AgriCapture CO_2

Regenerating soils for climate and farmers

5 January 2023

D5.4 PILOT year 2 report

Activities and results of the use cases, M13 – M24

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Executive summary

The AgriCaptureCO2 project seeks to make it easier and more profitable for farmers to adopt regenerative farming practices. We bring together pioneering farmers, agronomists, soil scientists, public bodies, and technology experts working in 6 pilot sites across Europe and Africa to co-develop a suite of valuable services powered by satellite data. At the same time, we are developing and promoting a European Regenerative Agriculture Community to facilitate engagement and knowledge transfer.

The main aim of WP5 is to study 5 different pilot sites across Europe and another one in Kenya, capturing different operating environments, in which the functionality of the platform and its services will be tested, verified and demonstrated.

Also, in these areas, the farmers will become familiar with the use and the advantages that this platform can provide, including demonstration and supporting services. Regarding the partners involved in WP5, 11 out of a total of 14 partners are participating in this WP (Table 1 in red). The leader of WP5 is the Hellenic Agricultural Organization "ELGO", in Greece.

Table 1. A list of partners involved in WP5 (marked with red).

Name	Abbreviation	Organization type	Country
1. GILab DOO Beograd (coordinator)	GILab	SME	Serbia
2. SatAgro	SatAgro	SME	Poland
3. One Carbon World Fund	OCW	Non-profit organisation	UK
4. European Environment Bureau	EEB	NGO	Belgium
5. Linking Environment and Farming	LEAF	NGO	UK
6. Game and Wildlife Conservation Trust	GWCT	Research organisation	UK
7. Agricultural University of Athens	AUA	Research organisation	Greece
8. Hellenic Agricultural Organization	DEMETER ELGO	Research organisation	Greece
9. Planet Lab Gmbh	Planet	Large company	German
10. EnvirometriX	ENMX	SME	the Netherlands
11. Farrington Oils ltd.	FrOils	SME	UK
12. Arthur's Legal	ARL	SME	the Netherlands
13. Lancashire County Council	LCC	Public authority	UK
14. Udruženje Poljoprivrednika Opštine Ruma	UPOR	Association AgriCoop	Serbia

The overall objective is to provide several varied real-world operational contexts, in which to test and co-develop AgriCapture iterations together with end-users

- To define operational plans for each case study
- To provide trainings and worskhops to participating farmers
- To iteratively the test AgriCapture platform and its services with end-users across several case studies and to collect feedback to drive improvements
- To define evaluation methodology, and to evaluate the case studies each year to improve the next

This report documents the activities conducted by the project's use cases during the second year and assesses performance in line with KPIs. Best-practices and room-for-improvement will be identified, on which basis the use case plans for the successive year will be re-examined.

List of abbreviations

AAS PA	Agricultural Advisory Service of Pancevo (Serbia)
AAS RU	Agricultural Advisory Service of Ruma (Serbia)
EA	The Environment Agency (UK)
EFSA	European Food Safety Authority
EU	European Union
JRC	Joint Research Centre of the European Union
KPI	Key Performance Indicator
GNSS	Global Navigation Satellite System
GPS	Global positioning satellite
ha	Hectar
IoT	Internet of Things
IPCC	Intergovernmental Panel on Climate Change
IPG	In-Practice Group
OGM	Organic Growth Medium
SCF	European Union Scientific Committee for Food
t	Tonnes
UK	United Kingdom
UN	United Nations
WP	Work Package

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1. Introduction

The PILOT report provides a description of the activities that were undertaken as a part of WP5 in the second year of the project year: January to December 2022. We seek to provide a comprehensive overview, with a balance between detail and brevity. At the same time, we seek to assess results, progress, and direction, identifying challenges/ opportunities, lessons learned/best practices, and to reflect on any changes that will be implemented in the successive year.

A similar report (of a similar format) has already been submitted for the first year and another one will also be drafted at the end of year 3 (month 36) to provide an overview of WP5 activities in these periods of time.

These reports are highly complementary to the technical reports. To avoid repetition, the technical report provides a top-down assessment of the work conducted in the work package, while the current report provides a bottom-up assessment. As such, this document provides a greater number of details on the level of the individual use cases, reporting but also reflecting on progress. The use case operational plans defined in Deliverable 2.5 are a reference point.

The rest of this chapter provides a "narrative" overview of the effort in the second year. Chapter 2 provides the activities in WP5, for the completion of the baseline through the analysis of soil samples, while the training and dissemination activities for each use case. Chapter 3 provides an overview of implementation activities and evaluates progress. Finally, Chapter 4 provides conclusions.

Walkthrough through the overall effort

The requirements for WP5 in the second year concerned the continuation of work in the fields of the use cases. Workshops and training events were critical to take place this year and continue next year. An excerpt of the GANTT chart for AgriCaptureCO2 WP5 is shown in the figure below.

					2022									
			Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct
Project		**Work Package/Task Title**	**M11**	**M12**	**M13**	**M14**	**M15**	**M16**	**M17**	**M18**	**M19**	**M20**	**M21**	**M22**
AgriCapture	**WP5**	**PILOT: Use cases in an operational environment**												
AgriCapture	T5.1	Use case operation plan & evaluation methodology												
AgriCapture	T5.2	Establish use case baselines												
AgriCapture	T5.3	Training & workshops		D5.6										
AgriCapture	T5.4	Use case deployment												
AgriCapture	T5.5	Use case evaluation		D5.3										

Figure 1. Gantt chart for WP5 in year 2 showing the timing of the different tasks and their respective deliverables.

The tracking of progress/impact also continued this year with use of key performance indicators and milestones defined the first year. In addition, the establishment of the baseline completed during the second year with the completion of the analysis of the soil sampling campaign.

In December, the use cases were asked to provide an overview of their activities based on a template prepared by ELGO. The template follows all the activities, and assesses progress according to timeplans, milestones and KPIs.

Close coordination with other Work Packages

In addition, WP5 partners coordinated with WP3 to provide data needed for the development of the AgriCaptureCO2 platform, and with WP2 to carry out the engagement targets. Finally, interaction with WP6 was bidirectional to support a coordinated dissemination effort and to consider key aspects of post-project exploitation for each use case.

Synthesis of WP5 activities in the second year

The plan that had been set from the first year was followed in the second year as well.

2. Activities of the AgriCaptureCO2 use cases

In Task 5.1, the partners for each use case developed and detailed the activities that they would implement as part of the project. This builds from the initial concepts presented in the proposal and the Grant Agreement, seeking to provide a concrete plan of action.

2.1. Establishing a baseline

The majority of the baseline activities were conducted in the first year, as was planned in the workplan. To summarise, there were two types of baselines established for the use cases: (i) the level of soil organic carbon in a soil before the regenerative agricultural practices implementation, to measure changes over the duration of the project; (ii) to measure the emissions of a farm, organisation or value chain (depending on the use case). For all of the use cases, the first of these is essential and is key to testing the Quantify service being developed in WP3. It was based on a soil sampling campaign that was coordinated with WP3, making use of the alpha version of the Quantify service to pinpoint exactly where to take soil samples.

Nonetheless, the planned work progressed at a different pace for different use cases, as described in the PILOT report for year 1, and there was soil sampling work to be done for several use cases in year 2. Furthermore, additional soil sampling was required for the UK use case (use case #3) in relation to the carbon credit project being developed in WP4, which we chose to classify as under this task for the sake of consistency (although arguably it is not strictly related to generating a use case baseline but rather a carbon credit project baseline).

To summarise, the majority of the baselining was completed in year 1 as planned, but residual tasks for some use cases were completed in year 2 as well. The project chose to classify all soil sampling as "baselining", and as such soil sampling in the UK use case related to activities in WP4 was also classified under this task and will also continue in year 3.

The subsections below provide further details on baseline activities for each use case.

Use case #1: Sustainable Olive Oil in Greece (Crete)

Mediterranean areas will feel the heat of climate change more than other place in Europe, with the largest increase in temperature and decrease in rainfall. Mediterranean agriculture, including olive cultivation, must adapt to new challenges that affect local water, energy and ecosystems.

On the island of Crete in Greece, agriculture is already the largest user of water. Working with two farmer cooperatives and their olive mills, ELGO researchers will:

- Advance a new regenerative approach to cultivating olives, protecting soil while ensuring efficient use of water and other inputs.
- Develop and market a low-emissions olive oil brand, rewarding regenerative farmers and motivate new adopters.

For the case study in Crete, 10 farms were selected in Eastern Crete as an area that faces the most acute issues with water availability, low amounts of SOC, and saltwater intrusion – and thus would have the largest need and benefit for the potential of regenerative practices to improve natural resource management.

The selection of the 10 parcels/farms was made in order to capture all the different olive cultivation characteristics in the extended area of Eastern Crete. Each parcel covers about 0.2 ha. In addition, historical data (regarding the practices and monitoring parameters) already exists from previous research and the oLIVE-CLIMA project funded under the LIFE programme.

The farms are family owned in which "traditional" production practices are used to produce olives. In all the selected farms (Figure 1), regenerative agriculture practices such as no-tillage, proper pruning, proper weed management (weed mowing), and proper plant protection have been applied.

At the beginning of the project, OCW calculated emissions (baseline) for each parcel regarding the already applied practices (details in the Pilot Year 1 Report).

Figure 2. The ten olive parcels/farms of the use case in Crete, Greece. The blue marks indicate the irrigated fields, while the red the rainfed fields

Based on these baseline emissions, for each parcel separately, the already (historical) applied practices redesigned in order to achieve lower emissions and promote regenerative agriculture. Redesign means that, based on the already known emissions the scientific team of ELGO supports and advise farmers to follow appropriate practices minimizing these values.

The soil sampling points were proposed by ENMX based on uncertainty-guided sampling strategy where SOC samples are distributed proportionally to the probability of initial prediction errors exceeding the threshold error. The final sampling plan in the study area of Crete includes 2 sampling campaigns of 30 points for each campaign. The first sampling campaign completed in January 2022 and the second will take place in early 2023. In turn, the soil samples were delivered to the ELGO soil analysis laboratory. The results of the analysis are presented below. The spatial distribution of the sampling points is shown in Figure 2. The soil samples are taken from 3 depths (0-20 cm), (20-50 cm) and below of 50 cm soil depth.

In Figure 2, at the top left, the municipality of Ag. Nikolaou in yellow is depicted, while the sub-basins in which the sampling points are located are in beige color. To better illustrate the results of the project, the scientific team of ELGO defined this area as the study area.

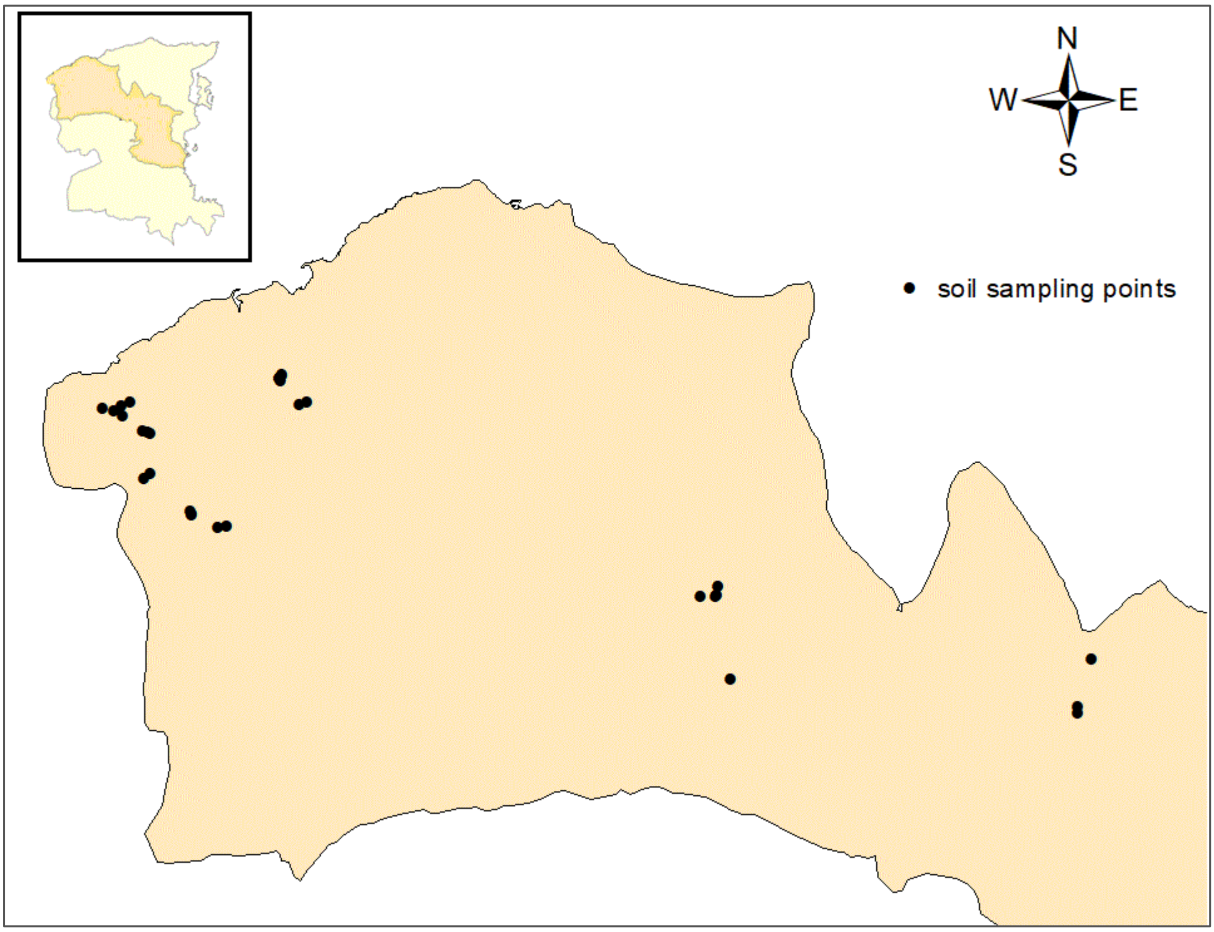


Figure 3. Spatial distribution of the soil sampling points in the study area

Results from the soil sampling campaign

The results from the first soil sampling campaign (organic matter, %C, %N, Ca, pH, soil texture, bulk density, etc.) are presented in this report.

Table 2. Results of soil analysis (indicative depth 0-50μm was selected)

	%C	%N	Rocks (% w/w)	% Ca	pH	Texture	Bulk Density (g/cm^3)	organic matter (%)
1	1.029	0.145	28.00	0.00	7.99	loam	1.90	1.771
2	2.679	0.327	12.46	0.00	7.39	loam	1.81	4.608
3	6.080	0.149	19.88	14.00	8.16	loam	1.63	6.847
4	1.765	0.158	20.01	0.00	7.63	loam	1.95	3.037
5	5.457	0.197	32.75	24.19	8.12	loam	1.81	3.145
6	0.873	0.103	16.40	0.00	7.11	sandy clay loam	1.76	1.501
7	1.951	0.177	2.66	0.00	7.60	clay loam	1.42	3.355
8	1.794	0.203	25.24	0.00	6.94	loam	1.57	3.086
9	3.755	0.180	15.44	11.65	7.98	loam	1.59	3.453
10	2.887	0.243	35.70	3.56	7.41	loam	1.18	3.128
11	1.964	0.201	7.89	0.00	7.81	clay loam	1.54	3.378
12	3.659	0.246	11.61	1.70	7.52	clay loam	1.42	5.417
13	4.598	0.293	15.96	10.36	8.13	sandy loam	1.53	5.236
14	2.124	0.138	5.89	1.86	7.75	clay loam	1.68	2.693
15	2.967	0.178	8.98	9.14	8.38	clay loam	1.63	2.745
16	0.729	0.070	19.78	0.00	7.18	loam	1.55	1.254
17	3.075	0.229	6.57	0.00	7.48	clay loam	1.40	5.288
18	5.895	0.267	12.09	2.59	7.65	loam	1.42	8.804
19	2.475	0.186	3.31	3.24	8.15	loam	1.35	2.587
20	2.812	0.249	24.69	2.75	7.82	loam	1.31	3.417
21	3.820	0.344	65.55	5.34	7.77	loam	1.73	3.815
22	3.846	0.274	23.40	1.21	7.59	loam	1.47	5.988
23	2.396	0.174	11.28	1.38	7.80	clay loam	1.44	3.412
24	1.426	0.146	19.02	0.00	7.36	clay loam	1.66	2.454
25	3.956	0.186	23.14	4.53	7.95	loam	1.74	4.466
26	0.755	0.089	32.52	0.00	6.93	sandy loam	1.95	1.299
27	0.803	0.070	26.35	1.46	8.13	sandy loam	1.85	0.629
28	1.558	0.154	9.79	0.00	7.13	clay loam	1.78	2.679
29	0.545	0.104	40.81	0.00	7.06	loam	1.77	0.938
30	4.195	0.261	13.47	4.05	7.95	sandy clay loam	1.78	5.128

According to the results from the 30 sampling points we can draw some general conclusions about the soil of the study area. The following Figures help to visualise these conclusions.

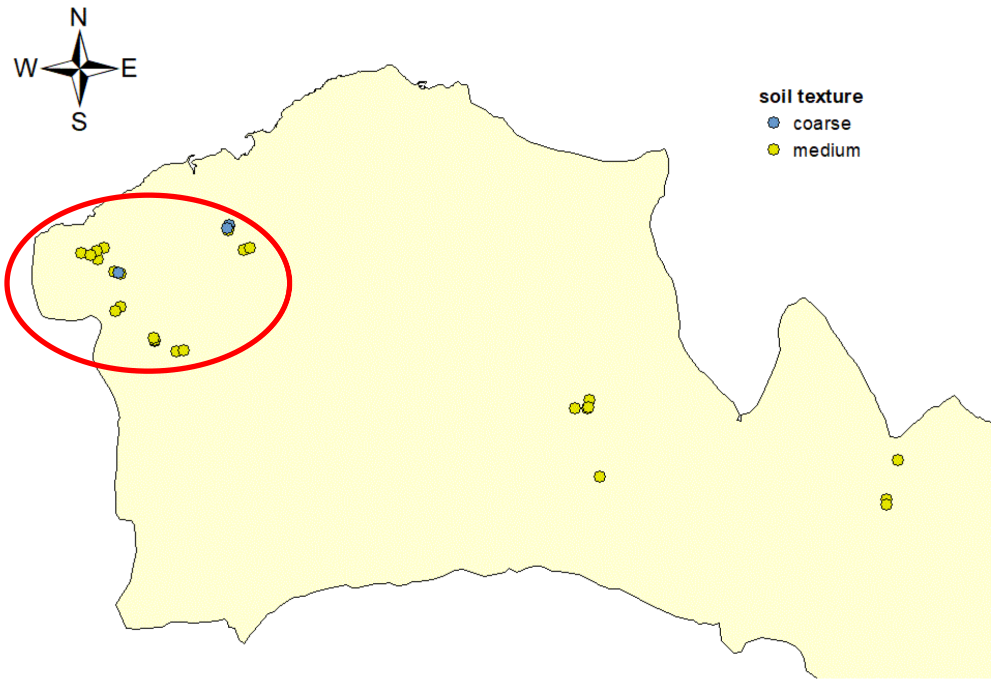


Figure 4. Soil texture results from the 1st sampling campaign

Regarding the soil texture, the analysis showed that 27 of the 30 samples are classified as medium texture (loam, clay loam, sandy clay loam) and the rest 3 as coarse (sandy loam). The coarse soil samples have been collected from the coastal area of the study area (red cycle). Other studies in the area confirm that there are parcels in the coastal zone with coarse soil.

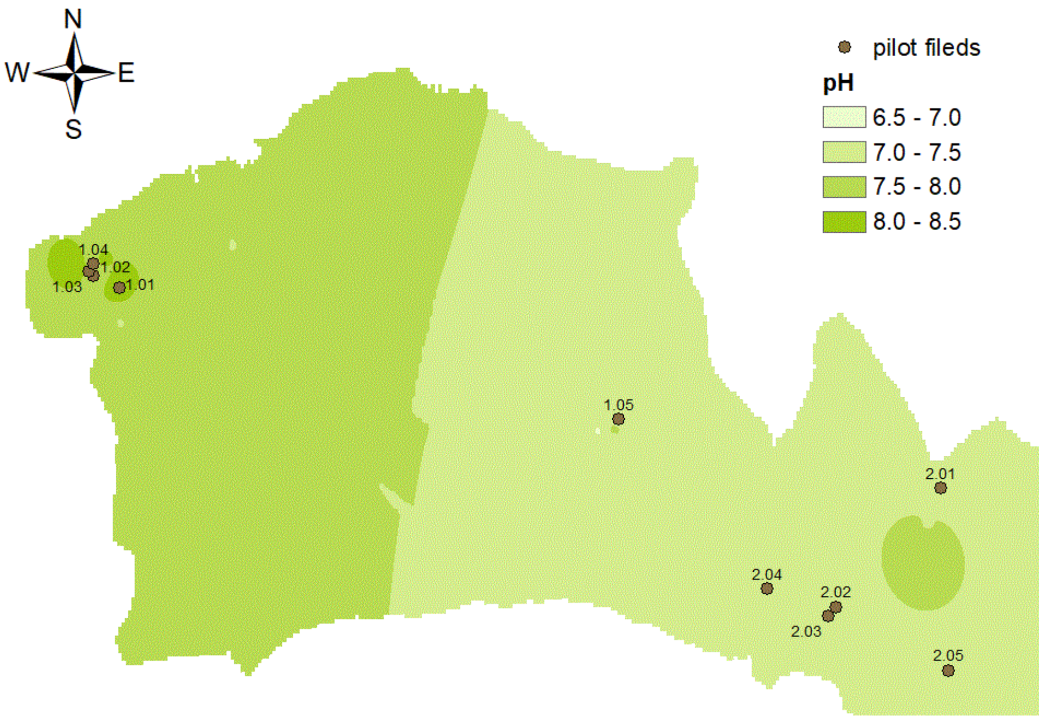


Figure 5. pH results from the 1st soil sampling campaign

Figure 5 shows that the soil of the western part of the study area has a higher level of pH, especially in the area where the pilot parcels 1.01, 1.02, 1.03 and 1.04 are located.

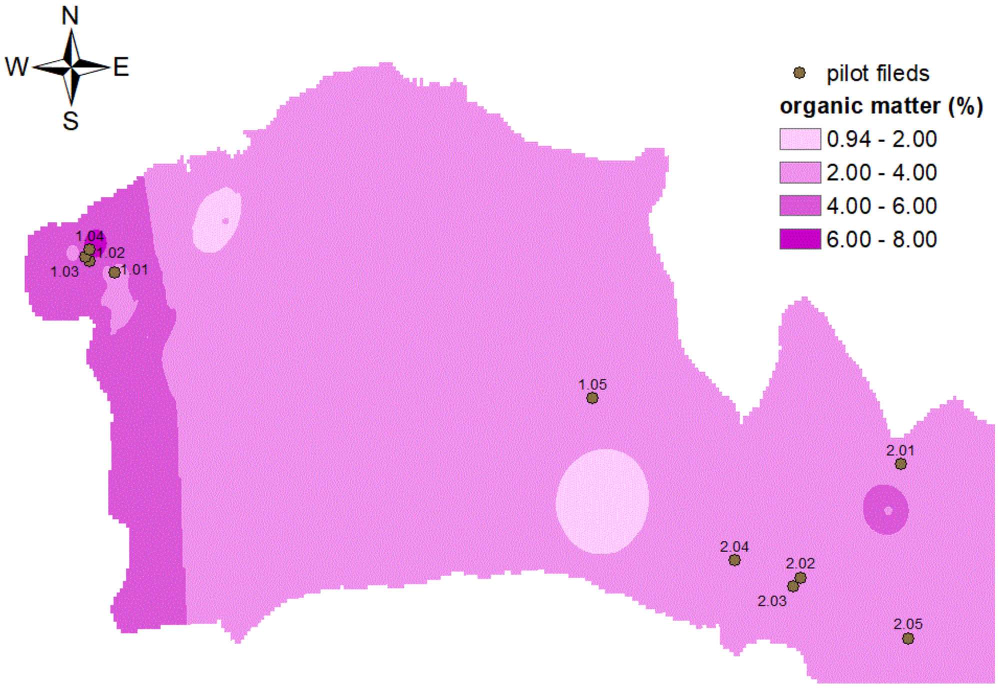


Figure 6. Organic matter results from the 1st soil sampling campaign

With the results for soil organic matter, the baseline is completed, regarding the level of soil organic carbon in soil before the regenerative agricultural practices implementation. Figure 6 shows that the soil of the western - coastal part of the study area has a higher content of organic carbon. This approach helps ELGO's scientific team to divide the area into management zones in order to give the proper cultivation advice.

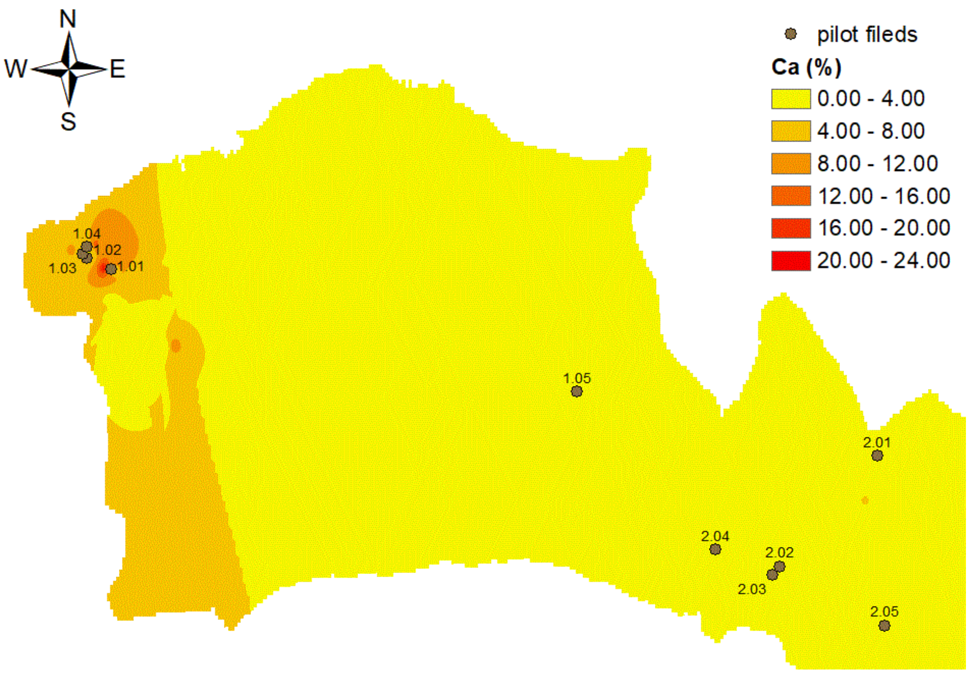


Figure 7. Calcium (%) results from the 1st soil sampling campaign

In the measurements we also included the percentage of calcium in the soil. Calcium is a factor that affects the measurement of organic matter. Indeed, from figures 6 and 7 we notice that in areas with higher calcium values we also have higher values of organic matter.

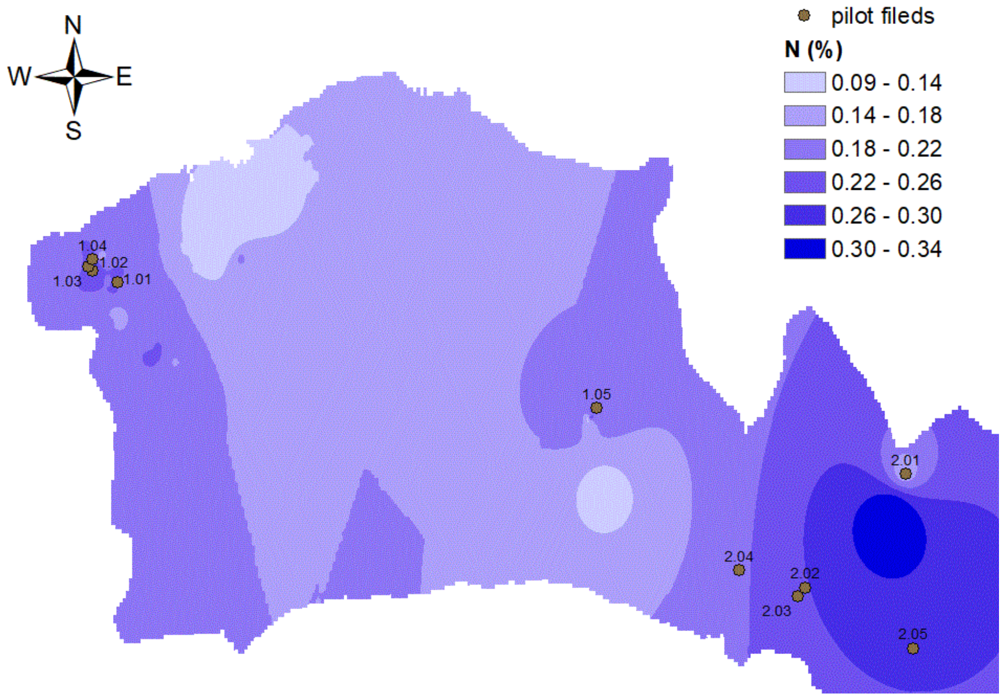


Figure 8. Nitrate (%) results from the 1st soil sampling campaign

From figure 7 some conclusions can be drawn about the areas where soil nitrogen is low so that appropriate advice for nitrogen fertilization can be given.

Use case #2: Nutrient & soil management on Europe's large farms in Poland

Due to a change in management at Top Farms, the sampling was delayed and is still pending. This sampling will be made in 2023 when conditions are permissive (i.e. after winter when the ground is not frozen).

The Polish use case was able to source a grid sample for a field of interest at Top Farms at the beginning of the year. This is quite a valuable development as it would allow for the veracity of Quantify (at least within the context of the Polish use case) to be tested. However, the data provided was partial and did not cover the entire field and negotiations are ongoing to source this information for the entire field.

In addition, in the second year SatAgro made a modified Quantify service to better suit the Polish context. Polish farmers are required to take soil samples for every 4 ha every 4 years, and the service was modified to ensure at least one sample point is requested on a 4 ha grid. A different algorithm was used to determine where these points are generated, based on long-term field performance rather than on uncertainty. If we are able to obtain the full grid points, we will be able to compare the performance of both the uncertainty and performance approaches to smart sampling. If this data will not be made available, we can nonetheless compare the performance between these two approaches.

In addition to the typical laboratory-based soil analysis, the campaign will encompass measurements performed with an affordable field spectrometer produced by the company QED (https://qed.ai/). The initial simulations have shown that although the instrument might not be robust enough to enable independent estimation of SOM, it might prove to be useful for a low-cost improvement of the spatial resolution of SOM mapping which is grounded with wet laboratory results.

Clearly, the collaboration with Top Farms is important to the use case. If we are not able to implement use case activities on their fields (which is our preference), alternative farms (SatAgro customers with which we have a close relationship) have already been identified and sampling maps have been generated. This will be our backstop.

Use case #3: Scaling certified-regenerative businesses in the UK

Additional soil samples were included as part of the use case.

As is explained later in this document, GWCT's Allerton Project farm and Farrington Oils' farm were included as the first test users of AgriCaptureCO2's carbon credit project registered in VERRA for regenerative farming in the UK. Samples at both of these farms were required to establish a baseline in the project documentation. In the case of GWCT, the samples were taken for the first time by the project. The AgriCapture Quantify service was used to identify optimal soil sample locations.

Use case #4: Managing public lands to meet net neutrality goals in the UK

Prior to the application of biochar and compost, soil sampling for soil organic carbon was undertaken by a post-doctoral researcher from Bangor University as part of a collaboration with the Biochar Demonstrator Project. Soil analysis is performed in-house by Bangor University.

Researchers from Nottingham and/or Bangor Universities will be given continued access to enable them to sample and monitor the trial sites on an ongoing basis as part of the *Biochar Demonstrator Project.*

Additional soil sampling will be undertaken to inform the WP3 Quantify service at locations within the trial sites and across the wider landholding in accordance with the AgriCaptureCO2 soil sampling protocol being used by all project partners.

Carbon analysis of biochar and compost samples will also be undertaken to estimate the total carbon added to the trial sites.

Use case #5: Promoting sustainable agriculture without public subsidies in Serbia

The Serbian use case did not perform any new baselining activities in the second year, as these activities were completed in year 1. Nonetheless, a summary is provided in this section.

The Serbian use case involved 16 farms and 42 agricultural parcels (fields). Only two farms are State Agriculture Advisory Services with experimental field and others are family-owned farms. They covered the region of north-east part of central Serbia near river Danube in the Autonomous Province of Vojvodina and include all productive soil types. Five farms have never applied any practices of Regenerative Agriculture and others have been practicing Reg Agri for more than seven years e.g., reduced or mulch tillage, no till with proper weed management and proper plant protection. Only one farm is a dairy production farm. Others are arable crops farms with winter wheat, corn, sunflower and soybean. Only two farms established cover crops in last two years.

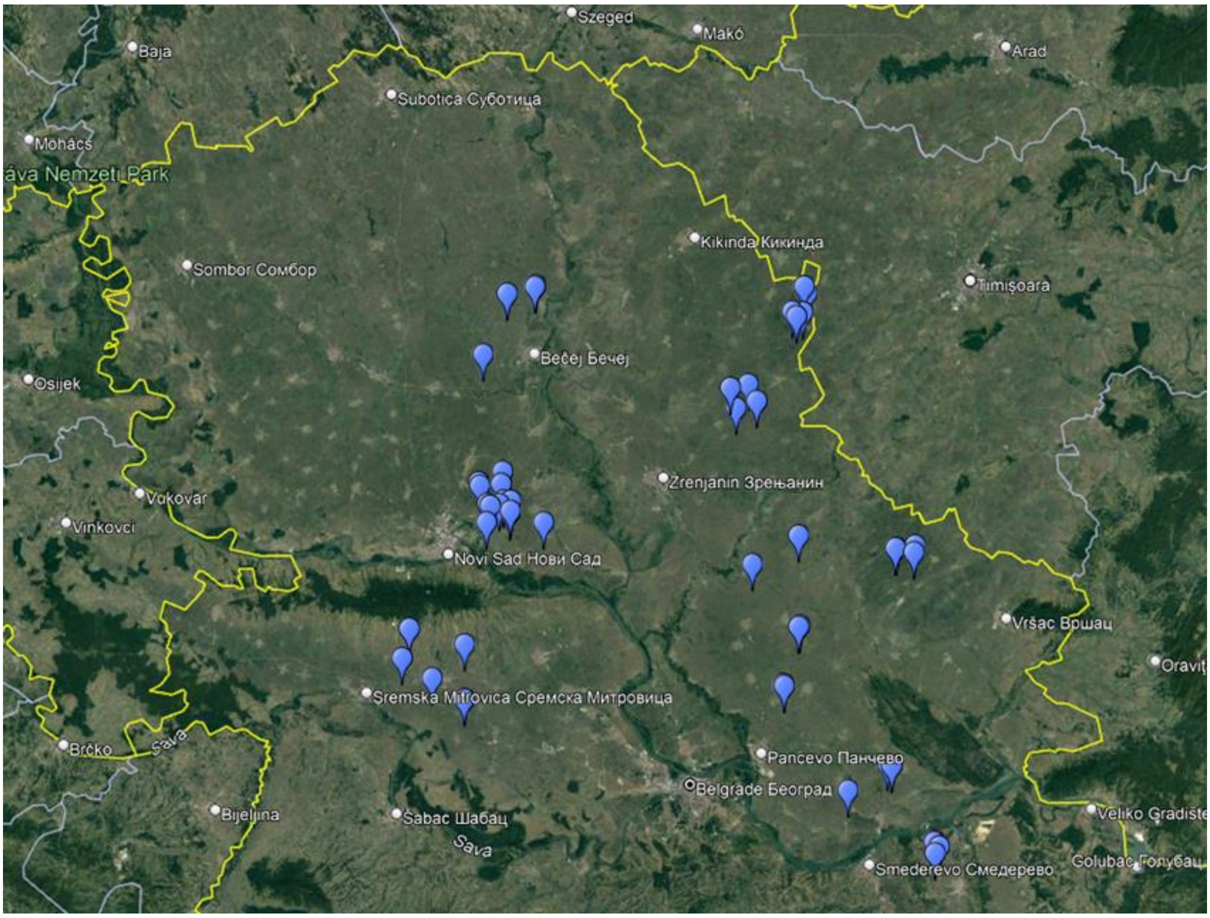


Figure 9. Distribution of the Serbian use case farms.

Blue symbols show parcels' locations.

To estimate the soil organic carbon stock at the field level, the AgriCaptureCO2 *Quantify* service was used to determine the optimal locations for soil samples (Figure 7). Soil samples were taken at a total number of 104 locations situated in the pilot fields during 2021.

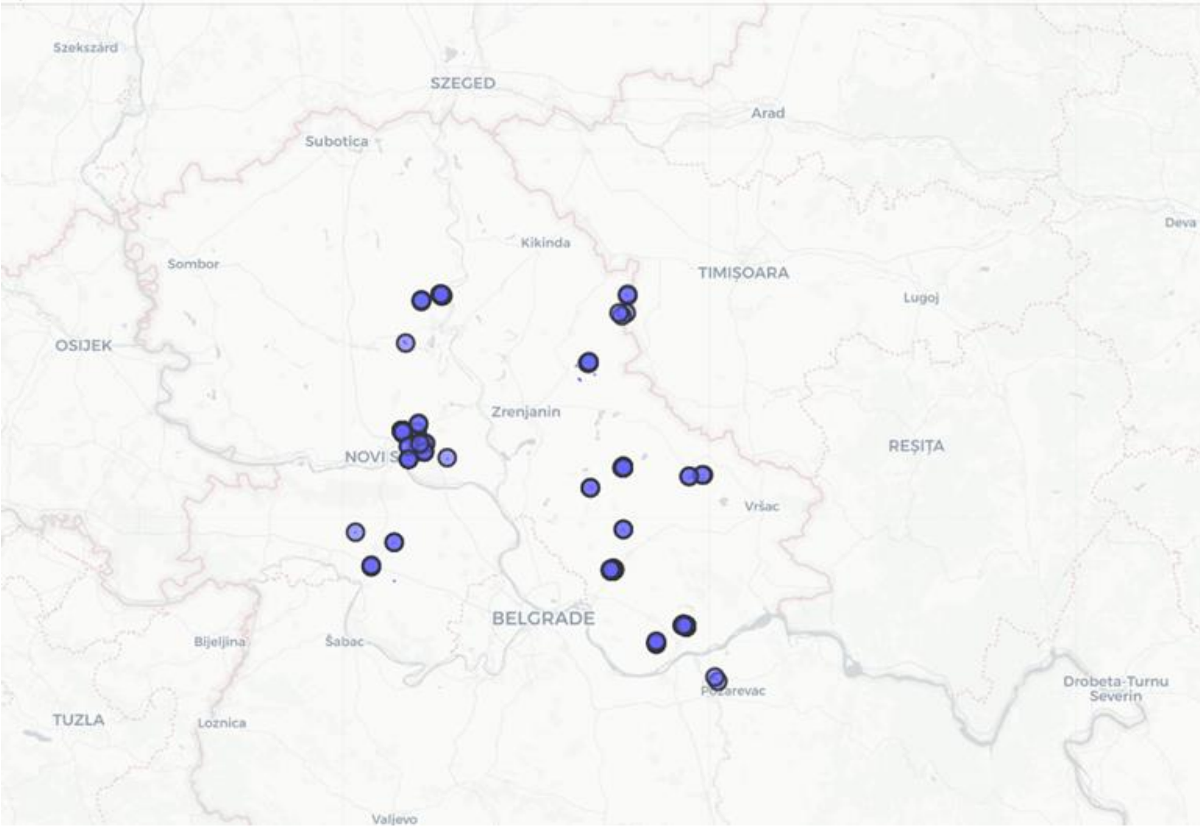


Figure 10. Spatial distribution of the soil sampling points.

Use case #6: Climate-proofing flower production in Kenya

No soil samples were taken by the project in relation to the Kenya use case.

2.2. Providing training

Use case #1: Greece

Table 3. Training and dissemination events of the use case 1 (Greece) during 2022

Event	Location	Date	Participants
Workshop on the adaptation of the Crete region to climate change	Chania	01 Apr. 2022	106 (farmers, group of producers, local authorities, agricultural cooperatives)
Training event at the Gramvousa producers' group	Chania	08 Jul. 2022	25 (farmers, group of producers)

Training event at the Timpaki producers' group	Heraklion	15 Jul. 2022	58 (farmers, group of producers, agricultural cooperatives)
Training event at the Peza producers' group	Heraklion	22 Jul. 2022	21 (farmers, group of producers)
10th International Conference on Information and Communication Technologies in Agriculture, Food & amp; Environment (HAICTA 2022)	Athens	22-25 Sep. 2022	aprox. 80 (scientists, agronomists)
29th Intrnational Fair for Agricultural Machinery, Equipment & Supplies (HELEXPO-AGROTICA)	Thessaloniki	20-23 Oct. 2022	aprox. 150 (farmers, group of producers, local authorities, agricultural cooperatives, agronomists, scientists)
Information seminar for producers in Meramvello	Neapoli (Lasithi)	03 Nov. 2022	17 (farmers, agricultural cooperatives, agronomists)
InnoDays 2022 - Innovation Days of the Region of Crete	Heraklion	25-27 Nov. 2022	aprox. 125 (farmers, group of producers, local authorities, agricultural cooperatives, agronomists, scientists)

Workshop on the adaptation of the Crete region to climate change

The project AgriCaptureCO2 and the regenerative agricultural practices were presented by ELGO DIMITRA (Dr. Nektarios Kourgialas) during a Workshop on Friday, April 1st, 2022 in Chania, Greece. The event was organised by the Prefectural Administration of Crete and the Ministry of Environment and Energy of Greece in the framework of the project LIFE Adaptivgreece. The event started with a plenary session with presentations about climate change adaptation and then participants were split into groups. The project AgriCaptureCO2 was presented in the session "Agricultural production". The audience showed particular interest in the implementation of the AgricaptureCO2 platform and asked about the benefits it can offer. They were informed that the completion of the AgriCaptureCO2 Platform will take place in the coming months, while several demonstration actions regarding the benefits and the use of the AgriCaptureCO2 Platform will take place during 2022 and 2023 in Crete (special workshops will be organized). They were also informed that the platform will provide information on the spatial distribution of soil organic carbon in olive groves as well as on proper irrigation. Information on implementing appropriate actions in order to promote regenerative agricultural practices and/or reduce emissions will also be provided.

Figure 11. Workshop on the adaptation of the Crete region to climate change

Training events at farmer organisations/groups

In July 2022, EGO (Dr. Nektarios Kourgialas) held training events for two producer groups in Eastern Crete and one in Western Crete:

- Training event at the Gramvousa producers' group (Chania) – 08/07/2022
- Training event at the Timpaki producers' group (Herakleion) – 15/07/2022
- Training event at the Peza producers' group (Herakleion) – 22/07/2022

The training was focus on training farmers about taking up regenerative agricultural practices. The total number of the participants was 104 (mainly farmers and processors).

Figure 12. Training event at the Gramvousa producers' group (Chania) – 08/07/2022, training on the field

Figure 13. Training event at the Gramvousa producers' group (Chania) – 08/07/2022

Figure 14. Training event at the Timpaki producers' group (Herakleion) – 15/07/2022

Figure 15. Training event at the Peza producers' group (Herakleion) – 22/07/2022

10th International Conference on Information and Communication Technologies in Agriculture

The 10th International Conference on Information and Communication Technologies in Agriculture, Food & Environment (HAICTA 2022- https://2022.haicta.gr/) held in Athens, Greece on September 22-25, 2022. During this conference ELGO (Dr. K. Tzerakis) presented the poster entitled "Development of an IoT-based platform for smart irrigation in olive groves using open-source technologies". The poster was part of the AgriCaptureCO2 project.

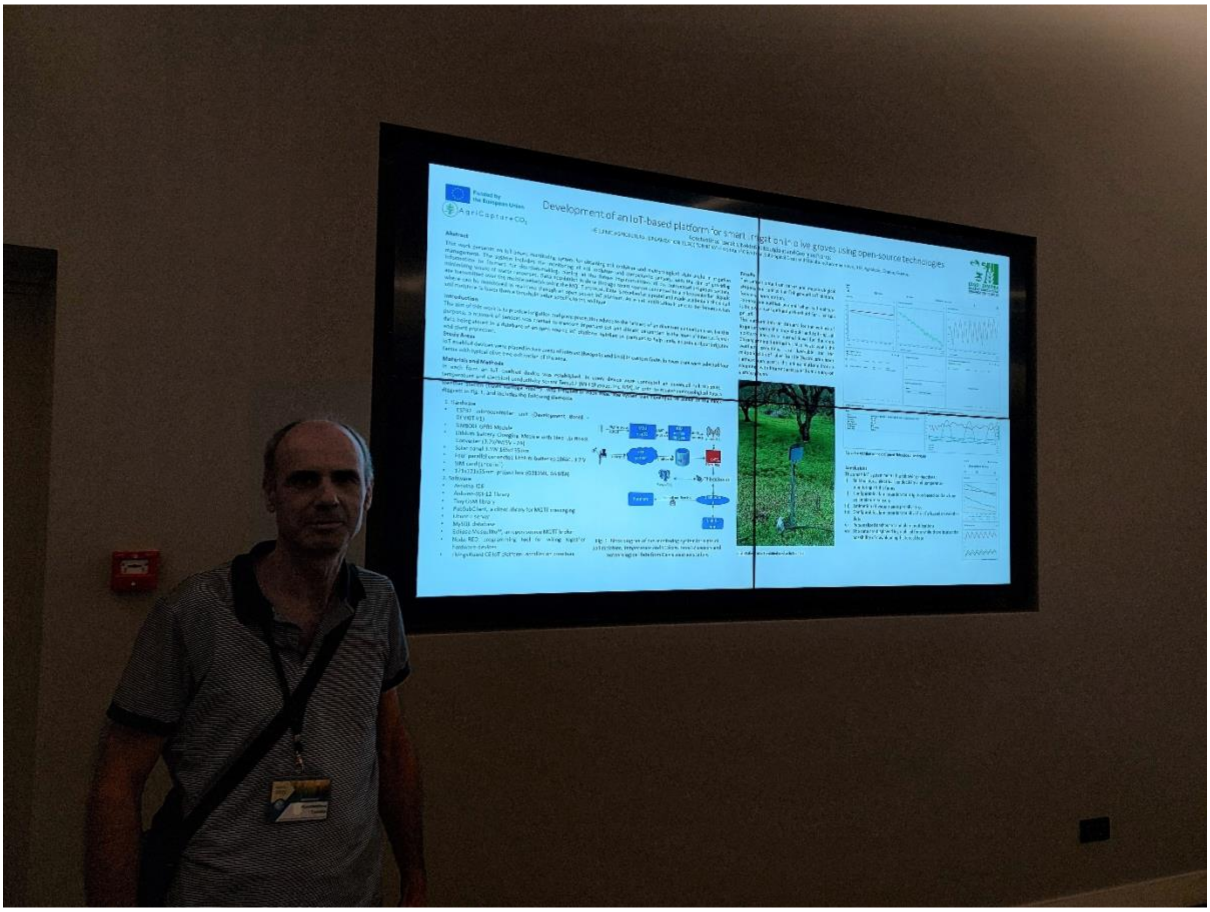


Figure 16. Dr. Konstantinos Tzerakis presenting the poster entitled "Development of an IoT-based platform for smart irrigation in olive groves using open-source technologies"

HELEXPO-AGROTICA 2022

The scope and results of the project were also presented by ELGO (Dr. Nektarios Kourgialas) in the 29th International Fair for Agricultural Machinery, Equipment & Supplies (Thessaloniki – 20-23/10/2022), the leading exhibition event in Greece in the agro-economic sector

Figure 17. Dr. Nektarios Kourgialas presenting the Agricapture project on the 29th Agrotica fair

Information seminar for producers in Meramvello

On 3 November 2022 a training event was held in the premises of Agricultural Cooperative Partnership Mirabello Union S.A. (EAS Mirabello), in Neapoli, Lasithi region. The training was focus on training farmers about taking up regenerative agricultural practices and an efficient irrigation plan on their plots by presenting the results of 1st year of the project. The results of the first sampling campaign were presented (soil organic carbon, pH, soil nutrients). The results from the leaf analysis and from the plant stress measurements were also presented. In this training event the overall goal of the project, the processes, the timeline and work to be completed were clarified.

Finally, the participants were informed about the next steps which includes training to empower farmers and other end-users to use the AgriCaptureCO2 platform and its services.

Figure 18. Pictures from Meramvello's training event

The scientific team of ELGO participated in Innovation Days of the Region of Crete (InnoDays 2022 – Heraklion) on 25-27 November 2022. At the exhibits of the fair included the project banner along with brochures and an example of a telemetry soil moisture monitoring station used in the project's pilot fields.

Figure 19. The project's banner and an example of a telemetry soil moisture monitoring station in the INNODAYS 2022 exhibition.

In addition, in a presentation made by Dr. Nektarios Kourgialas, the purpose and the first results of the AgriCaptureCO2 project were mentioned in detail.

Figure 20. presentation by Dr. Kourgilas at INNODAYS 2022.

Use case #2: Poland

SatAgro provided training to the use case participants on how to make use of the new modules/services developed, specifically the profitability calculator and the smart sampling approach: Top Farms, TerraNostra, BNP Paribas, and Vantage Polska. As the services linked to the new CAP will be launched this winter (late January), this will enable a new strain of local outreach, with concrete and practical advice.

Use case #3: UK (certified regenerative agriculture)

As mentioned in the previous annual PILOT report, this use case represents a "mature ecosystem" wherein regenerative agriculture is already being implemented, for which trainings and workshops were not seen as an appropriate instrument for target farmers. No effort was estimated for Farrington's Oils and LEAF under this task.

Nonetheless, GWCT and Farrington Oils presented present the AgriCaptureCO2 platform during their inhouse regenerative agriculture trainings and talks, where GWCT alone and see some 2000 visitors per year to their demonstration farm.

Two specific AgriCaptureCO2 events were however held in the UK in 2022, one at Farrington's Oils (20.4.22) and one at GWCT Allerton Project (1.6.22). Both events sought to explain the concepts of AgriCaptureCO2 to the audience, which was targeted at farmers and closely associated industries – i.e. agronomists. Igor Milosavljevic was kind enough to speak at both events remotely to demonstrate the AgriCaptureCO2 platform, and LEAF supported the event at Farrington's Oils. Both events included indoor discussion & farm walks, with Duncan Farrington demonstrating the fields he has entered as the AgriCaptureCO2 test case. We also sourced an external speaker in the form of John Williams, a senior soil specialist from ADAS the UK farm advisory service.

As predicted, and despite best efforts of both GWCT & LEAF, turnout to both events was very low, with UK farmers spoiled for choice in terms of events they can attend, many if not most concerned with regenerative agriculture. Until we have results of the test cases and/or a fully operable software offering, there is little reason to UK farmers (many of whom are already advanced in the field of Reg Agri) to attend such events. Further events will be held in 2023 (both in person and online) but we must be mindful of the cost/benefit of organising poorly attended events.

Figure 21. Training event at Farrington Oils (Northamptonshire) UK – 20/04/22

Use case #4: UK (public bodies)

The training materials and programme for the Lancashire case study are built upon the practical experience gained from the project implementation. The original project timescale would have seen application of biochar and compost in Spring/early Summer 2022 when grazing livestock were removed.

The regulatory framework (and general level of skills and knowledge) supporting the agricultural use of biochar in the UK is not well established, consequently various delays were encountered (described below) before application finally commenced on 5th October 2022. These delays have impacted the development and provision of training and evidence sharing events.

A presentation on the pilot proposals was made to the Climate Change Working Group of Chorley Borough Council on 7th July 2022. The Chisnall Hall pilot site lies within this council area.

A short video of the 'story' of the Chisnall Hall pilot site is available via the LCC website: https://news.lancashire.gov.uk/news/groundbreaking-carbon-reduction-technology-piloted-in-lancashire

The Lancashire pilot has agreed to make a presentation at a farmer-facing event on Biochar being organised at the GWCT Allerton Project in the Spring 2023.

The Lancashire pilot is planning site visits and workshops at the Chisnall Hall pilot site aimed at local government officers (and probably a separate event aimed specifically at farmers/foresters/contractors) starting in May 2023. GWCT and Bangor University staff have provisionally indicated they could assist with presentations at these events.

Use case #5: Serbia

Activities with farmers during 2022 were the following:

- 13/6/2022: AgriCapture workshop with farmers at TamisPa experimental farm where AgriCapture technology was demonstrated and Regenerative Agriculture discussed, the examples of best practices presented, and farmers shared the experience.
- 24 and 30/5 and 24/10/2022: education events for agriculture advisors that are being trained in regenerative agriculture
- Viber group established for regenerative farmers for exchanging experience, quick questions and advises
- A number of farm visits by AgriCapture expert Bogdan Garalejic to provide knowledge support to use case farmers
- September 2022: Distribution of cover crops seed to the pilot farmers and work with farmers.
- Preparation of training materials - translation and adaptation of the training materials created by GWCT for training local farmers.

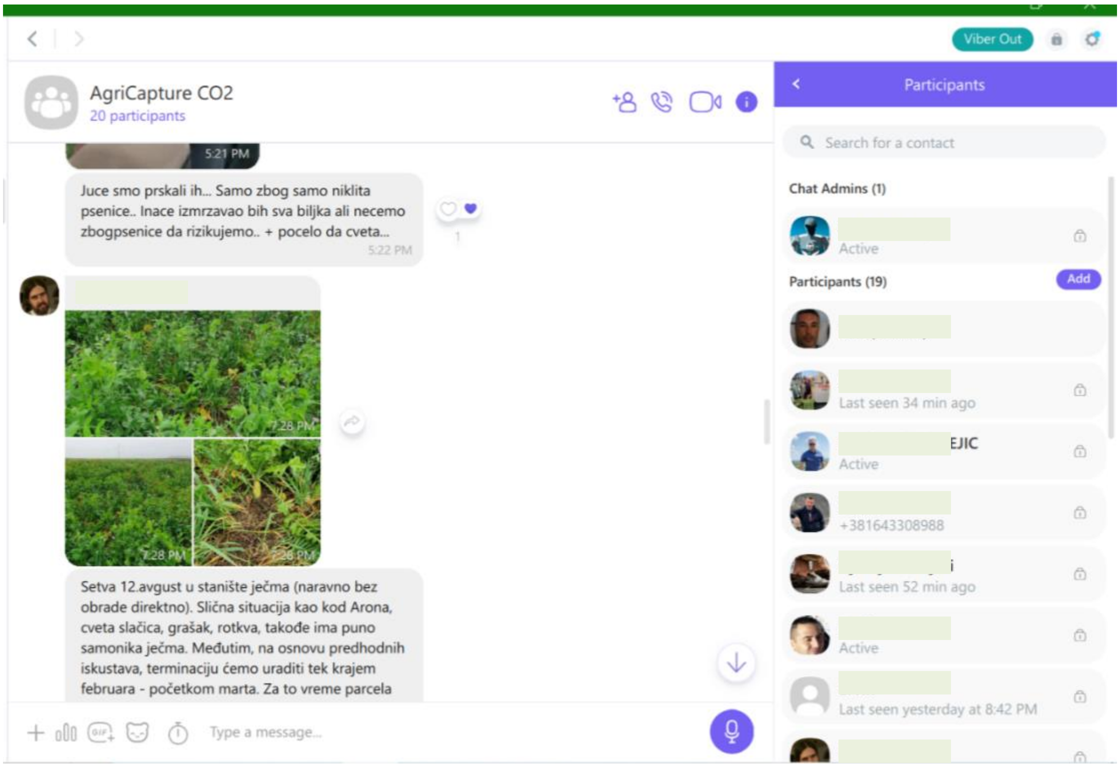


Figure 22. AgriCaptureCO2 farmers' Viber group

Figure 23. AgriCapture workshop at TamisPa experimental farm

Use case 6: Kenya

Training activities were not relevant to the use case in Kenya.

3. Implementing AgriCaptureCO2 use cases

The use cases have implemented activities specific to the context, needs and goals of their use cases, in line with the use case plans presented in deliverable 5.1.

Throughout the activities, there is a clear common thread: engaging and involving stakeholders and implementing regenerative agricultural practices in the field. All use cases have coordinated with WP2 (engage the local ecosystem and "plug-in" to the European Regenerative Agricultural Network), WP3 (contribute to co-creation by providing user needs, feedback from first service iteration, etc.), and WP6 (assess and test business hypothesis, provide input for communication materials and make use of them, etc.). Most use cases have also interacted with WP4 (exploring potential for registering carbon credits).

This section goes into detail on each use case to present the activities implemented during the second year of the project. The use case operational plans are the reference from which this is done.

3.1 Implementing use case 1: Greece

3.1.1. Summary

Objectives

To apply appropriate/demonstrate actions in order to promote regenerative agricultural practices and reduce emissions (different parts of the whole olive production chain), as well as to provide the necessary inputs, at farm level, for establishment of the AgriCaptureCO2 platform.

AgriCaptureCO2 Support services will be tailored for the needs of olive production in arid areas according to the specific regenerative approach developed by ELGO, for:

- Optimal timing/quantity of irrigation and fertigation, recommendations for reduce risk of pathogens.
- SOC data taken on the fields will be used to generate the SOC map at field level for quantification and monitoring of SOC sequestration.
- Soil moisture data will be visualised through Support service and is relevant for the farmers.
- Meteo data will be also visualised through Support service and is relevant for the farmers.

The data on activities will be used to calibrate and test the Verification service models.

Information for the proposed plan

Based on the historical data of the parcels, baseline greenhouse gas emission values were counted for each parcel regarding the already applied practices. Based on these values, in each of the 10 parcels, the already applied practices should be redesigned in order to achieve lower emissions and promote regenerative agriculture. Redesigning means that the scientific team of ELGO will support and advise farmers to follow appropriate water and soil practices. The regenerative practices applied include:

- Cover crops
- No weed mowing during winter / No soil tillage
- Weed mowing in spring and summer (soil mulching)
- Winter pruning/summer pruning - Shredding of pruning
- Application of organic material (winter period)
- Irrigation according to meteorological and soil moisture data
- Application of fertigation
- Foliar application of fertilizers (in case that is needed)
- Recommendations for plant protection, minimizing the risk for pathogens

ELGO has taken appropriate sampling measurements and made analyses in the selected parcels; it has also set in place the adequate instruments (soil moisture sensors and a meteo-station) that will generate data to be used for the *Support* service, in order to provide advice and support the practices and measures that should be applied from the farmers in their parcels to promote the above mentioned regenerative agricultural practices or/and minimize the emissions and achieve the standards of KPIs, while ensuring their yield at the same time (quantity and quality of the product). For instance, this includes advice for: no tillage, applied soil organic matter at specific dose, applied proper irrigation (amount and rate), proper pest/weed control, etc.

In turn, based on the proposed changes in the applied practices and the KPIs will be recorded in each year and for each studied parcel.

Eastern Crete is an area that faces the most acute issues with water availability, low soil organic carbon, and saltwater intrusion. A high priority in this case study is given to the proper irrigation management, as water shortage is a crucial problem for Crete and the Eastern Mediterranean area in general (Kourgialas, 2021). Also, demonstration actions regarding the benefits and the use of the AgriCaptureCO2 Platform with emphasis in sustainable olive oil irrigation and soil management will take place.

In the study area of the eastern part of Crete the only crop included in the use case was olive and the 10 plots were dedicated to this single crop. In eastern Crete, due to water shortage, irrigated orchards are less common that rainfed orchards, and as such proper irrigation and soil management are important actions that could be effectively supported by this project.

Table 4. The main characteristics of the 10 farms included in the Greek use case.

Farm	GPS Location	Irrigated / rainfed	Parcel area (ha)	Number of Trees
PARASKEVOPOULOU ELEFTHERIA-PRATIKOU-2.02	351439, 253750	Irrigated	0.34	60
EVAGGELINAKIS IOANNIS-SOXORO-2.03	351434, 253744	Irrigated	0.20	30
LEMBIDAKI MARIA-SFAKIANOY-1.01	351740, 252959	Irrigated	0.75	189
LEMBIDAKI MARIA-KRITSOTI-1.02	351738, 253002	Irrigated	0.57	129
LEMBIDAKI MARIA-NEROLAKKOS-1.03	351740, 252959	Irrigated	1.35	356
LEMBIDAKI MARIA-MPAMPOURA-1.04	351744, 253002	Irrigated	0.79	200
MASTORAKIS DIMITRIOS-MOIRATZANI-2.01	351540, 253857	Rainfed	0.20	21
MASTORAKIS DIMITRIOS-AGIOS NIKOLAOS-2.05	351406, 253859	Rainfed	0.20	15
SYSKAKIS NIKOLAOS-KSERIZOMA-2.04	351449, 253706	Irrigated	0.20	40
TZORTZI OURANIA- PERA MERA-1.05	351619, 253654	Rainfed	0.50	78

In many cases, the common/traditional agricultural practices, involving uncontrolled application of large quantities of irrigation water for the perceived maximization of crop yield has led to:

- The reduction of the quantity of water resources through over-pumping resulting in the lowering of the groundwater levels (groundwater is the main sources of water in the study area), and
- The qualitative degradation of large sections of coastal aquifers due to the pumping induced seawater intrusion (salinization).

The above, combined with climatic instability or change, which, according to global climate models, will strongly affect Mediterranean countries and may lead to the occurrence of periodic droughts of increasing intensity and frequency, desertification, and the loss of agricultural-productive soils through erosion. Thus, sustainable management of water resources in agriculture needs to be studied and supported as a part of this project. In line to the above, a list of regenerative agricultural practices that will be applied in this project is presented below.

3.1.2. Main activities and results

During the previous year (2021), ELGO installed an IoT enabled device was established, connected with an advanced soil moisture, temperature and electrical conductivity sensor Teros12 (METER group, Inc. USA) in each of seven (7) irrigated pilot fields of our study. In addition, a telemetric weather station in the coastal study area was installed by ELGO (M1) (Davis Vantage Pro2™). This station, in combination with the already existing meteorological station (M2) located in the inland study area, can capture adequately the metrological conditions in the whole study area of Eastern Crete. These two stations provide the platform with real time climatological parameters (rainfall, max-min-average temperature, solar radiation, wind speed and direction, air humidity, ET, with a time interval of 10 minutes). Detailed information about the stations, the sensor's types and the coordinates of the sensors installed as well as photographic material is given in Pilot Year 1 Report.

IoT-based monitoring system (soil sensors & weather stations)

During 2022, an IoT-based monitoring system for obtaining soil moisture and meteorological data useful in irrigation management was developed. The system includes the monitoring of soil moisture and atmospheric sensors (installed in 2021), with the aim of providing information to farmers for decision-making, aiming at the future implementation of an automated irrigation system, minimizing waste of water resources. Data acquisition is done through smart sensors connected to a microcontroller. Signals are transmitted over the mobile network using the MQTT protocol. Data is received at a portal and made available in the cloud where can be monitored in real-time through an open source IoT platform. An e-mail notification is sent to the farmers when soil moisture is lower than a threshold value specific to the soil type. The platform informs farmers for the volume of irrigation water requirements of their crops in order to restore soil moisture to a predefined optimal level. Corresponding information is also provided when the weather conditions are favorable for an outbreak (significant increase) of olive fruit fly (*Bactrocera oleae*) population. Farmers can access the online platform through relevant apps for PC, or android smart phone through this link.

Figure 24. The IoT enabled device in the field

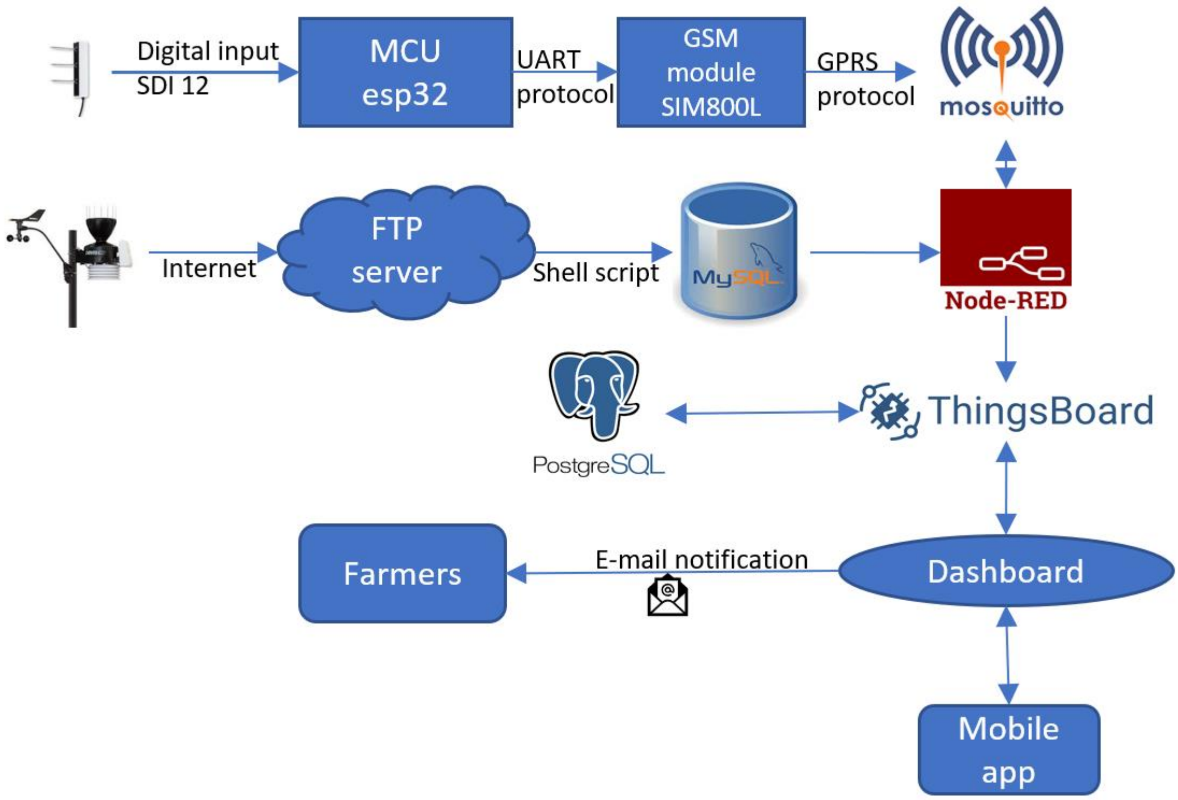


Figure 25. Block diagram of the monitoring system for signs of soil moisture, temperature, and EC from Teros12 sensors and meteorological data from Davis weather stations

Figure 26. IoT-based platform for smart irrigation, screenshot from computer (left) & screenshot from mobile phone (right)

Leaf analysis

The analysis of leaf samples taken from the 10 pilot fields are also presented in table 5

Table 5. Leaf analysis for each farm

Farm	B (ppm)	N % (dry matter)
PARASKEVOPOULOU ELEFTHERIA-PRATIKOU-2.02	14.18	1.611
EVAGGELINAKIS IOANNIS-SOXORO-2.03	14.66	1.879
LEMBIDAKI MARIA-SFAKIANOY-1.01	14.08	1.536
LEMBIDAKI MARIA-KRITSOTI-1.02	15.09	1.747
LEMBIDAKI MARIA-NEROLAKKOS-1.03	15.29	1.690
LEMBIDAKI MARIA-MPAMPOURA-1.04	15.38	1.776
MASTORAKIS DIMITRIOS-MOIRATZANI-2.01	13.35	1.409
MASTORAKIS DIMITRIOS-AGIOS NIKOLAOS-2.05	13.07	1.517
SYSKAKIS NIKOLAOS-KSERIZOMA-2.04	14.85	1.932

TZORTZI OURANIA- PERA MERA-1.05	14.37	1.784

According to the results of leaf analysis, Boron is low (<15 ppm) in all plots. Nitrogen is generally at normal levels except for plots 1.01, 1.02 and 2.01 which is low (<1.6%). All plots were advised to foliar spray with boron and nitrogen fertilization.

Quality and Quantity of olive oil

5 kg of fruit were sampled from each field (November 2022) and the analysis are awaited from the olive oil laboratory of ELGO. Acidity, number of peroxides, K232, K270 and DK indicators, total phenols (spectrophotometrically) will be determined, while an organoleptic evaluation will be done by the accredited group of testers of the Laboratory.

ELGO's Food Technology Laboratory in Chania is recognized by the International Olive Council and accredited according to the International Standard ELOT EN ISO/IEC 17025:2017. This means that after the olive oil analysis of each pilot parcel, certification of the quality olive oil will be given to the producer.

Figure 27. Olive samples, 5kg from each pilot field

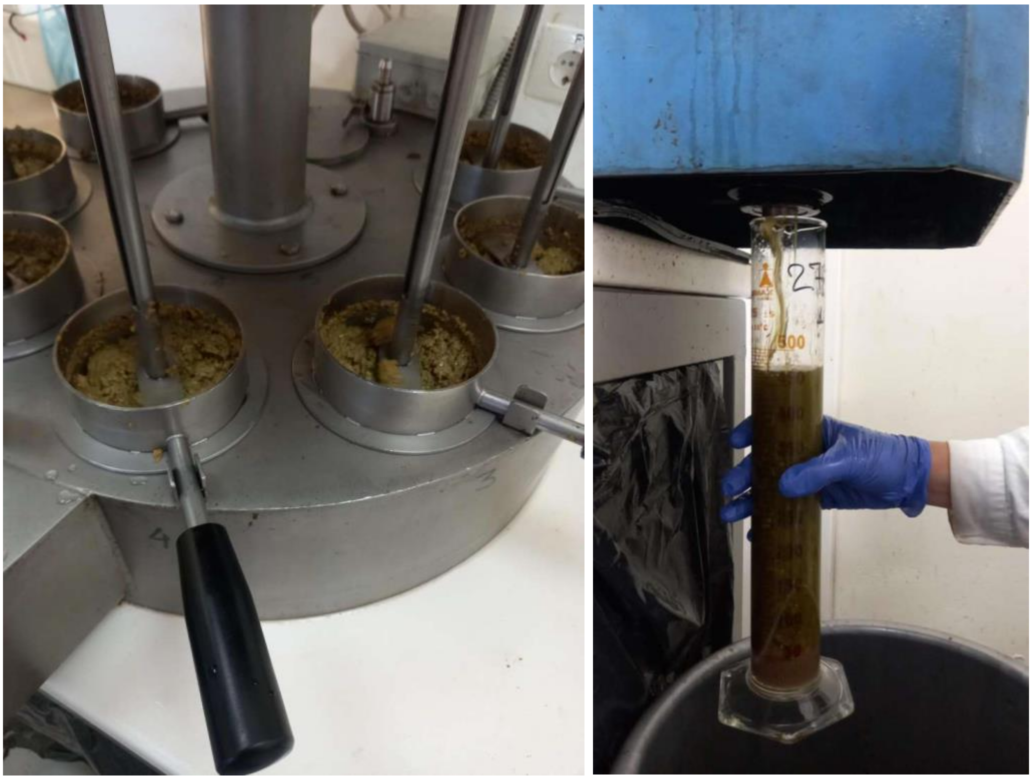


Figure 28. Procedure of olive oil analysis

Discussions that were done with olive producers and olive mill owners about the possibility of branding of low-emission olive oil brand and the certification based on the benefits provided by the results of this project.

Figure 29. Pictures from the olive mills in the Meramvello area

Effects of soil salinity

The soil sensors placed in the irrigated plots also measure the electrical conductivity of the soil (continuous measurements). Electrical conductivity (EC) is a parameter that helps estimate soil salinity. At the same time, measurements are also made with the instrument for the water stress of the plant, for these measurements a correlation is made with the above EC measurements.

Chlorophyll fluorescence analysis has become one of the most powerful and widely used techniques available to plant physiologists and ecophysiologists. The OS-30p+ Chlorophyll Fluorometer is a versatile measuring instrument designed to precisely measure chlorophyll fluorescent parameter Fv/Fm (maximum PSII photochemical efficiency).

For most species, the optimal Fv/Fm reading for stress free plants is in the range of 0.790 to 0.840 (Maxwell and Johnson 2000). Increasing salinity, the Fv/Fm is significantly reduced in olive leaves. Specifically, according to literature measurements in olive leaves from no soil salinity treatments indicate Fv/Fm values above 0.800, showing no stress, while leaves from high salinity treatments indicate Fv/Fm values lower than 0.75 showing stress due to NaCl. According to Woo et al., 2008, well-watered plants had RWCs (plant relative water content) of 80–90% and Fv/Fm levels of ~0.800. Under drought/salinity conditions, for RWCs in the range of 20–80%, Fv/Fm varied between 0.700–0.750. Plants experiencing critical levels of water deficiency (RWC of 10–20%) displayed noticeably depressed Fv/Fm levels, in the range of 0.500–0.750. Hence the upper and lower limited values for Fv/Fm levels can be considered between 0.500 and 0.800.

In our case, for estimation soil salinity effects after irrigation period of 2022, measurements were performed based on the Portable instrument of plants stress. More specifically, for each of the 10 studied olive grove farms, we select 3 trees that represent the average condition of the trees throughout the olive grove (Figure 13).

The average Fv/Fm value concerning the effects of soil salinity in olive trees for 2022 is equal to 0.729. This average value is higher that the corresponding value for 2021 that was equal to 0.708. The average Fv/Fm value of 0.729 for 2022 indicates a slight better condition (minimize the negative effects on soil salinity per 7%) compared to the baseline condition concerning the negative effect from soil salinity in olive grove farms of the study area.

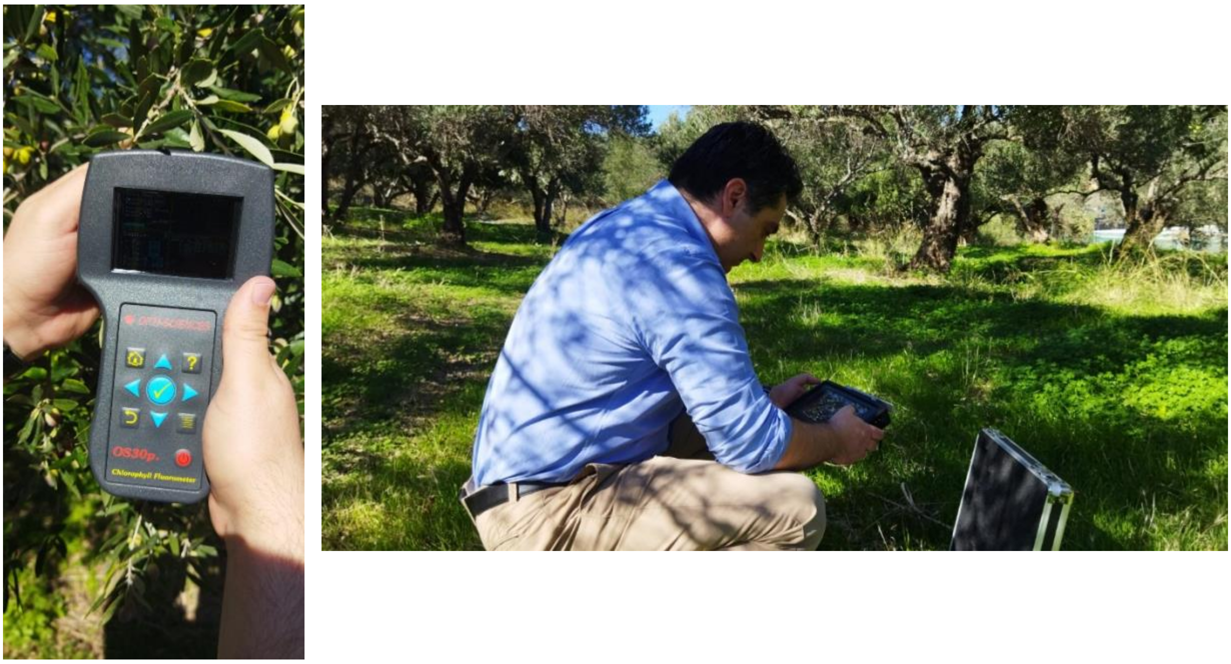


Figure 30. Measurements with the portable instrument of plants stress

Other monitoring parameters

In 2022, the first olive growing season has been completed. The ELGO team, during the olive growing season 2021 - 2022, collected all the data regarding the use of water, fuel, fertilisers, etc. While they also recorded the quantities of fruit and olive oil that each field produced.

Table 6. olive growing season 2021-2022 monitoring parameters

olive growing season 2021 - 2022					
Farm	**fruits (kg/ha)**	**olive oil (kg/ha)**	**irrigation water (m^3/ha)**	**fuels (lt/ha)**	**fuel use**
PARASKEVOPOULOU ELEFTHERIA-PRATIKOU-2.02	7205.88	1544.12	296.47	101.47	transportation, pruning, weeds mowing & sprays
EVAGGELINAKIS IOANNIS-SOXORO-2.03	14625.00	2790.00	252.00	130.00	transportation, weeds mowing & sprays
LEMBIDAKI MARIA-SFAKIANOY-1.01	2666.67	701.75	3840.00	16.55	transportation
LEMBIDAKI MARIA-KRITSOTI-1.02	1578.95	358.85	2526.32	14.76	transportation
LEMBIDAKI MARIA-NEROLAKKOS-1.03	533.33	115.94	2133.33	5.49	transportation
LEMBIDAKI MARIA-MPAMPOURA-1.04	379.75	82.55	1822.78	6.85	transportation
TZORTZI OURANIA-PERA MERA-1.05	2800.00	528.00	0.00	15.00	transportation & harvest tools
MASTORAKIS DIMITRIOS-MOIRATZANI-2.01	0.00	0.00	0.00	0.00	-

MASTORAKIS DIMITRIOS-AGIOS NIKOLAOS-2.05	2250.00	450.00	0.00	49.71	transportation
SYSKAKIS NIKOLAOS-KSERIZOMA-2.04	9500.00	1900.00	825.00	74.41	sprays

According to the farm-specific action plans that have been reported in Deliverable 5.1, the list of monitoring actions and their frequency are presented in the first two columns of the following table 6, while the last column represents the progress of each monitoring action taken in 2022.

Table 7. Monitoring actions and the progress of each parameter or procedure in parcels during 2022

Monitoring parameter or procedure in parcels	Number of samples/monitoring parameters per time	Progress of monitoring actions taken in 2022
Soil moisture monitoring	Telemetric soil moisture system in irrigated parcels / Frequency: Continuous	Continuous recording. The data are used from open source IoT platform
Soil nutrient content and soil organic matter	Soil sampling at specific locations/Frequency: One at the beginning and one at the end of the project	During the 2022 the analysis of the soil samples from the first soil sampling (2021) campaign has been completed.
Leaf nutrient content	One sample for each farm/ Frequency: Every year (Proper leaf sampling period during winder period of each year)	The leaf sampling campaign took place (December 2021) and during the first period of 2022 we had the results.
Fuel use per ha	Collecting data and feedback from farmers/Frequency: Continuous	The data collection has been done for 2022
Irrigation water data sets	Collecting data and feedback from irrigated farms/Frequency: During irrigation period	Data collection has been done (olive yield for the period 2022)
Fruit yield (Quality and Quantity of olive oil)	Collecting data and feedback from farmers/Frequency: Every year	5 kg of fruit were sampled from each field (November 2022) and the analyzes are awaited from the olive oil laboratory of ELGO
Multi-spectral UAV imagery	One demonstration survey at the end of the project - Images	No action

Meteorological data sets – telemetric station	Telemetric station / Frequency: Continuous - meteorological parameters	Continuous recording. The data are used from open source IoT platform
Effects of Soil Salinity	Monitoring in parcels/ Frequency: after irrigation period - Portable instrument for Measuring plant stress	Continuous through soil sensors (EC) & 10 measurements by portable instrument of plant stress

Table 8. Key performance indicators for use case 1, Greece.

Indicator	Remarks – Average values of the ten (10) studied farms (period 2022)	Expected Target
Added value to products	The specific Average KPI value is equal to the olive oil production (kg/h) multiply by olive oil price (euro/kg) 941.25 Kg/ha * 3.0 euro/kg = 2,823.74 euro/ha	+20%
C sequestration per ha	This KPI is expressed by the percentage of organic matter which was calculated from the soil samples of the 1st sampling campaign. The average value of the area is 3.52%	+10%
Water efficiency	The irrigation water use efficiency (WUEi) is expressed: WUEi=Yield (kg/ha)/Irrigation water volume (m^3/ha) = 13.66 kg/m^3	+20%
Fuel use per ha	The average value of 2022 is 46.03 lt/ha	-10%
Effects on soil salinity	The average KPI value (Fv/Fm) concerning the effects of soil salinity in olive trees for 2022 is equal to 0.729. This average value is higher that the corresponding value for 2021 that was equal to 0.708. The average Fv/Fm value of 0.729 for 2022 indicates a slight better condition (minimize the negative effects on soil salinity per 7%) compared to the baseline condition concerning the negative effect from soil salinity in olive grove farms of the study area.	-20%

3.1.3. Progress according to the use case plan

Table 9. Milestones for use case 1

#	Name	Month	How you know you reached it
1	Baseline definition	5	All trial site parcels defined, shapefiles provided to WP3, historical data provided to OCW.

2	Use case operation plan & evaluation methodology	10	Agreement on an operation site plans
3	Informative session with farmers	11, 18, 23	Meetings / Trainings

There was one milestone for 2022, namely informative session with farmers. It was successfully achieved. Meetings and training events were held with farmers in July and November 2022.

Regarding the use case plan of activities, a deviation in schedule occurred the previous year, related to soil sampling for establishing the baseline. This activity was delayed starting as of December 2021 because of the plans to rent a soil scanner for estimation of SOC content as an alternative to the conventional soil analysis in laboratory. The soil analysis from the 1st soil campaign was successfully completed at the beginning of 2022.

3.1.4. Lessons learned and next steps

Lessons learned after second year of implementation:

- Great interest from producers and agricultural cooperatives to be informed and implement regenerative agricultural practice, although most of the practices traditionally used could be already considered as regenerative ones.
- Great interest from producers and agronomists to learn about the smart irrigation systems (IoT based monitoring system based on ground sensors & weather stations) proposed by this project to be installed on the farm to increase water use efficiency.
- Lack of knowledge about carbon credits and certification procedure as well as interest from some olive mill owners to inform about the possibility of branding of low-emission olive oil brand and the certification based on the benefits provided by the results of this project.
- Good communication between the farmers, local authorities, and the science community.

3.2. Implementing use case 2: Poland

3.2.1. Summary

Objectives

The overall objective of this case study is to demonstrate implementation of a regenerative agriculture project in a large-scale crop cultivation case, supported by services implemented in the SatAgro platform.

To deliver this objective, the specific objectives are:

- To provide the necessary inputs for the establishment of the AgriCapture project and platform.
- To create the AgriCapture platform as an extension of the SatAgro platform.
- To demonstrate the benefits of the AgriCapture platform.
- To apply appropriate actions in order to promote regenerative agricultural practices.

Information for the proposed plan

In 2022, the collaboration with the Pilot partners: Top Farms and TerraNostra has continued and was focused on the digital support in the area of soil management. As stated in the previous report, the main motivation for this line of work is that the carbon footprint assessment of Top Farms Głubczyce (done by One Carbon World) confirmed that the use of synthetic fertilisers constitutes the largest part (63.29 % of the core emissions). As this farm represents a typical case of industrial arable farming, it was concluded that linking nutrient (fertiliser) management with the effort to implement regenerative practices has a chance to bring in the biggest net reduction in the carbon footprint. The work done in this area is described in more detail in the section *3.2.2. Main activities and results*.

As regards field research, a unique dataset of dense sampling result (760 samples over 50 ha) was obtained from Top Farms Głubczyce (visualised in the figure below) with the purpose of testing the efficacy of alternative sampling strategies. The wider area sampling under AgricaptureCO2 has been postponed until the Spring 2023 in order to include the measurements of mineral nitrogen, and to demonstrate the use of this parameter in fertiliser use planning (with the new module built for this purpose). Moreover, the campaign will demonstrate the use of another module which supports on-farm soil surveying, compatible with the VMD0018 methodology, shown in the section *3.2.2. Main activities and results,* below.

Finally, in addition to the typical laboratory-based soil analysis, the campaign will encompass measurements performed with an affordable field spectrometer produced by the company QED (https://qed.ai/). The initial simulations have shown that although the instrument might not be robust enough to enable independent estimation of SOM, it might prove to be useful for a low-cost improvement of the spatial resolution of SOM mapping which is grounded with wet laboratory results.

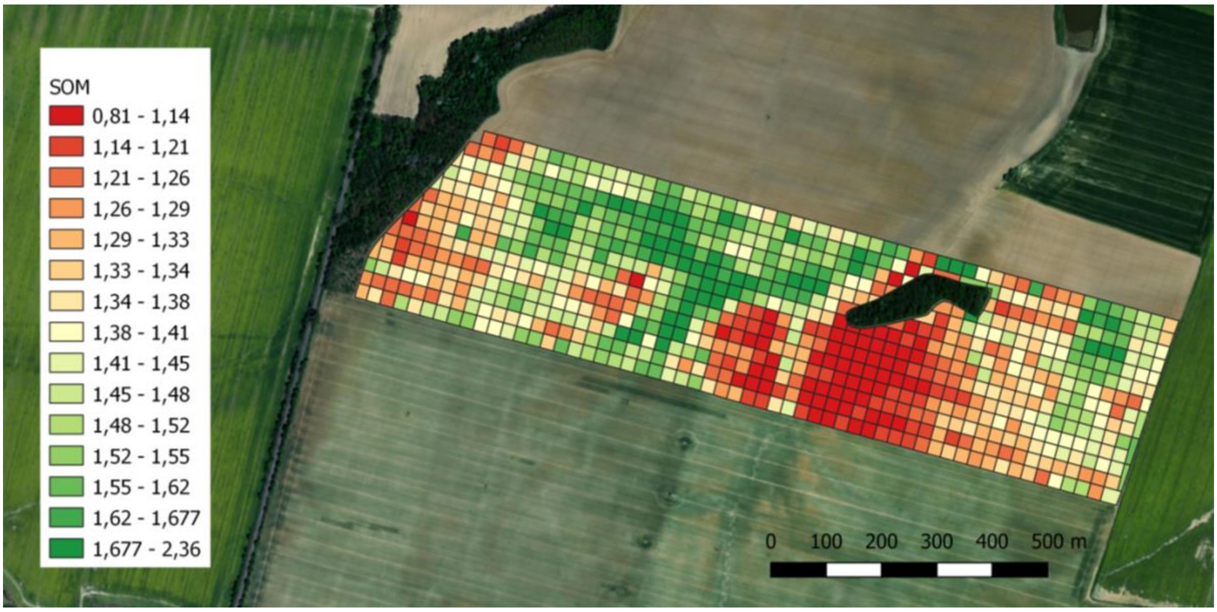


Figure 31. Soil Organic Carbon sampling results obtained from Top Farms Głubczyce.

Regarding the business aspect of the developed service, it should be noted that for the most part of 2022 the work was conducted without clarity as regards the legal and market conditions, which determine any potential business opportunities. Specifically, it was not clear into what extent the financial support for regenerative practices will be provided under the Common Agricultural Policy (CAP) on one hand, and from the private sector on the other. For this reason, SatAgro was monitoring the developments around the Strategic Plans implementing the new CAP, and at the same time it was considering the options to create an offering within voluntary carbon markets. In the scope of the latter, a closer relationship was established with the Polish branch of BNP Paribas, who would like to become an important player in regional carbon markets linked to farms (which constitute an important part of the bank's client portfolio). Moreover, SatAgro was involved in the UK Use case which implements the VRA methodology.

In the second part of the year the rules of the financial support under the new CAP, within the territory of Poland, started to be clear (the Polish Strategic Plan was accepted on the 31st of August). From that moment SatAgro has directed most of its effort towards the implementation of the so-called Eco-Scheme "Carbon Farming and Nutrient Management" (one of 5 defined under the Polish Strategic Plan). It started with the creation of the comprehensive fertilisation plan module which is compatible with precision farming and takes into account regenerative practices (more details in the section 3.2.2. Main activities and results). Details of the Carbon Farming and Nutrient Management eco-scheme are presented in the table below. The scheme does not encompass precision farming; therefore, Variable Rate Application might be the area where there is a scope for an additional support from the private sector.

In conclusion, it can be said that the Polish use case now represents the typical scenario of intensive farming incentivised to adopt regenerative practices directly through a scheme linked to the new CAP.

Table 10. Components of the "Eco-scheme" Carbon Farming and Nutrient Management and respective strategies to implement them in the support platform.

One point will have a monetary equivalent, to be distributed under the CAP system of subsidies.

Winter catch crops/intercrops - 5 pts
Many crops can be cultivated as either regular crops (with some or all biomass harvested) or cover crops (with biomass destined to be mixed with soil). A new parameter in crop history definition enables the user to specify the purpose of the crop. Crops database has been expanded onto nutrient equivalent value which is used in the fertilisation plan.
Design and adherence to fertilization plan - basic variant - 1 pts
A new module *Fertilisation plan* was built, which is compatible with precision farming and takes into account regenerative practices
Design and adherence to fertilization plan - variant with liming - 3 pts
as above
Diversified crop rotation - 3 pts
A statistic describing a number of crops per time period can be calculated automatically and compared with the required threshold
Manure mixed on arable land within 12 hours of application - 2 pts
The definition of a natural fertilization event has been expanded to cover the majority of types, as well as the nutritional value of fertilisers (utilised in the Fertilisation plan module). A test of time difference between two defined events (fertilisation and soil cultivation) can be done automatically. An option to enable attaching additional evidence is being considered
Application of liquid manures by other methods than splash application - 3 pts
The type of application is evidenced by the type of machinery used
Simplified cultivation systems - 4 pts
The definition of a cultivation event has been expanded to enable the user to specify intensity. The type of cultivation is evidenced by the type of machinery used
Straw-soil mixing - 2 pts
The type of cultivation is evidenced by the type of machinery used
Extensive use of stocked permanent grassland - 5 pts
A new, higher level of land use classification will be introduced, and the currently utilised list of crops will be associated with the category "Cropland". Grassland (with the case of pasture) will form another category. Stocking density needs to be implemented as a parameter of this land use.

3.2.2. Main activities and results

In 2022, use case implementation focussed on the design and creation of digital support services, according to the principles and in response to circumstances described above. The implementation was done with frequent consultations with local partners: Top Farms, TerraNostra, BNP Paribas, and Vantage Polska.

The main achievements are the Fertilisation Plan module, and Soil Sampling module, both described and shown below. In addition, an interpretation of soil sampling results according to the Mehlich-3 method is being implemented (estimated completion in February 2023), since this method is likely to gain in popularity with time. Moreover, the list of crop types has been expanded to 490, internationalised and made compatible with biological systematics. The part of the database linked to crops has been expanded to include several parameters linked to plant nutrition management.

The Fertilisation plan module (shown below) has been recognised as a critical part of farm's support which links the general principles of agronomy with the methods used by both precision agriculture and regenerative agriculture. For example, the fertilisation plan determines crop nutrient requirement in a standard way, but as an added value it enables the user to take into account variability in yield and soil properties, as well as to decrease the planned mineral fertiliser input according to the defined supply from pre-crop residues, intercrop and past natural fertilisation events. It can be concluded that the module promotes the implementation of regenerative agriculture principles and connects them with both the typical agronomical practice, as well as with precision farming practice. As a result, the support acts both on carbon reductions and removals.

It should be noted that the Fertilisation plan module is also an important step towards the support in the area of farms' economic profitability. The Profitability module, presented in the previous report, allows dynamic mapping of costs and revenue, and it can help to pinpoint low-income areas which might be suitable for nature strips. The Fertilisation plan automatically links the economic aspect of farms' functioning, as analysed by the Profitability module, with the principles of agronomy.

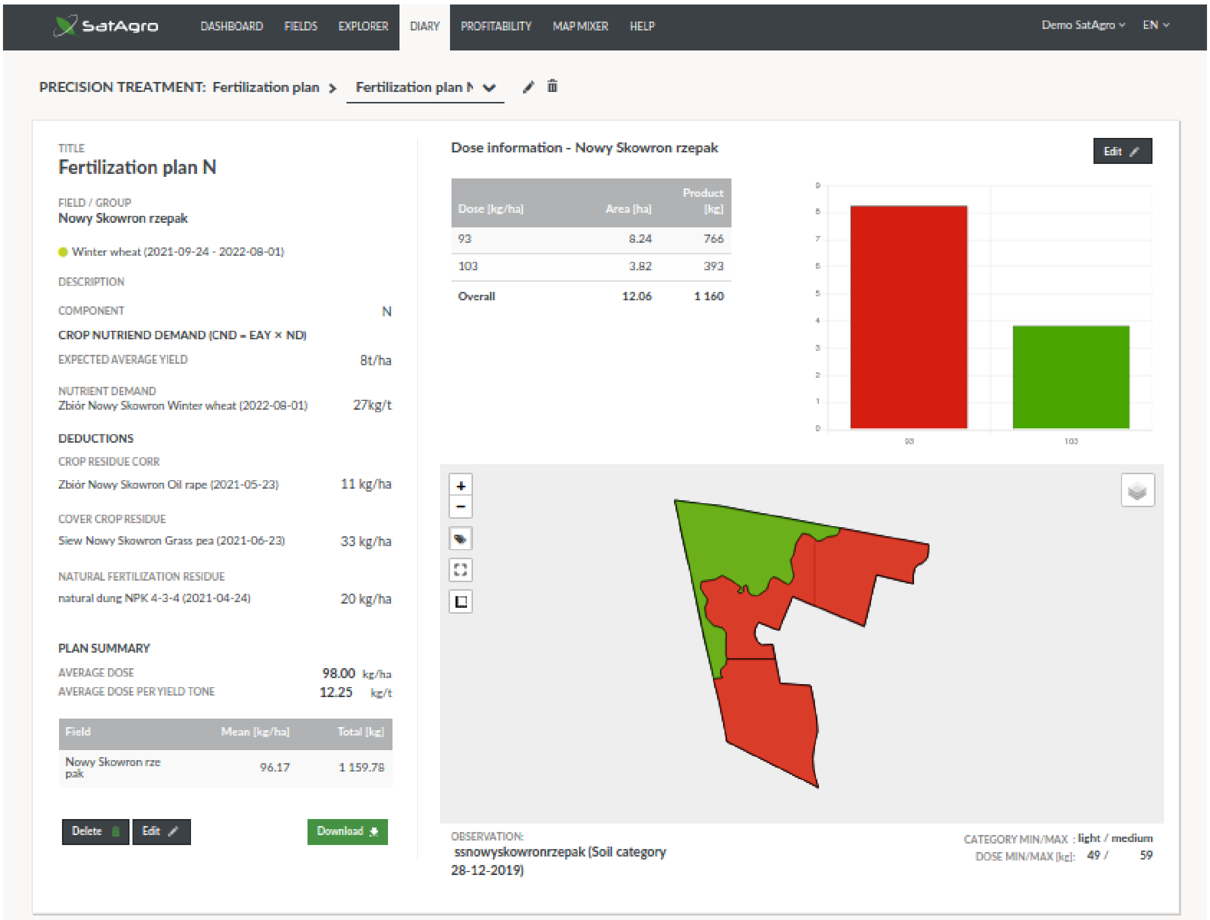


Figure 32. View on the new module of the SatAgro platform: Fertilisation plan.

The module is a key part of the support for the implementation of the eco-scheme Carbon Farming and Nutrient Management linked to the new CAP.

The Soil sampling module is meant to optimise the process of on-farm soil survey, which is a key element of evidence for plan nutrition management and validation of the effectiveness of regenerative practices. The module is compatible with the principles outlined in the VMD0018 methodology. The module can be used for the implementation of SOC sampling design with land split into strata, which strengthens the results and optimises the sampling effort. In essence, it facilitates outlining of sampling zones, which correspond to natural boundaries of soil units (in contrast to a regular grid), and at the same time conform to pre-defined size limits. In Poland, a sampling zone cannot be larger than 4 ha. On the other hand, sampling of very small zones cannot be justified economically.

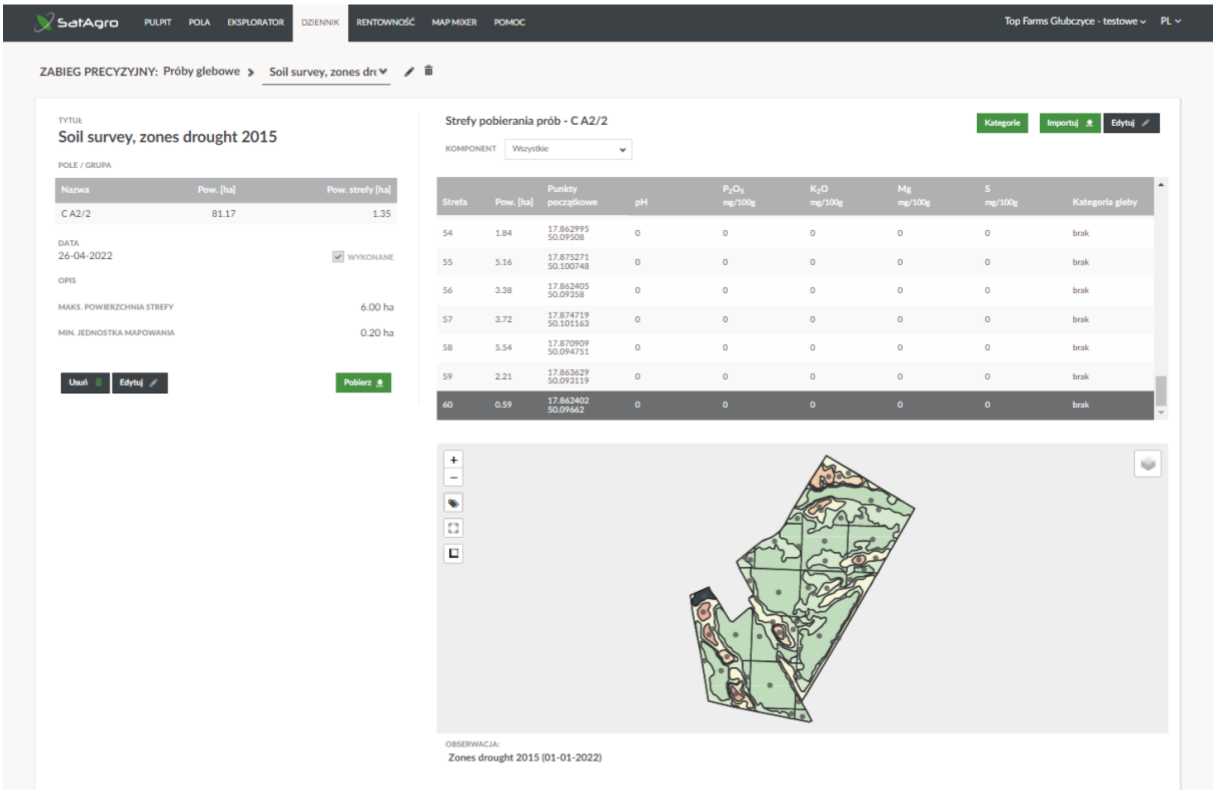


Figure 33. View on the new module of the SatAgro platform: the Soil Sampling module.

3.2.3. Progress according to the use case plan

By now, the conducted work corresponds to all foreseen major activities and linked milestones (see the table below), although the main effort has been in the design and creation of digital support services, according to the principles and in response to circumstances described above, and in frequent consultation with local partners.

Until now, the wider outreach has been limited and mainly linked with the AgriCaptureCO2-wide activities, such as the events linked to the European Regenerative Agriculture Community (ERAC). In addition, Top Farms, TerraNostra, BNP Paribas, and Vantage Polska were trained in the use of the new modules. As the services linked to the new CAP will be launched this winter (late January), this will enable a new strain of local outreach, with concrete and practical advice.

Table 11. Major milestones of Use Case 2

#	Name	Month	How you know you reached it
1	Use case kick-off	5	All local authorities have audits and priorities identified by OCW. All trial site parcels defined, shapefiles provided to WP3, historical data provided to OCW

2	Establish a baseline	4	Agreement on an operation site plans
3	Supporting farmers	13, 25, 34	Training workshops based on the content and tools available online
4	Promote and liaise with new end-users	32	Final demo day
5	Building AgriCaptureCO2 online tools	13, 25, 34	Release of new integration of AgricaptureCO2 tools with SatAgro
6	Manage use case	11, 23, 35	Agricapture platform review

3.2.4. Lessons learned and next steps

Key lessons learned:

1. Fertiliser use plan is the keystone element in farm's operations which links the key source of emissions (fertilisers) with key practices leading to removals (such as cover crops or leaving crop residues)
2. The majority of financial support for carbon farming in the EU will be linked to the new CAP and the schemes which crystallised very recently.
3. Variable Rate Application might be the area where there is a scope for an additional support from the private sector

Key next steps

1. Compare alternative soil sampling strategies based on the SOM dataset received from the Top Farms partner
2. Execute the first soil sampling campaign for the Polish pilot.
3. Propose methodology to estimate the impact of precision treatments on the farm's carbon footprint
4. Develop/adjust the methods for an assessment of soil regeneration potential for the territory of Poland.
5. Expand the new Profitability assessment tool to be able to summarise key emissions in a spatially-explicit way.

3.3. Implementing use case 3: UK (certified regenerative agriculture)

3.3.1. Summary

Objectives

The overall objective of this case study is to facilitate cultivation within a regenerative agriculture-related certification scheme. The case study will define, promote, support, and monitor regenerative agricultural practices to boost nutrient use efficiency, enhance soil health, and ensure productivity. Throughout this use case, peer-to-peer knowledge exchange and learning opportunities will be facilitated and encouraged.

This objective was moderately edited for the sake of clarity compared to the previous annual report, without changing the meaning of the content.

To deliver this objective, the specific objectives are:

- To provide the necessary inputs for the establishment of the AgriCaptureCO2 platform.
- To demonstrate the benefits of the AgriCaptureCO2 platform.
- Deliver activities and opportunities to promote regenerative agricultural practices and/or reduce emissions on farm.
- Develop a portfolio of audio and visual resources to evidence and support the case study.
- Gap analysis of existing LEAF Marque standard with regards to regenerative agricultural practices.

As mentioned in the previous annual PILOT report, the use case plan specified that practices in rapeseed production would be the focus of the use case, which was expanded to include all arable crops.

Information for the proposed plan

The use case focuses on developing and validating two main business cases:

- Enabling in-setting for agri-processors with 0-emissions certification, such as Farrington Oils. We will accurately quantify the carbon being sequestered in soils used to produce raw material for the agri-processors to enable this amount to be used in environmental footprint calculations of the supply chain (Scope 3). This strongly relies on AgriCaptureCO2's quantify service.

There has been significant progress to create a mechanism to actualize this business case. The strong linkage with an expanded scope of activity in WP4, i.e. to actually certify a carbon credit group of projects and create a pipeline that can onboard and certify regenerative UK farms for their offsets, provides a robust mechanism to quantify own emissions and count them against their own unavoidable emissions. As Farrington Oils has participated in this carbon credit project, quantifying their carbon soil sequestration and certifying these offsets will allow them to use this against the unavoidable offsets from their business operations.

- "Improve" upon processes used for regenerative agriculture certification schemes, such as LEAF's Marque. AgriCaptureCO2 can lower costs, increase transparency and promote simplicity particularly through assessing the potential of the Validate and Support services.

  LEAF has brokered discussions between the use case and LEAF Marque, an affiliated entity overseeing the LEAF Marque certification program. The discussion led to a good understanding of the quality assurance process implemented by LEAF. Overall, there was significant scepticism that AgriCaptureCO2 tools can be adopted by the standard's external auditors (see details below). Instead, the project decided to adapt the tools that can be evaluated to provide useful support tools designed for regenerative farmers directly (as opposed to auditors) to still deliver on the goals of transparency, simplicity, and lower effort/costs.

This text has not been changed from the previous PILOT report, in line with the use case plan. The italicized comments on the progress made and relevant strategic decisions.

3.3.2. Main activities and results

Establishing a carbon credits pipeline in the UK

As mentioned in the previous annual report, the use case was chosen as the test bed for the expanded "learn by doing" activities of WP4. Specifically, a "pipeline" was created that could identify and onboard farmers to certify their soil carbon sequestration into carbon credit offset under the VERRA standard, which can either be used for offsets within the value chain or sold in the carbon market.

Specifically, the pipeline entails registering a "group of projects" which provides a framework for registering soil carbon sequestration projects that meet the scope of the framework. The framework establishes the methodology that will be used across all the projects that will be included under it, in this case including AgriCaptureCO2 services to optimise its efficiency and costs. In simple words, the group of projects makes it simpler to register multiple similar projects (soil carbon sequestration from regenerative farming in the UK) by providing common parts of the project methodology that apply to all instances and, simplifying the process of registering an individual instance to the VERRA registry. In turn, the pipeline also includes establishing processes for onboarding and interacting with participants, which includes a degree of sales, marketing, process management, and document management. The overall pipeline was branded as the Great British Sustainable Farming Project.

In addition to documentation and customer service processes, WP4 recognized that carbon credit projects in regenerative agriculture have to be supported by training where the farmer is new to sustainable farming practices (this conclusion was also echoed in practical experience in the Serbian use case). As such, OCW has factored in training as a key part of the overall carbon credit project approach being developed in WP4. For the Great British Sustainable Farming Project, the training will be provided by GWCT which is already active in this domain as one of their core activities at the Allerton Project. So far discussions have identified three scenarios for the UK:

- A farmer or set of farmers is onboarded that do not have regenerative farming experience and GWCT provides training. This can either be in the form of existing or custom training programs depending on the context. We have also discussed that connecting to the peer-to-peer network of regenerative farmers would be very important.
- GWCT already has a roster of farmers interested in adopting regenerative farming in the form of farmers that join their regular trainings. They represent potential participants in the Great British Sustainable Farming Project, and indeed revenues from sale of carbon credits can help finance this transition. GWCT has agreed to assess promoting the Great British Sustainable Farming Project as a part of its regular courses once the Project is more advanced. This would represent a significant and highly relevant "sales channel" after the lifetime of the AgriCaptureCO2 project.
- Farmers currently implementing regenerative practices (for where additionality is relevant) join the Great British Sustainable Farming Project and do not require training. This scenario in principle has relatively low potential for generating carbon credits as large potential soil carbon sequestration comes from fields where intensive carbon depleting practices have been implemented before the start of a project. Nonetheless, these cases are likely to occur and will be included where their costs can be financially justified (e.g. scale, timing of transition, soil type, etc.).

Farrington Oils and GWCT were both onboarded as primary test farms for the carbon credit pipeline. As described elsewhere, the goal of this "hands on approach" is to "learn by doing", designing and fine tuning the onboarding and certification processes, the result of which should be a smoothly working, efficient, and customer friendly process. As test farms, Farrington Oils and GWCT answered onboarding questionnaires designed by OCW, collected and provided required documentation (e.g. proof of land ownership), defined the field area under consideration in a shape file, and provided other information required to prepare carbon credit documentation. OCW (with support from GILab where relevant) processed this information, established eligibility for the carbon credit program, defined sample points using the AgriCaptureCO2 Quantify service, and prepared the documentation to register the project instances under the overall "group of projects" framework.

The Great British Sustainable Farming Project has also engaged other parties at various stages – one of these is advanced enough to be currently planning the soil sampling (using Quantify service). Specific examples will not be provided here due to confidentiality.

Applying AgriCaptureCO2 services to support regenerative farmers

A gap analysis was conducted to analyse the LEAF Marque assurance model and recognise "entry points" for AgriCaptureCO2 services, i.e. processes where the use of the services could represent significant added value.

LEAF led and organized a series of discussions between LEAF Marque (a separate department of LEAF newly involved in the project), use case partners, and WP3 developer partners (led by GILab). The discussions involved a declaration of intent in line with the use case objective, commentary and feedback, and exchange of documentation (particularly significant background documentation provided by LEAF Marque).

LEAF Marque was initially sceptical of our pitch to use EO services to improve their processes, but we concluded that we needed to "better speak each other's language". We provided a better description of what the services involve and how they use satellite data, and how we generally propose they are used. LEAF Marque provided their certification guidance documents, technical description of the LEAF assurance model, and research findings from a previous ISEAL-supported feasibility study project for remote LEAF Marque audits. Farrington Oils agreed to provide their LEAF Marque audit documentation as an example for the project.

With regards to the ISEAL study, LEAF Marque had assessed the use of videoconferencing to replace some of the activities of a site visit. The immediate impetus for this project was the COVID-19 pandemic and the practical complexity to have in person physical limits. The study had recognized that this was feasible and LEAF Marque was cautiously implementing videoconferencing site visits alongside in person site visits. This was clearly a different approach than what we were proposing so we organized a specific online meeting for GILab to present the AgriCaptureCO2 platform and how remote sensing data could provide robust data to significantly change the nature of external audits. We also prepared a document outlining specific "checks" in the assurance model that could be remotely verified using AgriCaptureCO2 services.

As we better understood the LEAF Marque assurance model (and the general concept of assurance systems as they apply to a certification scheme) and LEAF Marque better understood our pitch, the discussions progressed to increasingly technical discussions. Overall, using remote sensing for verification would require significantly altering the LEAF Marque assurance model (to a risk-based approach) rather than changing some of their procedures, a change which was not strategically of interest for LEAF Marque. Practically speaking, this would also be very difficult to implement as it would require collecting a body of evidence to show that the proposed assurance system is *better* (i.e. results in efficacy gains in terms of certification: more efficient, process lead to better assurance) compared to the current system. This evidence would then have to be submitted to a government body, United Kingdom Accreditation Service (UKAS), that has certified the LEAF Marque assurance model. These activities were beyond the lifetime of the AgriCaptureCO2 project and did not have the enthusiastic support of LEAF Marque.

Successively, we discussed alternatives to ensure that the project delivers value to LEAF farmers in line with the use case objective. One proposal was to use the same algorithms developed by the project to help farmers simplify documentation preparation for the project. This proposal would also allow evidence to be collected for potential improvements to the assurance systems over time and could lead to changes in the LEAF Marque assurance system over the long-run. However, although this proposal was met with enthusiasm for LEAF, the required technical work was beyond the scope of the project. Also, LEAF was involved in another project, ENVISION, which had this precise objective.

The ambition of this new proposal was successively reflected in the decision to develop a custom UK version of the soil passport, which at this point was being proposed from the Serbian use case. This would allow for the main use case objectives of ensuring transparency, simplicity and cost/time savings for farmers to be realized.

The use case organised a meeting with WP3, dispersed a survey for WP3 to collect user needs, and helped WP3 define a service description for a UK version of the soil passport. In line with the significant difference in the farming contexts between UK and Serbia, this service description results in a very different product. The strong synergy between the soil passport and the Great British Sustainable Farming Project is also being explored.

Exploring project potential for synergy with biochar trials

GWCT has linked with LCC in the other UK use case with regards to using biochar applications for permanent soil carbon sequestration. The Allerton Project is already engaged in this activity from another research project and, in addition to interacting with LCC and the wider network of biochar stakeholders in the UK, is assessing how this can have synergy with AgriCaptureCO2. Discussions are ongoing to how it can link to the Great British Sustainable Farming Project and to the AgriCaptureCO2 services, and to following up with activities to actualise potential synergy.

3.3.3. Progress according to the use case plan

The milestones for the use case (see table below) were fully achieved in the schedule foreseen for the use case.

Table 12. Milestones in year 1 for use case 3.

#	Name	Month	How you know you reached it
3	Assessment of interventions and gap analysis	15-19	An internal assessment of the LEAF Marque quality assurance model was completed and a plan on how to apply AgriCapture services to the use case context (LEAF Marque certified farmers and other regenerative farmers) was completed.

The KPIs defined in the previous annual report are not relevant as they strongly refer to a scenario where external auditors use AgriCaptureCO2 services, which as described above was considered to not be a good strategic direction for the project based on our gap analysis. The most significant KPIs are (1) generating carbon credits from the Great British Project (these will be limited for a 2-to-3-year period as soil carbon sequestration is a slow long-term process), and (2) area registered under the soil passport in the UK.

3.3.4. Lessons learned and next steps

The main lessons learned were:

- The farmer experience vis a vis a "carbon credit project" supplier is fundamental in designing a successful carbon credit program. As such, the use case worked with WP4 to create not only documentation management processes but also sales and customer management processes to optimise customer experience. This will continue in the coming year with "learning through doing".
- The process that AgriCaptureCO2 uses for soil sampling (as part of the Quantify service) must be tailored to existing farming context of the country, e.g., field size and division as it relates to homo-/heterogeneity of field soil properties, existing (legally mandated) practices for sampling soil, etc. The process should be clear but also carefully finetuned to make it easy for farmers to implement in full.
- The gap analysis of the LEAF Marque assurance model led to a change in direction for part of the use case due to the technical context involved. Although it is unlikely that AgriCaptureCO2 can improve LEAF Marque audit processes, it will nonetheless improve carbon credit validation/verification processes (with external auditors) and will provide farmers with tools to simplify documentation for regenerative farming.
- Biochar has significant potential to sequester carbon in soils. There is synergy with another AgriCaptureCO2 use case and the Great British Sustainable Farming Project which is currently being explored.

In the next year the use case will:

- Further expand the Great British Sustainable Farming Project.
- Work with WP3 to develop a tailored soil passport for the UK use case, promoting the product and arranging testing with farmers.
- Work together with LCC to realize the potential of biochar for soil carbon sequestration.

3.4. Implementing use case 4: UK (public bodies)

3.4.1. Summary

Objectives

Use AgriCapture to assess various management options for public lands and inform an actionable plan to achieve climate neutrality of Lancashire County by 2030.

Lancashire County Council (LCC) is the lead project partner on behalf of the 14 district and unitary authorities in 'Greater Lancashire.' We are the only public authority partnership in the AgriCaptureCO2 project. We are investigating how the public sector can learn from regenerative agricultural practices, and how these can be applied to public land to enable councils utilise their land holdings to help address their net-zero objectives.

Most Lancashire councils have declared climate emergencies or set ambitious targets and pathways for achieving net zero. Meeting these will require the reappraisal of existing policies and practices to identify opportunities for carbon in setting and offsetting.

Councils are already promoting and investigating alternate land use options to address climate change, including woodland establishment, habitat restoration, and developing renewable energy schemes. Whilst such approaches have their place, they are not necessarily compatible with other essential land uses and activities councils must perform, and in these areas a different approach will be required.

Whilst the Lancashire councils have little land under active agricultural management, we are collectively responsible for substantial areas of managed grasslands: parks; playing fields; school grounds; and highway verges, all of which are broadly comparable to agriculturally managed grasslands. We need to identify the regenerative agricultural techniques which may be transferrable to these situations and then understand how they may be best applied.

Regulated systems of carbon credits have been established for woodland and peatland, but not as yet for agricultural soils which collectively make up the largest single land use type in Lancashire, and which have significant potential for helping to deliver net zero objectives if managed appropriately. However, to deliver this we need an effective system for assessing and mapping soil carbon and also for monitoring compliance.


Figure 34 Biochar ,10-20mm fines size (left); PAS 100 Compost (right)

We have chosen to focus on the use of biochar and PAS 100 compost as these materials could be applied whilst still retaining the existing functionality of the land, so utiliding areas which may otherwise have limited potential to contribute to our councils' net zero objectives.

The trials will enable the relative merits of this approach to carbon capture to be assessed. This will permit the capacity of wider council owned land under different management regimes to be determined, and indicate the potential councils have to contribute to meeting their own net zero objectives through this approach.

3.4.2. Main activities and results

Year 1 of the project sawn baseline carbon audits prepared for the 14 district and unitary authorities in Lancashire. The second year has seen the development and implementation of pilot studies (at two sites: Chisnall Hall and Midgeland Road) utilising biochar and PAS 100 Compost. Biochar was applied to each trial site at a rate of 10t/ha. Compost was applied in areas to be tree planted at 630t/ha (Chisnall Hall only).

The agricultural use of biochar in the UK is not well established and different regulatory frameworks apply in the constituent Nations. In England, The Environment Agency (EA) is the body which regulates the use of biochar (and PAS 100 compost). The current published EA position on biochar only addresses it in relation to use as a soil conditioner and does not cover its value as a potential store of carbon. The EA position is that, in many instances, biochar is a waste product, and its use is controlled by legislation relating to waste. This position is currently under review. Through the pilot we hope to influence the development of new guidance for its use.

During the second project year the Lancashire pilot has established a working relationship with another UKRI funded *Biochar Demonstrator Project* being run by Nottingham Bangor Universities. This project is also undertaking biochar field trials in England in 2022.

Current UK regulatory framework for the use of biochar

Under the *Low Risk Waste Position 61: Storing and spreading biochar to benefit land*, up to 1t/ha can be applied to benefit land without the need for an environmental permit. The proposed Lancashire pilot application rates of 10t/ha exceed this.

Following discussions with local Environment Agency staff, and with reference to the internal EA guidance set out in *Bio Char EPR permitting briefing note 13 Dec 2021,* applications of biochar at 10t/ha were considered acceptable on the Lancashire trial sites so long as the biochar used can be demonstrated not to be a waste.

Use of a waste biochar would require either a permit, or an approved trial under the EA's system for regulating trials of waste management operations: *RPS 182*. This is the same approach which has been adopted by EA in respect of the biochar trials being undertaken by Nottingham Bangor Universities as part of the *Biochar Demonstrator Project.*

Bio Char EPR permitting briefing note 13 Dec 2021 assumes that all biochar is waste unless demonstrated otherwise. It identifies pathways by which the non/end of waste status of biochar can be established (end of waste status can be self-assessed):

1. Biochar resulting from the thermal treatment of waste is likely to be a waste but may achieve end of waste status if it meets the key tests. As part of that test a comparator assessment against a non-waste product will be essential. See: *https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/404761/Product_comparators_for_materials_applied_to_land_-_biochar.pdf*

   It is also possible for the biochar to be considered a by-product, but again a case-by-case assessment would be needed.

2. Biochar resulting from the thermal treatment of non-waste where the char is an unavoidable consequence, but not the main output of the thermal process is likely to be a waste. On a case-by-case assessment the material may be a by-product (non-waste), a waste, or an end of waste material (i.e. the material was waste but it has been shown it achieves end of waste status).
3. Biochar resulting from the thermal treatment of non-waste where production of the char is the target output of the thermal process. This may be an intended product i.e not waste. However, that biochar would have to be demonstrated as being the primary aim of running a thermal treatment process and that there was a legitimate market for the product.

For the Lancashire field trials, the biochar to be used at both sites is supplied by Lancashire-based company Rectella International Ltd (*Positive BioCarbon*).

The UK market for biochar is currently not well developed and there is limited UK-based production. *Positive BioCarbon* is currently imported from Namibia where it is the intentional output from a planned land management programme, the Bush Control and Biomass Utilisation Project, which aims to manage Acacia, an invasive species on Namibian rangelands.

Namibia is affected by bush encroachment on a massive scale. Bush encroachment of Namibian savanna is attributed to decades of unsustainable land management and climate change. The phenomenon currently affects up to 45 million hectares of farmland in 11 of the country's 14 political regions which amounts to up to 50 per cent of Namibia's land area.

The virgin wood from this clearance is used for a variety of purposed including fodder, wood chip, charcoal and commercial biochar, providing a range of socio-economic benefits.

Environmental permits

The biochar used in the Lancashire pilot is not a waste as it can be demonstrated to satisfy *Bio Char EPR permitting briefing note* pathway 3 above: the biochar is intentionally produced from virgin wood as part of a planned programme of forestry operations to thin bush and restore the ecological diversity of Namibian rangelands. The resulting forestry products are sold to the established global livestock feed, biofuel, and soil conditioning markets, as set out in *Biochar from Namibian Encroacher Bush practical guidelines for producers* published by the Bush Control and Biomass Utilisation Project.

Furthermore, laboratory analysis results provided by the supplier establish that this biochar complies with the requirements of the EU fertiliser legislation concerning the maximum content of heavy metals and of organic contaminants, particularly PACs/PAHs with carcinogenicity for the 16 EPA priority PAH compounds, and comparison to priority PAHs defined by European Food Safety Authority (EFSA), EU Scientific Committee for Food (SCF) and EU.

It will also meet the European Biochar Certificate, an industry standard overseeing the use of biochar in agriculture.

Consequently, it is determined that there was no requirement to seek a permit from the EA, or approval with a formal Regulating Trials (RPS 182) submission.

Application for an environmental permit using SR2010/4: mobile plant for land-spreading and associated LDP1 forms apply to "wastes". This is not appropriate for biochar trials as biochar is not a waste, rather it is a product with intrinsic value both as a smokeless fuel and for carbon sequestration of CO2, the latter being a growing market with the potential to contribute to the UK's net zero carbon economy in the effort to mitigate climate change. The wood feedstock used for biochar production is also a commercial product and not a waste.

Compost

The compost used in the trials is produced in Lancashire from local green waste collections and is produced using the 'PAS100 Standard' and 'Compost Quality Protocol'.

All the compost used in the trials conforms with the PAS 100 standard, meaning the material is no longer subject to the EA waste regulatory controls and has achieved product/end of waste status.

The County Council has a standard 'buy-back' option from its green waste contractors. In view of the low bulk density of PAS 100 compost, and associated transport impacts, compost for the Lancashire pilot is to be sourced from the contractor nearest the trial sites.

Potential risks of contamination with ferrous, or non-ferrous metals, plastics and pathogens are inherent in all PAS100 compost. As a precautionary measure compost will not be applied to land to be returned to agricultural pasture/silage management and will only be utilised in woodland establishment areas, to promote tree establishment and growth, and as a mulch to avoid the need for chemical weed control. Biodegradable tree guards will be used in planting areas.

Proposed operation

Chisnall Hall Treatment Site

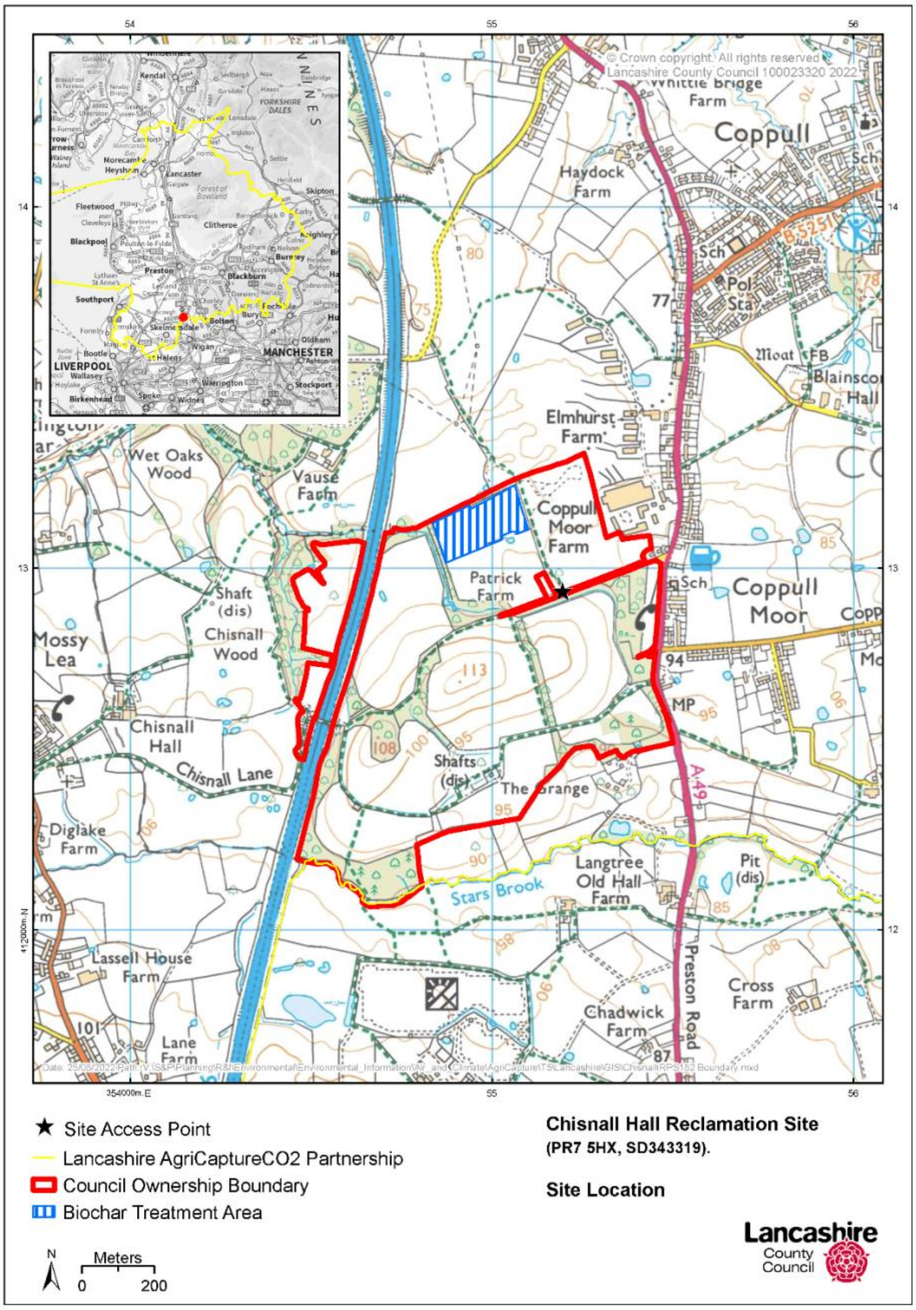
Site Information:

Location: The site lies in NW England in the county of Lancashire. It lies within the Borough of Chorley. PR7 5HX, SD549131.

Ownership: The site is owned by Lancashire County Council.

Plot size: The entire site is 79.6ha, the trial plots is c. 3ha.

Crops: The biochar treatment site is currently managed for grazing and silage cuts.



Chisnall Hall Reclamation Site (PR7 5HX, SD549131) is owned and maintained by Lancashire County Council. It is an 80ha former colliery site which was restored to woodland and pastureland by the County Council in the 1970s, with subsequent additional woodland planting. There is public access to part of the site, other areas are areas managed under grazing licences.

The extent of Council ownership and the location of the area to be treated with biochar are shown on the Location Plan, below. The site will be accessed via the gated track off Chisnall Lane at SD55191293. The treatment area will be entered via the access point at SD55081314. The treatment area is a level field currently managed for silage and winter grazing.

Figure 35. Site Access off Chisnall Lane

Treatment areas access

c.3ha of the site will be treated biochar with PAS100 compost subsequently applied to c.1ka of this. Following treatment two management compartments will be established, these are identified on the Biochar Treatment Area plan:

- Treated with biochar & compost (c.100mm depth), fenced & tree planted (c.1ha),
- Treated with biochar and returned to grazing management (c.2ha);
- Untreated areas of the field will remain as a control.

Biochar (10-20mm fines) will be applied across the whole trial plot, top dressed at a rate of 10% (equal to 1Kg/m2 or 10t/ha). 10t/ha is a conservative value selected based on literature reports such that physical and chemical impacts upon the soil are expected to be minimal. Where not defined by physical features, plot boundaries were clearly defined on the ground using aerosol marker spray and marker poles.

The soils of Chisnall Hall Reclamation Site are mostly man-made: thin soils on top of colliery spoil. However, within the biochar treatment area the soils are believed to be largely undisturbed, evidenced by remaining trees which are on the line of boundaries shown on historic (1840s) mapping, and previous site investigations undertaken when Chisnall Hall was being assessed for tree planting using Organic Growth Medium (OGM).

The soils of the treatment area have been subject to normal agricultural management practices by the tenant farmer, including the application of paper waste.

Site hazards

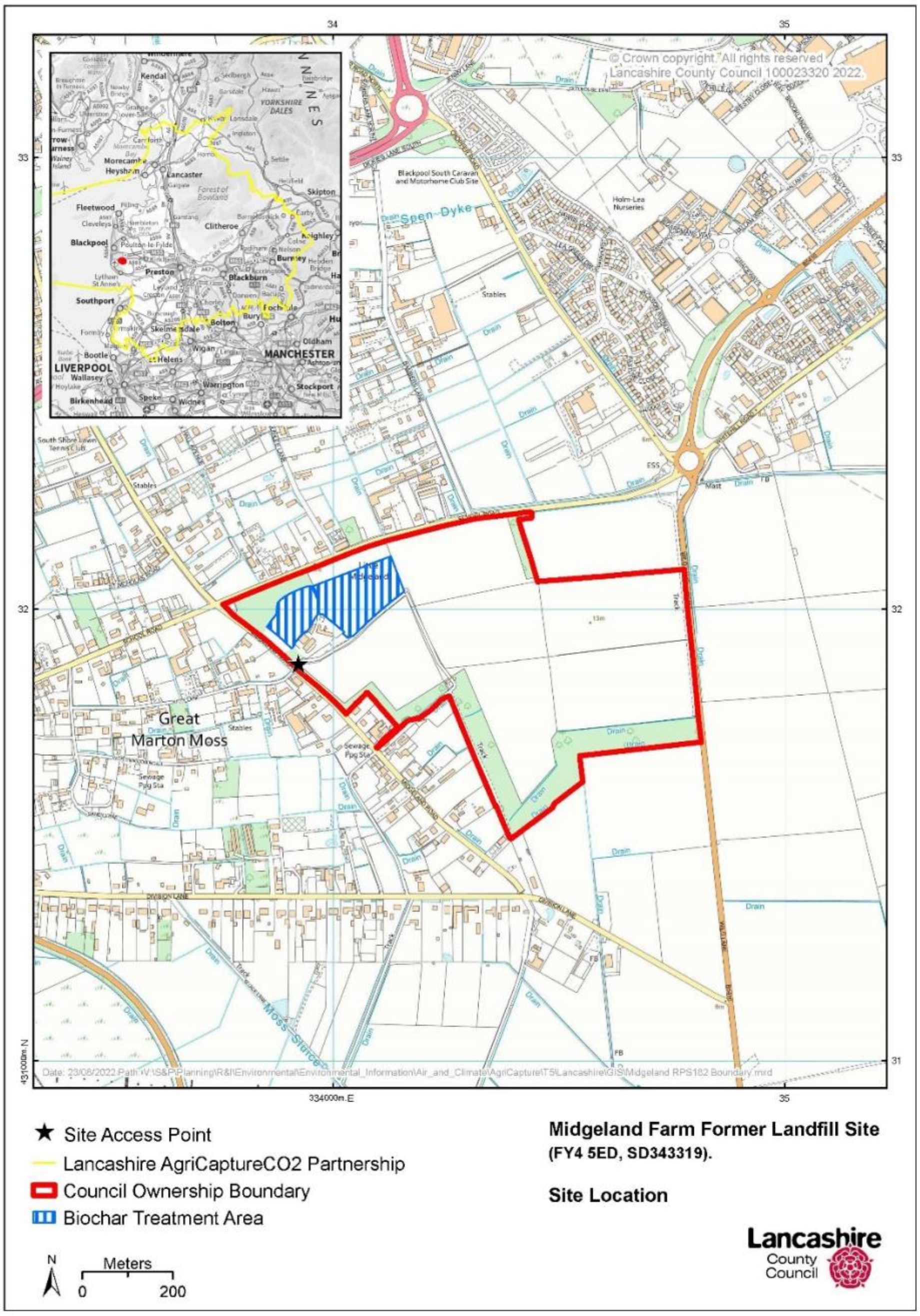
There is no public access to the treatment area and it does not share any boundaries with public highways. A gated private access track runs adjoins the hedgerow which forms the North-Eastern boundary of the treatment area (c.120m). The track is owned by Lancashire County Council and let to Chorley Borough Council and South Lancashire BMX Club. A Public Right of Way footpath also follows this track.

An open field drain adjoins the North-Western boundary of the treatment area for c.115m, another watercourse lies within woodland to the South West.

A field pond lies adjacent to the hedgerow which forms the South-Eastern boundary of the treatment area. There is a single residential property c.130m from the treatment area. Powerlines cross the North-Western corner of the treatment area.

Neither of the proposed Lancashire biochar trial sites lies within a Nitrate Vulnerable Zone.

Midgeland Road Landfill Site



Site Information:

Location: The site lies in NW England in the county of Lancashire. It straddles the boroughs of Blackpool and Fylde. UK NGR SD343319, Lat/Long 53.779269, -2.9980695.

Ownership: The site is owned by Lancashire County Council.

Plot size: The entire site is 39.1ha, the trial plots is c. 3ha.

Crops: The site is currently managed for grazing and silage cuts.

Midgeland Road (FY4 5ED, SD339320, see Site Location plan) a 39ha former landfill site which is now capped and has a periphery of woodland with the central areas managed under grazing licence. The extent of Council ownership and the location of the area to be treated with biochar are shown on the Location Plan, below. The Midgeland Road former landfill site is securely fenced and gated. The site will be accessed via the gate off Midgeland Road at SD339318.

The site is owned and maintained by Lancashire County Council. LCC Scientific Services are currently undertaking a review of the whole Midland Road landfill site with a view to implementing any remedial action identified in respect of the past landfill operations. The AgriCaptureCO2 proposals have been drawn up in close liaison with LCC Scientific Services so that they will not impact on any future works.

The soils of Midgeland Road are entirely man-made, established over a restored landfill site. Midgeland Road Landfill Site was planned under the 'dilute and disperse' principal and the waste was capped with clay and soils. Subsequent to restoration, additional inert soil forming material has been added to the original cap to a depth of 1-2m. The soils have been subject to continued agricultural improvement by the grazing tenant.

c.3ha of the site will be treated with biochar. Following treatment, the entire area will be returned to agricultural management. Untreated areas of the field will remain as a control.

Biochar (10-20mm fines) will be applied across the whole trial plot, top dressed at a rate of 10% (equal to 1Kg/m2 or 10t/ha). 10t/ha is a conservative value selected based on literature reports such that physical and chemical impacts upon the soil are expected to be minimal.

Fire Risk

The possibility of biochar applications acting as a fuel source and increasing the potential risk of landfill fires was raised as a matter of substantial concern by Scientific Services who were concerned over its potential to increase the risks around underground tip fires.

There has been research on the flammability of raw biochars which found that none of 34 studied samples qualified as flammable substances, assessed using the applicable UN method. The majority of biochars (67%) had no combustion front propagation distance at all (Zhao et al., 2014). Given the characteristic of biochar to hold water, any risk is likely to be even lower. Consequently, it is considered that application of biochar to Midgeland Road will not significantly increase the risk of landfill fires, or act as a fuel source.

Additionally, there appears to be evidence that biochar may have other potential beneficial attributes for reducing pollution from landfill sites and enhancing soil stability of reclamation:

- The addition of biochar to cover soil can greatly improve the CH_4 oxidation capability of landfill cover soil system. Biochar-amended soil cover may be best suited for small and/or old, abandoned landfills where a gas collection system is not required and the gas-to-energy systems are not applicable (Yaghoubi, 2012).
- Biochar can be used to control leachate from landfill as an alternative to activated carbon (Abedin, 2017; Jayawardana et al., 2016).
- Biochar amendment increases soil hydraulic conductivity, decreases soil compressibility, and increases soil shear strength, all of which are desired geotechnical properties for stable landfill cover materials (Reddy et al., 2015).

In determining the location and extent of biochar application areas the requirements of regulations and guidance for the materials have been addressed.

Site hazards

There are no residential properties within or adjacent to the treatment area. Midgeland Road lies adjacent to the treatment area, the buildings are currently unoccupied, derelict, and due for demolition.

The old farmhouse and associated buildings are considered dangerous and entry is now prohibited (see right). Asbestos roof has partially collapsed, contaminating the interior and locally around the exterior of the building.

The perimeter of area is secured with Heras fencing, ground level windows and doors are boarded and there are regular visits by a security agency.

There is no public access to the treatment area.

The treatment area shares two boundaries with public highways. To obtain the desired trial plot size of 3ha within the field, it is possible to achieve a buffer of 24-38m between the public highway and the biochar treatment area. Where not defined by physical features, plot boundaries were clearly defined on the ground using aerosol marker spray and marker poles.

There are no open watercourses within or adjacent to the treatment area.

Biochar treatment at pilot sites

In determining the location and extent of biochar and compost application areas the requirements of current and emerging English regulations and guidance for the materials have been addressed.

The biochar used is high quality (EBC Agro II) and resistant to degradation once in soil, therefore, the major risks from biochar are likely to only occur during the application of the material. An overarching risk mitigation strategy is the application of only 10 t/ha.

Table 13. Comparator of the Positive BioCarbon parameters for the biochar used in the AgriCaptureCO2 Lancashire trails.

Element	Positive BioCarbon	Typical Biochar Values	EU fert. regs.	EBI Standards	IBI Standards
				European Biochar Certificate V4.8	IBI Biochar Standards V2.0
C content	74%		>50%		>60%
Organics					
H/C_{org}	N/A	0.1-0.4	<0.7		0.7 maximum
PCB ug/kg	<0.2	<1	<0.2	0.2 mg/kg	0.2 - 0.5
PAH mg/kg	<8.8		<6.0	<12	6-300
Elements (mg/kg)					
Cd	0.12	<0.2-0.8	<0.10	<0.1	1.4 – 39
Cu	5.35	30-90			
Cr	2.2	10-40	2.0	80	64 - 1200
Hg	<0.1	<0.1	1.0	1.0	1 – 17
Ni	1.9	5-30	50	30	47 – 600
Zn	8.36	70-180		<400	200-7000
Mo	0.2			n.a.	5-20
Co	<1			n.a.	40-150
Pb	1.89	10-30	120	120	70 – 500

Benefits and Potential Risks of Biochar Amendment

Biochar has been extensively researched for its potential application on agricultural land with field trials across the EU identifying some agricultural benefit at amendment levels of *c.* 10 t/ha[1]. These levels have shown no detrimental effects in traditional farming, and are the magnitude required for biochar to make a significant contribution to UK net zero targets (the mix of GGR technologies required equates to *c.* 35 MtCO2 p.a[2], of which biochar could provide ~50 MtCO2 over the course of ~50 years).

Many councils and other organisations are currently focussing their net zero land management proposals around the establishment of woodland. Typically, these use native broadleaved species as these can bring additional benefits relating to landscape, biodiversity and water quality. A new native woodland can capture 300-400 tonnes of CO2 equivalent per hectare by year 50[3]. Applications of biochar at 10t/ha could achieve similar results within 10-13 years.

In addition to being a carbon sink, it is well documented that biochar can provide several potential benefits to soil, including:

- Improving soil water holding capacity and soil structure (aeration), leading to potential benefits to crop yields.
- Positively impacting the chemical properties of soils, for example the addition of an alkaline char will have a neutralising effect on acidic soils.
- Positively impact the nutrient status of the soil by reducing the runoff of applied fertilizers.
- Increasing speed of establishment of planted trees and decreasing losses.

These benefits present the use of biochar as an amendment on agricultural soils as an attractive carbon capture strategy. Not only helping to address climate change concerns but also improving soil function and mitigating fertilizer runoff into waterways.

Biochar application Chisnall Hall

Biochar and compost were applied to the areas identified on the plan.

Figure 36. Signage was utilised to notify the public using the wider site of the nature of the works and also hazards from machinery

Biochar and compost spreading was performed by experienced contractors using their own equipment. No additional infrastructure is required beyond standard agricultural equipment.

The biochar was delivered to the contractor's facility and transferred to site in 5 spreader loads for direct application. All biochar and compost delivery and application works were largely undertaken by a single machine operator.

Figure 37. Images showing field application of biochar

Spreading of biochar and compost was undertaken with a single GPS enabled tractor and spreader (Samson Flex 16) with vertical beater bars.

This is able to achieve accurate and even application of materials over a 12m spread in a single pass. The capacity of the spreader is 10-12t PAS 100, a single load takes 2-3 minutes to spread. Compost application rates of 70t/hr can be achieved with single tractor/spreader and loader. In practice, it was found that the spreader capacity for dry biochar was around half that for compost c.6t due to the volume of the material.

Biochar application was completed in one day (5/10/22), it rained for much of the day but there was little wind.

Figure 38. Images showing field application of biochar

The main issue encountered was dust which settled within the application site and did not cause any issues to adjacent properties.

This was compounded at Chisnall as part (30%) of the biochar supplied was a dust (0mm+) rather than the 10-20mm ordered. This is believed to be a consequence of supply difficulties arising from the limited availability of biochar in the UK. To overcome this, the bulk bags were opened on the ground and mixed with a machine and bucket to achieve a more consistent product. This was loaded into the spreader by hydraulic bucket.

Figure 39. The biochar in Lancashire treatment fields

In the path of the tractor-trailer unit the individual chars tended to settle in the tyre tread marks. Prolonged periods of rain in the following weeks suppressed any subsequent dust issues.

Figure 40. Treatment field 6 days after biochar spreading (11/10/2022)

Compost Application

Following application of biochar to the whole treatment area, 634t of PAS 100 compost was by applied to c.1ha of the trial site to a depth of c.100mm.

The compost will add further carbon and nutrients to the soil and will aid tree growth and establishment. It will also act as a mulch reducing the need for subsequent weed control.

Due to the volume of PAS 100 compost being applied to the site, and the risk of soil compaction through transport across the application field, a licence to use an adjacent private access track was negotiated with a neighbouring tenant.

Compost delivered to site in bulk and tipped. Entry to the treatment area is via an access point from the neighbouring track and car park.

Figure 41. Images showing loading of compost for field application

Tipped compost loaded into spreader. Bog matting was laid in in areas of high activity to minimise the potential for damage to the sward/soil due to the volume of PAS 100 compost being delivered and loaded into spreaders.

Figure 42. Images showing field application of compost

Figure 43. Images of the applied compost on test fields

Compost spreading on top of biochar in tree planting area. The garden green waste has been composted for 8 weeks before approval as PAS 100 and application. After application it will continue to mature on the ground for a further 16-24 weeks.

One potential impact of applying raw biochar to agricultural soils is a temporary reduction in productivity as the biochar undergoes a biochemical reaction with the soil micro-organisms. The general advice is that this can be reduced by the co-application of compost.

This procedure was considered at an early stage in the Lancashire pilot project development; however, PAS 100 compost has not yet completely broken down, and it can also cause a similar dip in productivity as the maturation process completes. Additionally, it can take a number of years for the compost to be fully integrated into the soil which creates issues for the management and harvesting of silage.

Although the PAS 100 compost is screened for contaminants it is impossible to guarantee removal of all contamination. Therefore, the use of this material on agricultural land which will be grazed, or where sileage will be harvested and fed to livestock, is not advisable for animal welfare reasons. These issues do not arise on arable lane.

Walk-over searches were performed of the area adjacent to the fenced compost-treated area to ensure that significant contaminants were collected and removed (see below).

Figure 44. Contaminants removed by walk-over included: plastics, glass, ceramics, ferrous and non-ferrous metals, stainless steel etc.

Woodland establishment

The area with compost treatments area was subsequently stock-fenced, tree planting will proceed in the 2022/23 planting season once the compost has finished its maturation process.

Figure 45. Newly fenced compost area ahead of tree planting.

The planting scheme is being developed by the LCC forestry team. It is being designed to maximise the potential of the planting to sequester carbon, support the development of local biochar production and benefit biodiversity.

The planting is based around a modern twist on a classic UK 'coppice-with-standards' system: it will comprise a coppice of fast-growing eucalyptus, coppiced for harvesting on a short rotation, with oak standards to develop into a woodland canopy with associated biodiversity benefits.

Additionally, we are investigating the potential for using this planting scheme to trial new biodegradable tree guards for the Forestry Commission.

Grazing livestock were removed from the treatment field until it is assessed that conditions are suitable for their return (anticipated to be Spring 2023 at latest).

Remedial works

On completion of the treatment works, some remedial maintenance was necessary to restore the surface of the private access track used under the agreed access licence.

Biochar application Midgeland Road

Figure 46. Biochar was delivered to site by HGV in palletised bulk bags. Bags typically contained 400-455kg biochar. Full trailer load was c. 20t.

Different agricultural contractors were used on the Chisnall Hall and Midgeland sites.

Figure 47. Biochar stockpiled for spreading.

Figure 48. Bulk bags created safe-handling and dust issues during loading.

The biochar supplier has been advised that bulk deliveries would be easier to handle and produce less waste (bulk bags).

Figure 49. Biochar spreading.

Figure 50. Biochar applied with Bunning Lowlander Mk4 with disc spreaders.

Figure 51. Field immediately after spreading with biochar. All the biochar supplied at Midgeland Road was 10-20mm fines.

Figure 52. Similar to Chisnall Hall: in the path of the tractor-trailer unit the individual chars tended to settle in the tyre tread marks.

Figure 53. Away from the vehicle path the biochar spread was more even.

On the day of spreading at Midgeland Road the weather was fine but there was a strong wind which caused the fine dust in the biochar to be caught and blown off site towards adjacent housing.

Consequently, these reasons spreading operations were suspended by the site manager after 10ha (10t) had been applied. A plan was then developed to address the dust issues and concerns around handling/loading the bulk bags.

In developing the alternate application plan, discussions were had with the GWCT Allerton Project which had also just applied 10t biochar to 1ha arable land. At GWCT they we able to apply biochar with no dust issues. The used a lime spreader rather than a muck spreader.

It also became apparent that the biochar GWCT received was delivered damp (and it stood in the open for several weeks ahead of spreading), whereas the material received in Lancashire was dry, in sealed bulk bags. This will mean that, although the application rates at the two sites are the same (10t/ha) the actual amount of biochar applied will be greater in Lancashire as it was dry weight.

GWCT also received biochar in bulk bags which caused them similar handling problems.

There are concerns that over-wetting the biochar may result in clogging a lime spreader as the hopper is gravity-fed, while muck spreaders have chain-driven beds feeding the spreaders. A potential benefit of this equipment is that it is developed for use with a fine, dry, dusty material and has a vertical curtain on a telescopic arm which can be extended beyond the spreader disc to limit dust egress.

Figure 54. Dust-free biochar spreading at the GWCT Allerton Project experimental farm.

The strategy developed to combat the dust and safe-handling issues:

- Un-stack bulk bags into single tier.
- Open sealed bulk bags to allow any rain to penetrate (although the bulk bags are a woven plastic fabric experience shows that very little water penetrates the sealing collar).
- Wet the biochar with water from a bowser.
- Open bulk bags on ground to avoid working at height.
- Load biochar into spreader with hydraulic bucket.

Based on experience gained in the 2022 biochar applications which were made with agricultural equipment we need to conduct further research to identify appropriate grounds maintenance equipment which would be more appropriate for use on parks, playing fields and other publicly accessible land. We are following up other UK biochar applications which we know have been undertaken on golf courses and sports pitches. This research will be continued in year 3 of the project.

Details of by-product generation and consumption

There is not considered to be any additional waste (energy, noise, materials) generated outside of standard agricultural practice for the application of soil amendments.

Additional energy costs for transport will depend on distance of the sites from biochar processors. The PAS100 compost is the material being used which has the greatest volume and transport requirements. We utilised the contractor with PAS100 production facility closest to the trial site to supply this material and minimise transport.

The bulk bags in which the biochar was supplied generated additional waste for disposal which is another factor against their use.

As with most biochar currently available in the UK the biochar being utilised is imported in bulk (from Namibia) by a local supplier. It is recognised that this is not ideal however it is a reflection of the present market state. Locally produced non-waste biochar should become more widely available with the establishment of a permitting/regulatory framework which addresses the use of biochar at rates sufficient to make a significant contribution to UK net zero targets.

Biochar suppliers will be reviewed in subsequent project years.

3.4.3. Progress according to the use case plan

It was originally intended to apply the biochar to the pilot sites in Spring 2022, however, a number of site-specific issues arose which meant that application had to be delayed until late Summer 2022, specifically:

- Need to demonstrate compliance with the current UK waste regulatory framework relating to biochar.

- Need to demonstrate that biochar did not pose an increased risk of tip fires by acting as a source of fuel or combustion.
- Negotiations to secure legal access agreement due to volumes of material; applied at CHisnall Hall.
- Agricultural management restrictions. In view of the delays created from the issues above, the timing of operations was then planned to take account of existing agricultural site management, with the biochar applied in the window after the second (late Summer) silage cut.
- Identification of a strategy to overcome safe-handling and dust issues which became apparent during application operation.

The delay arising from these issues has resulted in delays to the provision of training and dissemination of information as this is built around the practical experiences gained through implementation.

3.4.4. Lessons learned and next steps

AgriCaptureCO2 Project (and beyond) Lancashire Pilot timescales

- **Year 1** Baseline carbon audits prepared for the 14 district and unitary councils.
- **Year 2** Field trials at 2 sites: Chisnall Hall (Chorley) and Midgeland Road (Fylde/Blackpool) will see biochar applied to c. 6 hectares of grazing land.
- **Year 3** Re-application of biochar to areas of the original trial sites under continuing agricultural management. Site monitoring. Information dissemination Including presentations. Investigation of biochar capacity of council land. Developing local biochar market. AgriCaptureCO2 final report preparation.
- **Year 4** (beyond AgriCaptureCO2 project funding) Re-application of biochar to c. 4ha of the original trial sites (those areas under continuing agricultural management). Monitoring, information dissemination and incorporation of results into LCC climate strategy.

Re-application of biochar

The initial pilot concept was to make a single application of biochar in 2022. The concept within the pilot project has now received considerable wider support within the authority. The proposal is now to make an additional biochar application to the pilot sites in 2023 and another in 2024, beyond the AgriCaptureCO2 project lifetime. Three years' experience of applications will enable us to further develop and refine techniques and procedures and give a sounder scientific understanding of the likely impacts on the soil. It will also further help establish the local biochar market.

Site monitoring

The County Council will continue to assess the effects of the applications as part of the on-going soil sampling and site monitoring, and through dialog with tenant farmers and by working cooperatively with Nottingham and Bangor Universities as part of the Biochar Demonstrator Project.

The AgriCaptureCO2 project will finish in December 2023. The Biochar Demonstrator project will continue until October 2025 to assess the impact on soil functioning through multiple cropping cycles and seasons.

After application it is anticipated that the first year will the most dramatic changes as the char weathers and equilibrates with the soil matrix. The subsequent years will be important in assessing the long-term impact of the char as it ages into the soil.

Information dissemination

In partnership with others, we will develop a program of information dissemination to local authority staff, farmers, foresters, and land agents about our experience with biochar and its potential for carbon storage.

We will continue to engage in dialogue with the EA, and other regulatory bodies, to facilitate the determination of an appropriate permit/regulatory stance. With the objective of reaching a consistent stance on biochar usage across England.

Investigation of biochar capacity of council land

Utilising the carbon audit of Lancashire local authorities, the experience gained from the application trials and the predictive soil carbon mapping prepared by Envirometrix (https://maps.opendatascience.eu), we will investigate the potential for soil carbon uplift in Lancashire and the potential for biochar to contribute to carbon insetting if it were to be applied across appropriate local authority landholdings.

Developing local biochar market

We will investigate the potential for the County Council to support the development of the local biochar market in Lancashire through:

- The sustainable management of woodland on its estate, including the management of highway trees to combat the impacts of ash dieback disease to provide non-waste feedstock for biochar production.
- The potential for green garden waste to be utilised as a feedstock for the production of biochar.
- Opportunities for the purchase and utilisation of locally-sourced biochar in landscaping and tree planting schemes.
- Opportunities to work with farmers and land managers to grow the private-sector biochar market through the Woodland Creation Accelerator Fund activities.

AgriCaptureCO2 final report

A final report will be prepared, drawing together the findings and experiences from the three years of the project.

3.5. Implementing use case 5: Serbia

3.5.1. Summary

Objectives

To promote, support and monitor regenerative agricultural practices in crop production in Serbia (and wider Western Balkans region) in order to enhance soil health, increase farmers' profit, decrease air/soil/water-pollution and improve biodiversity in agricultural landscapes. Thus, to create a model for wider adoption of regenerative agriculture that will be supported by digital decision tools and financial incentives.

To deliver this objective, the specific objectives are:

- To work with farmers to promote new regenerative practices that benefit the environment and the farm.
- To demonstrate actions regarding the benefits and the use of the AgriCaptureCO2 platform.
- To explore and implement novel technology-supported means for value-addition, cost savings, and/or novel revenue streams.

Information for the proposed plan

The regenerative practices being used in the Serbian use case include:

- Cover crops
- No/low soil tillage
- Leaving crop residues

In the second year of the project, 15 farms have participated in the use case, 14 of them continuing from the first year while one new (experimental farm) joined. Two of the initial farms dropped. The details for each of the farms is presented in the table below (names of the farms has been anonymised for this public report).

The group of development farms measured yield and fuel consumption in the experimental farms to compare the results from regenerative vs conventional plots. The In Practice group analysed the results of applied cover crops as the addition to no/reduced till in 2021. They repeated the exercise with cover crops in 2022.

Table 14. The main characteristics of the use case farms in Serbia in year 2.

Farm	Parcel area (ha)	Regenerative practice	Regenerative practice applied before
RS01	20.00 17.73 10.49	Low till, Cover crop, Leaving crop residues	Yes, except cover crops
RS02	5.70 5.00 3.68	Low till, Cover crop, Leaving crop residues	Yes, except cover crops
RS03	2.70 11.10 4.62	Low till, Cover crop, Leaving crop residues	Yes, all
RS04	42.48 41.80 23.37	Low till, Cover crop, Leaving crop residues	Yes, except cover crops
RS05	4.14 3.14 2.56 2.36	No till, Low till, Cover crop, Leaving crop residues	Yes, except cover crops
RS06	1.25 1.25 1.25 1.25	Experimental farm. Combinations of No till, Low till, Cover crop, Leaving crop residues vs conventional practices	
RS07	6.58	Low till, Cover crop, Leaving crop residues	Yes, except cover crops
RS08	3.19 4.44 4.58 2.92 5.50	Low till, Cover crop, Leaving crop residues	Yes, except cover crops
RS09	31.00 10.00 10.00	Low till, Cover crop, Leaving crop residues	Yes, except cover crops
RS10	1.35 3.27 2.90 1.58	Low till, Cover crop, Leaving crop residues	Yes, all
RS11	2.52	Low till, Cover crop, Leaving crop residues	No
RS12	1.09	Low till, Cover crop, Leaving crop residues	No

RS13	1.35	Low till, Cover crop, Leaving crop residues	No
RS14	1.15 1.15 1.15 0.93	Low till, Cover crop, Leaving crop residues	No
RS15	19.05	Low till, Cover crop, Leaving crop residues	No

3.5.2. Main activities and results

Within the group of new regenerative farmers which did comparative experimentation between conventional vs regenerative practices (no/reduced till + cover crops), most of them experienced significantly lower yield of their crops in the regenerative part of the field. Only one farmer had the same yield at both plots, due to the fact that the field got enough water from the local rain. However, fuel consumption was significantly lower in the regenerative case compared to conventional, marking a 20l/h decrease in average.

September 2021 was extremely dry, which affected the weaker emergence and growth of cover crops. October was cold and rainy influenced the development of cover crops to the end of fall. In certain localities, this influenced the low positive effect of cover crops. Growing season was followed by extreme drought, which decreased yields. Acceptance of economic indicators such as the less consumption of fuel, mineral fertilizsrs, working hours of machines, etc. was nothing compared to the income achieved by the yield and price of products in conventional production.

Based on experience in the first year, it is necessary for farmers who switch to the application of the principles and practices of regenerative agriculture to have constant support from advisors, to connect at the local level with other farmers, perhaps even at the regional level, for the common use of necessary mechanisation, such as machine rings. When there are no subsidies for regenerative or conservation agriculture, this is the only way the transition period will be sustainable. Farmers have to transition into regenerative crop production step by step. We think that the transition period should last a minimum 5-7 years.

The agronomist who was leading the experimental field for the Agricultural Advisory Service of Ruma (AAS RU) did not choose the optimal selection of the cultivated crop in 2022 which resulted in much lower yield in the regenerative plot. They sowed 2 hectares of 3 cover crop mixes which started to emerge in late October and survived to spring under snow. In this condition they planted no-till corn which had a good start after herbicide treatment and in the first one and half months of growing period before extreme hot and dry conditions.

The regenerative/conservation practice group of farmers, known as In-Practice Group (IPG) in the same climate conditions have different results on his fields. Example: dairy farm members had no emerged cover crops resulting from dry late summer conditions. Others had cover crops in different growing levels. For all who had cover crops in spring the important thing was how to manage them because some species in the mix survived the winter under the snow and continued to grow in the spring. It was important to transfer the experience of farmers who have been using cover crops for many years and to enable the normal growth of the main crops sown in the spring of 2022.

During late August, September and October 2022, farmers from the IPG group and AAS PA sowed the following cover crop mix on their plots same as last year "Tillage mix KEVE" which consists of: 74% Horse beans, 24% spring Black oats and 2% Phacelia. All crops are spring varieties and freeze over the winter. Their function is to produce biomass, protect topsoil and provide nitrogen fixation. Details of monitoring the results in the test fields is presented in the table below.

Table 15. Monitoring parameters and details for the use case in Serbia.

Monitoring parameter or procedure in parcels	Number of samples/monitoring parameters per time	Progress of monitoring actions taken in 2022
Soil moisture monitoring*	Soil samples taken on experimental field with long term 4 different tillage systems/ Frequency: Every 10 days through vegetation period of crop. Alternative, a survey can be conducted to collect the feedback from farmers regarding their own experience.	From the sowing of corn in a trial with 4 tillage systems, we took samples on all systems in three depths /0-30;30-60 and 60-90cm) and two repetitions where we determined soil moisture content expressed in weight percentages. For the period from April 28 to June 30, we took samples 5 times. From 1st July extreme drought and heat started. The results are as follows: see Table 15.1 below.
Soil nutrient content*	Soil sampling at specific locations, depth 0-5 cm; 5-10 cm; 10-20cm and 20-30 cm/ Frequency: Every year after harvest	We did not do that because of the extreme drought. It was not possible to take samples with an auger and shovel too.
Soil organic matter*	Soil sampling at specific locations according to AgriCaptureCO2 methodology. First campaign will be conducted in 2021-2022 and the second campaign in 2023	Soil Organic Carbon and Bulk density sampling and analysis has been completed in 2022. In total 204 samples were taken and analysed.
Efficiency of cover crop mix*	Soil sampling at specific locations. Available N for next crop as N-NO_3 , from 0-90 cm Frequency: Every year	Results are in Tab. 15.2 below

Coverage harvest residues and management*	Measuring for each registered field/ Frequency: Every year after harvest	We had w.wheat, maize, soybeans and sunflower on parcels with regenerative practice. Average of residue coverage was (in % used Line Transect Method): w.wheat 55 - 65 maize 65-80 soybean 50-70 sunflower 30-35
Soil compaction*	Measuring for each registered field/ Frequency: Every year before and after crop production	We did not do that because of the extreme drought. Not possible to determine the low pan.
Yield*	Measuring for each registered field/ Frequency: Every year in harvest	Average yield which depends on extreme drought* was: wheat 6.5 - 8.5 t/ha (no drought impact) maize* 5 - 7 t/ha soybean* 3.2 t/ha (late growth irrigation) sunflower* 3-4 t/ha
Fuel use per ha*	Collecting data and feedback from farmers/Frequency: Continuous	In the Development group of farmers, the savings in fuel was 20 l/ha compared to classical production.
Application of fertilisers*	Records of types and quantities of applied fertilizers/ Frequency: Continuous	Farmers in the Development group used the same amount of NPK and N mineral fertilizers in the first year. Farmers in IPG decrease NPK mineral fertilizers by 30% and N mineral fertilizers by 10-15%.

Table 16. Soil moisture content on four tillage systems, three depth and five sampling times from April 28 - June 30, 2022.

Agriculture Advisory Service of Pancevo (weight %)

Tillage systems	**soil moisture (weight %)**			
	0-30 cm depth	**30-60 cm depth**	**60-90 cm depth**	**SUM of 0-90 cm profile**
Mulch till	19.95	19.96	22.05	**20.65**

Strip till	18.03	18.94	22.14	**19.70**
No till	19.62	19.59	22.36	**20.52**
Moldboard plow	19.53	20.58	21.48	**20.53**

Table 17. Nitrate nitrogen content in soil under cover crop and without cover crop in Development group of farmers and AAS of Ruma.

Measured by Nmin method Wehrmann and Scharpf (kg/ha)

	N-NO3 (kg/ha), 0-90 cm layer with Cover Crop	N-NO3 (kg/ha), 0-90 cm layer without Cover Crop
Farmer 1	133	150
Farmer 2/1	70	156
Farmer 2/2	82	123
Farmer 3	129	182
Farmer 4	124	258
AAS of Ruma	102	169
Average amount N-NO3 (kg/ha)	**107**	**173**

Figure 55. Experimental fields with 3 different regenerative tillage systems and one conventional (plowing)

Upper left - mulch till; upper right - strip or zone tillage; lower left - conventional tillage, moldboard plow; and lower right - no till planted corn in cover crop

Figure 56. Direct drilling cover crops after winter wheat, August 2022, by one farmer from IPG

Figure 57. Soil samples in cylinders from different locations, soil types and depth after drying

Figure 58. Samples for measuring bulk density

Figure 59. In soil pit with the project farmers, AAS of Pancevo 2022

Figure 60. No till planted soybean in no till produced winter wheat July 2022, by one farmer from IPG

3.5.3. Progress according to the use case plan

Table 18. Milestones for use case 5.

#	Name	Month	How you know you reached it
1	Baseline definition	5	All parcels defined, shapefiles provided to WP3, historical data provided to OCW
2	Use case operation plan & evaluation methodology	5	Agreement on an operation plan
3	Informative session with farmers	7, 19, 30	Trainings

There was one milestone for 2022, namely training provided to the farmers which was successfully achieved. The AgriCaptureCO2 workshop with farmers was organized in June, while there were a number of bilateral support activities to the use case farmers (providing expert knowledge and advice, distribution cover crop seeds and instructions) and several trainings in regenerative agriculture to agriculture advisors.

In addition, soil sampling campaign to establish the baseline was conducted and completed. The samples are taken from 104 locations within the use case fields at three depths, covering all involved farms. The samples are analysed for SOC content and bulk density. The campaign followed the sampling protocol agreed through AgriCaptureCO2 Quantify service.

3.5.4. Lessons learned and next steps

Conclusions for the Development Group (farmers without experience in Regenerative Agriculture):

- Difficult acceptance of a change of practice in a year with unfavourable conditions for some regenerative practices (extreme high temperatures and extreme drought). Transition to Regenerative Agriculture is a marathon, not a sprint.
- Non-existence of government subsidies.
- Strong need for continuous education in regenerative practice.
- Closed and conservative agriculture science without research in this area or research results not available to farmers.
- Lack of appropriate equipment to correctly apply some of the regenerative practices is a problem (e.g., for application of cover crops and intermediate crops as).
- Insufficient trust and negligence in data entry when using digital platforms and applications that help monitoring agricultural production.

Conclusions for In-Practice Group:

- Lack of knowledge about Carbon credits and certification procedure.
- Regular practices are used of cover crops and start to use intermediate crops in wide row crops production.
- Insufficient trust and negligence in data entry when using digital platforms and applications that help monitor agricultural production.
- Insufficient will to form a regenerative agriculture association by farmers.

Next steps:

- Measuring N content in soil under regenerative practices.
- Measuring soil organic carbon content for the monitoring of C sequestration.
- Filling out a production cost checklist using Croplab Field book.
- Using and testing CropLab crop monitoring services to optimize the application of regenerative practices.
- Organizing workshops and trainings.

- Monitoring of moisture content on experimental plots in Pancevo on 4 tillage systems long term trial established in 2006 (If soil conditions and precipitation allow).
- Set up trial of 4-5 cover crop mixes in Pancevo as education and data collect trial for the end of Project.
- Organizing farmers visits to regenerative farms in Vojvodina.

4. Conclusion

During the second year of the project experimental work in the field was continued and the plan developed in the first year (direction, goals, activities, KPIs, etc.) was followed. In large part, the work of the WP was successful, in the sense that they have achieved progress according to plan and have proved a valuable technical and business test bed for the whole project. The establishment of the baseline which began in the first year, was completed with the soil analyses carried out in several use cases in the second year.

There was a successful interaction with other WPs, especially with WP3. WP3's contribution was decisive for the sampling campaign and the interaction between the two Work packages is critical for the development of the project platform. In addition, the support of ELGO and GILAB to all use cases with regular contact was vital. This process will be further improved and replicated in the successive year.

In the third and final year of the project, the project will continue experimental work in the field, where relevant. The sampling campaign will be repeated to assess the impact of the regenerative agricultural practices. In addition, more workshops, training events and farmers visits to regenerative farms will be organized in the next year. Moreover, trainings must be given to farmers for the use the project's platform

Continuing closer collaboration with the other WPs is necessary to ensure that the WPs contribute as much as possible to the overall objectives of the project, and indeed to the ambition of the participants and volunteers with which each use case works.

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