# Final report

## CSP – Data platform for increasing soil carbon in Australian agricultural systems

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# Abstract

This project aims to dramatically improve the financial returns of soil carbon projects for producers by significantly reducing the cost and increasing the accuracy of soil carbon quantification. This will result in a higher and more timely production of Australian Carbon Credit Units (ACCUs) at a lower cost which will markedly increase the financial returns of soil carbon projects for producers. Achieving this will unlock large areas of additional land for soil carbon projects for the betterment of land productivity and decarbonisation.

# Executive summary


## Background

Increasing soil organic carbon levels in pastures increases pasture productivity and resilience, and also provides an additional revenue stream to red meat producers by monetising the drawdown of carbon from the atmosphere and storing it in their soils.

To date, the significant barriers of high cost and low accuracy driven by the sub-optimal soil coring approach to soil carbon measurement have prevented many producers from monetising soil carbon increases. A better way to quantify soil carbon changes to overcome these barriers was needed.

## Objectives

This project aims to improve the financial returns of soil carbon projects for producers by significantly reducing the cost and increasing the accuracy of soil carbon quantification. This will result in a higher and more timely production of ACCUs at a lower cost which will dramatically increase the financial returns of soil carbon projects for producers.

The project also aims to have its approach approved by the Clean Energy Regulator (CER) to ensure the benefits of the technology produced flow through to producers via ACCUs.

## Methodology

The techniques to be used in this project combine proven soil carbon modelling with frequent data inputs from multiple sources combined with sensitive and accurate carbon measurement devices called eddy co-variance flux towers (flux towers). When combined with soil carbon models, the flux towers can detect much smaller changes in soil carbon levels through atmospheric detection of "carbon fluxes" without the cost of invasive soil testing and laboratory analysis. The flux towers are used to calibrate the soil carbon model as well as verify it is accurately tracking the actual soil carbon levels in the soil.

The project has successfully developed a toolkit that involves a model and flux tower calibrations, combined with other data inputs, to successfully quantify changes in soil carbon on producers' properties. The toolkit has been branded "Agrimix Flux" and is being readied for commercial launch into the marketplace.

The CER implemented a "measure-model" ruling in its soil carbon method (Schedule 2) which enables this new approach; ,however there are opportunities to improve this method and Agrimix's submission to the CER for this improvement has been well received with a commitment for future support. In addition, the CER announced a review of the current soil carbon method for which this approach is well placed.

## Benefits to industry

The development of Agrimix Flux means that the traditional barriers of higher cost and lower accuracy are able to be overcome leading to more attractive soil carbon project outcomes for producers. This will mean more soil carbon projects and increased efforts to sequester more soil carbon with the resulting pasture productivity and commercial benefits to producers. Agrimix Flux can also measure drivers of productivity which enhance the producer's information availability for better decision-making and profitability.

## Future research and recommendations

Agrimix Flux development now needs to focus on the commercial application in all geographies and pasture regions. It's development to date has focussed on Queensland and NSW but it is beneficial to all producers both in Australia and beyond.

It is recommended that the 'blind validation' performed by QUT, comparing the Agrimix Flux model to historical soil cores sourced from the NSW DPI, as reported in the MLA Integrated Management Systems (IMS) report, be submitted to a scientific journal for peer review and publication – this will give the market confidence in the scalability and applicability of the Brigalow-calibrated model more generally.

The Agrimix approach prioritises investigations of SOC change over time in response to management. Future studies should look to include calibrations of additional practice changes into the model to broaden its application and use across more CER-approved eligible activities for building soil carbon in a CER soil carbon project, for example rotational grazing and planting of Leucaena.

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# 1. Project objectives

This project aims to improve the financial returns of soil carbon projects for producers by significantly reducing the cost and increasing the accuracy of soil carbon quantification. This will result in a higher and more timely production of ACCUs at a lower cost which will dramatically increase the financial returns of soil carbon projects for producers.

Objectives of the project include:

a) Improve the accuracy of prediction of ACCU generation per project to enable the optimisation of land management practice changes to achieve a soil carbon project's maximum financial outcome. At present there is no model-based approach to forecast specific soil carbon sequestration in a specific location for particular management practice changes, meaning current forecasts are very rudimentary and inaccurate. The MMV model is expected to forecast to an accuracy of +/- 20% for like management practice changes. This predictive capability will be one of the features of the product released at the end of the product development stage which is anticipated to be by February 2025.

b) Significantly reduce the ACCU discount as compared to the current CER soil carbon measurement method through the recognition of higher soil carbon quantification accuracy in a new CER approved soil carbon method using the MMV approach. The current soil carbon measurement approach includes a 50% discount in the recognised soil carbon levels recorded from soil testing. The MMV approach aims to reduce this discount to less than 20% through the CER method by February 2025.

c) Reduce the cost for registered CER soil carbon projects to use this new method and associated tools in line with the Australian Government's $3 per hectare per year stretch target. The current cost to conduct soil testing is in the order of $25 per hectare.

d) Enable an annual ACCU recognition so that carbon project owners can achieve an annual payment for any ACCUs achieved. Currently soil carbon projects are typically measured every 3-5 years due to the time taken to build soil carbon to a statistically significant increase able to be detected using soil testing techniques. The annual ACCU recognition will be part of the CER method approval that Agrimix will aim to achieve before February 2025

In terms of specific products to be developed by the project, the overarching objective was to achieve a CER approved soil carbon quantification toolkit including a Graphical User Interface (GUI) which producers and their carbon developers can use to manage their soil carbon projects from inception to ACCU realisation for the full life of the soil carbon project.

Specifically the project will deliver the following products:

a) A network of high-resolution datasets of soil and plant carbon dynamics in response to innovative management practices across multiple climates and soil types to underpin the calibration of soil C models.

b) A measure-model-verify (MMV) platform with validated models capable of predicting soil carbon change in response to innovative management which can be applied to specific C estimation areas to accurately quantify and verify soil carbon change.

c) Appropriate submission for publication of scientific papers outlining the MMV approach for predicting soil carbon change.

d) A CER approved soil carbon method using the MMV platform which conforms to the CER guidelines.

e) A user interface that will enable producers and carbon developers to use the MMV platform to plan and manage their carbon projects. Communications material will be developed in accordance with MLA communications guidelines.

f) The support and process established to continue to develop datasets for further management practice changes

## 2. Methodology

Full GHG budget (or Global Warming Potential assessment) is required to underpin the development of an official soil C offset methodology based on the incorporation of new management practices and technologies (e.g. integration of Desmanthus in broad acre pastoral systems of northern Australia, cell grazing, application of soil nutrition, etc.).

Establishing the C offset benefit also requires direct comparisons between existing farming systems (Business as Usual - BAU) and those including the new practices, in terms of both establishment and on-going maintenance of these agricultural systems.

The following research and development (R&D) activities involve the necessary comparisons of BAU and new practices. The activities are proposed over multiple years across different soil types and climate regimes to provide the necessary variability and diversity in climate, soil and plant productivity for robust calibration and validation of the underpinning models. Some of the measurements in this Module include:

a) High temporal resolution $CO_2$, $N_2O$ and $CH_4$ emissions from soils (two years minimum).
b) Quantification of changes in above and below ground plant biomass for soil C and GHG modelling (three years minimum).
c) High temporal resolution measurements of net carbon exchange with respect to changes in plant biomass (above and belowground) and soil C (including practice establishment phase) for calibration of soil C models (three years minimum).
d) Soil C sampling of existing sites with diverse climate and soil locations with known history of new practice and BAU (for validation of soil C models) (two years minimum).
e) Calibration and validation of soil C models to determine soil C sequestration rates and GHG emissions (three years minimum).

From a commercial perspective, at present the financial risk-return trade-off for soil carbon projects is problematic and presents a significant barrier to the large-scale adoption of these projects. The major contributors to this problematic financial risk-return trade-off include:

a) The large initial financial outlay required to establish a soil carbon baseline (typically more than $20 per hectare).
b) The large cost to measure actual soil carbon accumulation to be able to realise ACCUs (typically more than $20 per hectare).
c) The financial impracticality of annual measuring resulting in significant elapsed time between ACCU revenue generation events (typically 3-5 years).
d) The large uncertainty in the current measurement method, which significantly discounts the measured soil carbon conversion into ACCUs and/or may result in the incorrect recognition of ACCUs in a soil carbon project.
e) The inability to accurately predict how soil carbon (and therefore ACCUs) will accumulate in specific project locations resulting in the inability to forecast financial returns with reasonable certainty.

Improving the financial risk-return trade-off will require a resolution of these key issues in the development of a valid soil C offset methodology for agricultural systems of Australia. To develop such a method requires a “Measure Model Verify (MMV)” approach.

The development of the MMV approach is achieved through the following method and materials.

Measurement includes direct observations of changes in soil C (and surrogate $CO_2$ data) and GHG emissions in both BAU and new practices. Modelling allows extrapolation of the impact of these practices and their relationship to BAU in both time and space. Verifying the accuracy of the model is essential for Measurement, Reporting and Verification (MRV) and auditing.

The MMV system is operationalised using a Geographic Information System (GIS) using climate and soil data layers combined with remoted sensed and modelled plant biomass information.

Extension pathway

The target market is all producers with clay based soils and a rainfall greater than 500mm per year. This is the market segment that has the greatest potential to build significant soil carbon and is estimated to be greater than 50m hectares in Queensland and NSW

# 3. Results

The project achieved the following key deliverables:

- Provision of an extensive body of research and a proof of concept for the MMVT approach using Eddy covariance flux towers and biogeochemical process model DayCent CABBI to quantify and predict soil carbon changes
- Delivery of a model-based approach to forecasting specific soil carbon sequestration on in a specific location for a particular management practice change, with a calibrated, validated soil carbon model now available for use by Australian landholders and producers
    - Over a 2-4 year period at a depth of 0-30 cms there was good agreement between simulated and observed SOC stocks across Agrimix and MLA's 7 research sites (see Figure 8). Analysis conducted returned the following outcomes:
        - **RMSE** = 2.8 tonnes of SOC per hectare
        - **nRMSE** = 7.4%
- The model enables annual estimation of ACCUs and because it can identify project additionality the risk of over-crediting is low. Annual crediting is a key improvement as it enables better cashflow (see Figure 1)
- This body of research has been communicated to Regulators and Agrimix is actively engaging on incorporating the advancements into the current Soil Carbon Method so that landholders can make full use of the measure-model-verify approach developed by Agrimix and QUT. This includes inclusion of eddy covariance measurement techniques as a verification tool in Schedule 2 of the 2021 Soil Carbon method (in addition to soil sampling), and reduced ACCU discounts due to the increased accuracy of the approach.
- Whilst research is ongoing, the ACCU discount on projects using the Agrimix Flux approach looks to be in the order of 20%, marking a significant reduction in ACCU discounts as compared to the Schedule 1 Measure-only approach with discounts of ~50%.
- This project aimed to reduce the cost per registered ERF soil carbon projects in line with the Australian Government's $3 per hectare per year stretch target. The Emissions Reduction Assurance Committee (ERAC) is currently undertaking a review of the soil carbon method for attaining ACCUs. If this review adopts Agrimix' recommendations, it will pave the way for model-based quantification of soil carbon estimates. It is noted however that one of the key costs for landholders is the baseline soil coring and it is expected that this requirement will be retained in the method at this stage for both Schedules 1 and 2 of the method.

  Whilst the cost of soil carbon quantification has been reduced by the Agrimix Flux approach, the current rules for a registered CER soil carbon project limit the cost savings that can be achieved. To reach the full potential of the toolkit, a model-based approach is advocated whereby no baseline soil coring is required (this approach is taken in the US).

The project has achieved its Product Objectives, a summary of these are provided in Table 1.

**Table 1: Product Objectives and Outcomes Summary**

| Product objective | Outcomes delivered |
|---|---|
| A network of high-resolution datasets of soil and plant carbon dynamics in response to innovative management practices across multiple climates and soil types to underpin the calibration of soil C models. | • The required data has been collected from 15 sites across Qld and NSW<br>• The soil C model has been successfully calibrated for the Brigalow bioregion and specific properties<br>• It has also been proven in a new bioregion in NSW |
| A measure-model-verify (MMV) platform with validated models capable of predicting soil carbon change in response to innovative management which can be applied to specific C estimation areas to accurately quantify and verify soil carbon change. | • The platform has been created to enable the model to be hosted and soil carbon projects to be initiated and managed<br>• The outcomes have been peer reviewed and published |
| Appropriate submission for publication of scientific papers outlining the MMV approach for predicting soil carbon change. | • The major paper detailing the approach has been published in the Soil Society of America journal<br>• Two further papers have been submitted to journals for publication |
| A CER approved soil carbon method using the MMV platform which conforms to the CER guidelines. | • The approach complies with the CER soil carbon method (Schedule 2)<br>• There are opportunities to improve the method to incorporate flux towers and other features and a submission was made and well received by the CERfor this. A second submission was provided to ERACfor their review into the soil carbon method which is currently underway |
| A user interface that will enable producers and carbon developers to use the MMV platform directly to plan and manage their carbon projects. Communications material will be developed in accordance with MLA communications guidelines. | • A platform with appropriate user interface has been developed which enables carbon projects to be managed via this platform |

## Overview of the Agrimix Flux Approach

An overview of the Agrimix Flux approach is provided below.

*The Scientific Foundation of the Agrimix Flux Approach*

While much of the research and commercial focus on SOC to date has centred on the spatial mapping of SOC, Agrimix has taken a fundamentally different approach. This approach prioritises a more critical and practical question: how does SOC change over time in response to management, and how can this change be accurately and cost-effectively quantified?

Addressing this question requires more than a snapshot of where carbon is located; it demands a dynamic understanding of how carbon moves through the system over time, and a scientifically robust framework for monitoring, reporting, and verifying those changes. To achieve this, Agrimix and QUT have developed a method that integrates two key components:

(1) a fully calibrated and validated biogeochemical model tailored to Australian conditions, and

(2) direct measurement of carbon fluxes using EC flux to verify model performance.

Calibrating process-based models for SOC cycling in Australia presents a unique challenge, primarily due to the limited availability of long-term SOC datasets. Only a small number of sites have soil coring records extending over 20 years, constraining the ability of traditional model calibration methods. To overcome this limitation, Agrimix and QUT enhanced the calibration process by combining available long-term soil data with high-frequency EC flux measurements (with an average duration of 2 years at each site).

The integration of **Eddy Covariance Flux Towers** is key to the superiority of Agrimix Flux's accuracy and performance, in summary they:

- Are **automated instruments** that sit in a paddock continuously taking **measurements of high-resolution $CO_2$, water and energy (radiation) fluxes** – all the elements of photosynthesis.
- 20-Hz (i.e., 20 times per second) flux measurements are processed into 30-min covariances, with post-processing conducted using **established standardised protocols**
- Enable the measurement of changes in carbon sequestration in real time **allowing drivers of change to be understood in months as opposed to 5+ years using soil coring**
- **Enable measurement to occur over large areas** to reduce spatial variability issues (20-50Ha)
- **Overcome high soil carbon variability** across paddocks - the primary barrier to soil carbon quantification using soil coring

**Agrimix/QUT accelerated the model calibration using Eddy Covariance (EC) flux data:** As seen in Figure 1, data on both short to medium-term processes and long-term carbon sequestration potential were collected. Flux data capture from 15 sites combined with paired paddock soil coring from 20 sites have enabled the sufficient collection of high quality data to calibrate and validate the soil carbon model. Note that time-controlled grazing datasets were collected by QUT under MLA Project P.PSH.2104.

Building Agrimix Flux has involved model selection, calibration and validation of soil carbon and GHGs, verification of change with integrated soil sampling, flux towers and remote sensing (see Figure 2).

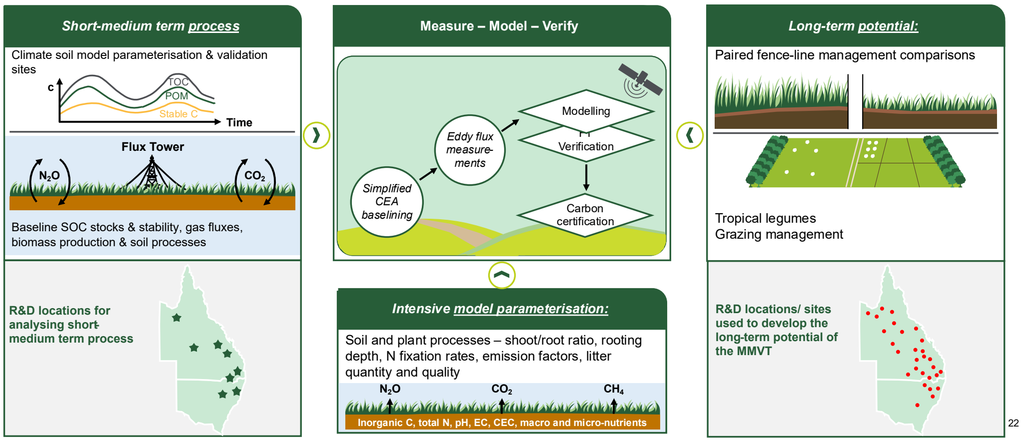



*Figure 1: Overview of the data collection to enable the creation of the Agrimix Flux toolkit*

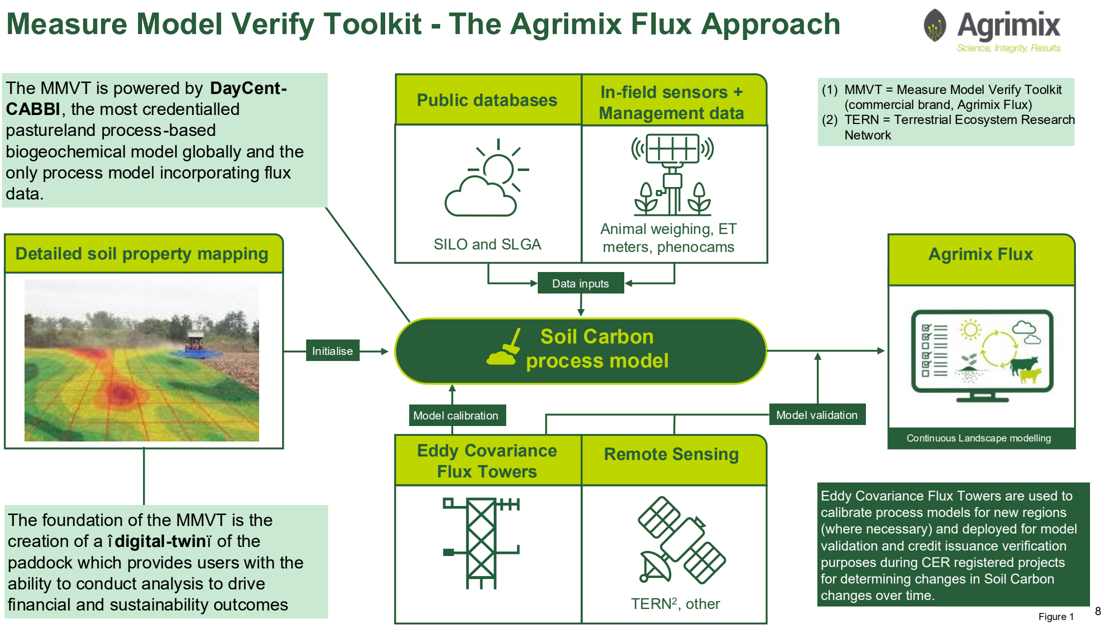



*Figure 2: Measure Model Verify Toolkit – The Agrimix Flux Approach*

Agrimix/QUT “supercharged” the calibration of biogeochemical process model DayCent-CABBI using high-resolution EC Flux Tower data, thereby addressing the scarcity of soil organic carbon datasets in Australia. This has resulted in the most robust model for Australian grazing systems, validated in both the calibration region (Brigalow bioregion) and in independent, unseen area (South Western Slopes NSW bioregion) (RMSE <10%). The calibrated model can now be reliably used to understand the drivers of SOC change, enabling clear differentiation between the effects of climate variability and those of project activities – a fundamental requirement for robust carbon accounting.

**Extrapolation of Measurements to Project Area**

EC flux towers provide high-frequency, integrated measurements of carbon and water fluxes for a specific area (typically 20-50 hectares); however, they do not directly cover the entire project area, which may span thousands of hectares.

To extrapolate these measurements across the broader project area, a calibrated biogeochemical process model is used as a scaling tool. This model, informed by EC flux data and site-specific characteristics for each stratum in a carbon estimation area (CEA), simulates key ecosystem processes over space and time. The result is a robust, project-wide estimate of soil carbon change that retains the scientific rigour of direct flux measurement while enabling cost-effective, large-scale application.

*Demonstrating the scientific basis for the Agrimix Flux approach*

To establish the credibility and robustness of the Agrimix Flux approach, it is essential to demonstrate strong alignment across three key components: EC flux measurements, soil coring data, and process-based model outputs. Each plays a distinct role in the methodology, and their coherence is critical for regulatory assurance, scientific integrity, and market confidence.

First, we must show that EC flux measurements and traditional soil coring produce consistent estimates of SOC change within the same area. This alignment is vital to give the CER confidence that the new approach yields results comparable to the established method.

Second, we must demonstrate that EC flux data can be used to validate the outputs of the process-based model (DayCent-CABBI). This is the cornerstone for scaling up: by proving that the model accurately reflects measured fluxes at the tower footprint, we can justify its application across the broader project area with confidence.

Finally, we need to establish that modelled outputs align with independent soil coring data. This reassures the regulator that the model is functioning as expected, not just under calibration conditions but also in 'unseen' applications.

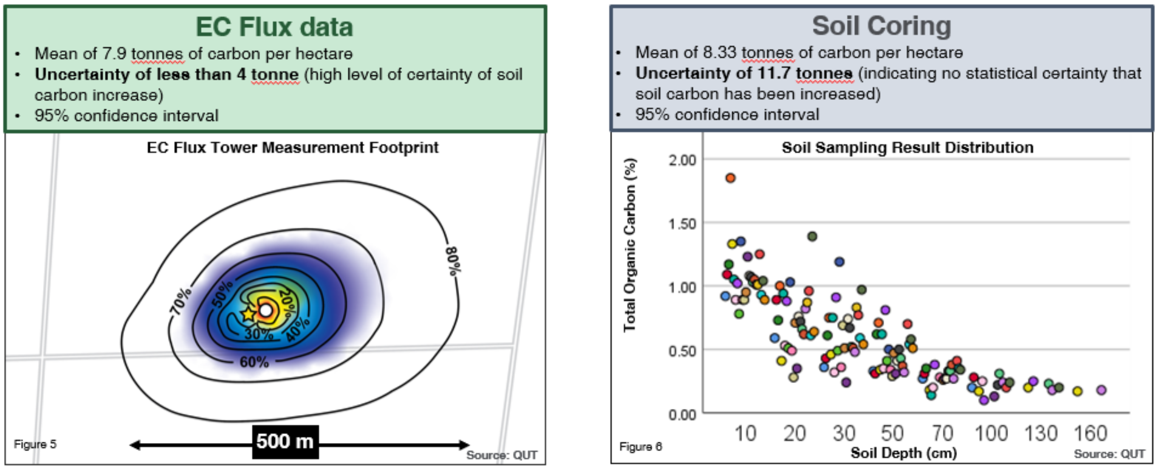
Together, these three points of alignment (between EC flux and soil coring, EC flux and modelled outputs, and modelled outputs and soil coring) form the scientific foundation of the Agrimix Flux approach and underpin the rationale for its inclusion under the Soil Carbon Method 2021.

1. **Alignment between soil coring and EC flux tower measurements.**

SOC change has been measured by QUT using both soil coring and EC flux on the same site (see Grace, 2024). EC flux data were collected continuously over a 2.5-year period, while soil cores were taken at the start and the end of this period. Both methods reported similar SOC gains of approximately 8 t C/Ha.

The associated levels of uncertainty, however, differed markedly: the uncertainty around the soil sampling estimate was ±11 t C/Ha (see Figure 3), compared to ±4 t C/ha for the EC flux method (95% confidence interval) (see Figure 4).

This means that, based on soil sampling alone, the confidence interval includes zero, and as such, we cannot state with statistical confidence that a true increase in SOC occurred. In contrast, the EC-based estimate shows a statistically significant increase in SOC over the same period.




*Figures 3 and 4: Measurement uncertainty of EC flux data versus soil coring*

2. **Alignment of EC flux with SOC models**

EC flux measurements of NEE and AET have been compared with DayCent-CABBI modelled NEE and AET outputs across multiple sites. Figure 5 shows a comparison of DayCent-CABBI modelled NEE and AET before and after calibration with EC flux measurements, showing the calibrated model performance is better.

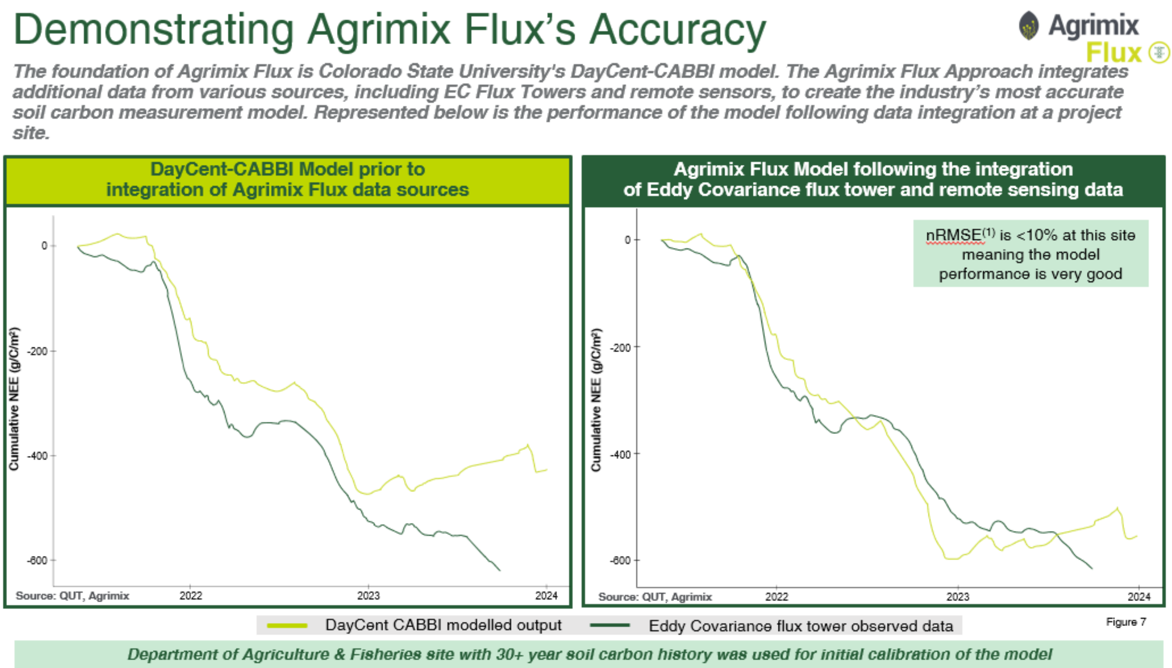



*Figure 5: DayCent-CABBI Model outputs compared to EC Flux data, before and after model calibration*

Figure 6 highlights three sites where the agreement between EC flux measurements and modelled NEE was strong, with a normalised root mean square error (nRMSE) of less than 10% for NEE. A low nRMSE (<10%) indicates a high level of agreement between the modelled and measured data, demonstrating that the calibrated DayCent-CABBI model is accurately capturing ecosystem dynamics.

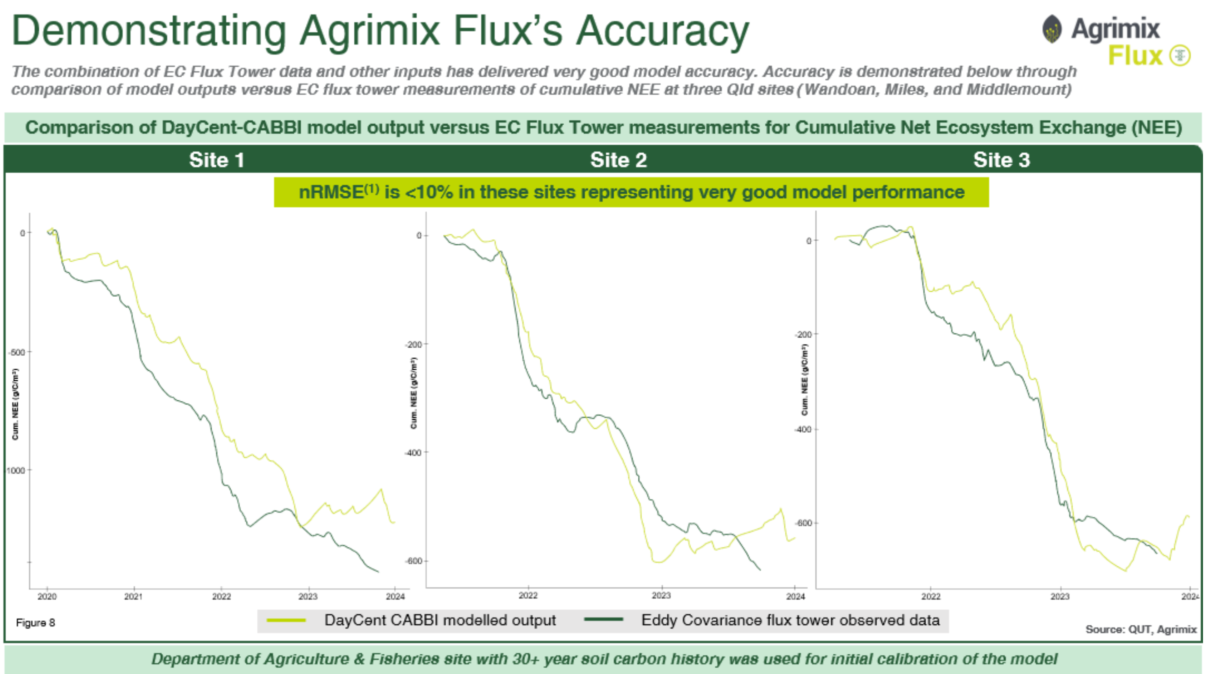



Figure 6. Comparison of modelled DayCent outputs and Eddy covariance flux observed data at three Queensland sites.

3. **Alignment of DayCent-CABBI model with soil coring measurements**

The accuracy of modelled soil organic carbon (SOC) has been validated across multiple sites and timeframes. This section presents a comparison between modelled SOC outputs and measured SOC from soil coring, demonstrating strong alignment in two key contexts:

(a) sites within the model's calibration zone, specifically the Brigalow Bioregion (see Takeda et al., 2025 for methodology and results and Figure 7 below); and

(b) independent, 'unseen' sites outside the calibration region, including 11 farms in South Western Slopes NSW bioregion participating in the NSW DPI CAMBI project (Figure 8) (see Badgery et al., 2020 for site details). This validation analysis was funded by a separate MLA Project, Project Code P.PSH.1333 and results were published in the Final Report which has been made available online.

These results underscore the model's robustness and its ability to generalise across a range of landscapes and production systems.

The strong performance at independent validation sites is particularly significant, as it indicates the model has not been overfitted or hyper-calibrated to a narrow set of conditions—an issue that often limits model transferability.

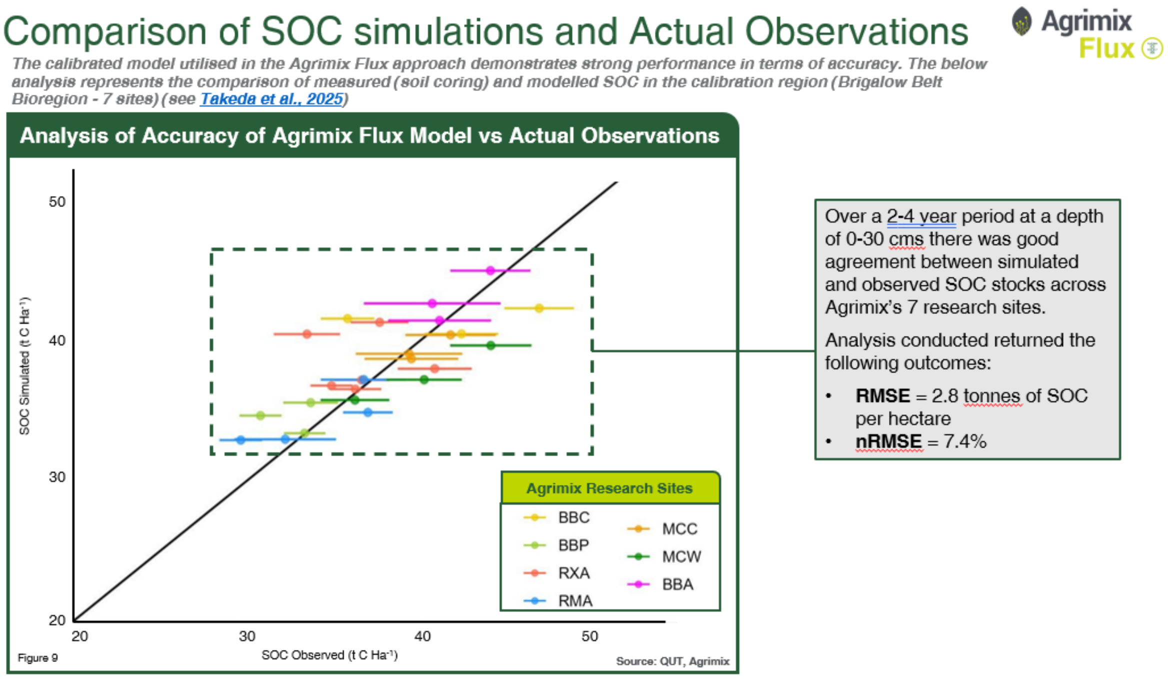



Figure 7: A comparison of measured and modelled SOC In the calibration region (Brigalow Bioregion) (7 sites – Agrimix and MLA sites) (see Takeda et al., 2025).

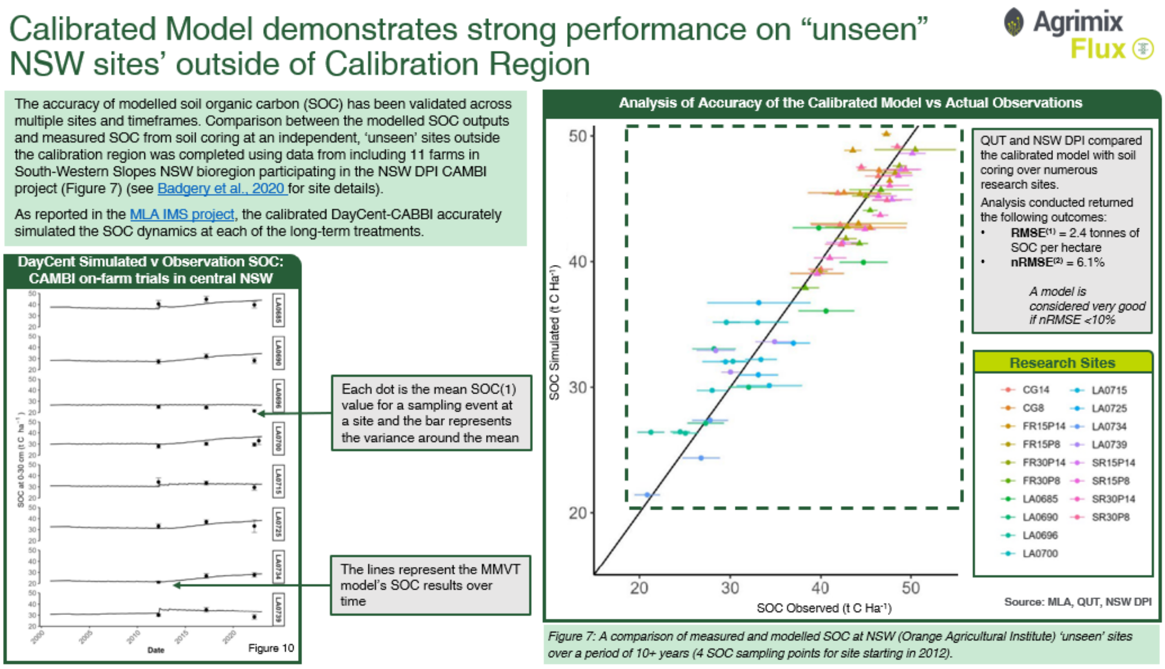



Figure 8: provides a time-series comparison of measured and modelled SOC over a period exceeding 10 years, visually reinforcing the close agreement between observed and simulated outcomes across long-term monitoring. Validation of the model performance in NSW sites, analysis performed by QUT and funded under the MLA Integrated Management Systems project (P.PSH.1333). Eckhard, R., Grace, P., Badgery W. (2025). Delivering Integrated Management System (IMS) options for CN30.

Meat & Livestock Australia, Project Code P.PSH.1333, Retrieved February 28, 2025, from https://www.mla.com.au/research-and-development/reports/2025/p.psh.1333---cn30-integrated-management-systems/

As reported in the MLA IMS Project report, DayCent-CABBI accurate simulated the SOC dynamics at each of the long term sites.

The Agrimix Flux model has the capability to simulate outputs, including SOC for pasture options. Figure 9 is an example of scenario analysis that compares the SOC of Buffel and Desmanthus Legumes using long term weather patterns over a 25 year period, aligned to an ACCU project.

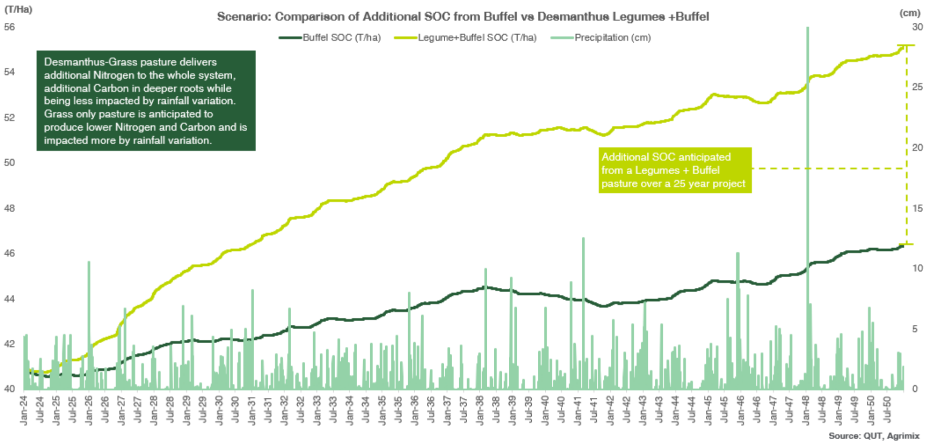



*Figure 9: Example Scenario Analysis – SOC from Buffel versus Desmanthus + Buffel*

Figure 10 is an example of scenario analysis conducted that compares the above ground biomass of Buffel and Desmanthus Legumes using long term weather patterns over a 25 year period, aligned to an ACCU project.

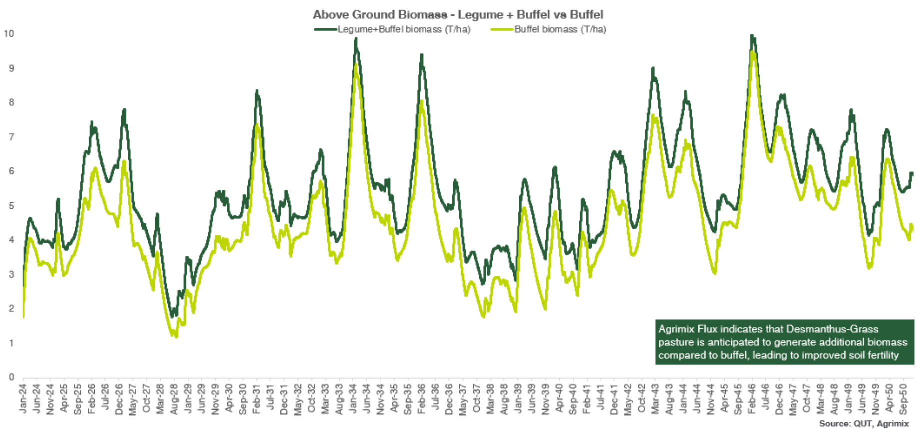



*Figure 10: Example scenario analysis – above ground biomass for Buffel versus Desmanthus + Buffel*

In summary, the benefits of the Agrimix Flux approach have been clearly proven against soil coring from both a cost and accuracy perspective, as shown in the Table 2. Agrimix and QUT have developed the only flux tower powered MMVT capable of certified soil carbon quantification for both offsets (ACCUs) and inset methods.

**Table 2: Benefits of Agrimix Flux over soil coring**

| **Soil Coring**<br>***The current approach to quantifying soil carbon change is compromised in many aspects:*** | **Agrimix Flux**<br>***Agrimix's measure model verify approach overcomes these compromises, accelerating soil carbon sequestration opportunities:*** |
|---|---|
| High upfront baseline and ongoing measurement costs – often makes a project unviable for a farmer, particularly in lower carbon sequestration areas | Costs are lower and smoothed out through the life of the project – increases the viability of many more projects |
| Very infrequent measurement periods (i.e. every 3-5 years) – cannot practically be used for insetting applications | Soil carbon quantity can be determined at any point – it's based on a daily calculation so is ideal for "rolling" insetting |
| No way to determine the effect of management practice change – only measures total soil carbon not the additionality which is not going to be valid in the longer term | It quantifies the effect of the management practice change ("additionality") which is critical for compliance with international carbon credit protocols |
| Limited insight as to the drivers of any change in soil carbon | It is based on a digital-twin process model of the paddock which shows the drivers of the change – this enables these drivers to be optimised to maximise production and soil carbon outcomes, allowing for active management of the landscape. |
| Limited ability to conduct simulations or scenario planning to help drive decision making and optimise financial and operational outcomes | Simulations on the impact of management practice changes can be run prior to implementation to ensure the optimum practices are designed to maximise profit and desired sustainability outcomes |
| High levels of uncertainty with soil coring due to spatial variability | Flux towers have been shown to have a far lower uncertainty |

## Method Development and Adoption Pathways

The Agrimix Flux approach was designed to meet the stringent requirements of the 2021 Soil Carbon Method under the Schedule 2 approach. Agrimix' primary market is determined by higher clay content soils (Vertosol, Sodosol, and Chromosol), those areas which receive 500mm+ annual rainfall.

### *Carbon Measurement Service Models for Offsets (ACCUs)*

Agrimix has conducted market testing and is continuing to refine the offsetting (ACCUs) service model and pricing. There is continued uncertainty around soil carbon measurement (see Mitchell et al., 2024) and the Emissions Reductions Assurance Committee has commenced a review of the 2021 Soil Carbon Method. This review will investigate whether the method continues to meet the offsets integrity standards. While this review is underway Agrimix is focused on additional adoption pathways for the toolkit, including for use in insetting across the beef supply chain.

### *Method Development Activities*

This project and the science delivered has been received favourably by the Clean Energy Regulator (CER) as demonstrated by their feedback on the Agrimix proponent led method change submission (See Appendix 2 for the ERAC assessment summary). Agrimix has subsequently provided a Submission to the Emissions Reductions Assurance Committee for their review into the current soil carbon method, recommending that flux towers be added to Schedule 2 as an alternative to soil coring for model validation.

### *Considerations for Method Development*

Agrimix's measure-model-verify approach differs substantially to soil sampling. The key differences between the approaches are:

- The current Soil Carbon Method relies on soil sampling, which introduces spatial and temporal variability, and applies both a statistical deduction (via t-distribution × SE) and a temporary discount at the first crediting period (25%).
- The MMV approach uses modelled data validated by EC flux measurements, with uncertainty handled through a model-based discount (U), replacing the need for both SE (accounting for spatial variability in soil coring) and the T1 discount.
- Because it can distinguish climate from management, the MMV approach avoids the need for an arbitrary discount for climatic variability.

Whilst the Agrimix Flux approach was designed to fit the 2021 soil carbon method, the method review that is now underway has afforded an opportunity to make additional recommendations to strengthen the method with recommendations informed by the QUT and Agrimix research platform.

Given the differing methodologies in accounting for SOC change, there is a need for a new schedule to create consistency and alignment. Additionally, subject to consideration of climatic variation, equitable treatment of climatic variation across all schedules to prevent any unintended consequences of introducing a Schedule which has the capacity to exclude of non-additional, climate-driven gains.

In our view, any imbalance can be managed through the application of deductions or discounts for climate variability or through new method development processes to ensure consistency and alignment.

Table 3 below compares the Soil Carbon Method 2021 with the Agrimix Flux Approach in terms of how each calculates and applies uncertainty in crediting SOC change.

**Table 3: Treatment of uncertainty in current method versus the Agrimix Flux MMV approach**

| Feature | Soil Carbon Method 2021 | Agrimix Flux (MMV Approach) |
|---|---|---|
| Crediting equation for CEA | ΔSOC = SOC_mean – (t_α,df × SE) × (1 – d) | ΔSOC_credited = ΔSOC_modelled × (1 – U) |
| Source of SOC change data | Direct soil sampling (baseline and remeasurement) | Biogeochemical process model verified with EC flux data |
| Uncertainty term | Standard error (SE) from soil sampling | Composite uncertainty (U): includes EC error, conversion, extrapolation |
| Use of t-distribution | Yes; applies t_α,df for probability of exceedance (e.g. 60%) | No; not required |
| Temporary discount at T1 | Yes; 0.25 (applied to first reporting round only) | No; not needed, model controls for climate |
| Spatial variability from soil cores | Included – increases SE and total uncertainty | Not applicable; no reliance on soil cores |
| Climate adjustment | Not separated from management effects | Explicitly separated through model–flux calibration |

## Platform Development

The foundation of the Agrimix Flux platform is the DayCent CABBI model which has been adapted to Australian conditions. Agrimix Flux builds on this foundation through the integration of various external data sources and inputs through API management to deliver soil carbon quantification and reporting through one platform. The back-end platform has been developed strategically to enable adaptation to new datasets and inputs whilst maintaining its scalability and flexibility to adapt to market and customer requirements. Outputs displayed on the Agrimix Flux dashboard are presented in Figure 10.

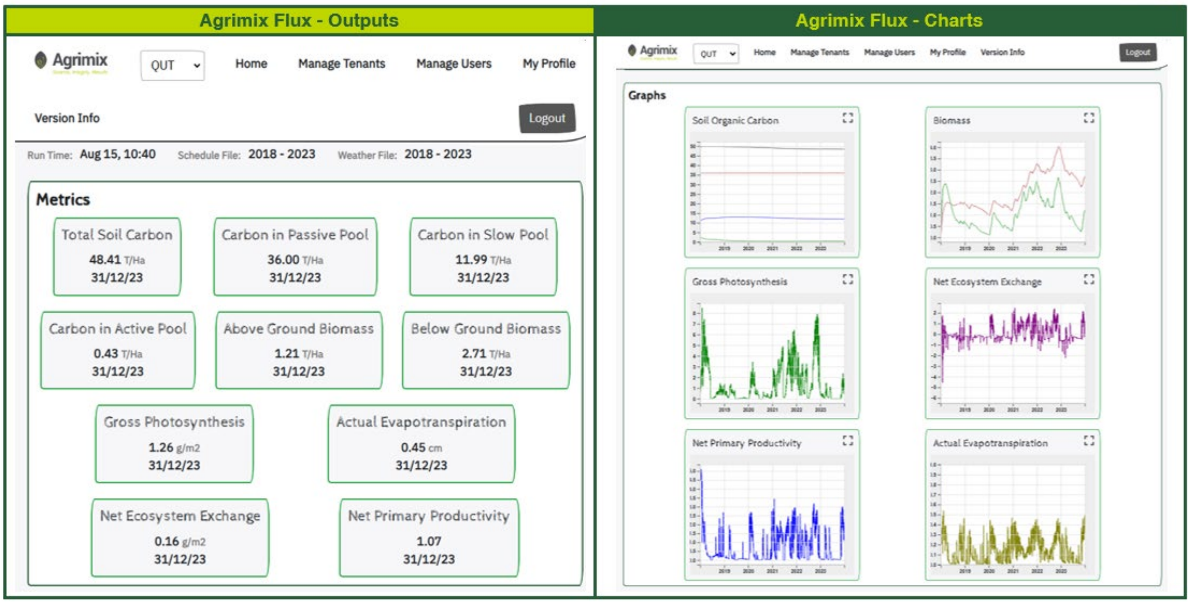



*Figure 10: Example outputs from the Agrimix Flux dashboard*

### *Driving profitability through grazing*

Agrimix Flux creates a digital twin of the Landholders paddock and can therefore be used beyond soil carbon outcomes. Figure 11 outlines the data produced using Agrimix Flux and how this data can be used to optimise grazing productivity. The digital paddock is the key to improving financial and operational grazing performance through enhanced forecasting and the ability to adapt to variations in weather patterns.

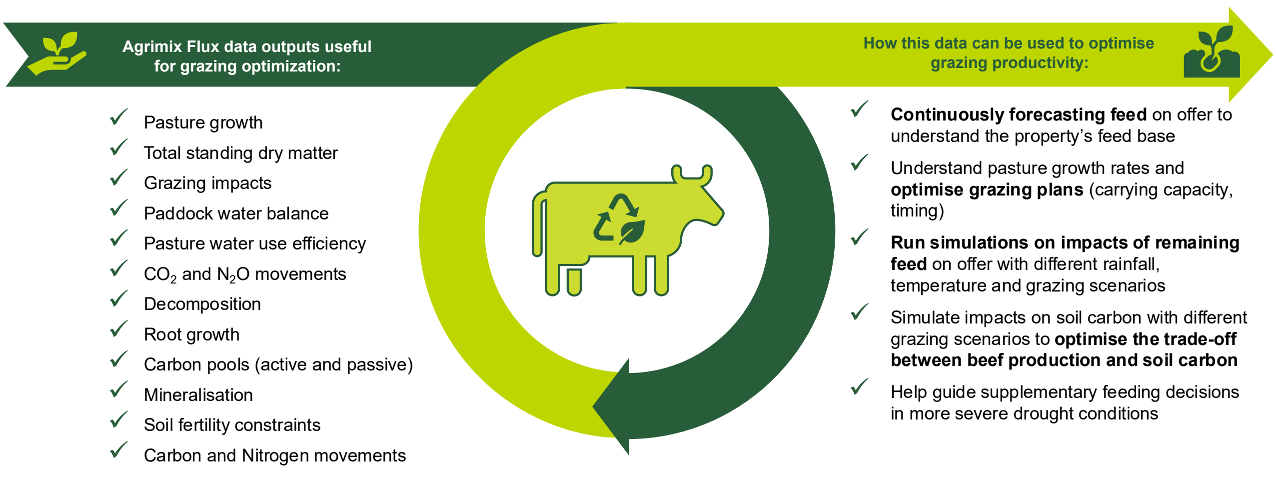



*Figure 11: Agrimix Flux benefits extend to driving productivity by optimising grazing*

## Paired site analysis of long term Desmanthus sites

Following a survey of industry experts, literature reviews of historic industry and government reports and discussions with farmers a total of 38 historic desmanthus plantings were identified with a known sowing date and a minimum age of 5 years, and where know good plant densities were previously observed. Current owner contact details were able to be determined for 30 sites ranging from the Gulf of Carpentaria to central-northwest NSW. Field surveys were conducted at sites prior to sampling to assess legume plant counts and persistence with a minimum visible plant stand of 0.2 plants per $m^2$ required to proceed to sampling. Only 18 of the 30 sites had high enough plant densities to sample, with no sites in NSW identified where desmanthus was present at the time of sampling.

For each site a paired control sampling area was carefully selected. Historic aerial photography and farmer interviews were used to ensure comparable land-use history (particularly clearing and cropping history), and control (and treatment) sites with heavy densities of other legume species were avoided. Scoping soil samples were collected on most sites and analysed to ensure comparable soil texture. Historic research sites as part of the 1992-1998 MLA funded program *Legumes for clay soils* (Clem 1998) were utilised where possible due to historic establishment and clear controls. A total of 14 pairs met the criteria to be the final analysis, but only three from historic research trials. Average age of plantings was 18 years, and each pair was rated for pair quality (based on soil type and land-use history, and plant density.

Soil samples were collected using a 3.8 mm ute mounted pneumatic/jackhammer soil sampling rig. Cores were collected to a maximum depth of 1 m from four transects of 3-6 cores each depending on the size and orientation of the sampling site. Sampling depths were standardised using cubic splines to a consistent equivalent soil mass between pairs. Estimated differences between desmanthus and control plots were determined using a gamma-distributed generalised mixed effect-model incorporating landform and bioregions as fixed effects, and a combined “pair quality” weighting as random effects. This approach allowed for the maximise degrees of freedom for teasing out any effects of the main treatment, while accounting for the structure of the data.

*<u>Paired Site Analysis - Results and discussion</u>*

Across the 14 paired sites sampled desmanthus increased soil SOC across 8 sites, with no change within the site area at the other 4 (Figure 12). Overall the mixed effects model showed desmanthus significantly increased ($P<0.036$, Figure 13) soil carbon stocks to one metre by 6 t SOC $ha^{-1}$. With an average planting age of 18 years this equated to 0.35 t SOC $ha^{-1}$ year, or 1.3 t $CO_2$ $ha^{-1}$ $year^{-1}$. Soil N showed no significant difference at either 30 cm soil depth or 1 m (Figure 14).

While this represents a positive finding the lack of a clear increase in soil organic N suggests the carbon cumulation is more related to the plants root architecture than the legume fixing atmospheric N. Results from the SERF trial show greater root volume and deeper distribution under desmanthus than pasture only. Due to the woody nature of these roots, they are also expected to have a higher lignin content (analysis pending), leading to the deposition of slower decomposable carbon at depth. The result also suggest that effective nodulation is not occurring at most of these historic sites, not surprising given the lack of seed inoculates applied during the early establishment of desmanthus.

Plant density varied widely across the surveyed areas, ranging from zero observed plants to >20 plants/m$^2$. Low plant density eliminated 12 sites from potential sites from inclusion in the analysis, with zero plants observed in most of these sites despite their confirmed presence in previous years. This was particularly evident in NSW, and was most likely a result of the wet springs allowing low-temperature threshold pastures to out compete new desmanthus seedlings. Given the relatively low plant density threshold for inclusion in the study the increase in SOC observed could be considered conservative with potential improvement from better rhizobium inoculation and grazing management to achieve optimal grass/legume balance. The importance of the latter is perhaps best shown with the highest sequestration rate (Glen Lomond) which was also a time-controlled grazing site (control was also TCG).

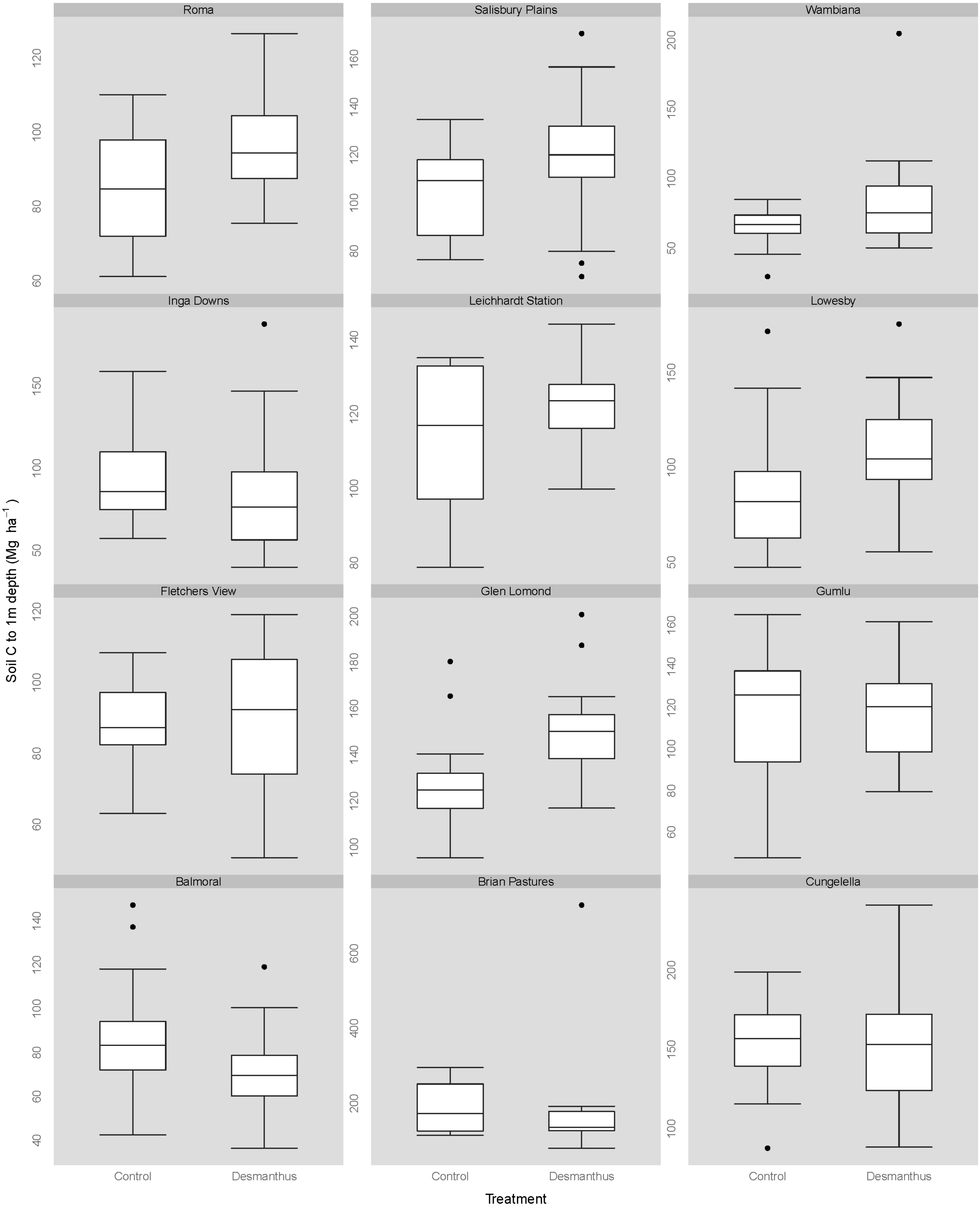
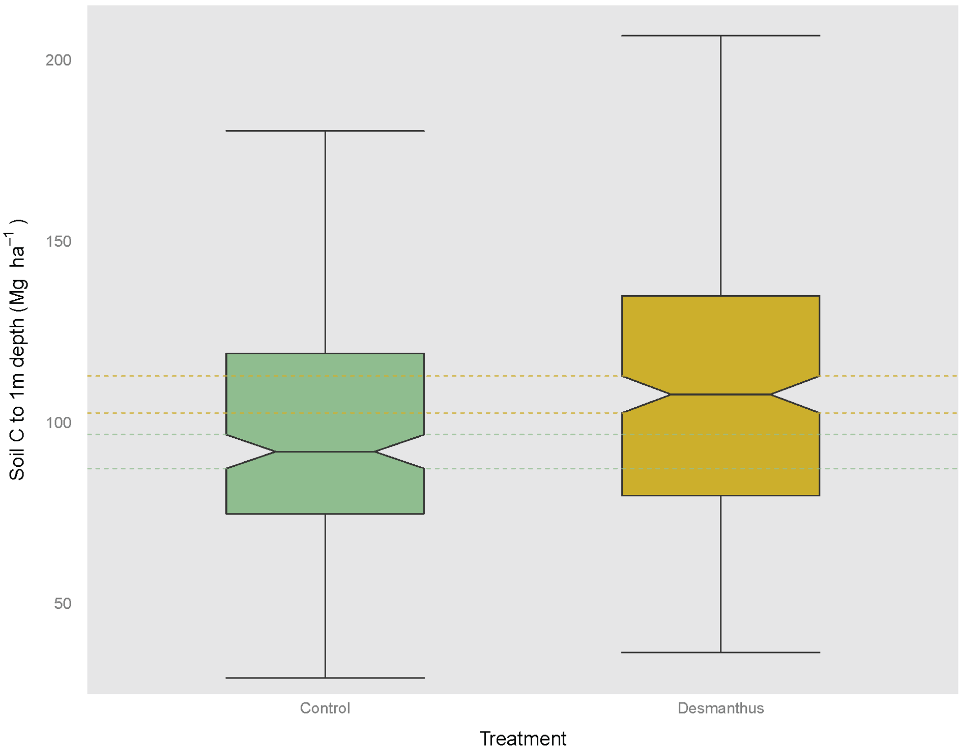



*Figure 12. Total soil C stocks (0-100 cm) for desmanthus planting (average age 16 years) compared to paired controls. Source: QUT*



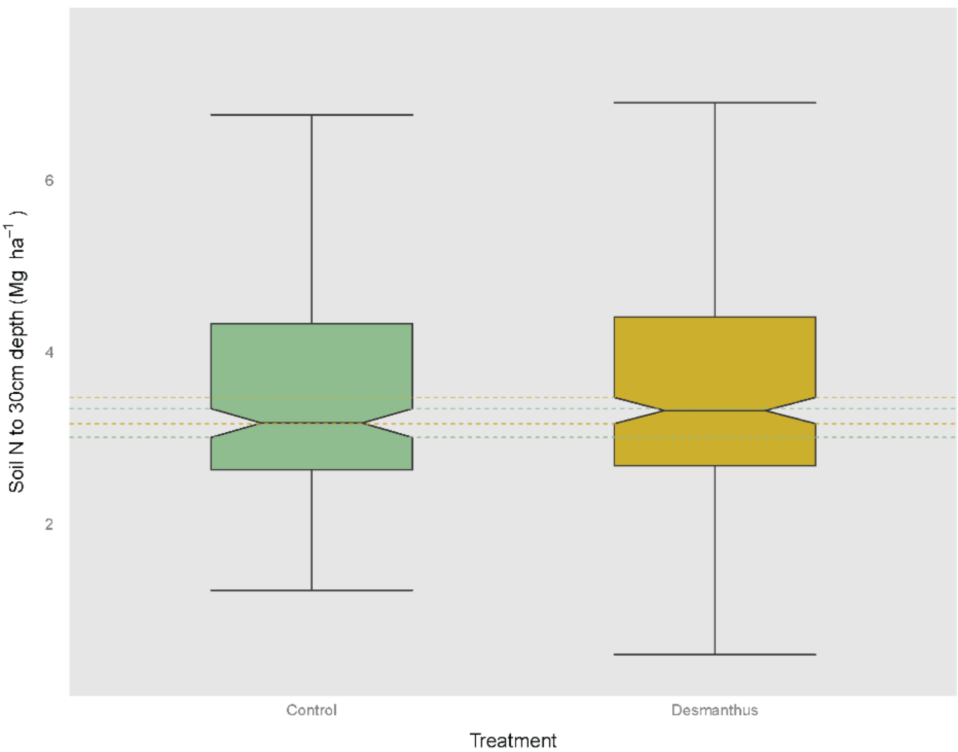




*Figure 13 and Figure 14. Notched box plots of the pairwise comparison of total SOC (0-100 cm) and total nitrogen (0-30 cm) under Desmanthus and control areas. The notches and associated horizontal lines represent the 95% confidence intervals for the treatment medians. Source: QUT*

# 4. Conclusion

The project has delivered on the objectives set for it. The Agrimix Flux toolkit progresses the soil carbon and productivity aspects of the red meat industry and offers a pathway to a lower cost and higher accuracy future. It is now ready to be rolled out commercially into the industry and enable producers to improve their productivity, sustainability and profitability.

The key benefits and outcomes of this approach are:

- **Dynamic baseline for project additionality:** DayCent-CABBI creates a digital twin of the farm, enabling the separation of climate and management effects which can not be achieved through soil coring.
- **Conservative crediting pathway:** The calibrated model can support early issuance of carbon credits in a conservative manner, with verification (e.g. soil coring or as we propose, through EC Flux Towers) at the 5-year mark. This balances financial incentives with scientific rigour early in the project.
- **Reduced landholder risk**: The Agrimix Flux approach avoids the risk of large crediting based on climatic variation, reducing the risk to landholders of over-crediting and future potential liability.
- **Enabling scale with EC-model integration**: The integration of EC data with process models reduces reliance on costly soil sampling that is vulnerable to spatial and temporal variation. This approach supports rapid scalability in regions that high-potential carbon sequestration locations (clay soils, >500 mm rainfall), where the model has been shown to perform reliably. We estimate this equates to c. 20m Ha.
- **Enabling better decision making**: the calibrated model enables scenario analysis which provides Landholders with actionable insights to build or retain SOC, as well as understand the impact on above ground biomass and water use efficiency under different climatic scenarios.
- **Improving productivity and business resilience**: The “digital-twin” can be leveraged to optimise grazing practices through continual feed forecasts, insights on pasture growth rates for optimised grazing plans, feed simulations based in climatic forecasts, guidance on supplementary feed requirements under severe drought conditions.
- The platform’s use of an Australian-calibrated model, validated by EC flux measurements and tested across multiple sites with registered soil carbon projects, positions it as a robust tool for improving the measurement and modelling underpinning the ACCU Scheme.
- This not only supports better on-farm decisions but also contributes to increased market confidence and acceptance of soil carbon credits by enhancing the transparency, reliability, and integrity of the claims made.

# 5. Future research and recommendations

Continued calibration in different geographies, pasture types and management practice changes will expand the application Agrimix Flux to a broader range of producers.

In addition, the CER soil carbon method review is expected to make the MMVT approach, such as Agrimix Flux, to be relatively more attractive for producers and therefore increase adoption.

Future Agrimix research and development activities are planned to align to regulatory change and industry needs, including:

- Productivity measurement tools developed to provide graziers with optimised pasture management information
- Further development of scenario planning tools, combined with financial analysis to optimise pasture improvement decisions and enterprise productivity and profitability
- Partnership with whole-of-farm emissions measurement calculators to enable carbon neutral / low carbon beef production
- Expansion into new bioregions and pasture systems

# Acknowledgements

Agrimix would like to express our sincere gratitude to all those who contributed to the successful completion of this project.

First and foremost, we thank the QUT research team, led by Professors Peter Grace and David Rowlings, for their dedication and expertise throughout the project. Their valuable insights and tireless efforts were instrumental in achieving the project's objectives.

We are deeply grateful to our funding agencies, MLA and the Department of Climate Change, Energy, the Environment and Water, and supporting red meat producers, whose financial support made this work possible. Their continued investment in research and innovation has enabled us to explore new solutions and generate impactful outcomes.

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Finally, we extend our appreciation MLA staff (past and present) particularly Doug McNicholl, Margaret Jewell, Julia Waite, Tom Dobbie and Joe McMeniman, for their input and support from the outset.

This project stands as a collective achievement, and we are thankful to all who played a role in its success.

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# Appendix

## Appendix 1: Extension activities undertaken during the project

| Date of activity | Title or name | Activity type | Topic/information presented | Who was involved | Number of attendees, conversations or reach | Link |
|---|---|---|---|---|---|---|
| 29/04/24 | A revolution in quantifying soil carbon change is coming | Beef Central Online editorial | Agrimix Measure Model Verify Toolkit for quantifying soil carbon sequestration | Agrimix | 145,000 unique browsers per month (Beef Central figures) | https://www.beefcentral.com/beef-2024-preview/a-revolution-in-quantifying-soil-carbon-change-is-coming/ |
| 08/05/24 | Using flux towers to measure carbon going in and out of the soil | Presentation during "Lunch and Learn" sessions at BeefWeek 2024 | Agrimix Measure Model Verify Toolkit for quantifying soil carbon sequestration | Agrimix | 50 | |
| 5-10/5/24 | Booth at BeefWeek 2024, Rockhampton Qld | Booth and displays with Agrimix staff attending in the ag tech section at BeefWeek | The full MMVT research and commercial application including instrument displays, videos, presentations, collateral etc | 5 Agrimix people dedicated for the full week | Estimated 200 direct engagements (2-way conversations) and thousands of indirect (passive consumption of information). +95 people completed a survey on soil carbon signed up to a mailing list | |
| 20-22/05/24 | Carbon Farming Industry Forum | Industry Forum | Attendance-only | Ben Sawley, Agrimix | | |
| 6/6/24 | MMVT field day at Juandah Plains, Qld | Field day showing the MMVT in operation | Review of the instruments in the paddock, data being generated and soil carbon measurements being output | Agrimix, Willinga Pastoral and neighbours, John and Kate Scott | 30. | |
| 19/6/24 | MMVT field day at Essex Grazing Co, Central Qld | Field day showing the MMVT in operation | Review of the instruments in the paddock, data being generated and soil carbon measurements being output | Agrimix, Quinn family | 6 | |
| 4/7/24 | MMVT field day at Gregory Downs, Northern Qld (Gulf) | Field day showing the MMVT in operation | Review of the instruments in the paddock, data being generated and soil carbon measurements being output | Agrimix, Paraway Pastoral Co | 7 | |

| | | | | | | |
|---|---|---|---|---|---|---|
| 5/9/24 | MMVT field day at Glencoe, NSW | Field day showing the MMVT in operation | Review of the instruments in the paddock, data being generated and soil carbon measurements being output | Agrimix, Property owner | 5 | |
| 28/02/25 | MMVT field day at Wandoan, QLD | Field day showing the MMVT in operation | Review of the instruments in the paddock, data being generated and soil carbon measurements being output. Presentations by Professor David Rowlings, Zac Geldof (Agrimix), and Phil Green (Greenleaf Enterprises) | Agrimix, Wilinga Pastoral, neighbouring producers, industry (e.g., Integrity Ag), and representatives from the Department of Climate Change, Energy, the Environment and Water | 40 | |

# Appendix 2: CER EOI Feedback Summary (also attached)

## Soil Carbon Model Accuracy Assessment Using Eddy Covariance Measurement Techniques, EOI2024-40

### Overview of the Expression of Interest (EOI)

The EOI relates to a variation of Schedule 2 – the Hybrid approach to estimating soil organic carbon sequestration, of the Soil Carbon method 2021[51] to add soil carbon measurement using an eddy covariance technique (EC). The hybrid approach in the Soil Carbon method 2021 uses both physical core sample measurement and modelling of soil organic carbon.

EC is an accepted and established measurement approach for determining atmospheric carbon dioxide ($CO_2$) flux. EC towers, both permanent and mobile, comprise an ultrasonic wind speed meter (anemometer) and infrared gas analyser.[52] The outputs from an EC tower must be modelled using specific software to derive flux and carbon values. The EC tower must also be calibrated with conventional soil carbon core measurements, preferably on a local scale.

### Proponent

Agrimix

### Assessment summary

**Overall recommendation:** Support for development, if / when resources permit, excellent alignment and ready for imminent development.

The EOI proposes a variation to the Soil Carbon method 2021 to include the use of EC measurement techniques to improve the accuracy of abatement credited under the method. The proposed variation would allow the use of soil carbon measurements determined by EC as an additional approach within Schedule 2.

As the proposal is for a variation to the measurement approaches under the Soil Carbon method 2021, it is assessed as meeting the additionality, project emissions, and conservativeness Offsets Integrity Standards (OIS).[53] This is because the proposed variation would not likely affect these OIS. The National Inventory Systems and International Reporting (NISIR) Branch has indicated the abatement would likely be eligible.[54] Further, the NISIR Branch would like to be included in data sharing arrangements to improve their data sets if the proposal is prioritised for development.

The proposal cites peer-reviewed literature on the use of EC soil carbon measurement indicating that it can be more accurate than the soil sampling approaches currently contained in Soil Carbon method 2021. However, the EOI provides minimal information on EC soil carbon measurement and how it would work. The proposal does not compare EC soil carbon measurements to other soil carbon

[51] Carbon Credits (Carbon Farming Initiative—Estimation of Soil Organic Carbon Sequestration Using Measurement and Models) Methodology Determination 2021

[52] The EC tower is positioned in the field in an upwind location. A 2m tower will have a measurement area of approximately 200m in radius. The tower measures air flow over time within a boundary layer in 3D and each turbulent vortex or "eddy" is resolved in a vertical component. The $CO_2$ flux in and $CO_2$ flux out in the vertical plane is measured and the difference is the amount of $CO_2$ absorbed within the plant/soil profile.

[53] s 133(1) of the *Carbon Credits (Carbon Farming Initiative) Act 2011* (the CFI Act)

[54] s 133(1)(c) of the CFI Act

measurement techniques and would have benefited from more detail on the limitations of EC soil carbon measurement.

EC soil carbon measurement approaches are complex, require expensive and specific equipment that may be difficult to access, and which require the use of specialised software. Both fixed and mobile EC towers are expensive equipment[55] and require trained experts to operate them, including the software. Consequently, the uptake of the proposed method variation may be limited at present and be dependent on a limited pool of specialist modelling services. Conversely, the variation if prioritised for development, may encourage equipment and vendor availability especially if use of EC towers for regional $CO_2$ flux studies becomes more widespread in Australia. The Committee notes the greater deployment of EC towers offers benefits beyond use in the Soil Carbon method 2021, in terms of capturing finer scale environmental information of use in several policy domains.

The project plan is optimistic and would be improved by considering further consultation. However, this could be addressed in the method development phase if the EOI is prioritised.

The proposed Eddy Covariance soil method could potentially be considered as a variation to Soil Carbon method 2021 when the Committee undertakes its planned periodic review of this method in 2025.

[55] There are varying reports that cover the costs associated with using EC towers to measure soil carbon. Work through the National Soil Innovation Challenge to identify lower-cost options to current soil sampling has suggested that using and hiring EC towers could be a viable alternative (Meat and Livestock Australia, 2022, Measuring soil carbon in grazing systems, Meat and Livestock Australia, Sydney, https://www.mla.com.au/contentassets/fc8e3606d85e403ca57832e02e1d1905/p.psh.1195-final-report.pdf).