[redacted]

Name:

Melanie Edwards

Which of the following best describes your situation?

Research and academia

Are you responding on behalf of an organisation or industry body?

Yes

Who are you responding on behalf of?

Australian Wildlife Services

How would you like to respond?

c. Both

[redacted]

What are the opportunities to reduce emissions and build carbon stores in agriculture and the land? What are the main barriers to action?

The main barriers to reduce emissions are business as usual, and products as usual, where there are no opportunities to reduce emissions and where reliance is on offsets. For example, there are limited opportunities to reduce methane in rangeland livestock, yet the redmeat industry continues to aim for increased numbers of livestock which will only increase emissions through methane emissions and soil organic carbon loss through overgrazing. Numbers of individuals need to reduce to reduce emissions and to enable soil carbon sequestration. There is opportunity to use Australian adapted red meat species such as kangaroos (which are mostly culled as pests and wasted), which don't emit methane, in place of, at least some conventional livestock. Sensible use of kangaroos (or a kangaroo grazing system) will see methane emissions reduced and increased soil carbon sequestration.

How can we progress emission reduction efforts whilst also building resilience and adapting to climate change?

The system needn't be all or nothing, but about finding those areas where a substantial impact can be made. It can be an adaption at the pace that best suits farmers, the climate and the kangaroo population. Progression could include a program that was specifically designed to address the issue of reducing methane and increasing soil organic carbon through alternative species grazing management.

Are there initiatives or innovative programs underway that could be applied or expanded on at a national scale?

There are state kangaroo management plans for kangaroo harvests. These could be utilised to incorporate carbon management through kangaroo use.

What are the most important options to be further adopted or supported, looking in the short and the longer-term?

Reduction in rangeland livestock numbers and replacement with low emitting species. Together, enteric methane emissions from cattle and sheep (greater than one year old) generate 6.3 per cent of all of Australia's emissions and it is nearly 10 percent including those younger than one year old. It is a huge amount to offset on a yearly basis, and nonsensical when a portion could be replaced by kangaroos, of which most carcases do not enter the production chain as the result of pest culling.

What are the practical solutions to increase uptake?

A practical solution to increase uptake would be to work towards increasing the value of kangaroos so farmers want to manage them. Adding value through carbon credits, environmental stewardship payments, and branding and marketing based on product quality and accurate description, health benefits, animal welfare credentials, and social and ethical attributes would increase uptake.

How do you see the agriculture and land sectors contributing over the medium and longer-term? What are the opportunities to deliver emission reductions in parallel with wider goals?

A Kangaroo Grazing System would be in parallel with reducing waste and increasing supply of protein to a growing population.

How can the Australian Government better support agriculture and land sectors to:

a) drive innovation

b) build capacity

c) ensure the system enables emissions reductions

Recognising and funding projects and programs which are uniquely Australian, products that are Australian and that have adapted to the Australian climate. Include support and promotion of products which reduce emissions or result in less emissions being emitted.

Is your response confidential?

No

Do you agree to your response being published on our website?

Yes

I have read and understood the privacy notice and consent to the collection, use and disclosure of my personal information as outlined in the privacy notice.

Yes

Confirm that you have read and understand this declaration.

Yes

Market opportunities for methane abatement and carbon storage through improved kangaroo grazing management

by Melanie Edwards and George Wilson
July 2023

AgriFutures® National Challenges and Opportunities

Market opportunities for methane abatement and carbon storage through improved kangaroo grazing management

Integrating kangaroos into pastoral production systems to assist in meeting the Paris Agreement emissions targets

by Melanie Edwards and George Wilson

July 2023

AgriFutures Australia publication no. 23-094
AgriFutures Australia project no. PRO-015092

ISBN 978-1-76053-387-8
ISSN 1440-6845

Market opportunities for methane abatement and carbon storage through improved kangaroo grazing management
Publication no. 23-094
Project no. PRO-015092

Researcher contact details

Melanie Edwards
Australian Wildlife Services
51 Stonehaven Cres
Deakin ACT 2600

0421 484 233
melanie.edwards@awt.com.au
www.awt.com.au

AgriFutures Australia contact details

Building 007, Tooma Way
Charles Sturt University
Locked Bag 588
Wagga Wagga NSW 2650

02 6923 6900
info@agrifutures.com.au
www.agrifutures.com.au

In submitting this report, the authors have agreed to AgriFutures Australia publishing this material in its edited form.

AgriFutures Australia is the trading name for Rural Industries Research and Development Corporation (RIRDC), a statutory authority of the Australian Government established by the *Primary Industries Research and Development Act 1989*.

Research investments made or managed by AgriFutures Australia, and publications and communication materials pertaining to those investments, are funded by industry levy payers and/or the Australian Government.

Foreword

Reductions in greenhouse gas emissions and increases in carbon sequestration are major challenges facing Australian agriculture. These challenges have to be aligned to the future global demand for food and the potential growth in agricultural output from Australian farms. To ensure Australian farmers and growers achieve key targets focused on sustainable food production, enterprise diversification is an important consideration. Kangaroos are a low-carbon source of red meat. The industry is small compared to the existing red meat sector but there are opportunities to grow the sector as an alternative red meat substitute, and by increasing soil carbon sequestration through reducing total stocking rate, duration and grazing intensity.

The project *Market opportunities for methane abatement and carbon storage through improved kangaroo grazing management: Integrating kangaroos into pastoral production systems to assist in meeting the Paris Agreement emissions target* was funded by AgriFutures Australia through its Carbon Initiative. The project aimed to understand whether (i) an identifiable solution could be sought for alternative grazing management through a Kangaroo Grazing System; (ii) there was an opportunity to reduce livestock and use kangaroos as an alternative red meat source to reduce enteric emissions and sequester carbon in soil; and (iii) those novel systems could be a source of carbon offsets.

The report identifies that the livestock sector requires greater sectoral knowledge and new technologies to reduce methane production derived from enteric fermentation, and that modelling suggests an integrated Kangaroo Grazing System could reduce total methane emissions from sector. Furthermore, the modelling identifies that through integrating kangaroos into pastoral sector, increased sequestration of carbon in soil would result. The report also reveals that income lost through diversifying livestock enterprises and reducing livestock herd numbers could be recouped through kangaroo harvesting, carbon credits for soil carbon sequestration, and future biodiversity stewardships payments.

A recommendation is that a strategic review of the future integration of kangaroos through livestock diversification, and their role in future emissions policies, is required as part of a proposed National Kangaroo Strategy. Such a strategy would clarify the population goals of kangaroo management, as well as the role of, and societal expectations for, kangaroos on pastoral properties. To progress the role of kangaroos in livestock diversification, and for future policy development, further research and extension is needed to understand methane abatement and soil carbon sequestration rates.

Michael Beer
General Manager, Rural Futures
AgriFutures Australia

About the authors

Melanie Edwards

Since 2007, Melanie Edwards has worked as a Research and Project Officer at Australian Wildlife Services, a consultancy that focuses on developing wildlife industries and tourism opportunities that support conservation and integrate traditional knowledge and wildlife science.

Melanie received her PhD (2013) and first-class Honours (2006) in Ecology, Evolution and Genetics from the Australian National University (ANU). She has worked and conducted research at a number of institutions, including Priam Australia, the Smithsonian Institution, ANU and the University of Canberra, where she investigated a diverse range of animals, including sea otters, bottle-nose dolphins, desert tortoises, brush-tail possums, wallabies, kangaroos, Australian and Amazonia parrots, and eastern bearded dragons. Her research has spanned multiple fields, including genetics, immunology, cytogenetics, nutrition, diagnostics, sex determination and wildlife management.

Melanie has taught hundreds of tertiary biology students and has also worked within industry-government committee partnerships at the Department of Agriculture, Water and the Environment. She has collaborated with Prof. George Wilson, the co-author of this report, on several papers, including kangaroos and greenhouse gas emissions and indigenous land management. Melanie remains dedicated to research that addresses climate change and healthy landscapes with rich biodiversity in Australia.

Prof. George Wilson

Prof. George Wilson is an Honorary Professor at the Australian National University's Fenner School of Environment and Society. He is also the Principal of Australian Wildlife Services. He has worked for the Australian and state government agencies, as well as British Government wildlife research agencies, in public policy, strategic analysis and scientific research. He has published more than 160 papers, articles and book chapters, and written three books.

His qualifications are Master Veterinary Science (University of Sydney) and PhD in Zoology (University of Aberdeen). He was made a Member of the Order of Australia in 2021. He is also a commercial pilot and aircraft owner. He has conducted extensive aerial surveys of wild animals and has more than 4000 hours of aeronautical experience.

As a veterinarian, he also has extensive experience in both practical animal welfare and policy, and was responsible for these matters within the Australian Government as Assistant Secretary/General Manager, Animal Resources Branch at the Bureau of Rural Resources from 1988-1994. For several years during this time, he was also Chief Veterinary Officer.

His continuing interest is kangaroo management, wildlife population ecology, threatened species management, complementing Indigenous wildlife management, and aerial surveying.

Acknowledgments

We would like to extend a special thank you to our colleagues Charlie Wilson and Samaa Kalsia for their expertise and contribution to the report, especially for their comprehension of international carbon markets and biodiversity stewardship programs, respectively.

We are grateful to the following experts outside of our organisation for their commentary, interest, and support: Fiona Garland, Geoff Wise, Leon Zanker, Dennis King, Russell Grant, Rob Kemp, Anita O'Connor, Terry Brill, Tanya Stephens, Josh Clarke, Erlina Compton and Sheridan Maher as members of the New South Wales (NSW) Kangaroo Management Task Force, NSW Western Local Land Services; Skye Glenday, Co-chief Executive Officer, Climate Active; Verra Carbon Standards support staff; and Mel Ford, General Manager, Emission Reduction Fund Method Development Branch, Clean Energy Regulator.

We met with The Hon. David Littleproud MP when he was Minister for Agriculture and Water Resources and the Hon. Mark Coulton MP when he was the Minister for Regional Health, Regional Communications and Local Government. We have also had helpful discussions with Reece Peddler and Rebecca West, Fowlers Gap Arid Zone Research Station, University of NSW. Big Ampi goat producer Rod Carey provided helpful insights into the rapidly growing goat industry in NSW. Ben Allen kept us informed about the scale of exclusion fencing Queensland and its intended and unintended consequences and opportunities for wildlife.

We also express our appreciation to the Carbon Initiative team at AgriFutures Australia. The Carbon Initiative was designed to fill gaps in knowledge, deliver innovative and novel approaches to solvable problems, and explore new market pathways for producers to collaborate on carbon projects. Therefore, we are immensely grateful to Program Manager and mentor Julian Hill and Senior Manager Jennifer Medway for supporting and making this research possible, and also Senior Manager Ellen Buckle, who is responsible for the Kangaroo Program.

Last, but most importantly, we would like to thank a team of ecologists, especially John Read and Graeme Coulson, who, with us, continue to champion improved management of overabundant kangaroos to improve biodiversity, ecosystem functions, animal welfare and greenhouse gas abatement, and reduce waste.

Abbreviations

ABS	Australian Bureau of Statistics
ACCU	Australian Carbon Credit Unit
ACT	Australian Capital Territory
AfN	Accounting for Nature
ALMS	Australian Landcare Management System
AL-MAP	Active Land Management and Agricultural Production
B	billion
BCA	Business Council of Australia
CDM	Clean Development Mechanism
CER	Clean Energy Regulator
CERC	certified emission reduction credits
CH_4	methane
CI	confidence intervals
cm	centimetre
CN30	carbon neutrality by 2030
CO_2	carbon dioxide
CO_2e	carbon dioxide equivalents
COP	Conference of the Parties
CSF	Climate Solutions Fund
CSIRO	Commonwealth Scientific and Industrial Research Organisation
C+B Pilot	Carbon and Biodiversity Pilot
DAFF	Department of Agriculture, Fisheries and Forestry
DISER	Department of Industry, Science, Energy and Resources
DSE	dry sheep equivalent
EOV	Ecological Outcomes Verification
ERAC	Emissions Reduction Assurance Committee
ERF	Emissions Reduction Fund
GDP	gross domestic product

GHG	greenhouse gas
Gg	gigagrams
GI	grazing index
Gt	gigatonne
ha	hectare
HIR	human-induced regeneration
kg	kilogram
KGS	Kangaroo Grazing System
KLC	kangaroo landscape conservation
kPa	kilopascal
km	kilometre
L	litre
M	million
MLA	Meat & Livestock Australia
MSA	Meat Standards Australia
NDCs	nationally determined contributions
NGO	non-government organisation
NLMP	National Livestock Methane Program
N_2O	nitrous oxide
NRM	natural resource management
NSF	natural sequence farming
NSW	New South Wales
NSWKMT	New South Wales Kangaroo Management Taskforce
NT	Northern Territory
Pg	petagram
PL&SB	Prime Lamb and Southern Beef
Qld	Queensland
RCS	Resource Consulting Services
RMAC	Red Meat Advisory Council

SA	South Australia
SA2	Statistical Area 2
t	tonnes
Tas	Tasmania
UNFCCC	United Nations Framework Convention on Climate Change
VCS	Verified Carbon Standard
Vic	Victoria
WA	Western Australia
3-NOP	3-Nitrooxypropanol
°C	degrees Celsius

Contents

Executive summary

What the report is about

There is global urgency to reduce greenhouse gas (GHG) emissions. In the agriculture sector this reduction must be balanced with meeting increasing global food demands. Australia's goal is to reach net zero by 2050 and the Australian red meat industry target is to be net zero by 2030. Achieving these objectives relies on offsets because current methods to reduce enteric methane (CH_4) emissions are not available for sheep or suitably demonstrated for cattle at scale. Increasing the herd and production, where no grazing management practices have been put into place will also likely increase ongoing soil organic carbon loss. This presents a dilemma that is yet to be rectified.

This report proposes lowering livestock numbers and using commercially harvested species of kangaroos – eastern grey kangaroos (*Macropus giganteus*), western grey kangaroos (*M. fuliginous*) and red kangaroos (*Osphranter rufus*) – as an alternative red meat production option to reduce enteric emissions and sequester carbon in soil. It explores options of gaining carbon credits through the Emissions Reduction Fund (ERF) and through the international market and offers insights to the feasibility of such an enterprise and other co-benefits.

The report considers implications of the proposal and offers solutions, along with a set of guidelines yet to be trialled for an integrated Kangaroo Grazing System (KGS) and an accompanying spreadsheet that aims to enable producers to assess their opportunities to undertake these alternative management activities.

Who is the report targeted at?

The report is targeted at pastoralists (graziers), particularly those looking to reduce their livestock GHG emissions, control pest kangaroos, or improve their grazing impact. Together with kangaroo harvesters and processors, they can generate a climate friendly, globally unique and sustainable product. The report provides them with some of the information needed to enter the carbon market.

Other potential beneficiaries of our report are policy makers with responsibilities for reducing Australia's GHG emissions; venture capitalists looking for opportunities in the food and land use sector; carbon aggregators; managers developing new ERF methodologies; the red meat industry more generally, who currently have no suitable opportunities, demonstrated at scale, to reduce an individual's enteric CH_4; and wildlife managers and conservationists looking to conserve biodiversity through sustainable use of natural resources.

The benefits will also flow on to rural communities more broadly through gains in employment, economic diversity and improvements in landscape scale ecosystem function.

Where are the relevant industries located in Australia?

Our proposed KGS would be best implemented in the rangelands, where there are overabundant kangaroos competing with livestock. This is also where the kangaroo industry is strongest, particularly New South Wales, Queensland and South Australia and kangaroos are already harvested commercially for meat for human or animal consumption, and skins for use as leather or fur. Kangaroo harvesting and processing is an established but small industry driven by market demand, which in 2020 was its lowest since 2000. For the previous 10 years, less than half the available quota was taken; in 2020 the proportion was 20 per cent. The low demand leads to low prices and alternative population management and fence construction.

Kangaroo industry exports are small and volatile, with important markets closing over the last two decades. The loss of access to the Russian market resulted in a 57 per cent reduction in the value of meat export markets, which halved the price paid to harvesters. The Californian market also collapsed due to a successful 2016 campaign to ban the import of skins to that state. Despite these closures, Australia has bilateral certification for edible kangaroo meat and/or meat products to be exported to more than 60 countries.

Background

The Paris Agreement under the United Nations Framework Convention on Climate Change is a legally binding international treaty adopted by 196 Parties that entered into force on 4 November 2016. Its goal is to limit global warming increases to below 2 degrees Celsius (°C), and preferably below 1.5 °C, compared to pre-industrial levels. To achieve this long-term temperature goal, countries aim to reach global peaking of GHG emissions as soon as possible and to achieve a climate neutral world by mid-century. However even if implemented on time, average global surface temperatures of 3 °C or more would be the consequence by 2100.

To keep to its temperature goals, global carbon emissions need be lowered at the faster rate of 7.6 per cent per year by 2030 from now, or by 2.7 per cent per year for the 2 °C warming limit.

CH_4 management is particularly important in achieving the outcome of the Paris Agreement. Early mitigation of CH_4 emissions would significantly increase the feasibility of establishing global warming below 1.5 °C, alongside having co-benefits for human and ecosystem health. Due to its much shorter lifetime, CH_4 has disproportionate impact on near-term temperature, and is estimated to account for almost one-third of the warming observed to date.

Concern about CH_4 lead to the Global Methane Pledge of 30 per cent reduction by 2030. It was proposed by the European Union and the United States of America (US) at the Conference of the Parties (COP) 26 and has been adopted by more than 122 Countries, including New Zealand. The Australian Government signed the pledge in 2022.

In Australia, enteric CH_4 from beef cattle and sheep contributes 47387.61 gigatonnes of carbon dioxide equivalents (CO_2e), or nine per cent of Australia's GHG emissions; Australia's projections include increasing the herd, which under current practice will also increase emissions. Less information is available about goats but they are 'livestock' and one of the red meats covered by the Red Meat Advisory Council that reports to the Australian Minister for Agriculture.

Livestock that generate CH_4 also impact soil carbon sequestration when they overgraze agricultural soils. The soil carbon that has been lost from soil can be sequestered by increasing the plant biomass through the management of stocking rate, duration or intensity of grazing. This means that through appropriate management there is the opportunity to reverse the loss and sequester carbon back into soils. Because of the vast size and extent of grazing lands, even a small improvement to store carbon translates into large sequestration rates.

Kangaroos could be used in place of livestock, or even partially in their place, to provide an alternative source of red meat that is carbon friendly. Although kangaroos are often compared with ruminants, the various macropod species show a wide range of unique adaptations to herbivory and they produce minimal amounts of CH_4. Kangaroos are also expected to have less effect on the soil and plant communities than domestic livestock, as they evolved within the Australian landscape and have less contact pressure with the ground.

In pastoral environments kangaroos compete with livestock for grasses and forbs, particularly during droughts, and often pastoralists seek to cull them as pests. When conditions and circumstances are formidable, kangaroos can die by the millions from starvation or extreme temperatures as the result of reduced resources. Their greater use and incorporation into traditional practices would reduce enteric CH_4 emissions and use a product that would otherwise be wasted. Further, their management could contribute significantly to soil carbon sequestration.

In this report we identify how improved kangaroo management could reduce GHG emissions and increase carbon sequestration in vegetation and soil with the intent of maintaining on-farm productivity. We evaluate the opportunity for the grazing system to be included under current carbon methodologies to generate new and achievable opportunities for producers.

Aims/objectives

The report objectives were to identify how improved kangaroo management could generate new and achievable opportunities for producers. Specifically, to enable:

- carbon storage in soil through grazing management
- a reduction of total enteric carbon emissions through greater use of kangaroos
- economic viability associated with returns generated from industry diversification and carbon storage and abatement
- co-benefits for the environment, animal welfare and the social licence to produce.

Methods used

In our report we use cattle and sheep population data provided by the Australian Bureau of Statistics and GHG emission data provided by the National Greenhouse Gas Inventory to determine the potential enteric CH_4 abatement from livestock. Soil carbon data was derived from Soils Revealed, and kangaroo population data was derived from state kangaroo management plans.

To assess options for stocking rates to increase storage of carbon in soils we used published scientific modelling on grazing indices. We determined total grazing pressure due to livestock numbers in Statistical Area 2 regions and incorporated kangaroo densities. QGIS3 was used to map cattle, sheep and kangaroo populations.

We reviewed both Australian and international soil and enteric CH_4 carbon methodologies to determine which could be implemented under a management regime that integrated kangaroos and livestock. We also looked at the opportunity for groups of landholders to work with harvesters and processes to participate in certification of kangaroo products under Climate Active.

Results/key findings

We describe an integrated KGS that would reduce the proportion of grazing pressure due to domestic livestock – cattle and sheep, while using commercial harvesting of kangaroos to manage the other portion of the grazing pressure, much of which is currently wasted.

Kangaroo populations would be managed to pre-determined, prescribed grazing levels so as to achieve a total grazing pressure that better integrates kangaroos and domestic livestock. The outcome would be an increase in soil and possibly vegetation carbon sequestration, a reduction in total CH_4 emissions, while at the same time achieving sustainable kangaroo populations and removing the extreme peaks of populations that precede crashes.

Reducing livestock emissions is possible through genetic selection and diet. Feed supplements have yet to be successfully applied beyond feedlots and dairies at scale on the vast spans of Australian rangelands.

Under our proposals, enteric CH_4 would be reduced by not restocking cattle and sheep after drought, and/or by lowering their numbers. On average cattle produce 1.55 tonnes (t) of CO_2e per head per year and sheep 0.18 t CO_2e per head per year. Kangaroos on the other hand produce 0.01 t CO_2e per head per year. Goats are not included as this stage but we believe they are a very important component of integrated management as more information becomes available.

Together, enteric emissions from cattle and sheep (greater than one year old) generate 6.3 per cent of all of Australia's emissions, that is approximately 33 megatonnes of CO_2e per year. When converted to saleable carcase, per head, in their last year of life, cattle and sheep produce 7.6 and 8.6 kg CO_2e per kilogram (kg) compared to 0.6 kg for kangaroos.

These calculations indicate significant potential to generate carbon credits by substituting kangaroo products for sheep and cattle products. Further work is needed to refine the opportunities and incorporate into the assessment, emissions from the growing goat industry.

The KGS would also result in increased carbon storage in soil through improved grazing management. Under current grazing practices, Australian soils are losing carbon. If stocking rates remain the same, it has been suggested losses will continue at a conservative rate of at least 0.15 to 0.29 t of CO_2e per hectare (ha) per year with large regional differences. Through better grassland management, sustainable pastures and adaptive management, Australian soils could sequester an average 2.24 t CO_2e per ha per 20 years, noting that this is in addition to not losing more carbon, under business as usual.

Soil carbon storage would be achieved by targeting an achievable grazing index, that is, the stocking rate to carrying capacity ratio, that encouraged forage biomass growth. Where pastoralists would otherwise manage livestock, they would incorporate kangaroos to calculate the target grazing index.

The KGS proposal would be more feasible in some areas than others. Over the years, kangaroos have contributed, on average, more than seven to 18 per cent of grazing pressure in Australia. These values are an underestimate as total kangaroo populations Australia wide are not assessed. In the rangelands, where kangaroo surveys are undertaken, in 2016, cattle were responsible for 63 per cent, sheep seven per cent and kangaroos 30 per cent of total grazing pressure. Again, this is likely to be an underrepresentation from kangaroos.

In some regions in New South Wales (Bourke-Brewarrina, Cobar, and Far West) and in Queensland (Far South West) grazing pressure from kangaroos reaches more than 65 per cent of the total. Removing livestock greater than one year old from this area and using kangaroos that are already there instead, could abate 785390 t CO_2e or 2.4 per cent of the total enteric CH_4 emissions of livestock (greater than one year old). While these calculations come from regions heavily populated with kangaroos, the regions that have more cattle and sheep could produce abatement measures that are much higher.

In 2020, approximately 4.5 million (M) kangaroos were not harvested under the allowable state management kangaroo harvest quotas. Those animals could have legally entered the commercial trade and would have potentially produced 80 M kg of kangaroo meat at approximately 18 kg per individual useable/saleable carcase. That is the equivalent of the product from approximately 400,000 steers at 200 kg per useable/saleable carcase.

The 4.5 M kangaroos produce approximately 0.048 Mt CO_2e, while 400,000 head cattle produce approximately 0.62 Mt CO_2e. If the kangaroo quota was met and replaced the equivalent amount of beef, it would abate approximately 0.57 Mt CO_2e. That is nearly two per cent of all beef livestock emissions.

The figure of 4.5 M kangaroos not harvested commercially is an underestimate. Many more kangaroos were destroyed as a pest mitigation activity by landholders and utilising them as proposed here would have saved even more CH_4 emissions.

While income would be lost from cattle and sheep substitution, gains could be made through kangaroo harvest and the sale of carbon credits for soil carbon sequestration and enteric CH_4 reduction. There is also scope for kangaroos and carbon credits to be worth more. If the Safeguard Mechanism, which sets limits for major polluters and takes effect like a carbon tax, is extended to the livestock industries or to agriculture more generally, penalties would apply for CH_4 emissions. This would increase the price differential between low emitting kangaroos and higher emitting cattle and sheep.

Integration of improved kangaroo management into stewardship schemes and proposed biodiversity offsets programs would also increase the value of kangaroos by receipt of payments for credits.

Attached to this report are guidelines and a spreadsheet that can be used to compare management options and potential returns. We have used a theoretical property to drive the spreadsheet but invite pastoralists to enter their own corresponding values. We offer three scenarios; (1) pastoralist turned harvester, (2) pastoralist charging access fees for kangaroos, and (3) the running of concurrent enterprises (with the latter also possible under the first two options).

Under current kangaroo prices and carbon values, all management options lose income. To make the proposed KGS economically viable, kangaroos and/or carbon credits need to be worth a lot more, and/or carbon emissions, and especially enteric CH_4 need to be taxed. Even if not implemented domestically, a price on carbon will be implemented internationally under systems such as the European Carbon Border Adjustment Mechanisms and initiatives to implement the Methane Pledge.

We have also identified a number of co-benefits under the KGS. Environmental benefits including reduction in soil compaction, and increase in litter, plant cover, and root biomass as the pressure exerted by kangaroos on the ground is lower than that of ungulates. These processes result in structural improvements to the soil that promote nutrients and water retention, and that in turn promote essential ecosystem functions and services. Encouraging the ground cover and abundance of native perennial grasses and forbs and allowing natural regeneration of shrubs and trees is one of the most effective strategies for promoting biodiversity in the long term.

Kangaroo grazing can be manipulated as a management tool to increase the availability of suitable habitat structure and niches for native fauna and flora species in which they find shelter from competition, protection from predators and increased availability of food and nutrients. These are also the management activities that would generate stewardship credits, such as nominating a target density and impact in relation to other herbivores and managing towards that objective.

Implications for relevant stakeholders

The ERF currently provides for a soil carbon sequestration methodology and credits for more efficient and productive cattle management and hence indirectly lower CH_4 emissions; however, there are no methodologies applicable to direct reduction in CH_4e emissions under the Fund. Enteric CH_4 abatement carbon credits, however, could be achieved through the international market. We have identified two possible options, either Verra's methodology VM0026 for sustainable grasslands management, or VM0032 methodology for the adoption of sustainable grasslands through adjustment of fire and grazing.

At current prices our integrated KGS would lower the financial return and profitability of pastoral enterprises. However, with the implementation of changes that we recommend there is scope for adding value through carbon credits, environmental stewardship payments, and branding and marketing based on product quality and accurate description, health benefits, animal welfare credentials, and social and ethical attributes.

Kangaroos can have large home ranges. They respond to patchy rainfall and storm events by moving and are not constrained by conventional livestock fences. While potentially challenging, there are a number of fencing and population monitoring innovations that could address this problem. They relate to legal questions and proprietorship.

Kangaroos are owned, managed and monitored by state governments. Pastoralists have limited legal control over their numbers and consequently kangaroos are regarded as pests when overabundant. In every state and territory, licences are available to reduce numbers of kangaroos that are damaging property or causing economic hardship. In most jurisdictions commercial use of kangaroos is permitted and is framed as sustainable use of the resource.

Notwithstanding these opportunities kangaroo numbers periodically contribute to excessive pressure on pastures and construction of exclusion fences has become widespread with the objective of greatly reducing, and in some cases eliminating kangaroos within them. Despite their high cost (>$5,000 per kilometre), investors regard the expense as justifiable because property owners have few other mechanisms for management of kangaroo movements and stabilising grazing pressure. They are not the proprietors of the kangaroos that migrate onto their properties.

Many fences are sponsored privately and some have government support where they enclose a cluster of properties and also address wild dog and feral pig impacts. So far most have been constructed in Queensland but in 2022 the number in New South Wales is rapidly growing, especially to support the goat industry.

We have proposed that once a minimal population within these fences is agreed as the accepted minimal population, pastoralists in trials should be permitted to receive a form of custodianship or proprietorship to enable harvesting of premium product and acquisition of carbon credits. They would integrate kangaroos into their other enterprises and effectively 'farm' kangaroos. Management and assessment of progress of a trial would proceed most easily within an exclosure fence. Doing so would help convert a current liability to an asset.

There could be complications over harvests; limits on permits may not line up with the number of kangaroos needed to maintain feed on offer or species for carbon sequestration and storage, and limits may also impact productivity and economic goals. Our proposal, which is to set minimal agreed populations, would change current practice and obviate any such issues. Small-scale population monitoring to ensure forage biomass and sustainable populations would facilitate confidence in sustainable harvests.

The KGS would reduce the number of kangaroos culled as pests, thereby reducing animal welfare liabilities related to the non-commercial code for kangaroo culling. This change would have benefits for stakeholders concerned about animal welfare and regulators seeking to improve the integrity of the monitoring of the take and enforcement of kangaroo protection standards. 'Shoot and let lie' means there is no revenue and that regulators cannot assess how many kangaroos are taken, which threatens the veracity of figures on numbers culled. Regulators are also unable to monitor shooter accuracy and skill procedures to reduce the number of animals that are wounded. Carcases are not brought to a nominated site for inspection but left in paddocks or used for domestic purposes.

Kangaroo populations follow boom and bust cycles with detrimental outcomes; during the bust there are mass mortalities caused by starvation. A KGS would manage population numbers so to reduce the impact of overabundant kangaroos on natural resource values and sustainability of landscapes. These changes would have implications for natural resource managers to flatten the population peaks and so reduce damage during the resulting drought induced troughs.

Pastoralists can destock their livestock during drought, but under current management they have limited options other than pest destruction to manage kangaroo numbers. While they take responsibility to protect their livestock; the welfare of kangaroos is outside their control. The deaths of kangaroos during drought are a psychological burden for pastoralists and others who witness mass dying events. Additionally, when kangaroos are left to starve on private properties, the public can perceive this as management incompetency with the potential to impact a producer's broader social licence to operate. The proposed KGS would lessen these adverse processes and have implications for pastoralists and others affected in a central manner.

Kangaroo management is currently wasteful; there is a small industry (AUD$200 M), but many (probably most) carcases do not enter the production chain as the result of pest culling and starvation when drought hits. Our novel grazing system would encourage the use of several million kilograms of meat and skins, which are being left in paddocks at a time when a growing global population needs sources of protein. It therefore has implications to the wider Australian community and natural resource management.

Conclusion and recommendations

We propose a grazing system for rangeland livestock producers that would reduce the stocking rate of livestock and allocate part of the available pasture to produce kangaroo meat and skins. It would reduce Australia's GHG emissions by up to, and possibly even more than nine per cent, depending on the extent it is implemented; and it would also increase soil sequestration of carbon. While income would be lost from a reduction in livestock, income diversification would arise from harvesting kangaroos to produce a premium product, as well as carbon and potentially biodiversity credits. Such a change should be relatively easy because the kangaroos are already there and many producers currently seek to reduce their impacts through pest culling.

Kangaroos remain undervalued and underutilised. There is considerable waste of most kangaroos available for commercial harvest and utilisation. Greater use could increase protein production and carbon credits offset.

However, potential investors in research and infrastructure, both on farm and in processing, are fearful of further industry contraction and declining demand of kangaroo products. They doubt the capacity of the industry, as it currently operates, to supply high-quality reliably and regularly, to accurately describe clean product and to meet animal welfare standards.

The current situation is an impediment to investment and represents a case of market failure. Pastoralists have no incentive to work towards increasing the value of kangaroos. They can neither act in their private interests, nor deliver the outcomes for kangaroo welfare or natural resources, which would be in the wider public interest.

The recommendations identified by this report include:

- Conduct a strategic review of the objectives and plans of kangaroo management to identify solutions to the major issues identified in this report.
- Conduct pilot trials of proposed kangaroo management integrated into other livestock management within exclosure fences.
- Conduct further research to monitor that the KGS would reduce enteric CH_4 emissions and increase soil carbon sequestration, while at the same time provide for the growing demand for protein and food security.
- Develop an ERF methodology that supports the KGS and a program that accounts for the co-benefits of the KGS.
- Develop a communication program that informs the wider community about the positive impact the alternative KGS could have for reducing and sequestering Australia's GHG while simultaneously providing a source of protein and an alternative livelihood for pastoralists.

Introduction

Global urgency of reducing greenhouse gas emissions

The atmospheric concentration of carbon dioxide (CO_2) and methane (CH_4) is impacting global temperatures and in turn the health and functioning of the biosphere (Figure 1). Multiple lines of evidence show that the incidence of extreme weather events will increase as the planet warms. Such events are a natural feature of the climate system, but there is strong evidence that many of them, such as heatwaves, bushfires, storms and coastal flooding, have become more frequent and intense in recent times (Seneviratne *et al*. 2012, UNEP & CCAC 2021). These extremes and their risks are likely to escalate as global temperatures continue to rise and our capacity to respond becomes compromised as the frequency increases (Seneviratne *et al*. 2012).

Our planet's living systems have evolved over thousands of years in a temperature range that includes relatively minor fluctuations around the long-term average; however, most cannot evolve quickly enough to accommodate the rapid increases in average temperatures we now observe and feel (AAS 2021). A halt, or even reversal, is needed to reduce the future increase in atmospheric greenhouse gas (GHG) concentrations. Anthropogenic actions need to be taken to reduce interactions that cause increases in either GHGs to flow to the atmospheric pool or that result in carbon being removed from the atmospheric pool (IPCC 2018) with 'avoid activities that cause emissions' as the most favoured option (Figure 2). While carbon sequestration is a large component of the global climate change strategy to reduce global temperatures, sequestration is time dependent and can take years to reach its full potential. If activities are not put in place soon, it will be too late for sequestration to have any reasonable effect. Policy makers are starting to discuss the future of sinks and how their role might decrease as climate change progresses.

The total emissions reductions currently pledged through the United Nations Framework Convention on Climate Change (UNFCCC) Paris Agreement, even if implemented on time, will translate as average global surface temperatures of 3 degrees Celsius (°C) or more above the pre-industrial period by 2100 (AAS 2021). The UNFCCC Paris Agreement, which came into force in 2016, aims to hold the increase in the global average temperature to well below 2 °C above pre-industrial levels, and to pursue efforts to limit temperature increase to 1.5 °C; however, limiting climate change to 1.5 °C is now virtually impossible (IPCC 2022). A rapid transition to net zero GHG emissions[1] is required if the international community is to limit warming to 'well below 2 °C' in line with the Paris Agreement (IPCC 2022).

Acting early and urgently reduces the scale of the impacts and can save many lives and livelihoods. This has significant potential benefits in terms of health and regional development and embracing the new economic opportunities associated with a move to net zero GHG emissions. To achieve this long-term temperature goal, countries party to the agreement aim to **reach the global peak of GHG emissions** to achieve a climate neutral world. Doing so makes good business sense. In 2016, the World Economic Forum's Global Risk Survey rated failure of climate change adaptation and mitigation as one of the top four long-term global risks of highest concern to business. Others were biodiversity loss and ecosystem collapse, water and food crises, and extreme weather events (World Economic Forum 2016).

Animal agriculture plays a large role in climate change with emissions at 87 per cent of human-induced GHG emissions (Rao 2020).

[1] Net zero, or neutrality, means that net zero emissions are achieved when anthropogenic emissions of greenhouse gases to the atmosphere are balanced by anthropogenic removals over a specified period.

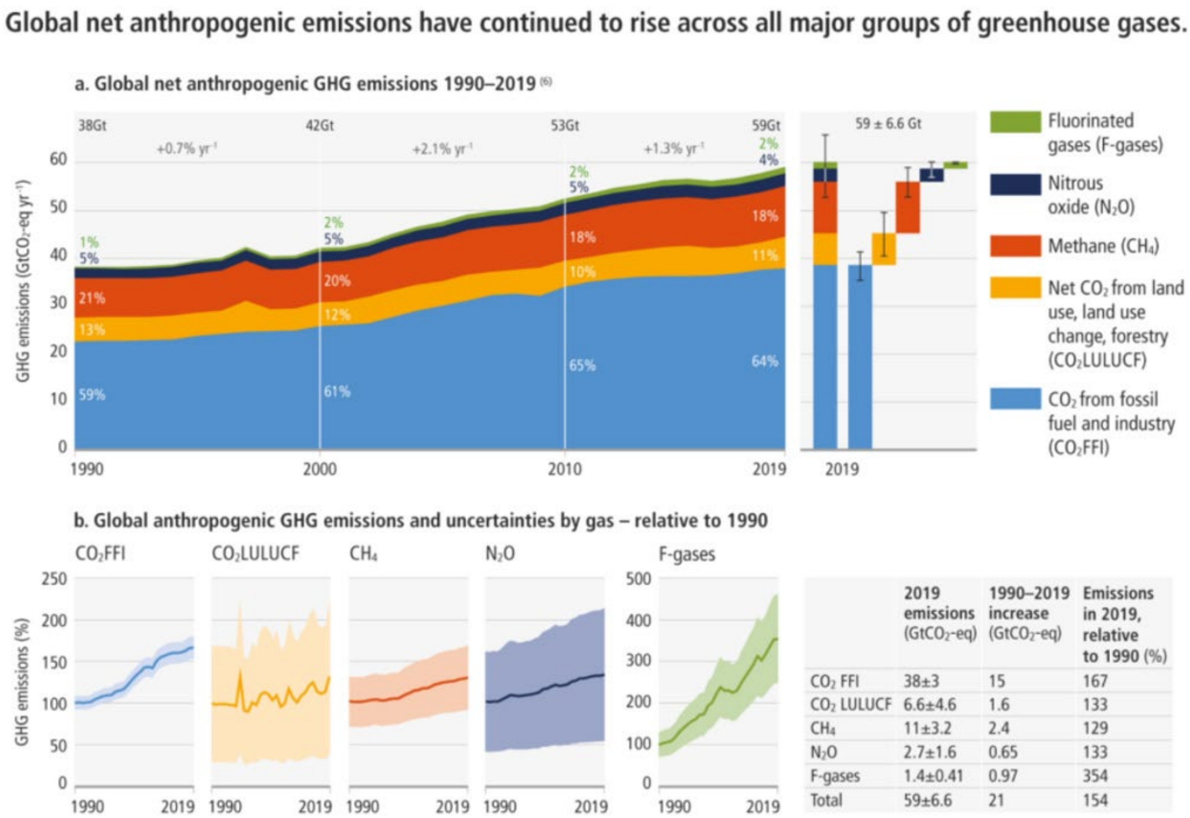


Figure 1. Total human-driven emissions (a) and their uncertainties (b). The solid line indicates the central estimate of emissions trends and the shaded area is uncertainty (IPCC 2022).

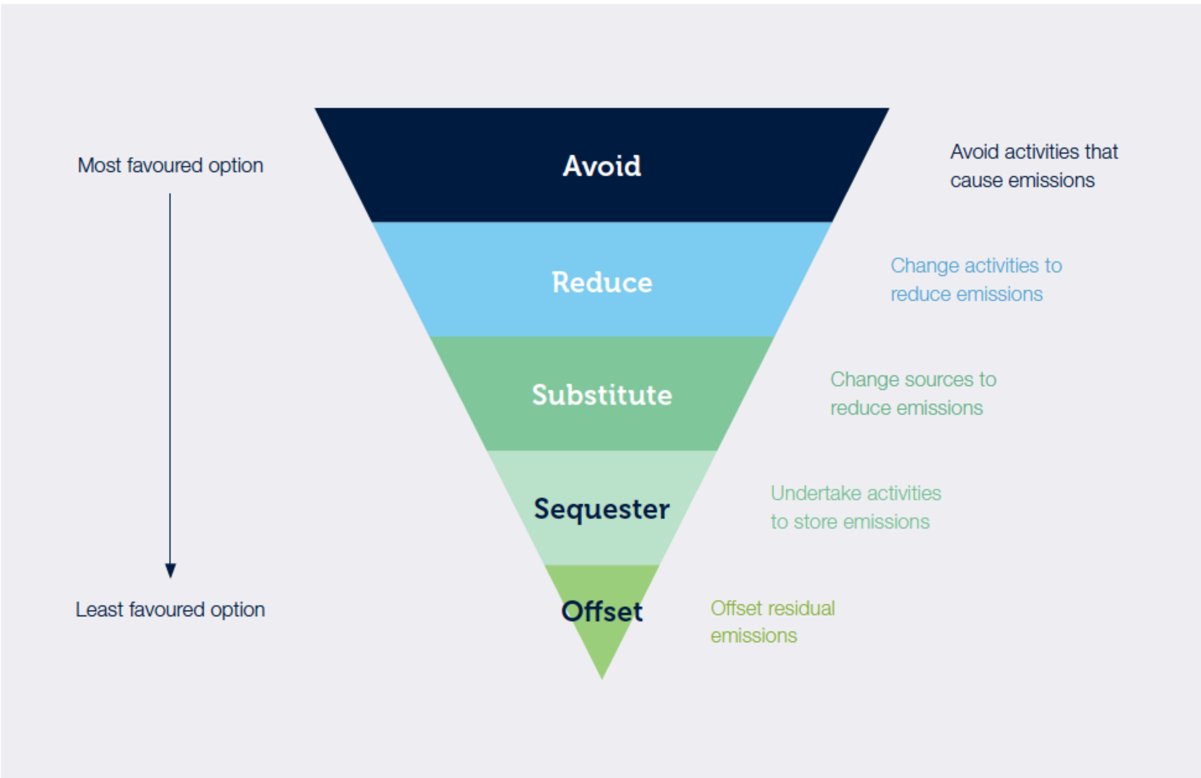


Figure 2. Most favoured to least favoured options for reducing emissions (Lou 2020).

Methane

CH_4 emissions have contributed almost one-quarter of the cumulative radiative forcings for CO_2, CH_4, and nitrous oxide (N_2O) combined since 1750 (Etminan *et al*. 2016). While CH_4 is far less abundant in the atmosphere than CO_2, CH_4 absorbs thermal infrared radiation much more efficiently and, thus, has a global warming potential approximately 86 times stronger per unit mass than CO_2 on a 20-year timescale and approximately 28 times more powerful on a 100-year time scale (IPCC 2014).

CH_4 has a shorter lifetime in the atmosphere compared to CO_2 (approximately nine years for the year 2010; Prather *et al*. 2012), which means that a stabilisation or reduction of CH_4 emissions leads more rapidly (compared to CO_2) to a stabilisation or reduction of its atmospheric concentration and its consequential radiative forcing. Reducing CH_4 emissions is therefore recognised as an effective option for rapid climate change mitigation, especially on decadal timescales (Shindell *et al*. 2012).

To date, atmospheric emissions and concentrations of CH_4 continue to increase, making CH_4 the second-most important human-influenced GHG in terms of climate forcing, after CO_2 (Forster *et al*. 2007). The relative importance of CH_4 is attributed to its shorter atmospheric lifetime, stronger warming potential, and variations in atmospheric growth rate over the past decade (Saunois *et al*. 2020).

CH_4 emissions are fuelled by livestock production (i.e., enteric fermentation in ruminant animals and manure management), rice cultivation, landfill, wastewater handling and fossil fuels (UNEP & CCAC 2021). Of these, livestock are the greatest producer of CH_4 (UNEP & CCAC 2021); however, in terms of future projections, enteric fermentation in ruminants is by far projected as the largest mitigation barrier with a projected 40 to 78 per cent of total remaining CH_4 emissions in the year 2100 using a strong 2 °C climate policy case (Harmsen *et al*. 2020).

An assessment by the United Nations Environment Programme shows that human-induced CH_4 emissions can be reduced by up to 45 per cent by 2030. Such reductions would avoid nearly 0.3 °C of global warming by 2045 and would be consistent with keeping the Paris Agreement's goal to limit the global temperature rise to 1.5 °C within reach. It would also have significant benefits for health, development, and food security (UNEP & CCAC 2021).

The Global Methane Pledge was launched at the 26th United Nations Climate Change Conference of the Parties (COP 26) in November 2021 in Glasgow. Participants joining the Pledge agree to take voluntary actions to contribute to a collective effort to reduce global CH_4 emissions of at least 30 per cent from 2020 levels by 2030, which could eliminate more than 0.2 °C warming by 2050. It is a global, not a national reduction target. More than 122 countries have joined, representing nearly 50 per cent of global anthropogenic CH_4 emissions and more than two-thirds of global gross domestic product (GDP).

Participants are contributing to the Pledge goal and preventing more than 8 Gigatonnes (Gt) CO_2 equivalent (CO_2e)[2] emissions from reaching the atmosphere annually by 2030. In October 2022, the Albanese Government signed the Pledge. The previous Morrison Government had not joined due to concern that it would be unable to meet the reductions unless it reduced livestock numbers.

The Global Livestock Environmental Assessment Model (GLEAM 2.0), a program under the Food and Agricultural Organization of the United Nations, reports that total GHG emissions from livestock supply chains are estimated at 8.1 Gt of CO_2e per year for the 2010 reference point (excluding land use changes), which is 15.4 per cent of global GHGs (see the Factory Farming Awareness Coalition website).

[2] The 'e' in CO_2e stands for 'equivalent' so giving other GHG such as CH_4 and N_2O, a value in CO_2 based on their global warming potential.

CH_4 is the highest-emitted gas from livestock and beef is the commodity with the highest amount of GHGs emitted per unit of output produced, with an average of more than 300 kilograms (kg) CO_2e emitted per kg of protein produced (Gerber *et al*. 2013). Options to reduce livestock emissions, including approaches that together may reduce emissions at the rate required by the Pledge, have been reviewed (Reisinger *et al*. 2021). The options involve more efficient production, technological advances, changes in demand for livestock-related products and land-based carbon storage.

Australia's commitment to emissions reduction

Australia's capacity to reduce emissions is very high because its emissions intensity[3] is roughly twice that of the United States of America (US) (twice as many tonnes (t) of CO_2e per $ M GDP) and about 2.5 times that of Europe.

Australia submitted its first Nationally Determined Contributions (NDCs), which is an emissions reduction commitment under the Paris Agreement, to the UNFCCC in 2016. Following the May 2022 General Election, the new Government submitted an updated version of the NDCs committing Australia to reducing its emissions to 43 per cent below 2005 levels by 2030. It also says it will reach net zero by 2050. All Australian states and the Northern Territory (NT) have pledged to achieve net zero emissions by 2050. The Australian Capital Territory (ACT) has pledged net zero by 2045.

Despite Australia's greater capacity to reduce emissions intensity, its goals are smaller than the US, which aims to achieve a 50 to 52 per cent reduction from 2005 levels in economy-wide net GHG pollution in 2030. Additionally, the US goals align with Article 4 of the Paris Agreement, which states that 'developed country Parties should continue taking the lead by undertaking **economy-wide absolute emission reduction targets**'.

Australia aims to achieve its goals by building on existing emissions reductions programs, by giving Australian industry a policy framework and by encouraging households, businesses and communities to embrace the opportunities presented by the transition to net zero (DISER 2022a). Activities have been and will continue to be developed under the Emissions Reduction Fund (ERF).

In 2023, Australia developed its first *National Climate Change and Agriculture Statement*. The statement is a collaboration between Commonwealth and state territory governments and draws on existing research and analysis and provides a 'point-in-time' assessment on why climate change and agriculture matters. It also presents a unified vision for climate change and agriculture; acknowledges and showcases the government-industry work already underway; and demonstrates strong national leadership, and heralds a commitment by Australia's agriculture ministers to support the sector and ensures Australia achieves its full potential as a world-leading, climate-smart producer and exporter of food and fibre (see the Department of Agriculture, Fisheries and Forestry website).

Agriculture and livestock emissions

In 2019, agriculture contributed around 14 per cent of Australia's GHG emissions with 72 per cent of agriculture's emissions, coming from enteric CH_4 produced by cows and other agricultural animals due to the fermentation of plant matter in their stomachs (NGGI 2021). Smaller volumes of emissions come from other sources such as fertiliser applied to vegetable crops and wastes, including manure and decaying vegetable matter (The Climate Council 2021).

Another separate source of emissions related to livestock is land clearing for pastures and grazing land. While the climate impact of land clearing is partly offset by land restoration activities and management of Australia's forests elsewhere, land clearing for agriculture nonetheless has contributed significantly to Australia's total emissions with land converted to grassland contributing 35,765.1

[3] Emissions intensity is the volume of emissions per unit of GDP so reducing it means that less pollution is being created per unit of GDP. But if GDP grows then so do total emissions. Therefore, an absolute reduction is the most relevant measure.

gigagrams (Gg) CO_2e in 2020 (DISER 2020). Australia has repeatedly been identified as a global hotspot for land-clearing, and much of this has occurred to facilitate the growth of the agricultural sector (The Climate Council 2021). Despite agricultures contribution to Australia's GHG emissions, its contribution to Australia's GHG targets is voluntary; however, the Australian Government signed the Global Methane Pledge in 2022.

A carbon-neutral livestock industry isn't possible – CSIRO

The Australian red meat industries had targeted carbon neutrality (net zero) or CN30, meaning that carbon equivalent emissions are to be balanced with carbon sequestered equivalents by 2030 (RMAC 2019, MLA 2020). Carbon neutrality was part of the shared vision of the peak industry body, the Red Meat Advisory Council (RMAC), which asserts that:

- by 2030 our industry's net carbon emissions will have been reduced, resulting in carbon neutrality
- customers, consumers and community approval and trust in our environmental management and stewardship has increased
- the red meat industry is recognised globally as a world leader in agricultural environmental management and stewardship practices, and that sustainability frameworks are a driving force for practice change.

Meat and Livestock Australia's (MLA) invested into CN30 research, development and adoption aims to enable and empower achievement of the target of reducing emissions while maintaining productivity gains.

A 2022 update to the Beef Sustainability Framework defined what 'sustainable beef production' looks like in practice and annually tracks how the industry is performing over a series of indicators. The framework was developed by the Australian beef industry in 2017 to meet the changing expectations of customers, investors, and other stakeholders (Sustainability Steering Group 2022).

MLA stated that achieving carbon neutrality for the red meat sector is possible with continued improvements in vegetation management combined with methods to reduce livestock emissions, to sequester carbon, and to maintain animal numbers. While there is large scope to reduce emissions in the livestock sector, there are minimal proven opportunities, especially for range fed cattle. The ambitious target would have required timely and substantial investment and policy support from private and government bodies.

However, a report by the Commonwealth Scientific and Industrial Research Organisation (CSIRO) shows that under current trajectories the red meat industry **will not meet its CN30 goals** and has suggested that it change its goals to align with climate neutrality (Ridoutt 2023). This means that instead of reducing their net emissions to zero they will aim for climate stabilisation, or when the effect of emissions is equal to the effect of natural atmospheric removal, balanced over the life of atmospheric CH_4 so there is no further increase in forcing or temperature. This occurs because if emissions remain constant, the bulk of the temperature change occurs rapidly and is significant, but the rate of increase declines after the initial results (Lynch *et al*. 2020). The red meat industries calculations include the plateau but do not extend into the past to show the large increase in forcing that has already taken place (i.e. dismissing historical emissions). There is very large scope for the industry to go beyond carbon storage or 'trees on farm' and reduce its CH_4 emissions, which will reverse a significant portion of warming over a relatively short timescale.

The challenge of increasing the livestock herd

While policy makers around the world try to reduce global GHG emissions and store carbon, agriculture production is set to increase, with the protein demand for 7.3 billion (B) people in the world currently at around 202 million tonnes (Mt), which is expected to increase by 76 per cent by 2050 (Henchion *et al*. 2017) with corresponding increases in the number of livestock. In 2019, there were approximately 1.25 B non-dairy cattle globally, 1.24 B sheep, and nearly as many goats, and they are projected to increase in 2050 to 1.49 B, 1.63 B and 1.41 B, respectively (FAO 2022).

Australia also plans to grow its livestock herd. The Australian red meat industry's strategy plan, Red Meat 2030, proposes doubling the value of Australian red meat sales by 2030 (RMAC 2019). While the plan emphasises that sustainability is integral to both increasing sales and trust, increasing livestock numbers is also anticipated. By 2026-27 beef cattle are expected to rise 9.8 per cent from 2020-21 and sheep by 8.5 per cent (Figure 3) (ABARES 2022).

These increases are anticipated before the development of cost-effective methods that can be applied at scale in rangeland livestock to reduce CH_4 emissions. Increasing the herd will not only increase emissions, but it will also increase ongoing soil organic carbon loss, where no grazing or pasture management practices for increasing or maintaining soil carbon have been put into place. Given the current lack of adoption of methodologies for enteric CH_4 production, any overall losses in GHG production with increased number of animals should be treated with caution and evaluated to determine that the reduction is not the result of smaller values used to calculate GHG emissions.

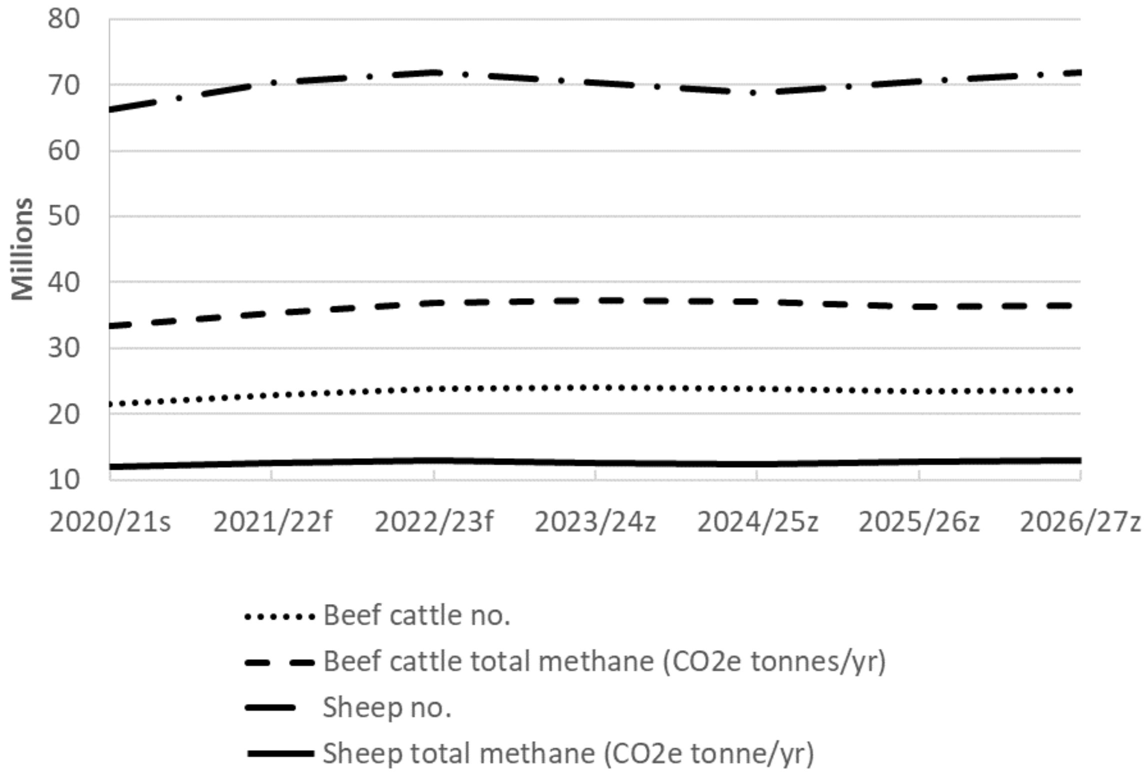


Figure 3. Numbers and projections of beef cattle and sheep numbers in Australia; s = estimate, f = forecast and z = projection. Numbers are converted to carbon dioxide equivalents using average emissions from cattle and sheep as calculated in the report (see section 'Scale of enteric methane produced by livestock', page 28) (ABARES 2022).

Consequences for enteric methane emissions

Domestic ruminant livestock

Domestic ruminant livestock, sheep and cattle are forestomach fermenters, with a rumen that is a 'single-stirred tank reactor'. This means they have microorganisms in the forestomach that process lignocellulose and produce hydrogen, CO_2 and short-chain fatty acids used for growth (Wolin *et al*. 1997, Joblin 1999). The partial pressure of hydrogen needs to be kept low to enable re-oxidation of NADH for digestion to proceed normally. Cattle and sheep contain microorganisms that reduce hydrogen during this process and produce CH_4 – a process called methanogenesis (Stevens and Hume 1998).

Globally, average CH_4 emissions from beef cattle are estimated at 1.47 tonnes (t) CO_2e/year (estimate generated from an intercontinental database of enteric production from Europe, North America, Brazil, Australia and South Korea; van Lingen *et al*. 2019). Of Australia's total GHG emissions, enteric fermentation produced by cattle (feedlot and pasture) and sheep accounts for nine per cent CO_2e (NGGI 2021). Based on 2017 data, the industry has calculated it needs to reduce and/or offset 55.7 Mt of CO_2e annually to achieve net zero GHG emissions on an annual basis (MLA 2020); enteric CH_4 makes up approximately 48.2 Mt CO_2e (DISER 2021). While the industry claims it has reduced emissions by 57 per cent (129.3 Mt of CO_2e in 2005 to 54.8 Mt CO_2e in 2016), it should be noted that the reduction is attributed to reduced land clearing (land use, land use change and forestry), which was high in 2005 and reversed in 2016 (DISER 2021), while enteric CH_4 emissions remain a main source.

Currently, 78 per cent of livestock emissions are from pasture-raised beef, followed by 18 per cent from sheep meat, four per cent from feedlots and less than one per cent from goats (Mayberry *et al*. 2019). Nunes *et al*. (2021) showed a mean per capita wild meat consumption of 41.7 kg/year for a population of approximately 150,000 residents at 49 Amazonian and Afrotropical Forest sites can spare approximately 71 Mt CO_2e annually under a bovine beef substitution scenario. This includes losses from deforestation and land use conversion, which is already widespread in Australia but does allow for reforestation opportunities.

Regardless of the need to reduce GHG, production of CH_4 is the source of a major inefficiency in animal production systems and an economic objective, with six to 10 per cent of gross energy intake lost as CH_4. This energy loss has been calculated as the equivalent of up to 60 days' grazing intake for ewes and steers (Agriculture Victoria 2022).

Current research to reduce methane emissions from livestock

Researchers have deliberated over ruminant production systems for decades to determine how best to reduce enteric CH_4. Eckard *et al*. (2010) and Mayberry *et al*. (2018) reviewed the abatement options, which can be grouped as animal, dietary and microbiota manipulation. Animal manipulation can involve breeding animals with low methanogenesis heritable qualities and reducing the number of unproductive animals. Breeding can achieve a 10 to 20 per cent reduction in CH_4; however, breeding for low methanogenesis may interrupt and alter existing breeding objectives (Arthur 2015).

Reducing the number of unproductive animals can also reduce CH_4 emissions. Strategies such as earlier finishing results in weights being achieved at a younger age with reduced lifetime emissions; however, feedlots will need to ensure, a lower finishing age is not assimilated with greater throughput of animals (Eckard *et al*. 2010). Greater through put would negate any reductions by increasing the number of animals through the production system.

Researchers have also explored the option of offering cattle and sheep different diets or nutritional supplements to reduce methanogenesis. Diet manipulation is complex and difficult to implement in grazing cattle. Attributes such as forage quality (low fibre and high soluble carbohydrates) and age can affect CH_4 production. Increased forage quality reduces the retention time in the rumen meaning that more forage is used for production rather than expelled as CH_4. There are also implications with cost, production and delivery. Again, pastoralists will also need to ensure increased efficiency is not coupled with greater throughput. Plant secondary compounds (such as condensed tannins and saponins), fats, oils, yeast cultures, dicarboxylic acids have reduced methanogenesis in sheep and beef by direct addition to diet or from manipulation of breeding plants to be used as forage (Eckard *et al*. 2010). Mayberry *et al*. (2018) also briefly suggest that feeding legumes, which can decrease CH_4 emissions through the action of secondary compounds and improved feed conversion efficiency could reduce grazing cattle enteric CH_4 emissions.

Almeida *et al*. (2021) conducted a meta-analysis of potential of dietary additives and rumen modifiers for CH_4 mitigation in ruminant production systems. They concluded of the available CH_4 mitigation strategies in ruminant production systems; red seaweed (*Asparagopsis* sp.), 3-Nitrooxypropanol (3-NOP), oil and nitrate, as feed additives were the most promising technical options for direct abatement of livestock CH_4 emissions from ruminant production in the next 10 to 20 years. However, whole-farm strategies that combine changes to on-farm management of livestock and improved feed base provide multiple and interacting opportunities to reduce total enteric emissions, emission intensity, and either increase production or reduce the land area used and number of stock required, enabling mitigation at regional and global scales. Further investigation is required of combinations of different strategies for CH_4 mitigation using a systemic approach, to inform policy recommendations.

Vaccinations and biological controls have also been explored in an attempt to reduce methanogens in the rumen with mixed results. Researchers have also experimented, and continue to experiment, with the introduction of different species of non-CH_4-producing microorganisms into the forestomach of livestock (Ouwerkerk *et al*. 2005, Klieve *et al*. 2007, Eckard *et al*. 2010, Hoedt *et al*. 2016).

MLA commissioned a report that identified theoretical pathways for the red meat industry to become carbon neutral by 2030, and a National Livestock Methane Program (NLMP) was developed to coordinate national research to reduce CH_4 emissions from livestock while increasing productivity. A marginal abatement cost analysis of practice options related to the NLMP suggested that, when all farming systems are considered at a national scale, the practice options with the greatest potential to reduce Australia's GHG emissions inventory are algae, 3-NOP, and the inclusion of legumes in ruminant diets (Mayberry *et al*. 2019), but the outputs from these analyses depend greatly on assumptions that do not yet have sufficient experimental results. The methods can also incur great costs and are likely not suitable for range fed livestock. In 2020, Harmsen *et al*. advised that it is likely that CH_4 emissions would not be avoided without a global change in human diets towards meat from animals that do not produce CH_4 or an increasingly plant-based diet. Another consideration is cultivated meat.

Soil and vegetation carbon sequestration

Soil carbon

The soil carbon pool (also known as the pedologic pool) is comprised of soil organic carbon and soil inorganic carbon and stores more than twice the amount of carbon found in the atmosphere (Lal 2008). While soil has the potential to sequester carbon across the globe, soil carbon is being lost to the atmosphere at rates of 0.8 to 1.2 petagrams (Pg) (80 million to 120 million t CO_2)/year through erosion and 60 Pg (60 trillion t CO_2)/year through respiration (Lal 2008). This transfer of soil organic carbon to the atmosphere is a major disruption to the global carbon cycle.

Soil organic carbon results from living organisms in and above the soil, which convert atmospheric CO_2 into a range of organic compounds and structures (Figure 4). Thus, soil organic carbon is made up of partly decomposed organic matter, organic materials at an early stage of decomposition, microbial biomass, microscopic living organisms, humus and charcoal. The sequestration of soil inorganic carbon occurs through conversion of CO_2 in soil into carbonic acid, and its reprecipitation as carbonates of calcium and magnesium. Inorganic carbon, such as calcite and dolomite, makes up about one-third of total soil carbon but is relatively stable and, except when applying lime, is not strongly influenced by land management. Therefore, it is usually discounted when considering the effects of soil carbon on agricultural production and carbon sequestration. There is however, a large focus on soil organic carbon and any changes in soil organic carbon storage have the potential to modify the global carbon cycle (Conant *et al*. 2001).

Biotic carbon

The biotic or life carbon pool is the smallest carbon pool, storing an estimated 560 Pg (Lal 2008). It contributes to atmospheric CO_2 concentrations through deforestation and biomass burning, but also constitutes a major sink from photosynthesis and storage in live and dead organic matter (Figure 5). Vegetation capture and storage differs between vegetation types and species, but also depends on the age of the vegetation. Young vegetation is usually efficient at capturing carbon as it grows quickly and absorbs carbon rapidly, while established or mature vegetation usually grow slower, but the amount of carbon captured and stored is relatively greater. When more vegetation is growing compared to those that are dying, the overall net productivity is positive and carbon capture is enhanced. Older vegetation usually has a more fixed, or less dynamic, carbon cycle; however, the carbon is well contained within the large vegetation, slowly rotting vegetation, thick leaf litter and soil (Norman and Kreye 2020).

Agricultural soils

Globally, it has been estimated that agricultural soils have lost 42 to 78 Pg (42 trillion t to 78 trillion t CO_2) of carbon relative to their preagricultural state (Lal 2004). The large losses mean that capturing and retaining additional carbon in soil can mitigate the emissions of GHGs (Viscarra Rossel *et al*. 2014). Studies have estimated that adopting appropriate land management practices alone might offset about one-third of the global annual GHGs (Lal 2004).

During grazing, animal interactions can physically affect pasture through consumption, excretion and traffic. When poorly managed or when grazing is intensified or persistent, these measures can result in a number of changes to the visual landscape, which can include a disturbance in the surface crust through compaction, increased risk of wind and water erosion, reduced amount of biomass above-ground, amount of vegetation cover, reduced litter cover, water storage and an altered above-ground biomass species composition (Hao and He 2019, Roesch *et al*. 2019, Wang *et al*. 2019). These changes can also impact the soil system below the pasture, which are less obvious; for example, litter input, root systems and microbial biomass are reduced (Hao and He 2019) (Figure 6). Interruptions to this plant-soil-microbe system reduces the soil's ability to store carbon (Dignac *et al*. 2017).

Grazing lands generally have climatic conditions and soil conditions that suggest they may not be able to store large quantities of carbon; however, with appropriate management, most agronomists and soil scientists agree that most agricultural soils can store more carbon than it does now (Sanderman and Farquharson 2010). This is especially important for Australian land management as the Australian agriculture sector is vast and covers approximately 60 per cent of land area, with 90 per cent of that area being used for low to medium density grazing of natural vegetation (Sanderman and Farquharson 2010). Because of the vast size and extent of grazing lands, even a small improvement to store carbon would translate into large sequestration rates.

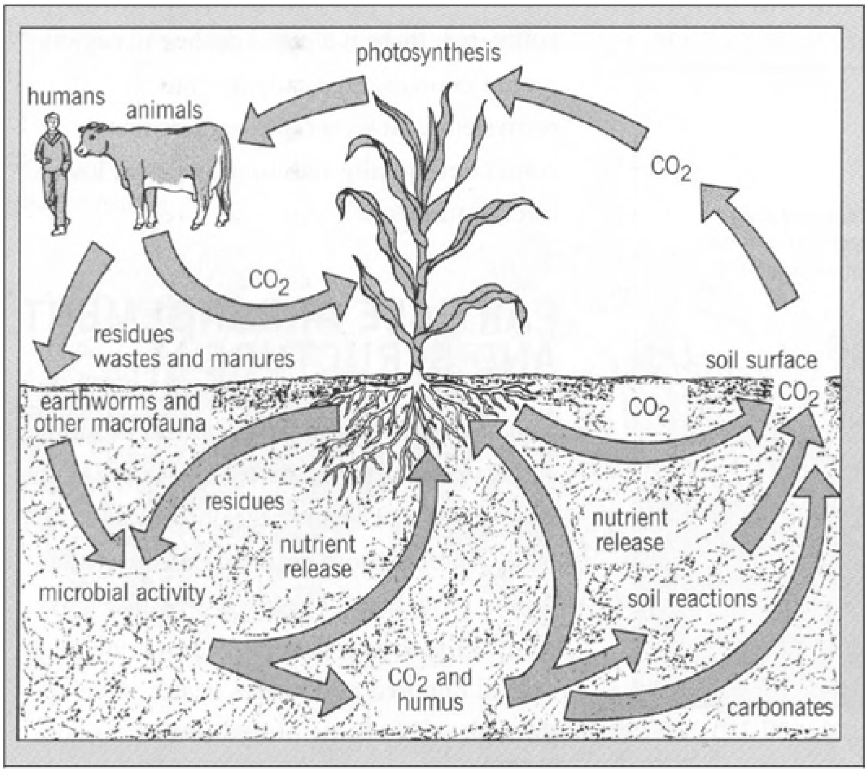


Figure 4. A simplified illustration of the carbon cycle in soil (Dubbin 2001).

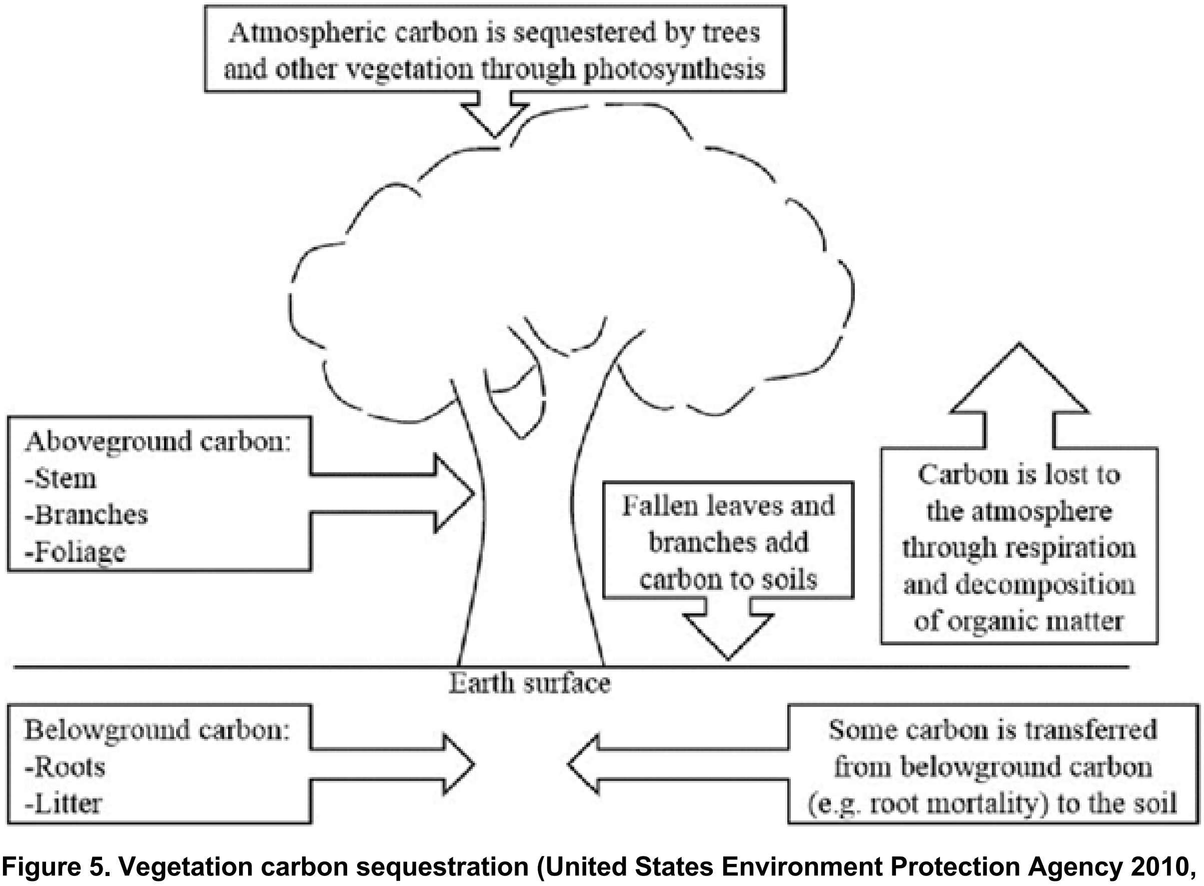


Figure 5. Vegetation carbon sequestration (United States Environment Protection Agency 2010, in Raihan *et al*. 2019).

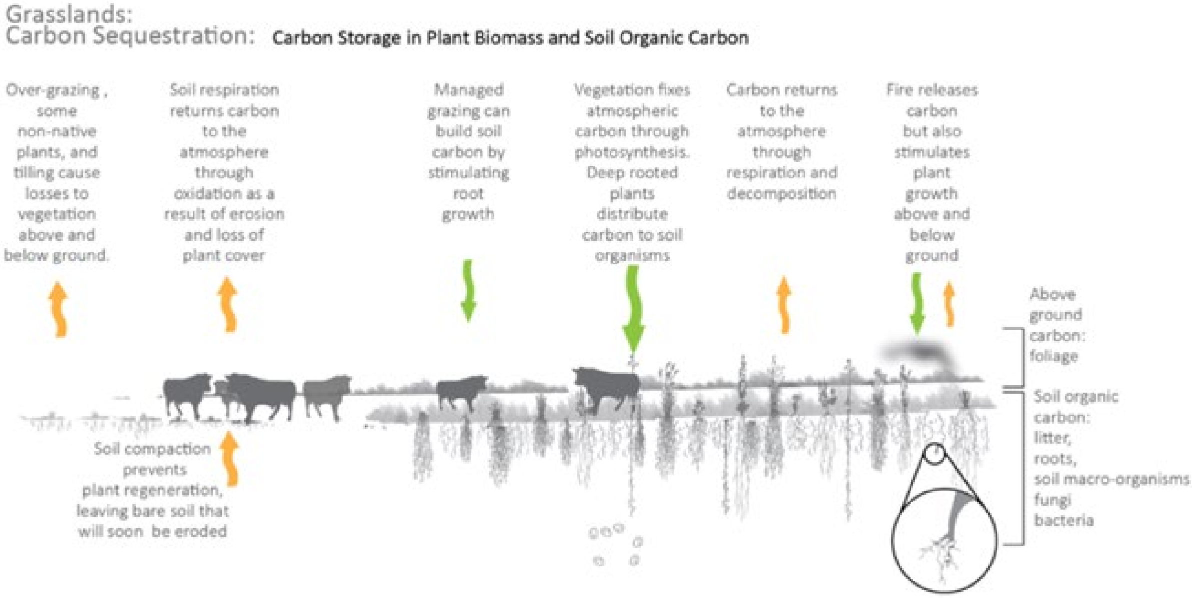


Figure 6. Carbon storage in grazing systems (MBWSR 2019).

A new opportunity

Decreasing the number of CH_4-emitting ruminants and making better use of low-CH_4-emitting replacements is an alternative to offsetting their emissions. Climate-conscious consumers are looking for alternative foods that have been produced with lower emissions. Making better use of commercially harvested species of kangaroos – eastern grey kangaroos (*Macropus giganteus*), western grey kangaroos (*M. fuliginous*) and red kangaroos (*Osphranter rufus*) – is an alternative for Australia's extensive rangelands especially before alternative technologies and cost-effective CH_4 reducing supplements have been developed.

The scale of the Australian rangelands

The Australian rangelands (the pastoral outback) occupy 57 per cent of New South Wales (NSW), almost 100 per cent of the NT, 90 per cent of Queensland, 85 per cent of South Australia (SA) and 87 per cent of Western Australia (WA), amounting to 75 per cent of total land mass in Australia (Figure 7) (Hill *et al*. 2006). The Australian grazing lands store a mean value of 24.35 t soil carbon per hectare (ha) (18.28 and 31.37, 95 per cent confidence intervals (CI)) with the total soil organic carbon stock of grazing lands at 8.53 Gt/ha (6.402 and 10.988 Gt/ha, 95 per cent CI; Viscarra Rossel *et al*. 2014).

The primary land use on the rangelands is grazing (Figure 8) and much of Australia's grassland is seriously degraded (Soils Revealed 2016, Williams *et al*. 2022, Bond University n.d.), which has contributed to a reduction of 10 per cent of soil carbon (see Figure 9 and Figure 10 for historic and current levels). Long term high-intensity grazing will result in continued loss of soil carbon with carrying capacities above 1, 5 and 6 dry sheep equivalents (DSE)/ha for arid/semi-arid, sub-humid and humid environments (respectively). In soil carbon and grazing management simulations, the stocking densities at 100 per cent of 1997 levels, predicts further soil carbon loss from rangelands at about 400 Mt in 40 per cent of five-year simulations (Hill *et al*. 2006).

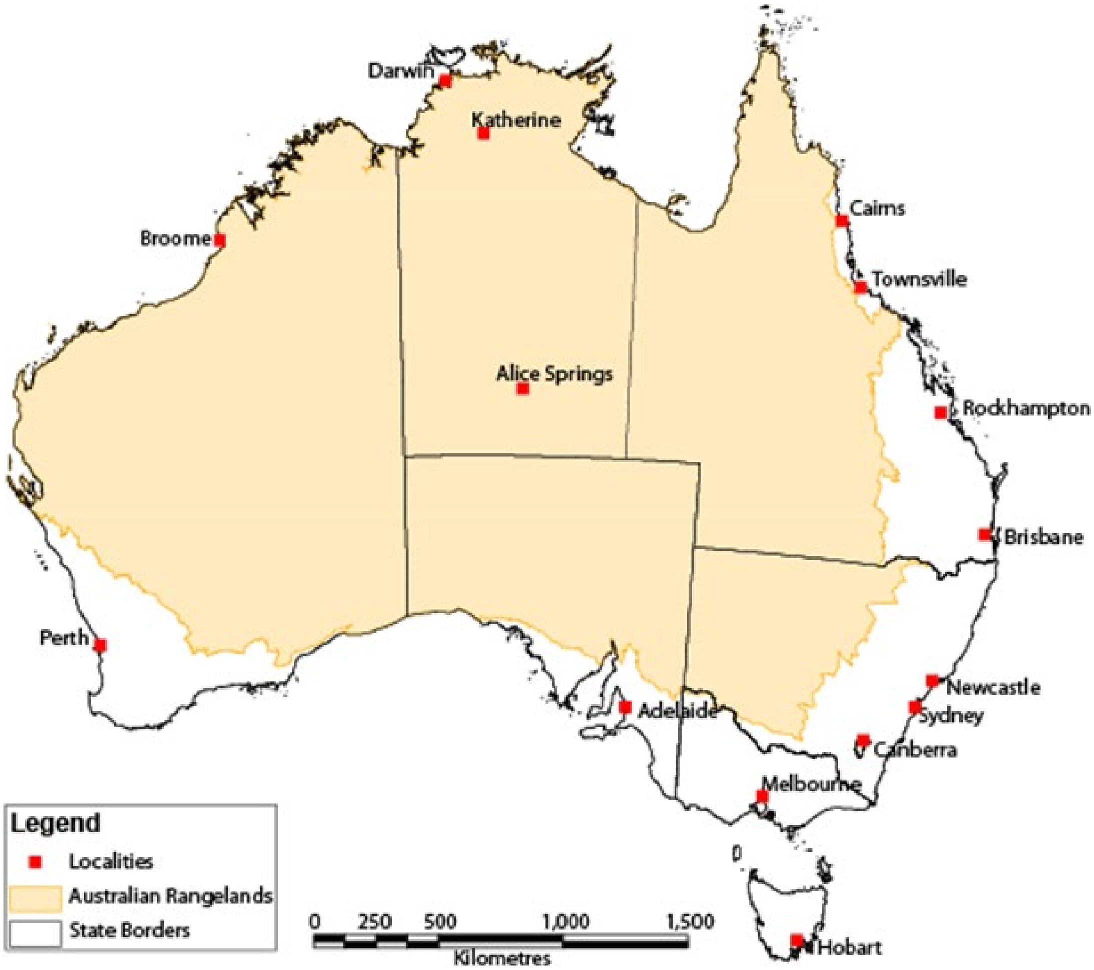


Figure 7. The Australian rangelands – the 'outback' – cover 75 per cent of Australia's land (DAWE 2021c).

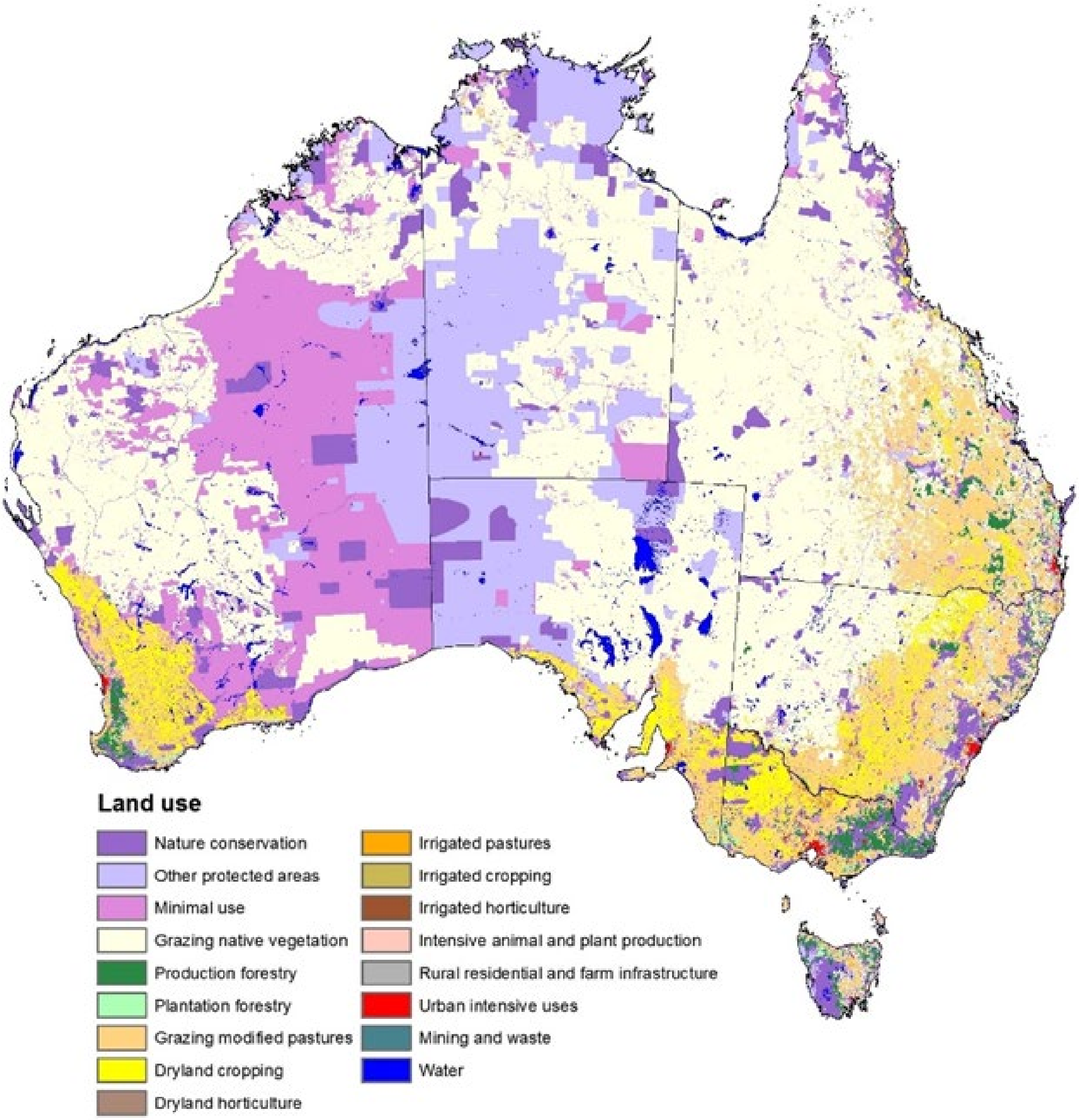


Figure 8. National-scale land use (based on ABARES 2016).

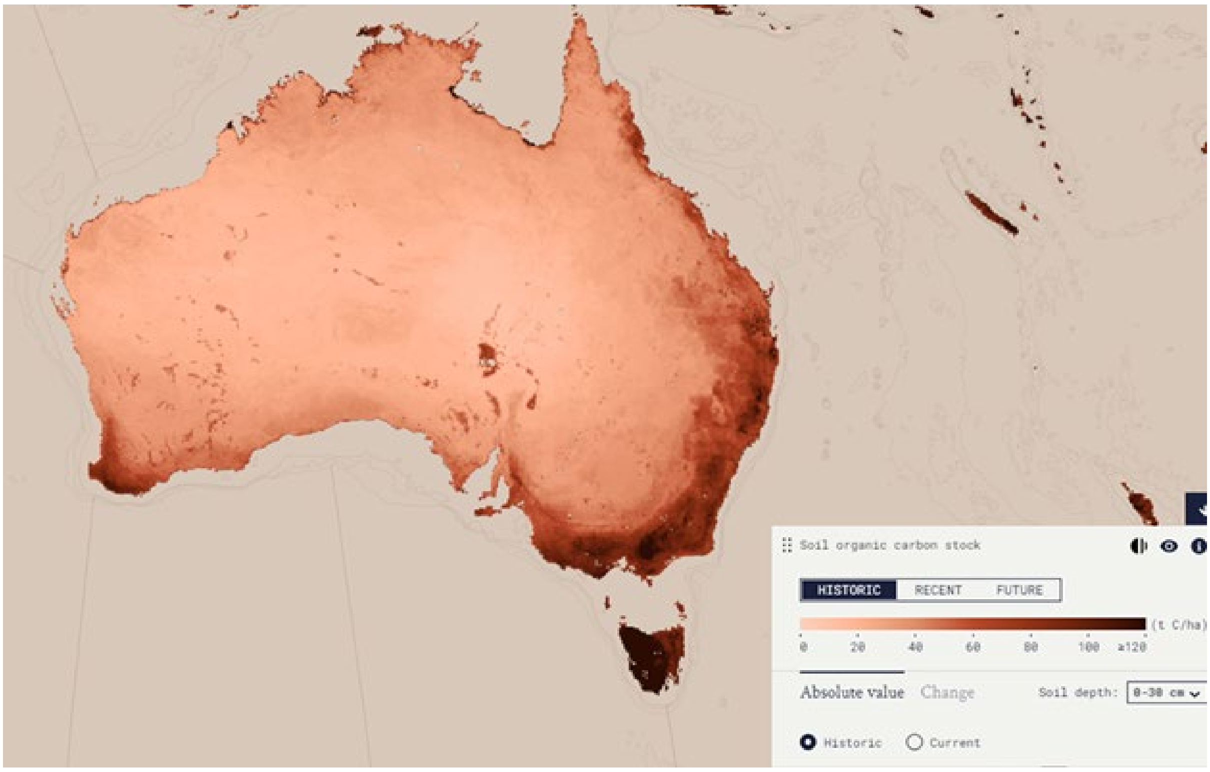


Figure 9. Historic organic soil carbon, pre-agriculture (Soils Revealed 2016).

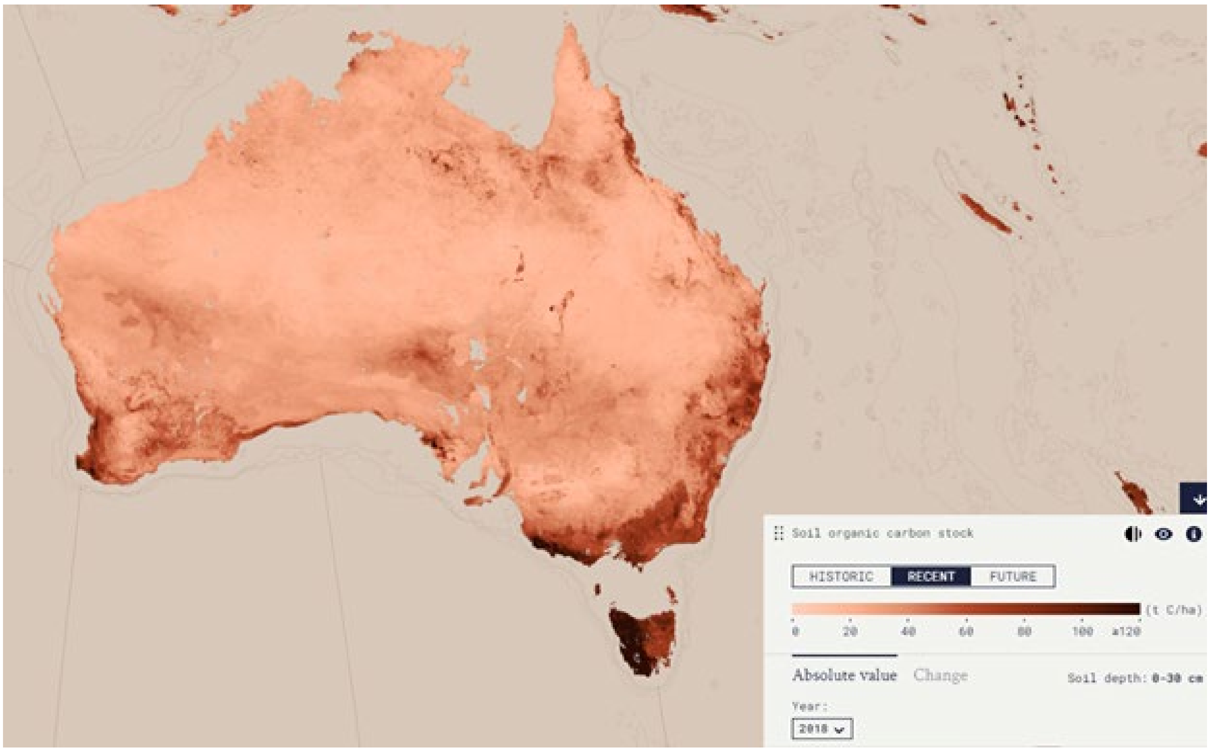


Figure 10. Current (2018) soil organic carbon, post-agriculture (Soils Revealed 2016).

Grazing species and total grazing pressure

An understanding of total grazing pressure, that is, forage demand from all herbivores relative to the forage supply (Hacker *et al*. 2019) is needed to determine livestock grazing densities that are sustainable (Fisher *et al*. 2004). Domestic livestock in the Australian rangelands include sheep (*Ovis aries*), cattle (*Bos taurus, Bos indicus*), and goats (*Capra hircus*), with goats and cattle also occurring as wild herbivores; however, add to this, other common wild herbivores such as kangaroos (*Macropus* spp.), rabbits (*Oryctolagus cuniculus*), hares (*Lepus europaeus*) feral horses (*Equus caballus*), donkeys (*E. asinus*), camels (*Camelus dromedaries*), and deer (*Cervus* spp., *Axis* spp. and *Dama dama*), and grazing management can become exceedingly complex. Invertebrates can also contribute to grazing, but they are not explicitly considered here.

Controlling grazing populations

The effects of grazing differ with herbivore type and intensity, position within a productivity gradient, aridity, and to a lesser extent, plant origin (native or exotic; Eldridge *et al*. 2018). Therefore, different species can be managed to reduce grazing impacts, maximise production efficiency and to shift grazing pressure off certain species. The outcome can be increased soil and vegetation carbon.

Cattle are less selective than sheep; with cattle preferring grasses and sheep forbs (Morris and Reich 2013). In a study in their use of southern rangelands, overlap is high between livestock and kangaroos, particularly for perennial grasses – the dominant forage (Pahl 2019b). In the southern rangelands, sheep, cattle and kangaroos all eat large amounts of green annual grasses, ephemeral forbs and the green leaf of perennial grasses when they are available. Overlap in use of these forages is concurrent and high; for example, overlap in the use of dry perennial grasses is high but sequential overlap in the use of chenopod and non-chenopod perennial forbs is moderately high and sequential (excluding for eastern greys and euros), whereas overlap in the use of browse is low. Grazing management strategies manipulate the type and or the number of grazing animals, the timing or duration of grazing, and/or the areas that livestock access. In most cases ecological responses to grazing management are anecdotal and the relative merits of various practices remain uncertain (Morris and Reich 2013).

Pastoralists can manage the grazing pressure from domestic livestock; however, there is often incapacity to manage both numbers and distribution of the wild herbivores. Spatial and temporal trends in unmanaged wild herbivores, both feral and native, result in pastoralists having, at times, control over less than half of the grazing pressure. The difficulty lies in the management of wild herbivores, which is complex because pastoralists have little influence over their distribution and numbers. Fences, and traps can keep some under control and bring them into captivity and ownership.

While eradication is the goal for introduced herbivores that remain wild, it is not the goal for native species, which are equally if not more difficult to manage. While native kangaroos and wallabies can contribute substantially to grazing pressure, their management falls under different legislation to wild introduced herbivores as they are partially protected. This leads to restrictions that make management even more complex especially because of their number, size and mobility; they evolved under different conditions to introduced species and cannot be trapped and can jump over traditional livestock fences (Shepherd 1983).

Pastoralists can have difficulty resting their paddocks, which becomes a problem for management such as rotational grazing, cell grazing, controlled grazing and stock removal. Overgrazing by kangaroos can reduce the complexity of the understorey vegetation, the cover of grasses, species richness of forbs and in turn, the depletion of soil carbon (Mills *et al*. 2020).

Managing kangaroo access to artificial watering points can be used in some situations to manage grazing pressure but is often not relevant because of availability of natural sources and ability of kangaroos to travel long distances to alternatives (Montague-Drake and Croft 2004). Other techniques include exclusion fences, which are costly but provides long term results, and culling (killing) or harvesting, which are both limited by permits, require time and skill and are short-term control methods.

Managing grazing to increase or maintain carbon in soil and vegetation

The stocking rate is the number of livestock per unit area of land, with the number of livestock that a pasture can support determined by the quality of forage available, which varies with season, grazing history, and local climatic conditions. Varying the stocking rate based on availability of forage can prevent overgrazing (Morris and Reich 2013). When determining stocking rates, the grazing pressure exerted by all grazers should be considered, including livestock and both native and non-native grazers.

The relationship between soil carbon and grazing management is complex; however, management can be implemented to manipulate carbon in soil, so long as the methods recognise, respect and restore the key features of the global, naturally occurring relationship that exists between soils, plants and grazing animals (Bond University n.d.). Understanding the impact of grazing intensity and livestock types under different management systems is a key to providing the most effective soil carbon management strategies. High grazing pressure can significantly lower soil carbon and research suggests that it is possible to build soil carbon by managing grazing (Sanderman and Farquharson 2010) through appropriate stocking levels to maintain or enhance soil carbon stocks.

When grazing is managed, carbon stocks build up through positive effects on vegetative growth and turnover of both above-ground shoots and below-ground roots (Orgill *et al*. 2017). The following are recognised grazing management methods to increase carbon in the soil:

- altering pasture species composition
- improving pasture cover
- increasing above-ground biomass production enhancing root growth and turnover
- increasing inputs of plant biomass into the soil.

Methods that aim to enhance carbon in soil by grazing pastures at appropriate stocking rates for growth of above-ground shoots and below-ground roots include:

- controlled grazing
- rotational grazing
- cell grazing
- removing stock
- exclusion fencing
- controlling watering points for native and feral animals.

A number of studies have examined different grazing treatments on soil carbon, with some finding grazing management increased, decreased or maintained soil carbon, with the contrasting results coming from different variables (Sanderman and Farquharson 2010, Orgill *et al*. 2017). A number of variables are thought to contribute to these inconsistencies in soil carbon storage, including:

- time treatment applied
- sampling variability ground cover and litter
- biomass
- tree cover
- vegetation community – species and heterogeneity
- soil type/texture
- climate – precipitation/temperature/drought

- C3/C4 balance
- land use period, degradation
- nature, frequency and intensity of disturbances
- length of growing season.

Experimental studies of these management practices demonstrate that ecological responses to grazing management are highly variable and that context is important in predicting grazing responses (Morris and Reich 2013). Each of these factors will interact overtime making it difficult to separate the respective conditions of variable and grazing management to the change in carbon in soil. This means that a management activity that builds soil carbon on one property or region will not necessarily build soil carbon on another.

Further research is needed to completely understand the influence of variables before greater confidence in grazing management practices can be achieved; however, soil carbon farming has been promoted as a key strategy for offsetting Australia's GHG emissions, with the ancillary benefit of improving soil health and farm productivity (White *et al*. 2021). If appropriately managed, grazing will have a positive impact on storing carbon in the soil. To address these challenges, persons responsible for soil carbon projects on grazing lands need to choose management activities that are right for their property.

Kangaroos integrated as a component of grass-fed red meat production

Our report draws attention to an opportunity that lies with improved management of some 30 million kangaroos on pastoral properties from which pastoralists currently get no return from. We suggest that with further information and instructional guidelines (see Appendix A) producers will be able to assess their opportunity to integrate kangaroos into their traditional practices and in turn, reduce enteric CH_4 emissions, increase soil carbon sequestration and enable greater opportunities to access the carbon market. The opportunity is there because past studies have shown that cattle generate approximately at least eight times more GHG per kilogram of meat produced compared to kangaroo (Wilson and Edwards 2021), while land clearing, primary production and erosion on grazing lands have depleted carbon in soil and vegetation.

We propose a grazing system for rangeland livestock producers that would reduce the stocking rate of livestock and allocate part of the available pasture to produce kangaroo meat. While income would be lost from a reduction in livestock, income diversification would arise from harvesting kangaroos, and carbon credits. Reducing total grazing pressure and stocking rates of livestock also has the co-benefits of improving sustainability and biodiversity, and can improve human and animal welfare while reducing the cost of managing a pest animal. Such a change should be relatively easy because the kangaroos are already there and many producers currently seek to reduce their impacts through pest culling.

Methane abatement

In 2008, we advocated making greater use of the kangaroos already on pastoral properties as an option to reduce CH_4 emissions, rather than trying to convert cattle digestive systems into that of kangaroos (Wilson and Edwards 2008). We suggested it could be possible to reduce a proportion of the cattle and sheep on the rangelands and increase the kangaroo population as a means to lowering the national CH_4 emissions while still producing equivalent amounts of red meat. The concept proposed could also lower grazing pressure and enhance soil and vegetation sequestration. There are also potential biodiversity co-benefits and an increased capacity for native species to resist other threats to their conservation (e.g., habitat loss). In 2021, Hegarty and Almeida (2021) reviewed the potential role and constraints on 'kangaroo farming' as a contribution to achieving carbon neutrality in the red meat industry of NSW by 2050. We welcome this consideration of the possibility by a government agricultural agency. We continue to advocate CH_4 abatement opportunities of improved kangaroo use as part of a case for strategic review of the objectives of kangaroo management (Wilson and Edwards 2021), which is also recommended by wildlife ecologist colleagues (Read *et al*. 2021b).

Early mitigation of CH_4 emissions would significantly contribute to the feasibility of stabilising global warming below 1.5 °C, alongside having co-benefits for human and ecosystem health (Collins *et al.* 2018). Harmsen *et al.* (2020) highlighted that direct CH_4 mitigation is crucial and more effective in bringing down GHGs than reducing fossil fuels.

Importantly, CH_4 emissions can be reduced immediately by reducing livestock. Kangaroos could be used in their place to provide an alternative source of red meat that is carbon friendly. Although they are often compared with ruminants, the various macropod species show a wide range of unique adaptations to herbivory. These differences include their forestomach's host microbes, which derive nutrients from lignocellulose-rich plants (Hume 1984, Pope *et al.* 2010).

While kangaroos are forestomach fermenters like cattle and sheep, the pregastric stomach in kangaroos is a 'multi-stirred tank reactor' with shorter retention times of ingested food (Hume 1999). Both kangaroos and livestock have microorganisms in the forestomach, which decompose vegetable matter and produce hydrogen, CO_2 and short-chain fatty acids used for growth (Wolin *et al.* 1997, Joblin 1999); however, the microorganisms in kangaroos and wallabies pregastric stomach emit little CH_4 (Kempton *et al.* 1976, von Engelhardt *et al.* 1978, Dellow *et al.* 1988, Hume 1999). This is probably because methanogens are slow growing and would be flushed out of the kangaroos' forestomach (Hume 1999) due to the shorter retention time because of the continuous transit of plant biomass through the herbivore gut (Pope *et al.* 2010). Instead, reductive acetogens have been identified in kangaroos suggesting that kangaroos use acetogenesis as the dominant hydrogen-utilising reaction (Ouwerkerk *et al.* 2007). Vendl *et al.* (2015) fed *M. rufus* and *M. fuliginous* an ad libitum lucerne hay diet and recorded values for CH_4 emissions as 2.6 +/- 0.61 litres (L)/day and 3.09 +/- 1.31 L/day, respectively, which equates to 0.016 and 0.020 t CO_2e/head/year. While previous measures showed *M. eugenii* produced 0.003 t CO_2e/head/year (Kempton *et al.* 1976). We use an average figure of 0.01 t CO_2e/head/year in this report's calculations.

It is difficult to convert emissions produced per individual per year to emissions produced per kilogram of meat when considering whole populations required to support the usable portion. This is because there is a supporting or breeding population (many more individuals) required to support those individuals that are used in production. Additionally, the number of years the animal takes to get to slaughter or harvest should also be taken into account. Omitting these concerns, we have calculated the CO_2e per kilogram of usable/saleable carcase per last year of life (annual emissions) for cattle, sheep, goats and kangaroo. Cattle, sheep and goats produce 7.6, 8.5[4] and 9.7[5] CO_2e/kg of useable-saleable carcase per last year of life while kangaroos produce 0.6 (Hopwood *et al.* 1976, Kempton *et al.* 1976, Vendl *et al.* 2015)[6] CO_2e/kg of useable/saleable carcase per last year of life.

Soil carbon sequestration

As difficult as they are to manage, kangaroos might be expected to have less effect on the soil and plant communities than domestic livestock. The contact pressure and width of the applied stress influences the depth of soil that becomes compacted from grazing animals; cattle have a larger mass and hoof (314 to 364 centimetre (cm)^2) than sheep (63 to 84 cm^2) and as a result cause greater compaction, with the loading pressure of cattle, 98 to 169 kilopascals (kPa), twice that of sheep, 48 to 83kPa, and kangaroos, 42 to 92 kPa (Greenwood and McKenzie 2001). Additionally, kangaroos have co-evolved with the existing vegetation, graze less intensively, and are less selective as the result of being unconstrained by fencing (Eldridge *et al.* 2018). Eldridge's study also shows that livestock grazing increases exotic species richness but reduces native richness, while kangaroo grazing increases native richness in environments with low productivity.

---

[4] Hopwood et al. 1976; Afolayan et al. 2002 – total number of meat cows less than one year old, all sheep; ABS 2019; MLA 2019 – total from bulls greater than one, cows greater than two, steers greater than one and cows 1-2, feed lot domestic, feedlot export long-fed and feedlot export mid-fed, all sheep; NGGI 2021

[5] NGGI 2005; Webb 2014; MLA 2019

[6] NGGI 2005; Webb 2014; MLA 2019

Kangaroo grazing has shown greater incorporation of litter and soil surface integrity leading to expected increased levels of soil multifunctionality (Eldridge *et al*. 2021). A study by Eldridge *et al*. (2021) supported the notion that kangaroo grazing, at low densities had no significant deleterious effect on soil surface health, as measured by morphology of the surface.

In pastoral environments kangaroos compete with livestock for grasses and forbs, particularly during droughts (Caughley *et al*. 1987). An extensive study across 451 sites in eastern Australia showed that when compared to European livestock, increasing kangaroo grazing had a few small but positive effects on soil functions with a slight relative reduction in soil nitrogen and phosphorus and an increase in biocrust cover (Eldridge *et al*. 2017).

When overgrazed the structural character of sites can be changed through reduced plant basal area, foliage cover and grass biomass, and increase the functional measures associated with surface stability, litter cover and plant richness (Northup *et al*. 1999). These reductions in structural complexity likely affect soil and carbon sequestration; however, given that the pressure exerted by kangaroos on the ground is lower than that of ungulates (Bennett 1999) we would expect them to have fewer physical disruptive effects on a range of ecosystem functions.

The number of grazing kangaroos, in order to achieve soil carbon sequestration, needs to be determined. In temperate grasslands in the ACT, kangaroo densities in the range of 100 to 160/kilometre $(km)^2$ can sustain appropriate herbage biomass (Gordon *et al*. 2021); however, these environments are not congruent with rangeland pastures. We would expect that by reducing livestock, and promoting herbage biomass that soil carbon sequestration would increase. Grazing kangaroos would be managed through harvesting to achieve the balance between grazing and soil carbon storage.

In this report we begin to evaluate opportunities for business owners in the livestock industry. The livestock industry contributes approximately nine per cent of Australia’s GHG liability in the form of enteric CH_4 from livestock, while grazing management in the rangelands has contributed to a loss in vegetation and soil carbon. Here we evaluate a novel grazing system, involving kangaroo management, and determine if it can theoretically reduce GHG emissions and increase carbon sequestration in vegetation and soil, all while maintaining productivity. We also evaluate the opportunity for the grazing system to be included under current, future and potential ERF methodologies and other voluntary market methodologies.

Objective and outcomes

Objective

The objective of this research was to identify, through improved kangaroo management, new and achievable opportunities for producers that enable:

- grazing and carbon storage in soil
- reduction of enteric carbon emissions
- economic viability associated with returns generated from industry diversification and carbon storage and abatement
- co-benefits for the environment, animal welfare and social licence to produce.

Outcomes

The outcomes of this research include:

- A novel meat and fibre-producing grazing system that addresses total grazing pressure and enables vegetation regrowth and soil conservation.
- Guidelines for a novel grazing system that enable producers to assess their ability to establish income diversification from kangaroo products, the carbon market and additional environmental credit markets.
- Increased awareness of the opportunity for pastoralists to reduce their carbon footprint by increasing the amount of carbon stored in soil and vegetation.
- Increased awareness of the opportunity for pastoralists to reduce their carbon footprint by reducing the number of livestock generating methane.

Should such a grazing system be implemented, the outcomes would include:

- Integration of kangaroos into pastoral practices with a balance of fewer livestock, increasing the amount of carbon stored in soil and vegetation through grazing management, and reducing carbon emissions from livestock through reduced stocking rates.
- Co-benefits of the above, including increased environmental benefits, increased animal welfare practices, diversified income streams and increased social licence to produce.

An integrated Kangaroo Grazing System

An integrated Kangaroo Grazing System (hereafter KGS) would reduce the proportion of DSE due to domestic livestock – cattle, sheep and goats – while using commercial harvesting of kangaroos to manage the other portion of the grazing pressure. Prescribed grazing levels would be set to achieve an increase in soil carbon sequestration.

In 2021 a group of concerned scientists published a joint statement on improving kangaroo management as part of a special edition on kangaroo management in the journal *Ecological Management & Restoration* (Read *et al*. 2021b). Our proposed KGS would align with the scope of the statement. Its recommended Terms of Reference are in Box 1.

Enteric CH_4 emissions would be reduced by not fully restocking livestock after drought, or by actually lowering the number of cattle and sheep. Goats have not been included in this prescription due to lack of good information about the numbers across Australia. Adoption of the KGS would lead to a drop in income from livestock sales. We have estimated the extent to which this could be offset by commercial benefits from kangaroo-use, plus carbon credits and potentially stewardship payments. The goal is for GHG abatement and sequestration, while at the same time maintaining or improving red meat productivity.

Box 1. Terms of Reference for a National Kangaroo Strategy

Terms of Reference for preparing a National Kangaroo Strategy should:

- Reflect and integrate the needs and priorities of all stakeholders, including Indigenous communities and private landholders, and build on existing successful regional initiatives (including those of governments).
- Recognise that setting and maintaining minimal forage thresholds is integral to retaining healthy landscapes, local kangaroo populations and sustainable production, and to ensure kangaroo densities do not cause negative environmental, welfare or economic impacts.
- Identify immediate steps to prevent unsustainable post-drought kangaroo population increases through setting clear kangaroo population thresholds.
- Identify objectives, roles and responsibilities of stakeholders and priority knowledge gaps that need to be addressed by targeted research.
- Recognise that non-lethal population management tools, such as relocation and sterilisation, are not practical at the scales required and that exclusion fencing alone does not prevent population build-up and has other impacts on biodiversity.
- Ensure the highest ethical and humaneness standards and progress towards a system where all harvesting and/or culling of kangaroos is undertaken under a single National Code of Practice.
- Consider opportunities to better integrate kangaroo harvesting into rangeland production systems by recognising that kangaroos evolved with Australia's fluctuating climate and could be grazed in a complementary way with domestic stock, producing low carbon emission, healthy meat with low impact on soils and vegetation.

Project communication

Consultations, conferences, webinars and field visits

The target audience for our proposal is livestock producers, investors and carbon aggregators. We have discussed the proposal with interested parties and groups, such as the NSW Kangaroo Management Taskforce (NSWKMT), Queensland Department of Agriculture and Fisheries, Remote Area Planning and Development Board, the South Australian Arid Lands Landscape Board, Landcare groups, state government wildlife management sectors, CSIRO and carbon farming groups.

We met with Ministers David Littleproud and Mark Coulton on 17 June 2021 to promote the case for a National Kangaroo Strategy that incorporates the carbon benefits of improved kangaroo management.

The concept and our findings were delivered as presentations at conferences including:

- Carbon Market Institute, June 2021
- Rangelands Society Conference Longreach, October 2021
- Australasian Wildlife Management Society Conference, December 2021.

We also attended webinars and workshops hosted by:

- NSWKMT
- Australian National University
- Institute for Climate, Energy & Disaster Solutions
- Carbon Market Institute
- Carbon Farmers of Australia
- Farmers for Climate Action
- Australian Land Conservation Alliance
- Future Drought Fund
- NSW Biodiversity Conservation Trust
- SA Kangaroo Partnerships Project (South Australian Arid Lands Landscape Board)
- CSIRO
- A collective partnership including the Royal Society of Victoria, the Royal Society of Queensland and the Royal Society of New South Wales, with support from the CSIRO.

Field visits were conducted during November and December 2021 to far west NSW (Broken Hill and Wild Deserts) to visit stakeholders including landholders, kangaroo harvesters and kangaroo managers to discuss the KGS applicability and potential issues with pastoralists and program managers. Some meetings were cancelled due to excess rain disrupting access.

Potential abatement and sequestration through improved grazing management

Grazing populations

Since 1997 cattle populations (pasture and feedlot) have been relatively stable (23.7 M in 1997 to 21.1 M in 2019), while sheep numbers have dramatically reduced from 120.2 M in 1997 to 63.5 M in 2019 (ABS 2019) (Figure 11). Of these there were slightly less than 9 M cattle and 5 M sheep on the rangelands in 2016 (Foran 2021). Since the year 2000 cattle numbers have declined slightly in the northern rangelands but increased in the southern rangelands leaving numbers relatively stable. Sheep numbers have declined by two-thirds in the southern rangelands and sheep were virtually absent from the northern rangelands by 2016 (Foran 2021).

Kangaroo population estimates in the commercial zones fluctuate (and have overall increased; 25.8 M to 28.5 M in 2021; Figure 11 (DAWE 2022c)). Some of the increase is probably due to the area surveyed increasing. Unlike the Australian Bureau of Statistics (ABS) survey data, kangaroo survey methods have changed and differ across regions. Some surveys are not carried out annually.

Nevertheless, we are confident that the results represent numbers that can be compared with conventional livestock. It can also be assumed that the national population is much higher. The area surveyed excludes parks and reserves and some sections of states and both territories (Figure 12).

When converted to bioregional scales, the highest numbers of kangaroos coincide with the highest numbers of sheep, while the largest number of cattle are in the NT (Figure 13). Note that these figures are useful for comparing species in the same region and less useful for comparing the same species between regions due to different sized regions. The figures for kangaroos (Figure 14 a, b and c) show that not all regions covering distribution ranges are surveyed. For example, although red kangaroos are in the NT, surveys are not conducted there.

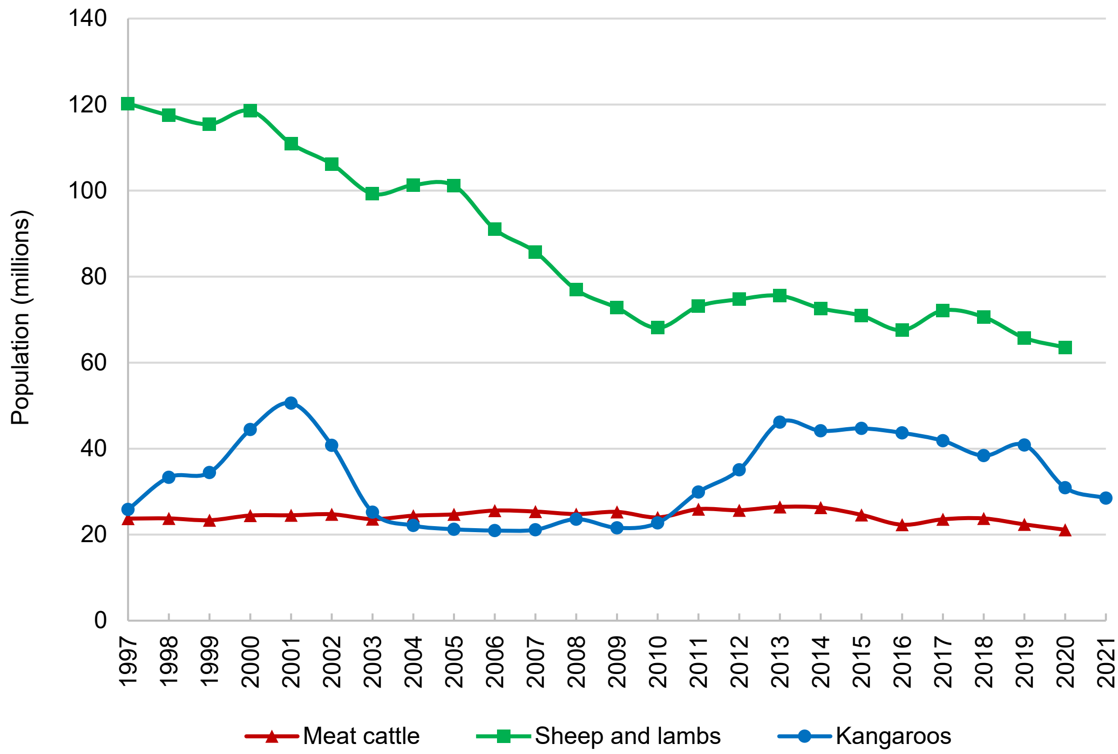


Figure 11. National population of meat cattle, sheep and kangaroos in the area surveyed (see Figure 12) (ABS 2019; DAWE 2022c).

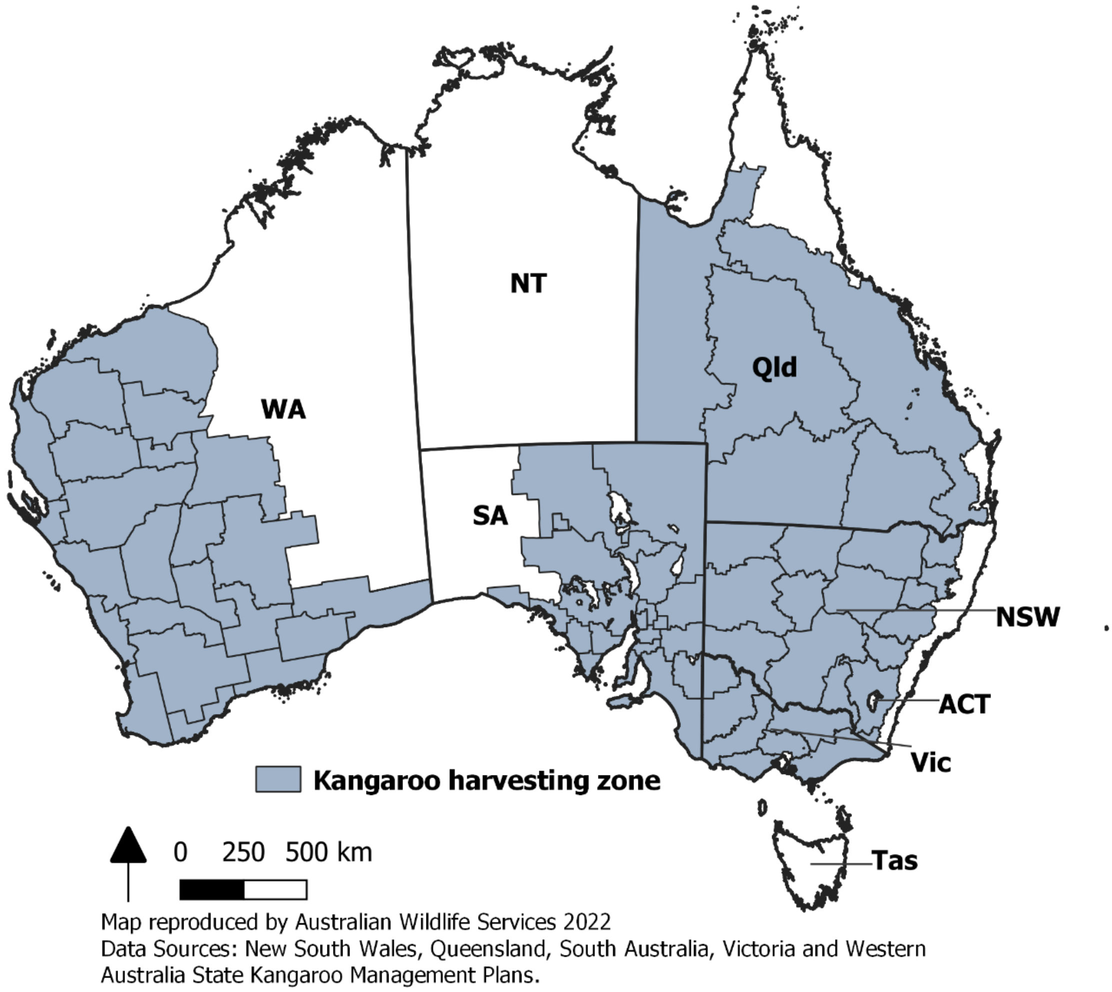


Figure 12.Commercial kangaroo harvesting zones in 2021, which coincide with areas surveyed.

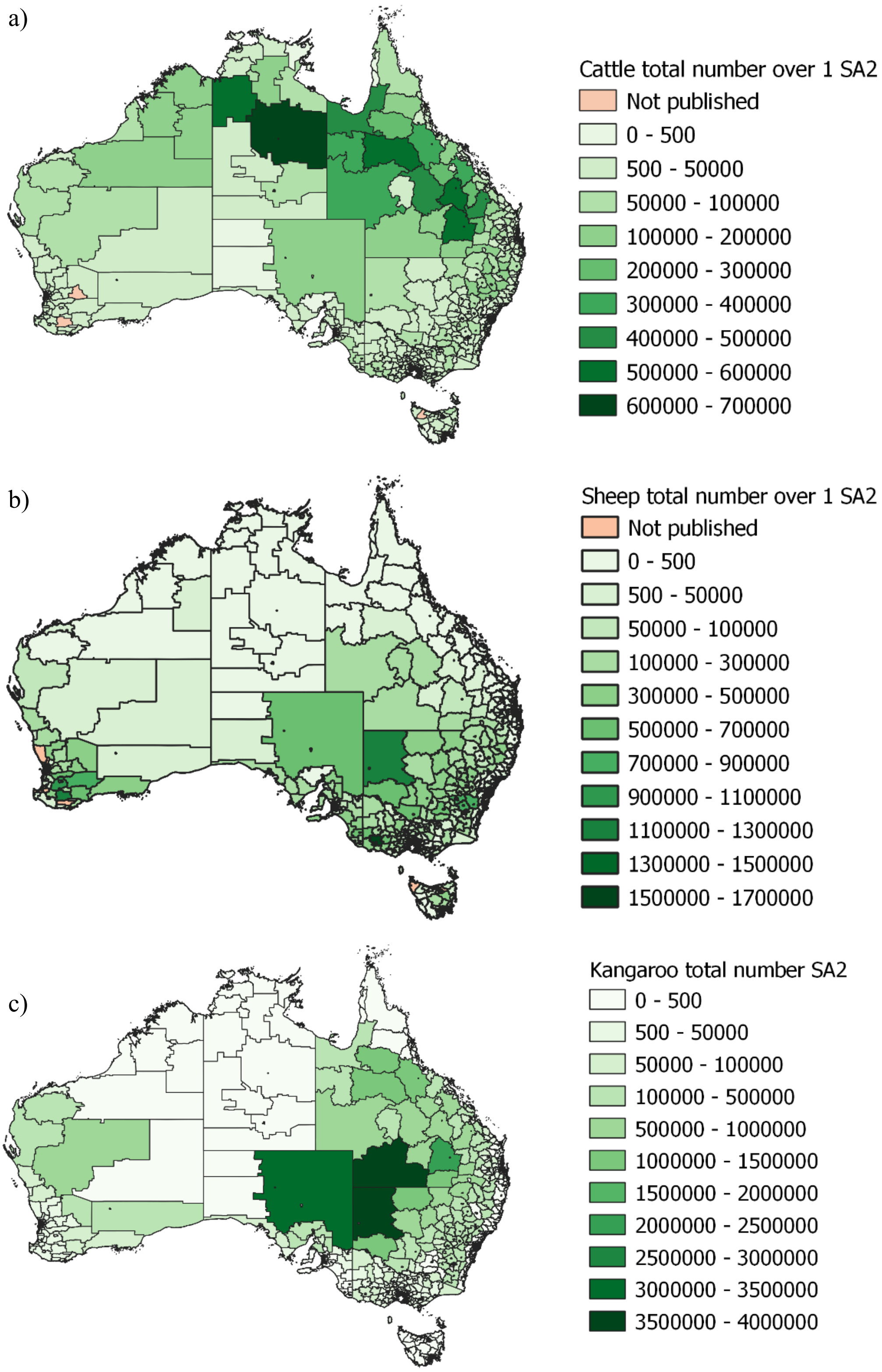


Figure 13. Cattle (a) sheep (b) (ABS livestock data for 2016) and kangaroo (c) numbers (2016 from state kangaroo management plans and allocated to the Statistical Area 2 regions).

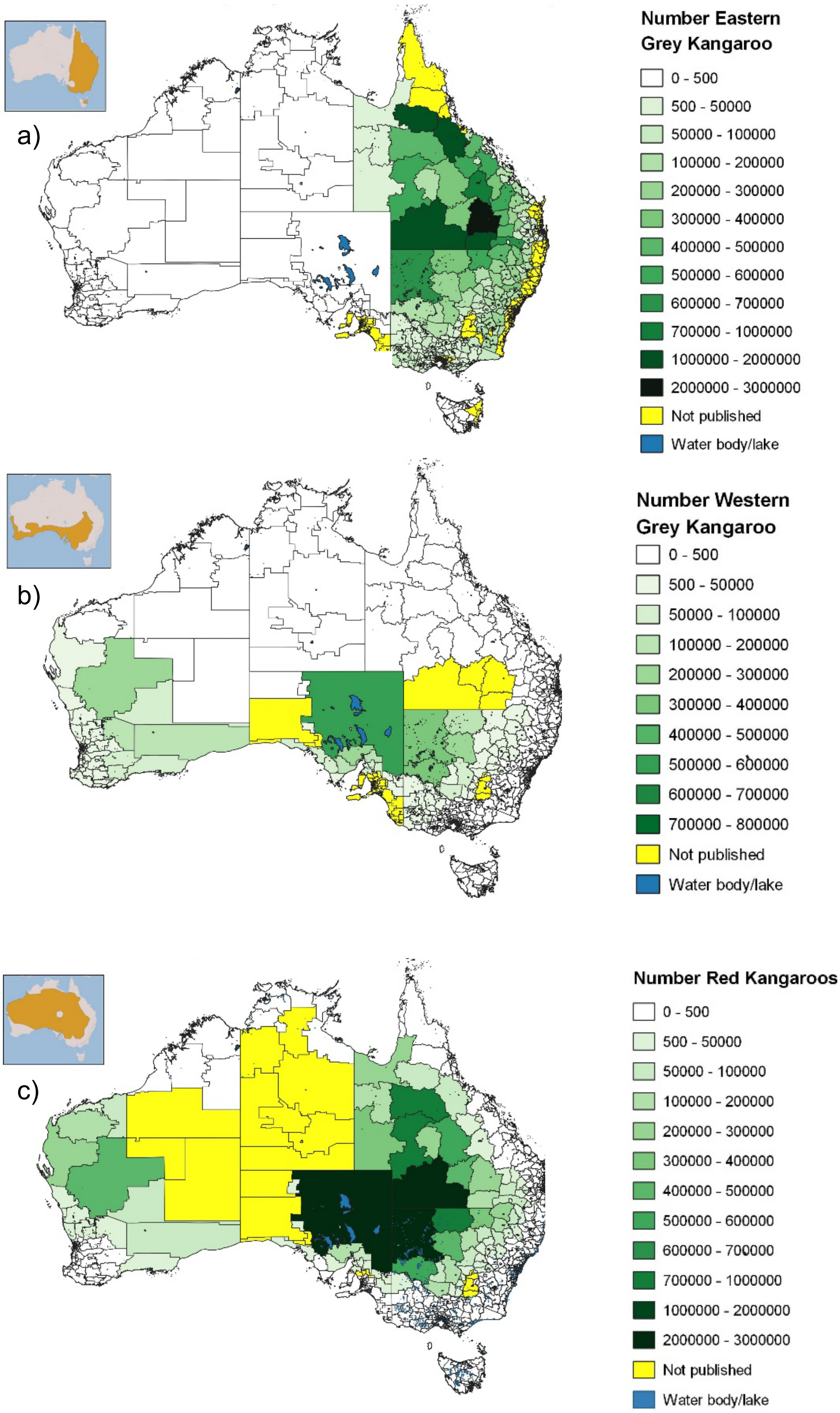


Figure 14. Number of kangaroos in the Statistical Area 2 regions by species: (a) eastern grey kangaroo; (b) western grey kangaroo; and (c) red kangaroo. Yellow shows areas of the species distribution where no surveys are conducted (data derived from state kangaroo management plans for 2016).

Scale of enteric methane produced by livestock

An equation to predict CH_4 production of forage-fed cattle was generated for Australia by Charmley *et al.* (2016). It showed northern beef cattle fed tropical grass hays, tropical legume hays, and lucerne hay produced between 20 to 200g CH_4/day while southern beef cattle fed lucerne oaten hay chaff produced 80 to 250g CH_4/day, which equates to 0.18 to 1.82 CO_2e/year and 0.73 to 2.28 CO_2e/year. In 2019, meat cattle greater than one year old produced 25514.20 Gg CO_2e or on average 1.55 t CO_2e/individual/year, while sheep (all ages) produced 11645.17 Gg or on average 0.18 t CO_2e/individual/year (ABS 2019, NGGI 2021). Goats produce approximately 0.13 t CO_2e/individual/year (NGGI 2005).

The number of cattle and sheep (greater than one year old in Australia), and their enteric CH_4 production (potential abatement if removed) are listed in Table 1. Sheep values are likely to be more as average individual CO_2e enteric CH_4 calculations are from animals including those younger than one year old.

Table 1. 2019 annual enteric CH_4 production from meat cattle and sheep greater than one year old presented as CO_2e (ABS 2019, NGGI 2021).

State	No. of cattle > one year old	% total cattle	Sheep > one year old	% total sheep	Total CO_2e tonnes cattle	Total CO_2e tonnes sheep	Total CO_2e tonnes cattle and sheep
NSW	2,722,209	16.51	14,211,687	32.98	4,219,424	2,558,103	6,777,527
Vic	1,432,837	8.69	10,284,005	23.87	2,220,897	1,851,121	4,072,018
Qld	8,361,577	50.70	1,528,039	3.55	12,960,444	275,047	13,235,491
NT	1,529,764	9.28	44	0.00	2,371,134	8	2,371,142
SA	628,079	3.81	6,377,301	14.80	973,522	1,147,914	2,121,437
WA	1,477,650	8.96	9,080,618	21.07	2,290,357	163,451	3,924,869
ACT	1,569	0.01	21,401	0.05	2,432	3,852	6,284
Tas	339,058	2.06	1,584,883	3.68	525,540	285,279	810,819
Australia	16,492,744	100	43,087,979	100	25,563,753	7,755,836	33,319,589

Lowering emissions by having less livestock

Australia could save five per cent of its total GHG emissions by lowering livestock numbers by 50 per cent (Figure 15) (ABS 2019, NGGI 2021). While such removal would be a drastic social and economic measure, and some would say politically impossible, we have included it for the purposes of discussion.

A transition would be best with trials of staged reductions of livestock numbers and corresponding harvest replacement so that protein production is not reduced and that infrastructure for kangaroo harvesting can cope with any increases.

The transition to lower livestock numbers and make greater use of kangaroos might be part of a program to include kangaroo products in hybrid beef and lamb sausages, mince, patties and rissoles. As synthetic meats grow in popularity, the livestock industries are considering such hybrid products as a way of the future. MLA is developing plans to blend real meat with synthetic meat (MLA 2022b).

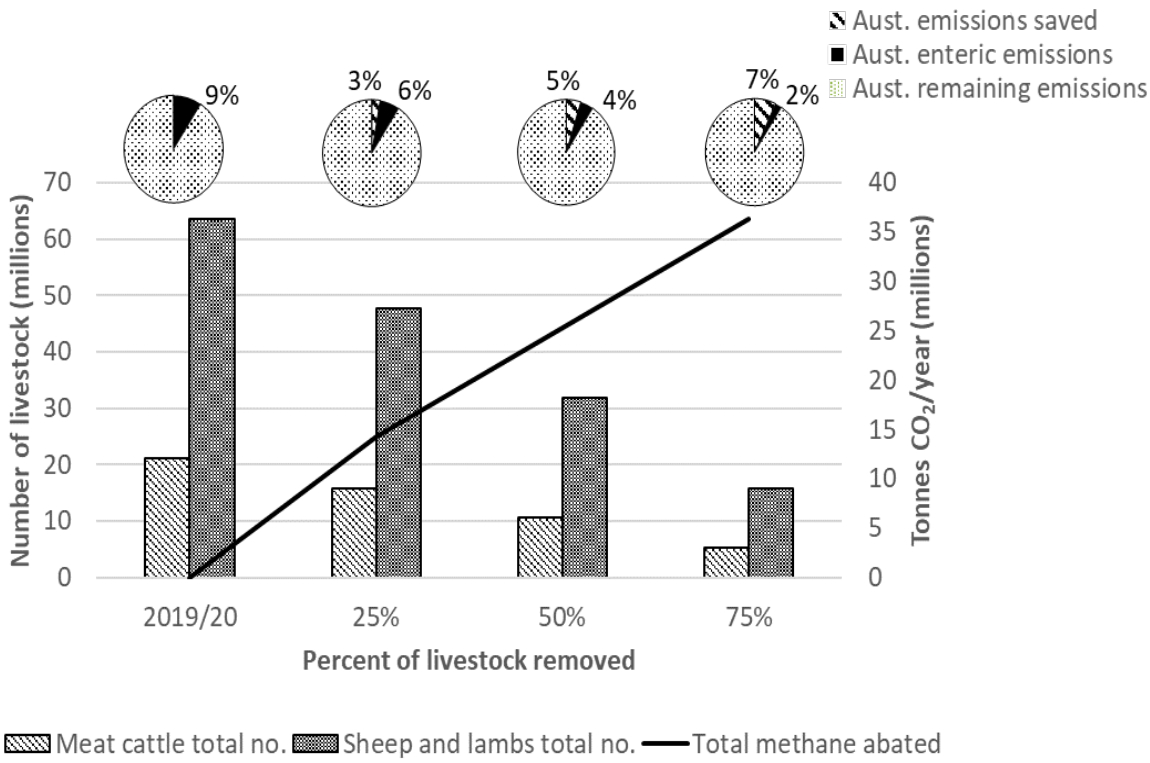


Figure 15. The national greenhouse gas savings in tonnes of C0₂e per year that Australia could generate by reducing the livestock herd by 25, 50 and 75 per cent. Pie charts show percentages.

Soil carbon sequestration

Under current grazing practices Australian soils are losing carbon. Figure 16 shows projected changes in soil carbon to year 2038 due to land degradation (Soils Revealed 2016); predicted grassland restoration (Figure 17) or management using sustainable pastures and adaptive grazing (Figure 18) offers substantial increases in soil carbon for most states and territories (Table 2) (Soils Revealed 2016). NSW and Queensland are predicted to make the most gains under management using sustainable pastures and adaptive grazing with average sequestration at 2.86 and 2.97 t/CO_2e/ha/20 years. While the larger sources of potential are along the east coast, significant gains can still be made within the rangelands (Soils Revealed 2016). If stocking rates remain, it has been suggested that losses will continue at a conservative rate of 0.15 to 0.29 t/CO_2e/ha/year with large regional differences (Hill *et al*. 2006, Sanderman and Farquharson 2010).

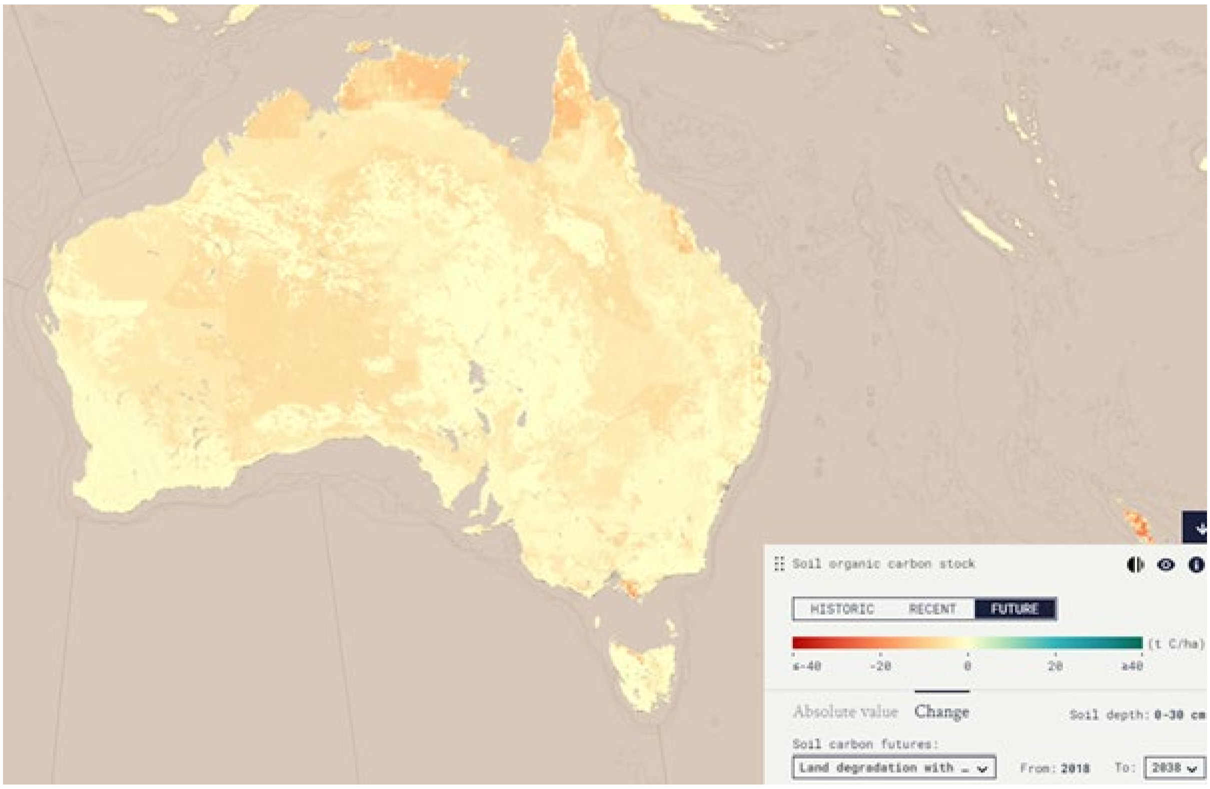


Figure 16. Projected change in organic soil carbon with land degradation (Soils Revealed 2016).

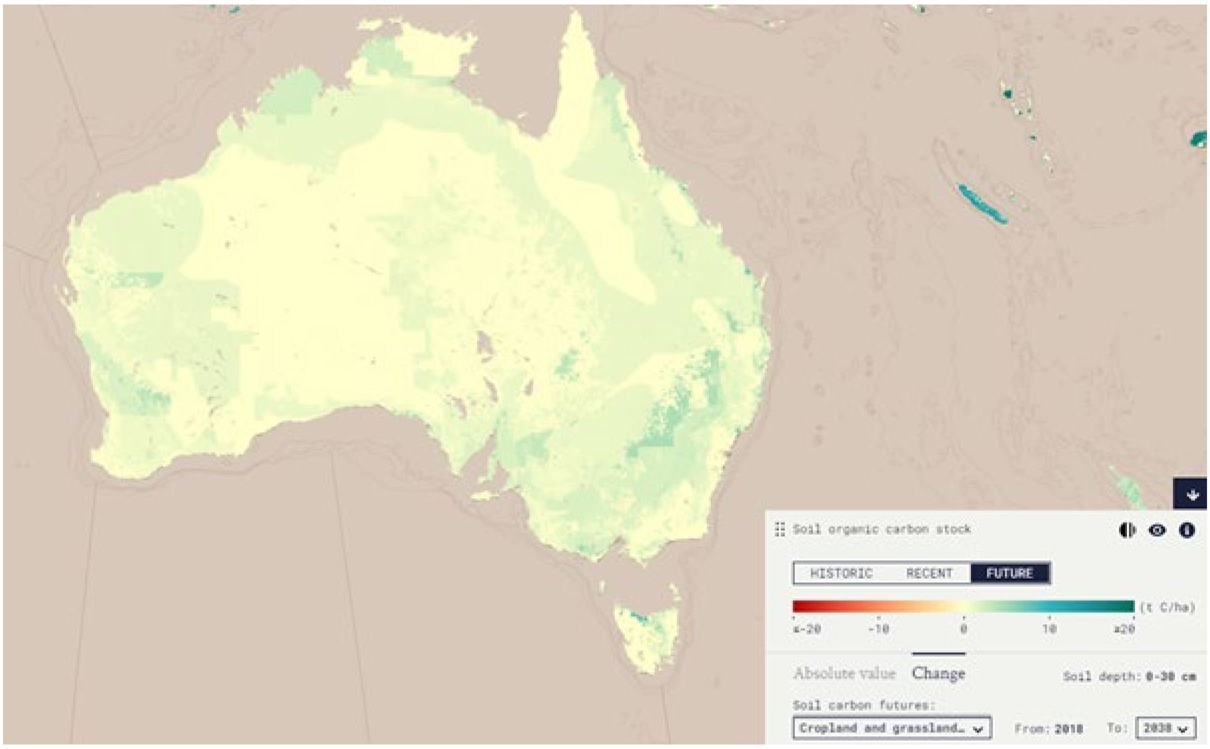


Figure 17. Soil carbon change with grassland restoration (Soils Revealed 2016).

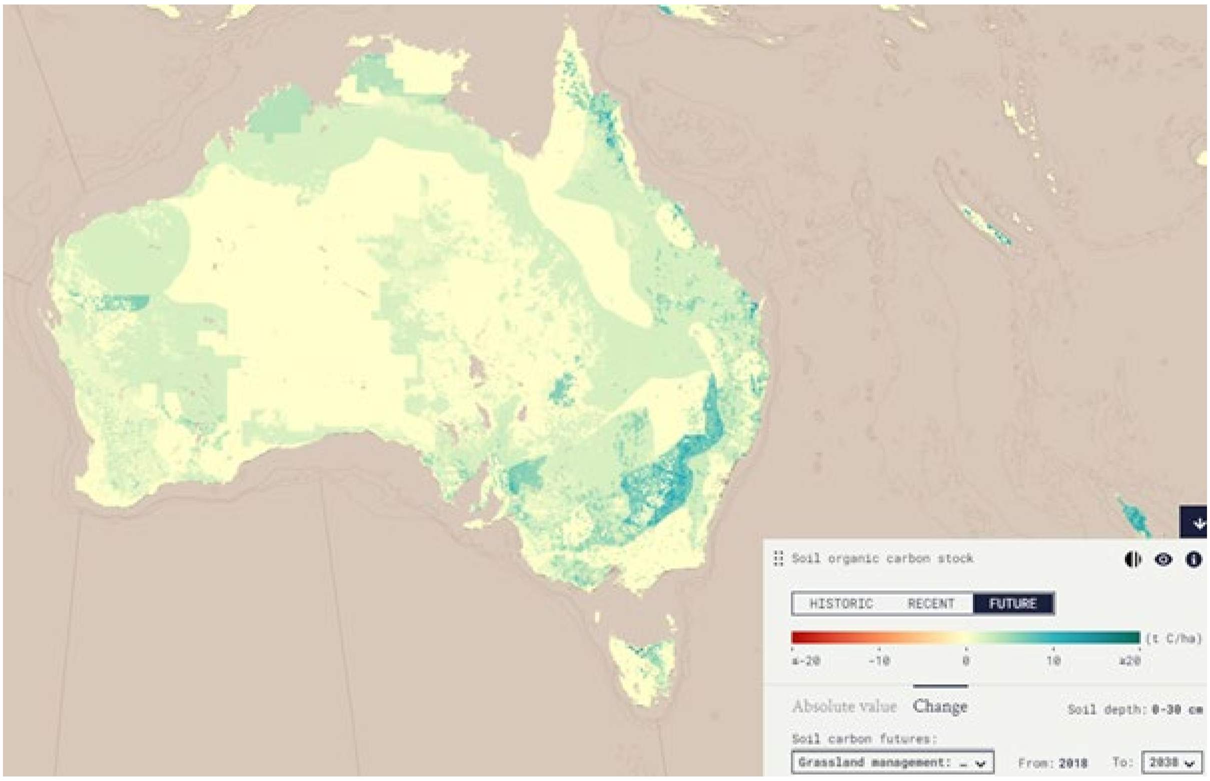


Figure 18. Projected change with grassland management sustainable pastures and adaptive management (Soils Revealed 2016).

Table 2. Estimated gain from 2018 to 2038 with sustainable pasture grassland management and adaptive management in soil organic carbon stock 0-30 cm (Soils Revealed 2016). Carbon converted to CO_2e using the conversion factor 3.67.

State	Average t CO_2e/ha/20 years (average ACCU available/ha/20 years)	Range (t CO_2e/ha/20 years)	Total gain for 20 years (Tg CO_2e)	Value at $15-30/tonne ($ mil) after 20 years
NSW	2.86	0-29.36	231.21	3,468-6,936
Vic	1.28	0-18.35	28.993	435-870
Qld	2.97	0-25.69	513.80	7,707-15,414
NT	2.02	0-22.02	271.58	4,074-8,147
SA	1.17	0-25.69	3115.97	1,740-3,479
WA	2.16	0-22.02	550.50	8,258-16,515
ACT	0.55	0-18.35	0.13	2-4
Tas	0.69	0-22.02	4.69	70-141
Australia	2.24	0-29.36	1,710.22	25,653-51,307

Tg = teragram = 1,000,000 tonnes = megatonne. ACCU is Australian Carbon Credit Units: 1 tonne CO_2e is equivalent to 1 ACCU.

Additional savings

While this report examines enteric CH_4 and soil carbon sequestration, the potential abatement is likely to be substantially more. Feed production and processing, and manure storage also contribute significantly to GHG production. A report on tackling climate change through livestock incorporates a number of modules, including the herd structure, manure and feed; this includes sources of N_2O and CO_2. Land use change emissions is also highly complex (Gerber *et al*. 2013); however, if the KGS enabled partial reforestation, additional GHG savings could be included. More work is needed to calculate the additional production costs of harvesting kangaroos; for example, the transport costs associated with harvesting and carcase delivery. Other harvested species, including but not limited to tammar wallabies (*M. eugenii*) and wallaroos (*M. robustus*), are also not included in the calculations.

Options for managing livestock and kangaroos

There are a number of ways to show how kangaroos can contribute to CH_4 abatement and carbon sequestration and storage. The sections below show how grazing management of livestock converted to grazing management of kangaroos can help store carbon in soil; the regions where the concept would be most feasible, i.e., regions with high kangaroo-to-livestock ratios; and how much CH_4 would be saved if the national kangaroo harvest quotas were met and replaced the equivalent amount of useable/saleable carcase from cattle.

Target grazing index: stocking rates lower than carrying capacity to support increased forage biomass and soil carbon

In this section we describe how grazing management can result in more soil carbon and livestock grazing can be converted to kangaroo grazing. The more productive lands support a larger number of herbivores and changes associated with pastoral development such as creating permanent waters, wild dog control and tree clearing. One cow can be compared to eight sheep, 11 goats, 12 kangaroos or 133 rabbits (Burrit and Forst 2006 and Lu 1998 in Morris and Reich 2013) (Table 3).

Table 3. Dry sheep equivalents attributed to livestock and kangaroos.

	DSE
Wether	1
Ram	2
Ewe	1.5
Bull	14
Steer	9
Cow	8
Weaner calf	6
Goat	0.73
Kangaroo	0.67

More recent studies show cattle DSEs as 8.3 and kangaroos as 1 DSE (Pahl 2019a). A study by Hill *et al*. (2006) looked at stocking rates and how managing grazing pressure could affect soil carbon over various modelled timeframes and condition. They found that at stocking rates that were at 100 per cent the level of 1997 stocking rate levels, the soil carbon from rangelands is lost at 400 Mt in 40 per cent of five-year simulations. With uncertainties and approximations taken into account the authors model a 40 per cent risk of a minimum of 100 to 400 Mt of soil carbon loss in a five-year reporting period.

The grazing index (GI) is a ratio of the stocking rate to carrying capacity (GI= stocking rate/carrying capacity): Index: 1 = <0.5; 2 = 0.5-0.8; 3 = 0.8-1; 4 = 1-1.5; 5 = >1.5. A GI 1-2 is considered low, 3 is considered normal/sustainable in the long term and 4-5 will result in pasture degradation.

Figure 19 shows the fate of Australian pastures under three different safe carrying capacity models – precipitation based carrying capacity, general capacity and regional carrying capacity with stocking rates at 25, 50, 75, 100, 150, and 200 per cent of the 1997 stocking rate (Hill *et al*. 2006). The study shows that across the majority of Australia, stocking rates need to decrease in order to restore and store carbon in the rangeland soils.

The stocking rate for kangaroos can be determined by converting the target DSE of livestock to kangaroos using a kangaroo DSE of 1 (Pahl 2019a). The stocking rate will become the target population and should be revised according to the environmental conditions that influence the carrying capacity and target GI.

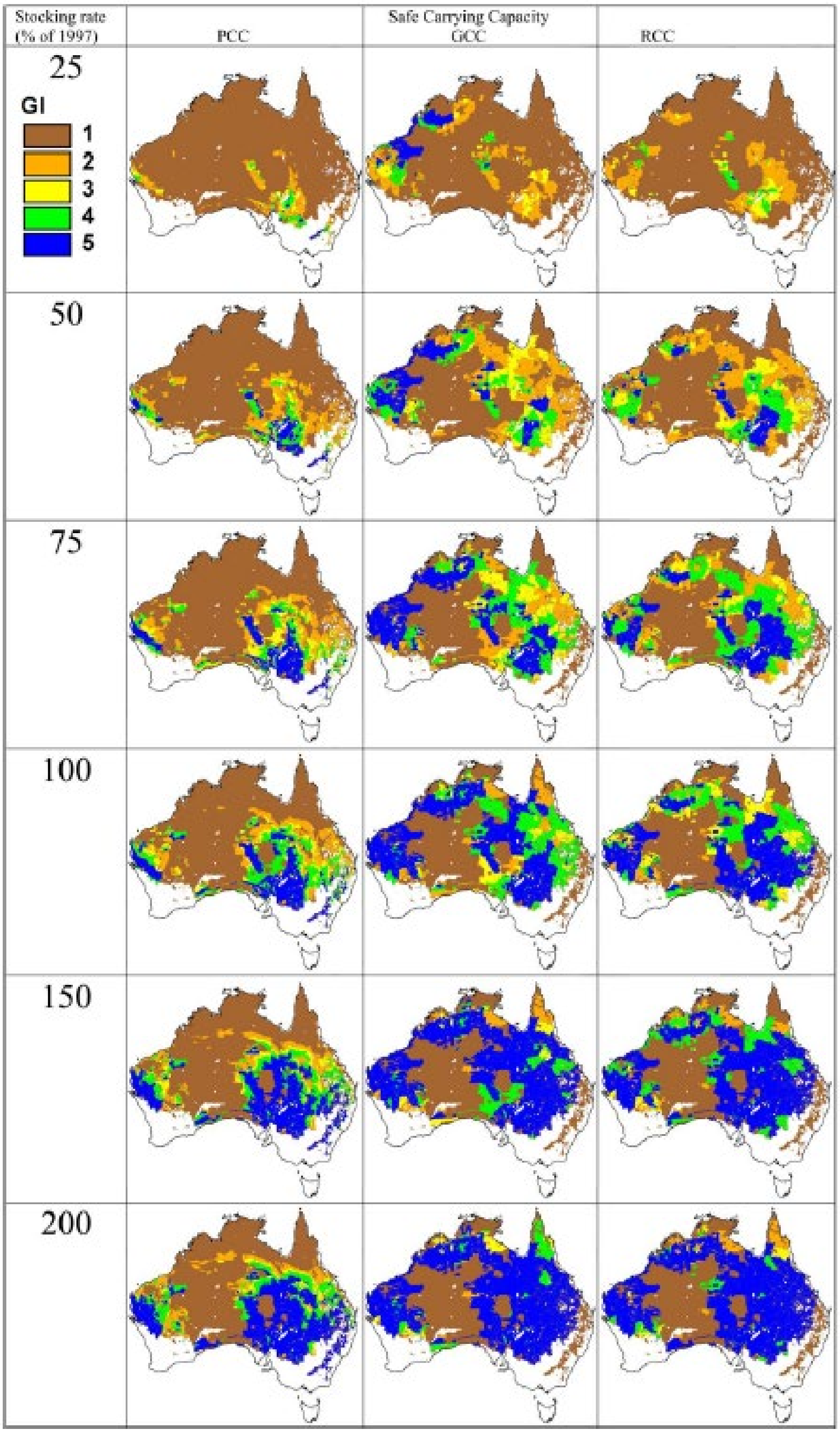


Figure 19. Spatial variation in grazing index associated with variation in stocking rate for three different methods of calculation for safe carrying capacity: first column – precipitation-based carrying capacity (PCC); second column – general carrying capacity (GCC); third column – regional carrying capacity (RCC) (Hill *et al.* 2006).

Regions with high populations of kangaroos

When converted to DSEs, kangaroo population numbers suggest kangaroos have contributed seven to 18 per cent of the recordable DSEs attributed by cattle, sheep and kangaroos (yearly) since 1997 (calculated from ABS 2019 and state kangaroo management plans). While the figures are likely to vary between regions, it is apparent that kangaroos are contributing and need to be managed for carbon to be increased in soil carbon. There is large scope to use KGS to reduce grazing pressure and increase the store of carbon in soil.

In the rangelands, 2016 values show kangaroos were responsible for approximately 30 per cent of total kangaroo, cattle and sheep DSEs while cattle were responsible for 73 per cent of total DSE and sheep for seven per cent (Figure 20). The values should be used with caution as it does not take into account other grazing herbivores and there are some challenges in achieving total population counts for kangaroos (see section 'Grazing populations').

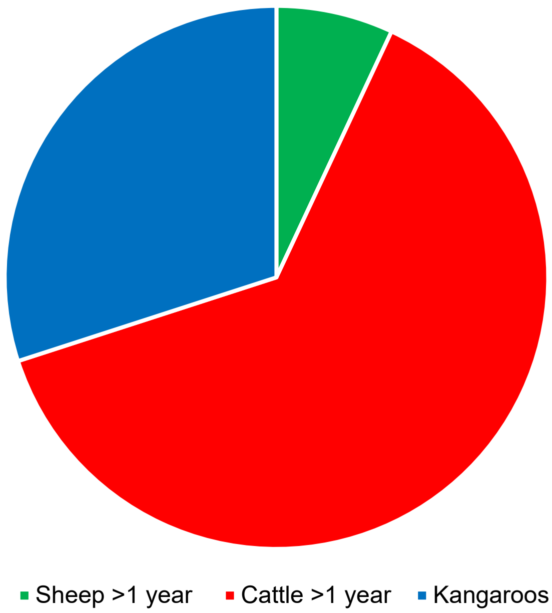


Figure 20. Portion of dry sheep equivalents attributed to cattle, sheep and kangaroos (not goats) in the rangelands.

We focus further on regions where kangaroo grazing pressure is highest to provide an indication of the GHG savings a potential grazing system could generate. Pastoralists interested in the novel grazing system would assess their own land and circumstances in order to determine if the proposed grazing system were applicable to them.

In north eastern SA, western NSW and south western Queensland, kangaroos can be responsible for more than 65 per cent of total cattle, sheep and kangaroo DSEs in some Statistical Area 2 regions (SA2). We have used these SA2s as examples of regions where the KGS might best be implemented. Note that while the South Australia SA2 Outback zone showed that kangaroos were responsible for more than 65 per cent of DSEs it was not included in the example as it contains vast protected areas and areas for nature conservation.

Figure 21 shows the estimated total number of kangaroos, cattle and sheep in each of the example SA2s. The predominant land use is grazing of native vegetation, with only a small amount of land used for nature conservation (Figure 8). In these four regions cattle and sheep (greater than one year old) are responsible for an estimated 785,390 t CO_2e/year (see Table 4 for regional values), which is 2.4 per cent of Australia's total cattle and sheep (greater than one year old) enteric emissions.

Under current approved state management plans, kangaroos can only be harvested for commercial purposes to a quota based on 15 to 20 per cent of the population. Thus, pastoralists ability to control grazing pressure using the commercial harvest could be limited. In recent years, however, the commercial harvest has been only 20 to 30 per cent of the permitted quota. Damage mitigation are also theoretically limited, although it is impossible to enforce limits that might apply to permits or assess the numbers actually taken.

Under the KGS, kangaroo populations could increase if livestock were reduced. If populations grow, so does the ability to harvest more kangaroos. In these areas harvesting kangaroos at 15 per cent of the population and reducing cattle by 10 per cent saves the equivalent of 13.6 to 14.5 per cent DSE, or by harvesting kangaroos at 15 per cent and culling sheep by 10 per cent you save 13.9 to 14.7 per cent DSE with the equivalent GHG savings from 10 per cent reduction in sheep and cattle.

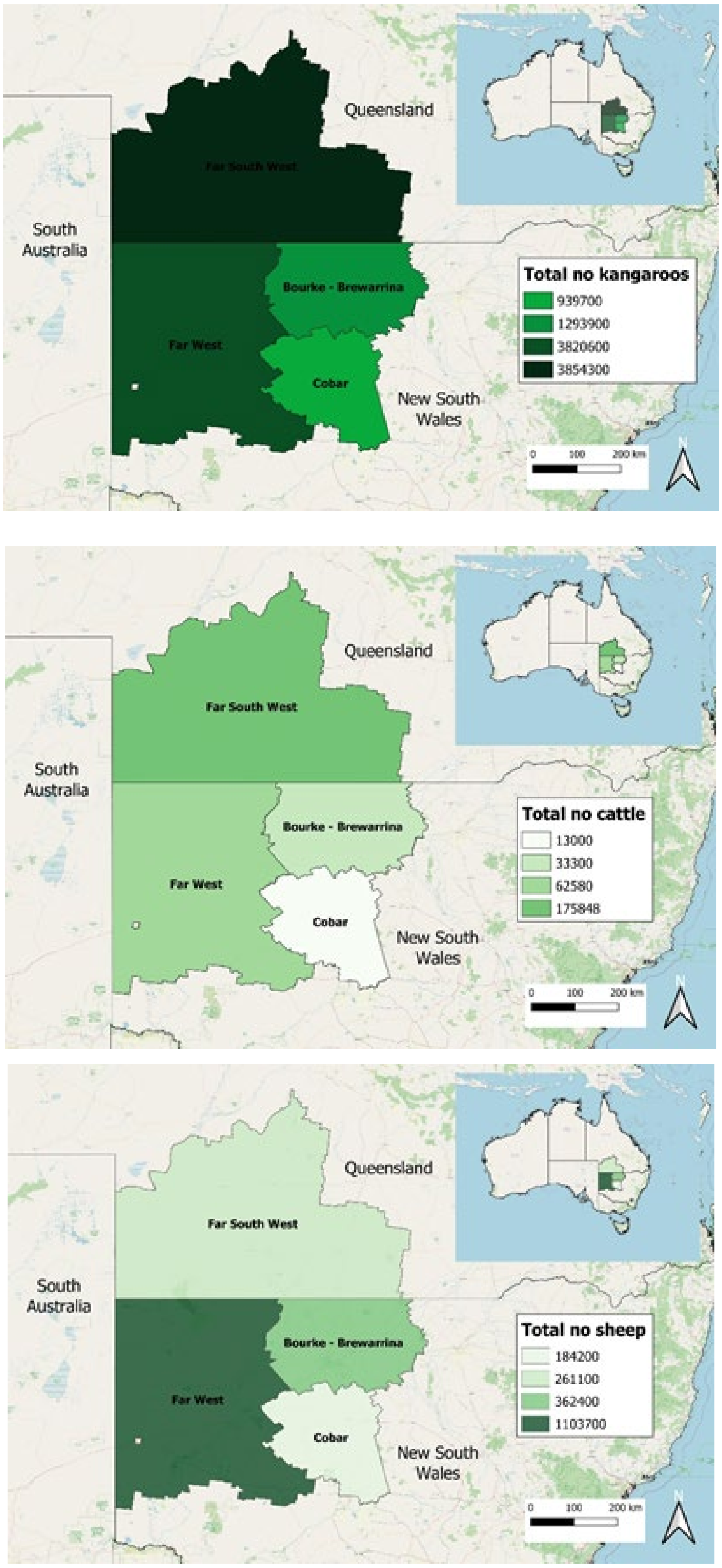


Figure 21. Estimates of number of kangaroos, cattle and sheep in Statistical Area 2 regions where kangaroos are responsible for greater than 65 per cent of dry sheep equivalents.

Table 4. Enteric emissions generated from cattle and sheep (tonnes CO_2e) in four regions where kangaroos are responsible for more than 65 per cent dry sheep equivalents.

Region	Emissions cattle > one year old (t CO_2e)	Emissions sheep > one year old (t CO_2e)	Total enteric emissions cattle and sheep cattle > one year old (t CO_2e)
Bourke-Brewarrina	51,609	65,230	116,839
Cobar	20,173	33,158	53,331
Far West	96,999	198,668	295,667
Far South West	272,564	46,989	319,554

Meeting the kangaroo harvesting quota

In 2020, there were approximately 4.5 M kangaroos that had not been harvested under the total allowable state management kangaroo harvest quotas (DAWE 2022c). At 18 kg per individual useable/saleable carcase (calculated from: Hopwood *et al*. 1976, NSWOEH 2019) this equates to approximately 80 M kg total of useable/saleable carcase and is the equivalent of approximately 400,000 steers at approximately 200 kg useable/saleable carcase (calculated from: Afolayan *et al*. 2002, MLA 2019). Where 4.5 M kangaroos produce approximately 0.048 Mt CO_2e (calculated from: Kempton *et al*. 1976, Vendl *et al*. 2015), cattle produce approximately 0.62 Mt CO_2e (calculated from: ABS 2019, NGGI 2021). If the allowable kangaroo quota was met and replaced the equivalent amount of beef, it would abate approximately 0.57 Mt CO_2e. That is nearly two per cent of all the total beef and sheep (greater than one year old) enteric livestock emissions.

Co-benefits

There is increasing interest in the development and implementation of grazing management strategies that attain co-benefits while promoting long-term commercial grazing (Dorrough *et al*. 2004). Indeed, some are suggesting that environmental, social and cultural co-benefits are the core benefit and that carbon sequestration or amelioration is the co-benefit. Regardless, the main challenge is to develop strategies that maintain environmental sustainability and enhance local and regional biodiversity. Kangaroo grazing management could be improved in such a way to improve all; however, management activities require considerable application, measurement and reporting from pastoralists and researchers. Additional co-benefits include improved sustainability, animal welfare, human welfare including indigenous employment and cultural maintenance, and food waste reduction.

Environment – soil, landscape and ecosystem services

Published research indicates the environmental benefits of reducing livestock and managing kangaroo numbers are profound. While the effects of grazing differ and are context dependent, with herbivore type and intensity, position within a productivity gradient, aridity and plant origin (Eldridge *et al*. 2017), adjusting livestock and kangaroo numbers to match available forage biomass brings benefits. Managed grazing has the capacity to increase litter and plant cover (i.e., less bare ground) and increase root biomass (LLS 2020a, Teague and Kreuter 2020). Under these conditions, soil health and structure improve through increases in nutrients and nutrient recycling and increases in capacity to hold water (LLS 2020b). A higher percentage of rainfall can infiltrate the soil where it can be used for plant growth rather than running off (LLS 2020b). The increased litter and plant cover, coupled with increased rainfall infiltration, lowers soil surface temperature and increases soil moisture, generating conditions that are associated with higher numbers of invertebrates, microbial biodiversity and biomass, which contribute even further to soil health and structure (Holt 1997, Morris and Reich 2013).

Cattle, sheep and goats have profound impacts on soil compaction, litter and plant cover, and root biomass, and while the pressure exerted by kangaroos on the ground is lower than that of ungulates (Bennett 1999), we would expect them to have fewer physical disruptive effects, especially at managed levels. Kangaroos can also create diggings (hip-holes) that may beneficially modify the chemical and physical properties of soils through the entrapment of faeces and litter, and soil turnover (Eldridge and Rath 2002); however, there must not be too many kangaroos (Mills *et al*. 2020).

Management of the population must enable growth or maintenance of vegetation, which in turn depends on the location and climatic conditions. For example, the grazing impact of eastern grey kangaroos, at 70 kangaroos/km^2 in a peri-urban mesic environment, was not detrimental to soil health (Eldridge *et al*. 2021) while higher densities (not estimated), significantly reduced soil nutrients (total carbon and nitrogen, and available phosphorus) relative to grazing exclusions at a site with low kangaroo numbers (Morris and Letnic 2017).

Kangaroos are important components of native Australian grassland environments with native grasslands ranked as being far more environmentally valuable than that of domestic species and improved pastures (Nadolny 1998). A KGS with reversion from improved pastures to native pastures brings key contributions to native landscape health. Healthy soils and native landscapes together promote essential Australian ecosystem functions and services such as cleaner air and water and improvements in biogeochemical cycles, pollination, seed dispersal, integrated pest management, recovery processes of degraded native communities (Freeman and Pobke 2021), and reduced impacts on regeneration of palatable plants after fire (Read *et al*. 2021a).

Biodiversity

Overgrazing from livestock is frequently reported as having a negative impact on Australia's biodiversity (Stevens 2001, Eldridge and Delgado-Baquerizo 2017) with declines of animals and plants (Fitzsimons *et al*. 2010, Legge *et al*. 2011). Under-grazing also encourages a few species that will overwhelm the pasture and reduce biodiversity. Total grazing pressure is therefore a major target for conservation monitoring and management (Freeman and Pobke 2021) with goals to maintain grazing at an optimal density to encourage a diversity of herbs and grasses (Koerner *et al*. 2018) Figure 22).

When dietary choice between animal species differs, driven by factors such as body size, digestive physiology and dental anatomy, species management can be utilised to manipulate diverse communities (Rook and Tallowin 2003). Although application requires consideration of conservation goals, whether at landscape, habitat, plant-animal community or plant-animal species level.

Encouraging the ground cover and abundance of native perennial grasses and forbs and allowing natural regeneration of shrubs and trees is one of the most effective strategies for promoting biodiversity in the long term. For example, grazing can be used to manage the invasive and highly combustible pasture grass species, Buffel Grass (*Cenchrus ciliaris*) and thereby help conserve fire-sensitive Brigalow (*Acacia harpophylla*) vegetation in reserves in Queensland (Lebbink *et al*. 2021).

Kangaroo grazing can be manipulated as a management tool to increase the availability of suitable habitat structure and niches for native fauna and flora species in which they find shelter from competition, protection from predators and increased availability of food and nutrients (Gordon *et al*. 2021).

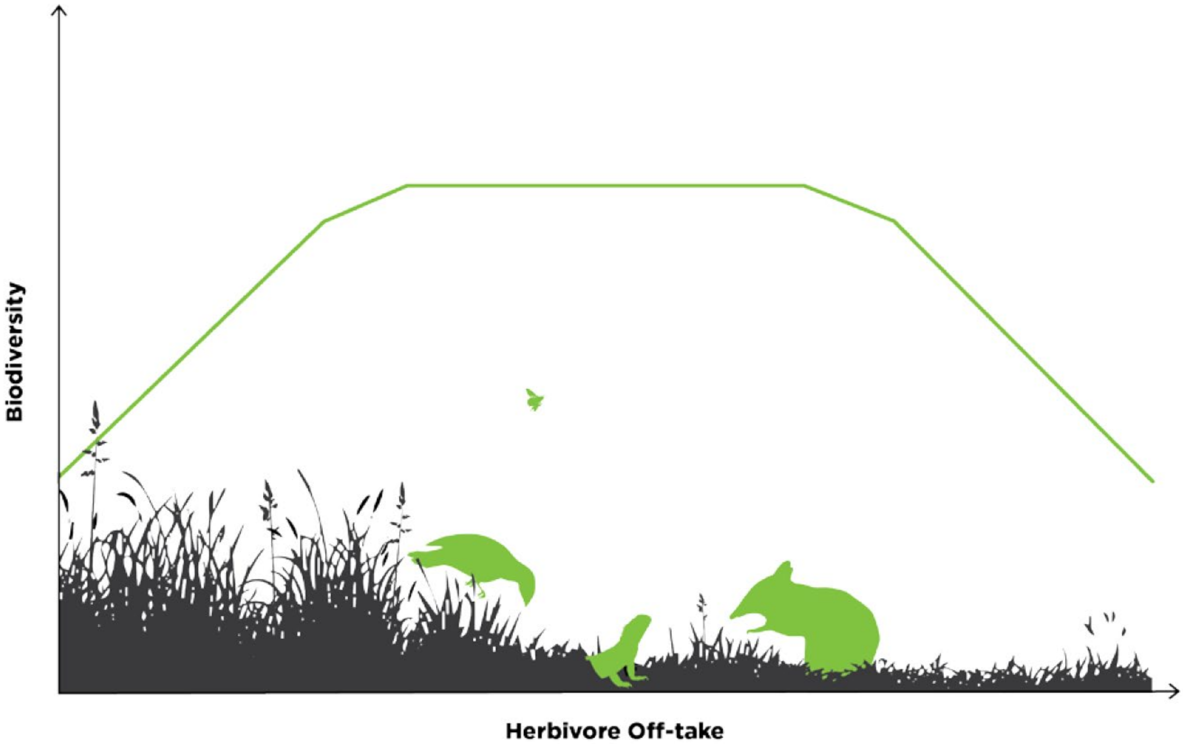


Figure 22. Overgrazing and under-grazing are not optimum for biodiversity. Different levels of grazing influence vegetation and their biodiversity (BCT 2020).

Enterprise diversity

The sustainability of agriculture and the future of producers and rural communities in regional Australia is becoming increasingly uncertain due to increased frequency of droughts. There is an emerging need for greater resilience, more stable profitability and reversal of human population decline (Infrastructure Australia 2019). Diversification is one way to build economic resilience and build employment opportunities while maintaining rural landscapes in the face of increasing financial and environmental pressures (Medhurst and Segrave 2007). Expansion of the kangaroo industry could be an innovative rural development opportunity with relatively low costs; the resource is already there, the industry is operating, albeit in a constrained form, and only a small proportion of the permitted quota is currently taken (Figure 23).

Sustainability

Kangaroos and the plants that make up their diet are native species adapted to the Australian environment, which means they are suited and will survive Australia's harsh and extreme climate conditions. When compared to conventional livestock, kangaroos have low water and metabolic requirements, and different reproductive strategies, so they can respond to changing conditions, including drought, and presumably require less provision of care (Wilson and Edwards 2019).

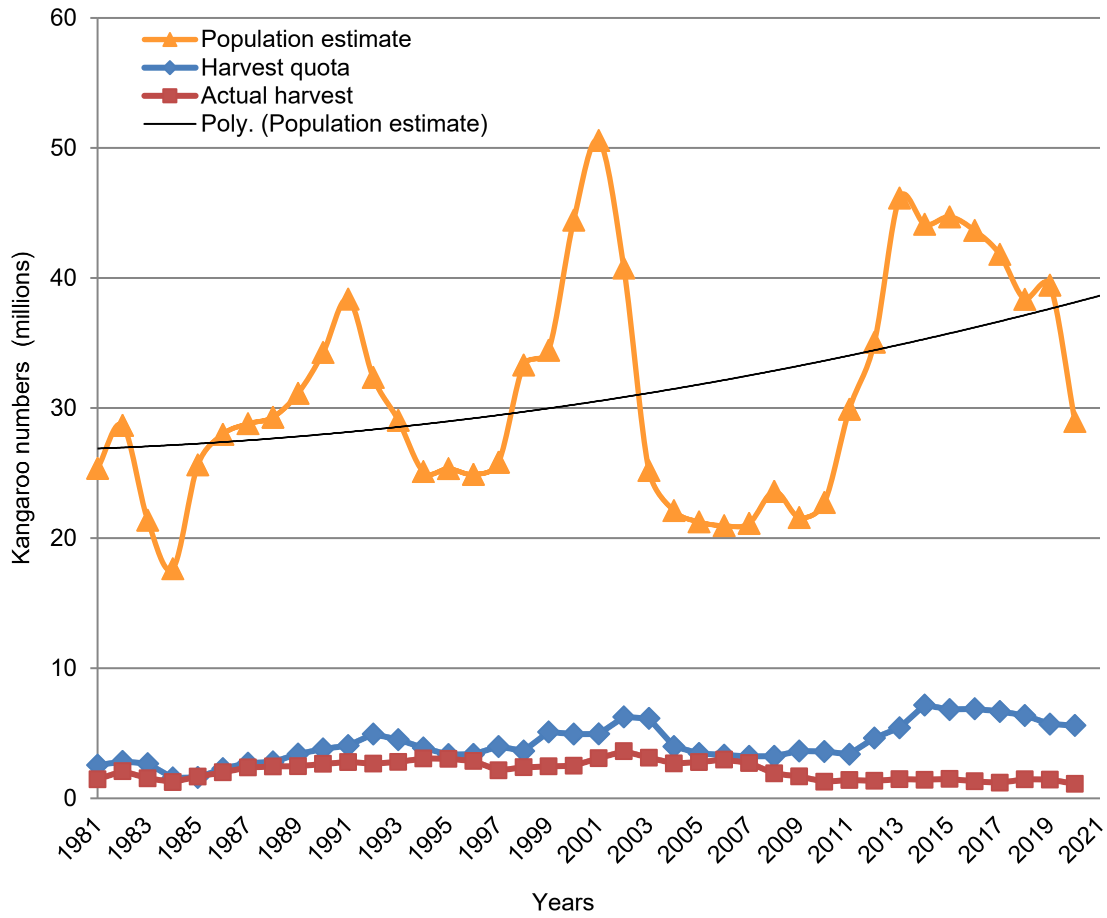


Figure 23. Kangaroo population estimates in commercial zones, harvest quotas and actual harvest. In the last 10 years the actual harvest has not reached the harvest quota and is a tiny proportion of the estimated population (DAWE 2022c).

Animal welfare

Culling

The *National Code of Practice for the Humane Shooting of Kangaroos and Wallabies for Commercial Purposes* (The Code) is a national document intended to guide regulation of humane harvesting practices for the commercial kangaroo industry in Australia. The code outlines a minimum standard of humane conduct in regard to the shooting of kangaroos and wallabies by professional shooters. It mandates head shots and instantaneous death (NRMMC 2008). There is a separate code for non-commercial culling.

While commercial harvesters are required to have a higher skill level and headshots at 100 metres, non-commercial shooters are also allowed to aim for the chest, which is a larger more stable target. In most jurisdictions in Australia, they do not have to comply with accuracy testing. There are also significant issues related to enforcement of the non-commercial code. 'Shoot and let lie' means that regulators cannot assess how many kangaroos are taken, which threatens the veracity of figures on numbers culled. Regulators are also unable to monitor shooter accuracy and skill. Carcases are not brought to a nominated site for inspection but left in paddocks or used for domestic purposes. There is little scope for improving the regulation of non-commercial culling; it occurs on a vast scale in remote areas. Our novel grazing system would promote commercial harvesting over non-commercial culling. It would reduce the animal welfare concerns associated with the difficulties of regulating non-commercial culling and promote compliance through the harvesting system.

Drought

Kangaroo populations follow cycles with detrimental outcomes during both the boom and the bust. During the boom there is the increased risk of proliferation of pathogens (Olsen and Braysher 2000) and then during the bust there are mass mortalities (Olsen and Low 2006, Read *et al*. 2021b). When drought makes water and food scarce the scale of the drop in kangaroo populations can be extreme. The Queensland population fell by about 12.1 million between 2013 and 2020 while the NSW population fell by about 7.1 million between 2014 and 2019, which includes a substantial number of kangaroos dying from starvation (Wilson and Edwards 2019).

A novel grazing system would manage population numbers so to not cause intense competition with livestock or damage to crops and so that populations don't boom to only bust during drought. Management through harvesting would reduce death by starvation as populations of kangaroos and livestock numbers would be managed to the land's capacity.

Human welfare

State governments have primary responsibility for kangaroo management, while the Australian Government regulates commercial resource management when the products are destined for export; pastoralists only have authority to cull and harvest kangaroos through licensing quota systems (with the exception of some species and time periods in WA). During drought when resources are limited, pastoralists can destock their livestock, but they are limited when it comes to managing kangaroos; they can take responsibility to protect their enterprises and the welfare of kangaroos, but when conditions and circumstances are formidable, kangaroos can die from starvation or extreme temperatures as the result of reduced resources (see Box 2). The deaths can impact and burden the pastoralists who witness the mass dying events. Additionally, when kangaroos are left to starve on private properties, the public can perceive this as management incompetency with the potential to impact a producer's social licence (Sinclair *et al*. 2019, McMurtrie and Kerle 2021, Zanker 2021).

Appropriate management of kangaroos through a novel grazing system would contribute to reducing the amplitude of population booms and busts, thereby reducing the devastating welfare issue and its impact on the social licence of pastoral production to operate on the rangelands. It would turn a negative environmental issue into a positive through the promotion of soil carbon and vegetation sequestration, and appropriate grazing management to help service ecosystem functions.

There is some contention over the co-benefits for Indigenous Australians. For some Indigenous communities, there is interest and enthusiasm in developing enterprises based on kangaroo harvest (Thomsen *et al*. 2006) as it is a source of sustenance and cultural maintenance (Croft and Witte 2021, Hunt *et al*. 2021). The Indigenous Land and Sea Corporation endorsed a joint statement on improving kangaroo management (Read *et al*. 2021b); it advocates "Consideration of opportunities to better integrate kangaroo harvesting into rangeland production systems. Kangaroos evolved with Australia's fluctuating climate and could be grazed in a complementary way with domestic stock, producing low-carbon-emission, healthy meat with low impact on soils and vegetation." Other Indigenous groups recoil at commercial harvesting, with some expressing any involvement in the commercial harvest as unacceptable.

Box 2. Pastoralist management options under current practice

"Our normal management strategy in response to the onset of drying seasonal conditions is to offload all our production livestock early and then match our core breeder numbers to feed availability. Impending loss of bodyweight and condition of our sheep, cattle and goats, together with the reduction in the quantity of palatable pasture, are important trigger points to recognise and act on.

"The (our) inability to manage the higher-than-normal kangaroo numbers and their impact on our pasture availability meant that by mid-to-late 2018, we had completely destocked all our country, resorting to containment feeding our few remaining core breeders. This was a first for us. Even during the Millennium Drought of 2002 to 2008, we were able to reduce and stabilise our core breeder numbers and see the drought through. However, we entered this drought with record high kangaroo populations across the western areas of NSW. So, despite total destocking, our country continued to be impacted by excessive kangaroo grazing pressure until early 2019, when all our surface waters had dried up, ground cover was virtually non-existent and most of our kangaroos were dead from starvation." – McMurtrie and Kerle (2021).

"To return and have to deal with the financial, environmental and emotional fallout on a day-to-day basis. During the summer of 2018-19, while being totally destocked, I was constantly checking a number of ground tanks that were going dry, for no other reason than to pull out bogged kangaroos and put them down. There is not much fun in being covered in black stinking sludge rescuing a frantic, bogged kangaroo, only to have to kill it because it can no longer hop away or having to retrieve the putrefying carcass. Dozens of kangaroos were dealt with in this way, and I estimate that many hundreds, if not thousands, died of starvation on my property that summer. The effect on the health and mental wellbeing of everybody having to deal with this type of situation cannot be overstated." – Zanker (2021).

Waste reduction

Damage mitigation culling or pest culling is undertaken on kangaroos that are considered a pest. Most often it is the result of crop degradation or pasture competition. States report damage mitigation culling differently. Queensland publicly reports the number of individuals culled; however, it is not possible to obtain the numbers of kangaroos culled from other states. NSW reports the number of animals licensed to be culled and the number of animals culled; however, the number of animals culled is not reliable as reports for licensees are not always submitted. SA issues permits to cull but do not monitor the number of kangaroos culled. WA includes kangaroos as managed fauna, which means in some areas and at certain times of the year, kangaroos can be culled without a licence. While it is not possible to determine a national figure for the number of animals culled non-commercially, we can use the data derived from Queensland to consider the potential impact of using kangaroos that would otherwise be culled under a damage mitigation permit to instead enter the harvesting process chain.

In Queensland from 2018 to 2020, there were between 84,429 and 294,311 kangaroos culled under damage mitigation permits, which accounted for 15 to 33 per cent of total kangaroos killed (Queensland DES 2022). This is between three and 10 per cent of the allowable quota, while harvesting made up 18 to 27 per cent of the allowable quota. Together culling and harvesting make up between 21 and 37 per cent of the allowable quota. Waste is substantiated further when drought or extreme temperatures cause mass deaths.

If kangaroos were managed to the lands capacity through a grazing system, we would see more kangaroos enter the harvesting system and used as a resource instead of being culled, dying of starvation in drought or from extreme temperatures. Current protein demand for the 7.3 B inhabitants of the world is approximately 202 Mt globally. However, even accepting a 2.3 B growth in population, vastly different outcomes in terms of demand for protein result depending on assumptions made about average consumption for the future (Henchion *et al*. 2017). At current consumption and average consumption for the world, projection is expected to be 267 Mt/year (Henchion *et al*. 2017).

While the United Nations, some governments and several non-government organisations (NGOs) are implementing campaigns to reduce the amount of meat consumed, global meat consumption is expected to increase by 76 per cent by 2050 (Alexandratos and Bruinsma 2012). The novel grazing system would encourage the use of several million kilograms of meat and skins, which are being left in paddocks at a time when a growing global population needs sources of protein (Wilson and Edwards 2019).

Receiving co-benefits

The co-benefits of the KGS are multifaceted, with some becoming achievable immediately and well before others, and with some requiring measurements and accounting to determine the extent of the co-benefit (Figure 24). When implementing a KGS, waste reduction and animal welfare co-benefits related to culling can be realised in the time taken to adopt a harvester in place of a shooter, or for a pastoralist/harvester to obtain the necessary licences, permits and equipment to harvest kangaroos.

Improvements in animal welfare, human welfare and social licence to produce are dependent on the transition from licensed culling to licensed harvesting. The time period is likely to be dependent on an individual enterprises time to transition to include increased harvesting of kangaroos. Human welfare and impact on a pastoralist's social licence to produce is not expected to be an issue when sufficient rainfall provides for resources that enable kangaroo populations to thrive. So long as management of kangaroos before drought conditions is undertaken, management of dying kangaroos should not be necessary.

The time taken to achieve co-benefits will depend on a number of variables including location, climate, previous land-use, plant composition, number of kangaroos, and number of livestock, number of livestock reduced, available infrastructure and input from the pastoralist. To achieve environmental benefits, native vegetation needs to be regenerated. Below we summarise the information from Resource Consulting Services (RCS n.d.). It provides detail about the state pasture should be in for optimal health and carbon storage. Kangaroo grazing should be managed to promote regenerative grazing through adaptive management (see Box 3).

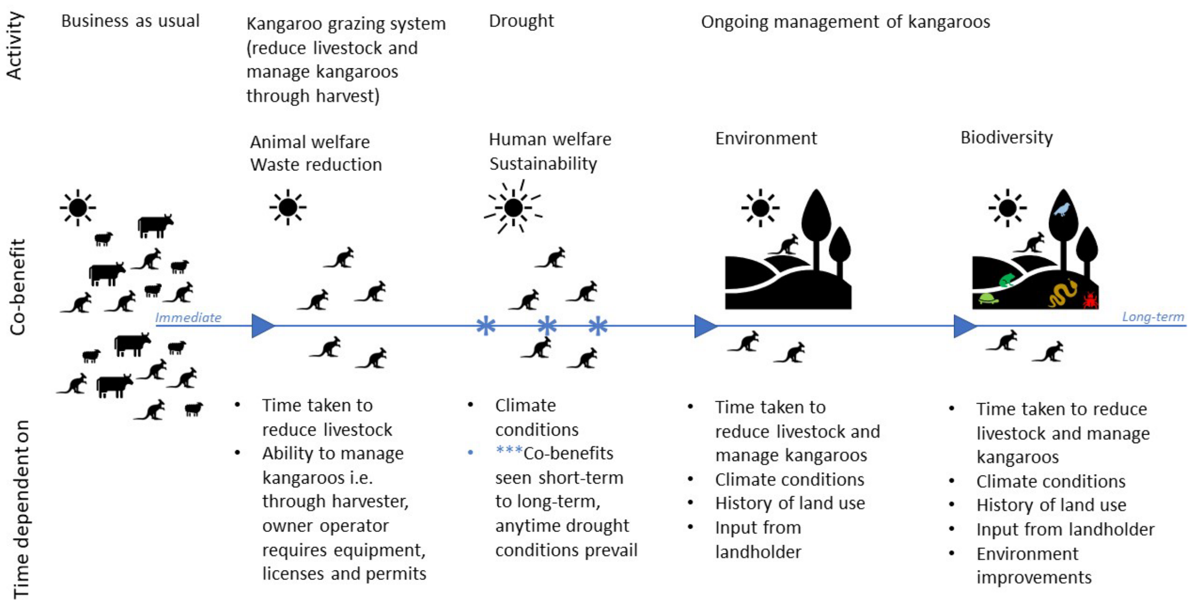


Figure 24. Comparison of co-benefits and time to delivery for the Kangaroo Grazing System.

Box 3. Regenerative grazing principles (RCS, n.d.)

Under regenerative grazing principles, the growth of plants is split into three stages: Phase I, Phase II and Phase III. In Phase I, the plant is either overgrazed or in a non-growing period due to climate, it has a small green leaf area, photosynthesis is restricted and energy for growth is supplied by roots. The second stage (Phase II) is characterised by increased green leaf area and an actively growing plant. Both leaf areas and root zones are expanding, with energy being supplied from the sun through photosynthesis. This is the prime time for grazing the plant and short graze periods will significantly extend this phase. Plants in Phase II have actively growing root systems and keeping plants in Phase II for longer periods increases root biomass. Plant microbiology has a symbiotic relationship to plant roots, where roots supply sugars (energy) in exchange for soilborne minerals and nutrients. The more root bulk, the better the soil health. Phase III is where the plant elongates, and leaf area is replaced by lignification. Plant cell walls become increasingly thicker, and photosynthesis is significantly reduced as plants stop growing and energy for growth is no longer needed. Plant roots are no longer important as the growth stage has finished, and root zones become much reduced. All efforts must be made to reduce this phase as much as possible.

The primary objective for regenerative grazing is to maintain grasses in Phase II. Plants in Phase II are optimising the sunlight energy for photosynthesis by maximising green leaf mass or chlorophyll. Energy produced through photosynthesis is used to grow the plant leaf area and root mass, as well as maximising the energy available to soil microbes. The maximisation of root mass is the primary pathway to building soil microbiology and humus, and soil health is the primary pathway to restore ecological health and balance to an ecosystem. If the prime objective of regenerative grazing is to maintain plants in Phase II, then grazing management is based around the plant recovery period. The recovery period required by a plant is the time it takes to regrow from defoliation until the root reserves have been restored. The recovery rate is therefore a function of growth rate.

Graze periods and rest periods change as growth rates vary from season to season and from month to month. The objective of regenerative grazing is to manage those graze periods and rest periods with grazing animals to optimise plant growth and plant health through shorter, higher-intensity grazing events. This dynamic can prevent bare ground caused by patchy overgrazing, improve pasture utilisation and increase perennialisation (the transition away from annual plants to perennials). Minimising bare ground not only maintains existing carbon in the soil by preventing erosion but also increases carbon inputs to the soil via increased above-ground (i.e., plant litter) and below-ground (i.e., root litter) biomass, (i) increasing soil respiration, topsoil depth and soil organic matter; (ii) improving water holding capacity and associated hydrological functions; (iii) increasing the retention and availability of soil nutrients; and (iv) reducing bare ground and stimulating vegetation growth.

Programs that can assist gaining natural capital

The following programs are available to help pastoralists improve their natural capital. Others exist and are covered in the sections below where they offer credits or certification for improvements.

Landcare Australia

Landcare Australia is a national organisation that supports the Landcare community with funding, capacity building, on-ground projects, information and networking. Landcare Australia has strong expertise in designing, managing and completing challenging and complex major ecological restoration projects involving large-scale revegetation and carbon abatement. Landcare Australia has worked collaboratively with federal, state and local governments, and their agencies, Landcare peak bodies, corporate and philanthropic partners, sponsors, community groups and individuals support the Landcare community.

Soils for Life

Soils for Life supports Australian farmers to regenerate soil and landscapes, to build natural and social capital, and transform food and fibre systems. Soils for Life supports a growing movement of farmers and rural leaders dedicated to farming in ways that improve soil and bring life back to the land.

Natural Sequence Farming

Natural Sequence Farming (NSF) is a rural landscape management technique aimed at restoring natural water cycles that allow the land to flourish despite drought conditions. NSF offers a low-cost, widely applicable method of reducing drought severity and boosting productivity on Australia's farms and landscapes. The technique is based on ecological principles, low input requirements and natural cycling of water and nutrients to make the land more resilient.

Resource Consulting Services Australia

Resource Consulting Services (RCS) Australia is a leading private provider of holistically integrated education, training and advisory services to the agricultural sector, both nationally and internationally. RCS works with individuals, families and corporate and government groups, empowering them to grow productive, profitable agricultural businesses within regenerative landscapes. RCS has collaborated with Queensland Land Restoration Fund, World Wildlife Fund Australia, Queensland Trust for Nature and beef producers in three pilot projects to prepare property management plans that identify management activities that would assist or promote the enhancement of key biodiversity values over a 25-year permanence period (Sommer and Bishop 2022). Carbon Link is a carbon aggregator that was spun out of RCS Australia in 2007.

Australian Landcare Management System

The Australian Landcare Management System (ALMS) is an externally audited, whole-of-farm, catchment-linked and nationally applicable environmental management system that complies with internationally accepted management standards. ALMS is designed primarily to assist a land manager develop and implement a land management system that is customised for their specific needs. ALMS also requires land managers to provide continuous support for biodiversity conservation and to have their management plan and its implementation externally audited. When used as a stand-alone tool, ALMS integrates all issues relevant to the development and implementation of a catchment-linked, property-based environment management system. ALMS is also a platform for the effective and efficient delivery of other NRM, eco-labelling, stewardship, quality control and occupational health and safety programs, and for assisting organisations with information management and reporting.

Kangaroo Grazing System and carbon and co-benefit markets

Under our proposed integrated KGS, the main management activity change is reducing the number of domestic livestock – cattle and/or sheep and goats – or not increasing numbers following destocking. The consequential loss in income is replaced by managing kangaroos through the kangaroo commercial harvesting industry. Below we examine potential carbon and co-benefit markets that could be accessed through a KGS using the kangaroos already found on the pasture.

Emissions Reduction Fund

Soil carbon methodologies

There are four ERF methodologies for soil carbon. The first and second, 'Sequestering carbon in soils in grazing systems method (2014)' and 'Measurement of soil carbon sequestration in agricultural systems method' are closed. The third and fourth, 'Estimating sequestration of carbon in soil using default values method (model-based soil carbon)' and 'Estimating soil organic carbon sequestration using measurement and models method' are open. The model-based soil carbon method is used in situations where measuring increases in soil carbon is not suitable. A model-based soil carbon project involves setting up specific project management activities on eligible land that aims to remove carbon from the atmosphere by increasing the amount of carbon added to the soil. As they grow, plants take up carbon and return it to the soil, where it is broken down to form soil carbon. A project using this method may also aim to decrease the amount of carbon biomass removed from the soil. The amount of carbon stored in the project area from each project management activity over the project reporting period is modelled using sequestration value maps. At least one of three types of 'project management activities' must be undertaken in a project. Each of these is made up of specific 'management actions':

- sustainable intensification – where new ways of productive land management are started with the aim to increase soil carbon content
- stubble retention – where crop residue that was previously removed by baling or burning is now retained in the field
- conversion to pasture – where cropped land is changed to permanent pasture.

As a sequestration activity, a model-based soil carbon project is subject to permanence obligations; this means the sequestration must be maintained for the nominated permanence period (either 25 or 100 years).

The 'Estimating soil organic carbon sequestration using measurement and models method' uses a measurement-only approach, or a hybrid approach that estimates results using a combination of soil carbon model estimates and soil core measurements. A soil carbon project stores carbon in agriculture soil to reduce the level of GHGs in the atmosphere. Soil carbon levels are improved by undertaking new, eligible land management activities. Eligible activities include:

- applying nutrients to the land in the form of a synthetic or non-synthetic fertiliser (from eligible sources) to address a material deficiency
- applying lime to remediate acid soils
- applying gypsum to remediate sodic or magnesic soils
- undertaking new irrigation
- 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
- using mechanical means to add or redistribute soil through the soil profile
- using legume species in cropping or pasture systems
- using cover crops to promote soil vegetation cover and/or improve soil health.

Undertaking one or more eligible management activities under this determination may not result in soil carbon increases and crediting depends on increasing the baseline level of soil carbon. To determine options and opportunities, a landscape options and opportunities for carbon abatement calculator produced by the CSIRO to determine soil carbon can be used. At the time of this research, there were 80 projects registered under the measurement of soil carbon sequestration in agricultural systems method to sequester soil carbon using grazing methods, but zero Australian Carbon Credit Units (ACCUs) had been issued (CER 2021). There were two projects contracted, one for 21,045 ACCUs (abatement) (however this project could be committed for seeding pasture) and one project had been contracted for 300,000 ACCUs (abatement) (CER 2021).

Human-induced regeneration of a permanent even-aged native forest

The 'Human-induced regeneration (HIR) of a permanent even-aged native forest' method is currently under review and applies to projects that store carbon by regenerating native forest using one or more eligible activities. Project activities must occur on eligible land where regrowth of native forest has been suppressed for at least 10 years. Additional benefits of running a HIR project may include improved quality of land and water supply, increased biodiversity and shade and shelter for stock. HIR activities include:

- excluding livestock and taking reasonable steps to keep livestock excluded
- managing the timing and extent of grazing
- managing feral animals in a humane manner
- managing plants that are not native to the project area
- implementing a decision to permanently cease mechanical or chemical destruction, or suppression, of native regrowth.

The carbon stored is calculated using the Full Carbon Accounting Model (Full CAM) tool. As of February 2020, HIR accounted for 23 per cent, respectively, of all ACCUs issued (CER 2020 reported in Baumber *et al*. 2020).

Beef herd methodology

A project using the 'Beef cattle herd management method' can reduce the emissions intensity of beef cattle production by reducing cattle emissions per kilogram of live weight produced. Herd management projects can reduce emissions by improving cattle productivity, reducing the average age of a herd, reducing the proportion of unproductive animals in the herd or changing the number of animals in each livestock class in the herd. Emissions intensity is the ratio of GHG emissions produced by an activity per unit of the final product. For beef cattle, emissions intensity is measured as tonne of GHG emitted for each tonne of beef produced.

The beef cattle herd management calculator helps project proponents estimate the abatement achieved by improving the efficiency of their pasture-fed beef cattle businesses. For reporting requirements under the method all projects must use the beef cattle herd management calculator to estimate emissions reductions. The calculator variables include:

- resident herd
- transient herd
- prerecording years and recording year
- number in animal classes
- diet
- liveweight
- liveweight gain.

There are five registered projects; three projects registered have a total of 414,554 ACCUs issued (CER 2021). There is only one project under contract, with 184,000 ACCUs committed (CER 2021).

Current Climate Solutions Fund methodologies and their potential applicability to the Kangaroo Grazing System

Under the ERF, carbon credits could potentially be obtained through sequestration of carbon in soil through one of the ERF soil methodologies, and/or through the HIR methodology. When grazing is managed through the reduction of cattle and sheep and through the reduction of kangaroo numbers through harvesting, soil carbon is expected to increase, and credits can be obtained under the estimating soil organic carbon sequestration using measurement and models method. Under the soil's sequestration and HIR methodology, projects must meet certain criteria Table 5 and Table 6.

A reduction in livestock and management of kangaroo grazing is not an eligible management activity under the estimating sequestration of carbon in soil using default values method (model-based soil carbon) and therefore could not be used to gain carbon credits.

Likewise, carbon credits could not be obtained through the beef herd methodology as the methodology measures the intensity of beef cattle production by reducing cattle emissions per kilogram of liveweight produced. Any removal of cattle, unless unproductive, would also decrease the liveweight produced. This represents a lost opportunity for any pastoralist seeking to improve grazing condition to improve soil carbon by reducing livestock.

Table 5. List of criteria for the soil carbon sequestration methodology.

Soil carbon sequestration	
Eligible land	Projects must include ‘eligible land’ (Determination—part 3) that has been used for pasture for the previous 10 years. Areas of eligible land in which carbon abatement is to be measured (carbon estimation areas) must not be forest land, land that was a wetland in the previous 10 years, or include dwellings or other structures.
Land management strategy	A land management strategy must be prepared or reviewed by an independent person— advising on what management activities are best suited to the site, including information on risks, monitoring and improvements.
Reporting and crediting	Each crediting application for ACCUs 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 (Determination—part 5). Statements must be provided from the proponent and the independent person responsible for sampling verifying, respectively, that the abatement is genuine and the soil carbon estimate accurate. Proponents can generally nominate the intervals of their reporting periods from one year to a maximum of five years, noting that sampling timing requirements in the supplement can impact reporting intervals.
Soil sampling	A baseline sampling (Determination—part 3) round must be undertaken to measure soil carbon stocks in carbon estimation areas in the first reporting period for new projects, or within 18 months of land being added to an existing project area. A subsequent sampling round must be conducted in every reporting period in the crediting period (including the first reporting period). An independent person must extract soil cores and measure soil carbon using laboratory measurements or laboratory calibrated in-field sensors. A consistent soil carbon estimation technology (for example, combustion or sensors) must be used within each carbon estimation area and each sampling round. Each carbon estimation area must be divided into at least three strata (subdivisions), and at least three soil cores must be taken from each strata. Other sampling requirements in the method and the supplement must be satisfied. The sampling guidance for measurement-based soil carbon methods sets out sampling assurance processes and controls to complement these documents.
Calculating net abatement	Under this method, net abatement (the amount used for crediting ACCUs) corresponds to the increase in soil carbon over time (Determination—part 3). Due to the impact of climatic, temporal and spatial variability on soil carbon stocks, the method applies a temporary discount to increases in soil carbon stocks after the second sampling round (withheld credits are effectively refunded if soil carbon stock increases are maintained after the third sampling round) as well as ongoing discounts for statistical uncertainty. These discounts reduce the risk of overestimation of carbon stock increases and of over-crediting. The ongoing discounts decrease as the certainty of soil carbon estimates increase.
Notification, record keeping and monitoring	In addition to the general requirements for all ERF projects, proponents participating under this method must: notify the Clean Energy Regulator (CER) of events that change the management activities, sampling locations or land management strategy prior to each sampling round keep records relating to land management activities, the independent person involved in a sampling, and the project’s land management strategy and other compliance requirements, and monitor livestock details in the project, tillage, harvested product, removed crop residues as well as inputs of fertiliser, biochar, lime, electricity and fuel. See more information in part 5 of the Determination.

Table 6. List of criteria for the human-induced regeneration methodology.

Human-induced regeneration	
Eligible land	Your land cannot have areas of existing forest and must have been managed in a way that suppressed regeneration of native vegetation in the ten years before you apply to register a project (e.g., the land will need to have been subject to mechanical clearing or grazed by livestock). Your land needs to have the potential to achieve forest cover if allowed to regenerate.
Legal status	The right to run your project and claim carbon credits – for example, holding a lease or land title, or having a signed agreement with other landholders to run a project on their land.
Regulatory approvals	Obtain regulatory approvals and consent from everyone with an eligible interest in the project land. Consent holders will vary. They may include banks, state governments (if the land is leased) or relevant native title bodies corporate.
New project status	You will need to adopt a new land management activity after you register your HIR project.
Running and reporting on your project	As part of registering a project, you will need to map your project boundary, identify vegetation groups and calculate your expected carbon credits. There are operating, reporting, monitoring and audit obligations in running a HIR project. You will need to report on how your native forest is regenerating at least once every five years. You will receive carbon credits for modelled increases in stored carbon over a period of 25 years. Your project must store carbon for 25 or 100 years to deliver a long-term benefit to the atmosphere (known as 'permanence'). If stored carbon is lost from regenerating forest, you may need to hand back carbon credits.

Additional opportunities and potential methodologies

Proposed Active Land Management and Agricultural Production method

Management of kangaroo grazing could be incorporated in the proposed Active Land Management and Agricultural Production (AL-MAP) Method. AL-MAP is a holistic agricultural production and land management method that establishes a 'whole-of landscape' framework combining vegetation and soil methods to allow land managers to receive carbon credits for multiple carbon farming activities on a single property. A blueprint has been developed as part of a collaboration between the carbon, agriculture and conservation sectors, with inputs from Traditional Owner groups, state governments, the Australian Government and researchers. Cross-sector participants have come together to support a harmonised land sector carbon method, choosing to unite resources as opposed to splitting efforts across a patchwork of land sector methods. In 2021 the Minister for Energy & Emissions proposed to adopt the blueprint and prioritised the development of a combined vegetation and soil method in 2022.

Kangaroo landscape conservation emissions reduction activity proposal

In 2021 we proposed to the Department of Industry, Science, Energy and Resources (DISER) that a new Kangaroo Landscape Conservation (KLC) methodology should be developed as an additional credit earning option for beef, sheep and goat producers and conservation and Indigenous reserve managers (Appendix B). Its development was not supported by the Minister for Emissions and Energy but it could be in the future or it could form a 'stack' in the proposed AL-MAP methodology.

A KLC methodology would involve active management of kangaroos through sustainable use to reduce grazing pressure and so increase carbon in soil and vegetation. Kangaroos would be integrated alongside other herbivores and livestock to find an optimal stocking rate for the environment and seasonal conditions. A co-benefit would be reduction of enteric CH_4 emissions from livestock. It could be measured through numbers of kangaroos and livestock removed to reduce grazing pressure and via soil and vegetation sequestration methodologies.

The KLC proposal could be adopted by land managers for pastoral properties, parks and reserves and Indigenous landholders and private conservation agencies with large land holdings such as Australian Wildlife Conservancy, Bush Heritage Australia, and NSW Biodiversity Conservation Trust.

Developing a standalone methane-reduction methodology

While soil carbon and vegetation methodologies already exist under the ERF, a methodology based on CH_4 reduction alone could also be developed. The methodology would calculate credits possible from production of low-emissions meat and other products compared to the liability or even the penalty that might apply to 'business-as-usual' production. It would compare CH_4 emissions from the production of the same quantity of meat (and hides) from kangaroos and livestock. The activities could include:

- calculate numbers of cattle, sheep, goats and kangaroos, and convert numbers/biomass of livestock to DSE
- substitute high-emissions products for low-emissions products in a model that outputs commercial return.

'Climate Active' certification for carbon neutrality

Certification through the Climate Active initiative is another potential mechanism through which the carbon-neutral attributes of kangaroo products could be promoted. Climate Active is a partnership between the Australian Government and Australian businesses that is aimed at encouraging voluntary climate action (Climate Active 2019).

The Climate Active initiative and Climate Active Carbon Neutral Standard supports and guides businesses to account for and reduce carbon emissions. The Climate Active stamp aims to help the community identify and choose brands and buy carbon-neutral products. Carbon-neutral certification against the Climate Active Carbon Neutral Standard (formerly the National Carbon Offset Standard) has been available to Australian businesses since 2010.

Organisations that become carbon neutral receive certification and can display the Climate Active trademark. For entities to be certified they must meet certain standards (DISER 2022b). Broadly, to achieve certification participants must measure emissions, reduce these where possible, offset remaining emissions and then publicly report on their achievements.

Although not a methodology under the ERF compliance market, the Climate Active initiative could be applied to a group of land holders and to the production of kangaroo of their properties and down the production chain. One group that could do this would be the Maranoa Kangaroos Harvesters and Growers Cooperative. Another would be for a group of landholders to collaborate with regional kangaroo processors such as the one at Longreach or Broken Hill.

Non-compliance markets and international opportunities

The two major global standards with methodologies applicable to Australia are the Verified Carbon Standard (VCS/Verra) and The Gold Standard. Other high-profile voluntary standards (e.g., Climate Action Reserve and American Carbon Registry) tend to focus on forestry or were born from the Californian trading system and focus on North America, while the Clean Development Mechanism (CDM) allows a country with an emissions-reduction or emissions-limitation commitment under the Kyoto Protocol (Annex B Party) to implement an emissions-reduction project in a developing country.

Verified Carbon Standard

The VCS has a number of approved methodologies that account for GHG removal through improved land management activities to the soil organic carbon pool, and for enteric CH_4 reduction.

Methodology for sustainable grassland management VM0026

The 'Methodology for sustainable grassland management VM0026' is an earlier method that can use direct sampling to calibrate soil organic carbon models. It also considers animal respiration and enteric fermentation. Where applicable soil samples already exist (either within project boundaries or outside the project boundaries) it would be possible to run this method with minimal/reduced soil sampling. This would however result in greater deductions in credit issuance due to the increased uncertainty.

Methodology for the adoption of sustainable grasslands through adjustment of fire and grazing VM0032

The 'Methodology for the adoption of sustainable grasslands through adjustment of fire and grazing VM0032' applies to projects with activities that manipulate number and type of domestic livestock grazing animals (e.g. cattle, sheep, horses, goats, camels, llamas, alpacas, guanacos, or buffalo) and/or grouping, timing and season of grazing (e.g., continuous unrestricted, planned rotational, bunched herd rotational or other means of restricting livestock access to forage in order to allow vegetation response) in ways that sequester soil carbon and/or reduce CH_4 emissions.

Methodology for improved agricultural land management VM0042

The 'Methodology for improved agricultural land management VM0042' also considers soil carbon and enteric CH_4 and is based on multiple methodologies. It is the latest and most advanced method relating to soil organic carbon modelling. It allows ex-ante calibration of the models using techniques such as remote sensing (where uncertainties are known) or direct sampling; however, like the ERF beef herd methodology, this methodology also requires emissions reduction with equivalent production of the same product. Therefore, it would not support credits for a KGS.

The Gold Standard

Soil Organic Carbon Framework Methodology

The 'Soil Organic Carbon Framework Methodology' is a relatively new methodology, approved in January 2020. It allows for a number of approaches for accounting GHG in the soil organic carbon pool, from direct sampling through to an Intergovernmental Panel on Climate Change reference value. It is applicable to grasslands and includes grazing management as an allowable activity. This makes it another good option for the Australian rangelands as the models can be calibrated with reference soils data, provided there is adequate evidence the soils are comparable. They have a grassland management methodology as part of the soil organic carbon framework methodology in development; however, the Gold Standard does not have a methodology that accounts for CH_4 emissions coming from meat livestock (there is one that is applicable to dairy cattle).

UNFCCC Clean Development Mechanism

A CDM project must provide emission reductions that are additional to what would otherwise have occurred. The projects must qualify through a rigorous and public registration and issuance process. Approval is given by the Designated National Authorities. Public funding for CDM project activities must not result in the diversion of official development assistance. The mechanism is overseen by the CDM Executive Board, answerable ultimately to the countries that have ratified the Kyoto Protocol and Paris Agreement. The CDM allows emission-reduction projects in developing countries to earn certified emission reduction credits (CERC), each equivalent to one tonne of CO_2. These CERCs can be traded and sold, and used by industrialized countries to meet a part of their emission reduction targets under the Kyoto Protocol. The mechanism stimulates sustainable development and emission reductions, while giving industrialised countries some flexibility in how they meet their emission reduction limitation targets. The CDM is the main source of income for the UNFCCC Adaptation

Fund, which was established to finance adaptation projects and programmes in developing country Parties to the Kyoto Protocol that are particularly vulnerable to the adverse effects of climate change. The Adaptation Fund is financed by a two per cent levy on CERCs issued by the CDM.

The pros and cons of international carbon markets

There are a number of **benefits** normally associated with the voluntary standards. They are:

- internationally validated and widely recognised
- co-benefits get greater recognition, making credits more attractive to impact investors, the private sector or NGOs
- voluntary projects don't have to participate in the ERF reverse auction, a process that can result in projects not being funded, or failing to reach break-even prices
- verification costs are potentially lower because the regulatory requirements are less.

The main **weakness** of the voluntary system is that the application process can become costly if there are eligibility issues that require methodology adjustments or the project documentation requires significant additional verification. This is a risk because it can be difficult up front to get a definitive answer without enlisting the services of a validation/verification body.

The above methods also require models and sampling techniques that have been peer reviewed and are applicable to the area. This represents a potential hurdle when applying methodologies in new areas as project documentation will require additional evidence as to the validity of the model in the project area. Evidence to support the use of remote sensing, soil samples from comparable soils would also be required. While these are additional hurdles, they could be overcome without too much additional cost and effort.

Co-benefit markets

Market demand is an increasingly strong driver of interest in products that have co-benefits. Below are some government and non-government program that support their development, which could be assessed for potential integration into the KGS.

National biodiversity and stewardship markets

Environmental Stewardship Program – DAFF

Department of Agriculture, Fisheries and Forestry (DAFF) Biodiversity Stewardship Package includes the Carbon + Biodiversity pilot (C+B Pilot), Enhancing Remnant Vegetation pilot, the Australian Farm Biodiversity Certification Scheme, and the Biodiversity Trading Platform (DAWE 2021a). The aim of the package is to improve on-farm land management practices and establish a market-based approach that rewards farmers for delivering biodiversity services.

Under the package, biodiversity certificates will act as a new form of tradable property rights that can be issued, owned and transferred between buyers and sellers. Payments for the various projects undertaken by farmers are not standard and typically depend on the value of land and the management activities executed by farmers (DAWE 2022a). The bill accompanying the stewardship programme, the *Agriculture Biodiversity Stewardship Market Bill*, is similar to the *Carbon Credits (Carbon Farming Initiative) Act*, with biodiversity certificates being similar to ACCUs, except that a biodiversity certificate is heterogenous and only a single certificate is issued per project. The certificate will outline consistent, verifiable information regarding each project, which will enable the market to assess its value (Herbert Smith Freehills 2022).

The program aims to diversify income streams and reward land managers/farmers who improve land function. It establishes a Biodiversity Trading Platform and aims to help farmers plan and evaluate biodiversity and carbon projects by integrating environmental data sets. Farmers can use the tool to map projects, estimate carbon abatement and identify high-value environmental assets on their properties.

Carbon + Biodiversity Pilot trials

The C+B Pilot is testing the concept of buying and selling biodiversity services from farmers. Farmers can gain multiple benefits and diversify their income by completing a project. The C+B Pilot aims to reward farmers for maximising biodiversity benefits by establishing and managing plantings on their property. Farmers who manage plantings for carbon can receive supplementary payments for increasing biodiversity, as well as a range of other benefits including shelter for animals provided by the plantings, protection of dams and waterways and reduced erosion (DAWE 2022a). The projects are required to be registered as eligible offsets projects under the ERF using the ‘Reforestation by environmental or mallee plantings-FullCAM method (DAWE 2021b). Rounds 1 and 2 of the programme include 12 natural resource management (NRM) regions (two NRM regions per state) in Queensland, NSW, Victoria, Tasmania, SA and WA.

The C+B Pilots were designed and delivered in partnership with the Australian National University and NRM organisations in each trial region. To complete a project farmers must undertake a new ERF environmental plantings project to plant native trees and shrubs in line with ERF requirements as well as the C+B Pilot planting protocols. The ERF environmental plantings method involves the planting or direct seeding of native tree and shrub species on land that has been clear of forest for more than five years. The purpose of these plantings is to store carbon. The C+B planting protocols set out rules about the location, dimensions, configuration and composition of plantings to ensure projects generate biodiversity benefits. Farmers must maintain C+B projects for 25 years.

Enhancing Remnant Vegetation

Together with the C+B Pilot, the Enhancing Remnant Vegetation Pilot is trialling mechanisms to pay farmers for improving biodiversity on farms. The Enhancing Remnant Vegetation Pilot will provide payment to farmers to protect, manage and enhance high conservation value native vegetation on their property by implementing actions such as fencing, weeding, pest control and replanting (DAWE 2021a). Similar to the C+B pilot, six NRM regions are included in this programme, across six Australian jurisdictions. This pilot aims to improve existing native vegetation on farms through locally adapted management protocols developed by the Australian National University in consultation with NRM organisations in six trial regions. Successful farmers could be eligible to receive payments to manage and enhance existing remnant native vegetation on-farm.

National Stewardship Trading Platform

A Bill before Parliament in May 2022 would establish a Biodiversity Trading Platform under which farmers will be able to gather information on market opportunities, sell biodiversity outcomes to potential buyers, and receive help in planning of potential projects on their land. It is supported by a $66 M package. The National Stewardship Trading Platform aims to:

- help farmers monetise the biodiversity services they provide by connecting them with buyers
- help corporate and/or philanthropic organisations to voluntarily buy biodiversity services to support their organisational goals
- kickstart private sector biodiversity markets by building transparency and credibility.

The online trading platform facilitates the exchange of biodiversity certificates through arrangements between buyers and sellers. The trading platform has two components: the project planning tool and the bulletin board. The planning tool gives landholders access to spatial information to plan projects, estimate carbon sequestration on-farm, and identify high-value environmental assets located on farm. The bulletin board provides a space for landholders and potential investors and buyers to post their interests and find each other. The environmental products themselves are not listed on the platform and all transactions would occur outside of the platform (Thomas *et al*. 2022). Additionally, under the Bill, other certificates, projects, units or credits relating to biodiversity projects can also be traded, despite being unregistered under the stewardship program, potentially creating opportunities for a range of other biodiversity-related projects (Gibson 2022).

State and territory biodiversity and stewardship markets

NSW, Queensland, SA and Victoria all have biodiversity or environmental credit or offset schemes that facilitate the creation of credits to landowners. These include Environmental Offsets for Queensland, Biodiversity Offsets Scheme for NSW, the Biodiversity Credit Exchange for SA and BushBroker for Victoria. WA, Tasmania and the ACT have Environmental Offset Schemes with no or very limited market systems that allow landholders to access credits for their offsets. In the NT, development of the Biodiversity Offsets Policy and associated Technical Guidelines is underway.

Non-government and private sector schemes

Eco-Markets Australia

Eco-Markets creates opportunities for Australian environmental markets and access to them. Eco-Markets provides independent administration and oversight of environmental market schemes and develops robust, transparent and practical environmental crediting standards, which set out the rules and requirements for developing projects and methodologies, the validation, registration, monitoring, verification, crediting and issuance process, and governance arrangements. Methodologies are approved, scientifically supported, formal mechanisms to account for, or measure the verified environmental benefits. While there are currently no credit schemes available for KGS, one could be developed using the platform developed by Eco-Markets.

Assessing the feasibility of integrating kangaroos

In the following section we describe how a pastoralist interested in a KGS can assess the potential to earn carbon credits, calculate the associated returns and losses, and determine a timeframe for implementation; Hegarty and Almeida (2021) have also reviewed the constraints and speculated on the opportunity. As kangaroo grazing management and harvesting includes multiple variables, we refer to our spreadsheet. The results form a layout that will help pastoralists make informed decisions about how a KGS could be implemented as a grazing management system to achieve carbon credits by sequestering carbon in soils and reducing enteric CH_4 emissions.

It is important to note that the model inputs will vary greatly from property to property. To address these differences, we invite pastoralists to enter into the worksheets to include their on-farm statistics; i.e., green boxes require specific on-farm values and orange boxes require values determined by research, which can be improved with local values. Local NRM Officers, or their equivalents, could assist in accessing local environmental data for inclusion. The remaining blue boxes are the results calculated from entered variables. We use a Prime Lamb and Southern Beef (PL&SB) Enterprise case study from MLA (2021) to pilot the Kangaroo Grazing Systems Spreadsheet 2022 (here after the spreadsheet). This report lists but does not calculate potential returns from co-benefits.

Earning carbon credits through the Kangaroo Grazing System

Soil carbon sequestration

Under a KGS, potential soil carbon sequestration can be determined by calculating the land size of the area where grazing is to be managed by the soil carbon potential. The potential to store carbon through adaptive grazing management will depend on location and history. Theoretical values can be obtained from Soils Revealed (Soils Revealed 2016) or other soil carbon sequestration programs, such as LOOC-C. The worksheet 'Potential carbon sequestration' in the spreadsheet uses the variables land size and soil carbon potential, which allows managers to enter their land size and potential soil carbon storage to determine the total potential. The worksheet uses the land size we estimated for the PL&SB case study, 2,931 ha (726 cattle and 3720 sheep), and the soil carbon storage potential is entered as the Australian average (2.24 t CO_2e/20 years). Using this example and under adaptive management grazing activities, the potential soil carbon storage is estimated at 328.08 t CO_2e/year (Figure 25).

	A	B	C
1	**Potentail carbon sesquestration in soil**	**Values**	**Explanatory notes**
2	Land size where grazing will be managed	2931.00	Land size calculated using 1 cow per 2.5 ha and 1 sheep per 0.3 ha, from the prime lamb/southern beef case study
3	Soil carbon potential (tonnes C02e/ha/20 years)	2.24	Australian average per 20 years under adaptive management see https://soilsrevealed.org/
4	Soil carbon potential (tonnes CO2e/ha/year)	0.11	Australian average per year under adaptive management
5	Potential carbon to be stored in soil (tonnes C02e/year)	328.08	
6			**Key:**
7			Land management factor - to be entered by pastoralist based on situation, vaules provided here are from a hypothetical case study
8			Research average or value - to be entered by pastoralist or NRM office, this value could be improved from local data
9			Result - Calculation which will be variable depending on the land management

Figure 25. Screen capture of the spreadsheet showing potential sequestration in soil using a hypothetical example.

Emission abatement

Under a KGS, potential CH_4 abatement per year can be determined by calculating the number of livestock and the amount of CH_4 they produce per year. The worksheet 'Potential emissions abatement' in the spreadsheet uses the following variables, which allows managers to enter their number of livestock, the number of livestock removed and CH_4 production to determine total abatement from removing livestock:

- number of cattle
- CH_4 production per individual (cattle) per year
- cattle removed
- number of sheep
- CH_4 production per individual (sheep) per year
- sheep removed.

The pastoralist should enter CH_4 production values that best represents their herd or flock, as CH_4 production from cattle and sheep vary greatly depending on breed, sex, size, herbage consumption type and amount and reproductive status. In the spreadsheet we use an average for sheep and an average for cattle (calculated from DISER and ABS). These calculations will give CO_2e savings for the percentage of population removed. Using this example, the abatement is 1125 t CO_2e/year for cattle and 669 t CO_2e for sheep (Figure 26).

	A	B	C
1	**Emision abatement**		**Explanatory notes**
2	**Cattle**		
3	No. cattle (n)	726	Values obtained from MLA prime lamb and southern beef case studies on cost production
4	methane production (t CO2e/ind/year)	1.55	Value determined from ABS and DISER
5	Cattle removed (%)	100	Number cattle to be removed - this value needs to be determined based on stocking rate and carrying capacity goals to ensure grazing management activity achieves carbon sequestration and abatement goals
6	CO2e savings if % removed (t CO2e/ind/year)	1125.3	
7	**Sheep**		
8	No. sheep (n)	3720	Values obtained from MLA prime lamb and southern beef case studies on cost of production
9	methane production (t CO2e/ind/year)	0.18	Value determined from ABS and DISER - value likey to be higher as individual CO2e enteric methane calculate from animals including those younger than 1 year old.
10	Sheep removed (%)	100	Number of sheep to be removed - this value needs to be determined based on stocking rate and carrying capacity goals to ensure grazing management activity achieves carbon sequestration and abatement goals
11	CO2e savings if % removed (t CO2e/year)	669.6	

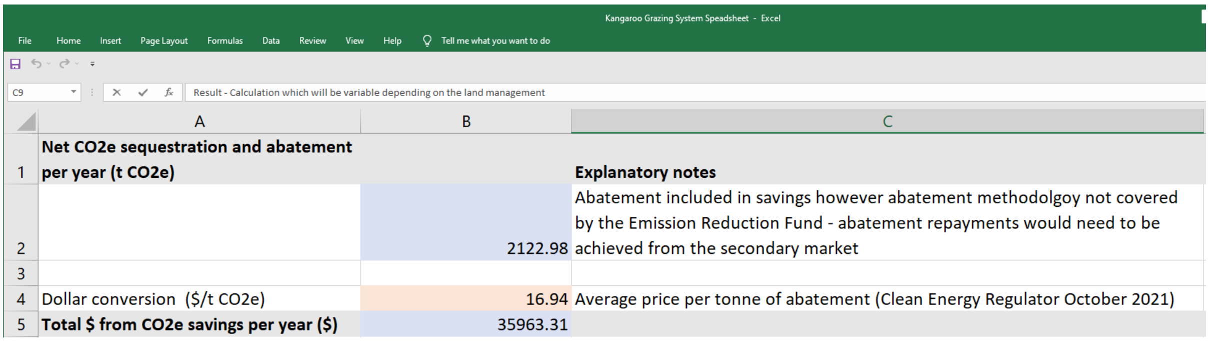
Figure 26. Screen capture of the spreadsheet showing potential emission abatement from cattle and sheep using a hypothetical example.

Credits from sequestration and abatement

The net sequestration and abatement to determine potential credits, is the sum of the sequestration in soil and abatement from reduced livestock enteric emissions multiplied by the value of an ACCU. The worksheet 'Seq + abmt (CO_2e-yr \$-yr)' in the spreadsheet uses the following variables to determine the potential amount of carbon credits that can be achieved:

- CO_2e/year
- dollar conversation (\$/t CO_2e).

In the spreadsheet we use the average price per tonne of abatement as listed on the CER website during October 2021 (Figure 27). However, as mentioned previously, under current methodologies a pastoralist cannot generate ACCUs from cattle enteric emissions by removing cattle or sheep to manage grazing. ACCUs can only be achieved for cattle if they are unproductive and removed. The potential calculated here is a missed opportunity. There is however, potential to gain carbons credits from the secondary/voluntary/international market. The pastoralist will need to make the decision to enter voluntary markets and adjust the calculations accordingly.


Kangaroo Grazing System Speadsheet - Excel

File Home Insert Page Layout Formulas Data Review View Help Tell me what you want to do

C9 | Result - Calculation which will be variable depending on the land management

	A	B	C
1	**Net CO2e sequestration and abatement per year (t CO2e)**		**Explanatory notes**
2		2122.98	Abatement included in savings however abatement methodolgoy not covered by the Emission Reduction Fund - abatement repayments would need to be achieved from the secondary market
3			
4	Dollar conversion ($/t CO2e)	16.94	Average price per tonne of abatement (Clean Energy Regulator October 2021)
5	**Total $ from CO2e savings per year ($)**	35963.31	

Figure 27. Screen capture of the spreadsheet showing potential net sequestration and abatement using a hypothetical example.

Kangaroo populations, harvest quotas and returns

Kangaroo population and allowable harvest

To enable a sustainable harvest, pastoralists need to know the number of kangaroos on the land being managed for grazing pressure to store carbon in soil. The population could be achieved by undertaking population counts with the assistance of an NRM officer. The worksheet ‘Kangaroo population and harvest’ uses the following variables to determine how many kangaroos can be harvested under commercial permits on the land being managed for soil carbon storage:

- total number of kangaroos
- portion harvest quota (per cent of population)
- portion harvest quota if regional quota is not met (per cent of population).

Alternatively, the pastoralist could estimate the population based on grazing pressure. In the worksheet we estimate the population of kangaroos on the PL&SB case study to be 6497, using the estimate that kangaroos are responsible for 40 per cent of attributed DSE in this hypothetical case study (DSEs; whereby a kangaroo and a sheep have a per individual DSE of 1 and cattle have a per individual DSE of 8.3 (Pahl 2019a) (Figure 28). The state quota for harvesting kangaroos for commercial purposes is 15 to 20 per cent of the population. If numbers are harvested at the regional allocation of the quota, it would impact a landholder’s capacity to harvest commercially. The worksheet caters for two cells to enable the pastoralist to compare 15 per cent population harvest to a potentially greater harvest portion.

Innovative technologies such as drones and thermal imaging are being trialled in 2022 with the support of the Future Drought Fund. They show considerable promise for improving the accuracy of property level population estimations (McLeod and Curtis, in preparation).

The target population can be determined by setting the grazing pressure target at a percent of the current grazing pressure. The target population can be manipulated depending on current and forecasted environmental conditions. This is important as too many kangaroos will amount to overgrazing and degrade soils.

	A	B	C
1	**Kangaroos**		**Explanatory notes**
2	Grazing pressure per cattle (DSE)	8.3	* Dry Sheep Equiivalent attributed to cattle from Pahl 2021
3	Grazing pressure per sheep (DSE)	1	* Dry Sheep Equivalent
4	Grazing pressure per kangaroo (DSE)	1	* Dry Sheep Equivalent attributed to kangaroo from Pahl 2021
5	Total cattle and sheep (DSE)	9745.8	* Total DSE's attributed from cattle and sheep
6	Kangaroo grazing pressue (% of total)	40	* Kangaroo's hypothetically attributed 40% of the DSE.
7	Total number of kangaroos (n)	6497.2	Ideally land managers would undertake population counts of kangaroos
8	Total cattle, sheep and kangaroo (DSE)	16243	Total DSEs from cattle, sheep and kangaroos
9	Portion of population allowed to harvest - quota (%)	15	Current rules allow maximum of 15-20% of kangaroo population to be harvested depending on region and species
10	Portion of population harevsted can increase if regional quota not reached (%)	20	As quotas for harvest are never reached it is likely a portion higher than 15% can be harvested
11	Number allowed to harvest - quoata, per year based on est population (n)	974.58	
12	Number allowed to harvest per year based on est population if regional quota not reached (n)	1299.44	

Figure 28. Screen capture of the spreadsheet showing kangaroo populations and harvest potential using a hypothetical example.

For greater land areas, where 15 per cent of the kangaroo population reaches into the thousands, the harvesting ability of the labour force, (for example time for harvesting storage and delivery) needs to be taken into account. For example, we estimated that one harvester can harvest 5,000 kangaroos, on average, in a year. In the case study, the grazing pressure (by DSE) target is 65 per cent of current levels (see worksheet '% of current DSE' and Figure 29), which would allow a kangaroo population of 10666, with no cattle and sheep. At 15 per cent of the population, 1,600 could be harvested. Note: implications arise when environmental factors and harvesting affect the population. However, management activities can be implemented to reduce the affects, in a similar manner to those that are implemented for domestic livestock (i.e., feed and water provision).

	A	B	C
1	**Percent DSE from original DSE**		
2	% of baseline DSE (%)	65.67	This is a key figure - if this is above 100 then there is more grazing than original and soil carbon won't be stored - this figure will be dependent on specific land manager goals, depending on climatic conditions and condition of land

Figure 29. Screen capture of the spreadsheet showing percentage DSE from original DSE using a hypothetical example.

The worksheet 'Grazing Index' allows pastoralists to determine their current GI and required stocking rate for their target GI for increasing soil carbon sequestration (Figure 30).

	A	B	C
1	**Current**		
2	Carrying capacity (DSE/ha)	4	Theoretical value
3	Stocking rate (DSE/ha)	5.541794609	This example includes kangaroos, cattle and sheep.
4	Ratio	1.385448652	
5			
6	**Goal**		
7	Carrying capacity (DSE/ha)	4	
8	Stocking rate (DSE/ha)	3.639258501	
9	Ratio	0.909814625	
10			
11	Ratio to Grazing Index (GI):		
12	**Ratio**	**GI**	
13	<0.5	1	Low
14	0.5-0.8	2	Low
15	0.8-1	3	Normal/sustainable
16	1-1.5	4	Result in pasture degradation
17	>1.5	5	Result in pasture degradation

Figure 30. Screen capture of the spreadsheet showing current carrying capacity and stocking rate to determine goal carrying capacity and stocking rate using grazing index using a hypothetical example.

Costs and returns from kangaroos – three options

Without taking cost of production into account, the return from harvesting kangaroos can be determined by the price paid per kangaroo and the number harvested. The worksheet 'Returns from kangaroos' (Figure 31) (which does not include costs) determines the return on individual kangaroos and total harvest using the variables:

- return per average 25 kg kangaroo
- the number of kangaroos harvested (from 'Kangaroo population and harvest' worksheet).

	A	B	C
1	**Returns from kangaroos**		**Explanatory notes**
2	Return per average 25kg kangaroo not including costs ($)	29.7	Depends on size of kangaroo and $ received per kilo, usually sold with head and viscera removed
3	Return on number allowed to harvest per year based on est population ($)	28945	*
4	Return on number allowed to harvest per year based on est population if quota not reached ($)	38593.4	*

Figure 31. Screen capture of the spreadsheet showing returns from kangaroos using a hypothetical example.

When kangaroos are sold by the harvester, they are partially dressed with their head and viscera removed. They are sold per kilogram to a chiller. The return per kangaroo varies like cattle and sheep prices. The worksheet 'Kangaroo harvest details' lists variables that may be manipulated to more accurately represent the size of a particular species of kangaroo or the dollar per kilogram achieved at local chillers:

- size
- dollar paid per kilogram.

Kangaroos are required to be shot by licenced harvesters. Under current practice, an independent harvester, with permission from the pastoralist, will access the pastoralists property and harvest kangaroos as a pest control activity. The only return the pastoralist receives is relief from unwanted grazing pressure. Under our proposed KGS, the pastoralist is more actively over-seeing kangaroos, and depending on the proportion of kangaroos harvested, expanding the enterprise and becoming a harvester (option 1), or they could fix a price for access to the kangaroos by independent harvesters (option 2) similar to share farming of crops. A third option comprises calculations for incorporation of kangaroos into cattle and sheep production (with the latter also possible under the first two options).

The pastoralist is set to receive income losses from livestock. The 'Losses from livestock' worksheet provides pastoralists with the option to enter the number of livestock reduced and income lost (Figure 32). This is lost income from livestock that would have otherwise been sold and lost income is total profit lost.

	A	B	C
1	**Lost income**		
2	**Cattle**		
3	Cattle sold (n)	452	Value from MLA prime lamb and southern beef case studies on cost of production
4	Income lost ($/year)	69213	Value from MLA prime lamb and southern beef case studies on cost of production
5	**Sheep**		
6	Sheep sold (n)	2003	Value from MLA prime lamb and southern beef case studies on cost of production
7	Income lost ($/year)	83178	Value from MLA prime lamb and southern beef case studies on cost of production
8	**Total income lost per year ($)**	152391	

Figure 32. Screen capture of the spreadsheet showing lost income from cattle and sheep using a hypothetical example.

When entering this data, a pastoralist should take into account all production costs and income earnt from livestock. In the worksheet, we have used the PL&SB case study profits from number of livestock sold.

Option 1 – Pastoralist/manager runs the harvest

The first option for harvesting explores the pastoralist running the harvest. The worksheet 'Cost v returns for kangaroos' and 'Option 1a) Pastoralist operator' lists costs involved in this option (Figure 33). Such costs include:

- initial investments for vehicle/tray/spotlight/tools/winch, firearm, firearm safe, and courses – use firearms to harvest wild game (firearms course), statement of attainment in game harvesting (can be fully subsidised if criteria are met), firearms licence (five years), firearms safety course (pre-licence qualification course).
- annual costs for maintenance of vehicle/tray/spotlight/tools/winch/firearms, administration, insurance public liability, licence – professional harvester, licence – food transport.

There are also costs attributed to the harvest per kangaroo, including:

- tag
- ammunition
- time (not included in calculations)
- fuel (not included in calculations).

	A	B	C
1	**Option 1a) Pastoralist operator**		**Explanatory notes**
2	Initial investment ($)	45751	See investment costs in kangaroo harvest details spreadsheet
3	Ongoing annual cost ($) not including fuel	7359.53	See annual costs in kangaroo harvest details spreadsheet
4	Costs per animal:		
5	*Tag*	1.17	Cost of tag depends on state
6	*Ammunition*	1.5	Likely to be variable
7	Return on number allowed to harvest per year based on est population ($)	18983.4	Not including intial investment - if negative value there are not enough kangaroos being harvested to cover annual costs
8	Return on number allowed to harvest per year based on est population if quota not reached ($)	27764.3	Not including intial investment - if negative value there are not enough kangaroos being harvested to cover annual costs
9	***1b) Need to increase number of kangaroos harvested, however not by too many or it will increase grazing pressure***		
10	The roo harvest needs to increase but not by too much that it overshoots the current DSE (no. harvested)	1600	2500 to be harvested will put this population at current grazing DSE thereby diminishing carbon sequestration potential, 1600 puts it at 65% of current DSE (or carrying capacity to stocking rate ratio of 3.6 or GI of 3) - land mangers should manipulate this factor so that generates the desired percentage reduction in DSEs given in the spreadsheet %of current DSE to generate carbon sequestration in soil from grazing maangement.
11	To increase the harvested roos the population would need to grow to:	10666.7	
12			
13	Harvest allowed (15%)	1600	5000 is average a harvester can shoot in one year
14	Return on allowed to harvest if population grew including annual cost ($)	38563.1	Depends heavily on size of kangaroo and $ received per kilo, usually sold with head and viscera removed
15	Harvest allowed if quota not reached (%)	20	This figure can be mainpulated if land managers gain access to greater than 15% harvest of the est population
16	Return on allowed increase harvest including annual cost ($)	50304.5	Depends heavily on size of kangaroo and $ received per kilo, usually sold with head and viscera removed

Figure 33. Screen capture of the spreadsheet showing the option of pastoralist turned harvester using a hypothetical example.

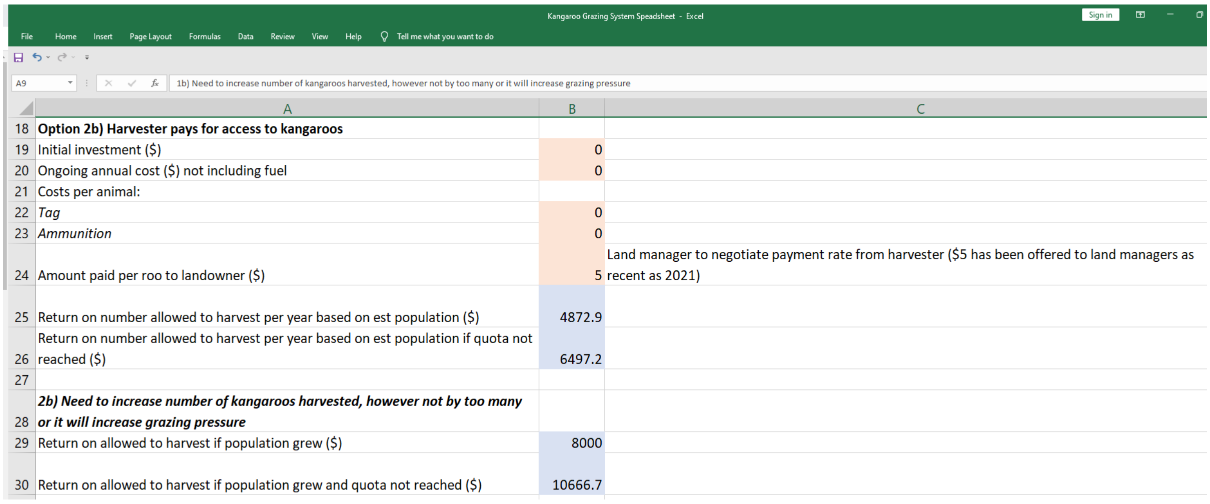
As described above in ‘Potential returns from kangaroos’, the number of kangaroos harvested will depend on the kangaroo population and number of permits granted for harvesting (set at 15 to 17 per cent for a region, with the option for pastoralists to receive more if the regional quota is not met). The case study values show that return on kangaroos, and not including initial investment, harvested at 15 to 20 per cent of the population is minimal (e.g., 15 per cent returns $18,983 and 20 per cent returns $27,764). In the given example, cattle and sheep have been completely removed, which enables the kangaroo population to increase. However there needs to be a balance between increasing the population to enable increased harvest, but not increasing the population too much so that grazing management activities are detrimental. Where livestock numbers are reduced kangaroo populations can increase until they reach the target grazing pressure, so to ensure that carbon is sequestered in soil. Pastoralists, with the assistance of NRM Officers or soil sequestration scientists need to know how to manage their grazing pressure in order to store carbon in the soil.

Option 2 – Pastoralist collects an access fee from the harvester

The second option ‘Harvester pays pastoralist for access to kangaroos’ involves harvesters paying the pastoralist for access to kangaroos (Figure 34). This option addresses a number of issues that arise when the pastoralist is the harvest operator, such as investment costs, harvesting competencies and lifestyle changes associated with movement away from traditional practices. Under this option, there are no investment costs to the pastoralist; however, the returns are likely to be reduced also, with the pastoralist only receiving access payments, rather than complete returns from the product. The variables for this option include:

- payment from harvester to pastoralist per kangaroo
- number of kangaroos harvested.

The kangaroo population would be carried to the same capacity as that mentioned above (target population), with the same harvesting opportunities, so to balance harvest number, population and grazing pressure.



Kangaroo Grazing System Speadsheet - Excel

File Home Insert Page Layout Formulas Data Review View Help Tell me what you want to do

A9 | 1b) Need to increase number of kangaroos harvested, however not by too many or it will increase grazing pressure

	A	B	C
18	**Option 2b) Harvester pays for access to kangaroos**		
19	Initial investment ($)	0	
20	Ongoing annual cost ($) not including fuel	0	
21	Costs per animal:		
22	*Tag*	0	
23	*Ammunition*	0	
24	Amount paid per roo to landowner ($)	5	Land manager to negotiate payment rate from harvester ($5 has been offered to land managers as recent as 2021)
25	Return on number allowed to harvest per year based on est population ($)	4872.9	
26	Return on number allowed to harvest per year based on est population if quota not reached ($)	6497.2	
27			
28	***2b) Need to increase number of kangaroos harvested, however not by too many or it will increase grazing pressure***		
29	Return on allowed to harvest if population grew ($)	8000	
30	Return on allowed to harvest if population grew and quota not reached ($)	10666.7	

Figure 34. Screen capture of the spreadsheet showing the option of pastoralist charging harvesters a fee using a hypothetical example.

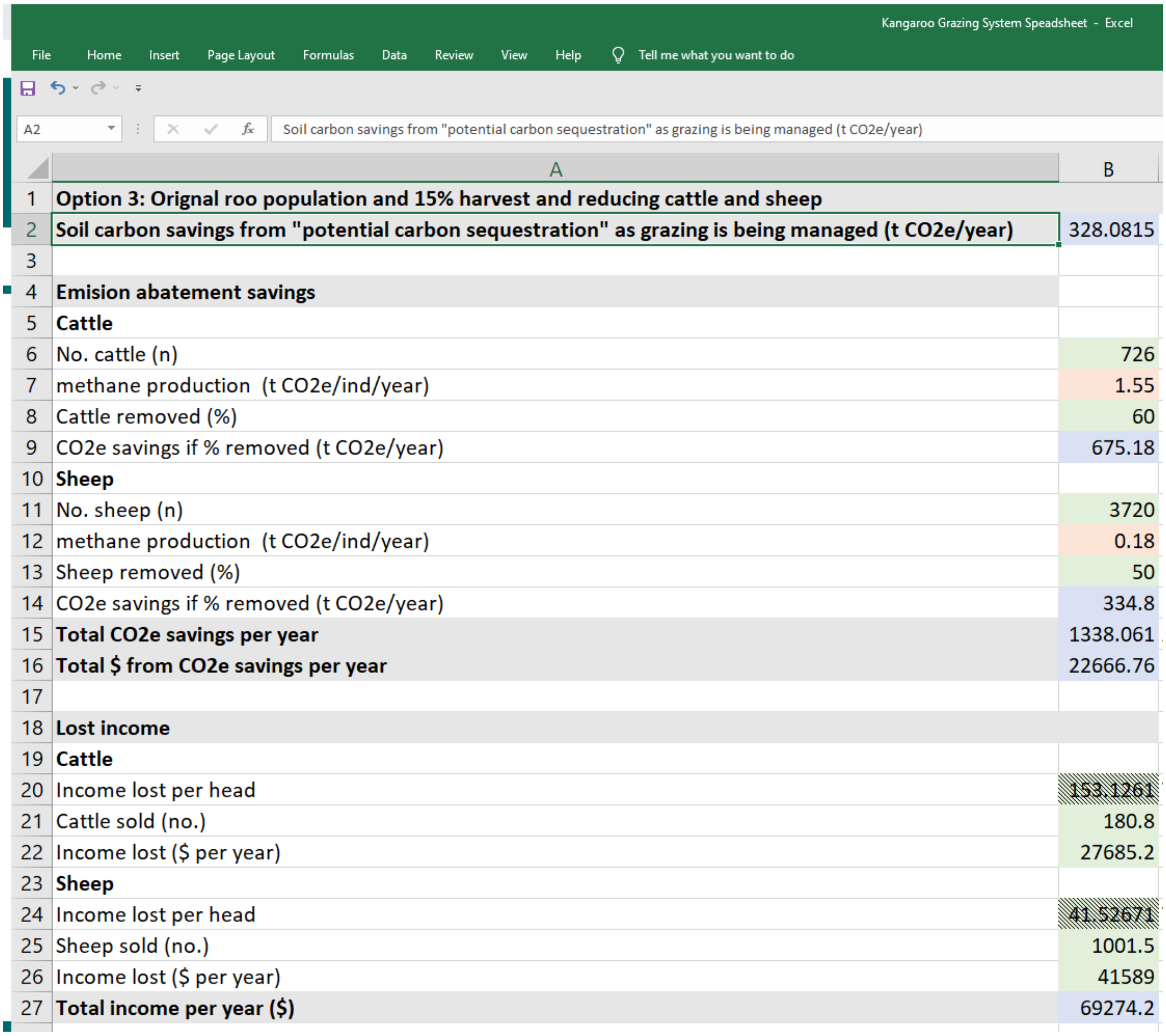
Option 3 – Concurrent enterprises

Under the third option a pastoralist may graze livestock and kangaroo and run the enterprises concurrently (Figure 35). Carbon sequestration comes from reducing the cattle and sheep population, which reduces grazing pressure. The kangaroo population is harvested at 15 per cent of the hypothetical population. Issues with this option include that there may be greater costs associated with livestock production, as less livestock are run (i.e., the cost of production per livestock increases as the number of livestock decrease). Nevertheless, the worksheet ‘Cattle sheep and kangaroo grazing’ enables a pastoralist to manipulate the proportions of grazing herbivores on their land so to determine how many cattle and sheep they can remove and how this affects their grazing capacity and income (Figure 36). There is the option for the pastoralist to enter lost income so to determine their prospective management options. This worksheet enables the pastoralist to manipulate values and explore different stocking values in one worksheet. Kangaroo start-up production costs are not included in this calculation.

Table 7 provides a summary of the different options and where they fit in comparison to the other options. A major game changer would be the increase in value of kangaroo and carbon payments. Note that option 3 depends on the proportion of livestock reduced.

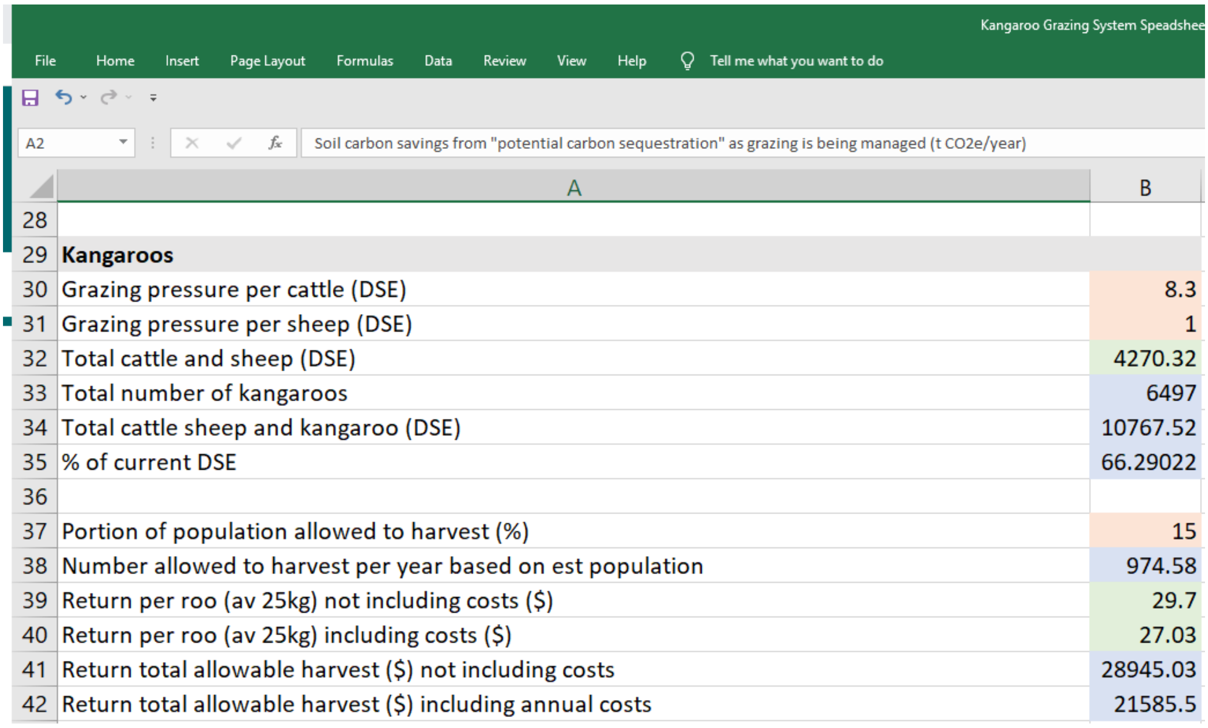
Table 7. Summary of harvesting options and a comparison of their benefits and disadvantages.

	Low		Intermediate		High
GHG savings		Option 3 «sliding»			Option 1 and 2
Financial returns	Option 1 and 2			Option 3 «sliding»	
Investment cost	Option 2		Option 3 «sliding»		Option 1
Ongoing cost	Option 1				Option 2 and 3
Workload	Option 2				Option 1 and 3



	A	B
1	**Option 3: Orignal roo population and 15% harvest and reducing cattle and sheep**	
2	**Soil carbon savings from "potential carbon sequestration" as grazing is being managed (t CO2e/year)**	328.0815
3		
4	**Emision abatement savings**	
5	**Cattle**	
6	No. cattle (n)	726
7	methane production (t CO2e/ind/year)	1.55
8	Cattle removed (%)	60
9	CO2e savings if % removed (t CO2e/year)	675.18
10	**Sheep**	
11	No. sheep (n)	3720
12	methane production (t CO2e/ind/year)	0.18
13	Sheep removed (%)	50
14	CO2e savings if % removed (t CO2e/year)	334.8
15	**Total CO2e savings per year**	1338.061
16	**Total $ from CO2e savings per year**	22666.76
17		
18	**Lost income**	
19	**Cattle**	
20	Income lost per head	153.1261
21	Cattle sold (no.)	180.8
22	Income lost ($ per year)	27685.2
23	**Sheep**	
24	Income lost per head	41.52671
25	Sheep sold (no.)	1001.5
26	Income lost ($ per year)	41589
27	**Total income per year ($)**	69274.2

Figure 35. Screen capture of the spreadsheet showing the option of running livestock and harvesting kangaroos using a hypothetical example.



	A	B
28		
29	**Kangaroos**	
30	Grazing pressure per cattle (DSE)	8.3
31	Grazing pressure per sheep (DSE)	1
32	Total cattle and sheep (DSE)	4270.32
33	Total number of kangaroos	6497
34	Total cattle sheep and kangaroo (DSE)	10767.52
35	% of current DSE	66.29022
36		
37	Portion of population allowed to harvest (%)	15
38	Number allowed to harvest per year based on est population	974.58
39	Return per roo (av 25kg) not including costs ($)	29.7
40	Return per roo (av 25kg) including costs ($)	27.03
41	Return total allowable harvest ($) not including costs	28945.03
42	Return total allowable harvest ($) including annual costs	21585.5

Figure 36. Screen capture of the spreadsheet showing how pastoralists can manipulate the proportions of grazing herbivores on their land so to determine how many cattle and sheep they can remove and how this affects their grazing capacity and income using a hypothetical example.

Timeframes

Carbon project

Pastoralists will need to assign time to ensure eligibility requirements are met for the applicable carbon methodologies, including to prepare a land management strategy and to register their project. There will be operating, sampling, reporting, auditing, notification, monitoring and record-keeping obligations in running a carbon project. Pastoralists will need to measure their soil carbon levels before and after their grazing management activities so they can calculate soil carbon changes. Under the ERF, pastoralists will need to report on their project at least once every five years. Pastoralists will receive carbon credits each time they report increases in soil carbon levels over a period of 25 years. See Figure 37 for a visual representation of a soil carbon project timeframe.

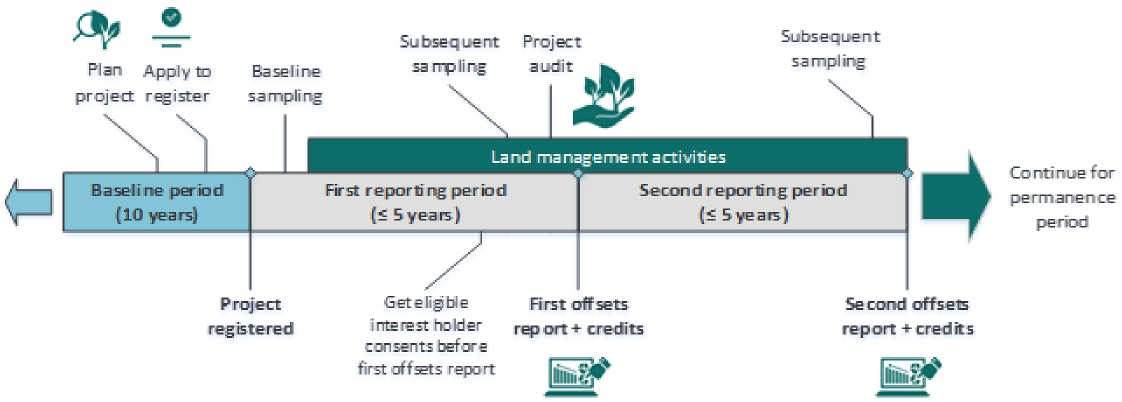


Figure 37. Timeline for a soil carbon sequestration project. Under a Kangaroo Grazing System, livestock reductions and kangaroo harvesting would occur over the land management activities timeframe to increase soil carbon sequestration and to reduce enteric CH_4 emissions (CSF 2020).

Kangaroo management

Prior to implementing a KGS, a number of activities are required. Kangaroo population counts may be provided to the pastoralist by state environment departments. The more data that is collected, the more informed the management decisions can be; for example, if data is collected on kangaroo populations including movement, emergent joeys, number of males, number of females and mortality then pastoralists may start to model what the population will look like in the following years. The pastoralist will also be required to determine allowable harvest number.

If the pastoralist is to diversify into kangaroo harvesting there will be time required for enterprise establishment including administration, training and purchasing; for example, to purchase equipment, attain licences and tags, attend training, map chiller location. There will be less time required for establishment if the pastoralist decides to engage an external harvester. These activities can be achieved during the 'Baseline sampling time point' as shown in Figure 37.

Land management activities (Figure 37) will be to destock cattle and sheep according to the pastoralists land management strategy. This activity can be immediate or gradual depending on pastoralists soil carbon storage aspirations and ability to supplement income. Kangaroos are to be managed to appropriate grazing target to enable soil carbon to be sequestered under land management strategy. There will be time management lags for this component of the KGS, while the balance between population increase to meet grazing targets and harvest quotas are determined.

The worksheet 'Kangaroo population management' will help pastoralists determine the timeframe for kangaroo populations to reach grazing targets and for harvest targets. The variables include:

- population number
- female-to-male ratio
- reproductive females
- joey mortality
- adult mortality
- migration (not included in calculations).

A local kangaroo population can be impacted by harvest rate, joey mortality, number of reproductive females and adult mortality. The variables will dictate the number of kangaroos harvested and potential for growth in the following years. The worksheet provides two scenarios (Figure 38). The first gives a high percentage for joey survival during high rainfall periods. The second gives a lower percentage for joey survival during low rainfall periods. Droughts would likely see a fall in populations and are not modelled in the worksheet; however, the variables can be manipulated to reflect drought conditions. Under the two modelled scenarios, populations reach grazing targets after three years.

Pastoralists can enter their data to determine their prospective timeframes, which will depend on their land, livestock, local kangaroo and environmental statistics.

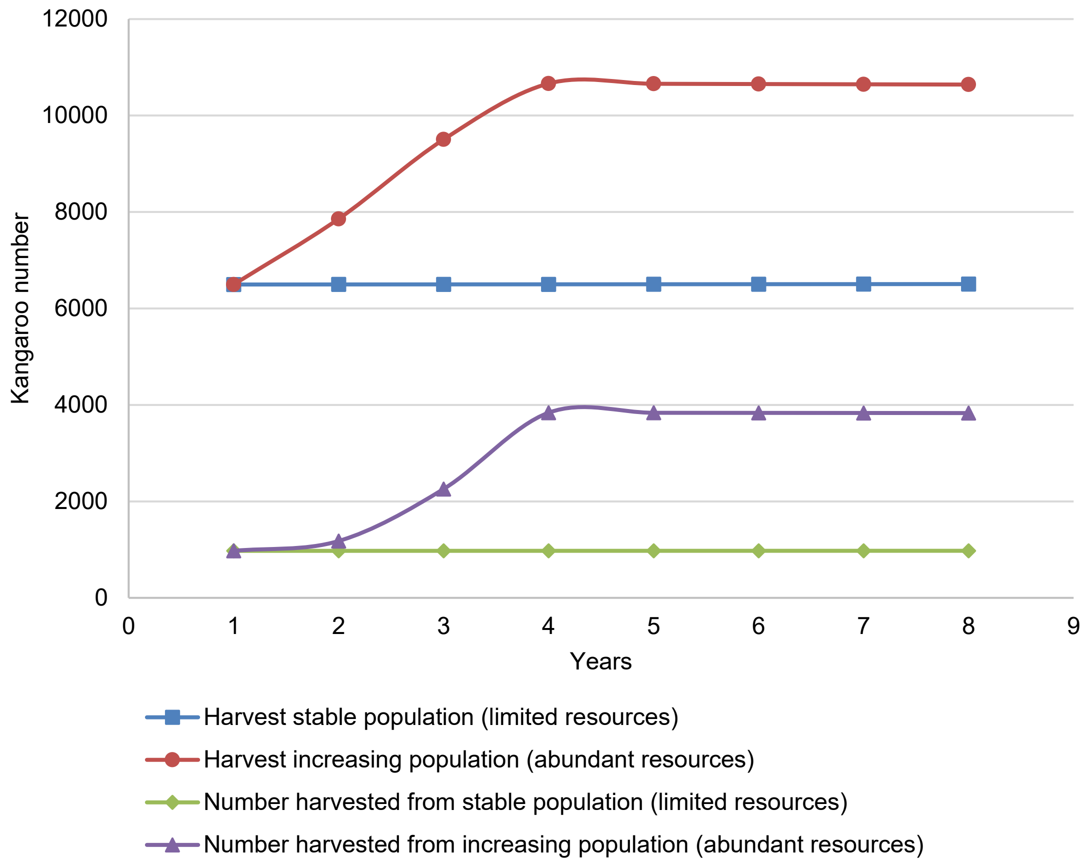


Figure 38. Kangaroo population modelling for the harvesting of a stable kangaroo population and the harvesting of an increasing population (due to favourable climatic conditions) to achieve maximum grazing targets for soil carbon sequestration.

Implications and constraints

Major issues

Livestock emissions are not penalised under Australia's current climate policies and programs

Australia's climate policies include the ERF/CSF, a National Energy Productivity Plan, ozone and hydrofluorocarbon measures, technology improvements and the Safeguard Mechanism (post 2020).

Safeguard Mechanism

The Safeguard Mechanism encourages large businesses that produce more than 100,000 t CO_2e/year not to increase their emissions above historical levels. It applies to energy generation and industrial process such as cement and steel making but not to livestock emissions because of the application of rule that it is a trade exposed industry. There are incentives and credits to be earnt from reducing fugitive emissions and emissions from fuel combustion and waste disposal.

If one allows that beef produces 2 t CO_2e per head per year and livestock were included, then corporations with more than 65,000 cattle would qualify. There are many herds with over 100,000 animals – and some feedlots. Indeed, the Business Council of Australia (BCA) has been calling for a lowering of eligibility city thresholds so that entities emitting 25,000 t CO_2e per year would be captured. This would mean that livestock enterprises with 15,000 cattle would be covered. The BCA argues that the baseline should be lowered predictably and gradually over time with various exclusions such as those exposed to international rivals. While the BCA backs the application of the Safeguard Mechanism, their first choice is quite an explicit economy wide carbon pricing mechanism (i.e., a carbon tax). While enteric emissions and soil carbon losses are not covered, there is little need and no real incentives for pastoralists to reduce their emissions. It nevertheless seems inevitable that red meat industries will be exposed to the Safeguard Mechanism.

Carbon Border Adjustment Mechanism

In the global setting, policies are being developed for carbon leakage, to prevent, or rather account for, companies that move their carbon-intensive production abroad or where products are replaced by more carbon-intensive imports to meet GHG targets. The European Union, the US and Canada are discussing the implementation of tools such as a Carbon Border Adjustment Mechanism, which includes higher costs (a levy based on the amount of carbon used) for carbon- intensive imports. Without the mechanism Australia is set to gain a competitive advantage as it does not have to meet the same GHG targets as international counterparts; with the mechanism the competitive advantage would be reduced.

Kangaroos and carbon credits are low-profit

The risk of reducing the stocking rate to promote a KGS is that it lowers profitability more than the current value of the saved carbon emissions and sale of kangaroos. Alcock and Hegarty (2006) reported that the stocking rate and also CH_4 production from a farm based on unimproved pastures was about 40 per cent of that for a farm based on improved pastures, but the gross margin of the less productive farm was only 25 per cent of the more productive farm ($139/ha v. $525/ha). To date, CO_2e emissions associated with altering the number of sheep on the farm is based on modelling studies (Alcock and Hegarty 2006, Young 2009, Alcock and Hegarty 2011). Without taking kangaroos into account the modelling analyses indicate that producers will be financially disadvantaged if they reduce stock numbers in order to reduce carbon emissions as the loss in profit is much greater than the potential compensation through the ERF. An ACCU is currently worth approximately $30 and has shown some volatility in the last six months. Kangaroos are currently worth $1.30 to $1.60/kg (Kangaroo processor, person comm 2022). At the time data was gathered for this report, cattle were worth approximately $2.60/kg (liveweight) and sheep $7.00/kg (liveweight) (2019 to 2020 statistics tables). We receive mixed messaging for kangaroo demand; in 2021 in NSW the total commercial harvest was 4.8 per cent of the total estimated population and 31 per cent of the available quota, which suggests low demand. Yet conversations with some processors indicate that they cannot get enough carcases through their facilities.

With the low price achieved from carbon credits and kangaroos and with no penalties attributed to soil carbon loss or CH_4 production from livestock, there are no financial incentives to employ the KGS. The low profit margin causes ongoing value-adding issues; less money is invested in research, development and marketing through levies. Levies paid by cattle and sheep pastoralists result in large investments in cattle and sheep research, while small levies are paid by kangaroo processors, which results in little funds being invested in research, development and marketing for kangaroo (DAWE 2022b).

Livestock prices have the potential to continue to increase while kangaroos will no doubt remain stagnant. A collective industry led program aimed at certifying kangaroo products could help raise the value of kangaroo products and make them a profitable natural resource. Under business as usual it is unlikely that kangaroo research and development and marketing will gain the progress it needs to initiate value-adding from current levy rates. Currently the kangaroo levy is at $0.03 for the National Residue Survey and $0.04 for research and development; this is 18 per cent of the goat levy and 1.4 per cent of the grass-fed cattle levy. If kangaroos were worth more, a levy could be raised and the industry could be self-supporting.

A kangaroo could be worth more than its current value. Goats, once worthless to pastoralists and costly to manage, are now comparable, if not worth more than over-the hook than cattle and sheep (MLA 2022a). The value of kangaroos could increase through various product management and marketing campaigns such as certification schemes that highlight the benefits of kangaroo products and ensure product quality.

Value-adding through carbon-saving branding

Kangaroos emit little CH_4 (Vendl *et al*. 2015). There is large potential for carbon branding, which could attract a premium. Product carbon footprinting addresses businesses' need to better understand how their products and supply chains impact carbon emissions, and to respond to growing consumer demand for carbon information and low-carbon products (Bolwig and Gibbon 2009). Product labelling provides further benefits, as seen from companies that have communicated their products' carbon footprints using the Carbon Trust Carbon Reduction Label (Carbon Trust 2022) through:

- realised additional emission and cost savings, driven by the Carbon Reduction Label's required commitment to ongoing reductions
- differentiated products to customers; in Australia, there are two carbon labelling schemes – the Carbon Reduction Label (Carbon Trust 2022) and Climate Active (formerly the National Carbon Offset Standard) (Australian Government 2011).

These labelling schemes draw on international standards, including:

- PAS 2050 – a publicly available specification for the assessment of the life cycle GHG emissions of goods and services
- GHG Protocol – a product standard developed by the World Resources Institute and the World Business Council for Sustainable Development
- ISO 14067 – an international standard for the carbon footprint of products.

Products can also display carbon-neutral claims and certification trademark. To achieve and maintain a valid and credible carbon-neutral claim against the Product & Service Standard, the responsible entity must:

- calculate emissions
- develop and implement an emissions reduction strategy
- purchase offsets to compensate for remaining emissions
- arrange independent validation and
- publish a public statement of the carbon-neutral claim.

More information is available at Climate Active (2020).

Value-adding through environmental and biodiversity branding

It is often asserted that kangaroos have less physical impact on the environment compared to sheep, goats and cattle as a result of their physical attributes and they also require less water. Grigg (2002) reviewed the impact and concluded that kangaroos 'soft feet' do less damage to land and vegetation compared to sheep and cattle at kilogram for kilogram. We note that the impact of hard-hoofed livestock is particularly profound in riparian areas and there have been major land and vegetation conservation programs to fence livestock out of creeks and rivers. We note the need for more comprehensive comparative studies to support this assertion and an extension of the work of Bennett (1999) and Noble and Tongway (1986).

Nevertheless, many golf courses will tolerate up to 100 kangaroos whereas there is no tolerance for sheep or cattle because of the damage that would be done to playing surfaces. Environmental claims can be a powerful marketing tool. Companies realise that consumers today have an increased awareness of the environmental impact that modern goods may have. Environmental claims are now relevant to a larger product range.

Many consumers consider environmental claims when evaluating products to purchase. Ecospecifier Global (2022) detail the number of different types of ecolabels and declarations including:

- Type 1 labels – third-party-certified environmental labels; these include multi-criteria-based, third-party-certified environmental labelling programs run in compliance with ISO 14024.
  - Compliance cannot be certified, so schemes self-declare compliance and ideally should be verified by external parties with appropriate competence.
- Type 2 labels – informative environment self-declaration claims (ISO 14021); these include assurance that their claims are scientifically sound and appropriately substantiated.
  - Consumers are entitled to rely on any environmental claims made and expect these claims to be truthful.
  - Any environmental claims need to be clearly and accurately explained. To be able to be substantiated, they should be honest and truthful, detail the specific part of the product or process it is referring to, use language the average member of the public can understand, and explain the significance of the benefit.
- Type 3 labels – quantified product information labels based on independent verification using pre-set indices that present quantified environmental information on the life cycle of a product to enable comparisons between products fulfilling the same function and in compliance with ISO 14040, with pre-determined parameters and independent verified lifecycle assessment data and inventory analysis.

In addition, there are single-issue labels granted by third-party certification agencies or government agencies that refer to a specific environmental or sometimes ethical characteristic of a product. See Australian Competition and Consumer Commission (2011) for more information.

The Australian Farm Biodiversity Certification Scheme

The Australian Farm Biodiversity Certification Scheme is part of DAFF's Agriculture Biodiversity Stewards Package, which will enable farmers to exhibit best practice NRM to improve biodiversity by acting as a credible, independent assessment of how farmers protect biodiversity on their property. The scheme could enhance farm profitability by creating price premiums for their produce, supporting access to markets, providing farmers with access to land management advice, and lowering capital costs. Reducing grazing pressure and improving kangaroo management could enhance on-farm biodiversity values by retaining native vegetation and reduce erosion by maintaining ground cover (DAWE 2021a).

Accounting for Nature

Accounting for Nature (AfN) works with farmers, indigenous land managers, private conservation organisations, businesses, impact investors, governments and regional NRM organisations to implement the AfN framework. The framework offers a system of rules and processes designed to ensure the integrity and transparency of environmental accounts, no matter the environmental asset being measured. These rules and processes are embodied in four interrelated core documents:

- the certification standard, which sets out rules and process
- the methods, which contain detailed management reporting and verification requirements for specific environmental assets
- claims rules and procedures, which govern the type of public claims that can be made by proponents with certified self-verified environmental accounts
- audit and verification rules.

These accounts can be used to underpin government and philanthropic grants, issuance and tracking of green bonds and other financial instruments, monitoring the efficacy of sustainable land management activities, consumer labelling on food and fibre products, undertaking due diligence on impact investments, and credibly linking environmental co-benefits to carbon offset units under different internationally recognised standards – a world-leading, scientifically rigorous methodology for measuring environmental condition.

Vegetation Assets, States and Transitions Handbook

The AfN Framework draws on the *Vegetation Assets, States and Transitions Handbook*, which sets out the process for developing ecological assessments of regenerative land management in agricultural landscapes. The handbook guides participants through:

- collection, collation and analysis of information required to conduct a valid and thorough ecological assessment of selected properties
- systematic appraisal of the property under review, in terms of the regenerative practices in place
- completion of an ecological assessment report for a property
- publication of the report.

MyFarmKey has been engaged to provide independent scientific validation of the land manager's ecological self-assessment. MyFarmKey provides a satellite-based assessment of the fractional groundcover (30-metre resolution) across the Australian landscape using measures of persistent green vegetation (broken down into trees, scrub, crops and perennial pasture), brown or hayed-off vegetation, and bare ground.

Ecological Outcomes Verification

Ecological Outcomes Verification (EOV) measures and trends key indicators of ecosystem function, which in the aggregate indicate positive or negative trends in the overall health of a landscape. In addition to providing an outcomes-based verification of the health of the land base, EOV also provides critical intelligence to the farmer as a steward and manager of the land. By recognising both land regeneration targets and trends, EOV endorsement and associated incentives are bestowed as long as land health moves in a net positive direction.

Value-adding through health benefit branding

Kangaroo meat has a lower fat and cholesterol content than lean beef and lean lamb. It provides more protein than beef, lamb, pork and chicken, has a higher iron content than lamb, pork and chicken (Table 8) (Food and Fogerty 1982) and has a desirable level of polyunsaturated fatty acids (reported in Spiegel and Greenwood (2019). These features allow kangaroo meat to provide the health benefits of white meat, while still maintaining its red meat status. Thus, kangaroo meat appeals to the health-conscious customers, which is a growing market. There is scope for kangaroo to include healthy product certification in branding and marketing.

Table 8. Nutritional values of kangaroo and other meat based on raw meat trimmed of all fat (Food and Fogerty 1982).

Source	Meat protein (%)	Fat (%)	Kilojoules (kJ/100 g)	Cholesterol (mg/100 g)	Iron (mg/100 g)
Kangaroo	24	1-3	500	56	2.60
Lean lamb	22	2-7	530	66	1.80
Lean beef	22	2-5	500	67	3.50
Lean pork	23	1-3	440	50	1.00
Lean chicken breast	23	2	470	50	0.60

Value-adding through social and ethical and branding

Purchasing kangaroo products should be an ethical choice for socially concerned consumers. Kangaroos live free and wild on a natural diet of native vegetation. Kangaroo meat is not farmed; it is free-range. The method of killing is humane; with a code of practice that requires instant kill in their natural habitat. Using kangaroos minimises waste when populations are being culled for damage mitigation purposes. A KGS would also reduce the likelihood of population crashes and associated welfare issues through population control, as populations crash resulting in animal welfare issues, such as starvation, when drought hits. While best practice animal welfare systems with certifications exist for other industries, there is no such program and certification for kangaroos. The system could be two-fold, including certification that aligns with current best practice animal welfare system, but also certification for the industry as a whole whereby management and use of the native resource reduces alternative animal welfare issues resulting from unmanaged populations.

Value-adding through improved quality and accuracy of description

In the early 1990s, the Australian beef industry had identified variable eating quality as a major contributor to declining beef consumption. It went on to develop Meat Standards Australia (MSA), a scheme that was released in 1998 by MLA to improve the eating quality consistency of beef and sheep meat. The ability to predict the eating quality of cooked beef prior to consumption was identified as the key. Consumer testing protocols were developed, which led to the implementation of MSA grading standards, defined by consumer score outcomes. Traditional carcase grading parameters had proved to be of little value in predicting consumer outcomes. Instead, a broader combination of factors was developed and forms the basis of an interactive model, which accurately predicts consumer scores for every carcase graded. A standard could be developed for kangaroos.

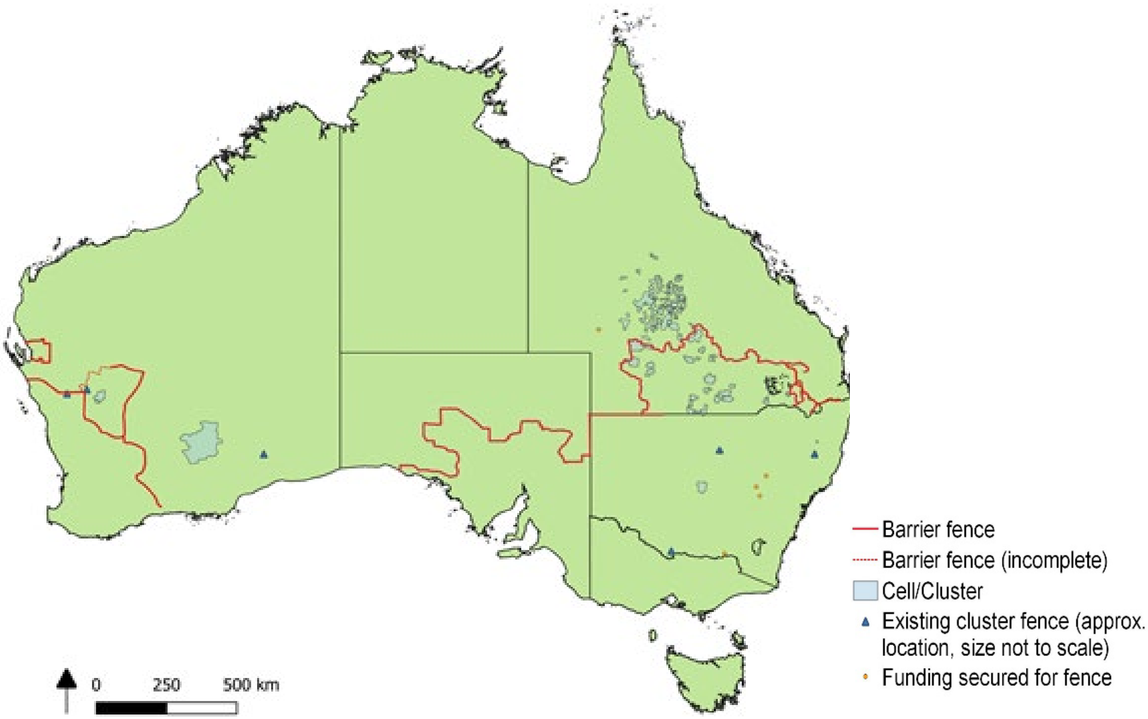
Kangaroos have a large home range and move differently to livestock

Unlike livestock, which are domestic animals, kangaroos are wild and not confined by traditional livestock fences. Kangaroos move and thrive in response to water and pasture availability. Kangaroos may have home ranges that span multiple properties, and they can migrate (Laubsch and Kitschke 2018, McLeod *et al*. 2021, Pedler *et al*. 2021). This makes managing numbers on pastures and forecasting harvesting yields difficult.

Exclusion fences

In recent years, pastoralists have been erecting taller 'exclusion' fences with the purpose of keeping wild predators and kangaroos out of their pastures, and to deter kangaroos from watering points. These fences also provide an opportunity to manage grazing pressure within more precisely because unwanted herbivores are controlled more effectively as pests.

To improve the cost benefit ratio some fences are erected around multiple properties and are termed cluster fences (Clark *et al*. 2018). They are often co-funded by state governments or the Australian Government because they are deemed to be community interest infra structure. Others are privately funded. The extent of their construction in Queensland is massive; 686 clusters (many subsidised, most not subsidised) as at February 2021. See Figure 39 for the extent of fences with publicly available information and Box 4 for an example showing how and why pastoralists invest in fences to exclude kangaroos.



Map reproduced by Australian Wildlife Services 2022
Data Sources: NSW: LLS Weed and Pest Animal Drought Project 2018-2019; QLD: DAWR 2017, Southwest NRM 2017, RAPAD 2019 and 2021; SA: PIRSA 2019; WA: DPIRD 2019.

Figure 39. Barrier and exclusion fences around Australia. There are many other private fences where data is not available.

Box 4. Account from *The Land* demonstrating reliance on exclusion fencing

In 2015, *The Land* reported western NSW merino graziers had invested heavily in an exclusion fence in an effort to exclude kangaroos, and were fencing their land, west of the Macquarie Marshes. The graziers planned to protect 2,830 ha of their 12,000 ha property with a 1.7 m high, 14-line tight exclusion fence. The fence cost approximately $5,500/km for materials and $5,000/km for labour and clearing. The fence was designed so that nothing could go underneath or over it. This was the only option to control kangaroos – there were as many kangaroos as sheep and the graziers wanted a total barrier. At least 40 km was reported as needing to be fenced; the cost was high, but construction needed to happen. Such exclusion fences are becoming popular among farmers in places like Walgett, Bourke and Mungindi. They can see the benefits associated with increased productivity, and in some cases are self-funding their own fences (Rural Property NSW 2019).

Goat fences

Goat-proof fences are being erected in NSW in particular as the rapidly growing goat industry transitions from wild capture to holding goats and managing them more intensively behind wire. We suggest a similar transition to a form of proprietorship can be applied to kangaroos, including by goat farmers, and that doing so will lead not only to improved capacity to manage total kangaroo grazing pressure, but also to production of higher-valued, premium products and the capture of carbon credits by the land manager/pastoralist.

Wild dogs and dingoes are a risk to sheep, goats and kangaroos, and a woven wire goat fence won't stop them. The typical dog-proof cluster fence is 2 m high mesh with an apron. These exclusion fences are being erected on the perimeters of individual properties and clusters to stop the transit of dogs and kangaroos.

Where exclusion fencing exists, variables can be controlled to test the KGS. To estimate grazing pressure, managers need to know the number and type of grazers present, and the feed on offer at any period. Kangaroos within these fences can be monitored and counted, with their effect on grazing pressure controlled and measured. To temporarily bypass the issues of movement, or to trial the concept, the KGS could begin on properties where exclusion or barrier fencing exists. The fences also enable the opportunity to protect threatened species (Smith *et al*. 2020).

Harvest restrictions and population assessments

To enable vegetation growth and soil carbon storage, the number of kangaroos harvested per property or region will need to be estimated. Improved monitoring techniques are needed to enable pastoralists to determine numbers on pastures and forecasting harvests. A property level monitoring tool is currently being developed by McLeod and Curtis to enable greater knowledge of kangaroo numbers on properties. Alternatively, pastoralists can employ a number of methods for small-scale surveys as described by Coulson and Raines (1985), including drive counts, transect counts and pellet counts. There is need to develop a model that tracks the number of head under baseline and project scenarios. For populations to be managed to reduce overgrazing and increase soil carbon storage while at the same time preventing population over-harvest, changes to the current kangaroo management strategy need to be considered. Currently, kangaroo harvest quotas are not met, and it is therefore likely that harvesting to meet vegetation and pasture growth goals can be met through commercial harvest. However, if the KGS is widely adopted there may become limits to the number of kangaroos that are allowed to be harvested (for example, current harvest limits are usually set at 15 per cent based on state management zone populations; see Box 5).

Box 5. Current state harvesting limits may restrict harvest and pasture management and prevent soil carbon storage if KGS is adopted widely

Kangaroo populations fluctuate widely. The current commercial harvest strategy, called 'proportional harvest', is used to set harvest quotas (Hilker and Liz 2019). Fluctuations in population abundance are tracked and quotas are adjusted accordingly, assuming the current population is the desired population. Proportional threshold harvesting is a modification of proportional harvesting and sets a threshold in population abundance, below which the proportion of the population that can be harvested is reduced eventually to zero. These harvest thresholds aim to lower the risk of over-harvesting by reducing harvest mortality at times of low population size. The strategy is effective in ensuring kangaroos are not over-harvested, which could cause genetic issues for the species and threaten the species with extinction.

Finding the balance between kangaroo population sustainability, harvest quotas and vegetation growth for soil carbon storage is complex, and while threshold limits protect the population from being exploited to a very low density, the current strategy does not manage the population for overabundance and impact on soil carbon and biodiversity. For example, culling regimes tested in an ACT model showed reductions greater than those set by a commercial quota were required to achieve vegetation responses that enabled the development of tussocky grass structures thought to be associated with conservation of threatened vertebrate species (Gordon *et al*. 2021).

The population response to threshold harvesting can be markedly different depending on the specific population model (Hilker and Liz 2019), and we see population response issues in kangaroos where overabundance can cause issues for overgrazing and carbon soil storage.

A better practice would be to set a population limit based on kangaroos as a component of total grazing pressure based on ecological/pasture carrying capacity. This is effectively an equilibrium with resources, natural predators, and competitors (Olsen and Braysher 2000). There would be a predefined minimum that changes on a yearly basis in response to the environment and climate where harvesting would occur above the minimum. The density based on vegetation grazing would ultimately depend on environmental conditions. Estimates for annual minimum density and regular counts to determine harvest potential would allow pastoralists to understand the population dynamics so that carbon can continue to be stored in the soil and so that kangaroos do not become overabundant or over-harvested. A minimum density would need to be determined that does not compromise soil carbon goals, and could be based on a plant-herbivore model developed for specific areas or regions. Olsen and Braysher (2000) state that this would require rigorous research over several seasons, which would be resource intensive both to develop and administer, and is probably only possible in more controlled areas (like parks and reserves) where stock is not a confounding factor.

Olsen and Braysher (2000) also state that on private land the problems of setting minimums, monitoring and managing all the major confounding factors that impinge on plant-herbivore systems management would be formidable, as would the actual maintenance of kangaroo numbers at a minimum. However, under the KGS, pastoralists would remove (or reduce) stock. Pastoralists would invest in kangaroos so as to develop knowledge and research over several seasons pertaining to kangaroo population growth and response to environmental conditions. Pastoralists would transform kangaroo management to an enterprise, the confounding factors and maintenance of kangaroo numbers would be beneficial and encouraged rather than cumbersome. This is discussed further below, where we explore the option of giving pastoralists greater permissions to manage kangaroo populations, which would enable kangaroos to be managed to a predefined density with opportunities to monitor and control the population to enable benefits for soil carbon storage and from harvesting. It would be in the pastoralists best interest to maintain the population for soil and for population sustainability.

Property-level or regional management coordination could include more regular and robust counts and cover wider areas than what is currently achieved by the states. There could be greater confidence in management if pastoralists could make adaptive management-based decisions about their local populations. Pastoralists would use population figures together with the population required to allow vegetation and soil carbon storage to estimate the harvest potential and requirement for their land.

When kangaroo numbers were much higher than the agreed minimal viable kangaroo population to be held on a regional basis, they would operate differently to when numbers were closer to the minimal viable kangaroo population. If harvest rates cannot be sustained, harvesters would have to reduce their off take. Persuading harvesters to incur such short-term opportunity costs, even just temporarily, would be difficult unless they can be compensated for any lost income. However, if kangaroo populations are maintained and managed properly, we would expect supply and harvest to mimic current management and supply of cattle and sheep. Harvesters could take advantage of good systems and then 'de-harvest', the equivalent of destocking when conditions are poor, or they could supply feed to enable ground biomass to continue to sequester carbon.

Kangaroos are perceived as pests and not part of production system

In pastoral environments, kangaroos can compete with conventional livestock for water and food, contributing significantly to grazing pressure (Waters 2018, Pahl 2019b). They can also severely impact crops and resting paddocks (Barnes and Hill 1992, Viggers and Hearn 2005, NSW Farmers 2019, Waters *et al*. 2019) and can be a great financial cost to pastoralists (see McLeod 2004; SWNRM 2017), and are often considered a pest.

Perceptions are difficult but not impossible to change. Goats were once considered a pest but moved to commodity status in areas where their numbers were large and difficult to manage. The growth of the industry is supported by Australian Government and state government programs, plus producer-backed levies for research, development and marketing.

Incorporate kangaroos into the red meat industry – plans and goals

To move kangaroos from pest status to sustainable resource, clarity is needed about the objectives of kangaroo management programs. A strategic review with participation by all stakeholders would address questions as profound as 'does Australia want more or less kangaroos?'. We are part of a group that has argued for development of a National Kangaroo Strategy to address such questions. The need is urgent before the onset of the next drought (Read *et al*. 2021b).

If kangaroo use were deemed to be a red meat industry, they could be covered by RMAC, which advises the Minister for Agriculture. An appropriate structure might look like that in Figure 40. The Kangaroo Industry Association of Australia, whose members are the kangaroo processors, would sit alongside a new organisation – the 'Kangaroo Producers Association' representing land holders similar to the sheep and goat producer associations. They would be supported by research and development corporations, including AgriFutures Australia.

Research and development needs investment. As the number of businesses involved with carbon farming has grown, and demand for ACCUs has risen, industry and government support has increased. Investors believe carbon farming will emerge as a strong option for farmers wanting to add to their income streams, and maintain farmers can be confident these types of programs will deliver a strong return on investment.

AgriFutures has a limited amount to spend on kangaroo research and development and it is focused on processing because that is where the levy funds come from. MLA cannot support kangaroo production on-farm because it's levies do not cover kangaroos. MLA receives levies from sheep meat, goats and beef cattle. Kangaroos are not prescribed under the same legislation, meaning that the prescribed industry bodies will not take them on, and thus proliferating their pest status. Kangaroo research would have to be prioritised by the Peak Industry Councils and fed back to MLA via a consultation process. If levies were received from kangaroos, there would be a change in their position.

Support for developing the kangaroo industry could come through collaboration from existing industry development and marketing agencies to produce premium products. Improving the consistency of supply, accuracy of their description, reliability of quality, and hence value are all things that MLA has mastered in collaboration with the producers – the levy-paying graziers. Kangaroos are red meat and MLA is the development agency and marketing organisation for other red meat, which are often regarded as competitors with one another – beef, sheep and goat.

As an interim measure, it might be possible for the red meat industry to support improvements in kangaroo production to reduce wastage, increase value for landholders, and improve welfare. In this way kangaroos would be incorporated into core activities for environmental sustainability.

The issues covered in this section of the report might appear to go beyond kangaroos and carbon but they are fundamental to effective integration of kangaroos and delivering the opportunities we have identified they present. They need to be communicated to pastoralists and the wider public.

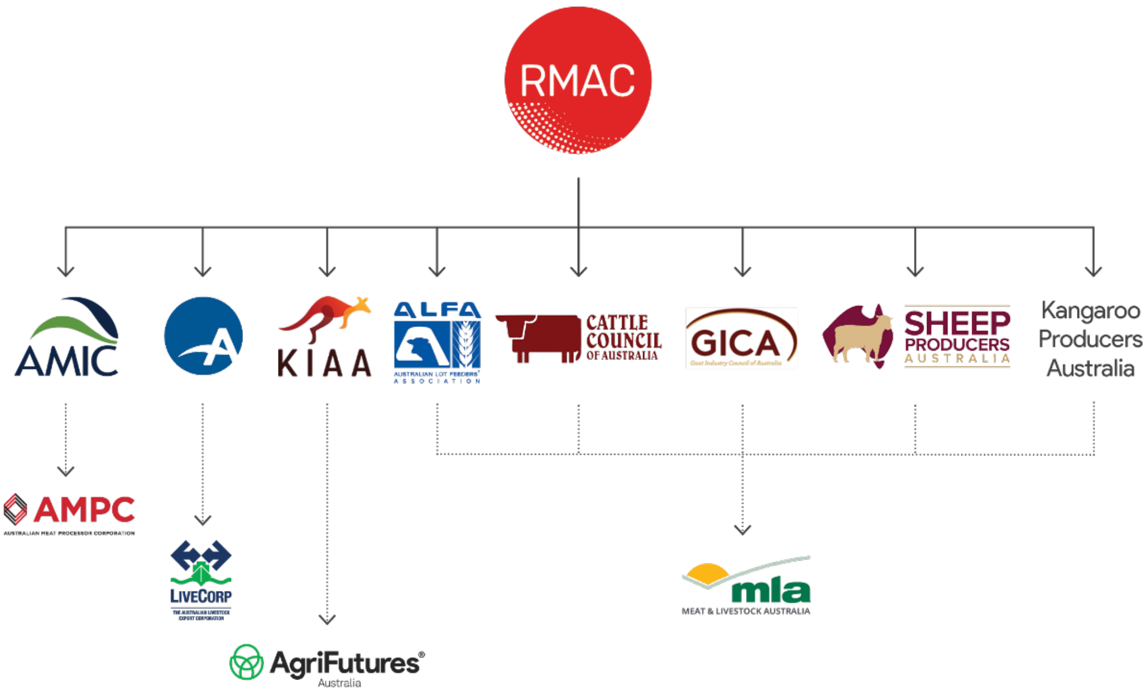


Figure 40. Potential incorporation of kangaroos into national policy structures as an additional source of red meat. A new industry group 'Kangaroo Producers Australia' would complement the Kangaroo Industry Association of Australia.

Goats

Along with sheep and cattle, goats are large CH_4 producers. Predictions about goat throughput are improving, but data is imperfect on numbers that are wild caught and husbanded behind wire. In NSW, goat management is intensifying away from wild harvest. More information is need on these trends to incorporate goats into the KGS. Their inclusion for replacement by kangaroos would make CH_4 emission abatement and soil sequestration even greater under the KGS.

Proprietorship

Kangaroos are a government owned wildlife asset and are protected species under state laws; they belong to the Crown until killed under licence and move into the commercial trade. While alive they are not the property of the pastoralist. This situation creates difficulties for management. Enabling proprietorship of kangaroos might improve management and enable increased up-take of the KGS. Previous attempts to establish proprietorship have failed because kangaroo management systems and government policy have been resistant to change (Ampt and Baumber 2006). The Maranoa Kangaroo Harvesters and Growers Co-operative Ltd owns and operates chiller boxes and takes kangaroos off properties of members, however, membership is small and it has not established all components of the model set out by Cooney *et al*. (2009), nor delivered financial returns to its members, including its major shareholder, the Maranoa and District Landcare Association (Wilson 2018).

The actual numbers of kangaroos are never really known to the level they are for domestic livestock. Proprietorship could put limits on harvest when numbers meet a threshold but also enable greater harvest limits when populations meet an upper threshold.

We have previously described in greater detail, a potential model for kangaroo management through pastoralist custodianship (Wilson and Edwards 2021). Based on the size of their properties, pastoralists participating in the process would agree to hold a proportion of the regional maintenance population and in return they would become custodians and given leases or proprietorship of the balance of the kangaroos on their properties. One way to test this would be to use established barrier fences (as described in the section ‘Kangaroos have a large home range and move differently to traditional livestock’). Kangaroos could be managed through licences within the exclosure or barrier fences. Well-defined, secure, and transferable property rights help to establish and capture the value of resources, thereby providing an incentive for owners to efficiently use and maintain them (Demsetz 1967).

Overseas, such changes have led to benefits (Wilson *et al*. 2020). They appear to be within the scope of current Acts and Regulations. Agriculture departments would have a greater interest in the management of kangaroos; they and food safety authorities would regulate welfare and quality standards. The ultimate control, however, would still reside with the environment departments, which would maintain a capacity to shut down or cancel the leases of animals held by pastoralists if deemed necessary and revert to current management practice. They would also ensure that populations do not fall below a prescribed number.

Pastoralists, including corporate agriculture, who wanted to take up regional property-based kangaroo management could form co-operatives, local companies, or conservancies to collectively manage kangaroos as described by Cooney *et al*. (2009). They could join with Landcare groups or cluster fence groups. The concept and opportunity could have particular relevance to Indigenous communities including on Indigenous Protected Areas. We have advocated these ideas and had begun trialling them on Angas Downs Indigenous Protected Area (Wilson *et al*. 2010, Wilson and Smits 2012).

Co-operatives could collaborate with kangaroo processors to produce higher-valued, differentiated product (Cooney *et al*. 2009). The strategic goal would be to supply high-quality, environmentally friendly, low-carbon product of higher value in best practice quality assurance programs.

Differentiated product could be achieved by a landholder/harvester agreement – a kangaroo production assurance scheme – which could be based on the Livestock Production Assurance program (LPA 2015). The Co-operative has previously sought to collaborate with processors to deliver improved quality management and to develop and implement best practice quality assurance programs. It could offer processors: a selection of specific size/sex/age/species combinations that may have meat attributes; exclusive access to consistent high-quality certified product from the properties of landholder members; products of specific size ranges (larger animals yield more profit to processors); a commitment to specific target volumes, and environmental labelling; minimal use of damage mitigation permits, a topic likely to become increasingly controversial; and best practice cold chain temperature control and innovation in pioneering paddock to plate trace back technologies. In 2007, the best marketing position was assessed as a gourmet, environmentally branded, and high- quality product (Chudleigh *et al*. 2008). All three would be vital to success. The environmental message alone would be unlikely to attract significant market advantages and increased prices.

Trials are needed of alternative management arrangements, including devolved custodianship from state ownership, and whether doing so creates incentives to encourage innovations to increase the value of kangaroo products.

Carbon methodologies

Emissions Reduction Fund

Under the ERF, a project using the ‘Beef cattle herd management method’ can reduce the emissions intensity of beef cattle production by reducing cattle emissions per kilogram of live weight produced. They reduce emissions by improving cattle productivity, lowering the average age of a herd, the proportion of unproductive animals in the herd or changing the number of animals in each livestock class in the herd.

Carbon credits from improved kangaroo management could not be obtained through the method because it measures the intensity of beef cattle production by reducing cattle emissions per kilogram of liveweight produced. Any removal of cattle, unless unproductive, would also decrease the liveweight produced. This represents a lost opportunity for any pastoralists (including cattle and sheep) seeking to improve grazing conditions to improve soil carbon by reducing livestock.

Carbon credits could also not be achieved from the ‘Estimating sequestration of carbon in soil using default values (model-based soil carbon) method’ as the management activity is not included as an eligible activity. Grazing management is however an eligible activity under the other soil carbon methodology, ‘Estimating soil organic carbon sequestration using measurement and models method’.

Management of kangaroo grazing could be incorporated into the HIR methodology; however, this has recently received some criticism (see Box 6). It could also be incorporated in the proposed and under-development AL-MAP method, or into a proposed KLC method or CH_4 abatement methodology, should they be prioritised as future methodologies.

Box 6. Criticism of the ‘Human-induced regeneration’ methodology and the Clean Energy Regulator – March 2022

While our analysis is not about vegetation methodologies, we do discuss grazing management and so have included a summary of the criticism of the CER and the controversial HIR methodology. In March 2022, a report was released by the Australian National University that claimed Australia’s ERF has serious governance flaws and is potentially wasting billions of dollars of taxpayers’ money (Macintosh *et al*. 2022a; Macintosh *et al*. 2022b). It proposed that grazing control has relatively limited impact on the biomass of uncleared woody vegetation in rangeland areas and is unlikely to result in areas attaining forest cover that have not previously been deforested. Rainfall, not grazing, is the determinant of vegetation growth and changes in woody cover associated with the analysed HIR projects (Macintosh *et al*. 2019).

The criticism asserted that most sequestration that has been credited to the analysed projects is unlikely to have ever occurred and, at best, the project activities may be responsible for a small increase in sparse woody and forest cover that would not otherwise have happened. The report recommended the HIR method be immediately revoked, followed by an audit of all registered projects to ensure they were complying with the method’s requirements.

The Emissions Reduction Assurance Committee (ERAC) responded to the claims with an assessment and stated it had not found persuasive evidence of a lack of integrity with the HIR method, any material problems with compliance or any evidence of over-crediting (ERAC 2022). ERAC also acknowledged that the issues raised are complex and welcomed a review, which has been established by the Australia Government under Professor Ian Chubb to ensure the integrity of ACCUs (DCCEEW (2022) lists the Terms of Reference for the independent review).

The *Carbon Credits (Carbon Farming Initiative) Act (2011)*

A description of excluded projects under Section 56 of the *Carbon Credits (Carbon Farming Initiative) Act (2011)* (the Act) includes that the Minister must have regard to whether there is material risk that the project will have a material adverse effect on the availability of water, the conservation of biodiversity, employment, the local community, and land access for agricultural production. The KGS is not expected to be considered an excluded project as it will not affect the availability of water, and it is expected to increase the conservation of biodiversity (see section 'Biodiversity'). It is also expected to increase enterprise diversification and employment through kangaroo harvesting and processing. The local community will benefit through improved ecosystem services and the land will be accessed for agricultural production; through kangaroo harvesting as an alternative for livestock production. Under a KGS, the pastoralist provides for and monitors the kangaroos, instead of livestock. Under a well-developed grazing system, the pastoralists would take custody of the animals through licences, thereby generating agricultural products.

The Act (s54) also states that a project is not an emissions avoidance offsets project if the project is a sequestration offsets project. This may have implications; the KGS is both avoidance in the form of enteric CH_4 and sequestration of carbon into the soil. However, with the current development of other methodologies that are also dependent on both avoidance and sequestration, the KGS could be developed using a comparable pathway.

Voluntary methodologies

The voluntary 'Methodology for improved agriculture land management VM0046' would not achieve carbon credits as the methodology does not support the KGS as it requires emissions reduction with equivalent production of the same product; however, the 'Methodology for sustainable grassland management VM0026' and the 'Methodology for the adoption and sustainable grasslands through adjustment of fire and grazing VM0032' would be applicable to achieve carbon credits.

Minor issues

Other issues that could arise from the KGS are the impacts of other herbivores. For example, in a study in central Australia, the removal of cattle grazing led to an increase in red kangaroo numbers, but landscape effects were confounded by the presence of camels (Frank *et al*. 2016). The presence of herbivores is likely to be location, time and climate specific, but something for pastoralists to consider. Other herbivores with the potential to impact the KGS are likely to be invasive species or invertebrates. When compared to native herbivores, which are considered protected species in all states and territories, invasive herbivores are likely to be easier to control, in that they respond better to control techniques, and are not subject to native species environmental legislation.

Another consideration is whether or not KGS fit in with lifestyle aspirations, management abilities and principals of current pastoralists or how a pastoralist/harvester KGS would work to support both the harvester and the pastoralist. There are large differences in the activities of rearing and selling of livestock and the harvesting of kangaroos. This will need to be a consideration of the pastoralist and will be specific to the individual. One option could be for a program where harvester pays to access a property utilising the KGS. The kangaroos could be certified and fetch a higher price.

A common issue with carbon certified methods is addressing leakage and additionality. Leakage refers to increases in emissions or reductions in removals that occur outside the project boundary as a consequence of the project activity. Leakage comes in two forms: direct and indirect. Direct leakage, also known as activity shifting, refers to instances where the project proponent physically moves the emitting activity to another location, outside the project boundary, while claiming credits for the reduction in emissions inside the project boundary (Macintosh *et al*. 2019). Indirect leakage refers to instances where the benefits of the abatement within the project boundary are negated by market-induced increases in emissions or reductions in removals outside of the project (Macintosh *et al*.

2019). In the KGS, leakage could come in the form of other pastoralists clearing more land to offset the livestock that were removed under the KGS. However, leakage can be prevented using the same methodologies outlined in VMD0033 Estimation of Emissions from Market Leakage.

Additionality occurs if carbon offsets would not have occurred in the absence of a market i.e., if they would have happened regardless, they are not additional. Under the KGS, livestock will be reduced and there is an increase in the use of kangaroos. It is unlikely that activity would occur otherwise, as pastoralists would face economic loss. Like leakage, additionality can be demonstrated using methods developed for the demonstration and assessment of additionality in VCS agriculture, forestry and other land use project activities.

Conclusion and recommendations

As the global population increases, agricultural production is projected to grow. This presents one of the world's greatest challenges, as agriculture is the largest single source of global anthropogenic CH_4 emissions, with ruminants as the dominant contributor. CH_4 is especially important because it is a potent GHG and has a short life span when compared to carbon. Its amelioration is therefore very effective against climate change.

In Australia, the livestock industries are not bound by Australian climate change legislation, despite the Paris Agreement stating that developed countries should continue undertaking economy-wide absolute emissions reduction. The livestock industries do however have their own targets and had planned to be carbon neutral (net zero GHG emissions) by 2030. However, we note that reducing CH_4 emissions faces significant implementation challenges as there are minimal proven opportunities to reduce CH_4 emissions, especially for range fed cattle. As a result, reaching the targets set by the livestock industries relies heavily on offsets. With time running out for sequestration and few enteric CH_4 reduction options the red meat industry has determined that the 2030 carbon neutrality target will not be met. Yet the Australian livestock industries still plan to increase production and to grow livestock herds. Doing so will only increase enteric emissions and in turn, the urgency for stopping land clearing and improving grazing management to restore depleted carbon in soil and vegetation.

Innovative systems are required to meet climate targets. Business as usual should not be an option. Long term policy thinking is vital. Bringing livestock into mainstream mitigation policies would make an important contribution towards reaching the temperature goal of the Paris Agreement. Without change, Australia will be expected to pay export carbon levies on products that fail to implement GHG reduction activities. It is also expected that GHG producing red meat will be replaced with low GHG producing alternatives or laboratory cultivated substitutes.

Integrating kangaroos into rangeland production should be part of the plan to increase production. Cattle generate approximately **12 times more GHG per kilogram of meat** produced compared to kangaroo and Australia has some 30 million kangaroos on pastoral properties that could provide an alternative low-emissions red meat. They should be an asset not a liability in the hands of landholders. We propose a grazing system for rangeland pastoralists that reduces the stocking rate of livestock and allocates part of the available pasture to produce kangaroo meat. Such a change should be possible because the kangaroos are already there and many producers are currently using wasteful practices to reduce their impacts through pest culling.

The KGS also includes managing the grazing of kangaroos so that carbon can be sequestered in soil. Under business as usual, carbon will continue to be lost from soils under many grazing management practices. The KGS could be part of sustainable pastures and adaptive management practices to improve carbon soil retention and sequestration.

If cattle and sheep numbers were reduced, Australia could reduce its GHG by up to nine per cent just from enteric CH_4 emissions. Additional GHG savings will come from reduced manure and fertiliser use and increased sequestration of carbon in soil. Ultimately, Australia could adopt the KGS into its climate policies to help it meet climate targets while still meeting protein demands and providing a livelihood to pastoralists. The advantage of controlling emissions reductions through this particular grazing system is that it can be staggered and numbers can be reduced to coincide with the ability for kangaroo harvesting and GHG targets. It is also a guaranteed and immediate mitigation activity.

This report provides information and accompanies instructional guidelines for pastoralists to assess their opportunity to integrate kangaroos into their traditional practices and in turn, access the carbon market. In 2022 carbon credits for soil sequestration could be achieved through the Australian market while CH_4 reduction would have to be achieved through the international market where enteric CH_4

reduction methods for reducing livestock numbers exist. There is also the option for pastoralists to harvest kangaroos in conjunction with implementing the HIR methodology. However, this methodology is controversial at this stage.

A KGS is viable to individual pastoralists or large stations, as most kangaroo quotas for commercial harvest and utilisation are not met. It would also address large human and animal welfare issues when overabundant kangaroos die in stressful circumstances, and reduce the cost of managing a pest animal. Reducing total grazing pressure and stocking rates of livestock also has the co-benefits of improving sustainability and biodiversity.

The KGS is not without issues that need attention. Those posing the greatest obstacles include that pastoralists currently get no return from kangaroos and potential investors in research and infrastructure, both on farm and in processing, are fearful of further industry contraction and declining demand. Investors doubt the capacity of the industry, as it currently operates, to supply high-quality reliably and regularly, accurately described clean product and meet animal welfare standards; However, with trials and further research to validate and improve the KGS and a review of policies to remove barriers, the issues could be addressed to make the KGS more economically viable.

The following recommendations would promote the implementation of KGS:

1. **Conduct a strategic review of the objectives and plans of kangaroo management to identify solutions to the major issues identified in this report.**

The review should lead to preparation of a National Kangaroo Strategy (Read *et al*. 2021), including asking the question 'do pastoralists want kangaroos to always be pests?'. It would instruct focused efforts for policy advocacy and reform, and coordinated research and development. Collaboration should come from other industry development and marketing agencies and Indigenous communities. The current lack of clarity and responsibility is an impediment to investment and represents a case of market failure.

Pastoralists have no incentive to work towards increasing the value of kangaroos. They can neither act in their private interests, nor deliver outcomes for kangaroo welfare or natural resources, which would be in the wider public interest. The review would incorporate innovative management arrangements for policy development and research and ensure the capacity for landholders including indigenous communities to capture carbon benefits from improved kangaroo management. It would consider the integration of kangaroos on pastoral lands as part of red meat production under a remit of RMAC.

To be actioned by AgriFutures Australia and MLA with support from Australian Government agriculture and environment departments.

2. **Conduct pilot trials of integrated kangaroo management.**

Pilot trials would determine sequestration and emissions reduction opportunities from innovative management, preferentially within a cluster or exclusion fence around a group of properties, to establish a form of proprietorship and a capacity to capture carbon credits, and to enable a prescribed kangaroo density to be set in relation to other grazing herbivores in a predator-controlled environment. The trials could also include investigations into achieving credits for the other co-benefits, such as for the environment and biodiversity.

Trials supported by research and development are needed to incentivise uptake of the KGS. Trials could improve product quality and consistency, and result in more detailed descriptions of products. Other price improvements could come from the development of a certification scheme, marketing, the introduction of meat standards and regular market updates.

Pastoralists risk losing market advantages if their peak industry bodies do not invest in more climate-friendly products, such as kangaroos. Without methods to reduce enteric CH_4 at scale, production of cultivated meat could increase and replace that of traditional meats to meet protein production goals while reducing national GHG emissions to achieve climate targets. An incentive could be to include low-GHG-producing kangaroo meat in addition to cultivated meat. Products that contain kangaroo and/or cultivated meat will produce less GHG than those containing livestock meat. While pastoralists cannot produce cultivated meat from their land, they can produce kangaroo. Products that also come from adaptively grazed land can also contribute to soil carbon sequestration.

To be actioned by corporate investment from landholders, carbon aggregators and ethical investors, with support from the Australian Government and with monitoring and evaluation by state environment departments and industry research bodies.

3. **Conduct further research to ensure the KGS would reduce enteric CH_4 emissions and increase soil carbon sequestration, while at the same time provide for the growing demand for protein.**

The Introduction and Background sections of this report state that kangaroos produce negligible amounts of CH_4, especially compared to livestock; however, research on a KGS for the purpose of reducing GHG across an economy and environment needs quantifying. Specific research projects could be incorporated into the trials. They should examine:

- quantification of enteric emissions by kangaroos as CH_4 produced per kilo of useable carcase
- the effect on total grazing pressure and soil carbon sequestration in the absence of, and in conjunction with, livestock
- production of meat at scale, in line with livestock production and especially entrepreneurs in the growing goat industry
- the effectiveness of exclusion fences to better manage total grazing pressure
- population growth, movement and harvesting for sustainable production over different environments and over La Niña and El Niño periods
- small-scale kangaroo survey techniques
- costs and benefits, including further input to the report spreadsheet, to enable pastoralists to assess their potential to implement the KGS
- life-cycle assessment, which would identify the true GHG savings potential taking into account (1) emissions from goats, manure, fertiliser, feed production and transport; (2) other GHGs, such as N_2O and CO_2, associated with these activities; and (3) greater protein calculations to also include harvested wallabies, which are not included in these calculations.

4. **Develop an ERF methodology that supports the KGS and a program that accounts for the co-benefits of the KGS.**

An alternative to a new methodology is the KGS being integrated into a current ERF method. The beef herd methodology could be expanded to include sheep, as well as an option for pastoralists to earn carbon credits from removing cattle and sheep, instead of removal being linked to liveweight production. Another option would be to offset livestock emissions by including kangaroo meat as part of the equivalent production. Lastly, the KGS could also be included in the new AL-MAP methodology.

This report covers a number of co-benefits, which under other activities or scenarios enable the manager to gain certification or credits for their efforts. While not impossible, it is difficult for a pastoralist implementing a KGS to apply for certification or credits under existing national or state environmental crediting schemes as there are no precedents. There is opportunity for a methodology to be developed in the private sector, which could also be aligned to the government-run markets; the methodology could be developed under the AfN Framework or Eco-Markets Australia.

To be actioned by research and development organisations that are supported and co-funded by red meat and livestock industry bodies and carbon aggregators.

5. **Develop a communications program to inform the wider community about the positive impact a KGS could have for reducing and sequestering Australia's GHG while simultaneously providing a source of protein and an alternative livelihood for pastoralists.**

Our background review revealed there are very few reviews that refer to systems similar to a KGS, despite similar modelling being conducted in 2008 – more than 14 years ago. The wider community is not aware the use of an alternative native species could bring about significant GHG savings for Australia. An informed community would advocate and encourage a KGS, leading to greater interest and uptake by pastoralists. While there may be some opposition from animal activist groups, which abhor the use of any animal for food, this should not undermine a KGS as an option.

A communications program would inform:

- the intention of the red meat industry to grow the livestock herd to meet protein demands without options to reduce greenhouse emissions
- that the proposed KGS is a new activity that would have a positive impact on reducing and sequestering Australia's GHG while simultaneously providing a source of protein and an alternative livelihood for pastoralists.

To be actioned by the Department of Climate Change, Energy, the Environment and Water.

References

AAS: Australian Academy of Science (2021). *The Risks to Australia of a 3°C Warmer World*. Canberra, ACT.

ABARES: Australian Bureau of Agricultural and Resource Economics and Sciences (2016). *Land use of Australia 2010-11*. Accessed: 7 May 2022, from: https://www.awe.gov.au/abares/aclump/land-use/land-use-of-australia-2010-11

ABARES: Australian Bureau of Agricultural and Resource Economics and Sciences (2022). *Agricultural Commodities and Trade Data*. Accessed: 3 May 2022, from: https://www.awe.gov.au/abares/research-topics/agricultural-outlook/data#agricultural-commodities

ABS: Australian Bureau of Statistics (2019). *Agricultural Commodities, Australia*. Accessed: 7 May 2022, from: https://www.abs.gov.au/statistics/industry/agriculture/agricultural-commodities-australia.

Afolayan, R. A., M. P. B. Deland, D. L. Rutley, C. D. K. Bottema, A. L. Elvers, R. W. Ponzoni and W. S. Pitchford (2002). Predictions of carcass meat, fat, and bone yield across diverse cattle genotypes using live-animal measures. *Animal Production Australia, 24,* 13-16.

Agriculture Victoria (2022). *Livestock Methane and Nitrogen Emissions*. Accessed: 7 May 2022, from: https://agriculture.vic.gov.au/climate-and-weather/understanding-carbon-and-emissions/livestock-methane-and-nitrogen-emissions

Alcock, D. and R. Hegarty (2006). Effects of pasture improvement on productivity, gross margin and methane emissions of a grazing sheep enterprise. *International Congress Series, 1293,* 103-106.

Alcock, D. J. and R. S. Hegarty (2011). Potential effects of animal management and genetic improvement on enteric methane emissions, emissions intensity and productivity of sheep enterprises at Cowra, Australia. *Animal Feed Science and Technology, 166-167,* 749-760.

Alexandratos, N. and J. Bruinsma (2012). *World Agriculture Towards 2030/2050: The 2012 Revision*. ESA Working Paper No. 12-03. Food and Agriculture Organization, Rome.

Almeida, A. K., R. S. Hegarty and A. Cowie (2021). Meta-analysis quantifying the potential of dietary additives and rumen modifiers for methane mitigation in ruminant production systems. *Animal Nutrition, 7,* 1219-1230.

Ampt, P. and A. Baumber (2006). Building connections between kangaroos, commerce and conservation in the rangelands. *Australian Zoologist, 33,* 398-409.

Arthur, P. (2015). *Genetic Technologies to Reduce Methane Emissions from Australian Beef Cattle*. New South Wales Department of Primary Industries, Orange, NSW.

Australian Competition and Consumer Commission (2011). *Green Marketing and the Australian Consumer Law*. Commonwealth of Australia, Canberra, ACT.

Australian Government (2011). *Rules for the Use of the National Carbon Offset Standard Certification Trademark*. IP Australia, Canberra, ACT.

Barnes, A. and G. Hill (1992). Estimating kangaroo damage to winter wheat crops in the Bungunya district of southern Queensland. *Wildlife Research, 19,* 417-427.

Baumber, A., C. Waters, R. Cross, G. Metternicht and M. Simpson (2020). Carbon farming for resilient rangelands: people, paddocks and policy. *The Rangeland Journal, 42,* 293-307.

BCT: Biodiversity Conservation Trust (2020). *Managing Overabundant Kangaroo Guidelines*. New South Wales Government, Sydney, NSW.

Bennett, M. B. (1999). Foot areas, ground reaction forces and pressures beneath the feet of kangaroos, wallabies and rat kangaroos (Marsupialia Macropodoidae). *Journal of Zoology (London), 247,* 365-369.

Bolwig, S. and P. Gibbon (2009). *Counting Carbon in the Market Place: Part 1 – Overview Paper: Report for the OECD*. Trade and Agriculture Directorate; Joint Working Party on Trade and Environment, Kongens Lyngby, Denmark.

Bond University (n.d.). *Growing Soil Carbon in Australia's Rangelands*. Soil Carbon Research Pty Limited, Gold Coast, Queensland.

Carbon Trust (2022). *What We Do*. Accessed: 16 March 2022, from: https://www.carbontrust.com/what-we-do.

Caughley, G., N. Shepherd and J. Short (1987). *Kangaroos, their Ecology and Management in the Sheep Rangelands of Australia*. Cambridge University Press, Melbourne, Victoria.

CER: Clean Energy Regulator (2021). *Emissions Reduction Fund Project Register*. Accessed: 4 July 2021, from: http://www.cleanenergyregulator.gov.au/ERF/project-and-contracts-registers/project-register

Charmley, E., S. R. O. Williams, P. J. Moate, R. S. Hegarty, R. M. Herd, V. H. Oddy, P. Reyenga, K. M. Staunton, A. Anderson and M. C. Hannah (2016). A universal equation to predict methane production of forage-fed cattle in Australia. *Animal Production Science, 56,* 169-180.

Chudleigh, P., D. Archbold, S. Simpson and J. Telford (2008). *Marketing Kangaroo Meat from the Sustainable Wildlife Enterprises: The Conservation Dimension*. Rural Industries Research and Development Corporation, Canberra, ACT.

Clark, P., E. Clark and B. L. Allen (2018). Sheep, dingoes and kangaroos: new challenges and a change of direction 20 years on. In: *Advances in Conservation through Sustainable Wildlife*. Eds: G. Baxter, N. Finch and P. Murray. University of Queensland, Brisbane, Queensland.

Climate Active (2019). *Australia's Collective Action*. Accessed: 10 May 2022, from: https://www.climateactive.org.au/.

Climate Active (2020). *Carbon Neutral Standard for Products and Services*. Commonwealth of Australia, Canberra, ACT.

Collins, W. J., C. P. Webber, P. M. Cox, C. Huntingford, J. Lowe, S. Sitch, S. E. Chadburn, E. Comyn-Platt, A. B. Harper, G. Hayman and T. Powell (2018). Increased importance of methane reduction for a 1.5 degree target. *Environmental Research Letters, 13,* 054003.

Conant, R. T., K. Paustian and E. T. Elliott (2001). Grassland management and conversion into grassland: effects on soil carbon. *Ecological Applications, 11,* 343-355.

Cooney, R., A. Baumber, P. Ampt and G. Wilson (2009). Sharing Skippy: how can landholders be involved in kangaroo production in Australia? *The Rangeland Journal, 31,* 283-292.

Coulson, G. M. and J. A. Raines (1985). Methods for small-scale surveys of grey kangaroo populations. *Wildlife Research, 12,* 119-125.

Croft, D. B. and I. Witte (2021). The perils of being populous: control and conservation of abundant kangaroo species. *Animals, 11,* 1753.

CSF: Climate Solutions Fund (2020). *Understanding your Soil Carbon Project: Climate Solutions Fund User Guide for Measured Soil Carbon Projects*. Clean Energy Regulator, Canberra, ACT.

DAWE: Department of Agriculture, Water and the Environment (2021a). *Agriculture Stewardship Package*. Canberra, ACT.

DAWE: Department of Agriculture, Water and the Environment (2021b). *Agricuture Stewardship Program Round 2 Frequently Asked Questions*. Accessed: 18 May 2022, from: https://www.awe.gov.au/sites/default/files/documents/ag-steward-program-round-2-faq.pdf

DAWE: Department of Agriculture, Water and the Environment (2021c). *Outback Australia – The Rangelands*. Accessed: 7 May 2022, from: https://www.awe.gov.au/agriculture-land/land/rangelands

DAWE: Department of Agriculture, Water and the Environment (2022a). *Carbon + Biodiversity Pilot*. Accessed: 18 May 2022, from: https://www.awe.gov.au/agriculture-land/farm-food-drought/natural-resources/landcare/sustaining-future-australian-farming/carbon-biodiversity-pilot

DAWE: Department of Agriculture, Water and the Environment (2022b). *Levy and Charge Rates*. Accessed: 11 March 2022, from: https://www.awe.gov.au/agriculture-land/farm-food-drought/levies/rates

DAWE: Department of Agriculture, Water and the Environment (2022c). *Macropod Quotas and Harvest for Commercial Harvest Areas in NSW, QLD, SA and WA*. Accessed: 7 May 2022, from: https://www.awe.gov.au/sites/default/files/env/pages/ee20f301-6c6c-44e4-aa24-62a32d412de5/files/kangaroo-statistics-states-2020.pdf

DCCEEW: Department of Climate Change, Energy, the Environment and Water (2022). *Independent Review of ACCUs*. Accessed: 4 July 2022, from: https://minister.dcceew.gov.au/bowen/media-releases/independent-review-accus

Dellow, D. W., I. D. Hume, R. T. J. Clarke and T. Bauchop (1988). Microbial activity in the forestomach of free-living macropodid marsupials: comparisons with laboratory studies. *Australian Journal of Zoology, 36,* 383-395.

Demsetz, H. (1967). Toward a theory of property rights. *American Economic Review, 57,* 347-359.

Dignac, M.-F., D. Derrien, P. Barré, S. Barot, L. Cécillon, C. Chenu, T. Chevallier, G. T. Freschet, P. Garnier, B. Guenet, M. Hedde, K. Klumpp, G. Lashermes, P.-A. Maron, N. Nunan, C. Roumet and I. Basile-Doelsch (2017). Increasing soil carbon storage: mechanisms, effects of agricultural practices and proxies: a review. *Agronomy for Sustainable Development, 37,* 14.

DISER: Department of Industry, Science, Energy and Resources (2020). *National Inventory Report: The Australian Government Submission to the United Nations Framework Convention on Climate Change Australian National Greenhouse Accounts.* Commonwealth of Australia, Canberra, ACT.

DISER: Department of Industry, Science, Energy and Resources (2021). *National Inventroy Report: The Australian Government Submission to the United Nations Framework Convention on Climate Change Australian National Greenhouse Accounts*. Commonwealth of Australia, Canberra, ACT.

DISER: Department of Industry, Science, Energy and Resources (2022a). *Australia Submits New Emissions Target to UNFCCC*. Accessed: 4 July 2022, from: https://www.dcceew.gov.au/about/news/australia-submits-new-emissions-target-to-unfccc

DISER: Department of Industry, Science, Energy and Resources, (2022b). *Climate Active*. Accessed: 10 May 2022, from: https://www.industry.gov.au/regulations-and-standards/climate-active

Dorrough, J., A. Yen, V. Turner, S. Clark, J. Crosthwaite and J. Hirth (2004). Livestock grazing management of biodiversity conservation in Australian temperate grassy landscapes. *Crop and Pasture Science, 55,* 279-295.

Dubbin, W. (2001). *Soils*. The Natural History Museum, London, United Kingdom.

Eckard, R. J., C. Grainger and C. A. M. de Klein (2010). Options for the abatement of methane and nitrous oxide from ruminant production: a review. *Livestock Science, 130,* 47-56.

Ecospecifier Global (2022). *Introduction to Ecolabels and Environmental Product Declarations*. Accessed: 16 March 2022, from: http://www.ecospecifier.com.au/knowledge-green/technical-guides/technical-guide-9-introduction-to-ecolabels-and-environmental-product-declarations/#type%20I

Eldridge, D. J. and M. Delgado-Baquerizo (2017). Continental-scale impacts of livestock grazing on ecosystem supporting and regulating services. *Land Degradation & Development, 28,* 1473-1481.

Eldridge, D. J., M. Delgado-Baquerizo, S. K. Travers, J. Val and I. Oliver (2017). Do grazing intensity and herbivore type affect soil health? Insights from a semi-arid productivity gradient. *Journal of Applied Ecology, 54,* 976-985.

Eldridge, D. J., M. Delgado-Baquerizo, S. K. Travers, J. Val, I. Oliver, J. W. Dorrough and S. Soliveres (2018). Livestock activity increases exotic plant richness, but wildlife increases native richness, with stronger effects under low productivity. *Journal of Applied Ecology, 55,* 766-776.

Eldridge, D. J., J. Ding and S. K. Travers (2021). Low-intensity kangaroo grazing has largely benign effects on soil health. *Ecological Management & Restoration, 22,* 58-63.

Eldridge, D. J. and D. Rath (2002). Hip holes: kangaroo (Macropus spp.) resting sites modify the physical and chemical environment of woodland soils. *Austral Ecology, 27,* 527-536.

ERAC: Emissions Reduction Assurance Committee (2022). *Emissions Reduction Assurance Committee Findings on the Emissions Reduction Fund's Human Induced Regeneration Method*. Clean Energy Regulator, Canberra, ACT.

Etminan, M., G. Myhre, E. J. Highwood and K. P. Shine (2016). Radiative forcing of carbon dioxide, methane, and nitrous oxide: a significant revision of the methane radiative forcing. *Geophysical Research Letters, 43,* 12614-12623.

FAO: Food and Agriculture Organization of the United Nations (2022). *FAOSTAT*. Accessed: 3 May 2022, from: https://www.fao.org/faostat/en/#data/GE

Fisher, A., L. Hunt, C. James, J. Landsberg, D. Phelps, A. Smyth and D. Watson (2004). *Review of Total Grazing Pressure Management Issues and Priorities for Biodiversity Conservation in Rangelands: A Resource to Aid NRM Planning*. Desert Knowledge CRC and Tropical Savannas CRC, Alice Springs, NT.

Fitzsimons, J., S. Legge, B. Traill and J. Woinarski (2010). *Into Oblivion? The Disappearing Native Mammals of Northern Australia*. The Nature Conservancy, Melbourne, Victoria.

Food, G. L. and A. C. Fogerty (1982). The fatty acids of kangaroo and wallaby meat. *CSIRO Food Quarterly, 42,* 57-60.

Foran, B. (2021). Australian rangeland futures: time now for systemic responses to interconnected challenges. *Proceedings of the Royal Society of Victoria, 133,* 7-13.

Forster, P., V. Ramaswamy, P. Artaxo, T. Berntsen, R. Betts, D. W. Fahey, J. Haywood, J. Lean, D. C. Lowe, G. Myhre, J. Nganga, R. Prinn, G. Raga, M. Schulz and R. Van Dorland, Eds. (2007). *Changes in Atmospheric Constituents and in Radiative Forcing. Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*. Cambridge University Press, Cambridge, United Kingdom.

Frank, A., G. Wardle, A. Greenville and C. Dickman (2016). Cattle removal in arid Australia benefits kangaroos in high quality habitat but does not affect camels. *The Rangeland Journal, 38,* 73-84.

Freeman, A. and K. Pobke (2021). Macropod management is critical for recovery of Sheoak Grassy Woodlands on Eyre Peninsula, South Australia. *Ecological Management & Restoration, 22,* 44-49.

Gerber, P. J., H. Steinfeld, B. Henderson, A. Mottet, C. Opio, J. Dijkman, A. Falcucci and G. Tempio (2013). *Tackling Climate Change through Livestock – A Global Assessment of Emissions and Mitigation Opportunities*. Food and Agriculture Organization of the United Nations, Rome, Italy.

Gibson, E. (2022). *Agriculture Biodiversity Stewardship Market Bill 2022*. Parliament of Australia, Canberra, ACT.

Gordon, I. J., M. A. Snape, D. Fletcher, B. Howland, G. Coulson, M. Festa-Bianchet, P. Caley, S. McIntyre, T. Pople, C. E. Wimpenny, G. Baines and D. Alcock (2021). Herbivore management for biodiversity conservation: a case study of kangaroos in the Australian Capital Territory. *Ecological Management & Restoration., 22,* 124-137.

Greenwood, K. L. and B. M. McKenzie (2001). Grazing effects on soil physical properties and the consequences for pastures: a review. *Australian Journal of Experimental Agriculture, 41,* 1231-1250.

Grigg, G. (2002). Conservation benefit from harvesting kangaroos: status report at the start of a new millennium. In: *A Zoological Revolution: Using Native Fauna to Assist in its Own Survival*. Eds: D. Lunney and C. Dickman. Royal Zoological Society of New South Wales Australian Museum, Mosman, NSW.

Hacker, R. B., K. Sinclair and C. M. Waters (2019). Total grazing pressure–a defining concept for extensive pastoral systems in the southern rangelands of Australia. *The Rangeland Journal, 41,* 457-460.

Hao, Y. and Z. He (2019). Effects of grazing patterns on grassland biomass and soil environments in China: a meta-analysis. *PloS one, 14,* e0215223.

Harmsen, J. H. M., D. Vuuren, B. Bodirsky, J. Chateau, O. Durand-Lasserve, L. Drouet, O. Fricko, S. Fujimori, D. Gernaat, T. Hanaoka, J. Hilaire, K. Keramidas, G. Luderer, M. C. Moura, F. Sano, S. Smith and K. Wada (2020). The role of methane in future climate strategies: mitigation potentials and climate impacts. *Climatic Change, 163,* 1409-1425.

Hegarty, R. S. and A. K. Almeida (2021). *Kangaroo Farming: A Role in Achieving Carbon Neutrality in the Red Meat Industry of NSW by 2050*. NSW Department of Primary Industries, Sydney, NSW.

Henchion, M., M. Hayes, A. M. Mullen, M. Fenelon and B. Tiwari (2017). Future Protein Supply and Demand: Strategies and Factors Influencing a Sustainable Equilibrium. *Foods (Basel, Switzerland), 6,* 53.

Herbert Smith Freehills (2022). *Biodiveristy Market Proposed for Australian Market*. Accessed: 18 May 2022, from: https://hsfnotes.com/environmentaustralia/2022/02/11/biodiversity-market-proposed-for-australian-agricultural-land/

Hilker, F. and E. Liz (2019). Proportional threshold harvesting in discrete-time population models. *Journal of Mathematical Biology, 79,* 1927-1951.

Hill, M. J., S. H. Roxburgh, G. M. McKeon, J. O. Carter and D. J. Barrett (2006). Analysis of soil carbon outcomes from interaction between climate and grazing pressure in Australian rangelands using Range-ASSESS. *Environmental Modelling & Software, 21,* 779-801.

Hoedt, E. C., P. Ó. Cuív, P. N. Evans, W. J. M. Smith, C. S. McSweeney, S. E. Denman and M. Morrison (2016). Differences down-under: alcohol-fueled methanogenesis by archaea present in Australian macropodids. *The ISME Journal, 10,* 2376-2388.

Holt, J. A. (1997). Grazing pressure and soil carbon, microbial biomass and enzyme activities in semi-arid northeastern Australia. *Applied Soil Ecology, 5,* 143-149.

Hopwood, P. R., M. Hilmi and R. M. Butterfield (1976). A comparative study of the carcass composition of kangaroos and sheep. *Australian Journal of Zoology, 24,* 1-6.

Hume, I. D. (1984). Microbial fermentation in herbivorous marsupials. *BioScience, 34,* 435-440.

Hume, I. D. (1999). *Marsupial Nutrition*. Cambridge University Press, Cambridge, United Kingdom.

Hunt, W., M. Bedoya-Perez, G. Geesink, A. Van Den Heuvel, J. Mullen and D. Frost (2021). Harvesting agile wallabies for human consumption in the Northern Territory of Australia. *Ecological Management & Restoration, 22,* 141-146.

Infrastructure Australia (2019). *Small Towns, Rural and Remote Areas: Australian Infrastructure Audit*. Australian Government, Sydney, NSW.

IPCC: Intergovernmental Panel on Climate Change (2014). *Climate Change 2014: Synthesis Report. Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change*. Geneva, Switzerland.

IPCC: Intergovernmental Panel on Climate Change (2018). *Global Warming of 1.5°C: An IPCC Special Report on the Impacts of Global Warming of 1.5°C Above Pre-industrial Levels and Related Global Greenhouse Gas Emission Pathways, in the Context of Strengthening the Global Response to the Threat of Climate Change, Sustainable Dvelopment, and Eforts to Eadicate Poverty*. Cambridge University Press, Cambridge, United Kingdom.

IPCC: Intergovernmental Panel on Climate Change (2022). *Climate Change 2022: Mitigation of Climate Change*. Geneva, Switzerland.

Joblin, K. N. (1999). Ruminal acetogens and their potential to lower ruminant methane emissions. *Australian Journal of Agricultural Research, 50,* 1307-1307.

Kempton, T. J., R. M. Murray and R. A. Leng (1976). Methane production and digestibility measurements in the grey kangaroo and sheep. *Australian Journal of Biological Sciences, 29,* 209-214.

Klieve, A. V. O., D, L. McMillen, A. J. Maguire and M. N. O'Leary (2007). *How to Make the Most from Kangaroos – A Ruminant Perspective*. Northern Beef Research Update Conference, Townsville, Queensland.

Koerner, S. E., M. D. Smith, D. E. Burkepile, N. P. Hanan, M. L. Avolio, S. L. Collins, A. K. Knapp, N. P. Lemoine, E. J. Forrestel, S. Eby, D. I. Thompson, G. A. Aguado-Santacruz, J. P. Anderson, T. M. Anderson, A. Angassa, S. Bagchi, E. S. Bakker, G. Bastin, L. E. Baur, K. H. Beard, E. A. Beever, P. J. Bohlen, E. H. Boughton, D. Canestro, A. Cesa, E. Chaneton, J. Cheng, C. M. D'Antonio, C. Deleglise, F. Dembélé, J. Dorrough, D. J. Eldridge, B. Fernandez-Going, S. Fernández-Lugo, L. H. Fraser, B. Freedman, G. García-Salgado, J. R. Goheen, L. Guo, S. Husheer, M. Karembé, J. M. H. Knops, T. Kraaij, A. Kulmatiski, M.-M. Kytöviita, F. Lezama, G. Loucougaray, A. Loydi, D. G. Milchunas, S. J. Milton, J. W. Morgan, C. Moxham, K. C. Nehring, H. Olff, T. M. Palmer, S. Rebollo, C. Riginos, A. C. Risch, M. Rueda, M. Sankaran, T. Sasaki, K. A. Schoenecker, N. L. Schultz, M. Schütz, A. Schwabe, F. Siebert, C. Smit, K. A. Stahlheber, C. Storm, D. J. Strong, J. Su, Y. V. Tiruvaimozhi, C. Tyler, J. Val, M. L. Vandegehuchte, K. E. Veblen, L. T. Vermeire, D. Ward, J. Wu, T. P. Young, Q. Yu and T. J. Zelikova (2018). Change in dominance determines herbivore effects on plant biodiversity. *Nature Ecology & Evolution, 2,* 1925-1932.

Lal, R. (2004). Soil carbon sequestration impacts on global climate change and food security. *Science, 304,* 1623-1627.

Lal, R. (2008). Carbon sequestration. *Philosophical Transactions of the Royal Society B: Biological Sciences, 363,* 815-830.

Laubsch, R. and M. Kitschke (2018). *Kangaroos Compound Drought Pressure*. Accessed: 11 March 2022, from: https://www.stockjournal.com.au/story/5681216/stock-feed-vanishing-as-kangaroos-invade/.

Lebbink, G., J. Dwyer and R. Fensham (2021). Managed livestock grazing for conservation outcomes in a Queensland fragmented landscape. *Ecological Management & Restoration, 22,* 5-9.

Legge, S., M. S. Kennedy, R. A. Y. Lloyd, S. A. Murphy and A. Fisher (2011). Rapid recovery of mammal fauna in the central Kimberley, northern Australia, following the removal of introduced herbivores. *Austral Ecology, 36,* 791-799.

LLS: Local Land Services (2020a). *Managing Pastures for Soil Health Fact Sheet 12*. State of New South Wales, Dubbo, NSW.

LLS: Local Land Services (2020b). *What is a Healthy Soil? Fact Sheet 11*. State of New South Wales, Dubbo, NSW.

Lou, J. (2020). *Carbon Management: A Step by Step Guide*. Paia, Skudai, Singapore.

LPA: Livestock Production Assurance (2015). *Livestock Production Assurance System Guidelines*. Sydney, NSW.

Lynch, J., M. Cain, R Pierrehumbert and M. Allen (2020). Demonstrating GWP*: a means of reporting warming – equivalent emissions that captures the contrasting impacts of short- and long- lived climate pollutants. *Environmental Research Letters, 15,* 044023.

Macintosh, A., D. Butler, D. Ansell and M. Waschka (2022a). *The Emissions Reduction Fund (ERF): Problems and Solutions*. Australian National University, Canberra, ACT.

Macintosh, A., D. Butler, M. Evans, P. Larraondo, D. Ansell and P. Gibbons (2022b). *The ERF's Human-induced Regeneration (HIR): What the Beare and Chambers Report Really Found and a Critique of its Method*. Australian National University, Canberra, ACT.

Macintosh, A., G. Roberts and S. Buchan (2019). *Improving Carbon Markets to Increase Farmer Participation*. AgriFutures Australia, Wagga Wagga, NSW.

Mayberry, D., H. Bartlett, J. Moss, S. Wiedemann and M. Herrero (2018). *Greenhouse Gas Mitigation Potential of the Australian Red Meat Production and Processing Sectors*. Meat & Livestock Australia Limited, North Sydney, NSW.

Mayberry, D., H. Bartlett, J. Moss, T. Davison and M. Herrero (2019). Pathways to carbon-neutrality for the Australian red meat sector. *Agricultural Systems, 175,* 13-21.

MBWSR: Minnesota Board of Water and Soil Resources (2019). *Carbon Sequestration in Grasslands*. Accessed: 7 May 2022, from: http://bwsr.state.mn.us/carbon-sequestration-grasslands.

McLeod, R. (2004). *Counting the Cost: Impact of Invasive Animals in Australia*. Pest Animal Control CRC, Canberra, ACT.

McLeod, S. R., N. Finch, G. Wallace and A. R. Pople (2021). Assessing the spatial and temporal organization of Red Kangaroo, Western Grey Kangaroo and Eastern Grey Kangaroo populations in eastern Australia using multivariate autoregressive state-space models. *Ecological Management & Restoration, 22,* 106-123.

McMurtrie, A. and A. Kerle (2021). The dying has begun. It's a pretty rough backdrop to a job. *Ecological Management & Restoration, 22,* 64-65.

Medhurst, A. and R. Segrave (2007). *Why Do Farming Families Diversify?* Rural Industries Research and Development Corporation, Barton, ACT.

Mills, C. H., H. Waudby, G. Finlayson, D. Parker, M. Cameron and M. Letnic (2020). Grazing by over-abundant native herbivores jeopardizes conservation goals in semi-arid reserves. *Global Ecology and Conservation, 24,* e01384.

MLA: Meat and Livestock Austalia (2021). *Cost of Production Beef, Lamb and Goat*. Accessed: 20 January 2022, from: https://www.mla.com.au/extension-training-and-tools/tools-calculators/Cost-of-production/#

MLA: Meat and Livestock Australia (2019). *State of the Industry Report: the Australian Red Meat and Livestock Industry*. Meat and Livestock Austalia, Sydney, NSW.

MLA: Meat and Livestock Australia (2020). *The Australian Red Meat Industry's Carbon Neutral by 2030 Roadmap*. Meat and Livestock Australia, Sydney, NSW.

MLA: Meat and Livestock Australia (2022a). *Prices and Markets Statistics for the Week Ending Tuesday, February 08, 2022*. Meat and Livestock Australia, Sydney, NSW.

MLA: Meat and Livestock Australia (2022b). *Protein Futures – Innovative Science and Technology for Today and Tomorrow.* CSIRO Conference 14-15 June, Brisbane, Queensland.

Montague-Drake, R. and D. B. Croft (2004). Do kangaroos exhibit water-focused grazing patterns in arid New South Wales? A case study in Sturt National Park. *Australian Mammalogy, 26,* 87-100.

Morris, K. and P. Reich (2013). *Understanding the Relationship between Livestock Grazing and Wetland Condition*. Department of Environment and Primary Industry, Heidelberg, Victoria.

Morris, T. and M. Letnic (2017). Removal of an apex predator initiates a trophic cascade that extends from herbivores to vegetation and the soil nutrient pool. *Proceedings of the Royal Society B: Biological Sciences, 284,* 20170111.

Nadolny, C. (1998). Towards integrating farming and conservation: the role of native pastures. *Pacific Conservation Biology, 4,* 70-78.

NGGI: National Greenhouse Gas Inventory (2005). *The Australian Government Submission to the United Nations Framework Convention on Climate Change*. Australian Greenhouse Office, Canberra, ACT.

NGGI: National Greenhouse Gas Inventory (2021). *National Greenhouse Gas Inventory – Paris Agreement Inventory*. Accessed: 8 September 2021, from: https://ageis.climatechange.gov.au/

Noble, J. C. and D. Tongway (1986). Herbivores in arid and semi-arid rangelands. In: *Australian Soils: The Human Impact*. Eds: J. Russell and R. Isbell. University of Queensland, Brisbane, Queensland.

Norman, C. and M. Kreye (2020). *How Forests Store Carbon*. Accessed: 13 May 2022, from: https://extension.psu.edu/how-forests-store-carbon

Northup, B. K., J. Brown and J. A. Holt (1999). Grazing impacts on the spatial distribution of soil microbial biomass around tussock grasses in a tropical grassland. *Applied Soil Ecology, 13,* 259-270.

NRMMC: Natural Resource Management Ministerial Council (2008). *National Code of Practice for the Humane Shooting of Kangaroos and Wallabies for Commercial Purposes*. Department of the Environment, Water, Heritage and the Arts, Canberra, ACT.

NSW Farmers: New South Wales Farmers (2019). *Kangaroos Decimate Farmers' Profits*. Accessed: 20 June 2020, from: http://www.nswfarmers.org.au/NSWFA/Posts/The_Farmer/Community/Kangaroos_decimate_farmers_profits.aspx

NSWOEH: New South Wales Office of Environment and Heritage (2019). *2018 Annual Report: New South Wales Commercial Kangaroo Harvest Management Plan 2017–21*. Office of Environment and Heritage, Sydney, NSW.

Nunes, A. V., C. A. Peres, P. de A. L. Constantino, E. Fischer and M. R. Nielsen (2021). Wild meat consumption in tropical forests spares a significant carbon footprint from the livestock production sector. *Scientific Reports, 11,* 19001-19001.

Olsen, P. and M. Braysher (2000). *Situation Analysis Report: Current State of Scientific Knowledge on Kangaroos in the Environment, including Ecological and Environmental Impact and Effect of Culling*. New South Wales National Parks and Wildlife Services, Sydney, NSW.

Olsen, P. and T. Low (2006). *Situation Analysis Report: Update on Current State of Scientific Knowledge on Kangaroos in the Environment, Including Ecological and Economic Impact and Effect of Culling*. New South Wales National Parks and Wildlife Services, Sydney, NSW.

Orgill, S. E., C. Waters, G. Melville, I. Toole, Y. Alemseged and W. Smith (2017). Sensitivity of soil organic carbon to grazing management in the semi-arid rangelands of south-eastern Australia. *The Rangeland Journal, 39,* 153-167.

Ouwerkerk, D., A. V. Klieve, R. J. Forster, J. M. Templeton and A. J. Maguire (2005). Characterization of culturable anaerobic bacteria from the forestomach of an eastern grey kangaroo, *Macropus giganteus*. *Letters in Applied Microbiology, 41,* 327-333.

Ouwerkerk, D., A. J. Maguire, L. McMillen and A. V. Klieve (2007). Why kangaroos do not produce methane. *Recent Advances in Animal Nutrition in Australia, 16,* 101-104.

Pahl, L. (2019a). Macropods, feral goats, sheep and cattle. 1. Equivalency in how much they eat. *The Rangeland Journal, 41,* 497-518.

Pahl, L. (2019b). Macropods, feral goats, sheep and cattle. 2. Equivalency in what and where they eat. *The Rangeland Journal, 41,* 519-533.

Pedler, R., J. Read, K. Moseby, R. Kingsford and R. West (2021). Proactive management of kangaroos for conservation and ecosystem restoration – Wild Deserts, Sturt National Park, NSW. *Ecological Management & Restoration, 22,* 90-98.

Pope, P. B., S. E. Denman, M. Jones, S. G. Tringe, K. Barry, S. A. Malfatti, A. C. McHardy, J. F. Cheng, P. Hugenholtz, C. S. McSweeney and M. Morrison (2010). Adaptation to herbivory by the Tammar wallaby includes bacterial and glycoside hydrolase profiles different from other herbivores. *Proceedings of the National Academy of Sciences of the United States of America, 107,* 14793-14798.

Prather, M. J., C. D. Holmes and J. Hsu (2012). Reactive greenhouse gas scenarios: systematic exploration of uncertainties and the role of atmospheric chemistry. *Geophysical Research Letters, 39,* L09803.

Queensland DES: Queensland Department of Environment and Science (2022). *Kangaroo Damage Mitigation Permits*. Accessed: 9 May 2022, from: https://environment.des.qld.gov.au/licences-permits/plants-animals/damage-mitigation-permits/kangaroo-dmp

Raihan, A., R. Begum, M. Nizam, S. Mastura and S. Syed Abdullah (2019). A review of emission reduction potential and cost savings through forest carbon sequestration. *Asian Journal of Water, Environment and Pollution, 16,* 1-7.

Rao, S. (2021). Animal Agriculture is the leading cause of climate change. *Journal of Ecological Society, 32-33*, 155-167.

RCS: Resource Consulting Services (n.d.). *RCS Regenerative Grazing Principles*. Accessed: 9 May 2022, from: https://www.rcsaustralia.com.au/wp-content/uploads/RCS-Regenerative-Grazing-Principles-Overview.pdf

Read, J., J. Guerin, D. Duval and K. Moseby (2021a). Charred and chewed chalkies: effects of fire and herbivory on the reintroduction of an endangered wattle. *Ecological Management & Restoration, 22,* 35-43.

Read, J. L., G. R. Wilson, G. Coulson, R. Cooney, D. C. Paton, K. E. Moseby, M. A. Snape and M. J. Edwards (2021b). Improving kangaroo management: a joint statement. *Ecological Management & Restoration, 22,* 186-192.

Reisinger, A., H. Clark, A. L. Cowie, J. Emmet-Booth, C. Gonzalez Fischer, M. Herrero, M. Howden and S. Leahy (2021). How necessary and feasible are reductions of methane emissions from livestock to support stringent temperature goals? *Philosophical Transactions of the Royal Society A: Mathematical, Physical and Engineering Sciences, 379,* 20200452.

Ridoutt, B. (2023). *Pathways to Climate Neutrality for the Australian Red Meat Industry*. Meat and Livestock Australia, North Sydney, NSW.

RMAC: Red Meat Advisory Council (2019). *Red Meat 2030: A Shared Vision and Direction for Australia's Red Meat and Livestock Businesses*. Red Meat Advisory Council, Canberra, ACT.

Roesch, A., P. Weisskopf, H. Oberholzer, A. Valsangiacomo and T. Nemecek (2019). An approach for describing the effects of grazing on soil quality in life-cycle assessment. *Sustainability, 11,* 4870.

Rook, A. and J. R. B. Tallowin (2003). Grazing and pasture management for biodiversity benefit. *Animal Research, 52,* 181-189.

Rural Property NSW: Rural Propery New South Wales (2019). *Tough Times Reveal Value of Exclusion Fencing*. Accessed: 11 March 2022, from: https://ruralpropertynsw.com.au/post/73/tough-times-reveal-value-of-exclusion-fencing

Sanderman, J. and R. Farquharson (2010). *Soil Carbon Sequestration Potential: A Review for Australian Agriculture*. CSIRO, Urrbrae, SA.

Saunois, M., A. R. Stavert, B. Poulter, P. Bousquet, J. G. Canadell, R. B. Jackson, P. A. Raymond, E. J. Dlugokencky, S. Houweling, P. K. Patra, P. Ciais, V. K. Arora, D. Bastviken, P. Bergamaschi, D. R. Blake, G. Brailsford, L. Bruhwiler, K. M. Carlson, M. Carrol, S. Castaldi, N. Chandra, C. Crevoisier, P. M. Crill, K. Covey, C. L. Curry, G. Etiope, C. Frankenberg, N. Gedney, M. I. Hegglin, L. Höglund-Isaksson, G. Hugelius, M. Ishizawa, A. Ito, G. Janssens-Maenhout, K. M. Jensen, F. Joos, T. Kleinen, P. B. Krummel, R. L. Langenfelds, G. G. Laruelle, L. Liu, T. Machida, S. Maksyutov, K. C. McDonald, J. McNorton, P. A. Miller, J. R. Melton, I. Morino, J. Müller, F. Murguia-Flores, V. Naik, Y. Niwa, S. Noce, S. O'Doherty, R. J. Parker, C. Peng, S. Peng, G. P. Peters, C. Prigent, R. Prinn, M. Ramonet, P. Regnier, W. J. Riley, J. A. Rosentreter, A. Segers, I. J. Simpson, H. Shi, S. J. Smith, L. P. Steele, B. F. Thornton, H. Tian, Y. Tohjima, F. N. Tubiello, A. Tsuruta, N. Viovy, A. Voulgarakis, T. S. Weber, M. van Weele, G. R. van der Werf, R. F. Weiss, D. Worthy, D. Wunch, Y. Yin, Y. Yoshida, W. Zhang, Z. Zhang, Y. Zhao, B. Zheng, Q. Zhu, Q. Zhu and Q. Zhuang (2020). The global methane budget 2000–2017. *Earth System Science Data, 12,* 1561-1623.

Seneviratne, S. I., N. Nicholls, D. Easterling, C. M. Goodess, S. Kanae, J. Kossin, Y. Luo, J. Marengo, K. McInnes, M. Rahimi, M. S. Reichstein, A., C. Vera and X. Zhang (2012). Changes in climate extremes and their impacts on the natural physical environment. In: *Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation*. Eds: C. B. Field, V. Barros, T. F. Stocker, D. Qin, D. J. Dokken, K. L. Ebi, M. D. Mastrandrea, K. J. Mach, G. K. Plattner, S. K. Allen, M. Tignor and P. M. Midgley. Cambridge University Press, Cambridge, United Kingdom.

Shepherd, N. C. (1983). The feasibility of farming kangaroos. *The Australian Rangeland Journal*, *5,* 35-44.

Shindell, D., C. I. Kuylenstierna Johan, E. Vignati, R. van Dingenen, M. Amann, Z. Klimont, C. Anenberg Susan, N. Muller, G. Janssens-Maenhout, F. Raes, J. Schwartz, G. Faluvegi, L. Pozzoli, K. Kupiainen, L. Höglund-Isaksson, L. Emberson, D. Streets, V. Ramanathan, K. Hicks, N. T. K. Oanh, G. Milly, M. Williams, V. Demkine and D. Fowler (2012). Simultaneously mitigating near-term climate change and improving human health and food security. *Science, 335,* 183-189.

Sinclair, K., A. L. Curtis, R. B. Hacker and T. Atkinson (2019). Stakeholder judgements of the social acceptability of control practices for kangaroos, unmanaged goats and feral pigs in the south-eastern rangelands of Australia. *The Rangeland Journal, 41,* 485-496.

Smith, D., K. Waddell and B. L. Allen (2020). Expansion of vertebrate pest exclusion fencing and its potential benefits for threatened fauna recovery in Australia. *Animals, 10,* 1550.

Soils Revealed (2016). *Soil Carbon Can Help Combat Climate Change*. Accessed: 7 May 2022, from: https://soilsrevealed.org/

Sommer, L. and J. Bishop (2022). *Carbon Farming and Biodiversity Conservation: Case Studies of Three Queensland Beef Properties*. WWF Australia, Sydney, NSW.

Spiegel, N. and P. Greenwood (2019). Meat production from wild kangaroo: the species, industry, carcass characteristics and meat quality traits. In: *More than Beef, Pork and Chicken – The Production, Processing, and Quality Traits of Other Sources of Meat for Human Diet*. Eds: J. M. Lorenzo, P. E. S. Munekata, F. J. Barba and F. Toldrá. Springer International Publishing, Cham, Switzerland.

Stevens, C. E. and I. D. Hume (1998). Contributions of microbes in vertebrate gastrointestinal tract to production and conservation of nutrients *Physiological Reviews, 78,* 393-427.

Stevens, W. (2001). *Declining Biodiversity and unsutainable Agricultural Production – Common Cause, Common Solution?* Science, Technology, Environment and Resources Group, Parliament of Australia, Canberra, ACT.

Sustainability Steering Group (2022). *Australian Beef Sustainability Framework – 2022 Annual Update*. Red Meat Advisory Council, Sydney, NSW.

SWNRM: South West Natural Resouce Management Ltd (2017). *Economic Impact Analysis Collaborative Area Management Phase 2*. Queensland Feral Pest Initiative, Charleville, Queensland.

Teague, R. and U. Kreuter (2020). Managing grazing to restore soil health, ecosystem function, and ecosystem services. *Frontiers in Sustainable Food Systems, 4,* 534187.

The Climate Council (2021). *Agriculture's Contribution to Australia's Greenhouse Emissions*. Accessed: 16 May 2022, from: https://www.climatecouncil.org.au/resources/australia-agriculture-climate-change-emissions-methane/

Thomas, N., C. Smith and P. Hinton (2022). *Australian Biodiversity Trading Platform Launched*. Accessed: 18 May 2022, from: https://www.claytonutz.com/knowledge/2021/december/australian-biodiversity-trading-platform-launched

Thomsen, D. A., K. Muir and J. Davies (2006). Aboriginal perspectives on kangaroo management in South Australia. *The Rangeland Journal, 28,* 127-137.

UNEP & CCAC: United Nations Environment Programme and Climate and Clean Air Coalition (2021). *Global Methane Assessment: Summary for Decision Makers*. United Nations Environment Programme, Nairobi, Kenya.

van Lingen, H. J., M. Niu, E. Kebreab, S. C. Valadares Filho, J. A. Rooke, C.-A. Duthie, A. Schwarm, M. Kreuzer, P. I. Hynd, M. Caetano, M. Eugène, C. Martin, M. McGee, P. O'Kiely, M. Hünerberg, T. A. McAllister, T. T. Berchielli, J. D. Messana, N. Peiren, A. V. Chaves, E. Charmley, N. A. Cole, K. E. Hales, S.-S. Lee, A. Berndt, C. K. Reynolds, L. A. Crompton, A.-R. Bayat, D. R. Yáñez-Ruiz, Z. Yu, A. Bannink, J. Dijkstra, D. P. Casper and A. N. Hristov (2019). Prediction of enteric methane production, yield and intensity of beef cattle using an intercontinental database. *Agriculture, Ecosystems & Environment, 283,* 106575.

Vendl, C., M. Clauss, M. Stewart, K. Leggett, J. Hummel, M. Kreuzer and A. Munn (2015). Decreasing methane yield with increasing food intake keeps daily methane emissions constant in two foregut fermenting marsupials, the western grey kangaroo and red kangaroo. *The Journal of Experimental Biology, 218,* 3425-3434.

Viggers, K. L. and J. P. Hearn (2005). The kangaroo conundrum: home range studies and implications for land management. *Journal of Applied Ecology, 42,* 99-107.

Viscarra Rossel, R. A., R. Webster, E. N. Bui and J. A. Baldock (2014). Baseline map of organic carbon in Australian soil to support national carbon accounting and monitoring under climate change. *Global Change Biology, 20,* 2953-2970.

von Engelhardt, W., S. Wolter, H. Lawrenz and J. A. Hemsley (1978). Production of methane in two non-ruminant herbivores. *Comparative Biochemistry and Physiology, 60,* 309-311.

Wang, S., J. Fan, Y. Li and L. Huang (2019). Effects of grazing exclusion on biomass growth and species diversity among various grassland types of the Tibetan Plateau. *Sustainability, 11,* 1705.

Waters, C. M. (2018). *Addressing Feed Supply and Demand through Total Grazing Pressure Management*. Meat and Livestock Australia, Sydney, NSW.

Waters, C. M., S. E. McDonald, J. Reseigh, R. Grant and D. G. Burnside (2019). Insights on the relationship between total grazing pressure management and sustainable land management: key indicators to verify impacts. *The Rangeland Journal, 41,* 535-556.

Webb, E. C. (2014). Goat meat production, composition, and quality. *Animal Frontiers, 4,* 33-37.

Wentworth Group of Concerned Scientists (2016). *Accounting for Nature; A Scientific Method for Constructing Environmental Asset Condition Accounts*. Sydney, NSW.

White, R., B. Davidson and R. Eckard (2021). *An Everyman's Guide for a Landholder to Participate in Soil Carbon Farming in Australia*. University of Melbourne, Melbourne, Victoria.

Williams, K., B. Hunter, B. Schmidt, E. Woodward and I. Cresswell (2022). *Australia State of the Environment 2021 Land*. Department of Agriculture, Fisheries and Forestry, Canberra, ACT.

Wilson, G. and M. Edwards (2008). Native wildlife on rangelands to minimize methane and produce lower-emission meat: kangaroos versus livestock. *Conservation Letters, 1,* 119-128.

Wilson, G., M. Edwards and N. Byron (2020). Custodianship of wildlife on private land to support conservation – an Australian model. *The Rangeland Journal, 42,* 309-321.

Wilson, G. and J. Smits (2012). Conservation for culture and livelihoods – Angas Downs, NT. In: *Innovation for 21st Century Conservation*. Eds: P. Figgis, J. Fitzsimons and J. Irving. Australian Committee for IUCN, Sydney.

Wilson, G. R. (2018). Co-production of livestock and kangaroos; a review of impediments and opportunities to collaborative regional management of wildlife resources. In: *Advances in Conservation Through Sustainable Use of Wildlife*. Eds: G. Baxter, N. Finch and P. Murray. University of Queensland, Brisbane, Queensland.

Wilson, G. R. and M. Edwards (2019). Professional kangaroo population control leads to better animal welfare, conservation outcomes and avoids waste. *Australian Zoologist, 40,* 181-202.

Wilson, G. R. and M. Edwards (2021). Options and rationale for regional property-based kangaroo production. *Ecological Management & Restoration, 22,* 176-185.

Wilson, G. R., M. J. Edwards and J. K. Smits (2010). Support for Indigenous wildlife management in Australia to enable sustainable use. *Wildlife Research, 37,* 255-263.

Wolin, M. J., T. L. Miller and C. S. Stewart (1997). Microbe-microbe interactions. In: *The Rumen Microbial Ecosystem*. Eds: P. N. Hobson and C. S. Stewart. Chapman and Hall, London, United Kingdom.

World Economic Forum (2016). *The Golbal Risks Report 2016*. Geneva, Switzerland.

Young, J. (2009). *Implications for Farm Management from Managing Greenhouse Gas Emissions*. University of New England, Armidale, NSW.

Zanker, L. (2021). Kangaroos, drought and a frustrated landowner. *Ecological Management & Restoration, 22,* 66-66.

Appendix A – Guidelines for a Kangaroo Grazing System integrated with livestock production

Guidelines for a Kangaroo Grazing System integrated with livestock production

Carbon market opportunities through novel grazing management

By Melanie Edwards and George Wilson

Introduction

Purpose of guidelines

Kangaroos produce an alternative carbon-friendly red meat, and although Australia has some 30 million kangaroos on pastoral properties, which are managed in places for overabundance, pastoralists currently get no return from them. These guidelines suggest a process, that with further information, will enable producers to assess their opportunity to integrate kangaroos into their traditional practices and in turn, access the carbon market. **The steps have yet to be trialled and field tested**.

While there is large scope to reduce emissions in the livestock sector, there are minimal proven opportunities, especially for range-fed cattle. Under our proposed grazing system, rangeland livestock producers would reduce stocking rates of livestock and allocate part of the available pasture to produce kangaroo meat. While income would be lost from a reduction in livestock, income diversification would arise from harvesting kangaroos, carbon credits and potentially from biodiversity credits.

Reducing total grazing pressure and stocking rates of livestock also has the co-benefits of improving sustainability and biodiversity and it can improve human and animal welfare while reducing cost of managing a pest animal. Such a change should be relatively easy because the kangaroos are already there and many producers currently seek to reduce their impacts through pest culling. It is also consistent with emerging priorities for sustainable and regenerative agriculture and fits with higher level objectives of natural resource management (NRM) agencies, and regional and national policy objectives. Examples are the Australian Agricultural Sustainability Framework being developed by the National Farmers' Federation as an overarching sustainability framework that can link to the various industry sustainability initiatives.

Who should use these guidelines?

Pastoralists within state kangaroo harvest zones (Figure 1) looking to increase methane (CH_4) abatement and carbon storage; promote biodiversity; improve ecosystem functions; increase drought resilience; reduce waste; and/or enter the carbon market.

Pastoralists looking to manage overabundant kangaroos, including eastern grey kangaroos (*Macropus giganteus*), western grey kangaroos (*M. fuliginous*), red kangaroos (*Osphranter rufus*) and wallaroos (*Osphranter robustus*) when they impact resting paddocks and total grazing pressure.

Principles of the Kangaroo Grazing System

The principles of the Kangaroo Grazing System (KGS) are:

- Livestock numbers and therefore CH_4 emissions are reduced.
- The impact of kangaroo grazing is managed through harvesting to reduce waste while simultaneously increasing carbon soil sequestration and promoting biodiversity.
- Culling is not used to managed kangaroos unless harvesting is not possible.
- Kangaroo populations should not be over-harvested to ensure ongoing population sustainability.
- Feral grazing herbivores are controlled.
- Harvesting is adaptive and reliant on environmental conditions.

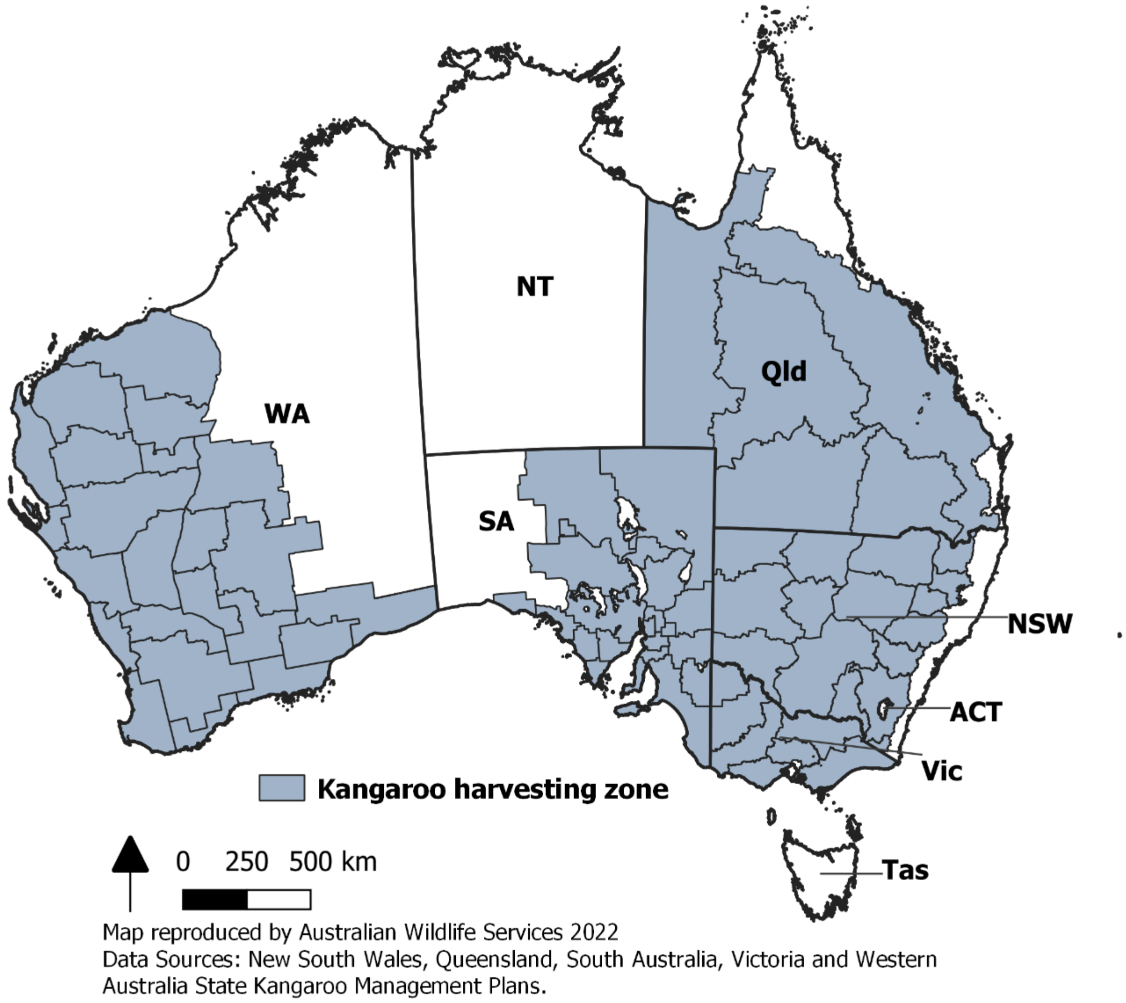


Figure 1. Australia's kangaroo harvesting zones.

Framework

1. Conduct resource assessment and opportunity evaluation

As the first step in integrating kangaroo management, pastoralists would be to evaluate sustainable production and economic opportunity of their land and compare herbivore alternatives including kangaroos and livestock.

In the following section we describe how a pastoralist interested in a Kangaroo Grazing System (KGS) can assess the potential to earn carbon credits, calculate the associated returns and losses, and determine a timeframe for implementation. As kangaroo grazing management and harvesting includes multiple variables, our guidelines refer to an accompanying spreadsheet. The results form a layout that will help pastoralists make informed decisions about how a KGS could be implemented as a grazing management system to achieve carbon credits by sequestering carbon in soils and reducing enteric CH_4 emissions.

Inputs to the model will vary greatly from property to property. To address these differences, we invite pastoralists to enter their on-farm statistics into the worksheets.

Green boxes require specific on-farm values and orange boxes require values determined by local research. NRM Officers, or their equivalents, could assist in accessing local environmental data for inclusion. The remaining blue boxes are the results calculated from entered variables. We use a Prime Lamb and Southern Beef Enterprise case study (PL&SB) from Meat and Livestock Australia (MLA 2021) to pilot the Kangaroo Grazing Systems Spreadsheet (here after the spreadsheet).

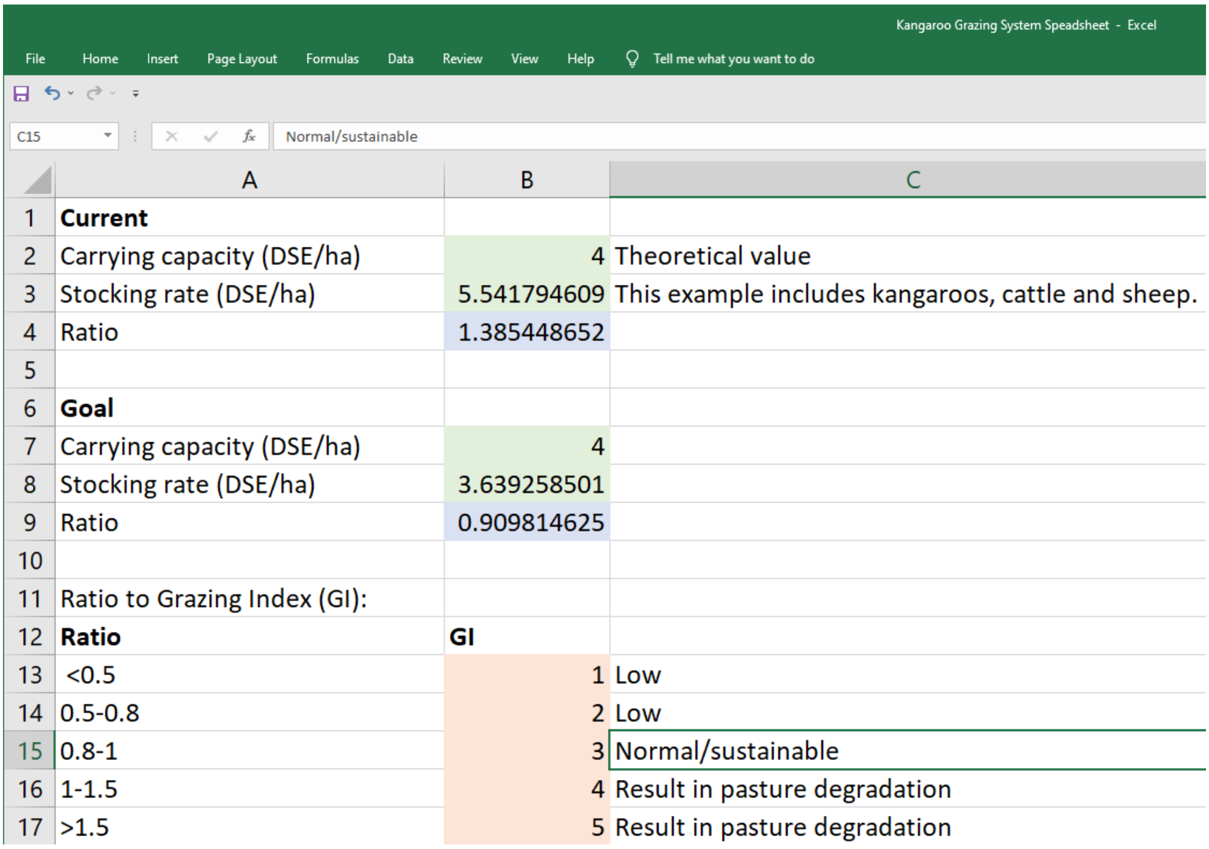
2. Map the boundaries for the Kangaroo Grazing System

Pastoralists would map the area to be used for the KGS. Maps will be useful for making calculations to support management decisions and for carbon credit applications. Predator and kangaroo exclusion fences and goat containment fences will be important markers in this process.

3. Estimate the current grazing index and the requirement to improve pasture growth and increase soil carbon

To increase soil carbon, modelling studies have shown that the grazing index (GI) (ratio of stocking rate to carrying capacity) often needs to be reduced (GI: 1 = <0.5; 2 = 0.5-0.8; 3 = 0.8-1; 4 = 1-1.5; 5 = >1.5) (Hill *et al*. 2006). A GI 1-2 is considered low, 3 is considered normal/sustainable in the long term and 4-5 will result in pasture degradation. While a GI of 3 or below should reduce grazing pressure to promote vegetation growth and soil carbon, the ideal GI will differ for each KGS based on a number of variables. Advice should be sought from an experienced local NRM Officer or carbon aggregator to estimate the appropriate GI for soil carbon storage to increase. Alternatively, pastoralists can use platforms like GrassGro or LOOC-C to quantify the variability in pasture and animal production. Pastoralists and NRM Officers can assess the risks that variable weather imposes on a grazing system. Users can test management options against a wide range of seasons to achieve more sustainable utilisation of grasslands.

The worksheet 'Grazing Index' aims to enable pastoralists to determine their current GI and explore their target stocking rate (Figure 2).



Kangaroo Grazing System Speadsheet - Excel

File Home Insert Page Layout Formulas Data Review View Help Tell me what you want to do

C15 Normal/sustainable

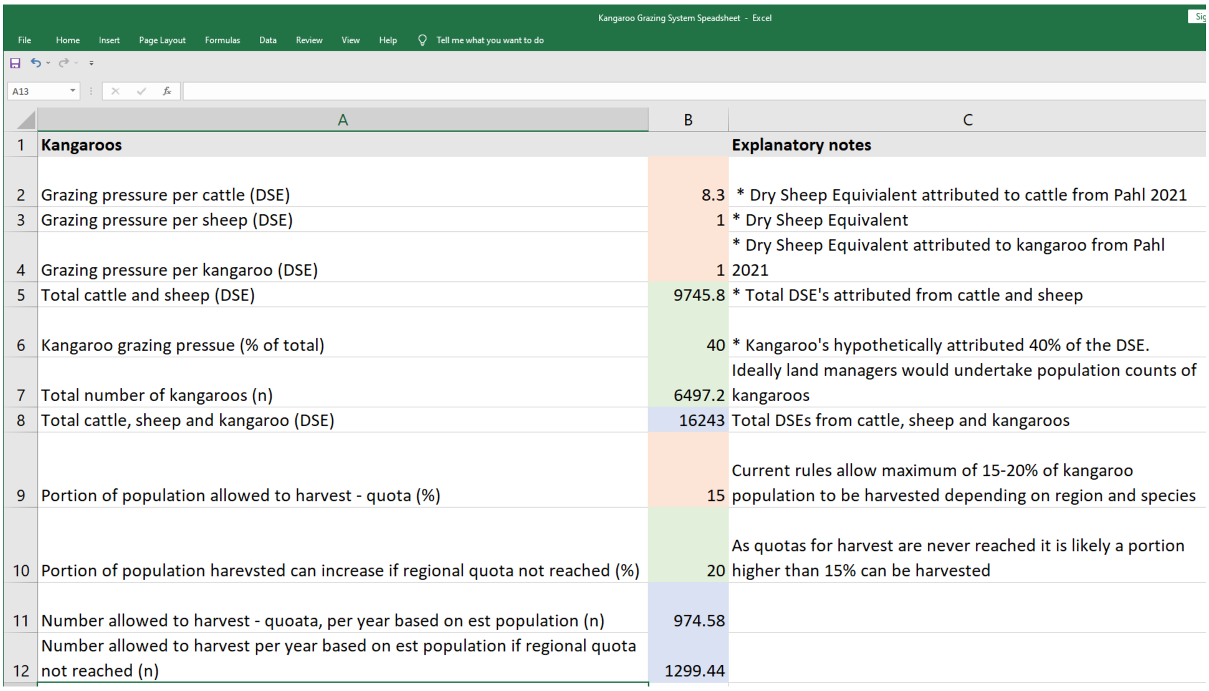
	A	B	C
1	**Current**		
2	Carrying capacity (DSE/ha)	4	Theoretical value
3	Stocking rate (DSE/ha)	5.541794609	This example includes kangaroos, cattle and sheep.
4	Ratio	1.385448652	
5			
6	**Goal**		
7	Carrying capacity (DSE/ha)	4	
8	Stocking rate (DSE/ha)	3.639258501	
9	Ratio	0.909814625	
10			
11	Ratio to Grazing Index (GI):		
12	**Ratio**	**GI**	
13	<0.5	1	Low
14	0.5-0.8	2	Low
15	0.8-1	3	Normal/sustainable
16	1-1.5	4	Result in pasture degradation
17	>1.5	5	Result in pasture degradation

Figure 2. Screen capture of the spreadsheet showing current carrying capacity and stocking rate to determine goal carrying capacity and stocking rate using grazing index using a hypothetical example.

4. Estimate the kangaroo population currently occupying the prospective grazing system area

Prior to implementing a KGS, kangaroo population counts are required (or data may be provided to the pastoralist by state environment departments). The more data that is collected, the more informed the management decisions can be. For example, if data is collected on kangaroo populations including emergent joeys, number of males, number of females and mortality then pastoralists may start to model what the population will look like in the following years. The pastoralist will also be required to determine allowable harvest number. To enable a sustainable harvest, pastoralists need to know the number of kangaroos on the land being managed for grazing pressure to store carbon in soil. The population could be achieved by undertaking population counts with the assistance of an NRM officer. The worksheet ‘Kangaroo population and harvest’ (Figure 3) uses the following variables to determine how many kangaroos can be harvested under commercial permits on the land being managed for soil carbon storage:

- total number of kangaroos
- portion harvest quota (per cent of population)
- portion harvest quota if regional quota not met (per cent of population).



	A	B	C
1	**Kangaroos**		**Explanatory notes**
2	Grazing pressure per cattle (DSE)	8.3	* Dry Sheep Equivialent attributed to cattle from Pahl 2021
3	Grazing pressure per sheep (DSE)	1	* Dry Sheep Equivalent
4	Grazing pressure per kangaroo (DSE)	1	* Dry Sheep Equivalent attributed to kangaroo from Pahl 2021
5	Total cattle and sheep (DSE)	9745.8	* Total DSE's attributed from cattle and sheep
6	Kangaroo grazing pressue (% of total)	40	* Kangaroo's hypothetically attributed 40% of the DSE.
7	Total number of kangaroos (n)	6497.2	Ideally land managers would undertake population counts of kangaroos
8	Total cattle, sheep and kangaroo (DSE)	16243	Total DSEs from cattle, sheep and kangaroos
9	Portion of population allowed to harvest - quota (%)	15	Current rules allow maximum of 15-20% of kangaroo population to be harvested depending on region and species
10	Portion of population harevsted can increase if regional quota not reached (%)	20	As quotas for harvest are never reached it is likely a portion higher than 15% can be harvested
11	Number allowed to harvest - quoata, per year based on est population (n)	974.58	
12	Number allowed to harvest per year based on est population if regional quota not reached (n)	1299.44	

Figure 3. Screen capture of the spreadsheet showing kangaroo populations and harvest potential using a hypothetical example.

Alternatively, the pastoralist could estimate the population based on grazing pressure. In the worksheet we estimate the population of kangaroos on the PL&SB case study to be 6497, using the estimate that kangaroos are responsible for 40 per cent of attributed dry sheep equivalents in this hypothetical case study (DSEs; whereby a kangaroo and a sheep have a per individual DSE of 1 and cattle have a per individual DSE of 8.3 (Pahl 2019)).

The quota for harvesting kangaroos is given as 15 per cent, which is the legislated allowable minimum quota; however, if a pastoralist is granted access to greater than 15 per cent through the permit system, they may use that value instead. The worksheet caters for two cells to enable the pastoralist to compare 15 per cent population harvest to a potentially greater harvest portion.

Population estimates can be determined in a number of ways (see Table 1). A direct count of all individuals may be feasible in small areas, where observers can become familiar with the land form and habitats, and behaviour of the target species, to ensure that none is missed or counted more than once. For example, two observers on foot could conduct a systematic count of eastern grey kangaroos on a 53-ha golf course. A similar, vehicle-based method has been used in the Australian Capital Territory (ACT), to count eastern grey kangaroos in small (20–184 ha) patches of open grassland (ACT Government 2010). Colgan *et al*. (2019) also used a vehicle for a direct count of eastern grey kangaroos in a much larger (1545 ha) fenced site, following a fixed route to count all kangaroos in six fenced compartments. Such counts require consistent results across repeated surveys to ensure meaningful estimates are obtained and to allow some estimate of precision. This measure is useful only if the population has a distinct boundary, so the population is closed to immigration and emigration.

Innovative technologies such as drones and thermal imaging are being trialled in 2022 with the support of the Future Drought Fund. They show considerable promise for improving the accuracy of property level population estimations (McLeod and Curtis, unpublished).

Table 1. Common survey techniques for quantifying kangaroo populations (Coulson *et al.* 2021).

Survey method	Metric	Bias	Precision	Survey platform	Detection mode	Sampling unit	Advantages	Disadvantages
Total counts								
Natural markings	Number	Negative	High	Foot	Sighting	–	Basic equipment; conceptually simple	Animals must be habituated; lengthy observer training
Direct count	Number	Minimal	Variable	Foot/ vehicle/ drone	Sighting/ camera	–	Basic equipment; conceptually simple; quick to implement	Requires site familiarity; requires tight coordination
Vantage point count	Number	Negative	Variable	Foot/ vehicle/ drone	Sighting/ camera	–	Basic equipment; conceptually simple; quick to implement	Requires site familiarity; relies on natural foraging behaviour; requires unobstructed view of entire site
Sweep count	Number	Minimal	High	Foot	Sighting	–	Basic equipment; conceptually simple; quick to implement	Requires site familiarity; challenging to coordinate
Transects								
Spotlight count	Index	Negative	Moderate	Foot/ vehicle	Sighting	Unbounded line	Basic equipment; conceptually simple	Detections influenced by many environmental factors
Strip transect	Estimate	Negative	Variable	Foot/ vehicle/ drone	Sighting/ camera	Fixed/variabl e width	Basic equipment; conceptually simple; suits datasets too small for distance sampling	Assumptions may be violated; detections influenced by habitat complexity
Distance sampling	Estimate	Negative	Moderate	Foot/ vehicle/ drone	Sighting	Unbounded line	Uses all sighting data; allows for variation in detectability	Requires large datasets; requires specialist equipment requires complex analysis; assumptions may be violated

5. Estimate the grazing impact of any other grazing herbivores, including pest species that may impact pasture regeneration and growth

The four significant pest species to manage under the KGS are goats, pigs, rabbits and deer. Unmanaged goats are the most significant feral animal species in regions of Australia. Control of goats is crucial before improved grazing management to increase groundcover can be implemented. Feral pigs are a major pest animal with a rapidly increasing range. Rabbits are a widespread pest occurring on most land types and populations are expected to increase as the population develops resistance to the calicivirus. Feral deer are becoming an increasing problem and have the potential to cause significant impact to grazing land. More information can be obtained from the National Deer Management Coordinator who is supporting community-led deer control in all states and territories across Australia. In all locations, efforts are under way to reduce feral deer impacts.

6. Estimate conversion of livestock stocking rate to kangaroo equivalents

The reduction in livestock should allow some replacement with kangaroo. The stocking rate for kangaroos can be determined by converting the target DSE of livestock to kangaroos using a kangaroo DSE of 1 (Pahl 2019). The stocking rate will become the target population and should be revised according to the environmental conditions, which influence the carrying capacity and target GI. Initial provisions should be calculated for both drought and non-drought conditions.

7. Estimate economic feasibility and potential return

Pastoralists can use the accompanying spreadsheet to assist in determining the economic feasibility and return of the KGS. Variables are listed in detail in the spreadsheet and include:

Costs

- Lost income from livestock (see worksheet ‘Losses from livestock’) (Figure 4)
- Kangaroo harvest establishment and running costs (see worksheet ‘Cost v return for kangaroos’) (Figure 5 and 6).

Returns

- Kangaroo income (see below costs and returns from kangaroos – three options)
- Carbon credits soil carbon storage (see worksheet ‘Potential carbon sequestration’ and ‘Seq+ abmt (CO_2e-yr and $-yr)’) (Figure 7 and 8)
- CH_4 abatement (voluntary market only; see worksheets ‘Potential emission abatement’ and ‘Seq+ abmt (CO_2e-yr and $-yr)’) (Figure 9 and 8)
- Co-benefit programs (not calculated).

Savings

- Livestock running costs (calculated in profit margin)
- Impact of drought on livestock production (calculated in profit margin).

Kangaroo Grazing System Speadsheet - Excel

	A	B	C
1	**Lost income**		
2	**Cattle**		
3	Cattle sold (n)	452	Value from MLA prime lamb and southern beef case studies on cost of production
4	Income lost ($/year)	69213	Value from MLA prime lamb and southern beef case studies on cost of production
5	**Sheep**		
6	Sheep sold (n)	2003	Value from MLA prime lamb and southern beef case studies on cost of production
7	Income lost ($/year)	83178	Value from MLA prime lamb and southern beef case studies on cost of production
8	**Total income lost per year ($)**	152391	

Figure 4. Screen capture of the spreadsheet showing lost income from cattle and sheep using a hypothetical example.

	A	B	C
1	**Option 1a) Pastoralist operator**		**Explanatory notes**
2	Initial investment ($)	45751	See investment costs in kangaroo harvest details spreadsheet
3	Ongoing annual cost ($) not including fuel	7359.53	See annual costs in kangaroo harvest details spreadsheet
4	Costs per animal:		
5	*Tag*	1.17	Cost of tag depends on state
6	*Ammunition*	1.5	Likely to be variable
7	Return on number allowed to harvest per year based on est population ($)	18983.4	Not including intial investment - if negative value there are not enough kangaroos being harvested to cover annual costs
8	Return on number allowed to harvest per year based on est population if quota not reached ($)	27764.3	Not including intial investment - if negative value there are not enough kangaroos being harvested to cover annual costs
9	***1b) Need to increase number of kangaroos harvested, however not by too many or it will increase grazing pressure***		
10	The roo harvest needs to increase but not by too much that it overshoots the current DSE (no. harvested)	1600	2500 to be harvested will put this population at current grazing DSE thereby diminishing carbon sequestration potential, 1600 puts it at 65% of current DSE (or carrying capacity to stocking rate ratio of 3.6 or GI of 3) - land mangers should manipulate this factor so that generates the desired percentage reduction in DSEs given in the spreadsheet %of current DSE to generate carbon sequestration in soil from grazing maangement.
11	To increase the harvested roos the population would need to grow to:	10666.7	
12			
13	Harvest allowed (15%)	1600	5000 is average a harvester can shoot in one year
14	Return on allowed to harvest if population grew including annual cost ($)	38563.1	Depends heavily on size of kangaroo and $ received per kilo, usually sold with head and viscera removed
15	Harvest allowed if quota not reached (%)	20	This figure can be mainpulated if land managers gain access to greater than 15% harvest of the est population
16	Return on allowed increase harvest including annual cost ($)	50304.5	Depends heavily on size of kangaroo and $ received per kilo, usually sold with head and viscera removed

Figure 5. Screen capture of the spreadsheet showing the option of pastoralist turned harvester using a hypothetical example.

	A	B	C
18	**Option 2b) Harvester pays for access to kangaroos**		
19	Initial investment ($)	0	
20	Ongoing annual cost ($) not including fuel	0	
21	Costs per animal:		
22	*Tag*	0	
23	*Ammunition*	0	
24	Amount paid per roo to landowner ($)	5	Land manager to negotiate payment rate from harvester ($5 has been offered to land managers as recent as 2021)
25	Return on number allowed to harvest per year based on est population ($)	4872.9	
26	Return on number allowed to harvest per year based on est population if quota not reached ($)	6497.2	
27			
28	***2b) Need to increase number of kangaroos harvested, however not by too many or it will increase grazing pressure***		
29	Return on allowed to harvest if population grew ($)	8000	
30	Return on allowed to harvest if population grew and quota not reached ($)	10666.7	

Figure 6. Screen capture of the spreadsheet showing the option of pastoralist charging harvesters a fee using a hypothetical example.

	A	B	C
1	**Potentail carbon sesquestration in soil**	**Values**	**Explanatory notes**
2	Land size where grazing will be managed	2931.00	Land size calculated using 1 cow per 2.5 ha and 1 sheep per 0.3 ha, from the prime lamb/southern beef case study
3	Soil carbon potential (tonnes C02e/ha/20 years)	2.24	Australian average per 20 years under adaptive management see https://soilsrevealed.org/
4	Soil carbon potential (tonnes CO2e/ha/year)	0.11	Australian average per year under adaptive management
5	Potential carbon to be stored in soil (tonnes C02e/year)	328.08	
6			**Key:**
7			Land management factor - to be entered by pastoralist based on situation, vaules provided here are from a hypothetical case study
8			Research average or value - to be entered by pastoralist or NRM office, this value could be improved from local data
9			Result - Calculation which will be variable depending on the land management

Figure 7. Screen capture of the spreadsheet showing potential sequestration in soil using a hypothetical example.

	A	B	C
1	**Net CO2e sequestration and abatement per year (t CO2e)**		**Explanatory notes**
2		2122.98	Abatement included in savings however abatement methodolgoy not covered by the Emission Reduction Fund - abatement repayments would need to be achieved from the secondary market
3			
4	Dollar conversion ($/t CO2e)	16.94	Average price per tonne of abatement (Clean Energy Regulator October 2021)
5	**Total $ from CO2e savings per year ($)**	35963.31	

Figure 8. Screen capture of the spreadsheet showing potential net sequestration and abatement using a hypothetical example.

	A	B	C
1	**Emision abatement**		**Explanatory notes**
2	**Cattle**		
3	No. cattle (n)	726	Values obtained from MLA prime lamb and southern beef case studies on cost production
4	methane production (t CO2e/ind/year)	1.55	Value determined from ABS and DISER
5	Cattle removed (%)	100	Number cattle to be removed - this value needs to be determined based on stocking rate and carrying capacity goals to ensure grazing management activity achieves carbon sequestration and abatement goals
6	CO2e savings if % removed (t CO2e/ind/year)	1125.3	
7	**Sheep**		
8	No. sheep (n)	3720	Values obtained from MLA prime lamb and southern beef case studies on cost of production
9	methane production (t CO2e/ind/year)	0.18	Value determined from ABS and DISER - value likey to be higher as individual CO2e enteric methane calculate from animals including those younger than 1 year old.
10	Sheep removed (%)	100	Number of sheep to be removed - this value needs to be determined based on stocking rate and carrying capacity goals to ensure grazing management activity achieves carbon sequestration and abatement goals
11	CO2e savings if % removed (t CO2e/year)	669.6	

Figure 9. Screen capture of the spreadsheet showing potential emission abatement from cattle and sheep using a hypothetical example.

While carbon credits can be achieved for CH_4 abatement and soil sequestration under the voluntary market, the voluntary market carbon credits are currently considerably less than the Australian Carbon Credit Unit (ACCU). Without taking cost of production into account, the return from harvesting kangaroos can be determined by the price paid per kangaroo and the number harvested. The worksheet 'Returns from kangaroos' (Figure 10) (which does not include costs) determines the return on individual kangaroos and total harvest using the variables:

- return per average 25 kg kangaroo
- the number of kangaroos harvested (from the 'Kangaroo population and harvest' worksheet).

	A	B	C
1	**Returns from kangaroos**		**Explanatory notes**
2	Return per average 25kg kangaroo not including costs ($)	29.7	Depends on size of kangaroo and $ received per kilo, usually sold with head and viscera removed
3	Return on number allowed to harvest per year based on est population ($)	28945	*
4	Return on number allowed to harvest per year based on est population if quota not reached ($)	38593.4	*

Figure 10. Screen capture of the spreadsheet showing returns from kangaroos using a hypothetical example.

When kangaroos are sold by the harvester, they are partially dressed with their head and viscera removed. They are sold per kilogram to a chiller. The return per kangaroo varies like cattle and sheep prices. The worksheet ‘Kangaroo harvest details’ lists variables that may be manipulated to more accurately represent the size of a particular species of kangaroo or the dollar per kilogram achieved at local chillers:

- size
- dollar paid per kilogram.

There are also costs associated with running carbon projects such as soil sampling and administration costs. These should also be taken into account when estimating the economic feasibility and potential return. Government websites should be explored for any incentive programs.

8. Choose from three management options

Kangaroos are required to be shot by licenced harvesters. Under most current practice, an independent harvester, with permission from the landholder, will access the property and harvest kangaroos. There is no return for the landholder. Under our proposed KGS, the landowners could diversify enterprise operations and they, or employees, could become harvesters (option 1), or they could fix a price for access to the kangaroos, similar to share farming (option 2). A third option focuses on calculations for the incorporation of kangaroos into cattle and sheep production.

Option 1 – Pastoralist/manager runs the harvest

The first option for harvesting explores the pastoralist running the harvest. The worksheet ‘Cost v returns for kangaroos’ and ‘Option 1a) Pastoralist operator’ lists costs involved in this option. Such costs include:

- initial investments for vehicle/tray/spotlight/tools/winch, firearm, firearm safe, and courses – use firearms to harvest wild game (firearms course), statement of attainment in game harvesting (can be fully subsidised if criteria are met), firearms licence (five years), firearms safety course (pre-licence qualification course).
- annual costs for maintenance of vehicle/tray/spotlight/tools/winch/firearms, administration, insurance public liability, licence – professional harvester, licence – food transport.

There are also costs attributed to the harvest per kangaroo, including:

- tag
- ammunition
- time (not included in calculations)
- fuel (not included in calculations).

As described above in ‘Potential returns from kangaroos’, the number of kangaroos harvested, under current policies will depend on the kangaroo population and regional quota set for harvesting (15 to 20 per cent depending on region, with the option for pastoralists to receive more if the regional quota is not met). The case study shows that return on kangaroos, excluding initial investment, is small (at 15 per cent it returns $16,839 and at 20 per cent returns $24,905).

For the purposes of modelling, we have assumed cattle and sheep have been completely removed, which enables the kangaroo population to increase. However there needs to be a balance between increasing the population to enable increased harvest, but not increasing the population too much so that grazing management activities are detrimental.

Where livestock numbers are reduced kangaroo populations can increase until they reach the target grazing pressure, so to ensure that carbon is sequestered in soil. Pastoralists, with the assistance of NRM Officers or soil sequestration scientists need to know how to manage their grazing pressure in order to store carbon in the soil. The target population can be determined by setting the grazing pressure target at a per cent of the current grazing pressure. The target population can be manipulated depending on current and forecasted environmental conditions. This is important as too many kangaroos will amount to overgrazing and degrade soils. For greater land areas, where 15 per cent of the kangaroo population reaches into the thousands, the harvesting ability of the labour force needs to be taken into account. For example, one harvester can harvest 5,000 kangaroos, on average, in a year.

In the case study, the grazing pressure (by DSE) target is 65 per cent of current levels (see worksheet '% of current DSE' or a GI reduced to 3 see worksheet 'Grazing Index'), which would allow a kangaroo population of 10,666, with no cattle and sheep. At 15 per cent of the population, 1,600 could be harvested. With an increase in kangaroos, harvesting 15 per cent of the population returns $35,043. If a pastoralist was able to receive permits to harvest 20 per cent of their population, the returns would be increased to $45,611. Note: implications arise when environmental factors and harvesting affect the population. However, management activities can be implemented to reduce the affects, in a similar manner to those that are implemented for domestic livestock (e.g., feed and water provision).

Option 2 – Pastoralist collects an access fee from the harvester

A second option 'Harvester pays pastoralist for access to kangaroos' involves harvesters paying the pastoralist for access to kangaroos (Figure 6). This option addresses a number of issues that arise when the pastoralist is the harvest operator, such as investment costs, harvesting competencies and lifestyle changes associated with movement away from traditional practices. Under this option, there are no investment costs to the pastoralist; however, the returns are likely to be reduced also, with the pastoralist only receiving access payments, rather than complete returns from the product. The variables for this option include:

- payment from harvester to pastoralist per kangaroo
- number of kangaroos harvested.

The kangaroo population would be carried to the same capacity as that mentioned in option 1, with the same harvesting opportunities, so to balance harvest number, population and grazing pressure.

Under both options the pastoralist is set to receive income losses from livestock. The 'Losses from livestock' worksheet provides pastoralists with the option to enter the number of livestock reduced and income lost. This is lost income from livestock that would have otherwise been sold and lost income is total profit lost. When entering this data, a pastoralist should take into account all production costs and income earnt from livestock. In the worksheet, we have used the PL&SB case study profits from number of livestock sold. It is important to note there is often more livestock on farm that are sold, this means that emissions per individual cattle do not easily transform to emissions per kilogram of beef.

Option 3 – Concurrent enterprises

A third option describes a scenario whereby a pastoralist may graze livestock and kangaroo and run the enterprises concurrently (Figure 11). Carbon sequestration comes from reducing the cattle and sheep population to reduce grazing pressure. The kangaroo population is harvested at 15 per cent of the hypothetical population. Issues with this option include there may be greater costs associated with livestock production, as less livestock are run (i.e., the cost of production per livestock increases as the number of livestock decrease). Nevertheless, the worksheet 'Cattle sheep and kangaroo grazing' enables a pastoralist to manipulate the proportions of grazing herbivores on their land so to determine how many cattle and sheep they can remove and how this affects their grazing capacity and income. There is the option for the pastoralist to enter lost income so to determine prospective management options. This worksheet enables the pastoralist to manipulate values and explore different stocking values.

	A	B
1	**Option 3: Orignal roo population and 15% harvest and reducing cattle and sheep**	
2	**Soil carbon savings from "potential carbon sequestration" as grazing is being managed (t CO2e/year)**	328.0815
3		
4	**Emision abatement savings**	
5	**Cattle**	
6	No. cattle (n)	726
7	methane production (t CO2e/ind/year)	1.55
8	Cattle removed (%)	60
9	CO2e savings if % removed (t CO2e/year)	675.18
10	**Sheep**	
11	No. sheep (n)	3720
12	methane production (t CO2e/ind/year)	0.18
13	Sheep removed (%)	50
14	CO2e savings if % removed (t CO2e/year)	334.8
15	**Total CO2e savings per year**	1338.061
16	**Total $ from CO2e savings per year**	22666.76
17		
18	**Lost income**	
19	**Cattle**	
20	Income lost per head	153.1261
21	Cattle sold (no.)	180.8
22	Income lost ($ per year)	27685.2
23	**Sheep**	
24	Income lost per head	41.52671
25	Sheep sold (no.)	1001.5
26	Income lost ($ per year)	41589
27	**Total income per year ($)**	69274.2

Figure 11. Screen capture of the spreadsheet showing the option of running livestock and harvesting kangaroos using a hypothetical example.

9. Estimate the potential for the prospective Kangaroo Grazing System to store soil carbon

Advice should be sought from local NRM officers. Estimates can be achieved through (but are not limited to) the following websites:

- Soils Revealed (Soils Revealed 2016) provides recent and future soil organic stock estimates under the grassland management practice 'sustainable pastures and adaptive grazing'. Property outlines can be drawn onto the map to estimate potential carbon storage.
- These estimates can then be used in the LOOC-C program to help estimate your target 0-30 cm soil carbon content.

The worksheet 'Potential carbon sequestration' in the spreadsheet uses the following variables, which allows managers to enter their land size and potential soil carbon storage to determine the total potential land size and soil carbon potential:

- land size
- soil carbon potential.

10. Estimate the potential for methane abatement credits from reducing livestock

Under a KGS, potential CH_4 abatement per year can be determined by calculating the number of livestock and the amount of CH_4 they produce per year. The worksheet 'Potential emission abatement' in the spreadsheet uses the following variables, which allows managers to enter their number of livestock, the number of livestock removed and CH_4 production to determine total abatement from removing livestock:

- number of cattle
- CH_4 production per individual (cattle) per year
- cattle removed or increases foregone under prior plans
- number of sheep
- CH_4 production per individual (sheep) per year
- sheep removed.

The pastoralist should enter CH_4 production values that best represents their herd or flock, as CH_4 production from cattle and sheep vary greatly depending on breed, sex, size, herbage type and amount consumed, and reproductive status. In the spreadsheet we use an average for sheep and an average for cattle (calculated from Department of Industry, Science, Energy and Resources and Australian Bureau of Statistics data). These calculations will give carbon dioxide equivalent (CO_2e) savings for the percentage of population removed. Using this example, the abatement is 1,125 t CO_2e/year for cattle and 669 t CO_2e for sheep. It should be noted that will achieve an estimate, and for carbon credits to be achieved, the calculations will need to follow the formulas set out in the selected methodology.

Credits from sequestration and abatement

The net sequestration and abatement to determine potential credits is the sum of the sequestration in soil and abatement from reduced livestock enteric emissions multiplied by the value of an ACCU. The worksheet 'Seq + abmt (CO_2e-yr \$-yr)' in the spreadsheet uses the following variables to determine the potential amount of carbon credits that can be achieved:

- CO_2e/yr
- dollar conversation (\$/t CO_2e).

In the spreadsheet we use the average price per tonne of abatement as listed on the Clean Energy Regulator website during October 2021. However, under current methodologies, a pastoralist cannot generate ACCUs from cattle enteric emissions by removing cattle or sheep to manage grazing. ACCUs can only be achieved for cattle if they are unproductive and removed. There is, however, potential to gain carbon credits from the secondary/voluntary/international market. The pastoralist will need to decide whether to enter voluntary markets, and adjust the calculations accordingly.

11. Determine which carbon crediting system is optimal

There are two avenues a pastoralist could choose to achieve carbon credits under the KGS – the compliance carbon market and voluntary carbon market. Under the voluntary carbon market, carbon credits could be achieved for both enteric CH_4 abatement and soil carbon storage through the Verified Carbon Standard (VCS) methodologies 'Methodology for sustainable grassland management VM0026' and 'Methodology for sustainable grasslands through adjustment of fire and grazing VM0032'.

Under the compliance carbon market in Australia, the Emissions Reduction Fund, carbon credits could be achieved for carbon storage in soil through the Carbon Credits (Carbon Farming Initiative—Estimation of Soil Organic Carbon Sequestration using Measurement and Models) Methodology.

12. Estimate the timeframe for initiating and managing changes

Pastoralists will need to assign time to ensure eligibility requirements are met for the carbon credit methodologies, including to prepare a land management strategy and to register their project. There will be operating, sampling, reporting, audit, notification, monitoring and record-keeping obligations in running a soil carbon project. Pastoralists will need to measure their soil carbon levels before and after their grazing management activities so they can calculate soil carbon changes. Under the ERF, pastoralists will need to report on their project at least once every five years. Pastoralists will receive carbon credits each time they report increases in soil carbon levels over a period of 25 years. See Figure 12 for a visual representation of a soil carbon project timeframe.

If the pastoralist is to diversify into kangaroo harvesting there will be time required for enterprise establishment including administration, training and purchasing. For example, purchase equipment, attain licences and tags, attend training, map chiller location. There will less time required for establishment if the pastoralist decides to engage an external harvester. These activities can be achieved during the 'Baseline sampling time point' as shown in Figure 12.

Land management activities (see Figure 12) will be to destock cattle and sheep according to the pastoralists land management strategy. This activity can be immediate or gradual depending on pastoralists soil carbon storage aspirations and ability to supplement income.

Kangaroos are to be managed to appropriate grazing target to enable soil carbon to be sequestered under land management strategy. There will be time management lags for this component of the KGS, while the balance between population increase to meet grazing targets and harvest quotas are determined. The worksheet 'Kangaroo population management' will help pastoralists determine the timeframe for kangaroo populations to reach grazing targets and for harvest targets. The variables include:

- population number
- female-to-male ratio
- reproductive females
- joey mortality
- adult mortality
- migration (not included in calculations).

A local kangaroo population can be impacted by harvest rate, joey mortality, number of reproductive females and adult mortality. The variables will dictate the number of kangaroos harvested and potential for growth in the following years. The worksheet provides two scenarios (see Figure 13). The first gives a high percentage for joey survival during high rainfall periods. The second gives a lower percentage for joey survival during low rainfall periods. Droughts would likely see a fall in populations and are not modelled in the worksheet; however, the variables can be manipulated to reflect drought conditions. Under the two scenarios modelled, populations reach grazing targets after three years.

Pastoralists can enter their data to determine their prospective timeframes, which will depend on their land, livestock, local kangaroo and environmental statistics.

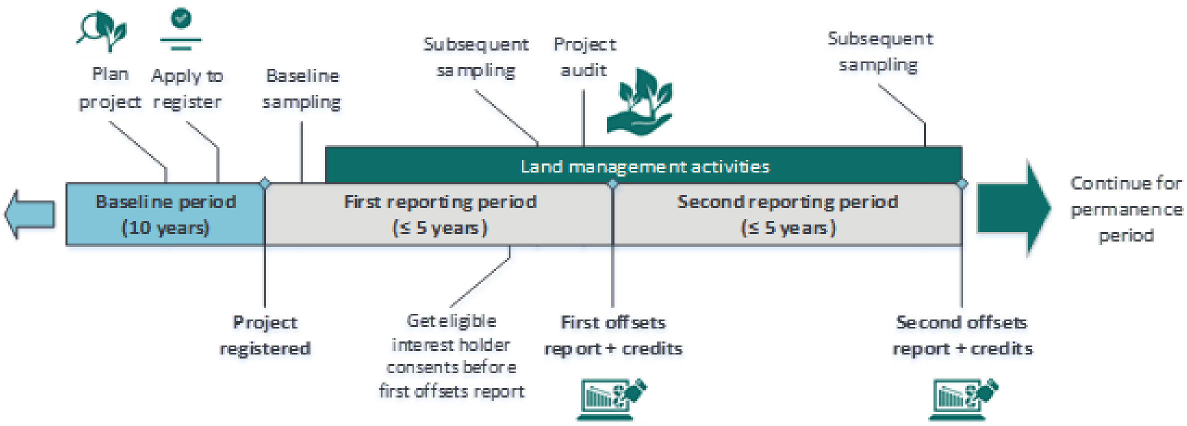


Figure 12. Timeline for a soil carbon sequestration project. Under a Kangaroo Grazing System, livestock reductions and kangaroo harvesting would occur over the land management activities timeframe to increase soil carbon sequestration and to reduce enteric CH_4 emissions.

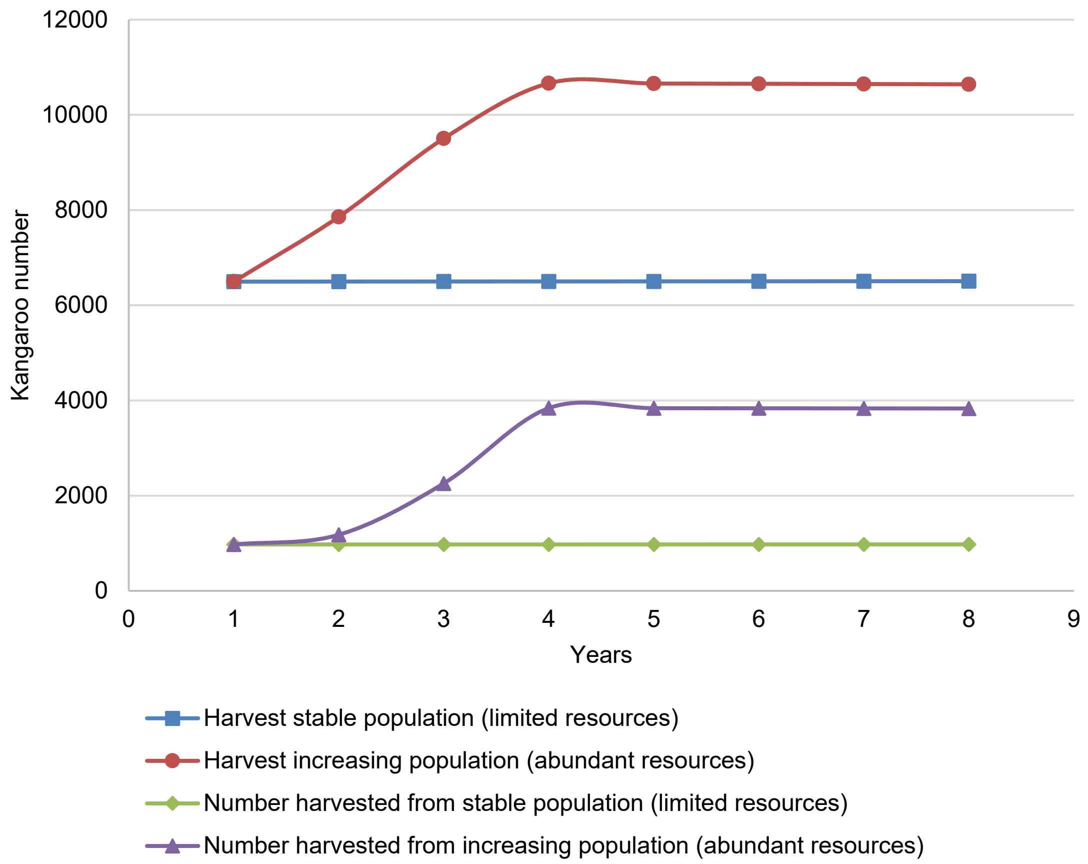


Figure 13. Kangaroo population modelling for the harvesting of a stable kangaroo population and the harvesting of an increasing population (due to favourable climatic conditions) to achieve maximum grazing targets for soil carbon sequestration.

13. Evaluate risks

A risk evaluation should also be carried out. Such things to consider include drought, as drought may negatively affect the soil's ability to store carbon due to decreased plant litter input and reduced litter decomposition (Deng *et al*. 2021), kangaroo movement, market volatility and harvest quota alignment with management goals. Interested parties should seek independent technical, legal, audit and/or financial advice regarding personal circumstances and requirements.

14. Select a carbon credit methodology

Verified Carbon Standard methodology for sustainable grassland management

The VCS 'Methodology for sustainable grassland management VM0026' is part of the voluntary carbon market and provides procedures to estimate the greenhouse gas (GHG) emissions reductions and removals from the adoption of sustainable grassland management practices, which includes limiting the timing and number of grazing animals on degraded pastures, and restoration of severely degraded land and ensuring appropriate management over the long-term.

The methodology quantifies emissions reductions and removals from increases in soil organic carbon stocks and reduction of non-CO_2 GHG emissions. Where biogeochemical models can be demonstrated to be applicable in the project region, they may be used in estimation of soil carbon pool changes. Where such models are not applicable, the methodology provides guidance for estimation of soil carbon pool changes using direct measurement methods. The methodology uses a project method to determine additionality and the crediting baseline.

The project area must meet the following requirements/conditions:

- The project area must be grassland at the start of the project and must be considered degraded under the Clean Development Mechanism (CDM) Tool for Identification of Degraded or Degrading Lands for Consideration in Implementing CDM Afforestation/Reforestation Project Activities.
- The project area must not have been cleared of native ecosystems within the 10-year period prior to the project start date.
- The project area is located in a region where precipitation is less than evapotranspiration for most of the year and leaching is unlikely to occur.

Steps include:

- Map your project area.
- Determine baseline values.
- Assess the profitability of an alternative land use scenario.
- Determine additionality using the VCS tool 'VT0001 Tool for the Demonstration and Assessment of Additionality in VCS Agriculture, Forestry and Other Land Use (AFOLU) Project Activities'.
- Determine leakage:
    - o through market leakage due to reduction in the production of livestock products within the project boundary – market leakage can be assessed through 'VMD0033 Estimation of emissions from market leakage'.
    - o through displacement of grazing beyond the project boundary (i.e., where do your livestock go if not to slaughter?) – displacement of grazing can be determined through 'Leakage from displacement of grazing activities VMD0040'.
- Determine project emissions abatement and storage.
- Undertake monitoring – project implementation, validation of biogeochemical model, sampling design and stratification, recording of data and parameters monitored.
- Complete the application process.

Verified Carbon Standard methodology for sustainable grasslands through adjustment of fire and grazing

The VCS ‘Methodology for sustainable grasslands through adjustment of fire and grazing VM0032’ is part of the voluntary carbon market and applies to project activities that adjust the number and type of domestic livestock grazing animals (e.g. cattle, sheep, horses, goats, camels, llamas, alpacas, guanacos, or buffalo) and/or grouping, timing and season of grazing (e.g., continuous unrestricted, planned rotational, bunched herd rotational or other means of restricting livestock access to forage in order to allow vegetation response) in ways that sequester soil carbon and/or reduce CH_4 emissions.

Lands are grazed and/or subject to fires in the baseline and/or project scenarios. Lands may be used for different purposes, such as livestock production, conservation, hunting or tourism.

Projects may rely on modelled or measured approaches and must meet the following conditions:

- It is expected such project activities will occur on grasslands that have historically experienced soil carbon loss.
- The project must result in no net increase in the density of, or time spent by, animals in confined corrals where dung can pile up and begin to decompose anaerobically, resulting in CH_4 and N_2O emissions, such as an increase in the number of livestock aggregated (e.g., kept in corrals or pens) that would result in more than 50 per cent of the ground area covered by dung.

Steps include:

- Determine baseline values (see methodology).
- Determine additionality using the VCS tool ‘VT0001 Tool for the Demonstration and Assessment of Additionality in VCS Agriculture, Forestry and Other Land Use (AFOLU) Project Activities’. In this tool, the project proponent must (1) identify alternative land use scenarios to the proposed project activity; (2) perform an investment analysis to confirm the proposed project activity is not the most economically or financially attractive of the identified land use scenarios; (3) identify key barriers; and (4) demonstrate how the proposed project activity deviates from common practice.
- Determine leakage that would occur primarily by displacement of livestock to other grazing lands in which grazing would result in loss of soil carbon and/or increased CH_4 emissions. Such displacement is limited by the applicability conditions for the methodology, but where displacement does occur, leakage emissions must be quantified according to the procedures within the methodology.
- Determine project emissions abatement and storage.
- Undertake monitoring, focusing on measuring the key parameters for calculating emissions and removals, demonstrating project management activities and measuring changes in soil carbon. The project activities key to changing CH_4 emissions are altering the number and species composition of livestock grazing animals and/or the species composition of forage plants; altering the duration, timing and intensity of grazing; and/or changing fire frequency, intensity and any accompanying vegetation change (such as in woody biomass). Changes in soil carbon density under the project scenario should also be monitored, and stratified according to management practices or soil and climatic conditions. Monitoring soil, vegetation, grazing intensity and occurrence and intensity of fires will fully employ permanent sampling stations.
- Application process.

Climate Solutions Fund soil carbon methodology

The 'Estimation of soil organic sequestration using measurement and models' is a compliance market methodology that exists under the Australian ERF. There are no methods that account for CH_4 reduction using the KGS.

Steps include:

- Plan your project, make sure the project is eligible, and ensure you hold legal right for the duration of the project.
- Check general and land eligibility requirements.
- Map your project area.
- Undertake sampling – use soil core measurements collected from an area or use the hybrid approach, which combines soil carbon estimates and soil core measurements. Sampling costs include to engage a soil technician to take soil samples, and laboratory analysis fees. If you are following a measurement-only approach, you need to sample the carbon estimation area at least once every five years. If you are following a hybrid approach, you need to sample each carbon estimation area at least once every 10 years, and factor in the cost of using a model.
- Determine baseline values.
- Complete the application process.

15. Contact a carbon aggregator

The Carbon Market Directory can be accessed to search for a project developer or carbon aggregator if you would like to engage one. Information on their expertise and experience with the voluntary market should be sought if required.

16. Conduct management activities

Confirm calculations from the preliminary evaluation

Confirm theoretical calculations for the new GI that enables you to achieve your target soil carbon sequestration, CH_4 abatement and stocking rate, which is to be converted to kangaroo equivalents. The methods should comply with the requirements of the carbon methodology that best suits your project.

Destocking livestock and managing kangaroos

Alter the stocking rate and duration or intensity of grazing to promote soil vegetation cover and/or improve soil health. Steps include:

- Generate a harvest plan – when and how many kangaroos to harvest. Apply for a harvest licence if required
- Generate a monitoring plan for pasture condition, soil carbon and the kangaroo population
- Destock
- Manage kangaroos
    - Option 1 – pastoralist/harvester operator
    - Option 2 – harvester access
    - Option 3 – concurrent enterprise

Controlling pest species

All grazing animals, including domestic, feral and native animals, need to be managed so native plant species are not overgrazed.

17. Assess opportunity for other programs to support co-benefits

Market demand is an increasingly strong driver of products that produce co-benefits. The report accompanying these guidelines describes other programs that can help producers gain other co-benefits. Programs that can be administered to achieve credits and certification are listed in the section 'Co-benefit markets'; certification to improve marketing opportunities is discussed in the value-adding sections of the report; and programs that help producers gain natural capital without specific marketing certification or credits are described in the 'Programs that can assist gaining natural capital' section.

References

ACT Government: Australian Capital Territory Government (2010). *ACT Kangaroo Management Plan*. Canberra, ACT, Australia.

Colgan, S. A., N. R. Perkins and L. A. Green (2019). The large-scale capture of eastern grey kangaroos (*Macropus giganteus*) and red kangaroos (*Osphranter rufus*) and its application to a population management project. *Australian Veterinary Journal, 97,* 515-523.

Coulson, G., M. A. Snape and J. K. Cripps (2021). How many macropods? A manager's guide to small-scale population surveys of kangaroos and wallabies. *Ecological Management & Restoration, 22,* 75-89.

Deng, L., C. Peng, D. G. Kim and J. Li (2021). Drought effects on soil carbon and nitrogen dynamics in global natural ecosystems. *Earth-Science Reviews, 214,* 103501.

Hill, M. J., S. H. Roxburgh, G. M. McKeon, J. O. Carter and D. J. Barrett (2006). Analysis of soil carbon outcomes from interaction between climate and grazing pressure in Australian rangelands using Range-ASSESS. *Environmental Modelling & Software, 21,* 779-801.

MLA: Meat and Livestock Austalia (2021). *Cost of Production Beef, Lamb and Goat*. Accessed: 20 January 2022, from: https://www.mla.com.au/extension-training-and-tools/tools-calculators/Cost-of-production/#.

Pahl, L. (2019). Macropods, feral goats, sheep and cattle. 1. Equivalency in how much they eat. *The Rangeland Journal, 41,* 497-518.

Soils Revealed (2016). *Soil Carbon Can Help Combat Climate Change*. Accessed: 7 May 2022, from: https://soilsrevealed.org/.

Appendix B – Submission to the Climate Solutions Fund method development priorities

Submitted on 2 September 2021 at 4.58pm (note: figures and references not included).

1. What is the name of the proposed emissions reduction activity?

Kangaroo landscape conservation (KLC) – an additional credit earning option for beef, sheep and goat producers, and conservation and Indigenous reserve managers.

2. Briefly describe the proposed emissions reduction activity.

The proposal is for active management of kangaroos through sustainable use to reduce grazing pressure and so increase carbon in soil and vegetation. Kangaroos would be integrated alongside other herbivores and livestock to find an optimal stocking rate for the environment and seasonal conditions. A co-benefit would be reduction of enteric methane emissions from livestock. The activity would be undertaken either within a new methodology or a module in a larger landscape methodology. It could be measured through numbers of kangaroos and livestock removed to reduce grazing pressure and via soil and vegetation sequestration methodologies.

Australia has at least some 35 million kangaroos on rangeland properties and many more on conservation and Indigenous reserves. They coexist with some 35 million sheep, three million goats and seven million cattle (Figure 1 and 2). Together they form a significant biomass that inhibits vegetation and soil sequestration. Managing them in an integrated manner is needed and would bring commercial and sustainability benefits to both pastoralists and conservation reserves.

At present kangaroos are comprehensively undervalued compared to domestic livestock (Figure 3). This methodology could create an incentive for less kangaroos to be taken as pests, thereby reducing waste and generating employment, diverse enterprises and a stronger rural economy. The recovery of a high-quality protein produced with low carbon emissions is much-needed in global terms.

Additional income could come from sustainable harvest of kangaroos to supplement sales of livestock. It would be a form of subsidy for sustainable production. Kangaroos emit almost no methane. Therefore, putting them into the value chain as low-emissions meat producers in lieu of increasing other meats could create carbon credits additional to those from soil and vegetation conservation.

Commercial use of abundant kangaroos is permitted by all mainland states and wallabies are harvested in Tasmania. Management is as highly regulated, as the more traditional red meat industries. Harvesting is conducted by professional marksmen and the commercial industry is deemed by attitudinal surveys to be the most appropriate method for managing unwanted kangaroo populations (Sinclair *et al*. 2019). This conclusion accords with the views of professional associations and natural resource management agencies. The RSPCA acknowledges that non-commercial culling is more likely to lead to poor animal welfare and that commercial harvesting is the most acceptable control mechanism (RSPCA 1985; RSPCA 2020).

This proposal is likely to be adopted by land managers for pastoral properties, parks and reserves and Indigenous landholders and private conservation agencies with large land holdings such as Australian Wildlife Conservancy, Bush Heritage and NSW Biodiversity Conservation Trust.

3. Is the emissions reduction activity currently business-as-usual?

No, kangaroos are not quantified as part of the reduction grazing pressure under either vegetation regeneration or soil methodologies. The primary enterprises are production of beef, sheep and some goats. Landholders do not gain any income from kangaroos removed from their properties. Neither are there incentives to produce low-emissions kangaroo meat even though kangaroo harvesting (for use) programs exist. Although the kangaroo commercial harvest management zone (Figure 4) is extensive and managed under state management plans they proceed independently of pastoral operations. Figure 5 shows results of population counts in place for NSW, Queensland, WA and SA over 30 years and newly initiated in Victoria in 2021.

The kangaroo harvest is currently much less than the authorised quota (Figure 6). When populations boom and competition with agriculture grows in drought, landholders seek permits to quickly reduce pressure on their resources and 'deal with pests'; but it is often too late. This non-commercial culling is rising, which is also a significant waste when several million kilograms of meat and skins are left to rot in paddocks at a time when a growing global population needs sources of protein and meat alternatives are being promoted as an environmental alternative (Wilson & Edwards 2019).

Under business-as-usual, kangaroo harvesting is not an attractive enterprise for landholders. Their value is too low compared to domestic livestock. Payments for ACCUs generated from improved soil and vegetation sequestration would help improve the attractiveness of kangaroo harvesting as an enterprise for pastoralists. ACCUs could encourage landholders to carry more kangaroos and less methane producing livestock thereby actually helping conserve the species. The opportunities above describe the management of kangaroos. They also apply to overabundant wallabies in Tasmania and on some islands (Wilson and Edwards 2021).

4. How has the emissions reduction activity been demonstrated to reduce emissions?

The relationship between soil carbon and grazing management is complex. Nevertheless, grazing is one of the most important factors that could change the soil carbon density in grassland systems, especially in the rangelands. Understanding the impact of grazing intensity and livestock types under different management systems is a key to providing the most effective soil carbon management strategies. High grazing pressure can significantly lower soil carbon and research suggests that it is possible to build soil carbon by managing grazing (Sanderman *et al*. 2010), with grazing at appropriate stocking levels maintaining or enhancing soil carbon stocks due to positive effects on vegetative growth and turnover of both underground shoots and below-ground roots.

The following grazing management methods are recognised to increase carbon in the soil:

- alter pasture species composition
- improve pasture cover
- increase above-ground biomass production
- enhance root growth and turnover
- increase inputs of plant biomass into the soil.

Methods aim to enhance carbon in soil by grazing pastures at appropriate stocking rates for growth of above-ground shoots and below-ground roots, and include:

- controlled grazing
- rotational grazing
- cell grazing
- removing stock
- exclusion fencing
- controlling watering points for native and feral animals.

A number of studies have examined different grazing treatments on soil carbon with some finding that grazing management increased, decreased or maintained soil carbon with the contrasting results coming from different variables. A number of variables are thought to contribute to these inconsistencies in soil carbon storage and include:

- time treatment applied
- sampling variability
- ground cover and litter
- biomass
- tree cover
- vegetation community – species and heterogeneity
- soil type/texture
- climate – precipitation/temperature/drought
- C3/C4 balance
- land use period, degradation
- nature, frequency and intensity of disturbances
- length of growing season.

Each of these factors will interact over time, making it difficult to separate the respective conditions of variable and grazing management to the change in carbon in soil. Therefore, a management activity that builds soil carbon on one property or region will not necessarily build soil carbon on another. However, overall, it is likely that if appropriately managed, grazing would have a positive impact on storing carbon in the soil.

Research has also shown that kangaroos are non-ruminant forestomach fermenters that produce negligible amounts of methane (Kempton *et al*. 1976, Vendl *et al*. 2015). Over a decade ago, Wilson and Edwards (2008) calculated the reduction in Australia's greenhouse gas liability that could be achieved by making greater use of kangaroos as meat producers on the rangelands. Cattle can produce up to 145 times per head, while goats and sheep produce 13 to 18 times the amount of methane that kangaroos produce (Wilson and Edwards 2021; Figure 7). These estimates are based on Australia's National Greenhouse Gas Inventory calculations (NGGI 2021) and Australian Bureau of Statistics population data (ABS 2020) for cattle and sheep and the National Greenhouse Gas Inventory (2005) for goats. From the data available, after converting per head methane production to methane produced per kilograms of meat, published figures suggest 7.11 kg CO_2 equivalents per year come from 1 kg beef whereas 0.83 kg CO_2 equivalents come from 1 kg of kangaroo meat, while 9.50 kg CO_2 equivalents per year come from 1 kg useable goat meat (Wilson and Edwards 2021; Figure 7). While comparisons between rangeland animals are difficult to make because most studies on cattle have been done on intensive animal production and feedlots and the numbers need further refinement with closer consideration of the number of months or years to slaughter and cull, they are suggestive that substantial greenhouse house gas savings can come from substituting livestock red meat enterprises to kangaroo harvest. Research designed to specifically examine these differences, rather than from inferring data, are warranted to enable more robust comparisons.

Leakage is a potential issue. There is high demand for beef and lamb. If herds and flocks are reduced in some regions, they may be increased in other regions to meet market demand. Market caps on livestock numbers may be a necessary measure to control leakage. However, as the demand for food in the world grows, it is possible that the free-range, low-maintenance production system of kangaroos, which are found nowhere else in the world, becomes more desirable. If kangaroo products could fetch a higher price that is equivalent to that of beef, sheep and goats, leakage would not be a great problem.

5. What is the likely uptake of the emissions reduction activity and the likely abatement volume?

Many graziers are already beneficiaries of the ERF. They have contracts with Clean Energy Regulator for carbon credits under the Carbon Farming Initiative – Avoided Clearing of Native Regrowth Methodology and Soil carbon. They are paid for avoiding clearing native forest for which clearing permits have been issued and that has historically been subject to clearing. Initial consultations with the carbon aggregators of these graziers have indicated that producers with properties with large numbers of kangaroos are interested in the concept. If financially viable, it is likely that there would be great levels of uptake where there are large numbers of kangaroos. With AgriFutures' support, we have been investigating how producers can manage their kangaroos to obtain carbon credits through an alternative grazing management strategy that incorporates kangaroos into traditional practices.

We have recently modelled potential grazing pressure in the rangelands by comparing numbers of kangaroos to sheep and cattle. In large regions, including western NSW, south-western Queensland and north-western SA, kangaroos are potentially responsible for upwards of 50 per cent of the grazing pressure.

Marketing the low-emissions benefits of consuming kangaroo meat is one of a number of mechanisms that would increase demand and therefore price and uptake. Abatement would come from a reduction in methane emissions and this would be dependent on the number of livestock removed. Sequestration would be increased in vegetation and soil. The volume would likely be large as the rangelands cover 75 % of Australia. Figure 8 shows the potential sequestration in all of Australia with projected changes with grassland sustainable management and adaptive management. These activities can only be achieved if the grazing pressure from kangaroos is managed.

6. Is the activity using technology or practice that is proven and commercially viable?

Current protein demand for the 7.3 billion inhabitants of the world is approximately 202 million tonnes globally. At current consumption and average consumption for the world is expected to be 267 million tonnes per annum (Henchion *et al*. 2017). Global meat consumption is expected to increase by 76% by 2050. Australia produces substantially more food than it consumes, as food projections grow so too will food produced in Australia. However, when drought makes water and food scarce, landholders face production difficulties. They are also faced with additional management costs (NSW Farmers 2018; The Land 2018) to remove kangaroos. They destock and then spend more time and therefore money on kangaroo management (Atkinson *et al*. 2019, Sinclair *et al*. 2019), a situation that detracts from their livelihoods and can incur untenable costs (Hacker *et al*. 2019). When grazing resources have been exhausted, especially during droughts, millions of kangaroos suffer and starve to death (Caughley *et al*. 1985, Robertson 1986, Bayliss 1987, The Land 2018). Harvesting, before they exhaust pastures, would reduce negative consequences for carbon sequestration. These optimal management goals for the carbon environment need to be implemented. There is an established kangaroo industry in place with export and domestic regulations, standards, and code of practices in place to ensure that the kangaroo product is safe for consumption and conducted in a humane manner. Harvesting by professional marksmen and the commercial industry is deemed by attitudinal surveys to be the most appropriate method for managing unwanted kangaroo populations (Sinclair *et al*. 2019).

This conclusion accords with the views of professional associations and natural resource management agencies. The RSPCA acknowledges that non-commercial culling is more likely to lead to poor animal welfare and that commercial harvesting is the most acceptable control mechanism (RSPCA 1985, RSPCA 2020). Technology or practices used to determine emission savings from livestock meat to kangaroo could emulate the equations used to determine current savings from the beef herd methodology; however there needs to be equivalent equations for sheep and goats. Carbon sequestration in soil and vegetation could be determined through current methodologies, however they may need to be reviewed to include kangaroo management.

7. Could the emissions reduction activity cause adverse environmental, economic or social impacts?

Kangaroos are the national icon and a protected native species; they are also at the same time pests, and a commercial resource. No other species of wildlife has such conflicting status. State governments have primary responsibility for kangaroos and are therefore required to find a balance between these competing objectives. Some people regard any consumptive use of kangaroos as unethical and distasteful. Animal rights activists in particular are opponents of the commercial kangaroo industry and also oppose all meat industries regardless of the species being used. Although a minority, they are very vocal, which makes many politicians, organisations, and potential funding sources wary of engaging and investing in kangaroo management.

The controversy contributes to the weak demand for kangaroo products and consequent low prices. As a result, kangaroos are not managed by the commercial industry as expected (Hacker *et al*. 2019, Sinclair *et al*. 2019), despite being the most appropriate method for management (Sinclair *et al*. 2019). Wide recognition of kangaroos as the producers of low-emissions meat could improve demand and raise their competitive value with other herbivores with who they share the rangelands. Harvesting is conducted by professional marksmen and the commercial industry is deemed by attitudinal surveys to be the most appropriate method for managing unwanted kangaroo populations (Sinclair *et al*. 2019).

This conclusion accords with the views of professional associations and natural resource management agencies.

The RSPCA acknowledges that non-commercial culling is more likely to lead to poor animal welfare and that commercial harvesting is the most acceptable control mechanism (RSPCA 1985, RSPCA 2020). Nevertheless, we understand the sensitivities of kangaroo harvesting and the difficulty it poses for policy initiatives and organisations that have a public profile. The driver behind our project is to move kangaroos from being pests on pastoral properties and so ensure better animal welfare. The initiative fits within broader strategic aims and objectives that an informal group of scientists are striving for (see second attachment). It aims to manage the grazing stock to find what is optimal for the environment and to do so in a manner that is socially and politically attractive. Focusing on improving carbon sequestration and vegetation on soils opens up many opportunities including for Indigenous involvement. It could be extended to cover improved management of buffalo and camels on indigenous land.

8. Are you aware of any other programs that could support the emissions reduction activity?

Not at present. The beef herd methodology comes close, but it does not allow use of alternative species. There are also no equivalent methodologies for sheep and goats. Additional benefits from grazing management could come from the soil carbon and human-induced regeneration methods. The methodology could also fit as a module of the wider landscape methodology, which is also being proposed as a priority.

9. How does the proposed emissions reduction activity align with broader government priorities and/or provide co-benefits?

The co-benefits of reducing livestock and substituting with a sustainable resource are vast and doing so can have widespread positive impacts on the environment and biodiversity, pest management, individual health and animal welfare. Reformed kangaroo management to increase sustainable use and reduce waste fits under the priorities of the Future Drought Fund:

a. Economic resilience – lifting the productivity and profitability of the agriculture sector.
b. Environmental resilience – enhancing the health and sustainability of Australia’s farming.
c. Social resilience – helping farms and communities be better prepared to respond to the impacts of drought and reduce their stress.

Reformed kangaroo management also contributes positively to biodiversity and land and water stewardship programs. Kangaroo management by use by landholders can reduce issues when too many kangaroos damage biodiversity and ecosystem services. For example, research in the ACT has shown that high densities of kangaroos can adversely affect a range of taxa; for example, beetle abundance and diversity are negatively affected (Barton *et al*. 2011), reptile abundance and occurrence is also affected by the change in grass structure (Howland *et al*. 2014), while the abundance of birds with grassland nesting, feeding and concealment needs is also heavily affected (Howland *et al*. 2016).

Reducing livestock stocking rates is a major component of Regenerative Agriculture, and Sustainable Farming Systems. Under current practise when paddocks are spelled, overabundant kangaroos move in and compromise the objectives of conservative grazing practice. We note that kangaroos evolved in, and are adapted to, the Australian environment with padded feet making their effects on the environment relatively benign (provided there are not too many of them in a small space). An outcome of the adoption of our proposal is more kangaroos being taken by commercial marksmen.

Kangaroos have less physical impact on the environment compared to sheep, goats and cattle as a result of their physical attributes. Grigg (2002) reviewed the impact and concluded that kangaroos 'soft feet' do less damage to land and vegetation compared to sheep and cattle at kilogram for kilogram. We note the impact of hard-hoofed livestock and that there have been major land and vegetation conservation programs to fence livestock out of creeks and rivers. Many golf courses will tolerate up to 100 kangaroos whereas we doubt they would tolerate any sheep and certainly no cattle because of the damage that would be done to playing surfaces. Increased use of kangaroos in the Australian diet would contribute to Organic Produce, Ethical Choices and Healthy Food programs. Australian Organic, the parent company of Australian Certified Organic (ACO) offers a Registration Program for Allowed Inputs (AI) and Approved Products (AP) that are used in organic farming or processing (ACO 2020). These are products such as fertilizers, natural pesticides, cleaners, animal health products and mineral based cosmetics products.

Purchasing kangaroo products should be an ethical choice for socially concerned consumers. Kangaroos live free and wild on a natural diet of native vegetation. Kangaroo meat is not farmed; it is harvested free-range. The method of killing is humane; instant kill in their natural habitat. Using kangaroos minimises waste when populations are being culled for damage mitigation purposes. Pest culling of kangaroos by amateurs is virtually impossible for regulators to monitor. Under 'shoot and let lie' neither the number of kangaroos taken, nor the accuracy and skill of the shooter nor compliance with welfare codes, can be assessed. If more kangaroos were managed through commercial harvest, animal welfare practices would improve through the nationally monitored commercial harvesting program. Increasing kangaroo harvest instead of culling kangaroos, means that kangaroos would be used a sustainable resource, instead of disposed as waste.

Kangaroo meat has a lower fat and cholesterol content than lean beef and lean lamb. It provides more protein than beef, lamb, pork and chicken and has a higher iron content than lamb, pork and chicken (Food and Fogerty 1982). These features allow kangaroo meat to provide the health benefits of white meat, while still maintaining its red meat status. Thus, kangaroo meat appeals to the health-conscious customers, which is a growing market. Furthermore, the product is wild harvested and therefore free-range. The National Farmers' Federation (NFF) has a vision to exceed $100 billion in farm gate output by 2030 and Meat and Livestock Australia projects the cattle herd will lift eight per cent in same period. These plans and aspirations will increase Australian methane emissions, plus require land use change, tree clearing and other developments. At the same time MLA has set a target for beef, lamb and goat production, including lot feeding and meat processing to be carbon neutral by 2030. Kangaroo production as outlined in this submission could be part of that aspiration.

10. Could the emissions reduction activity be promoted more efficiently through other measures?

Expansion of the kangaroo industry could be an innovative rural development with relatively low costs; the resource is already there, and the industry is operating, albeit in a constrained form. An increase in value is needed as an incentive for pastoralists to integrate kangaroos into their production strategies. This concept, and in particular the use of the phrase ‘sheep replacement therapy’ by Gordon Grigg, has been repeated for over 40 years by wildlife managers and conservation biologists. (Wilson 1974, Grigg 1987, Grigg 1988, Archer 2002, Lunney 2018) There has been little progress due to a lack of economic incentives for change. Increasing value is a critical component of converting kangaroos from an unmanageable liability to an asset. An increase in value would enable pastoralists to benefit as they do for other livestock. Landholders would diversify their enterprises and so enhance both their resilience and that of their communities. Such changes are possible when one considers the increases in feral goat value in recent years from pest to valuable resource currently worth $112 per head for an average 35 kg adult goat (The Land 2019).

AgriFutures®
National Challenges
and Opportunities

Market opportunities for methane abatement and carbon storage through improved kangaroo grazing management

by Melanie Edwards and George Wilson
July 2023

AgriFutures Australia publication no. **23-094**
AgriFutures Australia project no. **PRO-015092**
ISBN: **978-1-76053-387-8**

AgriFutures Australia

Building 007
Tooma Way
Charles Sturt University
Locked Bag 588
Wagga Wagga NSW 2650

02 6923 6900
info@agrifutures.com.au

agrifutures.com.au