PIRSA

Carbon Opportunities in the South Australian Mallee

Literature Review

SOUTH AUSTRALIA

Government of South Australia

Primary Industries and Regions SA

Carbon Opportunities in the South Australian Mallee

Information current as of 10th May 2021

Disclaimer

All Enquiries

Department of Primary Industries and Regions
Bonnie Armour (Author) Rural Solutions SA
Level 14, 25 Grenfell Street
GPO Box 1671, Adelaide SA 5001
T 08 8568 6422 M 0428 050 118
E bonnie.armour@sa.gov.au

Department of Primary Industries and Regions
Brian Hughes (Project Leader) Rural Solutions SA
Level 14, 25 Grenfell Street
GPO Box 1671, Adelaide SA 5001
T 08 8568 6411 M 0429 691 468
E brian.hughes@sa.gov.au

Report reviewed by Amanda Schapel (PIRSA) & Jennifer Barwick (PIRSA)

Contents

Contents

Summary of Findings

- South Australia's poor uptake of carbon farming projects is influenced by the lack of concise information, limited understanding on project methodologies and requirements, uncertainty around who is available to support and assist and current farming systems, i.e. most farmers readily practice stubble retention and no till.

- Offsetting carbon opportunities in the Mallee exist through either the Emission Reduction Fund (ERF), voluntary carbon markets and independent carbon farming.

- Regardless of the type of opportunity, there is growing industry acceptance that carbon farming practices also achieve other co-benefits such as reducing erosion, improving soil structure and fertility, increased biodiversity and plant productivity, buffering against drought, improved animal health and increased water efficiency.

- There are six broad components of agricultural emissions, five of which apply to the Mallee and include: field burning of agricultural residues, enteric fermentation, manure management, agricultural soils and vegetation burning or clearing.

- The Mallee encompasses varying environmental conditions, with variable low to medium rainfall spread across the region, as well as variable soil types. As a result, the approach of 'one-size fits all,' is arguably unattainable in regards to applying ERF methods.

- Most carbon framing practices listed in this review are achievable in the Mallee, regardless of them being an eligible method in the current carbon market e.g. ERF. However, practices that are most applicable to the Mallee under an ERF method appear to be environmental plantings in the form of windbreaks, converting urea lick blocks to nitrate lick blocks for beef cattle, improved herd management (refer to page 24 for full list of practices), applying nutrients and soil amendments, revegetation of Mallee scrub, animal effluent management and cropping and pasture management.

- Major limitations for farmers participating in carbon markets appear to be cost to establish and manage an ERF project, and misunderstanding, particularly of ERF methods. ERF methods, voluntary markets, as well as additional governmental support programs and incentives are constantly evolving. There seems to be significant government and industry investment and effort underway to encourage more farmers to participate.

Introduction

Carbon farming is gaining new momentum as an effective method to address climate change through emission reduction and carbon sequestration. In the past 10 years, more evolved methodologies and markets have been developed and released alongside growing international and national attention and impetus for emission reduction and climate resilience.

Carbon farming is farming in a way that reduces Greenhouse Gas (GHG) emissions or captures and holds carbon in vegetation and soils. It seeks to reduce emissions generated through production processes, while increasing production and sequestering carbon in the landscape. All primary industry sectors have opportunities to reduce emissions and participate in carbon farming, however some carbon farming opportunities are more developed than others, particularly in land-based abatement.

The Climate Council (2018) have reported that Australia's 26-28% emission reduction target for 2030 on a 2005 baseline is not adequate to meet the Paris Climate Agreement targets. Agriculture is Australia's third largest emitter, however there is growing commitment across the agriculture sector to lower its emissions and support other emission reduction opportunities.

Rising participation in carbon farming has also recently been linked to increasing re-sale value for properties. For example, some farmers in WA have been able to sell property with increased value due to their implementation of a carbon project, where carbon is now being attributed as an asset (Seaman, R, 2021, pers. comm., 12 May). Carbon opportunities can exist for farmers through two streams: *offsetting programs* that formally quantify the carbon a farm sequesters; and *insetting programs* were farmers participate in supply-chain initiatives via downstream organisations such as food companies who aim to reduce emissions throughout the entire supply chain (Pryor, 2021). Offsetting programs in Australia broadly occur within three main themes (demonstrated in Figure 1) and these will form the basis of this review.

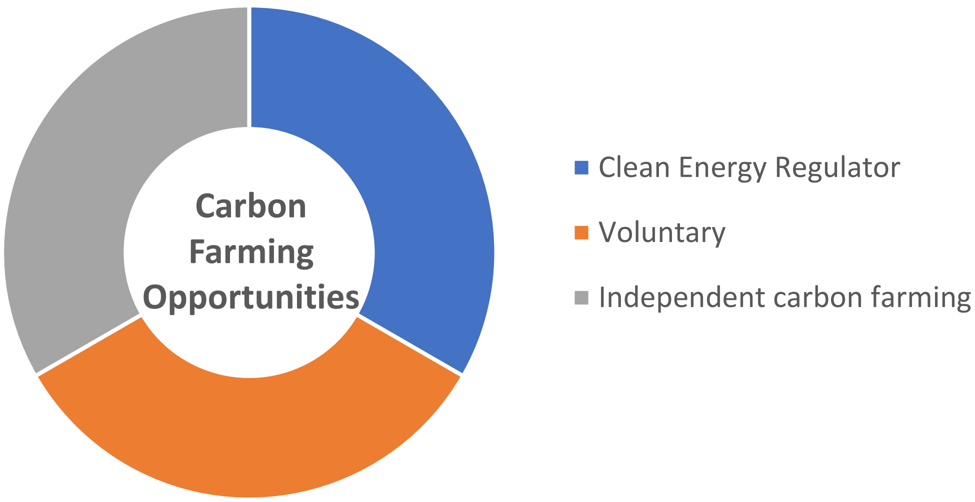


Figure 1. Carbon farming opportunities in Australia expressed through three overarching themes. Please note that displayed proportion of each activity is not representative of scale.

Clean Energy Regulator

The Clean Energy Regulator (CER) is an Australian Government independent statutory authority responsible for administering legislation to reduce carbon emissions. The CER initiated the Emission Reduction Fund (ERF), which represents the major carbon credit scheme in Australia and builds on the Carbon Farming Initiative (CFI) enabling farmers and land managers to generate Australian Carbon Credit Units (ACCUs) for sale into the carbon market. The CFI and ERF were designed so that land managers can either participate individually or collectively, however, owing to the complex and new nature of the system, many early adopters have partnered with external service providers (RegenCo, 2021.).

In order to generate an ACCU, an approved 'method' must be followed, which outlines the rules that apply to a specific project such as what activities can be delivered, how they are monitored and the location they will take place. Carbon Farmers of Australia (2020) have listed the five most common available carbon methods for farmers Australia wide to use including: (this list is not in any order)

- Storing carbon in your soils
- Planting native trees and shrubs (Native Forest)
- Managing stock to allow native forest to regrow
- Beef Herd Improvement – reducing methane
- Reducing nitrous oxide emissions from irrigated cotton

The ERF and the above methods could, one day, have an important role to play in achieving the actions identified in the recently released *SA Government Climate Change Action Plan 2021-2025* (Government of South Australia, 2021). The plan seeks to encourage greater uptake of carbon farming and emission reduction across primary industries. In particular, improvement of soils, establishment or regeneration of trees and native species, reducing methane production from livestock through feed supplements or other technologies and using agricultural waste to produce soil improvement products, bioplastics and energy are highlighted as productive low emission methods.

To date, agricultural-related projects have dominated the ERF, with more than 70% of registered projects and 65% of issued ACCUs (Macintosh, Roberts & Buchan, 2019). However, uptake of carbon offset projects have been inconsistent with most of the uptake involving regeneration or protection of native forests on grazing lands in semi-arid regions. Moreover, carbon projects in Australia are unevenly distributed across states, with most projects occurring in NSW, QLD and WA as seen in Figure 2. Reasons for the project dominance in these three states pertain to the vegetation sequestration opportunities and jurisdictional policy settings that has allowed early participation.
To date, South Australia has a total of 32 ERF registered projects, with 2 falling under the method 'Energy Efficiency,' 9 to 'Landfill and Waste,' 12 to 'Vegetation' and 9 to 'Agriculture,' outlined in Table 1.

Table 1. South Australia's ERF Agriculture and Vegetation projects (Emissions Reduction Fund, 2021).

Project Method	Project Name	Landscape Management Region	ACCUs Issued
Agriculture	Cirus Carbon project	Alinytijara Wilurara	0
Agriculture	Riviera Carbon project	Northern and Yorke	0
Agriculture	Lynch Carbon project	Hills and Fleurieu	0
Agriculture	Prestige Carbon project	Limestone Coast	0
Agriculture	Brinkley Biogas Flaring project	Murraylands and Riverland	6,168
Agriculture	Sandalwood Carbon Project	Limestone Coast	0
Agriculture	Sandalwood Part Two Carbon Project	Limestone Coast	0
Agriculture	Bamford Carbon project	Hills and Fleurieu	0

Project Method	Project Name	Landscape Management Region	ACCUs Issued
Agriculture	Crawford Carbon Project	Limestone Coast	0
Vegetation	Wintinna Station Forest Regeneration Project	South Australia Arid Lands	0
Vegetation	South Australia Ediacaran Landscape Regeneration Project	South Australia Arid Lands	0
Vegetation	South Australian Conservation Alliance – Site #2	South Australia Arid Lands	0
Vegetation	South Australian NPWS Environmental Plantings Project	Eyre Peninsula	0
Vegetation	Arbon – Tooligie - HIR	Eyre Peninsula	111,815
Vegetation	Canegrass Station Carbon Sequestration Project	Northern and Yorke	0
Vegetation	Biodiverse Carbon Conservation SAW1	Hills and Fleurieu	15,675
Vegetation	Glenthorne Farm and Southern Adelaide Biodiverse Carbon Rehabilitation	Hills and Fleurieu	0
Vegetation	Biodiverse Carbon Conservation Morella	Hills and Fleurieu	62,072
Vegetation	2020 AGE CLASS. LIMESTONE PLANTINGS	Limestone Coast	0
Vegetation	South Australian Conservation Alliance	Limestone Coast	0
Vegetation	Biodiverse Carbon South Australian Environmental Planting Project 2021	Eyre Peninsula	0

Bagery, et al, (2019) conducted a pilot study in Central West New South Wales to trial the use of a marketbased instrument to encurage farmers to change farm management to increase organic carbon (OC). The results demonstrated increases in OC using quantification methods consistent with the current Measurement Method of the Australian Government's ERF policy used to generate ACCUs (Badgery, et al, 2019). They found that pasture had a higher rate of OC sequestration than reduced tillage cropping and organic ammendments had higher rates of OC sequestration than without. The pilot intentionally seleted sites with initially low OC in order to ensure carbon sequestration. Consequentially, this example may differ depending on the farming system and landscape conditions however does offer a broad example of the potential success following the carbon market offers.

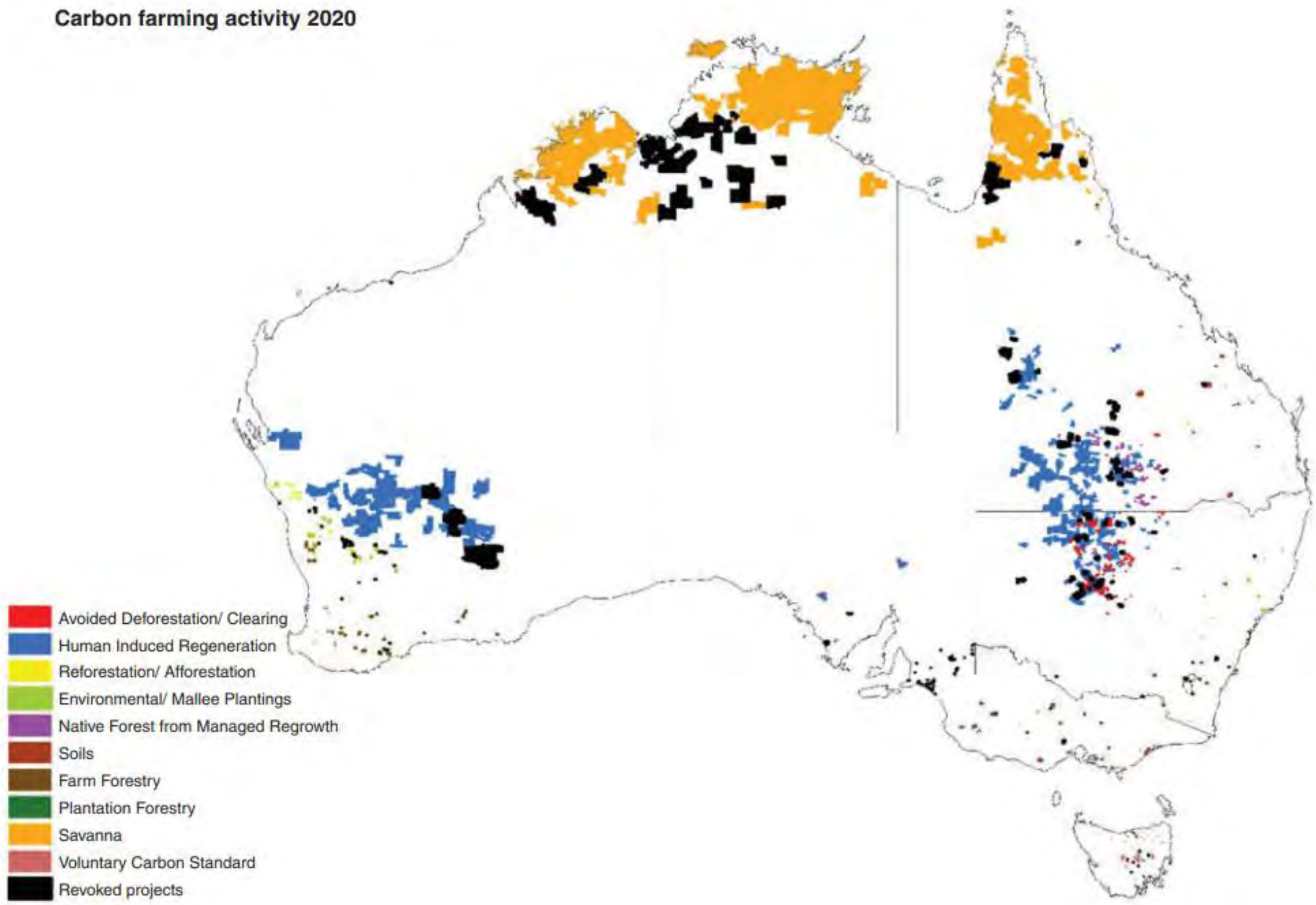


Figure 2. Current distribution of different carbon farming projects across Australia where Human Induced Regeneration (HIR) and Savannah projects dominate the eastern and western states. South Australia is markedly bare compared to other states (Baumber, et al, 2020).

Voluntary Markets

The ERF is a voluntary scheme however a wide variety of other voluntary (private) markets exist that allow organisations to offset their emissions without following the ERF's own rigorous and mandated scheme. It should be noted that private markets will be referred to as 'voluntary markets' to compliment current terminology.

The use of and trading in voluntary carbon markets is increasing, with the CER recently reporting that demand from the voluntary, independent and state and territory government markets surged in 2020 with 4.9 million Australian units and certificates surrendered, four times the volume of 2019 (Barwick, J, 2021, pers. comm., 29 April). However, it is also projected that there will need to be around a 15-fold increase in demand in these markets by 2030 in order to support the investment needed to achieve a 1.5°C pathway. (de Wit, 2020). An example of this in play is the recent Microsoft deal with a cattle operation in NSW.

Case Example: Microsoft buys carbon credits from NSW farmer

The beef operation, Wilmot Cattle Co has entered a deal Microsoft to sell approximately half a million dollars' worth of carbon credits. The credits are available in the form of over 40,000 tonnes of sequestered soil carbon and this was achieved through controlled grazing management (Goodwin, 2021). The management included controlled rotational grazing, decreased paddock size and increased stocking density resulting in increasing soil OC from 2.5 to 4.5 per cent as well as additional benefits such as, increased ground cover, biomass and water-holding capacity.

This private agreement falls under a voluntary carbon market as the credits were verified and sold by the United States company, Regen Network, which awarded them CarbonPlus Grassland Credits (Goodwin, 2021).

Two of the major voluntary carbon markets are Gold Standard and Verra. The Gold Standard is one of the most rigorous certification standards for carbon offset projects, linking the UN's Sustainable Development Goals and ensuring emission reduction and long-term sustainability. Similarly, Verra's global standards, assessment models and accounting methodologies allow for a high level of success and accountability. Verra also includes more options for sustainable grazing compared to Gold Standard (Seaman, R, 2021, pers. comm., 12 May).

It is important to note that an individual farmer cannot participate in the voluntary markets without a financial services license and as it stands, farmers without this license will participate through the ERF, which does not require the license (Seaman, R, 2021, pers. comm., 12 May).

However, it's worth noting that with a growing number of voluntary carbon market operators, there is also growing concern about the authenticity and accountability of each one. To ensure there is a unity amongst standards, the Institute for International Finance have established a private-sector Taskforce on Scaling Voluntary Carbon Markets. This Taskforce has developed a 'roadmap' that outlines the infrastructure solutions required to achieve the large-scale voluntary carbon markets necessary for the private sector to achieve the 'net zero' targets (de Wit, 2020).

Independent Carbon Farming

A farmer does not need to participate in a regulated scheme to decrease their carbon footprint – many farmers will do this regardless for environmental and productivity values. Carbon farming manages the land, water, plants, and animals in order to reduce emissions in production processes, while increasing production and sequestering carbon in the landscape (Carbon Farmers of Australia, 2020). Practices such as planting vegetation, transitioning to pasture cropping, no-till cropping, mulching and manuring, rumen inoculants, natural fertilisers and aiming for maximum groundcover can also result in co-benefits such as reducing erosion, improving soil structure and fertility, increase biodiversity and plant productivity, buffer against drought and increase water efficiency. The Goyder Institute (2019) have given examples of three case studies where the co-benefits of land use changing, including improved pollination, shelter belts to improve lambing yields and riparian vegetation to improve water quality indicate possibilities of achieving economic viability. Even though the improved pollination and reduced lamb mortality provided farm production benefits, they were not enough for combined carbon and co-benefit values to offset implementation costs. Comparatively, water quality benefits achieved through biodiverse carbon plantings were closer in justifying carbon credits and co-benefits (Goyder Institute, 2019). Despite these economic findings, they represent case studies, where in fact farming systems would need to be assessed on a case-by-case scenario to determine specific economic return. Furthermore, the environmental benefits from changing certain farming practices should not be dismissed due to short-term economics as they will provide a suite of benefits long-term.

Greencollar (2017) have stated that landholders with carbon farming projects create additional co-benefits for landholders, producers, communities, and the environment and enhance long-term productivity and sustainability. Some of these co-benefits include: (copied from Greencollar, 2017).

Farming infrastructure and management changes

- Water conservation techniques
- Improved fencing
- Fire management activities
- Potential for lower stocking rates
- Increase and maintain ground cover
- Feral animal and pest control and
- Ability to afford supplementary feed in adverse conditions.

Risk mitigation

- Resilient income not reliant on commodity prices or affected by drought/weather and
- Implementation of closer monitoring and recording to make timely decisions.

Improving natural capital and surrounding environment

- Reducing wind and water erosion
- Improving soil health and water retention
- Higher productivity and improved animal health
- Restoring habitat for native flora and fauna
- Improving biodiversity and ecosystem connectivity and
- Reducing impacts of agriculture activities and adverse flow on effects.

Co-benefits are also recognised in the Agriculture Stewardship Package, where farmers are encouraged and rewarded for improving on-farm management practices to protect biodiversity and identify other sustainability opportunities (Australian Government, Department of Agriculture, Water and the Environment, 2021). This package is worth $34 million and has recently received additional funding from the 2021-22 Australian Budget (Australian Government, Department of Agriculture, Water and the Environment, 2021). Using environmental markets and certification systems, farmers can diversify and boost farm income through protecting and improving biodiversity. For example, the Carbon and Biodiversity Pilot will work with farmers who undertake plantings for carbon and provide additional payment for maximising biodiversity benefits by planting a mix of species and managing and looking after the vegetation (Australian Government, Department of Agriculture, Water and the Environment, 2021). The Carbon + Biodiversity Pilot currently takes place in six Natural Resource Management regions around Australia. This does not currently include the Mallee. However, if the pilot is successful, wider regions will be considered and the Mallee may be considered to participate (Department of Agriculture, Water and Environment, pers. comms., 7 May 2021).
Similarly, the proposed Enhanced Remnant Vegetation Pilot, also part of the Agriculture Stewardship Package, would pay farmers to enhance on-farm high conservation value remnant native vegetation through activities such

as installing fencing, weeding and pest control and replanting of native vegetation (Australian Government, Department of Agriculture, Water and the Environment, 2021). This pilot is still being scoped and expected to be released later in 2021.

The Commonwealth's Stewardship package is also proposing the establishment of an Australian Farm Biodiversity Certification Scheme, which will allow farmers to demonstrate best practice natural resource management to sustain and build biodiversity. This certification will initially be achieved through participation in the Carbon and Biodiversity Pilot and will allow consumers to identify Australian produce from farms that sustain and promote biodiversity (Australian Government, Department of Agriculture, Water and the Environment, 2021). Consequently, this certification could improve farmers' access to markets, create price premiums for produce, lower capital costs and improve education about beneficial land management practices.

Acting as an independent carbon farmer may also allow entry into selling carbon neutral products. For example, the global market is shifting towards demanding carbon neutral products, where multinational companies have demanded carbon neutral sugar, coffee and cocoa and wool retailers are requiring carbon neutral accounts for products (Curnow, M, 2021, pers. comm., 28 April). However, if farmers on-sell their carbon as offsets to other buyers, this may prevent them in settling their carbon neutral status and impede their ability to participate in markets demanding carbon neutral products (Curnow, M, 2021, pers. comm., 28 April).

Double counting should also be considered as a risk in the carbon market, where an abatement option linked with an offset project is used to meet multiple emission reduction targets (Macintosh, Roberts and Buchan, 2019). Without robust global guidelines, double counting can exist and so it is important that whatever market is engaged, it has transparency and accountability to reduce the risk of double counting.

Purpose of the literature review

South Australia's poor uptake of carbon farming projects is influenced by the lack of concise information, limited understanding on project methodologies and requirements and uncertainty around who is available to support and assist, i.e. independent advisors or brokers. South Australia's current farming systems may also have a role in the lack of uptake. For example, most farmers practice no till and stubble retention. Additionally, savannah burning, and land clearing are redundant practices compared to QLD and NSW, which have participated heavily in these two areas. The lack of uptake is reflected in Table 1, where excluding NT and ACT, South Australia has the lowest number of approved ERF Agricultural projects. This is further expanded on in the report 'Supporting agriculture to adapt to climate change,' (Department of Jobs, Precincts and Regions, 2019) where the inconsistent national climate change policy framework acts as a disincentive to industry, markets, and government to reduce carbon emissions.

More recently, the Australian and South Australian governments have emphasised and/or prioritised the importance of carbon farming initiatives in recent budgets and action plans, i.e. the SA Government is developing a *Carbon Farming Roadmap* to identify opportunities and remove barriers to the uptake of emission reduction and carbon sequestration opportunities. It's hoped this renewed governmental agenda will improve awareness and uptake of carbon farming initiatives. Additionally, the Carbon Market Institute, have recently recognised the number of farming activities that are not supported under the ERF scheme and are currently working with stakeholders to develop a method to capture all farming activities (de Wit, E, 2021, pers. comm., 29 April). Other state governments are also focussing efforts on independent carbon opportunities, in particular new carbon farming or carbon abatement programs being announced in NSW and Victoria (Barwick, J, 2021, pers. comms., 12 May).

Overcoming the barriers that limit South Australia's carbon farming potential will also present multiple opportunities for farmers to increase productivity, as well as reduce emissions and sequester carbon.

The purpose of this literature review is to explore carbon opportunities that apply to the South Australian Mallee region. The South Australian Mallee is bounded to the north and west by the Murray River, to the east by the Victorian border and extends approximately 50km south of the Mallee highway. The region receives between 200 – 450mm average annual rainfall with sandy dunes and loamy to clayey swales.

Cropping, grazing and land used for animal production (refer to Figure 3) will form the basis of this study, excluding activities such as horticulture and irrigated land as carbon opportunities in dryland settings will assist in replicating methods in similar areas around South Australia. Cropping and grazing throughout the Mallee specifically includes cereals, pasture legumes, native and exotic pastures, woody fodder plants, sown grasses, hay and silage, oilseeds, pulses, piggeries, poultry farms, feedlots and horse studs based on the Australian Land Use and Management 2016 spatial datasets.

The extent of cropping and grazing land throughout the Mallee opens up possibilities for carbon farming previously unventured. However, given the relatively inoperative status of current carbon projects in the region, the limitations preventing new uptake must first be understood.

This literature review will also explore factors preventing adoption of carbon projects to determine what is preventing industry as well as farmers in investing in this area.

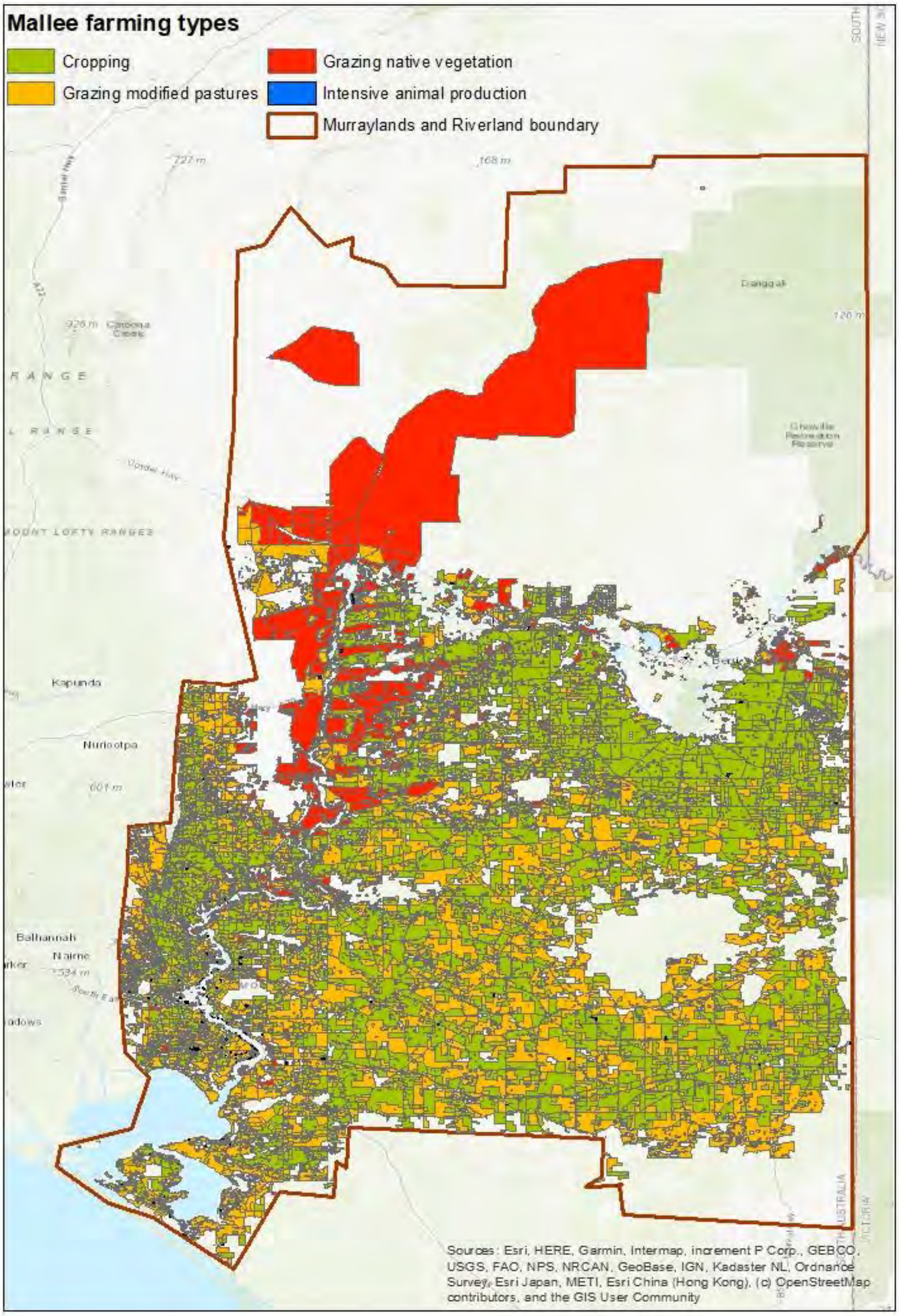


Figure 3. Murraylands and Riverland boundary encompassing the dominant farming types throughout the Mallee region, i.e. the southern extent of the map.

Carbon opportunities for the Mallee

Current ERF approved projects

Between 2015 and 2020, Australia experienced an expansion in carbon farming primarily driven by the Australian Government's acquiring of ACCUs under the AUD$2.5 billion ERF (Baumber, et al, 2020). A further AUD$2billion was directed from the Carbon Solutions Fund to continue the investment with the ERF (Baumber, et al 2020). Interestingly, Baumber et al, (2020) state that although there was rapid growth in ERF investment between 2015 and 2018, there has been reduced volumes of ACCUs sold due to the Clean Energy Regulator's reluctance to pay higher prices and potential sellers discouraged by the scheme's complicated administration. To increase the value of carbon projects, 'value-stacking' mechanisms, with co-benefits in production, environmental and social realms have been realised and should they grow, further expansion in carbon markets is expected (Baumber, et al, 2020). This mechanism was also pointed out by King, et al, (2019), where they recommended that multiple ERF projects on the same property using different methods should instead be submitted as a single, aggregated offset report covering each individual component as well as auditing of each individual project to occur at once rather than separately.

Along with 'vegetation' methods that can broadly cover things such as reforestation, revegetation and protecting native vegetation that is at risk of clearing, 'Agriculture' methods are also an option for carbon farming projects. As of April 2020, there have been several Agriculture and Vegetation methods registered with the ERF, outlined in Table 2.

Table 2. List of current ERF approved Agriculture and Vegetation methods as of April 2020 (Emissions Reduction Fund, 2021). Note that a closed Status means apart from existing projects, the method is not available for new projects.

Method	Category	Method	Status
Agriculture	Piggery	Destruction of methane generated from manure in piggeries	Closed
Agriculture	Piggery	Destruction of methane generated from manure in piggeries V1.1	Closed
Agriculture	Piggery	Destruction of methane from piggeries using engineered biodigesters	Closed
Agriculture	Piggery	Animal effluent management method	Open
Agriculture	Cattle	Reducing greenhouse gas emissions by feeding nitrates to beef cattle	Open
Agriculture	Cattle	Beef cattle herd management	Open
Agriculture	Dairy	Destruction of methane generated from dairy manure in covered anaerobic ponds	Closed
Agriculture	Dairy	Reducing greenhouse gas emissions by feeding dietary additives to milking cows	Open
Agriculture	Dairy	Animal effluent management method	Open
Agriculture	Irrigated cotton	Reducing greenhouse gas emissions from fertiliser in irrigated cotton	Open
Agriculture	Soil Carbon	Measurement of soil carbon sequestration in agriculture systems method	Open
Agriculture	Soil Carbon	Sequestering carbon in soil in grazing systems	Closed
Agriculture	Soil Carbon	Estimating sequestration of carbon in soil using default values (model-based soil carbon)	Open

Method	Category	Method	Status
Vegetation	HIR	Human-Induced regeneration of a permanent even-aged native forest	Closed
Vegetation	HIR	Human-Induced regeneration of a permanent even-aged native forest V1.1	Open
Vegetation	HIR	Avoided clearing of native growth	Open
Vegetation	HIR	Native forest for managed regrowth	Open
Vegetation	Environmental Plantings	Plantation forestry	Open
Vegetation	Environmental Plantings	Measurement based methods for new farm forestry plantations	Open
Vegetation	HIR	Avoided deforestation	Closed
Vegetation	HIR	Avoided deforestation V1.1	Open
Vegetation	Environmental Plantings	Quantifying carbon sequestration by permanent environmental plantings of native species using the CFI reforestation modelling tool	Closed
Vegetation	Environmental Plantings	Quantifying carbon sequestration by permanent environmental plantings of native Mallee Eucalypt species using the CFI reforestation modelling tool	Closed
Vegetation	Environmental Plantings	Reforestation and afforestation V1.0, V1.1 and V1.2	Closed
Vegetation	Environmental Plantings	Reforestation and afforestation V2.0	Open
Vegetation	Environmental Plantings	Reforestation by Environmental or Mallee Plantings – FullCAM	Open
Vegetation	Unknown	Verified carbon standard project	Open

The methods in Table 2 are constantly being updated and new methods developed. The Minister for Energy and Emissions Reduction, supported by the Department of Industry, Science, Energy and Resources develops the priorities for the new ERF methods and these currently include soil carbon, carbon capture and storage, biomethane, plantation forestry and blue carbon (Emissions Reduction Fund, 2021). A 'decision tree' (refer to Figure 4) has been developed by the CER to assist farmers in determining whether they are eligible under an ERF method.

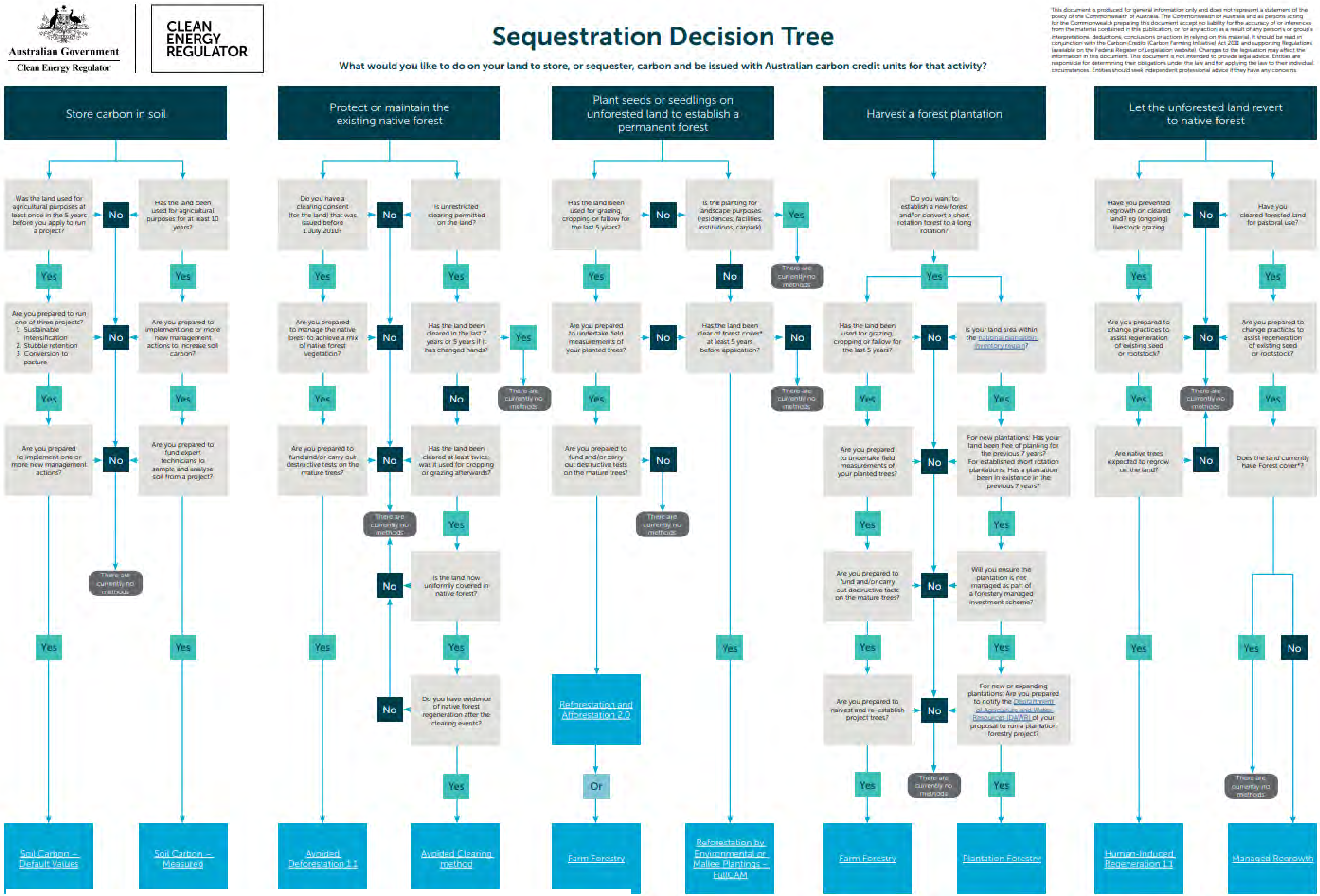


Figure 4. Demonstrating eligibility under an ERF method (CER, n.d.).

The ambiguity behind the ERF methods remains a limitation to uptake of projects and will be further explored in order to better understand the potential opportunity for Mallee farmers. The Kondinin Group's '*Workshop Manual: The business case for carbon farming: improving your farm's sustainability*,' (2021) explores ERF methods further by summarising and also outlining some of the major limitations.

Table 3. Summary of selected ERF agricultural methodologies (copied from Kondinin Group, Farming Ahead, 2021).

Method	Scope	Timeframe	Emissions targeted	Baseline	Calculation
	Defines the activities under the methodology	*Timing guidelines and the crediting period a project can apply to claim ACCUs*	*Defines the sources of emissions or savings covered by the methodology*	*Initial information required to evaluate the baseline case*	*The type of calculations or models used for calculating emissions*
Animal effluent management	For piggeries and dairies to develop new facilities for the treatment of animal effluent by emission destruction, emissions avoidance or both	Projects that generate electricity can have up to a 7-year crediting period. Projects that do not generate electricity, including projects that flare only have a 12-year crediting period	Organic effluent that would normally be treated in an anaerobic pond. Eligible material must be produced by either an eligible animal facility or a facility that produces a particular type or types of material as a waste stream.	The treatment can reasonably be expected to result in fewer emissions that if the effluent were treated in an anaerobic pond	The amount of emissions destroyed or avoided, then subtracting emissions from ineligible material and project emissions, such as from the use of fuel or electricity
Beef cattle herd management	Reduces the emissions intensity of beef cattle production by reducing cattle emissions per kg of liveweight produced	Seven years. It is recommended that the participant select a crediting period start date that is later than the declaration date of the project	Improving cattle productivity, reducing the average age of a herd, reducing the proportion of unproductive animals in a herd or changing the number of animals in each livestock class in the herd	Each herd must have historical emissions intensity data from the project's reference period, with the emissions intensity reference period calculated using three of the immediate past seven years	The difference between the herds' historical baseline emissions (minus four per cent) and the herds' emissions following implementation of project activities
Estimating sequestration of carbon in soil using default values	Specific project management activities on eligible land that aim to	Twenty-five years	Removing carbon from the atmosphere and storing it in the soil by setting	The baseline emissions period is five years before the project starts, representing the	Modelled using the Sequestration Value Maps, with calculations based on default values,

Method	Scope	Timeframe	Emissions targeted	Baseline	Calculation
	remove carbon from the atmosphere by increasing the amount of carbon added to the soil		up project management activities that change agricultural soil conditions to improve crop and pasture growth	level of emissions that would have been produced if your project did not go ahead	instead of measured values. The default values have already been modelled by FullCAM
Reducing greenhouse gas emissions by feeding dietary additives to milking cows	Increasing the fat content of a milking cow's diet reduces methane emissions produced as a result of enteric fermentation, done via feeding the following eligible additives to milking cows: canola meal; cold-pressed canola meal; brewers grain; hominy meal; or dried distillers grain.	Seven years	Improving feed quality for milking cows in this way means the animals can use energy from the feed more efficiently while enabling faster feed passage through the rumen, reducing the amount of enteric methane released	Baseline emissions are established by using data from three consecutive years in the seven years prior to the commencement of the project	The net abatement amount for each milking herd for each project year is calculated by entering data into the Dietary Fats Calculator which is available on the Department of Environment and Energy's website
Measurement of soil carbon sequestration in agricultural systems	Credits measured increases in soil carbon as a result of one or more new or materially different management activities in grazing or cropping land (including woody horticulture) that store carbon in that land.	The project must be maintained for a nominated period of either 100 or 25 years. Proponents can generally nominate the intervals of their reporting periods from one year to a maximum of five years	Corresponds to the increase in soil carbon over time, after the emissions caused by additional activities used to build soil carbon (for example extra fertiliser applications beyond the baseline) have been subtracted	Each crediting application requires at least one round of soil sampling, the calculation of net carbon abatement and inclusion of this and other required information in an offset report	Soil carbon stocks must be estimated using specified soil sampling methods and samples must be measured for soil carbon content using specified laboratory techniques or calibrated in-field sensors.

Method	Scope	Timeframe	Emissions targeted	Baseline	Calculation
Reforestation and afforestation V2.0	Involves planting forest trees in agricultural areas	Twenty-five years	This method helps to reduce the amount of greenhouse gas entering the atmosphere, as carbon remains stored in the trees while they grow	A permanent planting on land that has been grazed, cropped, or allowed to lie fallow (between grazing and cropping) for at least five years before you apply to run a project. The land must not be cleared native forest and must also be able to support the growth of new forest	The carbon stored by the project is calculated by directly measuring trees in sample plots using infield measurements, such as full inventory and permanent sample plot assessment.
Avoided clearing of native regrowth method	Protection of native forest areas for which clearing consent has previously been issued	Twenty-five years	Emissions from fuel use and fires. Carbon stocks in live and dead biomass	The baseline scenario involves modelling regeneration, clearing, and windrow and burn fires over a 100-year period. The project scenario is also a series of modelled events, which are only modelled as they occur	The difference between two scenarios is the amount of additional carbon stored as a result of your project. The net amount of abatement for the reporting period is then determined by subtracting any emissions due to fires from the total change in carbon stock.
Human-induced regeneration of a permanent even-aged native forest	Enabling native vegetation to regenerate	Twenty-five years	Emissions from fuel use and fires. Carbon stocks in live and dead biomass	The project area must not have any forest cover during the 10 year baseline period. The baseline period is determined by the date land was included in the project	Net abatement for each reporting period is calculated as the change in the amount of carbon stored in all carbon estimation areas, minus the emissions resulting from fire and fuel used in the process of establishing and maintaining the project.

Some of the major limitations and/or considerations of the methods outlined by the manual include:

- **Sequestering carbon in soils in grazing systems:** The methodology is technically complex particularly as it is based on samples or direct measurements. Specialist and technical assistance will be required if utilising this method; currently the cost of applying the accepted activity, sampling and administration is estimated to be more than the expected carbon sequestration payment;
- **Avoided emissions-animal waste:** Underlying technology is well established and the monitoring and measuring requirements under these methodologies substantial. Continual monitoring is needed to account for any breakdowns that occur during the project;
- **Avoided emissions-enteric fermentation in dairy cows:** According to scientific knowledge, this methodology plans for a dietary regime that will result in lower emissions per animal. This methodology requires continual measuring of feed inputs, milk production and the number of cows; and
- **Sequestration from vegetation plantings:** Forests established under these methodologies cannot be harvested for commercial purposes. Some of the sequestration methodologies require specific measurement and recording of all aspects of forest growth and development. The methodologies also include considerations when dealing with fire and other disturbances (Kondinin Group, Farming Ahead, 2021).

ERF mitigation options for SA agriculture were also identified by Schapel (2019) to include soil carbon, cattle and vegetation management. Within the methodologies, Schapel (2019) identified several pathways that could deliver carbon credits for SA agriculture including:

1. Reducing GHG emissions
    a. Reducing methane emissions from ruminant livestock through faster growth rates and earlier age to slaughter through increased pasture productivity and suitable pasture species selection
    b. Use of low methogenic pasture species for grass fed animals – work is required to extend findings of *Future Farm Industries Enrich* project (a SARDI led project)
2. Sequestering carbon
    a. Increase soil OC under cropped or pasture soils following adoption of an accepted activity including optimising use of fertilisers (inorganic or organic), application of a soil amendment to overcome a production constraint, pasture management and species selection for improved soil carbon input, optimising stocking rates, transitional soil improvement technique such as clay addition to sands or use of a subsoiler to improve crop or pasture productivity
    b. Reforestation of farms - replanting land no longer suitable for cropping under climate change, planting windbreaks for livestock health that also follows vegetation methodology

As well as ERF methods, there are large gaps in knowledge surrounding existing farming practices and whether they qualify under current ERF methods or as private entities. For example, clay spreading, stubble retention, shifted land use from cropping to pasture or transforming poor performing land to saltbush or lucerne are practices with potential carbon gains but remain in a state of question as to their place on a carbon market platform.

Emissions from farms will also need to be considered separately compared to whole farm emissions. For example, emissions can be accounted for through a farm's total emissions or through product intensity emissions, i.e. emissions per kg of animal. This is important as a number of significant export markets, including the EU, US and UK, are considering introducing tariffs on products with high carbon emissions or from countries with poor emission targets. In the near future, agriculture products will need to demonstrate they are accounting for and reducing whole-farm emissions to avoid tariffs (Curnow, M, 2021, pers. comm., 28 April. Current ERF methodologies require assessment for GHG emissions however farmers do not often have years of historical emission data. There is increased focus amongst industry, universities and governments in developing tools and resources to help producers measure and track their emissions.

Revegetation Activities

Mallee plantings

Australia's National Carbon Accounting System ensures credibility and aims to account for greenhouse gas emissions from land-based sectors in Australia and the tool FullCAM is used to quantify emission and credit return estimations (Hobbs et al, 2010). Hobbs et al (2010) claim that these tools were able to successfully quantify carbon estimations for commercial forestry under high rainfall zones however information for other native woody crop species and productivity rates of environmental plantings for medium to lower rainfall regions (<650mm) was poorly developed in South Australia and nationally. Despite the absence of comprehensive data throughout the region, Hobbs, et al, describe landscapes utilised for dryland agriculture in the lower rainfall regions (300-650mm) as having the greatest viability and prospects for investment in revegetation for carbon sequestration, sustainable woody crop production and beneficial environmental outcomes (Hobbs et al, 2010).
Trees For Life (TFL) is the dominant provider for trees and shrubs for environmental plantings through the Mallee region, providing 94% of the plants for revegetation as seen in Table 4 (Hobbs, et al, 2010).

Table 4. The top 50 most commonly planted species throughout the Murray Mallee based on 10 year s of TFL plant seedling distribution data (1999-200) (Hobbs, et al, 2010).

Species	Total Plants Last 10 Years
Eucalyptus fasciculosa	149,197
Allocasuarina verticillata	142,803
Eucalyptus leucoxylon	129,513
Eucalyptus camaldulensis	115,809
Acacia pycnantha	107,173
Melaleuca lanceolata	105,802
Dodonaea viscosa	71,591
Eucalyptus socialis	63,136
Eucalyptus porosa	59,291
Eucalyptus gracilis	51,282
Melaleuca halmaturorum	49,245
Eucalyptus incrassata	43,188
Callistemon rugulosus	39,858
Acacia paradoxa	39,350
Eucalyptus odorata	38,761
Eucalyptus dumosa	38,375
Eucalyptus leptophylla	36,347
Melaleuca uncinata	36,044
Acacia brachybotrya	33,784
Melaleuca acuminata	31,275
Eucalyptus oleosa	31,240
Eucalyptus viminalis	30,478
Eucalyptus largiflorens	30,061
Callitris gracilis	29,537
Eucalyptus calycogona	27,648
Acacia acinacea	26,595

Species	Total Plants Last 10 Years
Acacia ligulata	26,289
Acacia myrtifolia	24,068
Bursaria spinosa	23,577
Allocasuarina muelleriana	22,931
Pittosporum angustifolium	22,140
Eucalyptus brachycalyx	21,828
Acacia microcarpa	21,776
Acacia calamifolia	21,673
Leptospermum lanigerum	18,735
Leptospermum continentale	18,147
Eucalyptus phenax	17,861
Melaleuca decussata	16,868
Eucalyptus baxteri	14,692
Acacia retinodes	14,448
Acacia rigens	14,153
Acacia longifolia ssp. sophorae	12,786
Acacia hakeoides	12,385
Eucalyptus cosmophylla	11,970
Acacia dodonaeifolia	10,650
Banksia marginata	10,460
Xanthorrhoea semiplana	10,234
Acacia cupularis	9,668
Eucalyptus diversifolia	9,428
Allocasuarina striata	8,997
All other species (n=84)	422,554
Total of all species (n=134)	2,375,702

The then SA Department of Water, Land and Biodiversity Conservation (now Department for Environment and Water) commissioned studies to estimate the number of hectares of commercial farm forestry and environmental revegetation planted across the state based on nursery surveys of plant sales and their distribution (Hobbs, et al, 2010). Minimal information on the Mallee region was available however it was estimated that a minimum of 2,400 hectares of environmental revegetation was planted between 1998 and 2008, with numbers increasing every year (Hobbs, et al, 2010). Whether or not land caretakers, including farmers, have been increasing planting numbers with the intention of carbon sequestration or to achieve some of the co-benefits mentioned previously is not known however would have been achieved regardless.

Interestingly, Hobbs, et al, (2010) claim that the carbon sequestration potential of environmental plantings may be increased through the use of increasing the proportion of fast growing and productive species in the plantings mix. Even though, combining more productive species tends to increase tradable carbon stocks and may have some natural resource management benefits they can also ultimately lower biodiversity values. This is supported by Neumann, et al, (2011) who state that species suited to the lower and medium rainfall environments include Sugar gum (*Eucalyptus cladocalyx),* WA Swamo yate (*E. occidentalis*) and Blue Mallee (*E. polybractea*) and are often more productive than environmental plantings at the same density. Neumann, et al, (2011) also state that if plantation productivity and carbon prices are the sole driver for investment then economic forces will tend to push carbon plantings towards these more productive species unless government subsidies, such as the recently introduced Biodiversity and Carbon pilot, bridge the economic gap.

Hobbs, et al, (2010) conducted a study across the Mallee in the low to medium rainfall zones (300-650mm) to assess plant growth and carbon sequestration rates from forestry and environmental plantings in order to improve understanding of plantation information. They found that planting density (tree per hectare) and average annual rainfall have the greatest influence on the productivity in woodlots, i.e. blocks and windbreaks containing monocultures and environmental plantings, i.e. blocks and windbreaks containing mixtures of native species for biodiverse/habitat plantings or other environmental services (Hobbs, et al, 2010). By analysing growth rates, they also found there was no statistically significant soil type or fertility influences on productivity. This is critical information as there is large variation in rainfall and soil type across the Mallee. Annual carbon sequestration rates for environmental and woodlot plantings are estimated by Hobbs, et al, (2010) in Table 5 and show that the Mallee can sequester between 5.29 CO_2-e t/ha/yr for woodlot plantings and 5.75 CO_2-e t/ha/yr for environmental plantings.

Table 5. Total land area and potential agricultural land for carbon sequestration activities by sub-region (Hobbs, et, al).

Regions	Annual Rainfall (mm) [range]	Total Land Area (ha)	Potential Agric. Land (ha)	% of Land Area	Carbon Sequestration (CO_2-e t/ha/yr) [range]	
					Woodlots at 800tph	Env.Plant. at 1400tph
IBRA Sub-region (part)						
Fleurieu	469 [313-650]	199,524	181,928	91%	7.49 [4.49-10.83]	6.74 [5.33-8.03]
Murray Mallee	339 [257-440]	992,324	889,548	90%	5.29 [2.98-7.13]	5.75 [4.41-6.61]
Murray Lakes & Coorong	413 [356-579]	141,076	97,131	69%	6.25 [4.40-9.32]	6.21 [5.29-7.49]
Lowan Mallee (N)	311 [282-347]	235,604	120,787	51%	4.53 [2.86-5.53]	5.35 [4.33-5.88]
Lowan Mallee (S)	400 [333-437]	357,271	98,468	28%	5.50 [4.49-6.97]	5.86 [5.34-6.55]
Tintinara	452 [377-521]	494,913	378,428	76%	6.59 [4.64-8.37]	6.37 [5.42-7.12]
NRM Region (part)						
Murray-Darling Basin (S)	365 [258-650]	1,814,839	1,363,283	75%	5.60 [2.86-10.83]	5.89 [4.33-8.03]
South East (N)	446 [375-522]	598,528	397,167	66%	6.49 [4.68-8.37]	6.33 [5.44-7.12]
Study Area	385 [257-650]	2,420,712	1,766,290	73%	5.81 [2.98-10.83]	5.99 [4.33-8.03]

Wind Breaks

Wind breaks are commonly used in Australian farming practices to improve the capacity of crop systems to increase yields as well as mitigate greenhouse gases. As well as storing carbon in their above and below-ground woody tissues, they also provide wind protection to crops, improve soil condition, wildlife habitat and increase crop yields over time. The potential of windbreaks within a carbon farming scenario in the Mallee has recently gained attention where further studies will be conducted (Seaman, R, 2021, pers. comm., 12 May). It was commented that windbreaks in the Mallee may be one of the most achievable carbon farming methods under the ERF at this point in time (Seaman, R, 2021, pers. comm., 12 May). Through the environmental planting methods, direct seeding or block planting can take place on land parcels usually up to a maximum of 200ha (specific for the Mallee) (Seaman, R, 2021, pers. comm., 12 May). Once established, Mallee farmers can then run stock through, provided ERF method requirements have been met.

Low-carbon value vegetation

Hobbs, et al, (2010) point out two characteristically Mallee plants as having low carbon value due to their makeup . For example, *Acacia* species can be highly productive in early stages of growth but may not persist over the long term and most saltbushes may not meet the minimum height requirements of 2m set out by the ERF methodologies.
However, roots play an important role in increasing OC at depth through increased root biomass, root exudates and sloughing of cells (Schapel, Davenport & Bell, 2021). The OC can be transformed through the clay fractions from particulate to a humic form via the root exudates encouraging microbes deeper into the soil (Schapel, Davenport & Bell, 2021). In the case of saltbush, OC will be captured but after five years, the saltbush will reach an equilibrium and more saltbush will need to be planted in order to continue the carbon cycle (Curnow, M, 2021, pers. comm., 28 April). Even though not currently recognised through the ERF scheme alone, saltbush may fall under the perennial pasture method or be considered under a voluntary carbon market (Curnow, M, 2021, pers. comm., 28 April).

Additionally, the Carbon Market Initiative is working with stakeholders and looking at how to capture all farming activities that take place on a farm (Elisa de Wit, 2021, pers. comm., 28 April). If successful, salt bush amongst other common farming practices that are not currently recognised may be accounted for under this new method. Another species that is currently under investigation (in WA) for being approved within an ERF method is Tagasaste. This perennial can be used in cattle and sheep systems as a food source and is increasing in popularity in many agriculture areas around South Australia (Curnow, M, 2021, pers. comm., 28 April).

Notedly, there has reportedly been periodic management clearing of vegetation in the Mallee, specifically 12 sites ranging from 55ha to 558ha (Hanisch, D, 2021, pers. comms., 31 March). There is potential here for the clearing to cease and instead implement a HIR project. A HIR method compliments this practice as it is classed as existing vegetation under 2m height or 20% canopy cover, where parts that are dozed, can regenerate from root stock. This method often suits pastoral lands, where managed grazing can take place given project requirements are met. In contrast, environmental planting methods may be more suitable for Mallee farmers compared to HIR methods as most land has been historically cleared for cropping and grazing.

Overall, planting out perennials, grasses and fodder shrubs throughout the Mallee will ultimately result in increased soil carbon and/or additional environmental benefits such as addressing emerging issues through the area such as salinity and seepage. The potential co-benefits of improved soil health and productivity may also improve farm business however more research is needed to quantify and demonstrate what these opportunities are. Likewise, areas planted, even though not considered directly under an ERF, can still sequester carbon and when whole-farm emissions are counted, can be used to offset other livestock/farming emissions (if not trading carbon).

There have been cases where projects being undertaken across pastoral zones have had negative land management outcomes. For example, forest plantings have meant that large areas previously considered as invasive native scrub is now valuable forest (RegenCo, 2021). Additionally, the HIR method encourages planting native woody species that may have previously been considered to negatively impact on natural resources through reduced ground cover and carrying capacity (RegenCo, 2021). Although this study involved pastoral rangelands with different land systems compared to the Mallee, it is still important to consider as more research will need to be done to identify if this concern is applicable to Mallee land.

Carbon project companies, such as Greencollar, RegenCo and others, have not yet had a strong presence in the Mallee region as current limitations such as carbon price and methodology requirements do not make it commercially viable (Daley, W, 2021, pers. comms., 14 May). However, improvements to methodology and technology to encompass the Mallee’s conditions will likely allow for greater participation and subsequently interest from carbon project companies.

Livestock Management

Carbon farming options for livestock is a particularly important avenue to consider as there are an increasing number of farmers in the Mallee incorporating livestock into a mixed-farming enterprise (Randall, R, 2021, pers. Comm., 30 April). Resultingly, this also means farmers are increasing their carbon footprint compared to cropping due to the increased methane emissions. As a general consequence of drought and the high return for livestock, farmers have integrated livestock into their systems and are realising the benefits of diversification.

Mallee farmers are often situated on non-wetting or poor-performing sandy soils (sandhills) and by planting out some of these areas to perennial pastures or native grasses and focusing their cropping or other enterprise on more productive areas, dual benefits can arise. For example, a diverse mix of pastures and grasses will increase resilience to drought through improving soil structure, water holding capacity and if grazed with appropriate management, can increase soil carbon through controlled grazing, manure and saliva stimulation, i.e. livestock saliva can stimulate plant growth (Liu, et al, 2021). These sandy areas would ideally be ameliorated with clay however given clay-spreading can be costly, planting out these areas may be more feasible for some farmers. More research and extension is needed in this area of work to validate consistency across vegetation species and environments, however there is strong premise for the co-benefits of increasing mixed pasture, grasses and grazing livestock.

In terms of the ERF and vegetation activities, HIR methods (Human-Induced regeneration of a permanent even-aged native forest), such as removing stock away from areas to allow re-growth, have reportedly lower upfront costs compared to environmental planting methods (Hanisch, D, 2021, pers. comm., 31 April). For example, in Kangaroo Island, farmers would allow stock to graze over a seven-year (or less) period and then remove stock to allow re-growth (Hanisch, D, 2021, pers. comm., 31 April). Any longer than seven years would disqualify this HIR method and it would fall under the Native Vegetation Act (Hanisch, D, 2021, pers. comm., 31 April). However, farmers reportedly lack the 10-year evidence needed to meet the CER's requirements, i.e. to demonstrate when land was cleared. Though removing stock can count towards a HIR method, a farmer would need to consider the value of grazing versus not grazing under an ERF method.
Nevertheless, this practice of grazing and then removing stock would be beneficial for carbon gains regardless if not worth it under an ERF method.

Macintosh, Roberts and Buchan (2019) reported on the opportunities for Australian agricultural producers to participate in carbon markets and the barriers that are preventing these opportunities to come to fruition. They identified that there were three categories of emissions that can arise from the management of livestock and these include:

- CH_4 emissions from enteric fermentation
- CH_4 and N_2O emissions from manure management and
- N_2O emissions from agricultural soils associated with urine and dung and the application of manure as organic fertiliser.

Detailing the main abatement options for each category, Macintosh, Roberts and Buchan (2019) suggest that through feed and herd management, livestock emissions could be reduced by approximately 20-30%; the equivalent of 10-15 $MtCO_2$-e yr^{-1}. For example, Table 6 shows the supply-side abatement options for enteric fermentation emissions. Even though these abatement options are targeted Australia wide, several of the options can be applied to farmers in the Mallee.

Table 6. Supply-side abatement options for enteric fermentation emissions (copied from Macintosh, Roberts and Buchan, 2019).

Abatement option	Description
Reducing livestock	Reducing the number of livestock
Animal breeding and genetic manipulation	Selective breeding or genetic manipulation of livestock to reduce methanogenesis or improve feed conversion efficiency
Improved management	Management of livestock herds to maintain or increase output while reducing emissions (e.g. reducing unproductive animal numbers, reducing slaughter ages, and extending lactation in dairy cows)
Improved feed quality	Improving the quality of feed eaten by livestock to reduce CH4 production per unit digested (e.g. by encouraging grazing on less mature grasses, switching from C4 to C3 grasses, and providing feeds with lower fibre and higher soluble carbohydrates)
Dietary supplements	The feeding of dietary supplements – yeast cultures, dicarboxylic acids, nitrates, condensed tannins etc. – that reduce methanogenesis
Biological control	Reducing CH4 production by introducing competitive or predatory microbes (e.g. bacteriophages and bacteriocins) to the rumen of livestock
Vaccination	Reducing CH4 production by vaccinating livestock against methanogens
Chemical defaunation	Reducing CH4 production in the rumen using chemicals (e.g. bromochloromethane, chloroform and monensin).

The idea of a feed additive is also explored by the South Australian Government Climate Action Plan (2021), where the commercial production of a species of seaweed that when processed and added to feed, can reduce livestock methane emissions by up to 80% with no impact to productivity. The native species of red seaweed, *Asparagopis*, contains chemicals that inhibit fermentation within a ruminant's gut and while there is no commercial production of the seaweed, it is currently being researched and refined and may provide Mallee livestock farmers an additional method to reduce methane emissions.

Issues or barriers around its commercial application and feasibility are also still being investigated. For example, what sort of delivery mechanisms are required for adequate uptake, i.e. will the seaweed be introduced into feed through pellet coatings, mixed into self-feeders, is it only appropriate for feedlots, how will it be used on broadacre settings, which rate is appropriate and can this be repeated all year and what is the cost and logistics of transporting this to the Mallee (Curnow, M, 2021, pers. comm., 28 April). Main (2021) was able to clarify some of these concerns by highlighting that it will be very efficient to transport the bagged seaweed to farmers in the Mallee. The feed will initially be available for dairy and feedlot supplementary feeding as well as other supplementary feeding, i.e. sheep and the feed will be available in the long term as specific doses for broadacre farmers to be delivered by drones (Main, A, 2021, pers. comm., 7 May). The feed is likely to become commercially available in early 2022 to early adopters (Crooks, R 2021, pers. comms., 17 May). Main (2021) also stated that the Australian Government's ERF scheme presents logistical limitations and instead, the seaweed feed is expected to be a success within voluntary carbon markets (Main, A, 2021, pers. comm., 7 May). Further research will need to validate these concerns and ensure the applicability of the feed in the Mallee setting.

The Australian Government, Department of Agriculture (2013) found that a range of tropical legumes and novel forages such as turnip, plantain and chicory as well as plant extracts and grape marc (specifically tested on dairy cows) have the potential to reduce methane production in the rumen while maintaining or increasing productivity. The most effective feed, with up to 50 per cent reduction in methane production (under laboratory conditions) was *Eremophila glabra,* or 'tar bush' (Australian Government, Department of Agriculture, 2013). Some of these forages are not a common Mallee feature and so researching the methane production potential of common Mallee pastures such as medic, Indian hedgemustard, and saltbush would be recommended.

Eligible feed additives under the 'Reducing greenhouse gas emissions by feeding dietary additives to milking cows' ERF method include:

- canola meal
- cold-pressed canola meal
- brewers grain
- hominy meal and
- dried distillers grain (Kondinin Group, Farming Ahead, 2021).

These feed additives are high in fat, enhancing the feed conversion efficiency and causing faster feed passage through the rumen (Kondinin Group, Farming Ahead, 2021). This process reduces the amount of enteric methane released and therefore avoids emitting methane. If implementing this under the ERF, the strict monitoring, measuring and reporting records will need to be followed however farmers can also adapt these additives into their own feeding schedule and participate in voluntary or independent carbon farming. More research would need to be done on specific voluntary markets that would take these practices on board.

In addition to feed additives, converting urea lick blocks to nitrate lick blocks is readily achievable for Mallee farmers and is increasing in occurrence throughout the area (Seaman, R, 2021, pers. comm., 12 May). Commercial lick blocks have been found to reduce methane production by 22 per cent in penned sheep and by 8 per cent in sheep grazing paddocks (Australian Government, Department of Agriculture, 2013). However, dietary nitrate is recommended in areas where forage quality is low otherwise this can pose the risk of nitrate poisoning (Australian Government, Department of Agriculture, 2013).

Work by SARDI has found that saponins in lucerne, annual medic and alternative legumes reduce methane emissions (Peck, D, 2021, pers. comm., 17 May). Lucerne and annual medics are widely used in Australia, are well understood by farmers and advisors, have an established seed industry and hence have no barriers to adoption of high saponins cultivars. Work SARDI conducted in 2013-2015 found that in late spring feeding unharvested vetch (grain component has high protein and DMD) or lucerne had higher liveweight gains and lower methane intensities than feeding unharvested oats or barley (Peck, D, 2021, pers. comm., 17 May). Supplementary feeding during the dry period may also have large impacts on methane emission intensities (Peck, D, 2021, pers. comm., 17 May).

The 'Animal effluent management,' ERF method lists the following management activities:

Emissions destruction

- generate biogas from organic effluent in an anaerobic digester, either with a covered pond or digester tank or
- capture and destroy the methane component of the biogas from the organic effluent by either flaring it or generating electricity.

Emissions avoidance

- remove material that includes volatile solids (diversion of the material) or
- treat the diverted material aerobically in a way that produces materially fewer total methane and nitrous oxide emissions than would be produced by treatment in an anaerobic pond (a post diversion treatment).

Similar to the feed additive method, if these effluent management activities are used under the ERF method, the exact project requirements will need to be followed. However, farmers can also use these methods under the voluntary market or as independent emission reduction options on farm. More research would also need to be done on specific voluntary markets that would take these practices on board.

Methane reducing activities was also stressed in the UN's recent report, 'Global Methane Assessment,' (2021) and echoes some of the same reduction methods previously mentioned. Methane is 84 times more powerful in trapping heat than carbon dioxide over a 20-year period, and the report states that 42% of human-caused methane emissions come from agriculture. i.e. manure and enteric fermentation as well as rice cultivation (Climate and Clean Air Coalition and United Nations Environment Programme, 2021). The report advocates for measures such as transitioning to renewable energy and economy-wide energy efficiency improvements and calls for a rising global tax on methane emissions starting from US$800 per tonne could reduce methane emissions by as much as 75 per cent by 2050 (2021).
The report also highlights that due to limited potential to address agriculture's methane emissions through technological measures, behavioural change measures and innovative policies are necessary, i.e. reducing food waste and loss, improving livestock management and the adoption of healthy diets (vegetarian or with a lower meat and dairy content) (2021). The following table includes the 'Targeted Measures' from the UN's report for the agriculture sector.

Table 7. Targeted and additional measures for reducing methane emissions in the agriculture sector (copied from the Climate and Clean Air Coalition and United Nations Environment Programme, 2021)

Targeted Measures	**Improve animal health and husbandry**: reduce enteric fermentation in cattle, sheep and other ruminants through: feed changes and supplements; selective breeding to improve productivity and animal health/fertility; shift from pastoral to intensive systems for cattle
	Livestock manure management: treatment in biogas digesters; decreased manure storage time; improve manure storage covering; improve housing systems and bedding; manure acidification.
	Agricultural crop residues: prevent burning of agricultural crop residues
Additional Beneficial Measures	**Reduced food waste and loss:** strengthen and expand food cold chains; consumer education campaigns; facilitate donation of unsold or excess food.
	Adoption of healthier diets: decrease intake where consumption of ruminant products is above recommended guidelines.

The targeted measures included in Table 7 would be possible for farmers in the Mallee to implement however the additional measures would require more research as to logistics and their applicability in the region.

Case Example: Katanning Research Facility, WA

The abatement options, improved management and animal breeding listed above, were identified by a research team at the Department of Primary Industries and Regional Development in WA working on the Katanning Research Facility in WA. The facility aimed to undertake a baseline carbon footprint assessment and an emissions reduction strategy with the goal of achieving carbon neutrality for the facility by 2030 (Department of Primary Industries and Regional Development, 2021). The Katanning research takes place on land with similar environmental characteristics to the Mallee, (Curnow, M, 2021, pers. comm., 28 April) and, as such, some of these options may be implemented into South Australian farming systems.

In order to reduce emissions, options such as reducing total sheep numbers by mating all replacement ewes to Merino sires or by buying replacement maiden ewes or adult ewes to run a sustainable stocking rate, breeding low methane sheep (an animal's methane production level is a heritable trait) and trialling methane-mitigation feedstuffs including legumes, 3NOP, and Red *Asparagopsis* (Department of Primary Industries and Regional Development, 2021). Additional agricultural options included:

- Improving pasture legume content before cropping to reducing the N fertiliser required as well as improving weed control
- Reducing the amount of crop or changing crop types
- Prevent soil erosion cause by wind and/or water and claying or liming to improve soil
- Including carbon into the soil through green and brown manuring and addition of biochar and
- Changing grazing pasture species to alternate legumes, saltbush and brown shrubs as well as rotationally grazing

The team also included options utilising vegetation including:

- Saltbush systems and fodder shrubs
- Alley farming, shelterbelts, shelter-paddocks and windbreaks
- Remnant vegetation rehabilitation and
- Permanent eucalyptus and Sandalwood plantations

Given there is intensive livestock systems such as piggery, chicken, sheep and cattle production throughout the Mallee, manure management should also be considered as an emission reduction method. Specifically, methane emissions are produced from the decomposition of organic matter in manure under anaerobic conditions and N_2O can either occur through the nitrification and denitrification of ammoniacal nitrogen wastes or via nitrogen runoff, leaching and the buildup of nitrogen volatilized from manure management systems (Macintosh, Roberts and Buchan, 2019). Macintosh, Roberts and Buchan (2019) state that there are several ways to mitigate emissions from manure and these are highlighted in Table 8.

Table 8. Supply-side abatement options for manure management (copied from Macintosh, Roberts and Buchan, 2019).

Abatement option	Description
Reducing crude protein	By reducing crude protein in an animal's diet, the amount of nitrogen in manure decreases (N2O emissions). However, this may also result in higher CH4 emissions.
Additives	Adding fibre, acids and enzymes to decrease NH4 in manure.
Air scrubbers	Scrubbers reduce NH3 emissions from livestock housing with forced ventilation.
Frequent waste removal	Increasing the frequency of the removal of waste.
Anaerobic digesters	Treating waste through an anaerobic digestor, where CH4 and CO2 is produced as by-products
Acidification	Adding acid to manure to lower the pH and inhibit urease-producing bacteria, which in turn can lower NH3 emissions.
Shallow injections	Shallow injection of manure into the soil, as opposed to surface spreading, to reduce the NH3 emissions, noting this may increase N2O emissions.

Acidification is also explored in the Global Methane Assessment report (2021), where widely available acids such as sulfuric or lactic acid is added to manure slurry ponds to reduce emissions. While both seem to offer the potential to significantly reduce methane as well as ammonia emissions, there has been limited use of such techniques worldwide due to the safety concerns of handling acids and uncertainty around the long-term impacts to the soil (Climate and Clean Air Coalition and United Nations Environment Programme, 2021). Further research will need to validate these concerns.

Livestock management also results in soil-related N_2O emissions, mostly through nitrification and denitrification of which account for almost 40% of annual agricultural soil emissions around Australia (Macintosh, Roberts and Buchan, 2019). However, NH4 and NO3 levels, anaerobicity, temperature, carbon content and acidity of the soil all influence the extent of N_2O emitted from the soil, presenting a technical barrier to mitigation as projections and estimations of the emissions impacts on abatement options become difficult.

Soil Management

Sandy soils throughout the Mallee have low nutrient and water retention, making it difficult to increase OC content. The low reactive surface area of sandy soils allowing only minor amounts of OC to be stabilised and protected is the underlying reason behind the difficulty in increasing OC content. Ingram and Fernandes (2001) in Schapel, Davenport and Bell's literature review (2021) have grouped factors influencing OC storage into potential, attainable and actual. Potential storage includes factors influencing soil type including, clay content (potential is greater for clay compared to sandy soils), mineralogy (high cation exchange capacity and presence of multivalent cations such as calcium, aluminum and iron enhances C sequestration), soil depth (OC decreases with depth) and bulk density (copied from, Schapel, Davenport and Bell 2021). Attainable storage is determined by environmental factors that directly affect plant production such as climate and solar radiation and actual storage is determined by management practices that increase OC inputs or decrease OC losses (copied from, Schapel, Davenport and Bell 2021).

However, the long-term storage of OC is only achieved through biological transformation of particulate OC to more stable fractions, humus and resistant OC as fewer stable forms are more readily lost from the soil following disturbance (Schapel, Davenport and Bell, 2021). OC occurs as four fractions with varying turnover time in the soil. The actively decomposing fraction consists of:

- dissolved and particulate fractions and has a turnover time of less than a few hours through to a few decades
- a stable humus pool and this generally lasts for decades to centuries and
- a resistant fraction, which can take several thousand years to decompose and is relatively inert (copied from, Schapel, Davenport and Bell 2021).

When organic matter moves through each fraction it increases with nutrients and becomes more resistant to decomposition by soil microbes (Schapel, Davenport and Bell 2021). The humus fraction as part of OC generally increases with depth and is influenced by soil texture and comparatively particulate fraction decreases with soil depth and is influenced by management and climate factors (Schapel, Davenport and Bell 2021). Regular and substantial OC inputs have been successful in improving the OC content of soils.

Subsoil Clay Addition

Subsoil clay addition to sandy soils (clay modification) aims to overcome water repellence, improve water retention, fertility and plant productivity, and is looked at by Schapel, et al, (2018) in the Goyder Institute Technical Report. Clay modified soils is included under the ERF soil carbon method, 'Measurement of Soil Carbon Sequestration in Agricultural Systems,' and must be conducted under the following rules to be eligible:

- any soil is sourced from a carbon estimation area that is part of the project
- sampling is undertaken at a depth greater than the depth of any soil and
- the land where any soil is sourced is remediated as soon as is practical.

Note: Remediation could involve returning sandy topsoil to a clay pit immediately after the clay is extracted.

Using existing South Australian information on soil OC in clay-modified soil and comparing results to unmodified sandy soil, Schapel, et al, (2018) found that soil OC can increase between 4-8t tha^{-1} in clay-modified soils. This is approximately 15-30 tons of CO2 equivalent (1 T C /ha = 3.67CO_2e). Additionally, UK field trials comparing the effectiveness of bentonite and kaolin addition to sandy soils found that both clay types increased crop growth, yield, increased CEC, OC, C:N ratio, microbial activity nutrient efficient, water retention and soil pore characteristics (Schapel, Davenport and Bell 2021).

Schapel, et al, (2018) also claim that further carbon sequestration is possible if factors affecting OC on varying soil types and rainfall zones are considered including:

- rainfall which governs the amount of above and below ground biomass that can be grown and ultimately contribute to OC
- clay concentration determines the amount of OC that can be bound and protected, governed by the amount of subsoil clay added to the sand and
- depth to subsoil clay (soil type) influences the movement of water and nutrients. Generally, subsoil clay is at depths greater than those modified by clay application (copied from Schapel, et al, 2018).

Additionally, Schapel, et al, (2018) identified several practices that would improve the likelihood of creating a clay-modified soil that can achieve its OC sequestration potential including:

- clay clod distribution (depth of incorporation and clay source) especially for soil types where subsoil clay is greater than 70 cm depth
- nutrient application matched to the new clay-modified regime to enable optimal biomass growth
- farming system suited to soil type and rainfall zone
- time since clay modification although this most likely reflects development of more effective clay modification practices over recent times and
- clay clod size and effect on OC concentration (copied from Schapel, et al, 2018).

Schapel, Davenport and Bell (2021) also state that in addition to the original clay added, organic matter incorporated during the clay amendment process les to higher OC stock compared to treatments missing the extra addition and may offset the loss of OC resulting from soil disturbance.

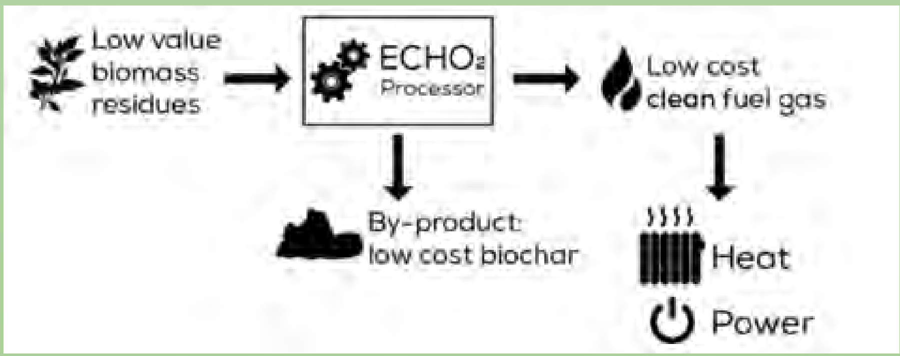
Soil Amendments

Livestock biochar is a natural feed additive made from charcoal and is produced by pyrolysis of biomass. During the digestion process, biochar is enriched with nitrogen-rich organic compounds (Schmidt, et al, 2019). The resulting biochar-manure is a more valuable organic fertiliser causing lower greenhouse gas emissions and nutrient losses during storage and soil application (Schmidt, et al, 2019).

As well as having multi-layered benefits for livestock, most commonly cattle, sheep and pigs, biochar's chief quality is as a soil ameliorant. Adding biochar to soil has the potential to increase carbon content and ultimately reduce overall greenhouse gas emissions (Australian Government, Department of Agriculture, Water and the Environment, 2019).

CASE EXAMPLE: RAINBOW BEE EATER – SA

The Australian company, Rainbow Bee Eater, uses a technology called, 'ECHO2,' where they produce biochar as well as the by-product, syngas as seen below:



A local example of their work was in Tantanoola, where they partnered with the herb-growing company Holla-Fresh. Plant material is brought to Holla-Fresh by the compost company, BioGro and processed through ECHO2. With a circular economy approach, Holla-Fresh utilise the syngas as energy for operating their production plant, BioGro take away the final biochar product and Rainbow Bee Eater are able to claim the carbon credits that this production of biochar produces (Burgess, P, 2021, pers. comms., 7 May).

Rainbow Bee Eater have used Puro.earth (voluntary carbon market) where Microsoft, Shopify and others have purchased the carbon credits. For farming communities and other regions with suitable biomass residues, this process may return the benefits of biochar and energy use as well as the possibility to use an ERF method where less fertiliser is used, i.e. reducing methane and nitrous oxide emissions. (Burgess, P, 2021, pers. comms., 7 May). More field-based research will need to be done on validating this claim.

Considerations include overall coordination, where the farmer will collect plant material and as syngas (a fuel gas) is produced there will need to be a local use for heat, electricity or in the near future hydrogen that can be generated, i.e. piggery, feedlot, electricity user etc otherwise energy can be returned to the grid (Burgess, P, 2021, pers. comms., 7 May). As a relatively new system for production, Rainbow Bee Eater presents an opportunity for farmers to collectively participate within a carbon farming opportunity presenting several forms of benefits.

However, the accuracy of measuring the carbon from the biochar is ambiguous as the carbon in the biochar needs to be analysed or it assumed that 100% of the mass of biochar applied is carbon and this can lead to an over or under estimation of the final carbon value (Schapel, A, 2021, pers. comm., 11 May).

Adding organic matter, such as green or brown manure is another amendment successful in sequestering soil carbon as well as providing co-benefits such as improved soil structure, improved plant growth, increases in soil nitrogen, prevention against erosion and increase water and nutrient retention. Addition of these organic amendments are allowed under the Soil Carbon Sequestration in Agricultural Systems Methodology provided the project's requirements are followed and met.

Soil Carbon Sequestration in Agricultural Systems Methodology

Although components of this method may have been mentioned throughout different sections of this review, a holistic view of the method is useful in summarising a range of actions that can build soil carbon. Additionally, these components can be practiced regardless of the ERF scheme, under voluntary markets or independent carbon faming to build soil carbon.

Provided the conditions of this specific method are met, such as using specific soil sampling techniques, projects can introduce one or more of the following activities:

- apply nutrients to the land in the form of synthetic or non-synthetic fertiliser to address a material deficiency
- apply lime to remediate acid soils
- apply gypsum to remediate sodic or magnesic soils
- undertake irrigation activities from new irrigation efficiency savings
- re-establish or rejuvenate a pasture by seeding establishing, or permanently maintaining, a pasture where there was previously no pasture, such as on cropland or bare fallow
- alter the stocking rate, duration or intensity of grazing
- retain stubble after a crop is harvested
- convert from intensive tillage practices to reduced or no tillage practices
- modify landscape or landform features to remediate land (e.g. undertake water ponding), or
- use mechanical methods to add or redistribute soil (copied from Kondinin Group, Farming Ahead, 2021).

Stubble retention, no till and altering fertiliser type, i.e switch to more nitrate-based fertilisers or adding soil amendments such as biochar have been commented on as farming practices that will be the most achievable for Mallee farmers in a cropping farming system (Seaman, R, 2021, pers. comm., 12 May). The importance of fertiliser use has also been mentioned by the Australian Government, Department of Agriculture (2013), where trials demonstrate that farmers can reduce nitrous oxide emissions and achieve productivity gains by increasing the efficiency of nitrogen use through improved fertiliser technology and management in cropping systems. For example, the amount and timing of fertiliser impacts the magnitude of emissions and liming acidic cropping soils where fertiliser has been applied can reduce nitrous oxide emissions as well as increase the uptake of methane (Australian Government, Department of Agriculture, 2013).

However, the majority of farmers are already practicing these methods so the opportunities for further gains in those areas may be low (Pannell, 2021). This issue is further explored by the Australian Government (2018), where success of increasing OC is highly dependent on factors such as management history, initial levels of OC, rainfall and proposed new management (Australian Government, 2018). For example, if the initial OC in a low rainfall zone (450 to 60 mm annual rainfall) on a Red Kandosol or Red Chromosol soil is 45 t/ha and the proposed land management is no till cropping, there is a high chance very little carbon will be sequestered (Australia Government, 2018). This set of conditions do not necessarily apply to the Mallee; however it would be important to pre-determine the carbon potential if aiming to participate in a carbon project for financial return.

Trials are underway throughout the Mallee investigating costs and benefits of summer cropping/cover, i.e. having cover not necessarily for harvest but for grazing and other co-benefits it provides (Randall, T, 2021, pers. comm., 30 April). This as well as multi-species cropping to add diversity are important considerations for farmers in terms of the overall advantages as well as harnessing that carbon potential. Additional trials are also underway in the Mallee with the focus on deep ripping as well as clay and organic matter additions to improve productivity of sandy soils (Wilhelm, N, 2021, pers. comms., 14 May). More research and field trials are needed to validate whether the improved productivity will improve carbon sequestration.

Sequestering Carbon in Soils in Grazing Systems

Similar to above, the Sequestering Carbon in Soils in Grazing System method contains components that can be implemented by a farmer to increase soil carbon regardless of the ERF method. This method is 'closed,' meaning unless already registered under this method, new projects are not considered. Management activities include:

- converting from continuous cropping to permanent pasture
- undertaking pasture cropping
- managing pasture by implementing or changing pasture irrigation, applying organic or synthetic fertiliser to pastures, or rejuvenating pastures, including by seeding, or
- managing grazing by changing stocking rates or altering the timing, duration, and intensity of grazing (copied from Kondinin Group, Farming Ahead, 2021).

Converting land from cropping to pasture has been criticised as impractical as switching to a pasture will most likely introduce stock numbers and ultimately increase methane emissions (Pannell, 2021). This would be influenced by a number of factors such as if livestock was already a part of the system or whether carbon farming practices such as methane reduction and livestock management were being implemented in conjunction with the switch of land use. Nevertheless, it is important to consider and would need further research. It would also be important to take a holistic approach towards the whole farming system.

Major barriers to uptake

The Mallee encompasses the difficult nature of varying environmental conditions, with variable low to medium rainfall spread across the region as well as soil type. Resultingly, the approach of 'one-size fits all,' is arguably unattainable in regard to applying ERF methods. For example, the low-rainfall areas of the Mallee (200mm of average annual rainfall or less), may not support environmental planting methods. Additionally, the cost of plantings may be prohibitive for areas with rainfall less than 400mm as the price of carbon is too expensive, i.e. carbon prices are approximately $18 per tonne of carbon dioxide equivalent (at the time of writing), which may not be enough to cover the cost of plantings (Hanisch, D, 2021, pers. comm., 31 April).

Likewise, the cost of establishing projects, undertaking the required soil sampling at a suitable scale, monitoring project delivery and change, and managing for risk of reversal are all factors that make soil carbon projects in the SA pastoral zone non-viable (RegenCo, 2021). Given that Mallee farms are significantly smaller in size with differing land management systems compared to the pastoral zone might mean that soil carbon projects are more achievable however these factors are still important to consider as potential barriers.

Given the recent $200 million budget allocation to the National Soil Strategy (May 2021), speculation has arisen to whether part of this may go towards improving soil methodology and increase uptake of soil carbon farming practices. This speculation is reaffirmed by the government claiming it will endeavor to reduce the cost of soil carbon measurements from approximately $30/ha to $3/ha through improvements in technology and data (Murphy, 2021). Additionally, recent support, particularly targeted at the Measurement of Soil Carbon Sequestration in Agricultural Systems method, has become available in the form of $5,000 rebate to go towards baseline sampling costs (Australian Government, Clean Energy Regulator, 2021). This $5,000 rebate is available under the conditions set out by the methodology and is for new baseline soil sampling only.

A repeated concern is that of permanence obligations in regard to sequestration activities. For example, if an ACCU is produced through sequestration, the increase in carbon must be maintained for the nominated permanence period, i.e. 25 or 100 years. However, farmers dealing with drought, fire or even if they sell their land ideally need permanence periods to be considered as part of the sequestration project's risk management strategy (RegenCo, 2021). To avoid this risk, once a project has been registered under the ERF, the Australian Government will acquire 5% of the credits issued, which acts as an 'insurance buffer' against natural disasters (Seaman, R, 2021, pers. comm., 12 May). Additionally, measures such as 'pausing' an area where ACCUs are not counted over a period of time or reducing the initial project area, i.e. if a fire resulted in part of the project area

being unable to regenerate, have been implemented to assist landholders under unfavourable conditions (Seaman, R, 2021, pers. comm., 12 May).
Permanence periods have also been criticised as allowing for reversal, i.e. once a permanence period is up, the carbon sequestered can be lost if a famer were to change land management practices (Pryor, 2021). However, South Australia has strict clearing policies and so even if a landowner held a clearing permit, there would be a small chance of approval (Hanish, D, 2021, pers. comms., 14 May). Additionally, clearing vegetation licenses appear to be uncommon throughout the Mallee region.

It is also important to consider that even though there is an increasing number of Mallee farmers incorporating livestock into their systems, most of the livestock throughout the Mallee to date are sheep (Woody, D, 2021, pers. comms., 12 May). In regard to the ERF methods, most apply to cattle and even though this will still apply throughout the region, there appears to be a lack of emphasis on the main livestock industry and related emission reduction processes. More methods for sheep-based farming systems are being developed however details are not available at this time (Seaman, R, 2021, pers. comm., 12 May).

Through evaluating current literature and conducting surveys of farmers (pig industry) and carbon service providers, Macintosh, Roberts and Buchan (2019) were able to highlight several significant findings for both motivators and barriers in uptake of carbon projects. Motivators from the carbon service industry survey suggest that what motivates farmers are the financial returns and opportunity to diversify their income sources. This was similar to the farmer responses however they also rated the potential to improve on-farm environmental outcomes a being almost as important. The barriers of uptake responses seemed to be far more extensive and are described below.

Barriers of uptake for sequestration projects (carbon service industry survey)

- Low carbon prices
- The risk of rule changes affecting participation and crediting
- Uncertainty about future carbon prices
- Difficulties in getting third party consents
- Permanence requirements
- Lack of awareness amongst farmers of carbon market opportunities
- Scope of methods and
- Lack of trust on behalf of farmers in parties offering carbon market information.

Barriers for agriculture emissions avoidance projects (carbon service industry survey)

- Scope of methods
- Risk of rule changes governing eligibility and crediting
- Third party consents
- Low carbon prices
- Conservative methods
- Uncertainty about future carbon prices
- Lack of trust in information providers and
- Lack of awareness of carbon market opportunities.

Barriers for agriculture carbon offset projects (farmer survey)

- Upfront capital costs
- Project design costs
- Lack of awareness of carbon market opportunities
- Lack of trust in information providers
- Risk of rule changes governing eligibility and crediting
- Cost and difficulty getting required government approvals and
- Reporting and monitoring costs.

Macintosh, Roberts and Buchan (2019) comment that there is large contrast between the highest-ranking barriers from the carbon service providers and farmers. For example, capital and project design cost were ranked highest on the pig farmers' list and did not feature on the carbon service providers' and this may reflect specific factors that form the manure management projects in piggeries (Macintosh, Roberts and Buchan, 2019).

Macintosh, Roberts and Buchan (2019) also found that the farmers' responses of barriers of participation differed depending on whether they have or had a carbon offset project or had not. The highest-ranking survey responses from the farmers that have or had participated in a project included reporting and monitoring costs, the risk of rule changes governing eligibility and crediting and upfront capital costs. Those who had not participated in a project responded with lack of awareness of carbon market opportunities, lack of trust in information providers, project design cost and upfront capital costs. Interestingly, the report also highlighted that awareness of carbon opportunities was at 100% amongst the largest farms and this decreased as farm size also declined (Macintosh, Roberts and Buchan, 2019). Whether this correlation is similar to grazing or cropping farms throughout the Mallee would be difficult to determine however is important to consider as farm sizes throughout the Mallee differ.

These barriers also mirror the barriers mentioned by Schapel, et al, (2018) who identified that the following limitations prevent land holders engaging in a soil carbon project:

- Lack of understanding about suitable ERF methods
- Cost of implementing the soil carbon project
- Paperwork and time constraints
- Cost of verifying the organic carbon stock (soil sampling)
- Lack of information
    - Best practice implementation of eligible activities
    - Location of best return on farm
    - Eligible activities and their effect on soil OC and productivity
    - Emissions created by implementing an eligible activity
- Surety of return on investment
- Long time frame of 100 years permanence
- Clear, consistent government policy
- Uncertainty regarding the price of carbon
- Farming adaptations that are required for farmer's survival, especially those that address climatic conditions and increased plant production, may contradict soil carbon accounting rules and
- Legal liability – will paddocks require encumbrances that restrict farming practice for the permanence period

Cost of verifying/auditing the project has been echoed as a significant barrier by Seaman (Seaman, R, 2021, pers. comm., 12 May). Farmers in the Mallee need to consider the return of ACCUs against the price of project operation as well as the price payed to third-party auditors, where for the most part the Mallee will not return enough financial incentive to outweigh the overall cost (Seaman, R, 2021, pers. comm., 12 May).

Misunderstanding of ERF methods was mentioned by Hanisch (Hanisch, D, 2021, pers. comm., 31 April), where he stated that farmers' reportedly think that under an ERF Environmental Planting method, stock are not allowed to return to the land. However, a farmer can eventually return stock to the planted area provided records are kept and the plantings meet the conditions set out by the method.

Furthermore, the requirements under the 'Beef cattle herd management' ERF method presents additional potential barriers to uptake. For example, the size of the herd required to economically deliver the method and the historical record keeping requirements excludes most pastoral produces and may exclude a number of Mallee farmers as well (RegenCo, 2021).

King’s, et al, (2020), report on incentivising low-cost abatement opportunities across the economy, found that the ERF can accommodate and incentivise further action. Following several recommendations, King, et al, (2020) have broadly stated that by improving the ERF, incentivising voluntary action on a broader scale and unlocking the technologies needed to decarbonise the economy, Australia can exceed its international commitments and improve ongoing emissions reductions. Specifically, the following recommendations have been made regarding agricultural-related projects:

- Allow certain ERF methods to award ACCUs on a compressed timeframe – reducing the barriers faced by projects with high upfront capital costs
- Create a fixed priced purchasing desk for small projects under the ERF – encouraging project uptake, particularly of agriculture and small-scale energy efficiency projects, by reducing price risks and marketing costs
- Create tailored small-scale ERF methods for particular types of agriculture projects, including shelterbelts and
- Facilitate ‘method-stacking,’ where multiple ERF projects are taken on the same property using different methods (copied from King, et al, 2020).

Another recommendation outlined in the report (2020) and echoed by Hanisch (Hanisch, D, 2021, pers. comm., 31 April) is including ‘simple admin projects,’ that do not require a project developer. Carbon project developers are reportedly too expensive for simple projects, particularly when they involve carbon farming practices that farmers already engage in such as shelterbelts (Hanisch, D, 2021, pers. comm., 31 April).

Although this list is not exhaustive (please refer to the report for full list of recommendations), it certainly gauges that major barriers to uptake have been acknowledged. Method-stacking and small-scale ERF methods, i.e. shelterbelts, would be particularly important in improving uptake of registered carbon farming in the Mallee. However, further research would be needed to validate the implementation of these recommendations.

Concluding remarks

There are six broad components of agricultural emissions, five of which apply to the Mallee and include:

- field burning of agricultural residues
- enteric fermentation
- manure management
- agricultural soils and
- vegetation burning or clearing.

As focus intensifies on reducing these sources of emissions and the importance of climate resilient farms, it's expected that ERF methods and voluntary carbon markets will diversify and new programs will encourage innovation towards new tillage systems, diverse multispecies cover crops adapted to particular seasons, strategic planting of shelter belts, livestock feed supplements and additives and effluent treatment methods.

Soils will continue to be in the spotlight for sequestering carbon, however, before initiating a soil project, Mallee farmers need to consider their existing carbon levels and their current farming practices to identify if there is potential to sequester more carbon.

Notedly, work is being done to develop more encompassing ERF methods and additional market opportunities to improve farmer participation in areas with variable environmental conditions, such as the Mallee. A calculator is under development by the CER, which would allow farmers to calculate the carbon potential of their soil (CER, 2021, pers. comms., 17 May). This is important as current soils methods, appear to be technically complex (based on samples and direct measurements) and commercially non-viable however, they would be beneficial in the Mallee once the methodology has been revised.

Similarly, a major area in need of work is including methodologies that apply to sheep, as well as Mallee conditioned vegetation. Literature supports the fact that there seems to be increased research in feed additives for livestock to reduce emissions and this would be an area for farmers to focus on as planting out more productive pasture species, grasses or adding feed supplements/inoculants would support the growing trend of Mallee farmers with livestock and mixed-enterprise. Additionally, the work being done on an all-inclusive ERF method, where all farming activities are considered would be a very useful platform for farmers, particularly those with mixed-farming enterprises.

The cost of projects, including broker and, project developer and auditing costs appear to be a major limitation for farmers to participate in the carbon market. Further work would need to ensure cost of implementation and running of projects are not a hindering factor for farmers, particularly those that are undertaking smaller projects or projects that may happen regardless of the market, i.e. shelterbelts, clay-spreading, planting out native grasses on erosion risk areas.

Misunderstanding of ERF methods also appears to be a limitation. Developing an easier guide for farmers to identify eligible practices or communicating it through existing farmer networks, i.e. local agriculture bureaus, farmer support groups and other representative industry bodies would be recommended. Additionally, further research is needed to validate whether farmers participating in a carbon market are still qualified to participate selling products as 'carbon neutral.'

A holistic view of farm management, instead of focusing solely on sequestering and/or reducing carbon emissions is needed in order to take advantage of overall environmental and social benefits. A holistic view is also important when considering the overall emission impact on introducing certain farming practices. For example, for liming to be considered a viable method for reducing greenhouse has emissions, emissions associated with production, transport dissolution of lime should not out-weigh the gains from on-farm emissions reductions (Australian

Government, Department of Agriculture, 2013). Similarly, if transitioning land from cropping to pasture, this may result in increase livestock numbers (current trend for the Mallee), resulting in increased methane emissions.

A team experts from UniSA, the University of Adelaide, SA Water and the Department for Environment and Water found that large-scale change to the primary carbon-sequestering land uses is unlikely in SA's intensive agricultural zone at current and foreseeable carbon credit prices (Goyder Institute, 2019). Even though incentivising additional revegetation via carbon credits remains economically challenging, there are a number of opportunities where additional co-benefits are valued by the landowner and where carbon sequestration potential is high (Goyder Institute, 2019). The Goyder Institute (2019) recommends that uptake of environmentally-beneficial carbon methods could be improved with clearer information about ERF requirements, the economics of participation and the potential value of co-benefits. They also recommend more research to understand how stacking multiple benefits and developing methods to accurately account for variable carbon sequestration rates, can help improve the economic viability of land-use change (Goyder Institute, 2019).

Another list of recommendations is set out by Pryor (2021) below:

- more work needed to be done on removing the disincentives for farmers to participate in the carbon market, such as the upfront investment costs for projects
- carbon credits need to be unique and traceable to eliminate the risk of double counting
- permanence periods need to be looked at, i.e. after 25 years the stored carbon cannot be reversed
- steer away from quantification and verification methods that favour 100 per cent accuracy over the cost of implementation as this can reduce the level of participation and
- identify who will best support, educate and drive change for farmers (it will most likely be organisations farmers already trust and have ongoing relationships with).

A summary of carbon farming practices that apply to the Mallee are listed in Table 9. They are given an 'X' when they apply under an ERF methodology and/or as an Independent carbon farming activity, i.e. a farmer can implement any of these strategies regardless of an ERF method. Independent carbon farming has been scored an X on all farming practices. This is important to demonstrate as farmers do not have to be a part of an accredited carbon market for them to participate in carbon farming. In fact, most farmers in the Mallee may be already implementing some of these practices and reaping the co-benefits. However, carbon markets should not be disregarded as they provide alternative sources of income, encourage further carbon sequestration and reduction as well as deliver substantial environmental, economic and social co-benefits.

Voluntary markets were not included in the list due to time constraints, however, further research will help determine the extent of voluntary markets and eligibility towards the Mallee. Additionally, 'ERF considerations' were included, where specific legislative requirements that were deemed noteworthy and applicable to the Mallee were mentioned. Please note that these considerations are not exhaustive, and methods will need to be considered on a case-by-case basis.

Table 9. Summary list of carbon farming practices that apply to the Mallee.

Category	Carbon Farming Practice	ERF Method	ERF considerations	Independent
Vegetation	Revegetation of mallee scrub (including windbreaks)	X		X
Vegetation	Revegetation using grasses and fodder shrubs	Maybe an option in the future (refer to page 23)	Can fall under the 'measurement of soil carbon sequestration in agricultural systems', method if production livestock can graze. However, will only include perennial grasses, annual grasses and/or legumes	X
Vegetation	Replanting land no longer suitable for cropping	X		X
Vegetation	Avoid clearing e.g. repeated clearance ever 5 years to satisfy Native Veg Act 1991	X		X
Soil	No till	X		X
Soil	Cropping and pasture management, g.g. stubble retention (prevent burning off stubbles) improving pasture legume content before cropping to reduce the N fertiliser, summer cover, multi-species cropping, increasing the efficiency of nitrogen use through improved fertiliser technology and management in cropping systems, converting from continuous cropping to permanent pasture, use of mechanical methods to add or redistribute soil	X	De-stocking of the land under pasture must not be conducted unless the land is converted to be a cropping system Nutrients that can be added include nitrogen, phosphorous, potassium and sulphur. Summer cover / multi-species cropping may fall under the activity 're-establishing or rejuvenating a pasture by seeding' or 'establishing and permanently maintaining a pasture where there was previously no pasture such as on cropland or bare fallow.' Will only include perennial grasses, annual grasses and/or legumes The fertiliser practices do not fall under a specific activity however may contribute if a farmer can prove that it 'enhances plant growth and fertility of soil.'	X
Soil	Soil amendment e.g. biochar, clay-spreading, green or brown manure, lime, gypsum	X	Green or brown manure may qualify if it is sourced from a *designated waste-stream*: • intensive animal production	X

Category	Carbon Farming Practice	ERF Method	ERF considerations	Independent
	Soil amendment e.g. biochar, clay-spreading, green or brown manure, lime, gypsum		• Food processing • Manufacturing • Sawmill residue or • Municipal or commercial waste collection processes. The 'non-synthetic' fertiliser should also be sourced from within a 'carbon estimation area' (CEA) that is part of the project Clay spreading is allowed if sourced from the project's CEA. Sampling must be taken at depth and any land where soil is sourced is remediated as soon as practical	
Livestock	Animal effluent management e.g. treatment in biogas digesters; decreased manure storage time; improve manure storage covering; improve housing systems and bedding; manure acidification.	X		X
Livestock	Feed additives to dairy cows	X	Must be milking pasture-fed cows for at least nine months of the year. Eligible additives include: canola meal, cold-pressed canola meal, brewers grain, hominy meal or dried distillers grain	X
Livestock	Supplementary feeding and feed inoculants e.g. low methogenic pasture species for grass fed animals, converting urea blocks to nitrate lick blocks	X - Does not apply for sheep at this point in time (refer to page 26)	Land where beef cattle herd is pastured has to have been used for urea supplementation at least once in the last five years to be eligible under the 'feeding nitrates to beef cattle method.' This method only considers fully or partially replacing urea supplements with nitrate supplements (nitrate lick blocks). Feedlot cattle are excluded from this method. Feeding with improved pastures falls under the Beef Cattle Herd Management method.	X

Category	Carbon Farming Practice	ERF Method	ERF considerations	Independent
Livestock	Animal breeding and genetic manipulation e.g. faster growth rates, reducing age to slaughter, reduce methanogenesis, improve feed conversion efficiency	X	Cattle has to be fed principally from grazing or forage Most of these practices will fall under the 'cattle herd management' method. Project's under this method cannot apply if feeding of cattle on land has been, for the purposes of the project, partially or wholly cleared of perennial woody vegetation	X
Livestock	Reducing CH4 production by vaccinating livestock against methanogens	Not specifically however maybe eligible if farmer can prove that by doing so it: increases the weight to age ratio, reduces the average age of the herd, reduces the proportion of unproductive animals and/or increase total annual liveweight gain by changing ratio of livestock class		X
Livestock	Herd management, e.g. changing number of animals in each livestock class, reducing proportion of unproductive animals in a herd, increased pasture productivity and suitable pasture species selection, improved stocking rates (for sheep: reducing total sheep numbers by mating all replacement ewes to Merino sires or by buying replacement maiden ewes or adult ewes to run a sustainable stocking rate)	X - Does not apply for sheep at this point in time	Cattle has to be fed principally from grazing or forage Most of these practices will fall under the 'cattle herd management' method. Project's under this method cannot apply if feeding of cattle on land has been, for the purposes of the project, partially or wholly cleared of perennial woody vegetation	X

References

Australian Government, Clean Energy Regulator, 2021, ‘Measurement of soil carbon sequestration in agricultural systems method,’ Available at: <http://www.cleanenergyregulator.gov.au/ERF/Pages/Choosing%20a%20project%20type/Opportunities%20for%20the%20land%20sector/Agricultural%20methods/The-measurement-of-soil-carbon-sequestration-in-agricultural-systems-method.aspx> (Accessed 14/5/2021)

Australian Government, Department of Agriculture, 2013, ‘Australian agriculture: reducing emissions and adapting to a changing climate,’ Available at: <https://www.agriculture.gov.au/sites/default/files/documents/reducing-emissons-adapting-changing-climate.pdf> (Accessed 13/5/2021)

Australian Government, Department of Agriculture, Fisheries and Forestry, n.d., ‘Climate Change Research Program - Reducing emissions from livestock,’ PDF file (Accessed 12/5/2021)

Australian Government, Department of Agriculture, Water and the Environment, 2021, ‘Agriculture Stewardship Package,’ Available at: <https://www.agriculture.gov.au/ag-farm-food/natural-resources/landcare/sustaining-future-australian-farming> (Accessed 13/5/2021)

Australian Government, Department of Agriculture, Water and the Environment, 2019, ‘Biochar,’ Available at: <https://www.agriculture.gov.au/ag-farm-food/climatechange/australias-farming-future/biochar> (Accessed 1/02/2021)

Australian Government, Department of Environment and Energy, 2018, ‘Increasing soil carbon under the Emissions Reduction Fun,’ PDF file, (Accessed 12/5/2021)

Badgery, W, Murphy, B, Cowie, A Orgill, S, Rawson, A, Simmons A & Crean, J, 2019, ‘Soil carbon market-based instrument pilot – the sequestration of soil organic carbon for the purpose of obtaining carbon credits,’ *Soil Research,* vol 59, Available at: <https://www.publish.csiro.au/sr/SR19331> (Accessed 13/5/2021)

Baumber, A, Waters, C, Cross, R, Metternicht, G and Simpson, M, 2020, ‘Carbon farming for resilient rangelands: people, paddocks and policy,’ *The Rangeland Journal,* Available at: <https://doi.org/10.1071/RJ20034 > (Accessed 19/01/2021)

Carbon Farmers of Australia, 2020, ‘CO2 Farming,’ Available at: <https://carbonfarmersofaustralia.com.au/carbon-farming/available-methods/> (Accessed 13/01/2021)

Clean Energy Regulator, n.d., ‘Sequestration decision tree,’ Available at: <http://www.cleanenergyregulator.gov.au/DocumentAssets/Pages/Sequestration-decision-tree.aspx> (Accessed 11/5/2021)

Climate Council, 2018, ‘Australia’s rising greenhouse gas emissions,’ Available at: <https://www.climatecouncil.org.au/wp-content/uploads/2018/06/CC_MVSA0143-Briefing-Paper-Australias-Rising-Emissions_V8-FA_Low-Res_Single-Pages.pdf> (Accessed 29/4/2021)

Climate and Clean Air Coalition and United Nations Environment Programme, 2021, ‘Global Methane Assessment,’ Available at: <https://www.ccacoalition.org/en/resources/global-methane-assessment-full-report> (Accessed 7/5/2021)

Climate Solutions Fund, 2020, 'Australian Government, Clean Energy Regulator,' Available at: <http://www.cleanenergyregulator.gov.au/csf/Pages/News-and-update---details.aspx?ListId=19b4efbb-6f5d-4637-94c4-121c1f96fcfe&ItemId=807> (Accessed 22/01/2020)

Department of Jobs, Precincts and Regions, 2019, 'Supporting Agriculture to adapt to climate change,' Available at: <https://www.agriculture.gov.au/sites/default/files/sitecollectiondocuments/ag-food/drought/stream-2-report.pdf> (Accessed 24/4/20201)

Department of Primary Industries and Regional Development, Government of Western Australia, 2021, 'Katanning Research Facility – Strategy to achieve carbon neutrality by 2030,' Available at: <https://www.agric.wa.gov.au/carbon-farming/katanning-research-facility-carbon-footprint-assessment-and-strategy-achieve-carbon> (Accessed 28/4/2021)

De Wit, E, 2020, 'Scaling voluntary carbon markets,' *Norton Rose Fulbright,* Available at: <https://www.nortonrosefulbright.com/en-au/knowledge/publications/b2e32d34/scaling-voluntary-carbon-markets#:~:text=Voluntary%20carbon%20markets%20enable%20organisations,to%20achieve%20a%201.5%C2%BAC%20pathway.> (Accessed 29/4/2021)

Emissions Reduction Fund, 2021, 'Agriculture methods,' *Australian Government, Clean Energy Regular,* Available at: <http://www.cleanenergyregulator.gov.au/ERF/Choosing-a-project-type/Opportunities-for-the-land-sector/Agricultural-methods> (Accessed 22/01/2021)

Emissions Reduction Fund, 2021, 'Interactive Map,' *Australian Government, Clean Energy Regulator,* Available at: <http://www.cleanenergyregulator.gov.au/maps/Pages/erf-projects/index.html#> (Accessed 19/01/2021)

Emissions Reduction Fund, 2021, 'Methods Development,' *Australian Government, Clean Energy Regulator,* Available at: <http://www.cleanenergyregulator.gov.au/ERF/Pages/Method-development.aspx> (Accessed 22/01/2021)

Goodwin, S, 2021, 'Microsoft buys carbon credits from NSW cattle operation,' *The Land,* Available at: <https://www.theland.com.au/story/7106034/microsoft-buys-carbon-credits-from-nsw-cattle-operation/> (Accessed 30/4/2021)

Government of South Australia, 2021, 'South Australian Government Climate Action Plan 2021-2025,' Available at: <file:///C:/UserData/Downloads/climate-change-action-plan-2021-2025.pdf> (Accessed 28/4/2021)

Goyder Institute, 2019, 'Carbon offsets research to support the State Carbon Sequestration Strategy,' Available at: <http://www.goyderinstitute.org/news/2019/carbon-offsets-research-to-support-the-state-carbon-sequestration-strategy/> (Accessed 13/5/2021)

Greencollar, 2017, 'Carbon Farming,' Available at:<https://greencollar.com.au/carbon-farming/> (Accessed 14/5//2021)

Hobbs, T. J., Neumann, C. R. & Tucker, M, 2010, 'Carbon Sequestration from Revegetation: Southern Murray-Darling Basin Region,' *Government of South Australia, Department of Water, Land and Biodiversity Conservation,* Available at: <https://data.environment.sa.gov.au/Content/Publications/carbonsequestrationrevegetationsmdb.pdf> (Accessed 1/4/2021)

King, G, Smith, S, Parker, G & Macintosh, A, 'Report of the Expert Panel examining additional sources of low cost abatement,' *Australian Government, Department of Industry, Science, Energy and Resources,* Available at: <https://www.industry.gov.au/sites/default/files/2020-05/expert-panel-report-examining-additional-sources-of-low-cost-abatement.pdf> (Accessed 11/5/2021)

Kondinin Group, Farming Ahead, 2021, '5.2 Examples of approved methodologies,' Available at: <https://www.farmingahead.com.au/research-reports/special-report/1403951/52-examples-of-approved-methodologies> (Accessed 7/5/2021)

Liu, J, Wang, L, Wang, D, Bonser, P. S., Sun, F, Zhou, Y, Gao, Y & Teng, X, 2021, 'Plant can benefit from herbivory: Stimulatory effects of sheep saliva on growth of *Leymus chinensis,' PLOS One,* Available at: <https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3251555/> (Accessed 30/4/2021)

Macintosh, A, Roberts, G and Buchan, S, 2019, 'Improving Carbon Markets to Increase Farmer Participation,' *AgriFutures National Rural Issues,* Available at: <https://www.agrifutures.com.au/wp-content/uploads/2019/07/19-026-Digital-1.pdf> (Accessed 1/4/2021)

Murphy, J, 2021, 'How farmers can reduce greenhouse gas while increasing yield,' *North Queensland Register,* Available at: <https://www.northqueenslandregister.com.au/story/7183056/how-farmers-can-reduce-greenhouse-gas-and-see-yields-surge/> (Accessed 13/5/2021)

Nature Foundation SA, 2019, 'naturematters,' Available at: <https://www.naturefoundation.org.au/getattachment/4b25cb15-274e-4378-ba5b-d3876e6f0c12/Issue-3,-2019> (Accessed 27/01/2021).

Neumann, C. R, Hobbs, T. J & Tucker, M, 2011, 'Carbon sequestration and biomass production rates from agroforestry in lower rainfall zones (300-650mm) of South Australia: Southern Murray-Darling Basin Region,' *Government of South Australia,* Available at: <https://www.researchgate.net/publication/304474957_Carbon_sequestration_and_biomass_production_rates_from_agroforestry_in_lower_rainfall_zones_of_SA_Southern_Murray-Darling_Basin_Region> (Accessed 1/4/2021)

Pannell, D, 2021, 'Soil carbon is a highly flawed climate policy, Part3,' *Pannell Discussions,* Available at: <https://www.pannelldiscussions.net/2021/05/348-soil-carbon-3/> (Accessed 12/5/2021)

Possu, B. W., 2015, 'Carbon storage potential of windbreaks on agriculture lands of the continental United States,' *University of Nebraska – Lincoln,* Available at: <https://digitalcommons.unl.edu/cgi/viewcontent.cgi?article=1119&context=natresdiss> (Accessed 1/02/2021)

Pryor, M, 2021, 'Making soil carbon a commodity,' *Agthentic,* Available at <https://blog.agthentic.com/making-soil-carbon-a-commodity-how-technology-can-redesign-carbon-markets-based-on-rewards-and-32adc408707d> (Accessed 13/5/2021)

RegenCo, 2021., 'SA Pastoral Rangelands: Carbon Potential Report,' Available at: <https://oca.sa.gov.au/sites/default/files/media/Carbon%20Potential%20Report.pdf> (Accessed 12/5/2021)

Schapel, A, 2019, 'GHG mitigation options for SA agriculture,' *PIRSA,* PDF file (Accessed 12/5/2021)

Schapel, A, Davenport, D, Bell, R, 2021, 'CRC for HPS: Project sandy soil organic and clay amendment project,' *PIRSA,* PDF file (Accessed 12/5/2021)

Schapel, A, Reseigh, J, Wurst, M, Mallants, D & Herrmann, T, 2018, 'Offsetting greenhouse gas emissions through increasing soil organic carbon in SA clay-modified soils: knowledge gap analysis,' *Goyder Institute for Water Research,* Available at: <file:///C:/UserData/Downloads/Goyder_TRS_18-05_SoilC_June2018_Final.pdf> (Accessed 28/4/2021)

Schmidt, H, Hagemann, N, Draper, K and Kammann, C, 2019, 'The use of biochar in animal feeding,' *PeerJ,* Available at: <https://www.ncbi.nlm.nih.gov/pmc/articles/PMC6679646/#:~:text=Biochar%2C%20that%20is%2C%20carbonized%20biomass,intake%20efficiency%20and%20thus%20productivity.> (Accessed 2/02/2021)

SOUTH AUSTRALIA

Government of South Australia

Primary Industries and Regions SA