CREDIBLE
EU carbon farming

Funded by
the European Union

Proximal sensing and digitalisation for carbon farming

Project CREDIBLE: "Building momentum and trust to achieve credible soil carbon farming in the EU".

Funded by the European Union under the Grant Agreement nº 101112951.

www.project-credible.eu

Executive summary

This document is part of the EU-funded project CREDIBLE, Grant Agreement 101112951, and it captures the main outputs of the first round of conversations within the Focus Group on “Proximal sensing and digitalisation” (FG3.2).

The main goal of this Focus Group is to generate recommendations or opinions that could be used in the development or deployment of relevant policies around carbon farming, and particularly in the definition of the Carbon Removal Certification Framework. These informed opinions have emerged through the active participation of experts (details provided in Tables 1 and 2) in a number of activities (with the main ones listed in Table 3).

In order to convey the recommendations to the broader possible audience, the following sections have been included in the document: i) an introduction, which helps clarifying the problem and why addressing this topic was considered important by the CREDIBLE consortium; ii) a short process report, which summarises the conversations held by the Focus Group, highlighting the key points and tensions that emerged and; iii) a summary of recommendations, listing in a concise way the opinion of the Focus Group on how to best solve some of these tensions.

1. Focus Group participation and activities

Table 1 - Partners of CREDIBLE who participated in the Focus Group.

Name of the expert	Affiliation	Role*	Country
Jon Atherton	University of Helsinki	co-Lead	Finland
Paulina Rajewicz	University of Helsinki	co-Lead	Finland
Pablo Fernandez	COOP Agricola	Member	Spain
Chiara Piccini	CREA	Member	Italy
Hannes Mollenhauer	UFZ	Member	Germany
Andrea Ferrarini	UCSC	Member	Italy
Panagiotis Tziachris	Soil and Water Resources Institute	Member	Greece

Table 2 - Members of the Focus Group external to CREDIBLE.

Name of the expert	Affiliation	Role	Country
Jussi Heinonsalo	University of Helsinki	Member	Finland
Catherine Preece	IRTA, Catalunya	Member	Spain
Valentin Knitsch	Fraunhofer Center for International Management and Knowledge Economy IMW	Member	Germany
Olli Nevalainen	Finnish Meteorological Institute	Member	Finland
Mari Knadel	Aarhus Uni	Member	Denmark
Mirco Boschetti	CNR-IREA	Member	Italy
Mari Pihlatie	University of Helsinki	Member	Finland
Fabio Castaldi	National Research Council of Italy	Member	Italy
Simone Priori	Università degli Studi della Tuscia	Member	Italy
Liisa Kulmala	Finnish Meteorological Institute	Member	Finland
Jonne Pohjankukka	Natural Resources Institute Finland (LUKE)	Member	Finland
Jaana Back	University of Helsinki	Member	Finland
Fernando Moyano	ClimateFarmers	Member	Spain
Guillaume Vial	MyEasyFarm	Member	France
Jan Viljainen	Tampere University of Technology	Member	Finland
Elisa Vainio	Finnish Meteorological Institute	Member	Finland
Chris Tolles	YardStick	Member	USA

Table 3 - List of main activities carried out to steer the conversations.

General description of the activity	Date of execution
Inaugural Focus Group online meeting	12th of December 2023
Discussions with separate FG members	January-March 2023
Meetings concerning preparation for the European Carbon Farming Summit with FG representatives	January-March 2023
2nd Focus Group online meeting	15th of February 2024
Plenary session presentation + panel during the European Carbon Farming Summit	6th of March 2024
Breakout session during the European Carbon Farming Summit	6th of March 2024
Meetings concerning summary and conclusions coming from the European Carbon Farming Summit with FG representatives	7th of March 2024
Post-summit discussions	March 2024

2. Introduction

Monitoring, reporting, and verification (MRV) systems are the bedrock of carbon farming and carbon credit schemes, ensuring that carbon farming initiatives meet their targets. Successful implementation of the monitoring component of MRV presents a major challenge in terms of balancing accuracy with cost-effectiveness. Emerging proximal sensing and digital methods have been proposed as potential solutions to this challenge. However, several concerns and open questions should be answered before proximal sensing and digitalisation can facilitate Europe-wide CREDIBLE MRV systems.

Focus Group 3.2. has centred conversations around three main themes related to MRV: 1. proximal sensing, 2. digitalisation, 3. the acceptance and transformative capacity, i.e., "social aspects" of these technologies. The three themes are connected via the monitoring needs at the farm scale and introduced below in more detail.

Theme 1: proximal sensing

Proximal sensing is loosely defined as the use of field-based sensors to obtain signals from the soil when the sensor's detector is in contact with or close to the soil. These sensors can potentially provide rapid, accurate, inexpensive, non-destructive measurements of soil organic carbon stocks and other properties. Specific proximal sensing technologies currently applied for soil property characterisation include Vis-NIR spectroscopy, gamma-ray spectroscopy, electrical conductivity, and laser-induced breakdown spectroscopy. It is worth noting that different definitions of proximal sensing are in use by differing parties and there may be a lack of consensus on the actual definition and the full range of techniques in use.

In comparison with traditional soil carbon sampling - which requires analysis in wet chemistry facilities – proximal sensing methods are less laborious and more cost-effective, hence attractive for practical MRV solutions. However, it is crucial to highlight that proximal sensing techniques will not replace wet chemistry measurements completely. This is because while proximal sensing can be used to determine spatial variability by increasing the net of data points in space, a limited number of wet laboratory analyses are still required to train estimation algorithms and validate results.

Soil spectroscopy methods are rapidly gaining ground as key proximal tools to map soil properties rapidly and cover large areas limiting the need for wet chemistry measurements. In particular, Vis-NIR spectroscopy is a widely used technique for quantifying soil organic carbon and a focus for current commercial activities. However,

the full range of carbon farming-related proximal sensing technologies should be assessed and described in terms of technology readiness levels, operators, and strengths and weaknesses.

Though promising, proximal sensing methods commonly lack standardisation and procedural guidelines, which are required for successful MRV systems. These guidelines are crucial given that proximal techniques are usually assumed to be less precise than other soil sampling methods and require extensive, single farm level, or regional level calibrations.

Theme 2: digitalisation

Going forward, digital technologies will play an increasingly important role in MRV, impacting data collection, processing, and quality control. Further, increased use of proximal sensing will result in new streams of data that require proper management guided by FAIR principles.

Digitalisation could result in automated, organised, and unified MRV systems, boosting the decarbonisation pathway undertaken by various land users. Digital solutions, including digital logbooks, AI- and ML-based tools, or electronic maps, could also help farmers in improving farm management planning and de-risk operations, increasing yield and profitability in tandem with reducing carbon emissions.

Although digital technology can break through the information-blocking constraints on farmers' behaviour (see Theme 3), digitalisation in European agriculture is not yet sufficient to meet the ambitious goals of fully automated MRV systems. There are two reasons for that: the technical one, e.g., lack of access to a sufficient internet connection or existing technologies and data sources, and the personal one, e.g., lack of digital skills, or low technology acceptance among farmers. Importantly, the stage of digitalisation varies among European regions as barriers to digitalisation are region-specific and thus should be considered at the regional scale. This is why it is important to map the stage of digitalisation in Europe in terms of aspects that play important roles in carbon farming. At the same time, the overarching barrier to Europe-wide operating MRV systems is the lack of standardisation in IT systems for data collection, storage, and analyses, as countries continue to maintain their national-level systems.

Finally, straightforward, far-reaching, and unified digitalisation for carbon farming is not possible without clear guidelines that can be followed by various land users across different regions in Europe. Farmers must be equipped with tools for easy and direct implementation of digital solutions at an individual farm level. These tools must,

therefore, consider the background of their users, which might differ on a regional scale and require regional adjustment (see Theme 3).

Theme 3: technology acceptance and transformative capacity

The term **technology acceptance** refers to a process of overcoming barriers to adopting new techniques. Considering technology acceptance of proximal sensing innovations or related digitalisation, the process requires consideration of paths and tools that might differ among regions or socioeconomic groups. The term **transformative capacity** regards the ability to navigate within a process of change, often related to complex multi-crisis settings. Transformative capacity is key for addressing climate change impacts, as it refers to the ability for profound and intentional change in response to current challenges and the move toward a more desirable and resilient state.

Barriers to innovation implementation vary regionally and can be influenced by individual characteristics like age, ethnicity, or farm prosperity. For example, in terms of digitalisation, barriers might include insufficient Internet connection or lack of essential skills among farmers. Importantly, these barriers appear to different extents in different regions in Europe. Therefore, before designing any methodology aimed at promoting new technologies sustainably, it is important to identify the competencies and knowledge needed across different regions. This regional background information is crucial for creating guidelines for new technologies implementation.

Moreover, the role of a strong support network for farmers cannot be neglected as it is essential for the effective integration and utilisation of new solutions. The support network must include collaboration between farmers, technology developers, and policymakers. Again, the support network must be designed regionally, including country-level support initiatives or utilisation of existing infrastructures or test sites to address technology acceptance and transformative capacity at a regional scale. Farmers need reliable, local, and continuous points of contact that manage stakeholder inclusion and collaboration.

Lastly, language and communication streams are crucial aspects of technology acceptance and transformative capacity. Different players in the carbon credit market, including scientists, digital solution developers, policymakers, and farmers (or other end-users) represent different perspectives and backgrounds, including education, socioeconomics, level of digital literacy, etc. Building a platform for communication between them – both on local and European levels – is crucial for successful and long-term involvement in carbon farming efforts. The key element of this communication is conscious listening to the end users, as they will be the ones accepting the new technologies and going through transformations. Therefore, the

farmers' perspective should be considered at every stage of new technology development and new solutions implementation.

3. Short process report

3a. focus group activities

Focus Group 3.2. has a diverse membership spanning academia (e.g., soil science, proximal sensing, social sciences), farmers, research institutes, and the private sector. There are currently 24 members in total, both internal and external to CREDIBLE (Table 1 and 2, respectively). The Focus Group kicked off with an online meeting in December 2023. In the first meeting, we brainstormed the main areas of interest and discussed points related to the three themes using online survey tools. In the subsequent online meeting in February 2024, we began to work on a living online document, which then constituted the basis for this report.

The outcomes of our hitherto work as the Focus Group 3.2. have been presented at the First European Carbon Summit (Valencia, 2024), at a plenary session on MRV and data management. We have also organised a breakout session 6 (BOS6) where the discussions on the three main themes continued. At the BOS6, approx. 40 participants, including representatives of the private sector, and academics of different fields, listened to seven pitches and took part in thematic brainstorming tables. The pitches focused on, among others, IoT and AI in carbon monitoring, data- and science-based analytics for scalable carbon markets, and a presentation of proximal sensing tools. A format of three brainstorming tables led by chairman was then used to gather more detailed perspectives from our BOS participants.

Our next step is to focus on methodologies for proximal sensing and related digitalisation in order to survey and evaluate technology readiness. Within the next year, we will report the outcomes of this survey and we will present them at the next Carbon Farming Summit (2025). By the end of the Credible Action, our goal is to distil the collected knowledge in order to facilitate the use of proximal sensing and related digital methods in credible carbon farming.

3b. key discussion points

Section 3b summarises key points, related to the three main themes, raised and considered by Focus Group 3.2. and discussed during the breakout session at the First European Carbon Farming Summit. Recommendations relating to these points follow in section 4.

Theme 1: proximal sensing

1. The need for **standardisation of proximal sensing approaches** - in terms of methods, devices, outputs, and accuracies - validated and supported with *in-situ* field measurements, that are applicable for different soil types and fractions including soils with low carbon content and all land types (agriculture, forestry, etc.).

2. Clarifying the **future role of proximal sensing in MRV**, concerning: i. the cost-effectiveness and technology readiness; ii. implementation of proximal sensing into MRV systems in tandem with other monitoring techniques e.g., remote sensing; iii. clearly defined and transparent accuracy and precision levels required for derived products; and iv. regional variation in technological needs and approaches.

Theme 2: digitalisation

1. There is uncertainty on the **current state of digitalisation across Europe's farms** and hence the readiness to implement data-heavy MRV systems across regions.

2. There is a need to **utilise existing digital resources** alongside new (e.g., proximal sensing) data in MRV systems by identifying, evaluating, integrating, and harmonising extant data sources such as land parcel identification system (LPIS), tractor sensors, and soil analyses to enhance accessibility and effectiveness.

3. **Seamless data exchange from farm to national levels** should be facilitated through technological advancements, like APIs, to optimise interoperability between platforms and applications in agricultural contexts.

Theme 3: technology acceptance and transformative capacity

1. **Innovations must co-evolve with farmers** to provide their best applicability at the regional level. This requires regional support networks consisting of policymakers (regional and state level) and the local community. Regional test sites are needed to establish what are the best solutions specific to a given region.

Existing infrastructures or test sites should be encouraged to provide fit-for-region support and guidelines (the concept of “farm lighthouses”).

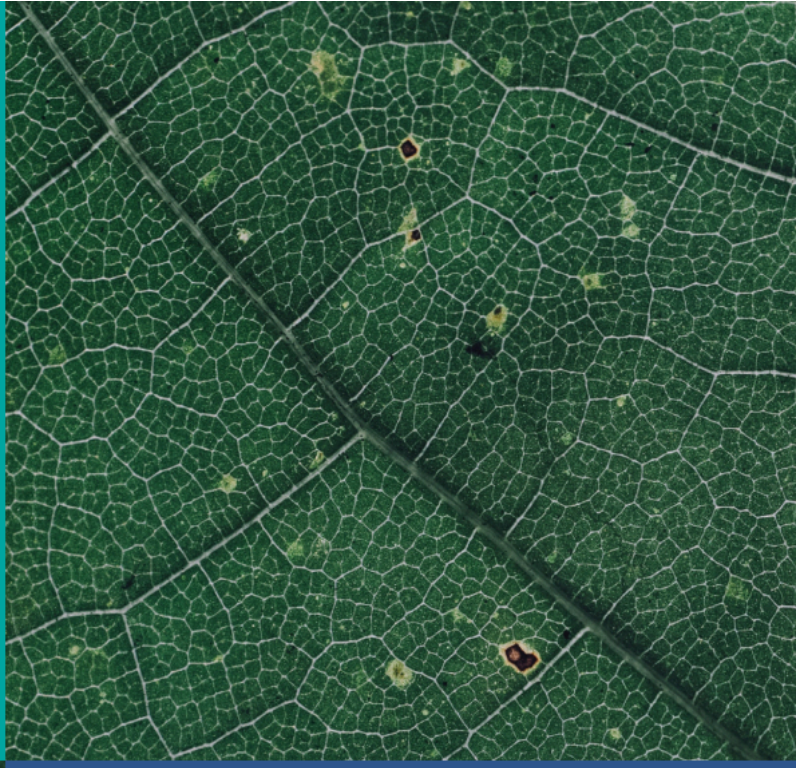
2. Farmers should be provided with **guidelines on new technologies**, including proximal sensing, that would clearly describe the benefits to the land, crops, nature, and overall prosperity of the land, i.e., presenting a holistic view. Given that different techniques might be chosen given different regional backgrounds, the guidelines for technology acceptance will also have to be designed on regional levels.

3. Related to the previous point, there is a lack of **communication** between individuals and organisations in the carbon farming activities and carbon credit market, including scientists, digital solution developers, policymakers, and most importantly farmers.

4. Summary of recommendations

Here we present recommendations based on the key discussion points arising from Focus Group 3.2 that can be used for CREDIBLE carbon farming:

1. To propose a clear definition of proximal sensing in carbon farming to ensure consistency and comparability across initiatives.
2. To develop a roadmap for the use of proximal sensing in MRV systems, which considers regionality, transparency, accuracy, and cost-effectiveness.
3. To utilise existing digital data resources alongside new (e.g., proximal sensing) data in MRV systems.
4. To provide user-friendly guidelines for farmers to implement proximal sensing and digital solutions, considering regional variations in farmers’ technology acceptance and transformative capacity.
5. To design regional support networks, including local test sites and “farm lighthouses”, that would address barriers to technology acceptance, increase transformative capacity, and facilitate effective communication between farmers.



CREDIBLE
EU carbon farming

Funded by
the European Union