soilcquest.org.au

soilcquest 2031

RESEARCH STRATEGY

2024

Table of Contents

Foreword

This strategy has been developed through a consultative process with a program logic foundation (see Appendix). A draft was prepared internally by research and operations staff consistent with the Board's organisational strategy, which was then peer-reviewed and corroborated by our research committee. The strategy is designed to be valid for 2024-2026 and will be reviewed at the end. Three years should be considered the minimum to facilitate a field-based research requirement to collect data over multiple seasons.

Introduction

SoilCQuest 2031 Ltd is a not-for-profit, for-impact research institute. Our purpose is:

Bringing farmers and scientists together to increase soil carbon and reduce emissions for profitable and resilient farms.

Constitutional purpose

The SoilCQuest constitution provides that the Principal Purpose of the Company is to protect and enhance the natural environment, including by

- Undertaking scientific research* which is of value to Australia, in particular, sequestration of atmospheric Carbon in soil;
- Engaging (directly or indirectly) in activities that are designed to increase the amount of atmospheric Carbon stored and retained in the soil through the implementation and commercialisation of research and Australian Carbon Credit Unit (ACCU) retirement mechanisms, including mechanisms that do not involve offsetting; and
- Acting as a not-for-profit research institution.

* "any activities in the fields of natural or applied science for the extension of knowledge" (defined in section 73A of the Income Tax Assessment Act 1936).

SoilCQuest objectives

- Prioritising carbon dioxide drawdown through improvements in soil carbon, particularly by increasing the durable soil carbon pool on a large scale.
- Addressing the gap between scientific knowledge and on-farm adoption.
- Initially focusing on mixed and cropping farming systems, acknowledging significant variations in the capacity to increase soil carbon associated with differences in rainfall, geography, soil type, and farming enterprises.
- Removing barriers to adopting new, innovative practices while ensuring these practices contribute to profitable and sustainable farming businesses.
- Evaluating investments through three critical lenses: economic viability, soil carbon and emissions reduction science, and adoptability.

Key stakeholders

Our primary stakeholders in SoilCQuest are farm owners and managers. Our secondary stakeholders are agronomists and other advisers who are in close communication with farmers. Farmers possess significant knowledge of what works for their farming systems, environments, and business practices, making them invaluable contributors to research and development. Farmers play a vital role in maximising the adoption of high-impact innovations through co-design approaches that recognise their individual and collective needs. These innovations are urgently needed for the agricultural sector to both mitigate and adapt to climate change.

Research strategy aims

- To act as a guiding document to help SoilCQuest evaluate potential research projects and decide whether the proposed project aligns with our purpose.
- To create boundaries of scope for SoilCQuest research activities.
- To communicate our methodological approach which takes into account our organisational goals and acknowledges our operational and logistical limitations.

Research goals

Goal 1: Increase the adoption of scientifically validated and economically viable farming practices that build soil carbon.

We believe conducting scientifically sound research at a farm-relevant scale is crucial to encouraging more farmers to adopt new carbon-building practices. Our research aims to provide farmers with the necessary data and evidence to make informed decisions about land management that are driven to sequester soil organic carbon and reduce greenhouse gas emissions.

Objectives:

- Increase engagement activities with farmers.
- Increase agro-ecological literacy among farmers and their advisers.
- Be a trusted voice for practices that build carbon for growers.

Goal 2: Support farmer innovation, scientifically validate their practices, and promote widespread adoption.

We believe that many of the agricultural solutions needed lie latent within experiential and observational knowledge of farmers. Through applied research and development work on farms, we support them to action their observations and latent knowledge.

Objectives:

- Establish a network of Exemplar Farms to demonstrate innovative soil management techniques, validate practices through on-farm research, and showcase methods for restoring agricultural soil health and function.
- Transform research and experiential findings into educational materials to facilitate broader adoption of innovative farming practices.

Research themes

Since European settlement, soil carbon stocks have declined due to land clearing, excessive tillage, continuous cropping with limited residue return, fallowing, soil erosion, improper water management, and drought. The Australian Carbon Credit Units (ACCU) Scheme (formerly known as the Emissions Reduction Fund) now financially incentivises Australian farmers to reverse this trend. Increasing photosynthetic carbon inputs and reducing soil carbon loss are vital pathways to enhance net soil carbon stocks. SoilCQuest researches methods concerned with these pathways across broadacre agriculture, including cropping and pasture systems. The research themes outlined in this document address one or both of these soil carbon sequestration pathways.

SoilCQuest prioritises specific research themes and potential topics to advance soil carbon sequestration. These themes focus on increasing carbon inputs to soil or reducing carbon losses. Notably, the proposed topics exclude research on tillage effects and stubble return to the soil, which have already undergone extensive investigation in recent decades (Kirkegaard, 1995; Chan et al., 2003; Luo et al., 2010). Given the widespread adoption of direct drilling and reduced tillage practices in Australian cropping farms, the emphasis shifts towards finding innovative ways to enhance carbon inputs to soil or overcome existing barriers, particularly considering "no-till" as the baseline.

We have identified the following 6 themes as relevant to SoilCQuest's research scope:

Theme 1: Amelioration of under-performing soils

Address adverse soil conditions hindering carbon sequestration potential via chemical and physical interventions.

Potential topics:

- Remediation of subsoil compaction, acidity, and sodicity.
- Application of lime, compost, and gypsum to improve soil health.
- Exploration of innovative pasture renovation techniques.

Theme 2: Increase plant species diversity in cropping and pastures

Investigate the relationship between above-ground plant diversity and soil organic carbon (SOC) levels.

Potential topics:

- Establishment of multi-species pastures.
- Implementation of cover cropping and intercropping practices.
- Extending the growing season of grain crops, e.g. Long coleoptile varieties, which can be sown early season.

Theme 3: Increase the use of perennial plants in agricultural landscapes

Assess the benefits of incorporating perennial plants into agricultural landscapes for enhanced carbon sequestration.

Potential topics:

- Evaluation of various perennial systems like agroforestry, alley cropping, and saltbush.
- Assessment of perennial grain varieties for their carbon sequestration potential.

Theme 4: 'Connecting the dots' – finding efficiencies and synergies

Identify strategies to improve efficiencies within agricultural systems to enhance carbon sequestration and cost-effectiveness.

Potential topics:

- Development of holistic farm carbon planning strategies.
- Enhancement of microbial carbon use efficiency through targeted fertilisation.
- Investigation of more efficient N and P fertilisers.

Theme 5: Biomass conversion for biochar production

Explore the potential of converting excess agricultural biomass into biochar for long-term carbon storage and soil quality improvement.

Potential topics:

- Evaluation of biochar production from biomass sources.
- Integration of biochar into organic fertiliser formulations.

Theme 6: Building soil carbon via bigger root systems

Investigate the role of root systems in soil carbon storage and explore methods to enhance root growth.

Potential topics:

- Application of root stimulants during germination to promote root growth.
- Evaluation of crop varieties with enhanced root systems.
- Examination of plant diversity effects on root proliferation and SOC.
- Enhancing root growth through early sowing.

Context

Our approach acknowledges that:

- Agriculture is multidisciplinary and encompasses agronomic, economic, social, cultural, and ecological dimensions.
- Soil carbon is important for both supporting the life of the soil (i.e. C cycling) and is itself an important terrestrial C sink (i.e. C storage).
- The profitability of a given practice is a key determinant of whether it will be adopted in Australian agriculture.
- Farming systems encompass various models influenced by enterprise, environment, soil type, markets, and risk.
- Response actions entail a holistic approach encompassing mitigation and adaptation strategies tailored to address the challenges of climate change, with a specific emphasis on CO2 drawdown.

Soil carbon sequestration potential

Assuming a 10% increase in long-term vegetation cover, Gray et al. (2021) modelled and predicted that across New South Wales, we could potentially increase soil organic carbon (SOC) by 5.4 tonnes C/ha in the 0-30cm depth over 20 years (0.27 tonnes/ha/yr).

However, this potential varies significantly due to climate and soil type. Clay-rich, fertile soils with adequate moisture show greater potential (15.9 tonnes C/ha over 20 years) than sandy soils with sparse vegetation (1.6 tonnes C/ha over 20 years). Rainfall primarily drives biomass production and carbon inputs, while clay content is crucial for forming soil aggregates that protect soil carbon from microbial consumption.

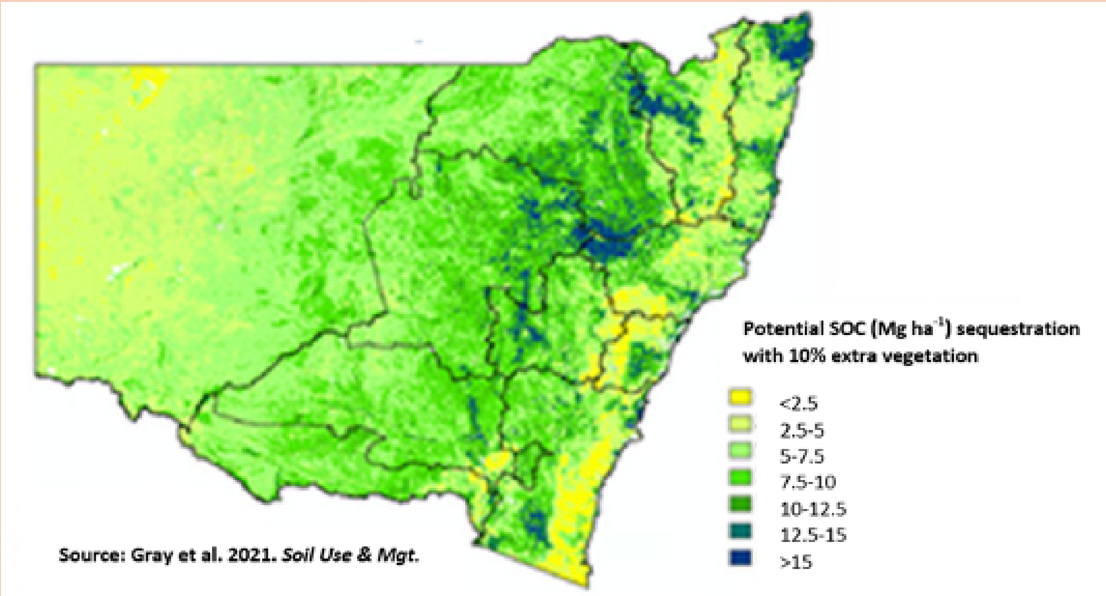


Fig. 1. Predicted SOC sequestration potential in NSW assuming a 10% increase in vegetation cover. Source: Gray et al. 2021.

The region of Central West NSW, where SoilCQuest conducts most of its research, features mainly land use types where we could anticipate an average increase of 6.9 tonnes C/ha over 20 years, or 345 kg/ha/yr (assuming a 10% increase in vegetation cover). This corresponds to approximately 1.2 ACCUs/ ha/yr, falling within the reported 1-2 ACCUs/ ha/yr from ERF soil carbon projects (Signor, 2023). A notable hotspot for soil carbon is in the southwest region of Orange, with sequestration rates exceeding 10 tonnes/ha/yr - attributed to the high fertility of mafic clays (see blue areas in Fig 2).

Soil carbon sequestration potential

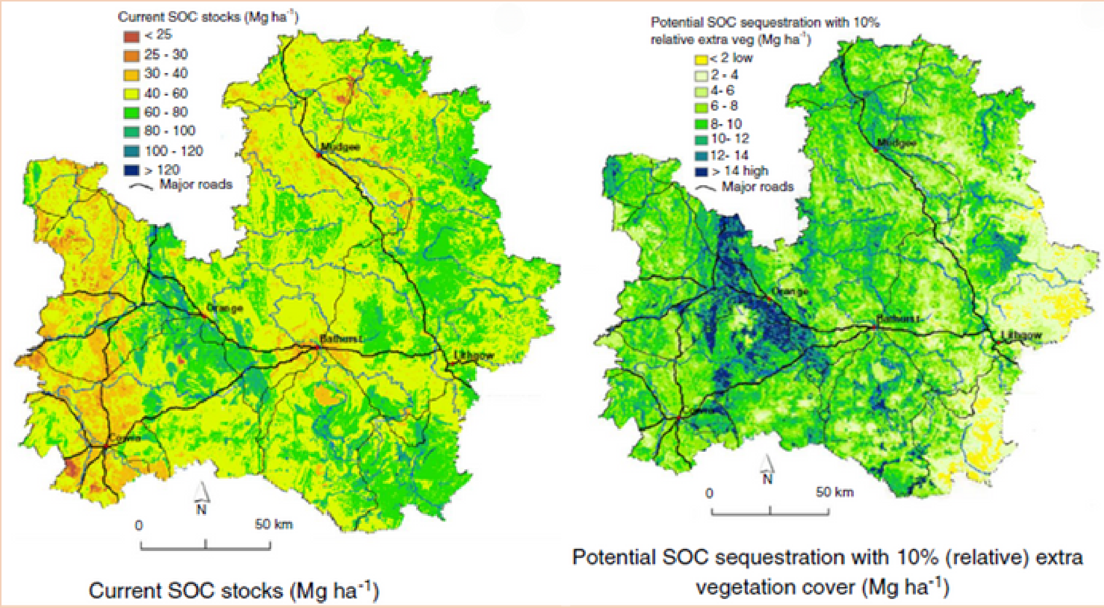


Fig 2. Current SOC stocks and SOC sequestration in Central Tablelands NRM. Source: Gray et al. 2021.

Gray et al.'s (2021) study assumes a hypothetical 10% increase in long-term vegetation cover. The authors suggest that:

'Changes in vegetation cover [by at least 10%] could be achieved through a variety of practices, including natural regeneration, tree planting, effective grazing management, feral pest control, perennial pasture establishment, crop residue management, and overcoming soil constraints to plant growth (e.g., liming to ameliorate acidic soil). It should not require additional water through irrigation to achieve the increase."

In essence, a 10% increase in vegetation cover can be achieved through various methods to increase carbon inputs to the soil.

Research approach and design

SoilCQuest is unique, working with farmers directly using co-design approaches to provide unbiased information that contextualises agricultural research within a commercial environment. Our primary objective is to address farmers' needs which guides our experimental research designs.

While we focus on practical outcomes rather than academic publications, we strive to design research projects that allow valid statistical analysis. We pursue peer-reviewed publications where results meet the requirements for scientific journals. If requirements exceed the capacity of a given project, we will publish findings in relevant trade magazines and on our website to benefit the agricultural community.

Research proposals are subject to approval by scientific experts on our Research Committee to ensure compliance with statistical standards and the generation of meaningful insights from collected data.

Finding our research niche

This involves recognising the landscape of agricultural research, which predominantly unfolds in university labs, greenhouses, and research stations, spearheaded by institutions like CSIRO and DPI across various states and university departments in Australia. These advancements contribute greatly to agriculture. However, there's a persistent gap between scientific understanding and practical agricultural implementation, particularly concerning soil degradation reversal. To narrow this divide and boost farmer uptake of improved practices, SoilCQuest champions a hands-on approach: conducting research and demonstration trials directly on farmer fields.

This applied strategy situates agricultural research within the real-world commercial environment, testing solutions on soils more representative of typical farms. Successes in these field trials are practical and inspirational, likely motivating other farmers grappling with similar challenges.

Guiding principles

The guiding principles for our research are as follows:

1. **Impactful:** Research drives meaningful change, particularly prioritising studies on farming practices that could significantly contribute to climate change mitigation/adaptation and enhance soil health if widely adopted.

2. **Collaborative:** Close collaboration with participating farmers and research partners is essential for better research and impact outcomes. On-farm experiments are co-designed by considering farmers' and research partners' interests, observations, and motivations.

3. **Resourceful:** Before initiating new research, a thorough gap analysis is conducted to understand previous research. Further research is undertaken where unique insights exist, building upon existing research and experiences. Existing initiatives, projects, networks, and funding are leveraged and contributed to maximising impact.

4. **Feasible:** The research considers the economic and logistical realities of broadacre and mixed farming. Experimental plans accommodate these realities to increase the likelihood of research adoption.

5. **Ethical:** The highest standards of professional and academic conduct are adhered to in the research. Activities deemed to violate the ethical charter by the board and research committee are refrained.

Other considerations

Logistics

Our chosen research path must align with our capacity for implementation, considering factors such as human resources, research infrastructure, and budgetary constraints. Research locations should also be accessible with minimal travel costs.

ACCU Scheme Alignment

Our aim is to encourage more farmers to participate in carbon projects as a mechanism for diversifying the income and assets of farmers. Therefore, SCQ research that is aligned with the ACCU Scheme methods is relevant. While there is a scientific foundation for the current ACCU methods, there is a need for additional research that can provide valuable verification of land management practices outcomes within a commercial farming context. Furthermore, it extends the research finding value by offering economic data, practical guidance, and real-world examples of management approaches on farms wherever possible.

The following practices are currently accepted as additional measures within an ACCU Scheme-approved soil carbon project:

- Applying nutrients to the land*
- Use of lime to remediate acid soils*
- Use of gypsum to remediate sodic or magnesic soils*
- Undertaking new irrigation
- Re-establishing or rejuvenating a pasture by seeding, establishing or pasture cropping*
- Establishing and permanently maintaining a pasture where there was previously no or limited pasture, such as on cropland or bare fallow*
- Altering the stocking rate, duration or intensity of grazing*
- Retaining stubble after a crop is harvested*
- Conversion from intensive tillage practices to reduced or no tillage practices
- Modifying the landscape or landform features to remediate the land
- Using mechanical methods to add or redistribute soil
- Using legume species in cropping or pasture systems* or
- Using a cover crop to promote soil vegetation cover, improve soil health, or both.*

*These methods and material differences associated with variable application, are considered particularly relevant to our research activities and expertise.

State-of-the-Art (SOA) research

Our research should push the boundaries of current knowledge, contributing to the advancement of methods and the trial of new practices. Alternatively, we can replicate, refine, and build upon existing SOA research in new contexts or regions to achieve impactful results. This may include exploring and supporting the development of methods not currently approved by the ACCU Scheme, such as biochar, purpose-grown bioenergy crops (e.g. hemp, miscanthus) and biofertilisers/biostimulants.

Whole-of-farm carbon planning presents a promising field of further interest, particularly in the extension and adoption of SoilCQuest research outcomes, aiming to holistically manage water, vegetation, animals, soil, and other resources to accelerate productivity increases and soil carbon sequestration.

Embracing digital and remote sensing tools

Leveraging the expanding array of data and tools enables remote research and facilitates the gathering and analysis of extensive data at reduced costs. Utilising tools such as GIS software, public databases for soil mapping, proprietary software, satellite data, weather stations, drones, and soil moisture probes enhances the efficiency and effectiveness of our research endeavours. Integrating digital technologies for the acquisition and application of historical data, progress monitoring, and research design refinement is a fundamental element of the research process.

Research methodology

SoilCQuest seeks to scale up the adoption of our findings by prioritising applied research directly on commercially viable farms rather than in controlled lab or greenhouse settings. We draw inspiration from researchers who have developed innovative methods for conducting high-quality analyses at the farm scale (Lacoste et al., 2022).

Paddock Scale Research

We see greater value in conducting farm experiments on a paddock scale rather than small plot trials to increase relevance for farmers and validate the economics of a given method. Dr Julia Easton from Curtin University compares research undertaken at paddock vs small plot scale (Table 1.).

Table 1. Comparison of Small plot trials vs paddock scale strip trials.
Source: Dr Julie Easton, Curtin University, On-Farm Experimentation project.

Small Plot Trials	Paddock Scale Strip Trials
Maximise treatment effects and interactions	Farmer driven questions, use farm equipment, cost effective
Minimise spatial/environmental variation and variability	Encompasses spatial/environmental variability and soil types
Initiated by external party, expensive, specialised equipment	Experiments integrated into commercial operation using farm equipment
Data are normally distributed	High spatial variability can create skewed results that are not normally distributed
Results difficult to translate to paddock scale	Results have more utility and relevance for farmers
ANOVA is suitable analytical approach to understand treatment effects	ANOVA is not an appropriate analytical approach for paddock scale trials

Paddock Scale Strip Trials

Conducting trials at the paddock scale yields more relevant and applicable data for farmers. Strip trials at this scale are also more cost-effective than small plot experiments, as they leverage existing farm equipment instead of relying on outside contractors who may incur significant travel expenses to maintain the field site.

Moreover, farmers are often more motivated to participate in strip trials because the results directly inform their farm management decisions. Multiple strip trials can be executed simultaneously across several farms each year, with each farm serving as a treatment replicate.

However, paddock-scale strip trials can present challenges due to the inherent variability of the land. The treatments traverse a larger and more diverse area than small plot trials, and variations in soil type across the paddock can obscure or confound treatment effects (Fig. 3).

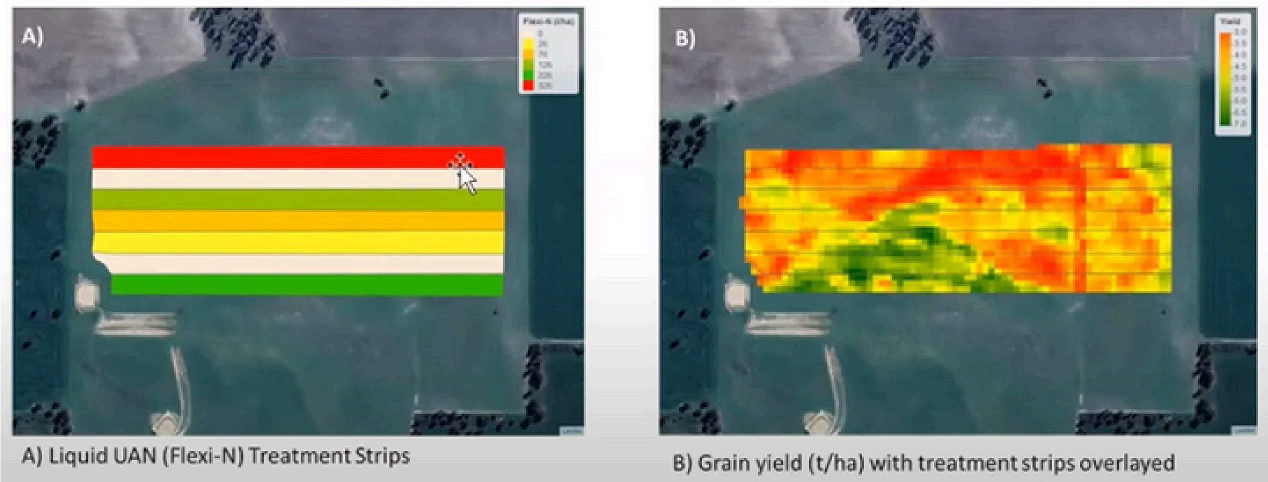


Fig. 3. Example of how strip trial treatment effects can be confounded by underlying soil variation, which affects plant yield response. Source: Dr Julia Easton, Curtin University: YouTube

Statistical analysis and data sources

To address field variation effectively, we will employ experimental designs and statistical analyses tailored to accommodate large paddocks' inherent variability. Techniques such as geographically weighted regression and linear mixed modelling of multiple pseudo environments within paddock boundaries (Evans et al., 2020; Stefanova et al., 2023) will be implemented. Assurance of appropriate statistical analysis for on-farm trials, as demonstrated by Piepo et al. (2011), will guide our approach.

We anticipate integrating yield data from harvesters with remote sensing data. Additionally, we will utilise historical farm data, legacy soil data from the field, and publicly available soil and weather data.

When header data is unavailable or inaccurate, the yield will be determined via chaser bins to establish a yield unit per strip. Experiments will be meticulously designed with multiple replicate strips across the field.

In addition to remotely derived data and digital tools, targeted soil sampling campaigns will be conducted to establish baseline soil data and assess the impact of trial treatments on soil quality, including soil biology, chemistry, and physics. Installation of on-farm weather stations and other monitoring equipment will be considered where feasible, providing critical co-variate data sources to enhance our analysis.

SoilCQuest will utilise various techniques and tools for gathering research data within a trial, depending on the research question. This may include both primary and secondary data collection. Primary data collection involves gathering data directly to answer our research question, while secondary data refers to existing data collected by researchers, agronomists, and farmers.

Need for multiple samples in time and space

Given the seasonal fluctuation of soil carbon, our focus will be on longitudinal research conducted over multiple years and across numerous farms (aiming for a minimum of 3 farms in the same region). To ensure reliable data collection, taking numerous samples within a season across multiple replicates will be necessary to capture seasonal and treatment variations effectively.

A dataset can tell a different story depending on how many samples were taken as demonstrated in Figure 4. Here we see that we might miss significant treatment trends or differences if we only take one sample during the season.

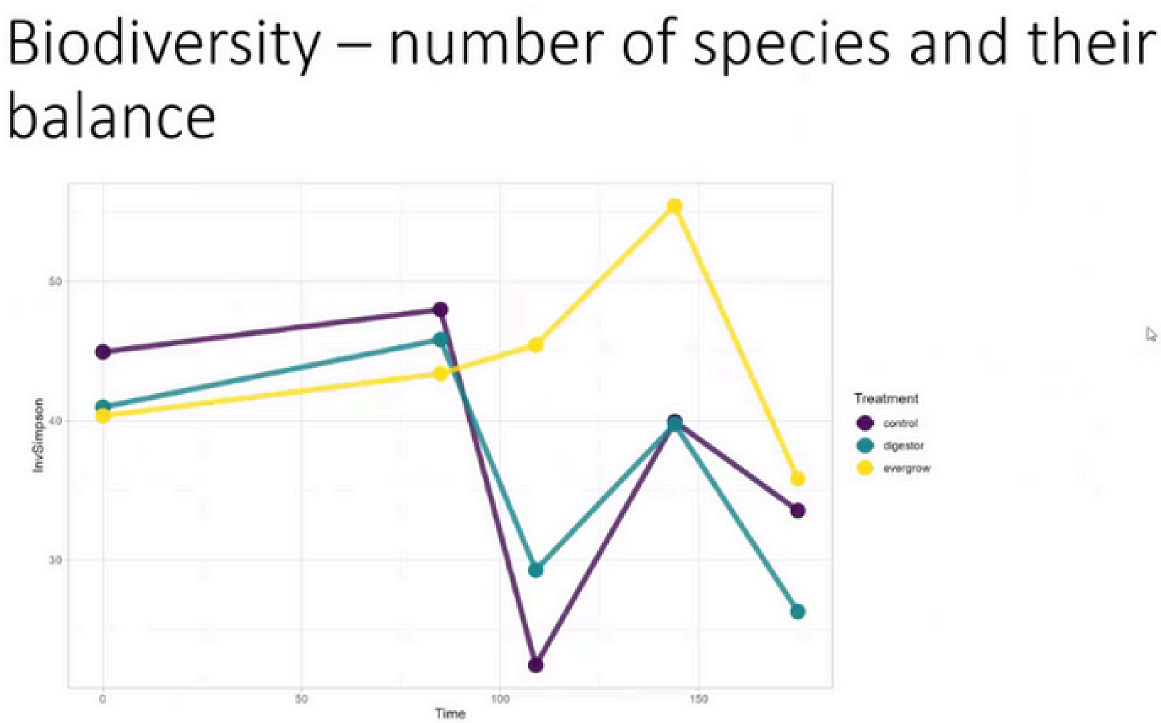


Fig. 4 Microbial Diversity at five points over 180 days. Source: Metagen Pty Ltd.

It's important to consider taking measurements before, during, and after the field season. Additional field visits may be necessary to assess crop establishment, weed, and pest pressure, which can significantly impact trial results. This approach affects the frequency of researchers' field visits and associated travel costs.

Keeping it simple

Professor Simon Cook, an expert on On-Farm Experimentation (OFE), recommends keeping trials simple and focused. Addressing too many questions in one trial can complicate things unnecessarily and reduce the number of replicates per treatment. Since we are working at the paddock scale, more replicates are needed to account for the expected variation. Having five replicates, for example, is better than three as it provides more confidence in identifying outliers. In OFE, the farmer's role is to define the research question, while the researcher's role is to provide advice and analysis to design, guide, analyse, and evaluate the experiment.

Mitigating risk in farm trials

On-farm research, where farmers conduct experiments and collect data, poses inherent risks due to factors beyond the control of SoilCQuest. There is a possibility of data loss due to human- error or miscommunication, and natural events like droughts, floods, and fires can also disrupt research progress.

Diversification is key to minimising these risks. We should strive to involve at least three farms in each research trial, spreading the risk in case of issues with one farm or farmer.

Another risk to consider is conducting trials on leased land. While we invest resources in baselining and research, there's a risk of losing access if the farmer relinquishes the land. Investing in sampling and research on land the farmer owns is preferable, ensuring a minimum 3-5 years commitment.

Ethics and standards in research

Ethical considerations are paramount in conducting and utilising research. Key issues include:

- Obtaining informed consent from participants
- Cultural sensitivity and respect
- Careful conduct of research involving vulnerable groups
- Privacy and confidentiality of data
- Proper retention and storage of data (data governance)
- Media releases; permission for audio, photographic, or video recordings in the public domain
- Accurate representation and reporting of research findings, including negative results
- Respect for intellectual property rights and acknowledgment of sources.

All researchers adhere to the National Statement on Ethical Conduct in Human Research 2007 and The Australian Code for the Responsible Conduct of Research.

References

Bektaş, H., and Waines, J. (2020). Effect of Grain Size on The Root System Architecture of Bread Wheat (Triticum aestivum L.). Türkiye Tarımsal Araştırmalar Dergisi, 7(1), 78–84. [DOI: 10.19159/tutad.668185] (https://doi.org/10.19159/tutad.668185).

Chan, K. Y., Heenan, D. P., and So, H. B. (2003). Sequestration of carbon and changes in soil quality under conservation tillage on light-textured soils in Australia: a review. Australian Journal of Experimental Agriculture, 43(4), 325–334. [DOI: 10.1071/EA02077] (https://doi.org/10.1071/EA02077).

Evans, F.H., Salas, A.R., Rakshit, S., Scanlan, C.A., Cook, S.E., (2020). Assessment of the use of geographically weighted regression to analyse large on-farm experiments and implications for practical application. Agronomy, 10. [DOI: 10.3390/agronomy10111720] (https://doi.org/10.3390/agronomy10111720).

Gray, J.M., Wang, B., Waters, C.M., Orgill, S.E., Cowie, A.L., Ng, E.L. (2021). Digital mapping of soil carbon sequestration potential with enhanced vegetation cover over New South Wales, Australia. Soil Use Management, 38:229–247. [DOI: 10.1111/sum.12766] (https://doi.org/10.1111/sum.12766).

Kirkegaard, J. A. (1995). A review of trends in wheat yield responses to conservation cropping in Australia. Australian Journal of Experimental Agriculture, 35(7), 835–848. [DOI: 10.1071/EA9950835] (https://doi.org/10.1071/EA9950835).

Kästner, M., Miltner, A., Thiele-Bruhn, S., and Liang, C. (2021). Microbial Necromass in Soils—Linking Microbes to Soil Processes and Carbon Turnover. Frontiers in Environmental Science, 9 (December), 1–18. [DOI: 10.3389/fenvs.2021.756378](https://doi.org/10.3389/fenvs.2021.756378).

Lacoste, M., Cook, S., McNee, M., Gale, D., Ingram, J., Bellon-Maurel, V., MacMillan, T., Sylvester-Bradley, R., Kindred, D., Bramley, R., Tremblay, N., Longchamps, L., Thompson, L., Ruiz, J., García, F.O., Maxwell, B., Griffin, T., Oberthür, T., Huyghe, C., Zhang, W., McNamara, J., Hall, A. (2022). On-Farm Experimentation to transform global agriculture. Nature Food. [DOI: 10.1038/s43016-021-00424-4](https://doi.org/10.1038/s43016-021-00424-4).

Luo, Z., Wang, E., and Sun, O. J. (2010). Can no-tillage stimulate carbon sequestration in agricultural soils? A meta-analysis of paired experiments. Agriculture, Ecosystems and Environment, 139(1–2), 224–231. [DOI: 10.1016/j.agee.2010.08.006](https://doi.org/10.1016/j.agee.2010.08.006).

Miltner, A., Bombach, P., Schmidt-Brücken, B., and Kästner, M. (2012). SOM genesis: Microbial biomass as a significant source. Biogeochemistry, 111(1–3), 41–55. [DOI: 10.1007/s10533-011-9658-z] (https://doi.org/10.1007/s10533-011-9658-z).

Piepho, H.P., Richter, C., Spilke, J., Hartung, K., Kunick, A., Thöle, H. (2011). Statistical aspects of on-farm experimentation. Crop and Pasture Science, 62, 721–735. [DOI: 10.1071/CP11175].

Prommer, J., Walker, T.W. N., Wanek, W., Braun, J., Zezula, D., Hu, Y., Hofhans, F., and Richter, A. (2019). Increased microbial growth, biomass, and turnover drive soil organic carbon accumulation at higher plant diversity. Global Change Biology, 2020;26:669–681. [DOI: 10.1111/gcb.14777](https://doi.org/10.1111/gcb.14777).

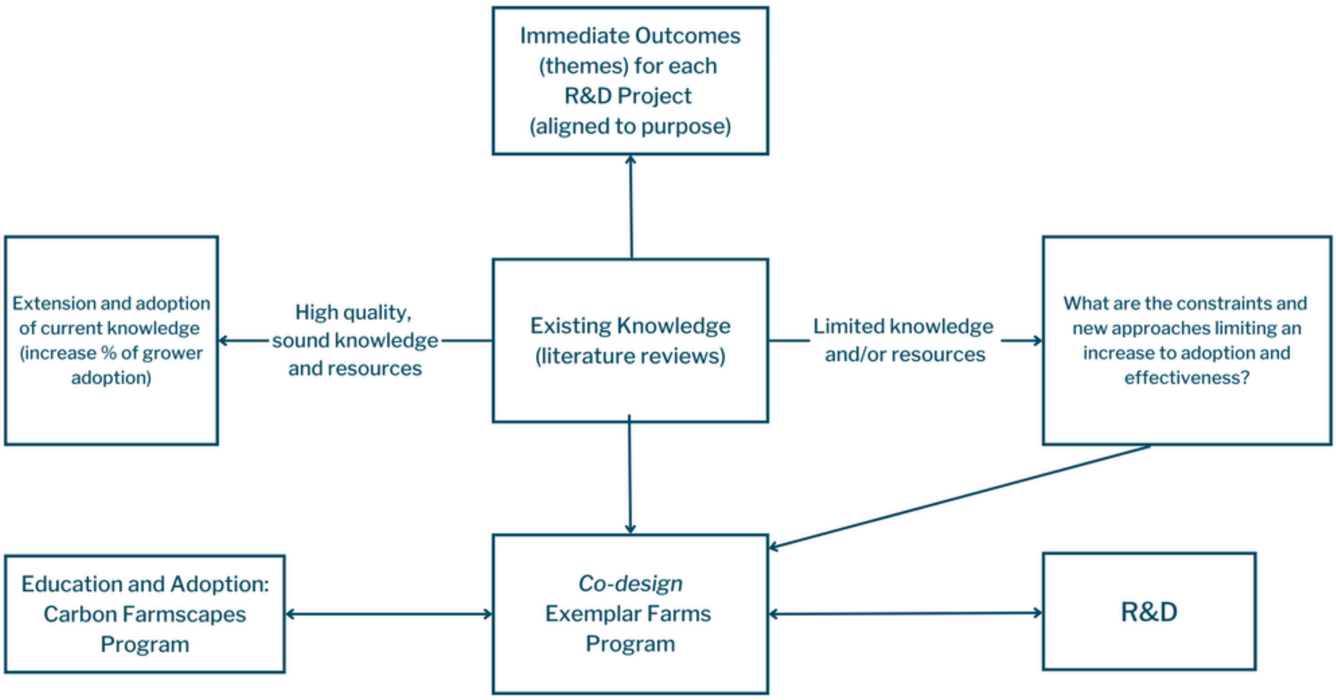
Rasse, D.P., Rumpell, C., and Dignac, M. F. (2005). Is soil carbon mostly root carbon? Mechanisms for a specific stabilisation. Plant and Soil, 269(1–2), 341–356. [DOI: 10.1007/s11104-004-0907-y] (https://doi.org/10.1007/s11104-004-0907-y).

Signor, L. (2023) Clean Energy Regulator. The Clean Energy Regulator (CER)- Emissions Reduction Fund, legislation, project registration. Presentation at the Soil Science Australia Sequestering Soil Carbon Workshop, Canberra, 13.10.2023.

Stefanova, K.T., Brown, J., Grose, A., Cao, Z., Chen, K., Gibberd, M., Rakshit, S. (2023). Statistical analysis of comparative experiments based on large strip on-farm trials. Field Crops . Research, 297, 108945. [DOI: 10.1016/j.fcr.2023.108945](https://doi.org/10.1016/j.fcr.2023.108945).

Appendix

A. Research strategy framework



Defining Outcomes

Utilise the SMART framework, ensuring objectives are Specific, Measurable, Achievable, Relevant and Time-bound while acknowledging underlying assumptions.

Purpose of Research

Assess the research's purpose and align it with

- Organisational and research strategy
- Economic feasibility and potential for adoption
- Budget constraints
- Co-dependencies within the research ecosystem.

Conduct Gap Analysis

Identify gaps in current knowledge and engagement through co-design processes. Consider:

- Motivation, including stakeholders' experiences and interests
- Knowledge gaps requiring further investigation
- Attitudes toward extension and education opportunities
- Technological requirements and availability.

Extension and Adoption Outputs

Determine tangible outputs, such as publications, technological innovations, and educational materials. Ensure alignment with the Carbon Farmscapes Program (CFP) and Exemplar Farms (EF) while validating assumptions underlying their effectiveness.

Reach and Scope

Define the research project's target audience, geographical reach, timing, and scale. Consider:

- Who will benefit from the research outcomes?
- Where will the research be conducted?
- When will the research take place?
- Scope and size of the project, including the number of participants or farms involved.

Apply the principles of program logic

- Participation: Involve stakeholders in developing program logic.
- Clear understanding: Ensure agreement on desired changes and the program's contribution to sustainability.
- Vision focus: Emphasise aspirations and visions over problem statements.
- Asset perspective: Consider assets to conceptualise necessary changes.
- Outcome clarity: Define immediate and intermediate outcomes to inform program strategies.
- External context analysis: Assess external conditions critical for program success.
- Address uncertainty: Explicitly state areas of uncertainty in the program logic.
- Assumption management: Tackle assumptions during evaluation processes and update program logic accordingly to enhance its value.

Apply the principles of program logic

- Participation: Involve stakeholders in developing program logic.
- Clear understanding: Ensure agreement on desired changes and the program's contribution to sustainability.
- Vision focus: Emphasise aspirations and visions over problem statements.
- Asset perspective: Consider assets to conceptualise necessary changes.
- Outcome clarity: Define immediate and intermediate outcomes to inform program strategies.
- External context analysis: Assess external conditions critical for program success.
- Address uncertainty: Explicitly state areas of uncertainty in the program logic.
- Assumption management: Tackle assumptions during evaluation processes and update program logic accordingly to enhance its value.

Key criteria to be addressed in the research proposed and undertaken

1. Outcomes: The desired practice change and the program's consequent impact on the intended stakeholders aligned to the organisation's PURPOSE.

2. Intermediate outcomes: Split higher-level outcomes into more manageable individual aspects that could be aligned with different stakeholders and/or constraints identified during gap analysis.

3. Gap Analysis: This should be developed to suit SoilCQuest's purpose. It already encompasses a literature review but could utilise stakeholder feedback to identify constraints and opportunities to practice change. Identifying gaps in knowledge, attitude, and skill is consistent with Bennett's original approach to practice change, but the inclusion of technology gaps should also be considered.

4. Assumptions linking the gap analysis with desired changes in practice: Ultimately, the delivery of an outcome should be documented and regularly reviewed. At each step, assumptions are required to underpin the thinking that links why a particular activity is needed and how the outputs are envisaged to impact practice change and the desired outcome to deliver on purpose. Being agile to promote pivoting as results are generated and new understanding evolves impacts the assumptions made.

5. Outputs: The most straightforward way to interpret an output is the desired result of an investment that addresses one or more of the gaps identified in delivering practice change. It may be a physical asset (e.g., the availability of new technology to apply compost) or targeted at behavioural change (e.g., the provision of education programs on soil C sequestration).

6. Activities: Describe the use of resources to undertake activities that realise outputs and outcomes.

7. Monitoring, evaluation, review and improvement activities

B. Research Proposal Process

The organisation's research proposal process, approved by the Board, follows these steps:

1. Submit a concise one-page overview of the proposed research to the Board.
2. Evaluation of the proposal by the Board in alignment with the organisational strategy. The Board may endorse its submission to the Research Committee, request revisions, or halt further progress.
3. If approved, a full co-design proposal applying program logic principles is submitted to the Research Committee for thorough review according to its terms of reference and per the research strategy.

The Research Committee and Board's protocol for refining the research strategy include:

- Evaluating the number of potential research themes, aiming for fewer well-resourced themes to maximise impact.
- Advancing the development of SMART outcomes for each theme, incorporating assumptions regarding the number of farmers expected to change practices and the potential impact on CO_2 drawdown.
- Conducting a more structured gap analysis based on Knowledge, Attitudes, Skills, and Actions (KASA) principles.
- Allocating investments and activities to address identified constraints and opportunities, ensuring alignment with organisational processes, procedures, and regulatory requirements.
- Assessing investment opportunities for driving innovation from the ground up using a Program Logic framework.
- Alignment of the investment with SoilCQuest's purpose and objectives.
- Clarity in articulating the desired practice change.
- Support from the gap analysis for the identified investment.
- Documentation and testing of associated assumptions.