scientifically investigated at the smaller (non-mechanised) scale at which our target audience is growing, the "How-to" section draws further on practitioner experience. For each practice, a standardised format was followed for the content presentation to ease understanding and use of info by practitioners. Each was illustrated, and includes a brief overview followed by benefits, specific considerations on how, when, or where they might be used and limitations to use, and some simple step-by-step instructions for how to do it (Figure 26).

Key practices for growing ecosystems

Implementing regenerative practices can mitigate the negative effects of intensive monoculture farming and the ongoing increase in soil sealing rates.

These negative effects can include the loss of biodiversity, the loss of natural areas (for example, forests, marshes, shrub and grasslands), and increased pollution due to extensive fertiliser and pesticide use or industrial and household waste. These are undesirable outcomes on their own, but they can also lead to the decline and loss of essential ecosystem services, such as water infiltration and purification, pollution buffering, carbon storage, natural pollination and pest control, and genetic diversity. They also push our systems closer to so-called tipping points. Once a tipping point is crossed, it is impossible to buffer back. Some ecosystems might take ages to restore, and others may not be able to recover at all. Using practices to grow ecosystems not only avoids mistakes and negative "side-effects", but it is also a smart way to make the best of nature's services for growing good, healthy foods, while supporting long-term land stewardship and green urban development.

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GROW OBSERVATORY

Find out more: growobservatory.org @GROWobservatory

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 690199

Two core ideas lie at the root of practices for growing ecosystems above ground: to restore natural land and diversify landscapes in general, even on a small scale; and to create wildlife areas, which can provide local and regional habitats and resources for animals, and ensure the movement of animals across landscapes.

Most often, these go hand in hand, and in practice, and cannot be separated. So, as a grower, what can you do?

Flowers

Flower strips or fields are a great way to improve the abundance and diversity of pollinators around your growing area, such as wild bees, bumblebees, butterflies and hoverflies. Wild bees including bumblebees are the heroes of pollination, and more efficient than honey bees.

To determine what kind of flower

colonies around your growing area long-term.

You could have flower strips and flowering plants in the form of: adjacent strips or field margins; as part of a crop rotation (planting different plants after one another on the same piece of land); as part of a multi-cropping design (planting different plants in a mixed design at the same time); or as temporary or longer-term fallows.

Sown flower strips

Sown flower strips can create additional, diverse habitats using annual and perennial flowers. These attract pollinators and natural enemies of pests by providing nectar and pollen throughout their active foraging period, especially during resource-limited times.

You can include:

Fig. 27: PDF documents online for audiences that don't use smartphones, or want to use the materials in other learning contexts (e.g., educators, community gardens etc.)

The information content for each topic, as well as overall insights into lack of available evidence at smaller scales of practices, is also expanded on during the free online courses (MOOCs) Citizen Science: from Soil to Sky (which includes further information on practices for water capture and water-use efficiency) and Citizen Science: Living Soils Growing Food. For audiences without smartphones this expanded information is further made accessible on the GROW website knowledge hub[10] as downloadable, multi-page PDF info sheets (Figure 27).

[10] https://knowledge.growobservatory.org/

The full information from the academic literature reviews that is condensed in these services is also added to the Permaculture Association Knowledge Base for longer-term availability. A literature review paper based on combined evidence from all practices is in preparation for submission to an academic journal. A practitioner-focused summary of this will also be shared by responsive blogs (see 5.2.3).

Function in GROW Missions

Changing Climate Mission	● Supporting growers to be aware of and easily implement more regenerative food growing practices. ● Information on practices aligned with soil moisture gives particularly relevant opportunities for participants in this Mission to consider such practices alongside their own sensor data and site information.
Living Soils Mission	● Supporting growers to be aware of and easily implement more regenerative food growing practices. ● Participants who took part in GROW's 2018 Experiment contribute data to assess the performance of polycultures vs. monocultures in their own growing sites. Results were fed back to participants at two levels: individual and collective findings.

5.3 Responsive online information service

To facilitate wider access to information content and to enable the sharing of information on emerging, timely, and requested topics, other media were also used to provide and share information to and among GROW participants. Some of this was responsive, addressing the needs and interests of participants that was not foreseen, and some was curated and programmed, addressing topics selected by the GROW team around project themes and stages. A number of curated online channels and environments were used, collectively referred to as the GROW Collaboration Hub. The main channels were the GROW blog[11] (hosted on Medium), the GROW discussion forum and knowledge base[12], and the GROW social media channels[13]. The GROW blog was a primary channel because it allows for an engaging journalistic style and shorter or longer pieces as appropriate. Use was also made of Padlet - where a collated collection of annotated images can be shared and added to by users, as well as via standard social media channels; Facebook, Twitter, Instagram and YouTube. Most of the blog posts created to date explaining the scientific approach or findings in GROW, and about a third of those giving info to help growers improve their practices, have been in response to participant's needs (Table 6).

[11] https://medium.com/grow-observatory-blog
[12] https://knowledge.growobservatory.org/
[13] Username @growobservatory on Twitter, Facebook, Instagram and other social media channels

	Info for growers	GROW Science	Community	Policy	GROW Promo
Other blogs	11	1	14	4	7
Responsive blogs	4	5			
TOTAL (47)	15	6	14	4	7

Table 6: Blog posts - blogs and main topics for responsive and other posts, 'Info for growers' - info that can change practice, 'GROW science' explains the scientific approach or results of GROW, 'Community' describes and connects growers, 'Policy' contextualises approach or results in wider terms and "GROW promo" is for blogs that promote GROW resources or activities.

GROW was thus able to respond to grower needs, and events, with timely information in a variety of appropriate formats. For example, the second year (2018) of running the free online course "Citizen Science: From Soil to Sky" coincided with heavy snowfall across much of Europe.

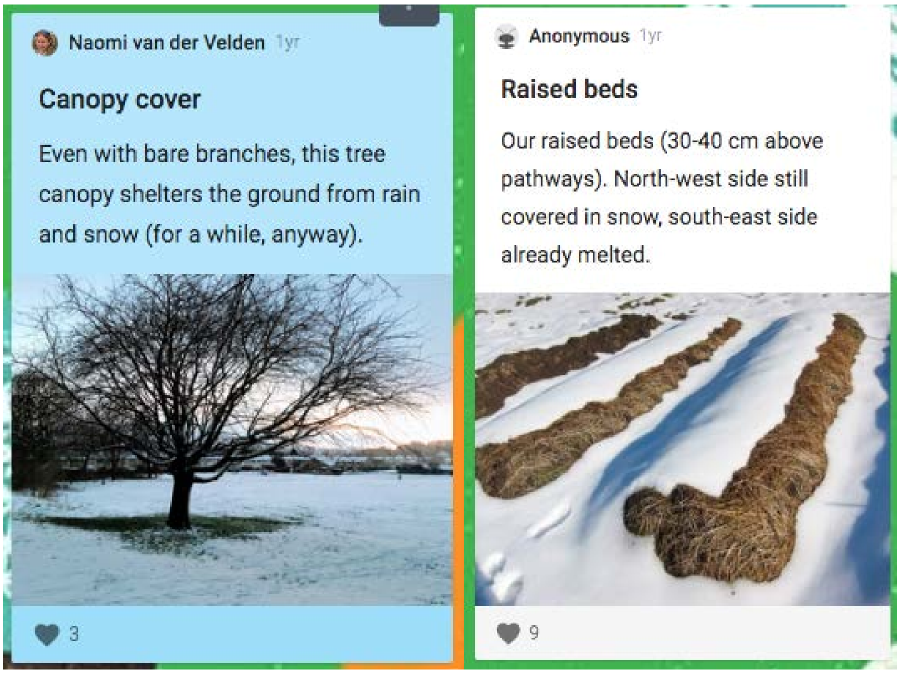
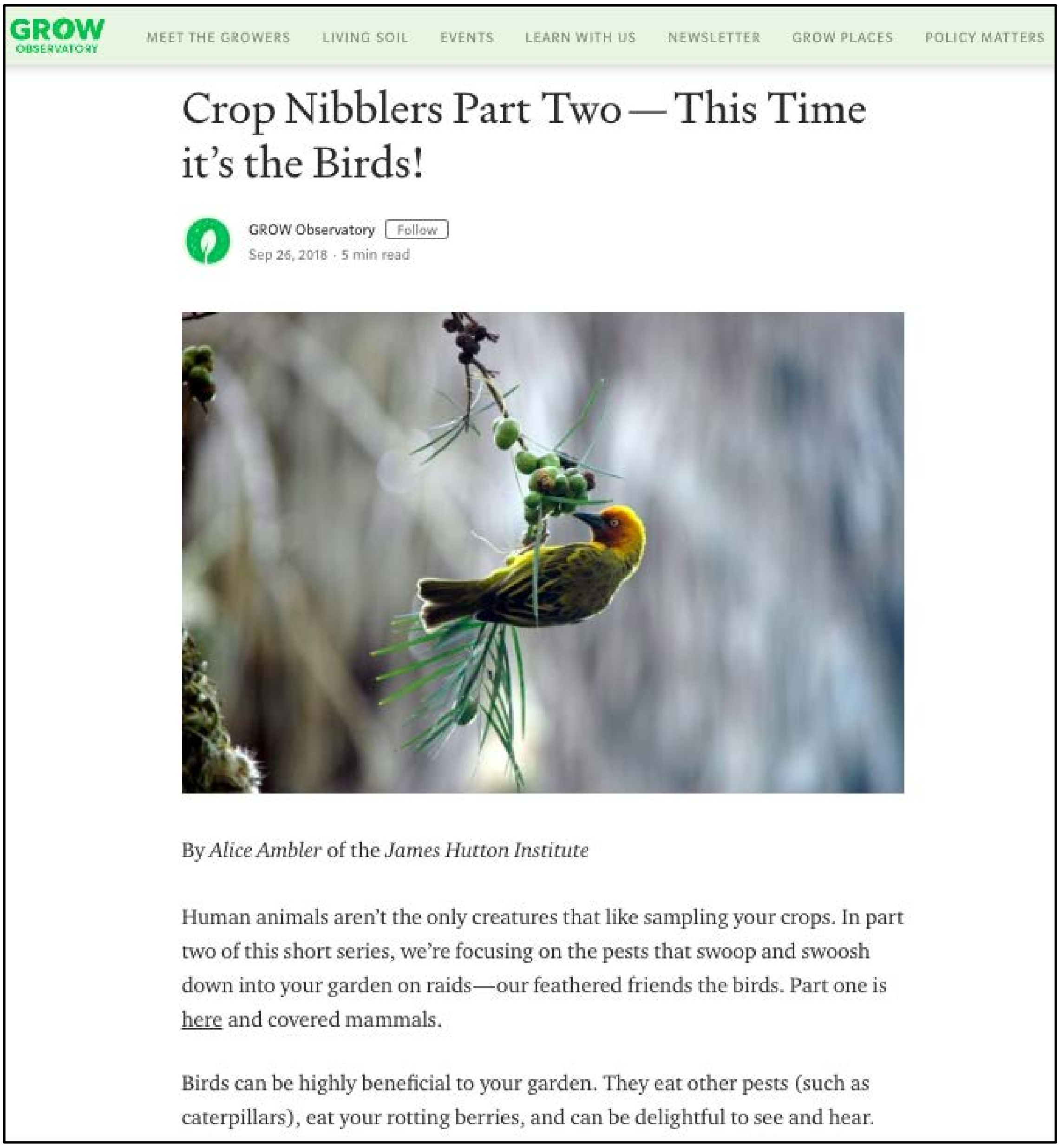


Fig. 27: Responsive information sharing inspired by unusual weather events

The course instructed users on how to take soil measurements relating to sensor placement (Changing Climate Mission) and the experiment (Living Soils Mission), but many participants reported being unable to access their soil due to snow or freezing conditions. A responsive activity was instead shared to take advantage of the weather conditions and demonstrate how snow could be used to "see" normally invisible microclimates (a topic also covered in the course). Illustrated examples were given and some participants shared their own observations in a specific Padlet page[14] (Figure 27).

[14] https://padlet.com/GROW/snow_shows_microclimates


GROW OBSERVATORY MEET THE GROWERS LIVING SOIL EVENTS LEARN WITH US NEWSLETTER GROW PLACES POLICY MATTERS

Crop Nibblers Part Two — This Time it's the Birds!

GROW Observatory Follow
Sep 26, 2018 · 5 min read

By *Alice Ambler* of the *James Hutton Institute*

Human animals aren't the only creatures that like sampling your crops. In part two of this short series, we're focusing on the pests that swoop and swoosh down into your garden on raids—our feathered friends the birds. Part one is here and covered mammals.

Birds can be highly beneficial to your garden. They eat other pests (such as caterpillars), eat your rotting berries, and can be delightful to see and hear.

Fig. 28: A series of responsive Medium blog posts picking up "pests" as a central theme

For example, participants in the Great GROW Experiment reported pest damage to their experiment crops and requested advice on how to deal with this. A series of three blog posts[15] covered approaches to dealing with mammals, birds, and invertebrates (Figure 28). Similarly, Changing Climate Mission participants asked for help understanding and using their soil moisture readings; an informative blog on soil moisture and how it relates to plant growth[16] was created, alongside guidance on the website for interpreting the readings from the sensors in the context of plant growth. As well as giving participants deeper information, blog posts were also used to help elicit greater engagement in the two participant-focused Missions, and address queries about approach. In response to sensor users asking about the purpose of their land survey data the blog on

15 https://medium.com/grow-observatory-blog/search?q=crop%20nibblers
16 https://medium.com/grow-observatory-blog/moisture-matters-a9e33dc880a1

“Tools for a Changing Climate”[17] was created to help growers understand the value of the land context in which they grow and how this impacts soil moisture.

Facebook, Twitter and Instagram were predominantly used to promote the GROW Observatory and engage participants in core activities. This often led to conversations and deeper engagement. Questions and queries were relayed to the appropriate partners for response which was then shared back alongside the original question. The Share My Planting Calendars Facebook page (see Section 5.2.1) has become a place for participants not only to share the planting and harvesting dates needed by the project, but also to exchange ideas and ask questions about growing which can be directly answered by the GROW scientists managing the page.

Fig. 29: Video filmed during GROW Place Austria event to share soil science information

YouTube has also been a very useful responsive information source allowing the wider sharing of videos created during the project. Whilst most videos have been intentional, a number have taken advantage of specific circumstances or availability of partners to offer timely and responsive information. These have especially supported understanding of topics including the science of soil[18] (Figure 29) and how to measure, e.g., soil texture[19] (Figure 30) or slope angle and aspect[20].

17 https://medium.com/grow-observatory-blog/tools-for-a-changing-climate-7d198c5da095
18 https://www.youtube.com/watch?v=c5YVYs1L73U
19 https://www.youtube.com/watch?v=Uc2buh3zHuE&feature=youtu.be
20 https://www.youtube.com/watch?v=yxpYmcP7RsQ

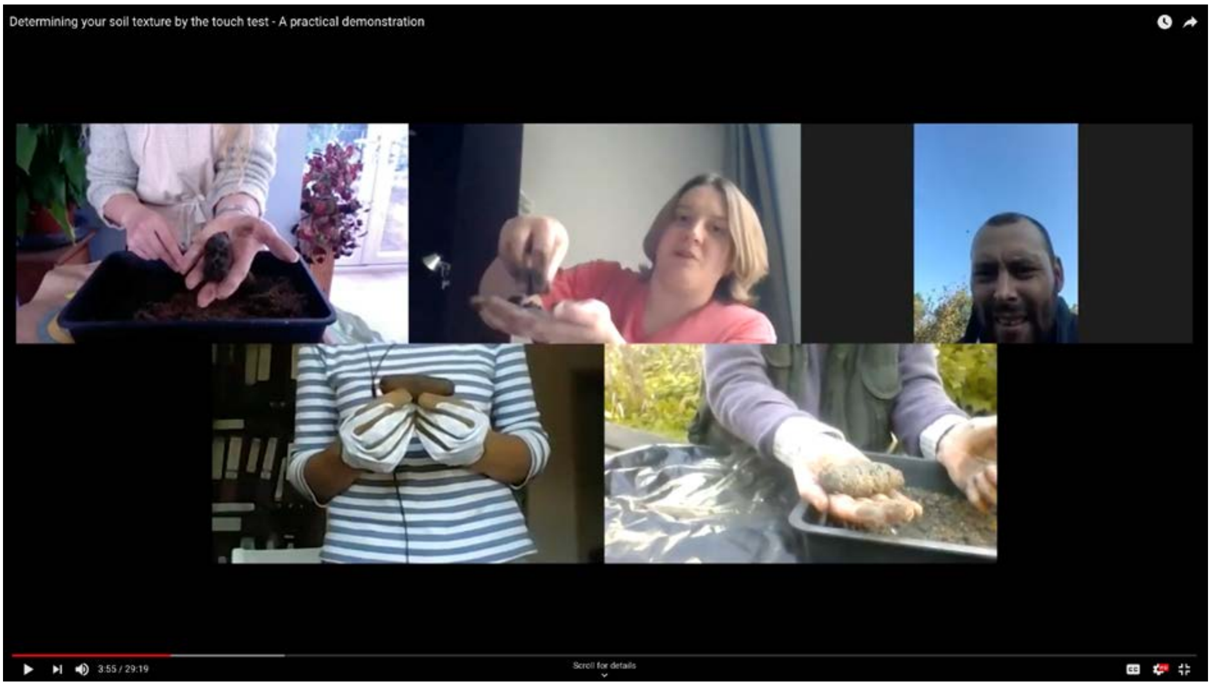


Fig. 30: Video of experiment participants in live online workshop on assessing soil texture. All major soil textures were represented making this a valuable information resource for others.

Function of responsive information services in GROW Missions

Overall, the ability of GROW to motivate citizen scientists and engage them in meaningful activity is dependent not only on the provision of high-quality initial resources to facilitate their engagement in science, but also the continuing conversations we have with them and thus their longer-term engagement. Being able to provide timely and useful information to them has been critical in maintaining that sense of momentum, in ensuring that their questions are answered and their needs met, and ensuring that participation in GROW is enjoyable and rewarding.

Changing Climate Mission	● Reward mechanism, such as increased visibility for participants' projects, stories and organisations ● Onboarding, context-providing and training purposes (blog posts)
Living Soils Mission	● Providing information to growers wishing to test regenerative food growing practices ● Providing additional support to growers trying new regenerative practices ● Serving as data submission platform for CS activities, e.g. Share My Planting Calendar Facebook group

5.3 Art as information innovation

GROW commissioned artists to create imaginative interfaces to the GROW continental-scale sensor network, open new perspectives on GROW data, and engage new audiences in the Copernicus programme. Whilst data art is not an informational service in a conventional sense, that is to say, it does not provide actionable information to address a user need, the data artwork provides new ways to understand data and the concept of a CO.

5.3.1 Data art commission

Uniquely in an EC H2020 Climate Action project, GROW included an art commission as an output, drawing on data and artistic expertise within the GROW consortium.[21] GROW commissioned artists Kasia Molga and Robin Rimbaud (aka Scanner) to deliver the GROW data art commission, alongside their participation in the STARTS residency (see section 5.3.2). The online artwork ***By the Code of Soil*** was developed from January 2018. The software application to run the artwork on one’s desktop computer can be downloaded since World Soil Day - 5 December 2018 from https://growobservatory.org/code-of-soil.

Artistic development

During the R&D phase of *By the Code of Soil*, the artists spent time analysing and reflecting on the importance and meaning of soil, building their understanding of biological processes within soil. They analysed data from GROW sensors and Sentinel satellites, and conducted interviews with soil and satellite scientists across the consortium. Their methodological approach was one of applying intuition, opportunity and iteration. A research trip to the GROW place in Greece gave opportunity to meet with small-scale food producers and growers to further refine visuals and interpretations and also link the art development with the overall user-centred approach of GROW.

The artwork

By the Code of Soil is a unique online data-driven artwork. It is a software application (see link above) for personal computers which creates an audio-visual artistic interpretation of sensor data from the cluster of GROW sensors in closest proximity to the participant by IP address. Hence, it is a networked piece using citizen-generated soil data (soil moisture, temperature and light data) from the cluster of GROW sensors closest to the audience's computer. The artwork is displayed on the computer screen each time the orbiting Sentinel-1 A satellite passes their location. The artists developed code and algorithms to translate dynamic data from soil sensors, combined with static data on soil texture and season, into different graphical shapes and electronic sounds, creating a 'data portrait' of soil properties in each place (Figure 31 and 32).

[21] The Principal Investigator and Coordinator of GROW, Drew Hemment, is an artist and curator with 25 years’ experience at the interface of Science, Technology and the Arts.

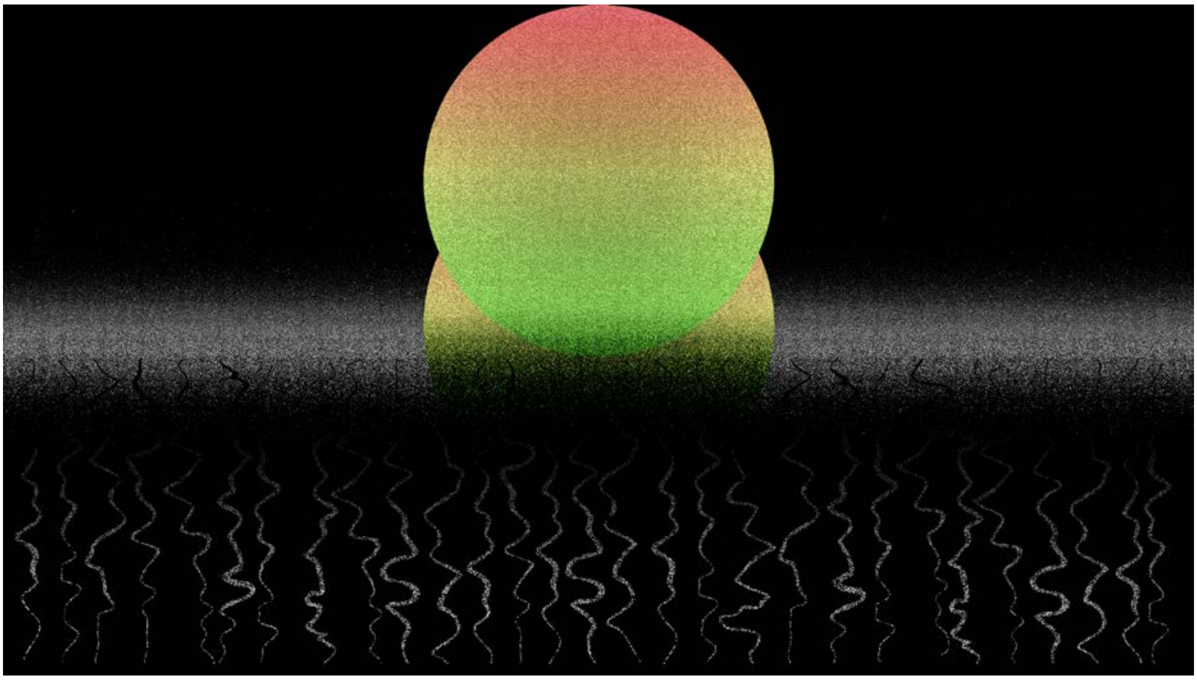


Fig. 31: By the Code of Soil image - representation of soil moisture and season.

To create the visuals, the artist took one pixel as a starting point – to represent a single entity like a grain of soil, from which the whole image is built using a matrix. *By the Code of Soil* starts in visual white noise, with imagery brought to life by algorithms and data. Various visual configurations – frequency, shape, speed of motion and size – give an abstract reflection of moisture, light, temperature as recorded by GROW sensors.

Audio files are written so that they can respond and reflect the values of data parameters. The sound maps small alterations in incoming data; the artists created sounds that frequently last half a second and mapped these across hundreds of different data alterations.

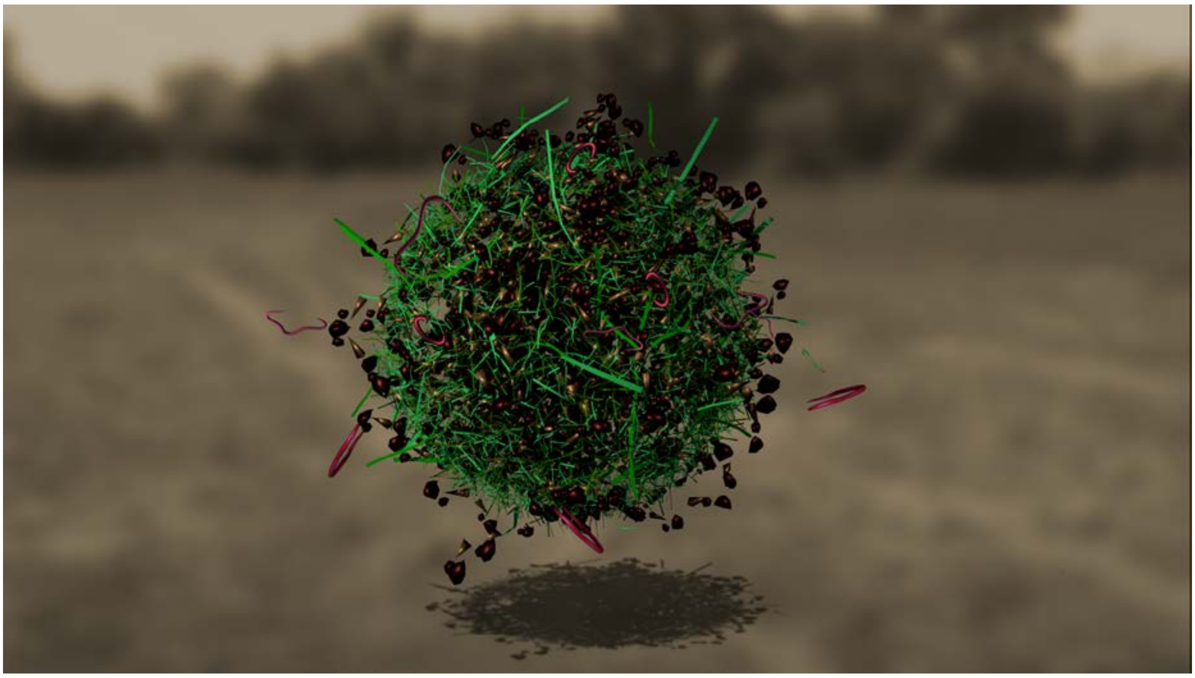


Fig. 32: visual representation of combined soil data parameters from a GROW place over a 10 day period.

By creating an artwork which appears on people's computer screens in conjunction with the local transit of Sentinel-1 satellites, the art commission draws attention to the instrumentation of Earth observation. An aim of the artwork is to represent and engage audiences in invisible networks above and below the soil. *By the Code of Soil* adds an imaginative dimension to the GROW continental-scale sensing network, and translates the connection between soil and satellites into an aesthetic experience for the audience.

5.3.2 STARTS residency

The STARTS Residencies Program (also known as VERTIGO) organises collaborations between artists and H2020 projects. VERTIGO is funded under the H2020 European STARTS initiative, promoting innovation at the nexus of Science Technology, and the Arts. STARTS positions the arts as a catalyst for efficient conversion of science and technology knowledge into products, services, and processes.

GROW applied for and was awarded a VERTIGO artist residency to complement and deepen the art component already a part of the GROW project. The ambition was for artists to contribute to innovative aspects of projects' research by bringing original perspectives through artistic practices, leading to the development of an original prototype artwork based on the project technology, ready for exhibition. The residency, like the art commission, was awarded by GROW and VERTIGO to artist Kasia Molga and Scanner, and produced by project partner FutureEverything.


images of (de) Compositions as completed in the artist's studio

Fig 33: image of (de) Compositions as completed in the artist's studio

The resulting artwork "*(de) Compositions*" builds a connection between earthworms (as biomarkers / living technology) and sensors - such as soil moisture sensors used in GROW (as agents monitoring the work of the living technology). *(de) Compositions* is a multi-sensory installation with different types of soil artistically arranged in a specially constructed monolith with tiger earthworms changing the condition of the soil through their actions (Figure 33). Moisture sensors continuously monitor soil conditions in the container whilst bespoke piezo sensors track the activity and number of worms. The sensors influence the sound transmitted around the container, distributed spatially across at 4 speakers.

VERTIGO aims to act as a platform to showcase works produced. There are discussions underway about a final exhibition of the outcomes of the VERTIGO programme in Paris, in Spring 2020.

Conclusion: Introducing art into Horizon 2020 and Climate Action

By introducing artists to the European Commission's Horizon 2020 and Climate Action programme, the GROW project engages new audiences and stimulates innovation in Earth observation. Art can change the way we see the world, and help bring curiosity and imagination to the science and technology themes. The inclusion of art in GROW introduces a novel way to illuminate concepts for new audiences, and to stimulate innovative ideas. The inclusion of data-driven art in the project offers new perspectives on GROW data through imaginative interfaces to the GROW continental-scale sensor network. It also opens the CO concept out to other sectors, particularly the art-science-tech world.

Function of data art in GROW Missions

Changing Climate Mission	● Building connection with satellite monitoring, through the triggering mechanism for viewing the artwork - when the Sentinel-1A satellite is over the location of personal computers on which the artwork application has been downloaded. ● Provide participants with an artistic reward for the sensor data contributions ● Provide participants with an alternative output format to share the CS activity they are involved with ● Reinforces a sense of place-based community for Mission participants and the general public. Each participant sees the use of citizen-

	generated soil data (soil moisture, temperature and light data) from the cluster of GROW sensors closest to their computer.
Living Soils Mission	● Raise awareness of the connections between soil moisture, the climate and satellite ● Encourage audiences to consider their relationship with soil, from obvious (e.g. food growers), to the more disconnected (urban consumers) ● Reinforces a sense of place-based community for Mission participants and the general public. Each participant sees the use of citizen-generated soil data (soil moisture, temperature and light data) from the cluster of GROW sensors closest to their computer.

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Appendix - Related GROW project deliverables

Deliverable	**Deliverable description**
D1.1 GROW Citizens' Observatory Framework	This deliverable outlines a framework and guidelines for engaging and collaborating with citizens and communities. This promotes a unified approach for engaging with partners and community champions.
D3.4 Business plan and service concept	Concept for new business, product or service using GROW data - This deliverable documents the concept for new business, product or service that could be developed by a third party business/SME using GROW data. This is an outcome of Datapitch challenge: this deliverable is linked to the 'Service Design Workshop" and will be its planned outcome.
D4.2 Assessment of GROW information services and their implementation	Assessment of GROW information services documented in a report. This deliverable will describe in detail the algorithms created for location specific recommendations on growing with identification of links with crowdsourced data. Climate and soil moisture data, results from soil tests, land cover data and known relationships between plant requirements and site conditions will be translated into a simple set of rules to feed into information services for growers.
D4.3 Report on science experiment(s) and protocol(s) and the collective creation of knowledge in GROW Missions.	Report on science experiment(s) and protocol(s) and the collective creation of knowledge in GROW Missions. This deliverable will describe the approach(es) used and the outcomes in both direct knowledge gained (e.g. results from experiment, scientific value of public-facing protocols) and in the use and interpretation of this collective knowledge (e.g. benefits to participants of own and shared data). It will offer insights into the use of crowd-sourced data and existing auxiliary data and expert knowledge to answer questions and provide information relevant to growers and researchers. It will discuss the value of supporting citizens to understand, contextualise and use their own data.
D4.4 Report on validation of remotely sensed soil moisture products	This deliverable will describe the exercises done to render the utilization of crowd-sourced in situ soil-moisture data from sensors for Sentinel 1 satellite data validation (e.g. Sentinel-1) with advanced statistical methods such as triple collocation and its interpretation towards practically useful gridded soil moisture information at regional and continental scales.

D6.5 Enhanced GROW social platform	This deliverable provides web applications and mobile services and a document describing the product design specification. The mobile app and eCollaboration web platform are extended with applications including personalised dashboards, feedback mechanism and visualisations to enable citizen scientists to interrogate (upload) data and results. This also includes a content management system, integrated social media platforms, and integrated external data using the Instagram API, Twitter's Streaming API; and embedded YouTube video functionality. A Thingful web widget is created that can be embedded in other webpages with a pre-agreed set of search or category parameters.
D6.7 Development of the GROW Observatory App	This deliverable reports on the development of the GROW Observatory mobile app (GROW app). The GROW app is a multi-functional app for smartphones that can serve different purposes within the GROW project. It is deliberately developed based on user surveys and detailed user requirements with the aim that the design and functionality of the app serve the needs of the GROW user community. It helps growers make better choices in managing their plants (e.g. soil management, how to attract pollinators etc.) and give recommendations on how to improve soil (incl. soil moisture), consider irrigation needs of plants or how to try growing practices that benefit the wider ecosystem. Other recommendations on, for example, choice of plants and timing of planting at a specific location are added according to the requirements of the growers. At the same time, the GROW app serves as an important data recording tool for land and soil data.

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