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Opinion

The Role of Agriculture in the Australian Government's Emission Reduction Fund

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Abstract

Australia's greenhouse gas emissions from agriculture in 2020 were 67.8 million (M) tonnes (t) of carbon dioxide equivalent (CO_2-e), amounting to 12.9% of total emissions. Erupted methane (CH_4) from ruminant animals comprised 42% of agricultural emissions. By 2030, the Australian Government aims to reduce total emissions by 43% from the 2005 level. The primary policy instrument for achieving this reduction is the Emissions Reduction Fund (ERF) in which there are two main pathways for agriculture – emission avoidance through suppression of CH_4 emissions and soil carbon sequestration (SCS) through approved projects. Although agriculture since 2014 has promised 15.2 Mt of abatement, by April 2022 it has delivered only 1.1 Mt. Examples are given of potential abatement by SCS for pasture and cropping land in different rainfall zones. Methods of suppressing CH_4 emissions have yet to be scaled up commercially and proven for grazing animals. The main constraints on SCS are the unreliability of Australian rainfall, the high cost of project management relative to the value of a C credit, and the opportunity cost of maintaining an approved land management for at least 25 years.

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Keywords
Agricultural emissions; methane emissions; soil carbon sequestration; carbon credits; biophysical and economic constraints

1. Introduction

Using the UNFCCC (United Nations Framework Convention for Climate Change) classification system, the Nationally Determined Contribution of greenhouse gas emissions (GHG) from agriculture in Australia in 2020 was reported as 67.8 million (M) tonnes (t) of carbon dioxide equivalent (CO_2-e) [1]. Total emissions were 523.69 Mt, which were reduced to 487.6 Mt when the natural disturbances (ND) provision was applied. The ND provision allows for the effect of extreme wildfires in temperate forests, which are beyond control in spite of the efforts of emergency management agencies. Agricultural emissions were 12.9% of total emissions, or 13.9% of the adjusted total. Of these emissions, approximately 42% are produced as erupted methane (CH_4) from ruminant animals (cattle, sheep and goats), and small amounts produced from manure and decaying vegetable matter [2].

The Australian Government has revised the 2030 target for a reduction of national emissions by 43% compared to the 2005 level. The primary policy instrument for achieving this goal is the Emissions Reduction Fund (ERF), which has been operating since 2014.

2. The Emission Reduction Fund

The ERF operates in conjunction with the Australian Government's Safeguard Mechanism, which applies to industrial and other facilities with direct (scope 1) GHG emissions exceeding 100,000 t CO_2-e per annum. Relevant entities are required to keep their net emissions at or below a baseline, with operators given flexibility to manage excess emissions through the purchase of Australian Carbon Credit Units (ACCUs) and by other means. The ERF offers several methods by which industries and businesses can contract to reduce emissions [3]. However, this article refers only to those methods applying to the land sector, which includes agriculture.

2.1 The Clean Energy Regulator

The Clean Energy Regulator (CER) has the legislated responsibility for managing participation in the ERF. The CER must approve any method designed to avoid emissions or to store carbon, called a negative emissions strategy. Businesses in the land sector, which includes agriculture, are incentivized to participate in the ERF through the potential to earn ACCUs, which have a monetary value when sold to the CER or traded in the voluntary market. One ACCU is equivalent to 1 t CO_2-e that is avoided or stored.

Before a carbon (C) sequestration project can be registered with the CER, the proponent must undertake to change the management of a chosen land area, called a Carbon Estimation Area (CEA). This is the condition of *additionality*, meaning that business-as-usual within the CEA is not acceptable. There must be a change to make a difference. The number of tonnes of CO_2-e to be sequestered is estimated and the 'permanence' period, for which the changed management will be maintained, is chosen as either 25 or 100 years. Any ACCUs earned for a project could be contracted for sale to the CER, the price being determined through a reverse auction held every six months. When a contract is activated and ACCUs are sold to the CER they are said to be delivered and 'retired'; the abatement achieved is counted towards the national inventory of emissions. Alternatively, scheme participants can sell their ACCUs on the voluntary market to businesses to be used as 'offsets' for their own emissions. Provided the credits are not sold overseas they can still count as abatement when retired by the government.

2.2 Achievements of the ERF

Table 1 summarizes the achievements of broad categories of emission-reduction activities under the ERF as of 11 April 2022. 'Contracted abatement' refers to ACCUs under contract to be delivered to the CER, whereas 'delivered abatement' refers to ACCUs actually delivered.

Table 1 Abatement contracted and delivered (Mt CO_2-e) to the CER for ERF projects up to 11 April 2022 [3].

Category	Contracted abatement	Delivered abatement
Vegetation	150.6	46.5
Landfill and waste	26.3	22.0
Agriculture	15.2	1.1
Savannah burning	13.6	4.1
Facilities	4.7	n.r.
Energy efficiency	3.4	1.8
Industrial fugitives	1.7	0.8
Transport	1.2	0.6

n.r.: not reported.

Within the land sector in general, emissions may be reduced by storing carbon in vegetation and soils, or alternatively by avoiding emissions, such as by not clearing woody vegetation, changing the timing of savannah burning, managing agricultural waste or reducing emissions from livestock. Under the ERF, the broad 'vegetation' category covers reforestation, revegetation, restoring rangelands and avoided clearance of native vegetation. It is important to note that these vegetation activities are not included under agriculture.

Within the agriculture sector two activities are paramount - avoided CH_4 emissions from ruminant animals and storing carbon in soils, the latter referred to as soil carbon sequestration (SCS). Overall, agricultural projects promise a significant contribution to abatement (15.2 Mt), but thus far have delivered very little (1.1 Mt). The primary reasons for this are first the small contribution made by reductions in CH_4 emissions, discussed in section 2.2.1, and secondly the uncertainties associated with SCS, as discussed in sections and 2.2.2 and 3, and the long timeline of 10-25 years for significant SCS results to be achieved [4].

2.2.1 Reduction of Enteric Methane Under the ERF

Reducing ruminant emissions can be achieved within a few years by changing pasture management to provide better feed for the grazing animals, so that they can be sent to market earlier. This is an acceptable methodology (the Beef Herd Methodology) under ERF regulations and thus far has delivered 593,563 ACCUs (Professor Richard Eckard, personal communication). Another opportunity is provided by feed supplements, such as the seaweed *Asparogopsis* and the chemical 3-Nitrooxypropanol (3-NOP) both of which have been reported to reduce CH_4 emissions from ruminants by as much as 82% [5, 6]. While likely to be suitable for feedlot animals and dairies, these supplements add to the costs of production, especially for dairies, and this can be a disincentive for some farmers. Furthermore, because an effective method for delivering such feed supplements to grazing animals has not yet been developed and tested, CH_4 suppression by feed supplements has not been approved as an eligible methodology under the ERF.

Because CH_4 has approximately 86 times the global warming potential of CO_2 over a 20-year timescale [7], reducing these emissions has an immediate abatement effect. On the other hand, SCS has a much longer timeline and some inbuilt uncertainties, as discussed below.

2.2.2 Soil Carbon Sequestration Under the ERF

Soil carbon sequestration was identified as a key strategy for reducing GHG emissions in the Australian Government's first Low Emissions Technology Statement (LETS 2020) [8] and has been enthusiastically promoted by commercial 'aggregators'.

The ERF website [3] offers two methods for soil C projects, guidance for which is provided in the CER's online publication '*Understanding your soil carbon project – a simple method guide'* [9]. Box 1 provides the list of management practices that are eligible for a project to be registered. An eligible activity already being carried out does not need to cease: merely that a new or materially different activity must be added.

Box 1 List of activities currently eligible to be registered as a soil C project with the CER.

- Applying nutrients to the land in the form of a synthetic or non-synthetic fertilizer to address a material deficiency. For example, applying compost or manure; applying lime to remediate acid soils; applying gypsum to remediate sodic or magnesic soils.
- Undertaking new irrigation. Applying new or additional irrigation obtained through improving the efficiency of on-farm irrigation infrastructure and/or management practices within the project area.
- Re-establishing or rejuvenating a pasture by seeding or pasture cropping.
- Re-establishing, and permanently maintaining, a pasture where there was previously no or limited pasture, such as on cropland or bare fallow.
- Altering the stocking rate, duration, or intensity of grazing to promote soil vegetation cover and/or improve soil health.
- Retaining stubble after a crop is harvested.
- Converting from intensive tillage practices to reduced or no tillage practices.
- Modifying landscape or landform features to remediate land. For example, practices implemented for erosion control, surface water management, drainage/flood control, or

alleviating soil compaction. Practices may include controlled traffic farming, deep ripping, water ponding or other means.
- Using mechanical means to add or redistribute soil through the soil profile. For example, clay delving or clay spreading.
- Using legume species in cropping or pasture systems.
- Using cover crops to promote soil vegetation cover and/or improve soil health.

Many of these activities, such as minimizing soil disturbance due to tillage, retention of crop residues and crop diversification, including cover cropping, are drawn from the practices of conservation agriculture [10-13]. Others, such as the use of compost and manures, are consistent with a tenet of regenerative agriculture, whereby synthetic fertilizers are replaced by organic materials such as compost and manure [14]. However, such a substitution runs the risk of *leakage*, which describes the situation where sites from which the organic materials are derived suffer a loss of C inputs. In this case, there is no net gain in SCS for the landscape; or it can be that, with the removal of material from the site of origin, an increase occurs in the release of other GHGs, such as nitrous oxide; or as a result of the removal, extra land is cleared for agriculture, which causes a net increase in emissions [15].

Because of possible leakage, restrictions are imposed on the use of compost and manure (labelled non-synthetic fertilizers (NSF)) and biochar. If these materials are obtained from outside a CEA, the amounts are limited to 100 kg C/ha/year: no quantity limits exist if they are derived from within the CEA or a designated waste stream. However, in the case of NSF, its C content must be deducted from the soil C stock when the latter is measured less than two years after the application of the NSF; after that period, it is assumed to have decomposed. Biochar, which is resistant to decomposition, is different so that biochar C must be deducted from any increase in soil C stock in calculating the net abatement [9]. The rationale for these regulations is likely to be that the added organic materials should stimulate the growth of a crop or pasture through the supply of nitrogen (N) and phosphorus (P), and hence predispose to the deposition of more shoot and root residues in the soil due to the enhanced plant growth.

The concept of using SCS as a net abatement strategy is predicated on the assumption that the extra soil C will be retained permanently. As indicated, the ERF offers two ‘permanence’ periods of 25 or 100 years, the latter being the permanence period recognized by the UNFCCC [16]. However, all the soil C projects currently registered with the CER are for 25 years so any ACCUs earned are discounted by 20% to compensate for this shorter ‘permanence’ period. Another consideration is the possible loss of stored C due to unpredictable environmental changes or singular events such as wildfires. To allow for such a possibility, an extra 5% discount is applied to all ACCUs to provide a risk-of-reversal buffer. These discounts, together with an aggregator’s fee for managing a project, can reduce the value of an ACCU earned by a farmer by as much as 50%.

3. Potential for Increasing Soil Carbon Sequestration

The potential for increasing SCS at any given site depends on the balance between the rate of C inputs relative to the rate of C losses. Assuming no loss of C through erosion or leaching of dissolved organic C, this balance can be expressed by the simple equation

$$\frac{dC}{dt} = A - kC$$

where $\frac{dC}{dt}$ is the rate of change in soil C content, *A* is the rate of C input in organic materials, and *k* is a composite rate coefficient for decomposition by the soil biota. This equation shows that as *C* increases the rate of C loss increases. For a constant input *A* under a constant environment, the soil C approaches a maximum and steady-state equilibrium is achieved when *A = kC*.

The eligible activities listed in Box 1 are intended, to varying degrees, to increase C inputs and decrease losses. Under the conditions imposed by the ERF, increased inputs of C materials are achieved through growing more plant material, which in Australia is determined primarily by rainfall. The rate of decomposition of soil C is primarily determined by whether the soil is disturbed through tillage or not. Hence, at a broad scale the projections of potential SCS for Australian agriculture have been based on rainfall zones for cropping land and pasture, as shown in Table 2. These figures were included in Australia's Long Term Emissions Reduction Plan [17], as reported to the Conference of Parties (COP26) in Glasgow in 2021. They assume 100% uptake by landholders in the two land-use categories, but do not specify the time period over which such sequestration would occur. The total estimate of 103 Mt CO_2-e abated per annum through SCS exceeded the estimate of 35-90 Mt given in a 2010 review by CSIRO [18], but the latter estimate applied only to one quarter of Australia's crop and grazing land. Clearly, projections for SCS in Australian farm land over time are uncertain because of the interaction of several factors, such as changes in the rate of C inputs, an increased rate of decomposition as soil C content increases, seasonal trends in rainfall and temperature, and changes in the number of participants in soil C projects.

Table 2 Potential carbon sequestration in Australian cropping and pasture land according to rainfall zones.

	Cropping land			Pasture land		
Rainfall (mm)	Area (Mha)	CO2-e (Mt) per year	SCS (t/ha/year)	Area (Mha)	CO2-e (Mt) per year	SCS (t/ha/year)
300-600	28	22.40	0.22	8.375	12.562	0.41
600-900	7.976	9.97	0.34	15.745	39.362	0.68
900-1200	0.305	0.488	0.44	3.510	11.583	0.90
1200-1500	0.085	0.178	0.57	0.705	3.032	1.17
>1500	0.210	0.472	0.61	0.615	2.768	1.23
Totals	36.576	33.509		28.95	69.307	

Adapted from Box 2.4 in the Long-Term Emissions Reduction Plan [17].

It is instructive to compare the figures for SCS (t/ha/year) in Table 2 with the published figures for the only soil C project so far awarded ACCUs. This project was based on a renovated pasture on a 100-ha field of a farm in West Gippsland, Victoria, which receives an annual rainfall of 1000 mm. Within the first five years of the project, 1,904 ACCUs were awarded [3], which, allowing for a combined 25% discount for its 25-year permanence period and risk-of-reversal buffer, amounted to a net 25.39 t CO_2-e/ha sequestered over two years; that is an average rate of 3.46 t C/ha/year (the change in other GHG emissions was negligible). Note that this value is nearly four times the potential value of 0.9 t C/ha/year given for the 900-1200 mm rainfall zone in Table 2. Up to August 2022, no additional ACCUs had been recorded and the reasons for this unusual result remain unexplained. When contacted for more detail, the CER responded that this was withheld because it was considered 'commercial-in-confidence'.

An even more unusual result was reported for a cattle property of 1094 ha of grassland in northern New South Wales (NSW). For the year 2018-19, after allowances were made for changes in GHG emissions other than CO_2 and measurement uncertainty, a total abatement of 28,689 t CO_2-e due to SCS was accredited by the American registry Regen Network Development. This amounted to a sequestration rate of 7.14 t C/ha/year. Although these data are no longer available on the Wilmot Cattle Company website [19], new data posted on the website show that between 2018 and 2019 the soil C concentration, measured to 0.15 m depth, increased from 4.4% to 4.7% [19]. At the previously quoted bulk density of 1.22 Mg/m^3, this amounts to 5.49 t C/ha/year. Even though this figure is less than the imputed figure of 7.14 t C/ha/year, the result is still exceptional and difficult to explain for a system where only the grazing management of an established pasture was modified. The discrepancy between these figures may be attributable to the fact that the original estimates of SCS were based on soil C values derived from a remote sensing (RS) technique. Unfortunately, calibration of the technique relied on a very small set of soil C measurements obtained from two farms 90 km apart. Overall, the errors associated with both sets of calculation are probably large.

Since the credits issued by Regen Network were sold overseas, they cannot be included in the farm's net emissions calculation nor in Australia's national inventory of emissions.

4. Future Prospects for Soil Carbon Sequestration

The Australian Government is undoubtedly banking on a significant contribution of SCS to achieving its commitment to net-zero emissions by 2050. This approach is strongly endorsed by the Carbon Market Institute [20] and several soil C project aggregators - for example Agriprove [21], Carbon Count [22] and FarmLab [23]. Even though the soil C methodology has been revised and simplified three times since its inception in 2014, the success rate, as indicated above by the results for the West Gippsland farm, has been very low. There are biophysical and economic reasons for this.

4.1 Biophysical Constraints

First, limitations are imposed by the Australian climate, especially the amount and reliability of rainfall. This constraint affects plant growth and hence can limit the amount of carbonaceous residues returned to the soil. For example, in the five years bracketing 2018-19, the annual rainfall at Ebor, the town nearest to Wilmot Farm (see above), ranged from 578 to 1571 mm. With such variation, even in a relatively high rainfall region, the imputed SCS rate of 5.49-7.14 t C/ha/year is most unlikely to be sustained over a longer period.

Second, soil C concentration in the field is highly variable and this creates uncertainty in the calculation of changes in soil C storage. The ERF's 2021 methodology offers two methods for measuring such changes [9]. For the first, a project proponent undertakes soil sampling according to an approved statistical design at not more than 5-year intervals. Soil C analysis is performed by dry combustion in an approved laboratory or by spectroscopic analysis (which requires calibration against dry combustion measurements). In the second method, after initial baseline sampling, soil

C changes are estimated by dynamic modelling, the outcome of which is checked by sampling and soil analysis at 10-year intervals. The second method was introduced in an effort to reduce on-going costs of measurement, which can be as much as AUD20-30 per ha, depending on the size of the CEA. Even for the first 'gold standard' method, the sampling error can be as much as 20% and the laboratory analytical error 10% (Professor Peter Grace, personal communication). Both methods require reporting at 5-year intervals. The error associated with the combination of estimation by modelling and less frequent soil sampling and analysis has yet to be quantified. It is important to note also that soil C storage to a specific depth, usually 0.3 m, is the product of two variables - soil C concentration and soil bulk density. The change in storage between two times (expressed in t C/ha/year) involves calculating the difference between two means, which to be accepted under the ERF must be significant at the 60% probability level.

4.2 Economic and Management Considerations

Project aspirants must also take account of economic factors. For example, White [24] identified the range of project start-up, on-going and compliance costs, the more significant of which are the mandated baseline soil sampling, the costs of expert advisors (who may be aggregators managing the project for a fee) and the cost of audits (at least three in 25 years). The Australian Government is offering an advance grant of AUD5000 per project to help defray start-up costs. With the aim of further reducing the cost of measurement to AUD3/ha/year by 2030, as stated in its LETS 2020 [8], the Australian government is supporting research on the non-destructive measurement of soil C by RS. For example, Downforce Technologies has received a grant to develop their RS measurement of soil C [25]. However, these methods are as yet in their infancy [16].

Another factor that may deter landholders from participating in the ERF is the lack of flexibility imposed by the need to maintain the changed land management for the permanence period, currently 25 years for all registered soil C projects [26]. Also, a major deterrent can be the opportunity cost of changing land management, measured as the change in gross margin of the farming business from before to after the change [27, 28]. White et al. [26] showed that the decrease in gross margin was especially marked for the change from dryland cropping to grazing livestock, based on data for gross margins from the NSW Department of Agriculture (reported in [27], adjusted from Australian Bureau of Agricultural and Resource Economics and Sciences survey data in *Agricultural Outlook*—Department of Agriculture). A sensitivity analysis revealed little effect of a 50% reduction in sampling and analysis costs, or a 50% increase in the value of an ACCU, or a 100% increase in the rate of SCS. Clearly, the result of this analysis will also depend on input costs relative to the value of products, a relativity that can change with time. In this context, a halving of the crop yield or a doubling of livestock yield per ha could produce a positive change in gross margin.

5. Conclusions

The two main pathways under the ERF by which agriculture can contribute to reducing Australia's GHG emissions are through minimizing enteric CH_4 emissions and by SCS. For the reasons discussed above, both abatement pathways are in the early stages of development and there are significant constraints to be overcome. However, through further research and commercial development, the suppression of CH_4 emissions from ruminants may make a significant reduction in agricultural emissions in a relatively short time. With respect to SCS, although the management practices most likely to achieve sequestration are known, uncertainty exists in the measurement of significant changes, primarily due to the natural variability of soil C in the field, and because of rainfall unreliability, which affects plant growth and the availability of C inputs. Other constraints are imposed by a low benefit:cost ratio, given the current value of an ACCU, project operating costs, and the lack of farm business flexibility under the requirement for a permanence period of at least 25 years.

Before March 2022, the majority of soil C projects were contracted to the CER and any ACCUs earned could be sold to the CER at a price averaging AUD13.98 over 14 auctions [3]. In March 2022 the Australian Government decided to exit the market for ACCUs. Existing project proponents were offered the option of buying out their contracts at the reserve price of AUD12 per ACCU, and then selling on the voluntary market where the price had risen as high as AUD50. With the perception that the supply of ACCUs to that market would be increased, the price fell substantially, but has since risen to about AUD28 [29]. If the cost of operating a soil C project can be substantially reduced, and the value of an ACCU sold on the voluntary market rises above AUD30, significantly more C abatement may be achieved through SCS.

Nevertheless, irrespective of whether a soil C project qualifies for credits under the ERF, the emphasis now placed on farmers' adopting better management practices (see Box 1) should lead to improved farm productivity and profitability, together with co-benefits such as increased soil resilience to adverse weather conditions and enhanced biodiversity [24]. An increase in soil C also contributes towards a farm business's attaining C-neutrality, which can confer a significant marketing advantage and may become a requirement of any future C-neutral supply chain. From a national perspective, however, there is concern that if polluting industries decide to buy relatively cheap C credits on the voluntary market instead of investing in technology to reduce their emissions at source, the contribution of agriculture to reducing emissions will be subverted.

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Author Contributions

The author did all the research work of this study.

Competing Interests

The author declares that no competing interests exist.

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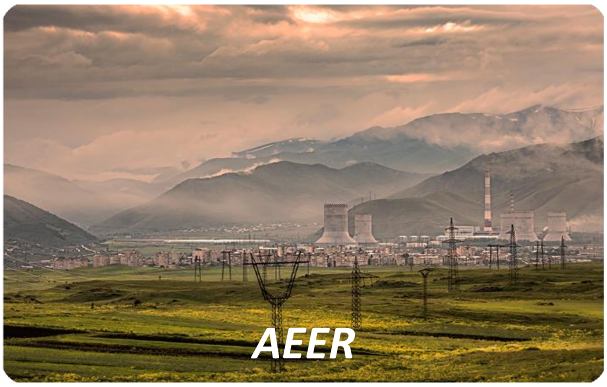

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