Australian Government
Department of Agriculture and Water Resources

Queensland Government

POLICY DELIVERY — ACTION ON THE GROUND ROUND 1

Application ID: AOTGR1 198

FINAL REPORT

Northern grazing carbon farming – integrating production and greenhouse gas outcomes 2.

AUTHORS AND REPORT STRUCTURE

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This report should be cited as: Bray, S., Phelps, D., Broad, K., Pahl, L. Whish, G. Emery, T. Houston I. and Sneath R. (2015) Northern grazing carbon farming – integrating production and greenhouse gas outcomes 2. Climate Clever Beef Final Report. Department of Agriculture and Fisheries, Rockhampton, Queensland.

PROJECT DESCRIPTION

Three major beef production regions in Queensland were studied for their potential to reduce methane emissions from cattle, and increase carbon stored in soil and vegetation, through on-farm practices. A whole-property case study approach was undertaken within the Maranoa Balonne, Mitchell Grass and Channel Country regions. Fifteen grazing businesses across these three regions were engaged as case studies to undertake demonstrations and evaluations. These businesses were used to represent the potential for climate change adaption within these large and diverse regions within northern Australia: This project was supported by the Queensland government, regional natural resource management groups, grazing businesses and the Australian Government's Action on the Ground program. In combination with project AOTGR1-161, these projects were part of the Climate Clever Beef initiative.

The extensive northern Australian grazing industry manages 15 million cattle on 250 million hectares and contributes 79% of Australia's agricultural greenhouse emissions. The case study properties manage more than 34,400 cattle and 291,000 ha; the three project regions run 3-4 million cattle. The project was designed to evaluate the integration of carbon farming practices to increase carbon stored in soil and vegetation and reduce methane emissions to lower the environmental impact of the beef industry, while maintaining herd productivity and business profitability. Additional 'carbon income' may be available to some grazing businesses through participation in the Australian Government's Emissions Reduction Fund (ERF). This project evaluated the magnitude and potential for reduction in methane emissions, improvement in emissions intensity, sequestration of carbon in soil and vegetation and potential to generate carbon credit units, along with identifying some of the practical limitations and tradeoffs for integrating carbon farming into northern Australian beef businesses.

The project provided an excellent opportunity to capitalize on established networks and genuine producer interest and participation built up in recent initiatives (e.g. CCRP Climate Clever Beef (Bray *et al*. 2014), Northern Grazing Systems project (Phelps *et al*. 2014), RELRP, SCaRP, SavannaPlan, CQ Beef). The knowledge and analytical tools developed during previous projects identified practices to: reduce the greenhouse gas emissions impact of beef businesses, manage climate variability, improve land condition and increase business profitability. The Climate Clever Beef analytical framework was used in this project to:

1. Collate baseline data to describe the current performance of each collaborating business.
2. Identify promising management options to reduce methane emissions from cattle and/or increase carbon stored in soil and vegetation and improve profitability and productivity.
3. Evaluate the likely impacts of these options on multiple aspects of business performance including impact on greenhouse gas emissions, carbon sequestration, productivity and profitability.

The project engaged with producers and industry advisers by establishing producer demonstration sites in each of the Maranoa Balonne, Mitchell Grass and Channel Country regions. The project findings have been communicated to over 810 people and 256 businesses via 19 field days and industry events and 25 publications, including case studies, fact sheets, conference papers, newsletter articles and journal papers. Thirty-one people from 16 businesses demonstrated practice change during the project by undertaking businesses analysis and/or changing an aspect of management on their property.

Case studies and fact sheets have documented the results from the analysis of options which are available on the Climate Clever Beef website (http://futurebeef.com.au/resources/projects/climate-clever-beef/), in conference and journal papers and in this final report. Journal publications are currently in press documenting the findings from the Maranoa Balonne, Mitchell Grass and Channel Country case studies.

EXECUTIVE SUMMARY

The northern Australian beef industry is large, managing 15 million cattle on 250 million hectares. Due to the size and nature of the industry there are areas where environmental impacts are likely to occur. Of concern are declines in land condition leading to reduced water quality and sediment transport, and emissions of greenhouse gases to the atmosphere. The northern Australian beef industry is estimated to contribute around 79% of Australia's agricultural greenhouse gas emissions (10% to Australia's total greenhouse gas emissions) through livestock emissions as well as impacting carbon stored in soil and vegetation. The northern Australian beef industry thus has a significant role to play through 'carbon farming' to assist Australia to meet its long term emissions reduction targets. However, productivity growth and returns on investment in the northern Australian beef industry are generally static or declining and together with high debt levels and increasing input costs, any new initiatives will require rigorous evaluation to ensure that business profitability is enhanced and financial risks are minimized.

'Carbon farming' was defined for this project as having potential to reduce greenhouse gas emissions, improve emissions intensity or increase carbon stored in soil or vegetation. Carbon farming practices may or may not have potential to generate 'carbon income' through participation in the Australian Government's Emissions Reduction Fund (ERF).

Fifteen grazing businesses were engaged across three large and diverse regions to identify, demonstrate and evaluate carbon farming management options to reduce methane emissions from cattle and/or increase carbon stored in soil and vegetation. Innovative engagement processes and decision support tools were used to assess the financial implications, practicality and tradeoffs of integrating carbon farming practices into existing beef businesses. The 15 collaborating businesses represent beef production systems across northern Australia and manage more than 291,000 ha and 34,400 cattle. This project was delivered in the Maranoa Balonne, Mitchell Grass and Channel Country regions in Queensland. The project had support from the Queensland government, regional natural resource management groups, 15 grazing businesses and from the Australian Government's Action on the Ground program.

On-farm trials and evaluations demonstrated there were opportunities for beef businesses in northern Australia to minimise the intensity of livestock methane emissions and increase carbon stored in vegetation.

Livestock emissions intensity and total emissions were improved through a number of management strategies trialed during the project. These included increasing growth rates of cattle through supplementation and the use of fodder crops and leuceana, improved management and reproductive performance of breeders and improved weaning rates. Emissions intensity improved in most scenarios with total emissions reduction being harder to achieve. Generally total emission reductions occurred when total stock numbers were reduced, which is not sustainable for a beef business in the long term due to reduced income from fewer sales. Utilising a suite of management practices together achieved a more positive outcome for improving emissions intensity. In addition, adopting best management practices in a beef business led to improvements in overall productivity and profitability for the business. This profitability increase was independent of carbon farming income. The ability of most beef businesses in northern Australia to derive income from the ERF through reducing livestock emissions is limited, due to the lack of scale in most businesses to offset the costs of participating with the carbon credits acquired.

Grazing management strategies that have led to improved pasture condition, increased pasture biomass and reduced drought risk have the ability to substantially increase the average amount of carbon stored in vegetation, particularly in grassland landscapes. This carbon farming practice has significant implications for landscape health, reduced off-farm impacts, long term business profitability and reduction of drought risk, but currently there is no opportunity to generate carbon income due to a lack of an ERF methodology and the perception that higher average pasture biomass is not a secure long term carbon store. This perception could be addressed by policy, leading to a significant improvement in the environmental impact (e.g. water quality, sediment transport, biodiversity) and drought preparedness of the northern Australian beef industry.

The impact of grazing land management and land condition on soil carbon was found to be negligible or inconsistent using SCaRP methodology across many soil types, regions and production systems (apart from converting cropping land to pasture, as documented in this project). This suggests that there is little scope for soil carbon sequestration ERF projects on northern Australian grazing land due to high project risk. Although change and trend in soil carbon could not be confidently measured, in general, management strategies that aim to increase the carbon stored in soil are desirable for grazing businesses due to the complementary improvements in pasture quantity and quality, which lead to improved livestock productivity.

The project engaged with producers and industry advisers by establishing producer demonstration sites in three regions. An extension and communication strategy has improved knowledge and awareness of beef producers, agencies, community, agribusiness, rural lenders, academics and policy personnel throughout Australia. Project findings have been communicated to 810 people and 256 businesses via 19 field days and industry events and 25 publications, including case studies, fact sheets, conference papers, newsletter articles and journal papers. Thirty-one people from 16 businesses demonstrated practice change during the project by undertaking businesses analysis and/or changing an aspect of management on their property.

Key findings from the case studies undertaken in the project include:

Reduce methane emissions

- Improving efficiency of production through increasing weaning rates, reducing age of first conception and/or improving lifetime reproductive efficiency can improve productivity, profitability and livestock emissions intensity within the Mitchell Grass and Channel Country regions of Queensland.
- Pregnancy testing can be a powerful tool to evaluate and improve herd reproductive performance and identify unproductive breeders to improve overall reproductive efficiency of the herd and manage available forage in dry seasons.
- The profitability and likely greenhouse emissions benefits of livestock supplementation are impacted by seasonal conditions and climate risk.

- The use of forages (e.g. leucaena and oats) can improve livestock productivity and greenhouse gas emissions intensity in regions suited to their use, such as the Maranoa Balonne.
- A suite of management changes will likely be required to substantially change productivity, profitability and greenhouse gas outcomes.
- Higher enterprise gross margin often coincides with the lower emissions intensity.
- Total livestock methane emissions can only substantially decline if stocking rates are reduced, which can have a large impact on business profitability even if individual animal productivity improves.
- Beef businesses should focus on cost-effective changes to improve production efficiency and the associated improvement in livestock revenue. Potential carbon income should be considered a bonus and not the basis for management change alone.

Increase carbon stored in soil and vegetation

- Wet season spelling and stocking rate management can be used to improve pasture biomass and carbon stored in pasture and improve or maintain land in good condition.
- Soil carbon stocks under different management options were generally not significantly different nor consistent when assessed using SCaRP methodology, with the exception of cropping land converted back to pastures.
- Returning cropping land to pasture can increase the amount of carbon and nitrogen stored in the soil.
- Land development and maintaining pasture in good condition is likely to have little impact on soil carbon stocks compared to remnant native vegetation.
- Based on the soil carbon work undertaken in this project (together with evidence from other published scientific studies), it is recommended that northern beef producers exercise caution when considering soil carbon sequestration ERF projects due to the risk of unpredictable (often unresponsive) and inconsistent changes in SOC stocks with change in management (apart from converting cropping land to pasture).
- Despite the limited potential for soil carbon income, our analyses confirm that pasture management to maintain good land condition does have significant productivity, profitability and land management benefits.

Innovative practices /technologies to reduce agricultural greenhouse gas emission /increase carbon stored in soil

Bioeconomic modelling found:

- Moderate stocking rate flexibility has potential to improve profitability, land condition and greenhouse gas emissions intensity with moderate risk of not being able to respond fast enough to changing climatic conditions.
- A suite of management changes is generally required to make a large enough impact on livestock emissions to potentially consider an ERF carbon farming project.

The extension strategy highlighted that:

- Business analysis can be a powerful component of extension activities encouraging practice change.

- Case studies and fact sheets were useful for producers and policy personnel to understand how management change could impact productivity, profitability and greenhouse gas emissions as part of a ‘real’ grazing business.
- Developing and maintaining trusting relationships with producers and colleagues was extremely important to successfully undertake comprehensive business analyses and facilitate practice change.

The findings from the analysis of options at the demonstration sites have been documented in case studies and fact sheets available on the Climate Clever Beef website (http://futurebeef.com.au/resources/projects/climate-clever-beef/), in conference and journal papers and in this final report. A special issue of The Rangeland Journal scheduled for publication in 2016 has been negotiated to provide a long-term legacy of the key case studies arising from the Climate Clever Beef project and from collaboration with allied projects.

Before this project commenced there was a perception that few carbon farming opportunities were available for the extensive beef industry in northern Australia. Furthermore, it was unclear to most producers and their advisors how (1) a carbon farming practice might be integrated into a beef business or (2) how to assess the business case for participation. Until these issues were addressed, we believed that the uptake of carbon farming practices in the northern beef industry would be low. This project has addressed many of the knowledge gaps and provides clear guidance for northern beef producers considering participation in the carbon economy.

TABLE OF CONTENTS

TABLE OF FIGURES

LIST OF TABLES

INTRODUCTION

The northern Australian beef industry is large, managing 15 million cattle on 250 million hectares. The expansive size of the industry means that significant environmental impacts are likely. Of concern are declines in land condition leading to reduced water quality and sediment transport, impacts on biodiversity and emissions of greenhouse gases to the atmosphere. The northern Australian beef industry is estimated to contribute around 79% of Australia's agricultural greenhouse gas emissions through livestock enteric methane as well as impacting carbon stored in vegetation and soil. The northern Australian beef industry thus has a significant role to play in assisting Australia to meet its long term emissions reduction targets.

As with many other agricultural industries, productivity growth and returns on investment are generally static or declining across much of the northern beef industry (McLean *et al*. 2014). Together with high debt levels and increasing input costs, the industry is struggling to improve production efficiency and profitability (Petty *et al*. 2013). Recent benchmarking data (McLean *et al*. 2014) shows that there are businesses that are performing well despite the prevailing conditions, which suggests there are opportunities for the wider industry to improve its profitability, but new initiatives will require rigorous evaluation to ensure the financial risks to businesses are minimal.

Two key profit drivers in extensive beef businesses are 'kilograms of beef produced per adult equivalent per year' and cost of production. Recent animal production and land management research in northern Australia has highlighted several opportunities to lift business performance in a cost-effective way. Common strategies include increasing breeder herd productivity (by increasing weaning rates and reducing mortality rates), improving weight for age, realizing under-utilized carrying capacity, and managing costs. Recommended practices include genetic and fertility selection, infrastructure development, stocking rate management, pasture improvement and/or finishing cattle elsewhere (Bentley *et al*. 2008, Henderson *et al*. 2012, Petty *et al*. 2013, Quigley & Poppi 2013, McGowan *et al*. 2014). These practices also have implications for greenhouse gas emissions and/or carbon sequestration and thus show potential for beef producers to participate in the carbon economy.

The degree to which these recommendations should be applied varies between regions in northern Australia. The Maranoa-Balonne region is well-advanced in terms of infrastructure and pasture improvement. The productivity experienced by businesses in this region is nearing capacity, and the size of properties and scale of production generally limits improvements in herd efficiency (McLean *et al*. 2014). In contrast, property size in the Channel Country is very large and run cattle herds of 5,000 head or more with a high labour unit efficiency. The potential for pasture improvement is low due to low and variable rainfall, but the opportunity for infrastructure development to run additional cattle or to implement pasture spelling practices is high.

Participation in the 'carbon economy' (emissions reduction and sequestration) may provide opportunities across northern Australia, but to varying degrees within different regions. For example the Mitchell Grass Downs region is dominated by naturally open country, with no scope for large-scale tree planting but potential to sequester carbon across large areas. Evaluating the business case for participation is not without significant challenges. Key challenges include:

- Poor understanding of the impact of management change on livestock business greenhouse gas emissions and carbon sequestration in vegetation and soil and the trade-offs with livestock productivity.
- Lack of market instruments to engage in the carbon economy (no extensive livestock ERF methodologies had been approved at the start of the project in 2012, some methodologies are now available see Table 1).
- Poor financial position of most grazing businesses and lack of financial literacy and skills to evaluate alternative income options.
- Highly volatile livestock markets (live export cessation, drought), high climate variability and little certainty of carbon prices and compliance costs contribute greatly to the risk associated with evaluating and undertaking a 'carbon project'.
- Highly dispersed and 'over-busy' (partly due to drought) business managers mean that extension and education support to undertake significant management change is difficult.

Despite these challenges, recent RD&E projects (e.g. Northern Grazing Systems, Climate Clever Beef and $avannaPlan) have identified and demonstrated practices that improve productivity, land condition and beef business resilience. Importantly, many of the identified practices also have 'carbon farming' implications supported by past and recent Australian Government supported research including RELRP (Reducing Emissions from Livestock Research Program), SCaRP (National Soil Carbon Research Program) and Cooperative Research Centre for Greenhouse Accounting.

In this report, 'Carbon farming' is defined as having potential to reduce greenhouse gas emissions, improve emissions intensity and/or sequester carbon in vegetation or soils. Carbon farming practices evaluated in this project may or may not have potential to generate 'carbon' income from the registration and sale of carbon credit units through the Emissions Reduction Fund (ERF).

In 2011, the Australian Government implemented the CFI (Carbon Farming Initiative) package to enable farmers to participate in a 'carbon market'. The land sector elements of the CFI package were about creating opportunities on the land whilst addressing carbon pollution under the premise that significant opportunities exist within Australia's agriculture sector to reduce carbon pollution and increase the amount of carbon stored on the land. The intent of the CFI program was that those who pursued these opportunities would be rewarded through the CFI, allowing farmers and land managers to create saleable credits for carbon bio-sequestration and pollution reduction activities associated with agricultural production. In 2014, the CFI was transitioned into the Australian Governments Emissions Reduction fund (ERF).

However, at the start of the project in 2012 there was a perception in the northern grazing industry that few carbon farming opportunities and no methodologies were available for extensive beef producers. Since 2012, a number of ERF methodologies, potentially applicable to the northern beef industry, have been developed (Table 1). This uncertainty highlighted a clear need to demonstrate the integration of practices to increase carbon sequestration and reduce greenhouse gas emissions, while maintaining or improving productivity and profitability. Furthermore, it was unclear to most producers and their advisors how:

1. A carbon farming project might be integrated into a beef business, or
2. How to assess the business case for adoption and participation in a carbon farming project.

Unless these issues were addressed, uptake of carbon farming projects and practices in the northern beef industry was likely to be limited.

Table 1 Emission Reduction Fund (ERF) methodologies potentially applicable to the northern beef industry.

Target	Methodology	Status
Soil carbon sequestration	Sequestering carbon in soils in grazing systems	Approved 2014
Livestock methane emissions	Reducing greenhouse gas emissions in beef cattle through feeding nitrate containing supplements	Approved 2014
Woody vegetation carbon sequestration	Native forest from managed regrowth	Approved 2013
Woody vegetation carbon sequestration	Reforestation and afforestation	Approved 2013
Fire emissions	Reduction of greenhouse gas emissions through early dry season savanna burning. High rainfall zone (above 1000 mm of average annual rainfall)	Approved 2012
Fire emissions	Reduction of greenhouse gas emissions through early dry season savanna burning. Low rainfall zone	Approved 2015
Livestock methane emissions	Beef cattle herd management	Approved 2015

PROJECT DEVELOPMENT AND REPORT STRUCTURE

To address the above issues, a multifaceted development project (the 'D' in RD&E) was devised under the Carbon Farming Futures Fund – Action on the Ground program.

The project undertook work in three regions across northern Australia. This report is structured to provide an overview of the project and address the Action on the Ground priorities (reduce methane emissions, increase carbon stored in soil and innovative practices and technologies) by drawing together previous research and key findings and learnings from the case studies.

The Action on the Ground program and project priorities were:

a) Reduce methane emissions

> The project evaluated and trialed on-farm practices that can reduce livestock methane emissions and improve emissions intensity to assist participating land managers gain knowledge and adopt management practices on their properties to reduce livestock methane emissions and/or improve livestock methane emissions intensity.

b) Increase carbon stored in soil

The project evaluated and trialed on-farm practices that can increase the sequestration of carbon in soil and vegetation to assist participating land managers identify and adopt management practices to increase and maintain carbon sequestered in soil and vegetation on their properties.

c) Innovative practices /technologies to reduce agricultural greenhouse gas emissions /increase carbon stored in soil

The project used innovative tools and bioeconomic models to evaluate and develop a business case for the integration of innovative on-farm practices at the whole-farm scale that can reduce methane emissions from cattle and increase carbon stored in soil and vegetation while maintaining or improving livestock productivity and improving business profitability. The business case took into account each property's stage of development.

An underlying objective was to help 'improve business efficiency' and provide demonstrated evidence that integrating a carbon farming practices into a beef business:

- Was economically viable.
- Optimized environmental outcomes.
- Did not compromise sustainable productivity.

The project was designed to deliver the following outcomes for the northern grazing industry, community and government:

1) Identification of the benefits and constraints to implementing carbon farming practices and demonstration of the conditions under which carbon farming practices would be commercially viable.
1) Increased capacity and tools for industry advisors to assist producers to evaluate and implement carbon farming practices.
2) Increased understanding of the realistic and likely magnitude of methane emissions reduction and carbon sequestration in soil and vegetation for diverse regions and production systems.
3) Professional and respected delivery of factual information about the project results, carbon economy, climate change and government policies and programs.

CARBON FARMING OPPORTUNITIES

Across northern Australian grazing land a range of carbon farming practices are potentially available, however regional differences exist due to climate, soil type, property scale, markets and history of land development. The opportunities and constraints are identified in each of the three project regions in Table 2, based on past research and experience. Available management practices are highlighted below.

REDUCE METHANE EMISSIONS

Previous research by CSIRO, DAF, DoR, MLA and RELRP indicated that the following practices would improve sustainable production and reduce methane emissions intensity:

- Identify and remove unproductive breeders to optimize weaning rates.
- Improve liveweight gains and decrease age of turnoff.
- Heifer management to improve lifetime fertility.
- Phosphorus supplementation to improve weaning rates.
- Manage stocking rates to improve land condition and diet quality.
- Feed legume pasture to increase growth rates and reduce lifetime emissions per head.
- Feed nitrate supplements to reduce daily methane emissions.

As an example of what can be achieved, Blanncourt Station in the Queensland Gulf implemented a range of management changes over 15 years (Broad *et al.* 2011) including; reducing stocking rates, wet season spelling, pasture improvement, supplementation and feeding of young cattle to meet weight-for-age targets. This suite of changes increased profitability by 93%, increased beef sold by 80%, improved land condition, reduced total emissions by 15% and improved emissions intensity by 53%.

Table 2 Opportunities and constraints for various carbon farming management practices in different regions.

Region	Reduce methane emissions	Increase carbon in soil	Increase carbon in vegetation
Mitchell Grass and Channel Country (Qld)	Options for improving breeder herd reproductive rates. Properties generally still developing fences and waters to increase carrying capacity, potentially leading to increased total livestock emissions.	No/little scientific evidence of being able to increase soil carbon by improving management/land condition.	Opportunity to improve average pasture biomass.
Maranoa Balonne (Qld)	Options for increasing growth rates of growing cattle.	Significant interest but little scientific evidence of being able to increase soil carbon with management, apart from returning cropping land to pasture.	Retention of brigalow and eucalypt regrowth provide options for sequestration. Opportunity to improve average pasture biomass.

Infrastructure development to increase herd size is a high priority for many producers in northern Australia. This is driven by the need to have as much of the land asset in production as possible. Under previous Australian carbon farming legislation, any rise in total emissions from increasing herd size would have precluded many northern producers from participating in the carbon market. Under current legislation, activities that lead to improvements in emissions intensity (achieved through improved production efficiency) are eligible for participation and methodologies are being developed along these lines. The improvement in the emissions trajectory as a result of productivity improvement is illustrated conceptually in (Figure 1). As a property is developed and technologies are adopted to increase livestock carrying capacity, total greenhouse gas emissions will increase proportionally unless there are simultaneous improvements in emissions intensity.

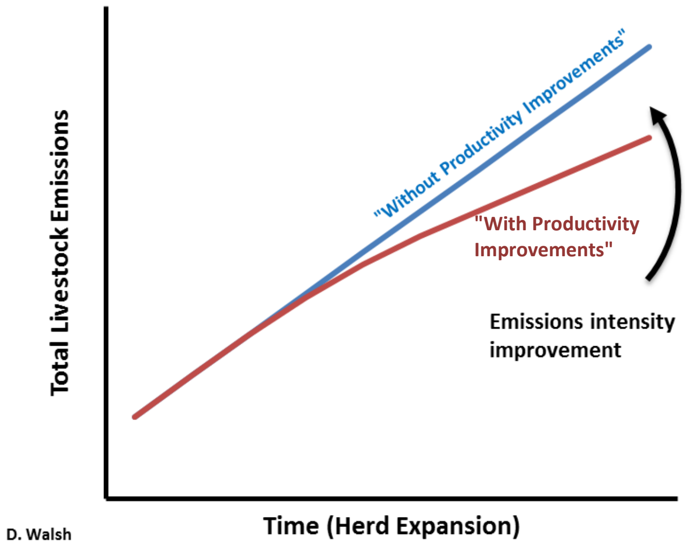


Figure 1 A conceptual representation of how total livestock emissions increase with increasing herd size and how productivity improvements can alter the emissions trajectory (Source D. Walsh).

INCREASE CARBON STORED IN SOIL AND VEGETATION

Research by SCaRP, DERM, DoR, CSIRO, DAF and the CRC for Greenhouse Accounting indicated that carbon sequestration is possible in northern grazing lands by improving land condition to maximize growth of herbaceous and/or woody vegetation and increasing the input of vegetation carbon into the soil (e.g. Ash *et al.* 1995; Holt 1997; Northup *et al.* 1999 and Pringle *et al.* 2011). However the results of recent soil carbon work using SCaRP methodology have shown inconsistent, unresponsive and contradictory responses to management (Allen *et al.* 2010; Allen *et al*. 2014; Bray *et al.* 2010; Pringle *et al.* 2011; 2014) and require further evaluation in a range of environments and production systems. Management practices that can theoretically increase carbon stored in soil and vegetation include:

- Sustainable grazing systems that increase ground cover and forage production.
- Rehabilitating degraded land to increase ground cover and perennial species.
- Woody regrowth retention to increase carbon in woody vegetation and potentially soil (Bray and Golden 2009; Donaghy *et al*. 2010).
- Introducing legumes into grass pastures to increase soil carbon (Abberton *et al.* 2010).

INNOVATIVE PRACTICES /TECHNOLOGIES TO REDUCE AGRICULTURAL GREENHOUSE GAS EMISSION /INCREASE CARBON STORED IN SOIL

Despite being recognized as important drivers for sustainable pastoral production, the above practices are not widespread in the northern beef industry due to economic or other barriers to implementation. To encourage adoption, the Climate Clever Beef project (Bray *et al.* 2014) worked with case study properties and regional champions to develop a framework to analyze businesses and identify options to improve business outcomes (Figure 2). This innovative process was used to evaluate and demonstrate the multiple benefits of undertaking a practice on profitability, productivity, land condition, greenhouse gas emissions and climate risk therefore improving the likelihood of implementation of carbon farming practices.

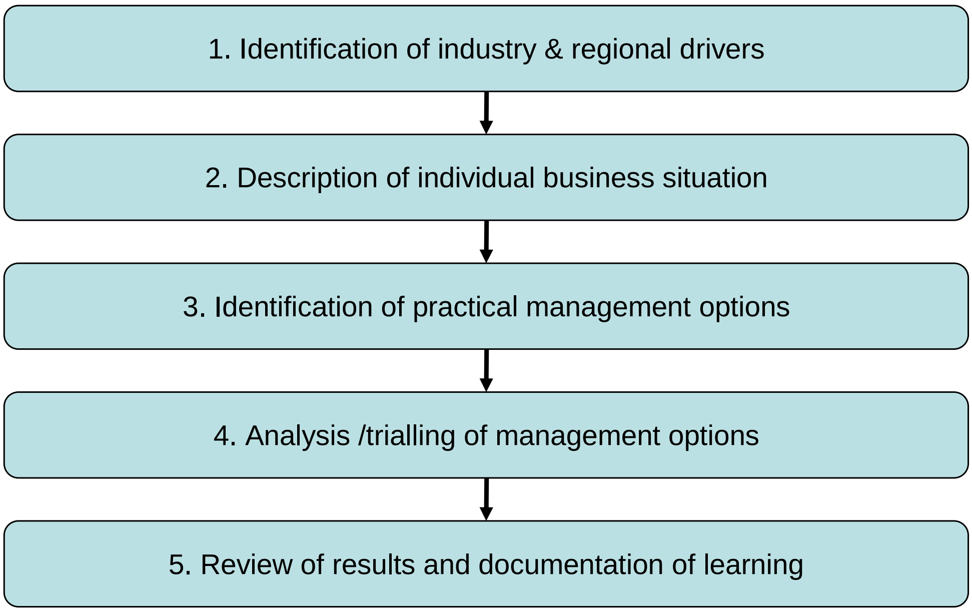


Figure 2 Climate Clever Beef framework used to systematically assess the performance of management options for improving business resilience.

To evaluate carbon farming practices, whole-farm bioeconomic modelling can integrate management practices, livestock, pasture dynamics, tree biomass and soil carbon at the whole property scale and over longer time frames spanning a number of climatic cycles than can be realistically trialled on-farm in a short-term project (e.g. Phelps *et al.* 2014 and Donaghy *et al.* 2010). The project used bioeconomic modelling to integrate on-farm measurements and data to assess to long term 20-30 years impact in three case studies.

Livestock methane emissions and livestock productivity (per head liveweight gain, age of turn-off or age of joining) are linked to stocking rate, forage availability and diet quality. Estimating the quantity of carry-over and new feed in relatively dry variable climates, understanding key decision-making dates, such as the start and finish of the growing season, and adjusting stock numbers to prevent overgrazing are essential for efficient and sustainable production. The project tested new innovative tools to improve forage budgeting by incorporating diet quality, refined visual aids to estimate pasture biomass and tested remote sensing and automated devices, with the aim to improve stocking rates decisions and production efficiency.

METHODOLOGY

REGIONAL APPROACH AND COLLABORATION

Due to the large geographic size of the northern Australian beef industry and to access a range of expertise the project was structured as a collaborative partnership on a regional basis. The project targeted three large and diverse regions across northern Australia (Figure 3):

- Maranoa Balonne in southern Queensland
- Mitchell Grass in western Queensland
- Channel Country in western Queensland

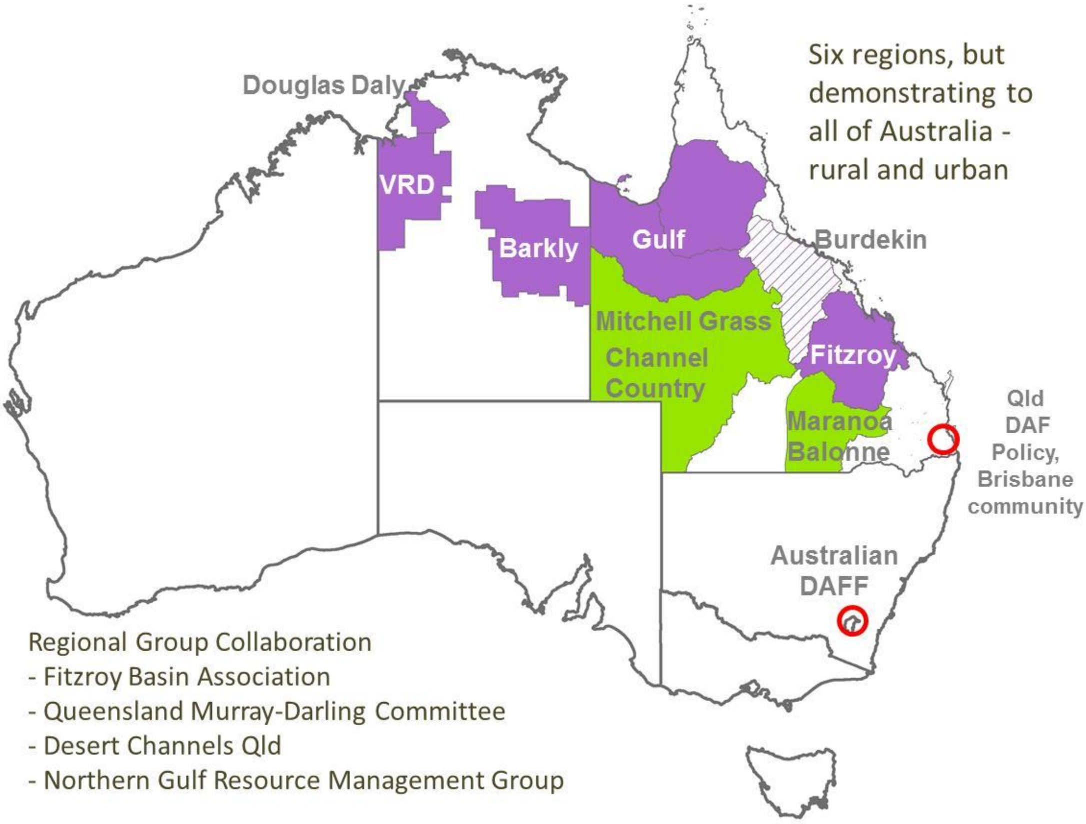


Figure 3 Map of targeted regions (green colored).

The benefits of the regional approach included:

- A larger cross section of research and extension teams being involved in understanding the opportunities and constraints of carbon farming.
- Sharing the learnings from different regions across northern Australia.
- Differences in opportunities between regions could be targeted (e.g. regrowth management is an opportunity in central and southern Queensland, soil carbon sequestration opportunities may exist

in mixed farming areas where cropping land is converted to pasture, managing property development leading to increasing herd numbers in the more extensive areas.)

Collaboration was seen as a key project strength across; borders, agencies, regional NRM bodies, projects and beef businesses. Collaborating partners included:

- Department of Agriculture and Fisheries, Queensland
- Desert Channels, Queensland
- Queensland Murray Darling Committee, Queensland
- 15 beef businesses

A key consideration of the project was recognition that the findings from the project were also of interest to policy and academics such as:

- Research institutions e.g. Melbourne University, CSIRO
- Policy development teams in State and Australian Governments
- Other government programs (e.g. Filling the Research Gap and Extension and Outreach)
- Industry organizations (e.g. Meat and Livestock Australia)
- Individuals interested in greenhouse gas emissions issues.

This project provided an excellent opportunity to capitalize on the established networks and genuine producer interest and participation built up in recent initiatives (e.g. CCRP Climate Clever Beef, Northern Grazing Systems project, RELRP, SCaRP, SavannaPlan, CQ Beef). The project team included research and extension professionals with decades of combined experience working with northern beef producers.

DEMONSTRATION PROPERTIES

Regional activities were centered around forming collaborative partnerships with beef businesses to host on-ground demonstrations in each region. Mitchell grass and Channel Country region engaged three businesses as demonstration sites with a fourth property as a backup to mitigate against the risk of losing a property mid-way through the project. The Maranoa Balonne region took a slightly different approach of forming a business analysis producer group of 12 businesses to identify, evaluate and implement opportunities together using group processes. Overall the project team evaluated options across three regions on 15 properties including:

- Two properties evaluated in the Mitchell Grass region and one family run group of properties in the Channel Country region. A fourth property was not progressed due to drought.
- Twelve businesses were part of a producer group undertaking trials and evaluations on their properties with nine businesses undertaking business analysis each year in the Maranoa Balonne region.

These 15 businesses managed a combined land area in excess of 291,000 ha and 34,400 cattle.

Each region had a risk management plan to address the potential for a business/es withdrawing from the project. Generally the risk management strategy was to identify an extra demonstration property than contractually required. This was an important risk management process for The Mitchell grass and

Channel Country region enabling them to deliver despite encountering some difficulties due to drought, specific landholder circumstances and factors outside the control of the project team.

Apart from directly engaging the collaborating businesses, many more producers were engaged through regional champions, established peer networks and extension events. Examples include:

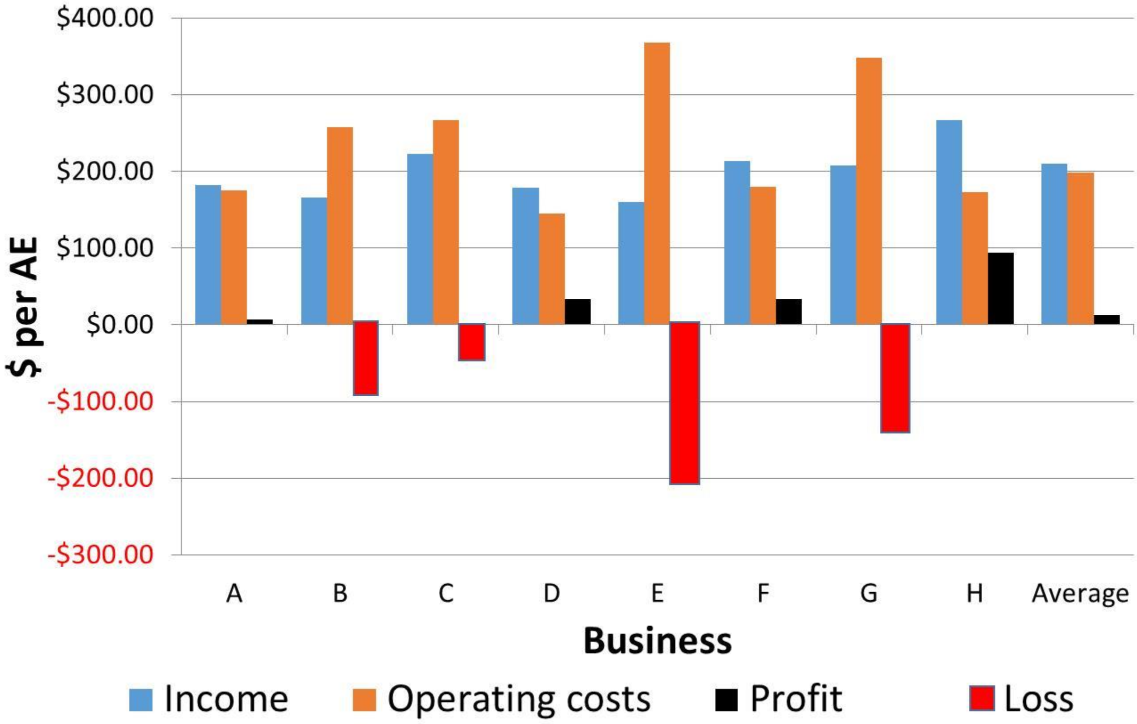
- In the Mitchell Grass and Channel Country region, engaging local champions was a strong focus. One collaborator was a Climate Champion and business consultant, another was a local Mayor and the third was an industry advocate and business consultant. The plan to run farm walks on other properties was hampered by the drought.
- The Maranoa-Balonne region used a producer group engagement method to undertake project activities and disseminate information. It was anticipated that a group experience would improve knowledge sharing and facilitate greater discussion between the businesses involved in the project, leading to improved learning outcomes.

The networks around the collaborators and collaborating properties greatly enhanced the successful delivery of information from the project.

BUSINESS BENCHMARKING AND IDENTIFICATION OF OPTIONS

The Climate Clever Beef business analysis framework (Figure 2) was used to produce baseline data for each collaborating property and to identify alternative management options. The economic potential, practicality and impact on greenhouse gas emissions or sequestration of alternative management practices were subsequently evaluated for each option or combination of options. This innovative process combined business records and output from several analysis tools including:

- Business financial benchmarking and analysis (e.g. property records, Business Analyser, industry consultants, Breedcow & Dynama). As an example,



- Figure 4 shows the income, costs and profit for eight businesses in the Maranoa Balonne producer group.
- Herd structure, productivity and herd modelling (e.g. property records, Breedcow & Dynama)
- Livestock emissions and sequestration calculators (e.g. FarmGAS, Greenhouse Accounting Frameworks)
- Bioeconomic modelling (e.g. GRASP and Enterprise, excel-based discounted cash flow bioeconomic models)
- Property mapping and assessment of land types, woody vegetation and land condition.

Invariably, the benchmarking process identified the strengths and weaknesses of each business and along with the business long term goals, this information was used to identify management options that had potential to also enhance productivity and profitability, reduce methane emissions or increase carbon stored in soil and vegetation. A key benefit of this activity was that the subsequent evaluations of options were based on 'real' (property relevant) local data which was much more accepted by the collaborators and peers in the region. It should be noted that several producers made significant positive changes to their business as a result of undertaking the business analysis process.

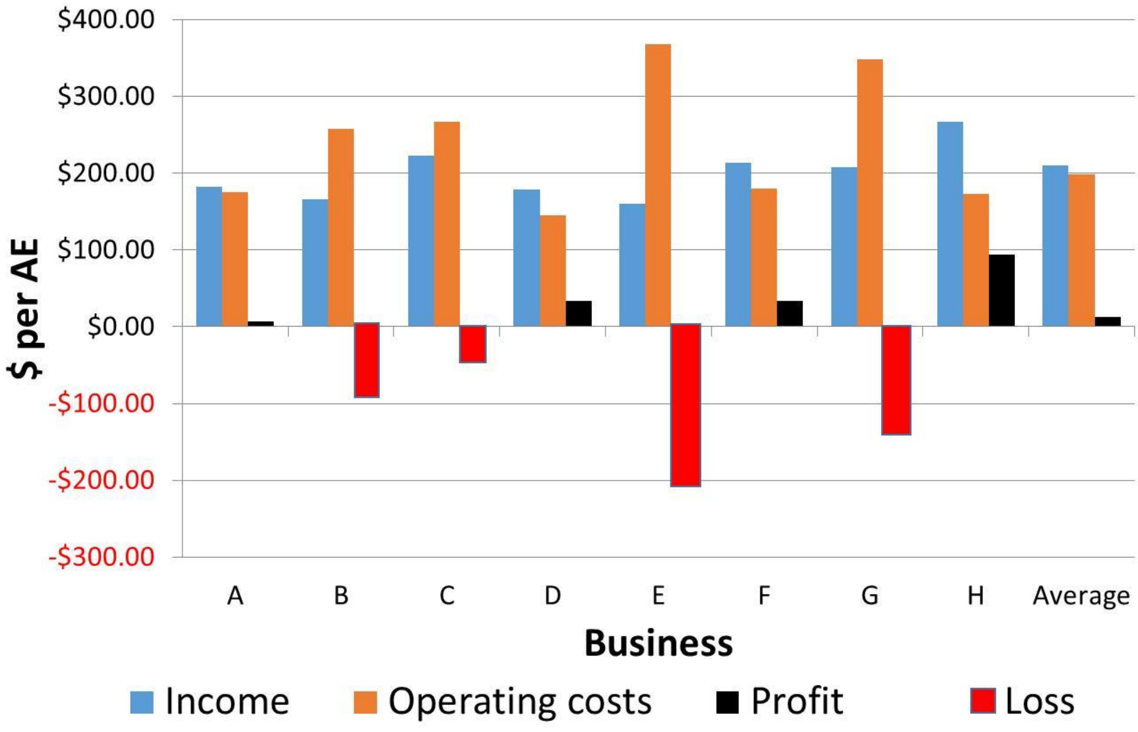


Figure 4 Business analysis data on income costs and profit for 8 businesses in the Maranoa Balonne producer group. Each business was allocated a letter, with their data shown clearly in comparison to the other businesses in the group. Red indicates a loss.

The Maranoa Balonne region group data provides an example of identification of issues using the business analysis. The range in operating costs relative to income between properties highlighted that poorer performing businesses had scope to make improvements. Common issues identified in the region over three years of the analysis included:

- Scale is an issue for many in the Maranoa Balonne region. Land area is often limiting the ability to carry the numbers of cattle required to offset overhead costs.
- Labour efficiency is low, meaning not enough cattle are managed for the number of labour units employed.
- Kilograms of beef produced per Adult Equivalent (AE) are low in some cases which impacted on cost of production and greenhouse gas emissions intensity.
- The use of off-farm income may be helpful for some businesses to improve labour efficiency and offset costs.

Using the information gained from individual reports and group debrief days, producers in the group were able to begin to pinpoint areas of the business which required attention or were holding the business back. These areas were then linked to on-farm trials and options modelling within the project. Areas targeted for evaluation included: selling strategies, reproductive performance, animal liveweight gains, age of turnoff, pasture types, pasture quality and supplementation strategies.

The group business analysis approach will be published in a special issue of The Rangeland Journal (Broad *et al.* submitted).

REDUCE METHANE EMISSIONS METHODS

The calculation of livestock methane emissions in northern Australia requires knowledge of seasonal numbers of livestock in each class (e.g. Heifers 1-2 years, Steers calves 0-1 years, etc.), average seasonal liveweight (LW) and liveweight gain (LWG). This information was generally compiled from a combination of property records (paddock records, sales and purchase records), property livestock schedules and herd modelling (e.g. Breedcow & Dynama modelling). One of the lessons learned from this process was that the lack of clean musters, substandard business records, variability in annual herd numbers and turnoff will make it very difficult to analyze baselines and carbon farming project performance for many businesses. The livestock data was then processed using a greenhouse gas emissions calculator (e.g. excel version of FarmGAS (http://www.farminstitute.org.au/calculators/farm-gas-calculator) or Greenhouse Accounting Frameworks (GAF) (http://www.greenhouse.unimelb.edu.au/Tools.htm).

Depending on the demonstration site, the current livestock data were compared to measured or projected livestock data for an alternative management option. Data to inform the management options were derived from:

- Historic property records.
- Research literature, reports or regional representative herd models.
- Expert opinion (departmental officers, the collaborator, other group members).
- Property measurements and experience.

For each management option evaluated, total livestock greenhouse gas emissions (t CO_2e) and emissions intensity (t CO_2e per t liveweight sold) were calculated and compared.

All regions assessed livestock methane emissions. Example management strategies assessed include:

- Improving herd fertility and reducing age to first calf in the Mitchell Grass and channel Country regions.
- Improving responsiveness to climatic conditions and forage availability in the Mitchell grass region.
- Improving animal performance with a view to improve emissions intensity from livestock in the Maranoa Balonne region. This occurred mainly through the use of supplementation in winter in the form of urea licks, fodder crops or through pasture improvement, such as establishing legumes (e.g. leucaena).
- Changing the enterprise mix to improve business performance and alter methane emissions in the Maranoa Balonne region.

SOIL CARBON METHODS

Soil carbon sampling during the project followed the SCaRP methodology for grazing land in northern Australia (Allen *et al.* 2010, Pringle *et al*. 2011) to collect, process and analyse the soil samples. In summary, at least ten cores were sampled per plot or paddock to a depth of 30 cm. Bulk density was calculated on intact core samples. Total soil organic carbon (SOC) stocks (t/ha) were calculated for the 0-10cm and 0-30cm depth intervals. The soil sampling was undertaken in collaboration with the soil carbon AotG project in the Maranoa Balonne region.

Key management strategies assessed for impact on soil carbon included:

- Land management in the Maranoa Balonne region. Remnant vegetation was compared to a range of management options including pasture, retired cropping and sown pasture (including legumes) at five properties.

No soil sampling was undertaken in the Mitchell Grass and Channel Country regions as two recent soil carbon projects indicated little scope for soil carbon change with management (Allen *et al.* 2014 and Pringle *et al.* 2014).

VEGETATION CARBON METHODS

Pasture vegetation was measured using the Botanal procedure (Tothill *et al.* 1992), cutting pasture quadrats or using GRASP pasture growth modelling (Littleboy and McKeon 1997).

BIOECONOMIC MODELLING METHODS

The bioeconomic approach was: GRASP pasture and animal production modelling.

The bioeconomic modelling (BEM) framework consisted of the GRASP pasture and animal production model (Littleboy and McKeon 1997) linked to the ENTERPRISE dynamic herd economic model (MacLeod *et al.* 2011). The whole property BEM framework was developed and tested during the Northern Grazing Systems project (Phelps *et al.* 2014). GRASP is a point-based model that simulates soil moisture, pasture growth and animal production from daily inputs of rainfall, temperature, humidity, evaporation and solar radiation. The model has been modified recently to enable it to simulate a wider range of stocking rate management strategies, dynamic tree growth and the impacts of pasture spelling. A recent variation to the ENTERPRISE dynamic herd economic model permits allocation of the herd to a maximum of 20 paddocks. The ENTERPRISE model uses the predicted liveweight gain per head from GRASP to estimate branding and mortality rates, and constructs a herd consistent with these rates, the stocking rates from GRASP, and the buying/selling rules within ENTERPRISE. The economic outcome for a given year is assessed using a whole-enterprise budgeting technique with a number of economic metrics generated.

Dunblane in the Mitchell Grass region was modelled using this approach: modelled stocking rate flexibility on livestock emissions, land condition and pasture biomass.

BUSINESS CASE DEVELOPMENT

The final product of the demonstration sites was to develop a case study document that would enable the reader to determine whether an option may be worthwhile pursuing for their business in a particular region. All demonstration sites collated and measured appropriate indicators and documented the costs, benefits, constraints and practical issues associated with carbon farming project implementation.

EXTENSION ACTIVITIES

In terms of community and industry engagement, the project used a suite of engagement and extension techniques across northern Australia. Methods included: engaging regional champions, programmed learning (training packages), information access (e.g. field days/forums, newsletter articles), consultant/mentor (one-on-one), on-property demonstrations and producer group activities. Field days and training packages improved producer awareness, knowledge and confidence while demonstrations and one-on-one delivery aimed to foster practice change. Ongoing support and mentoring with the case study properties and other beef producers enabled the delivery team to understand production, profitability and practicality issues as well as the link between herd productivity and greenhouse gas emissions.

Apart from the direct one-on-one extension with the demonstration property businesses and associated groups, other extension activities included:

- Field days and field day presentations at events held by other organizations or projects (e.g.), leading to training workshops and one-on-one follow-up.
- Fact sheets and case studies used as handouts and available on the project website.
- Project website providing a project overview as well as hosting the links to fact sheets, case studies, field day notes, newsletter articles, conference papers and posters.
- Industry newsletter articles.
- Media press releases and interviews.
- Webinars.
- Presentations at industry forums and conferences attended by landholders and other technical people.
- Participation in hosting the Young Carbon Farmers tour.
- Collaboration and support for other projects, e.g.
    - Soil carbon research and demonstration. Dave Lawrence
    - Livestock emissions. Melbourne University Richard Eckard, Brendan Cullen
    - Sown pasture rundown. Stuart Buck

PROJECT LEGACY

To ensure the project has an enduring legacy a number of options have been pursued:

- The Rangeland Journal special issue has been negotiated to be published late 2016. The issue will contain approximately 10 journal papers from this and associated projects around the theme ‘Climate Clever Beef’.

- Conference papers and posters for a range of conferences including: Northern Beef Research Update Conference (2013), Australian Rangelands Conference (2015).
- Strong regional, inter-regional and inter-agency collaborative relationships.
- Better informed agency officers.
- Comprehensive final report.
- Climate Clever Beef webpages hosted on the FutureBeef website.

ANNUAL PROJECT MEETINGS

Four whole-of-project meetings were held during the project in: Brisbane, the Atherton Tableland in north Queensland, Roma in southern Queensland and Boulia in far western Queensland. The whole project team was invited to participate along with departmental managers, an Action-on-the-Ground (AotG) representative, the project reviewer and guest speakers (e.g. Michael Martin from the methodology development team in the Australian Department of Environment, Rhonda Toms-Morgan on the AotG soil carbon and fire projects in the Maranoa Balonne). AotG representatives were unable to attend any of the annual project meetings apart from the first planning meeting.

The goal of the annual meetings was to:

- Share the progress and future plans for each region (referring to project plan and communications plan documents).
- Discuss the upcoming reporting requirements.
- Get ongoing updates on the CFI, ERF and other policy changes
- Hear about other AotG projects in the region.
- Visit project sites and learn about different production systems in different regions.

PROJECT REVIEWER

The independent reviewer for the project was Dr Mick Quirk. Dr Quirk was invited to be the project reviewer due to his industry expertise and to maintain links and synergies between this project and other current and future industry supported projects. The project reviewer attended all annual project meetings and provided ongoing constructive feedback on the approach and findings of the project.

RESULTS AND DISCUSSION

The project was highly successful at engaging with collaborating properties across northern Australia with 15 properties evaluating and trialing alternative management practices. Results of the demonstrations are presented and discussed under the Action-on-the-Ground priority headings.

REDUCE METHANE EMISSIONS

If livestock productivity is to be maintained or improved at the property scale, reduction in total methane emissions or improvement in emissions intensity are related to:

- Having fewer unproductive livestock on the property (i.e. cows and heifers that do not have a calf) and minimizing impact of extreme climatic conditions leading to low productivity.
- Increasing the number of calves per breeder lifetime (e.g. reducing the time to first joining and weaning a calf every year thereafter).
- Reducing the time to achieve market weight (faster growth).
- Reducing the methane produced per day by using methane reducing technologies (e.g. some feed supplements).

The reducing methane emissions options evaluated in this project can be split into four categories:

1. Improving breeder herd efficiency
2. Improving growth rates
3. Changing the enterprise mix
4. Innovative supplements and forages

Examples of results from a range of case studies are presented in the following sections.

IMPROVING BREEDER HERD EFFICIENCY – IMPROVING LAND CONDITION AND HERD REPRODUCTIVE EFFICIENCY IN THE MITCHELL GRASS AND CHANNEL COUNTRY

David Phelps and Ian Houston in collaboration with Brendan Cullen and Richard Eckard

The Mitchell grassland and Channel Country case studies focused on improving their pasture, land condition and livestock management for greater production efficiency, while minimizing the impact of extreme climatic conditions on productivity. This was achieved by a combination of

- Wet season pasture spelling
- Matching livestock classes to land types
- Adjusting stocking rates to match forage availability
- Livestock genetic improvement
- Management to improve livestock reproductive performance.

On-ground and desktop studies indicated that improving beef cattle herd reproductive efficiency and adjusting livestock numbers to match available forage reduced emissions intensity by 7-28% and enhanced on-farm income by 50% depending on the scenario.

The Longreach case study maintained livestock numbers, but increased beef turnoff in 'early joining' and 'early joining/high fertility' herds by 8 and 39% respectively compared to a typical herd in the region. Total greenhouse gas emissions were similar across the herds as livestock carrying capacity was kept constant. Livestock enteric methane accounted for 95% of CO_2e emissions. Emissions intensity improved by 7 and 28% for the early joining and early joining/high fertility herd respectively, compared to a typical herd (14.9 t CO_2e / t LW sold). The gross margin for the early joining/high fertility herd was more than double that of the typical herd. The case study from Boulia in the Channel country region had a similar outcome.

By modifying the Longreach scenarios to allow livestock numbers to change and instead focus on maintaining beef turn-off, the stock numbers in the early joining and early joining/high fertility herds were reduced 7 and 28% compared to the typical herd, with similar percentage reductions in total greenhouse gas emissions. Gross margins (including CFI income at a net price of $10/t CO_2e) were lowest in the typical herd and highest in the early joining/high fertility herd. The gross margin advantage for the early joining compared to typical herd was 10%, with the CFI income contributing 15% (~$2,600) of the gross margin advantage. For the early joining/high fertility herd the gross margin was 76% higher than the typical herd with CFI income making up 8% (~$9,900) of the gross margin advantage. This analysis assumed that project costs were covered by the net price of $10/t CO_2e (i.e. the actual carbon price the credits were sold would be much higher).

While the 'maintain beef production' scenario was not as profitable as the 'maintain stock numbers' scenario (gross margin 20% lower), the maintain beef production scenario could lead to substantial reductions in greenhouse gas emissions from the industry. The northern beef industry is estimated to produce around 5% of national emissions (27.7 Mt CO_2e) based on livestock numbers. If 25% of farms achieved the 25% reduction in emissions intensity documented in this study, then the same beef turnoff could be achieved with 1.7 Mt CO_2e fewer emissions per annum.

On a cautionary note the current drought has highlighted potential difficulties in maintaining reproductive efficiency at high levels throughout the climate cycle, however the reproductive performance of a typical herd would also be impacted during drought so the relative differences should be maintained.

Key findings from the improving land condition and herd reproductive efficiency case study include:

- Improving efficiency of production through increasing weaning rates, early mating and cross breeding is a highly profitable strategy for some regions of northern Australia.
- The gains achieved across the case study properties with markedly different rainfall, country types, and property size suggest similar improvements can be made on-farm across much of northern Australia.

This case study will be published in a special issue of The Rangeland Journal (Cullen *et al.* submitted).

IMPROVING BREEDER HERD EFFICIENCY - EVALUATE REPRODUCTIVE PERFORMANCE USING PREGNANCY TESTING IN THE MARANOA BALONNE REGION

Kiri Broad and Tim Emery

Four properties in the Maranoa Balonne region trialed the use of pregnancy testing as a tool to assess reproductive performance and make culling decisions, with one property also evaluating the effectiveness of a wet season supplementation program. Ingaby Station used pregnancy testing for 5 years from 2010 to 2014. Initially pregnancy rates were quite high (81-87%), however pregnancy rates have declined in the last two years (66-75%) in response to drought. The climatic influence has masked identifying possible benefits from the supplementation program. However, pregnancy testing during the dry years enabled unproductive breeders to be identified, thus enabling decisions to be made on whether to sell to increase cash flow and conserve pasture for the remaining cattle. Culling unproductive breeders from the herd will assist to improve reproductive rates through improving herd fertility and genetics which should see reproductive rates climb back to pre-drought levels when the seasons improve again. From this trial, it can be concluded that feeding phosphorus to these cattle was not economical as pregnancy rates in normal seasons were already high. This will assist with maintaining a low emissions intensity for this breeder herd.

Key findings from the evaluate reproductive performance using pregnancy testing case study include:

- Pregnancy testing can be a powerful tool to evaluate and improve herd reproductive performance.
- Culling unproductive breeders can help to improve genetic selection, leading to improved reproductive performance in the future.
- Pregnancy testing to remove unproductive breeders is a useful way to manage available forage in dry seasons.

IMPROVING GROWTH RATES – FEEDING SUPPLEMENTS TO GROWING CATTLE IN THE MARANOA BALONNE REGION

Kiri Broad and Tim Emery

Feeding supplements to growing cattle can increase liveweight gain and decrease time to turnoff potentially improving productivity and profitability (depending on supplementation costs relative to additional income) and potentially reduce methane emissions (reduced time to slaughter) and improve emissions intensity (more beef produced for the amount of emissions).

Two dry season supplementation trials of young growing cattle were undertaken at Ninderra in the Maranoa Balonne region. The pastures were good quality buffel grass, so there was some uncertainty whether dry season supplementation would be profitable. The results of the trial in 2014 showed that there was no difference in terms of average daily liveweight gain between the supplemented and un-supplemented groups. From these results there was no evidence that supplementation was of any benefit over not supplementing cattle. However, when coupled with NIRS faecal sample results, it was apparent why this may have been the case in this particular year. Rain fell on the property during the course of the trial in August (38mm) and September (21mm and 14mm). Therefore the pasture began to shoot and the crude protein of the pasture increased. This was particularly apparent in the paddock where cattle were not supplemented. When the faecal NIRS values are assessed in terms of the nutrient requirements of the cattle, it showed that the pasture quality of the un-supplemented paddock rose high enough to provide enough nutrients to match the production performance of the cattle on supplement. Interestingly, if the cattle with supplement did not have supplement, they may not have performed as well.

A cost benefit analysis of the trial showed that it was not economical to supplement cattle in this particular year, losing $0.08 for every $1 spent. However, the cost benefit of the small trial undertaken in 2013 suggested supplementation of young cattle may be profitable in years with a very dry winter period and no early storms.

Key findings from the feeding supplements to growing cattle in the Maranoa Balonne region case study include:

- Producers need to consider seasonal conditions and assess climate risk as part of evaluation of the profitability and likely greenhouse emissions benefits of livestock supplementation.

IMPROVING GROWTH RATES USEIN INNOVATIVE FORAGES – GRAZING LEGUMES IN THE MARANOA BALONNE

Kiri Broad and Tim Emery

The shrub legume leucaena can be used within a grazing system to improve liveweight gain and increase turnover (reduced time to turnoff). Establishing leucaena can increase the average annual livestock carrying capacity and increase business scale without the need to purchase more land. If carrying capacity is increased total livestock emissions will also increase, however, because the livestock are growing faster (reducing time to turnoff) greenhouse gas emissions intensity is likely to improve. In addition leucaena has been shown to have anti-methanogenic properties potentially reducing the amount of methane emissions per head per day (Harrison *et al.* 2015).

Leucaena feeding was evaluated on Springtime, a small property in the Maranoa Balonne region. The steers grazing leucaena were able to maintain weight gain throughout the year due to higher forage crude protein and digestibility (results from NIRS faecal analysis). In addition to achieving higher weight gains and reducing the time taken for cattle to reach slaughter weights, the leucaena system also has had an impact on lifetime greenhouse gas emissions and emissions intensity.

Greenhouse gas emissions modelling was undertaken for the Springtime leucaena pasture system versus a grass only pasture system. Due to higher average liveweight and liveweight gain the total greenhouse gas emissions were 9% higher on the leucaena system (Table 3)(not accounting for possible anti-methanogenic activity). However, emissions intensity was significantly superior in the leucaena system (19% improvement) due to higher turnoff (20% higher). In this business, improving the feedbase to improve animal performance has helped to ensure that for every unit of CO_2e emitted, beef production was maximized and efficiency was improved. The increase in weight gain and turnover would also assist in offsetting the cost of establishing the leucaena, which will help to ensure that improving the feedbase did not come at a negative cost to the business overall. The High Output Forage project found that over 20 years leucaena was the most profitable forage of those tested, including oats, forage sorghum and grass only pasture (Bowen *et al.* 2015).

Table 3 Livestock greenhouse gas emissions comparison for Grass vs Leucaena grazing systems at Springtime in the Maranoa Balonne.

GREENHOUSE EMISSIONS	Leucaena	Grass
LIVESTOCK:		
Methane (CH_4)	511.4	525.3
Nitrous Oxide (N_2O)	29.7	30.1
TOTAL Livestock Emissions (t CO_2e)	541.1	555.4
TOTAL Pasture Emissions (t CO_2e)	63	0
TOTAL EMISSIONS (t CO_2e)	**604.2**	**555.4**
Turnoff (t LW sold)	63.5	52.9
Emissions per Ha (t CO_2e /Ha)	**1.01**	**0.93**
Emissions intensity (t CO_2e/ t LW)	**8.52**	**10.50**
Emissions per AE (t CO_2e /AE)	**2.11**	**2.08**

Similar results were also found for using forage oats to increase liveweight gain and finish the 'tail of the mob' for slaughter at Dunwoodie in the Maranoa Balonne region.

Key findings from the grazing legumes in the Maranoa Balonne case study include:

- The use of forages (e.g. leucaena and oats) can improve livestock productivity and greenhouse gas emissions intensity.

CHANGING THE ENTERPRISE MIX – AGE OF TURNOFF IN THE MARANOA BALONNE

Kiri Broad and Tim Emery

From the business analysis group results in the Maranoa Balonne, it was clear that one property, which was mainly a backgrounding operation, was performing financially better than the other businesses in the group. This was mainly due to greater labour efficiency and lower than average costs per AE.
As a result of seeing this, one property (Havelock) decided to undertake business options modelling. Currently Havelock is a breeding operation, selling all progeny (with the exception of replacement heifers) as weaners. Breedcow & Dynama modelling was used to evaluate alternative animal turnoff options on gross margin. The alternative turnoff scenarios evaluated were: selling yearling steers only; selling both females and males as yearlings; or selling yearling heifers and males as bullocks. The analysis indicated that selling steers as bullocks or yearlings would likely improve the gross margin of the business (Options 2 and 3; Table 4). This was largely due to the turnoff per AE and also the higher sale price, with very few extra costs associated with holding onto older animals.

This strategy had an impact on the greenhouse gas emissions of Havelock with total emissions increasing by up to 3.3% while emissions intensity improved by more than 11%. The best scenario from a profitability and greenhouse emission intensity point of view was scenario 3: selling weaner heifers and yearling steers.

Table 4 Economic and greenhouse gas emissions outcomes for five turn-off strategies at Havelock.

FARM CHARACTERISTICS	1. Current Management /Turnoff	2. Weaner heifers, bullocks	3. Weaner heifers, yearling steers	4. Yearling heifers, bullocks	5. Yearling heifers, yearling steers
Total herd size (AE)	1600	1600	1600	1600	1600
Farm area (Ha)	14000	14000	14000	14000	14000
Total turn-off (t live weight sold)	**281**	**327**	**332**	**318**	**321**
Turn-off/breeding cow>3 years (t live weight sold/cow>3years)	0.41	0.55	0.49	0.58	0.52
HERD GROSS MARGIN					
Gross margin before interest (% increase on current)	-	11%	14%	2%	3%
Gross margin after interest (% increase on current)	**-**	**8%**	**13%**	**-4%**	**-2%**
GREENHOUSE GAS EMISSIONS					
Total GHG emissions (t CO2-e/year)	**2981**	**3080**	**3012**	**3107**	**3047**
GHG emissions/AE (t CO2-e/AE)	**1.86**	**1.93**	**1.88**	**1.94**	**1.90**
GHG emissions/turn-off (t CO2-e/t live weight sold)	**10.60**	**9.41**	**9.06**	**9.78**	**9.49**
GHG emissions/ha (t CO2-e/ha)	**0.213**	**0.220**	**0.215**	**0.222**	**0.217**

Key findings for the age of turnoff in the Maranoa Balonne region include:

- Changing age of turnoff can substantially change profitability and alter total emissions and emissions intensity. Individual property evaluations are thus required to identify the best strategy.
- Higher enterprise gross margin often coincides with the better emissions intensity.

KEY FINDINGS FOR REDUCING METHANE EMISSIONS

- Improving efficiency of production through increasing weaning rates, early mating and cross breeding is a profitable strategy for many regions of northern Australia.
- Changing age of turnoff can change profitability and alter total emissions and emissions intensity, however individual property evaluations are required to identify the best strategy.

- The use of forages (e.g. leucaena and oats) can improve livestock productivity, business profitability and greenhouse gas emissions intensity in regions suited to their use, such as the Maranoa Balonne.
- Pregnancy testing to remove unproductive breeders and improve herd reproductive performance is a useful way to manage available forage in dry seasons and improve emissions intensity.
- A suite of management changes will likely be required to substantially change productivity, profitability and greenhouse gas outcomes.
- The gains achieved across the case study properties with markedly different rainfall, country types, and property size suggest similar improvements can be made on-farm across much of northern Australia.
- Total greenhouse gas emissions can decline if stocking rates are reduced. However, reduced sales income following stocking rates reductions can be difficult to offset with individual livestock productivity gains.
- Need to consider seasonal conditions and assess climate risk as part of evaluation of the profitability and likely greenhouse emissions benefits of livestock supplementation.
- Higher enterprise gross margin often coincides with the better emissions intensity.
- Carbon farming profits will be highly sensitive to project management costs and carbon price.
- Beef businesses should focus on cost-effective changes to improve production efficiency and the associated improvement in livestock revenues. Potential carbon income should be considered a bonus and not the basis for management change alone.

INCREASE CARBON STORED IN SOIL AND VEGETATION

To increase carbon stored in soil and vegetation two broad practices were evaluated:

1. Establishing improved pasture and legumes
2. Converting cropping land to pasture

INCREASING CARBON STORED IN SOIL AND VEGETATION – ESTABLISHING SOWN PASTURE AND LEGUMES

Kiri Broad, Tim Emery

Soil sampling in the Maranoa Balonne region which found no consistent differences in soil carbon between native pasture and improved pasture sites. The unresponsiveness of soil carbon to management and land condition will reduce the likelihood of producers making decisions to change management based on soil carbon outcomes, as the soil carbon differences are often minimal and not necessarily positive at some sites.

Key findings for the establishing sown pasture and legumes case studies included:

- There was no consistent evidence to indicate that soil carbon will increase with the establishment of improved pastures.

- The unresponsiveness of soil carbon to management means that a soil carbon 'carbon farming' project will be risky.
- Accumulation of soil nitrogen was found at one site with legumes which will likely increase pasture productivity but also nitrous oxide emissions.

INCREASE CARBON STORED IN SOIL AND VEGETATION – CONVERTING CROPPING LAND TO PASTURE IN THE MARANOA BALONNE

Ram Dalal, Kiri Broad, Tim Emery and Roger Sneath

Soil sampling over a period of 20 years was undertaken at 'Rolston' a block that is part of the 'Canberra' aggregation in the Maranoa Balonne region. In the mid 1980's, soil sampling was undertaken on a continuous cropping system, with the length of time paddocks were used for cropping varying between 12 and 31 years. Twenty years ago, the cropping areas were returned to pasture and have since been used for livestock grazing. Soil samples in remnant vegetation, cropping areas and these same areas returned to pasture were assessed to identify the levels of soil organic carbon (SOC) and total nitrogen (N) under each system. This work was undertaken by Ram Dalal (DSITI) in collaboration with the current project team.

Results showed there were significant losses of SOC and total N under the continuous cropping system following clearing of the remnant vegetation (Table 5). Following the conversion of the cropped area to pasture, increases in SOC and total N were observed, with the percentage gains in total N much larger than the gains in SOC.

Table 5 Changes in soil organic carbon (SOC) and total nitrogen (N) stocks with land use change from remnant vegetation to 20 years cropping, and from cropping to 20 years pasture.

Soil property	**Soil depth**	**Remnant vegetation**	**Remnant vegetation to cropping**	**Cropping to pasture**	
	Approximate depth interval (m)	Mean	Mean change after 20 years cropping	Change after 20 years pasture	Annual rate of change under pasture
SOC stock ($t\ C\ ha^{-1}$)	0-0.1	19.74	-9.84	+1.96	0.09
	0.1-0.3	17.25	-7.35	+2.69	+0.13
	0.3-0.5	12.11	-4.81	+1.07	+0.05
N stocks ($t\ N\ ha^{-1}$)	0-0.1	1.37	-0.63	+0.30	+0.015
	0.1-0.3	1.33	-0.53	+0.43	+0.022
	0.3-0.5	1.15	-0.41	+0.37	+0.018

These results indicate potential for producers to sequester SOC and total N in regions of the Maranoa Balonne where cropping has been or is likely to be returned to pasture, especially as returns from cropping become more marginal in the region due to rising input costs and difficult climatic conditions affecting crop yields. As the percentage gains in SOC were much lower than total N, it is unlikely that large scale opportunities to enter into a soil carbon ERF project will be feasible. However, the increases in total N are likely to result in improved pasture quality and potentially yield, leading to improved animal productivity. In turn, this will likely lead to improved livestock emissions intensity and potentially reduced lifetime emissions from ruminants grazing these pastures.

Key findings for the converting cropping land to pasture in the Maranoa Balonne case study included:

- Cropping substantially reduces soil carbon and nitrogen over time.
- Returning cropping land to pasture can increase the amount of carbon and nitrogen stored in the soil.

KEY FINDINGS FOR INCREASING CARBON STORED IN SOIL AND VEGETATION

- No consistent differences between uncleared remnant vegetation and good condition developed pasture were found indicating that soil carbon is not adversely affected by clearing and pasture development.
- No consistent evidence to indicate that soil carbon will increase with establishment of improved pastures.
- Returning cropping land to pasture can increase the amount of carbon and nitrogen stored in the soil.
- No consistent evidence was found to support the widely-held belief that soil organic carbon stocks are higher in locations that are in good land condition.
- Based on the soil carbon work undertaken in this project (together with evidence from other published scientific studies), it is recommended that northern beef producers exercise caution when considering soil carbon sequestration ERF projects due to the risk of unpredictable (often unresponsive) and inconsistent changes in SOC stocks with change in management.
- Despite the limited potential for soil carbon income, our analyses confirm that pasture management to maintain good land condition can have significant productivity, profitability and land management benefits.

INNOVATIVE PRACTICES /TECHNOLOGIES TO REDUCE AGRICULTURAL GREENHOUSE GAS EMISSIONS / INCREASE CARBON STORED IN SOIL

Bioeconomic modelling (BEM) analyses integrating livestock, vegetation, prices and land condition were used to evaluate a suite of management changes at the whole-property scale. These analyses assessed the impact of implementation on animal productivity, profitability, greenhouse gas emissions and carbon stored in vegetation and soil over a 20-30 year period. The purpose of the BEM was to evaluate the long-term performance of these strategies over a wider range of seasonal conditions than was possible during the project period. Other innovative tools were also evaluated to assist grazing businesses to make better decisions on stocking rates in response to climatic conditions.

INNOVATIVE PRACTICES AND TECHNOLOGIES – EVALUATING STOCKING RATE FLEXIBILITY STRATEGIES

Lester Pahl, Giselle Whish and David Phelps

Adjusting stocking rates (stocking rate flexibility) in response to forage availability and climatic conditions has potential to improve productivity through better utilization of the available feed and reduced impact on pastures during drought conditions. However, flexible stocking strategies do have inherent risks if livestock numbers are built up and can't or aren't reduced fast enough when conditions turn dry resulting in reduced land condition and livestock production.

The performance of low, moderate and high flexibility stocking rate strategies were compared with fixed stocking (baseline for the Dunblane property in the Mitchell grass region) over 30 years using a bioeconomic modelling framework. High flexibility generated the largest average annual herd size, followed in descending order by moderate flexibility, fixed stocking and low flexibility (Figure 5). The three flexibility strategies produced higher average annual pasture yields and liveweight gains per head (LWG/hd) than did fixed stocking. Of the flexible strategies, moderate flexibility achieved the highest pasture yields and LWG/hd, followed by low flexibility and high flexibility. However, high flexibility generated the highest average annual profit and enterprise gross margins, and also had the highest herd production.

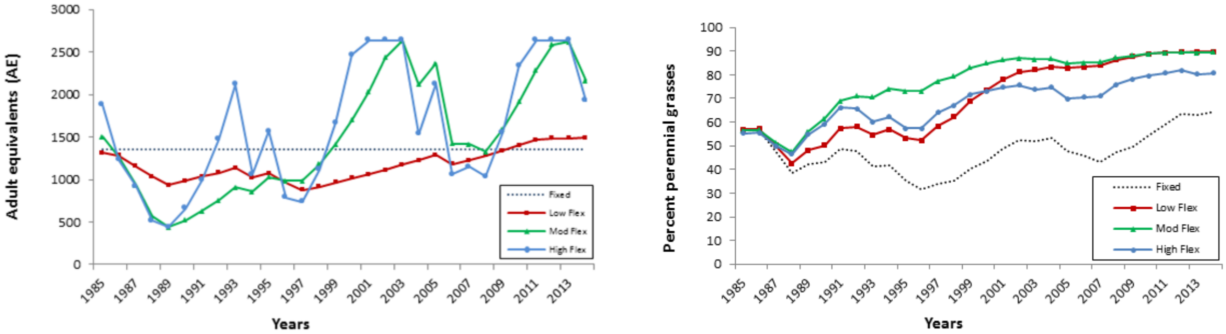


Figure 5 Modelled herd size and percent perennial grasses under different stocking rate flexibility strategies at Dunblane.

All three flexibility strategies sequestered carbon in pasture biomass compared to fixed stocking due to higher average pasture yields, and both moderate and high flexibility strategies emitted more carbon emissions from livestock than did fixed stocking due to larger herd sizes (Table 6).

Table 6 Liveweight sold, livestock emissions and emissions intensity for Dunblane stocking rate flexibility modelling.

Flexibility	Net AE (Sold-purchased)	Net LW sold (Sold-purchased) t LW	Livestock emissions tCO_2e	Emissions intensity tCO_2e/t LW sold
Fixed	12990	5846	81360	14
Low	12000	5400	70620	13
Moderate	15870	7142	87720	12
High	18780	8451	92940	11

Conversely, emissions intensity improved as the degree of flexibility of stocking rate strategies increased, with the high flexibility strategy achieving the lowest emissions intensity of 11 t CO_2e per t liveweight sold. Hence, although net carbon emissions were least for low flexibility, in terms of cattle sales, this strategy was $3.5 million less profitable than high flexibility over 30 years, meaning that it cost the property $129 for every t CO_2e carbon removed from the atmosphere.

For many beef businesses it is economically risky or not possible to buy and sell cattle quickly, particularly in remote regions to the degree required by high flexibility. The net carbon position on the case study property was better under a moderate flexibility strategy with increased profitability by $3.3 million over the 30 years. Dunblane's current strategy of using agistment cattle for matching cattle numbers to forage supply has potential to be more practical and less economically risky than buying and selling cattle to the degree required by high flexibility.

Key findings from the evaluating stocking rate flexibility strategies case study include:

- Lower average stocking rates to achieve carbon or land condition outcomes can be a significant cost to the producers if not offset by alternative income (e.g. carbon income).
- Consideration and management of climate risk and livestock market risk are important components of more flexible stocking rate strategies. Significant damage to pasture and reduced livestock productivity can occur if stocking rates are not reduced fast enough in dry seasons.
- Moderate stocking rate flexibility has potential to improve profitability, land condition and greenhouse gas emissions intensity with moderate climate risk and livestock market risk.

INNOVATIVE PRACTICES AND TECHNOLOGIES – TOOLS TO IMPROVE FORAGE BUDGETING AND GRAZING MANAGEMENT DECISIONS

David Phelps and Ian Houston

Livestock emissions in arid Mitchell grasslands and Channel Country regions are linked to stocking rates, to the effect of relatively poor diet quality on emissions per animal and to the efficiency of production (e.g. per head liveweight gain, age of turnoff or age of joining). Estimating the quantity of carry-over and new feed in these arid climates, understanding key decision making dates (such as the start and finish of the growing season) and adjusting stock numbers to prevent over-grazing which impacts on both land condition and animal productivity, are essential for efficient and sustainable production.

New innovative tools to improve forage budgeting were developed and tested by integrating diet quality, refining visual aids to estimate biomass and automated NDVI (greenness sensing) devices, with the aim to improve stocking rates decisions and production efficiency. Remotely sensed NDVI was found to be a good predictor of green biomass for Mitchell grass pasture in fair land condition (R^2= 0.74). However a simple linear regression between NDVI and crude protein was relatively weak (R^2= 0.24) suggesting that NDVI is not a good indicator of diet quality, particularly during the leaf growth stage.

In this study, despite NDVI, green biomass and crude protein declining from March onwards sheep liveweight increased from 31.5 kg/hd in January to a final weight of 51 kg/hd in November as the hoggets matured towards adult weights (Figure 6). NDVI and green biomass may be useful tools to help adjust livestock numbers but appears to be a poor predictor of animal performance.

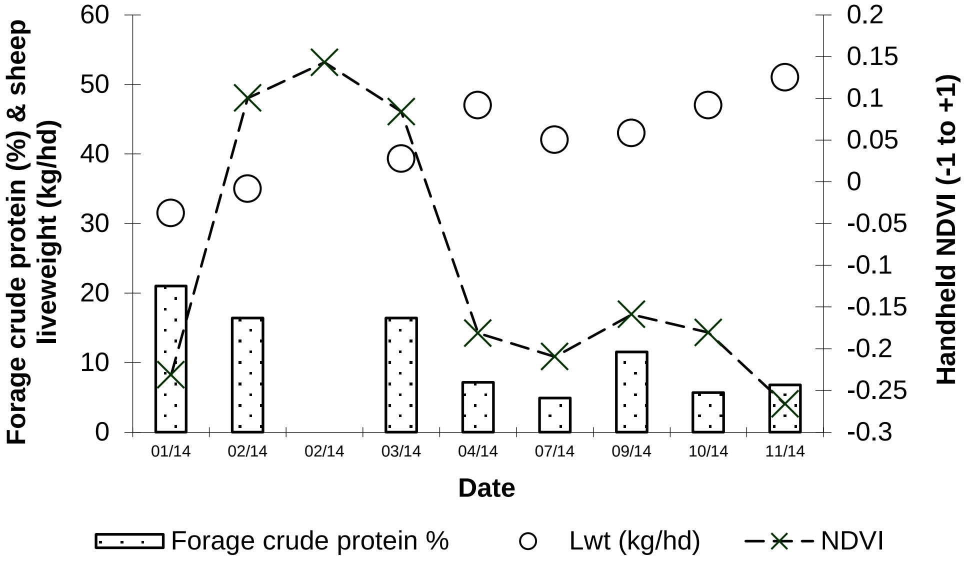


Figure 6 Forage crude protein (%, bars), sheep live-weight (kg/hd, open circles) and NDVI (dashed line) profiles between January and November 2014.

Key finding of the tools to improve forage budgeting and grazing management decisions work include:

- Real-time tools which can estimate pasture greenness (e.g. NDVI) and green biomass at the paddock scale may be useful for livestock managers to help adjust livestock numbers, but appear to be a poor predictor of animal performance.

KEY FINDINGS FOR INNOVATIVE PRACTICES / TECHNOLOGIES TO REDUCE AGRICULTURAL GREENHOUSE GAS EMISSION / INCREASE CARBON STORED IN SOIL

- Moderate stocking rates are better than high stocking rates for greenhouse gas emissions, carbon in vegetation and profitability.
- Lower average stocking rates to achieve carbon or land condition outcomes can be a significant cost to producers if not offset by alternative income (e.g. carbon income).
- Moderate stocking rate flexibility has the potential to improve profitability, land condition and greenhouse gas emission intensity with moderate climate and livestock market risk.
- Consideration and management of climate risk and livestock markets are important components of more flexible stocking rate strategies. Significant damage to pasture and reduced livestock productivity can occur if stocking rates are not reduced fast enough in dry seasons.

- Real-time tools which can estimate pasture greenness (e.g. NDVI) and green biomass at the paddock scale may be useful for livestock managers to help adjust livestock numbers but appear to be a poor predictor of animal performance.

REGIONAL DIFFERENCES

Case studies and evaluations were undertaken on 15 beef grazing properties across three regions in northern Australia. There were regional differences in the opportunities for carbon farming, however, overall there was little difference in response to similar management options between regions. The business response to improving herd productivity and profitability was similar across regions and generally, improved herd efficiency led to improved greenhouse gas emissions intensity. Due to the high sensitivity of grazing businesses to input costs, the implementation of new management strategies needs to be carefully considered in all regions on a business-by-business basis.

Soil carbon responses to management practices as measured using SCaRP methodology were found to be inconsistent and variable (apart from converting cropping land to pasture), leading to the conclusion that there is little opportunity to generate carbon income from a soil carbon ERF project in northern Australian grazing land as the business risk will be too high.

The biggest difference between regions was one of scale, particularly when considering beef herd management activities for carbon farming. Suites of management practices (as opposed to a single change) were able to substantially improve emissions intensity (e.g. by 10-30%), however very large herd sizes are required to offset current indicative project costs. This means that for most family businesses there is little opportunity for carbon farming profits and any livestock practice change needs to be carefully evaluated to ensure it is profitable from solely livestock income. Some opportunities to dilute carbon project costs may be available if businesses are able to 'stack' a number of carbon farming projects (e.g. nitrate feeding, herd management, fire abatement and/or regrowth management) or aggregate projects with other businesses.

Key findings from the regional differences assessment were:

- A suite of management changes are required to make a large enough impact to potentially consider registering a carbon farming project.
- To dilute current indicative carbon project costs, producers will need to consider 'stacking' multiple projects or aggregate projects with other businesses.
- Soil carbon responses to management practices as measured using SCaRP methodology were found to be inconsistent and variable (apart from converting cropping land to pasture), leading to the conclusion that there is little opportunity to generate carbon income from a soil carbon ERF project in northern Australian grazing land as the business risk will be high.

EXTENSION AND COMMUNICATION ACTIVITIES AND LEGACY PRODUCTS

The project used a suite of engagement and extension techniques across northern Australia to raise awareness with over 810 people and 255 businesses across northern Australia. Thirty-one people from 16 businesses demonstrated practice change during the project by undertaking businesses analysis and/or changing an aspect of management on their property. Engagement and extension methods include engaging regional champions, programmed learning (training packages), information access (e.g. field days/forums, newsletter articles), consultant/mentoring (one-on-one), on-property demonstrations and producer group activities. Ongoing support and mentoring with the 15 case study properties and other beef producers enabled the delivery team to understand production, profitability and practicality issues as well as the link between herd productivity and greenhouse gas emissions.

Across the three years of the project, the project team has interacted with industry stakeholders via:

- The establishment and promotion of 15 demonstration sites
- 11 project case studies and fact sheets
- 5 field days/paddock walks
- 10 industry events/forums/briefings/seminars
- 4 conference papers/posters
- 7 newsletter/on-line articles
- 3 webinars
- 3 radio and TV interviews
- 3 journal papers

Using the above extension and communication activities the project significantly exceeded its extension and communication targets (Table 7).

Table 7 Extension and communication achievement and targets.

Type of impact	Impact	Original Targets
Increased awareness about the project and carbon issues	Direct interaction with 810 people and 255 businesses Broad media awareness - >50,000 people	Direct interaction – 160 Broad awareness - 2400
Demonstrated increase in KASA (Knowledge, Attitudes, Skills & Aspirations)	89 people representing at least 36 businesses	40 producers
Demonstrated Practice Change, influenced by the project	31 people representing at least 16 businesses	13 producers

An end-of-project survey, distributed to the Maranoa Balonne business analysis group found that producers involved in the project have increased their knowledge of carbon farming as a result of being involved with the project activities. Some key results from the survey showed:

- 85% of respondents indicated they increased or significantly increased their knowledge and understanding of carbon farming and implications for an extensive beef business, with benefits including understanding soil carbon and benefits to soils and beef production and understanding baseline soil carbon data for the property through on-farm trials.
- All respondents that completed the business analysis aspect of the project indicated they found it useful. The reasons included: outlining problems in the business to work on, better understanding profit drivers of the business, data on long-term impacts of management decisions and benchmarking against other businesses.
- 67% of respondents that completed the business analysis indicated they somewhat or significantly improved their financial literacy skills as a result of being involved in this activity.
- 43% of respondents indicated they had made changes to the business as a result of being involved in the project, while 29% indicated they hadn't made changes.

Overall the feedback across all regions indicated that the project helped producers to improve their knowledge of carbon farming and increased their knowledge of on-farm management to either decrease methane emissions or increase carbon in soil and vegetation. The business analysis approach used by the project helped producers identify weaknesses and strengths in the business and identify and evaluate strategies to target the underperforming areas to improve herd and business performance. However, producers identified that the business analysis was not solely responsible for the change occurring, suggesting instead that extension, producer group discussion or other external activities are also very important for producers to gain the knowledge and confidence to undertake practice change.

The project team was keen to ensure the project had a legacy past the end of the funding period and therefore has focused on a range of legacy products, including:

- 11 case studies and fact sheets.
- Climate Clever Beef website.
- 7 conference and scientific journal papers.
- The Rangeland Journal Special Issue – Climate Clever Beef (scheduled for publishing in 2016).
- Development of many long lasting relationships with producers and other colleagues across a range of agencies and organizations.

Key findings from the extension and communication activities include:

- Business analysis can be a powerful component of extension activities encouraging practice change.
- Case studies and fact sheets were useful for producers and policy personnel to understand how management change could impact productivity, profitability and greenhouse gas emissions as part of a 'real' business.
- Developing and maintaining trusting relationships with producers and colleagues is extremely important to successfully undertake comprehensive business analyses and facilitate practice change.

IMPLICATIONS FOR AUSTRALIAN AGRICULTURE

The northern Australian beef industry is large, managing 15 million cattle on 250 million hectares. The expansive size of the industry means that significant environmental impacts are likely. Of concern are declines in land condition leading to reduced water quality and sediment transport and emissions of greenhouse gases to the atmosphere. The northern Australian beef industry is estimated to contribute around 79% of Australia's agricultural greenhouse gas emissions (10% to Australia's total greenhouse gas emissions) through livestock emissions as well as impacting carbon stored in soil and vegetation. The northern Australian beef industry thus has a significant role to play through 'carbon farming' to assist Australia to meet its long term emissions reduction targets. However, productivity growth and returns on investment in the northern Australian beef industry are generally static or declining and together with high debt levels and increasing input costs, any new carbon farming activities will require rigorous evaluation to ensure that business profitability is improved and financial risks are minimized.

'Carbon farming' was defined for this project as having potential to reduce greenhouse gas emissions, improve emissions intensity or increase carbon stored in soil or vegetation. Carbon farming practices may or may not have potential to generate 'carbon income' through participation in the Australian Government's Emissions Reduction Fund (ERF).

On-farm trials and evaluations on 15 beef businesses in northern Australia demonstrated there were opportunities to minimise the intensity of livestock methane emissions and increase carbon stored in vegetation.

A number of livestock management strategies were identified, which led to an improvement in livestock emissions intensity of 10 to 30% including: improving weaning rates, increasing lifetime reproductive performance and improving growth rates. Generally adoption of a suite of management changes and tools were required to achieve the desired outcomes (e.g. pregnancy testing, supplementation, heifer management and pasture improvement). Currently, there is little opportunity for most northern beef businesses to profitably generate and sell carbon credits from reducing livestock methane emissions because the scale of most businesses is not adequate to offset current indicative project management costs and carbon price risk. In many cases, the livestock management options identified improved the productivity and profitability of the business without 'carbon income'. Therefore, if producers are undertaking best livestock management practices, they are likely to be achieving desirable carbon farming outcomes. Reduction in total emissions was only achieved when stocking rates were reduced which can have a significant impact on business profitability through reduced sales, even if individual livestock productivity is improved.

Grazing management strategies that lead to improved pasture condition, pasture biomass and reduced drought risk have the ability to substantially increase the average amount of carbon stored in vegetation, particularly in grassland landscapes. This carbon farming practice has significant implications for landscape health, reduced off-farm impacts, long term business profitability and reduction of drought risk, but currently has no opportunity to generate carbon income due to a lack of a ERF methodology and the perception that higher average pasture biomass is not a secure long-term carbon store. This carbon farming opportunity could be addressed by policy and lead to a significant improvement in the environmental impact of the northern Australian beef industry and address a number of the Governments priorities:

- Reef water quality
- Drought preparedness
- Sustainable landscapes
- Carbon storage
- Leasehold land monitoring

The impact of grazing land management and land condition on soil carbon was found to be negligible or inconsistent using SCaRP methodology across many soil types, regions and production systems. This has led to the conclusion that there is limited scope for soil carbon sequestration ERF projects across the majority of northern Australian grazing land due to high project risk. Soil carbon was found to increase when cropping land was converted to pasture. Although consistent and strong changes in soil carbon with land condition were not found, in general, management strategies that aim to increase the carbon stored in soil are desirable for grazing businesses due to the complementary improvements in pasture quantity and quality which should lead to improved long term livestock productivity.

The findings from the analysis of options at the demonstration sites have been documented in case studies and fact sheets available on the Climate Clever Beef website (http://futurebeef.com.au/resources/projects/climate-clever-beef/), in conference and journal papers and in this final report. A special issue of The Rangeland Journal has been negotiated to provide a long-term legacy of the key case studies arising from this project and from inter-project collaboration.

ENDORSEMENT

I endorse this report. It clearly describes how a combination of approaches was implemented within 3 regions of northern Australia to meet the project's objectives. As a result, beef producers in northern Australia can now make a much more informed and systematic assessment of:

- the management options for reducing methane emissions, improving livestock emissions intensity, and/or increasing sequestration of carbon in vegetation and soil;
- the impact of these options on business profitability with and without associated carbon income;
- the likelihood of significant and sustainable carbon income from these options, given the magnitude and consistency of impacts, the ease of measurement and compliance, and the costs of selling carbon credits.

By necessity, some of the demonstrations and analyses were relatively short-term and/or partially based on best estimates of biological rates. However, the approach was robust enough to provide very useful guidance on (1) those management options for deriving carbon income that are worthy of further evaluation and (2) the factors which will negate or limit the implementation of different options.

The project leader and team are to be congratulated for tackling such an ambitious project and for not shying away from the complexity of the questions the project addressed – the management options that potentially lead to carbon-based income in these production systems are often multifaceted and their impacts on business performance, both with and without carbon income, are equally complex.

The project has produced important information and much food-for-thought for beef producers and those who advise them. The project outputs should therefore be communicated widely and with some urgency.

Dr. Michael Quirk
(Livestock production and NRM specialist)
Project Reviewer

ACKNOWLEDGEMENTS

This project was supported by the Queensland government, regional NRM groups (Desert Channels Queensland and Queensland Murray-Darling Committee), the Australian Government's Carbon Farming Futures Fund – Action on the Ground Program and 15 grazing businesses.

The 15 grazing businesses are specifically acknowledged for their trust in the project team and participation in the project. Without their support, this project would not have been possible. Being able to put carbon farming practices in the context of real businesses is a powerful development and extension mechanism.

Dr Mick Quirk as project reviewer is thanked for his participation in annual meetings and providing insightful feedback and guidance through the project.

PUBLICATION LIST

JOURNAL AND CONFERENCE PAPERS

Broad, K., Sneath, R., and Emery, T. (submitted) Use of business analysis in beef businesses to direct management practice change for climate adaptation outcomes *The Rangeland Journal.*

Broad, K., Emery, T., Sneath, R., McLean, I., and Bray, S. (2015) Using business analysis to inform management decisions in beef businesses. In 'Australian Rangelands Conference.' Alice Springs.

Bray, S., Allen, D., Harms, B., Reid, D., Fraser, G., Dalal, R., Walsh, D., Phelps, D., and Gunther, R. (Submitted) Is land condition a useful indicator of soil organic carbon stock in Australia's northern grazing land? *The Rangeland Journal.*

Bray, S., Walsh, D., Phelps, D., Rolfe, J., Broad, K., Whish, G., and Quirk, M. (Submitted) Climate Clever Beef: practical measures to reduce carbon emissions in northern Australia. *The Rangeland Journal.*

Cullen, B.R., Timms, M., Eckard, R., Mitchell, R.A., Whip, P., and Phelps, D. (2013) The effect of earlier mating and improving fertility on emissions intensity of beef production in a northern Australian herd. In 'Proceedings of the 5th International Greenhouse Gas and Animal Agriculture Conference (GGAA 2013). Vol. Volume 4, Part 2.' pp. 403. (Advances in Animal Biosciences, .Cambridge University Press. ISBN 978-0-906562-69-7: Dublin, Ireland.)

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CASE STUDIES AND FACT SHEETS

- Soil organic matter and carbon in agriculture
- Soil carbon in the Maranoa Balonne
- Business analysis from the Maranoa Balonne region
- Improving greenhouse gas outcomes in a beef business- Maranoa Balonne
- Driving sustainability and profits through use of legumes, spelling and documented herd management
- Efficient management & objective measurement - keys to productivity & profitability
- Pasture spelling within a highly variable climate, Goodwood Boulia. https://futurebeefnew-daff.netdna-ssl.com/wp-content/uploads/Case-Study-Goodwood_final.pdf
- Green biomass estimation and pasture quality fact sheets.
- Increasing profits and reducing carbon emissions. Peter Whip, Landholder and Climate Change Champion, Longreach.
- Cullen, B., Eckard, R., Timms, M., and Phelps, D. (accepted) The effect of earlier mating and improving fertility on greenhouse gas emissions intensity of beef production in northern Australian herds. *The Rangeland Journal*. (Goodwood and Royston case study)
- Project report to landholders: Dunblane case study. Ian Houston and David Phelps 2015
- Project report to landholders: Tarrina case study. Ian Houston and David Phelps 2015

MEDIA AND OTHER ARTICLES

- FutureBeef e-bulletin- "Research Update: Climate Clever Beef" featured in the FutureBeef e-bulletin #8. This bulletin was distributed to 450 subscribers from Australia and internationally, with 54 pageviews for this article.
- Article "research Update: Climate Clever Beef" featured in the BeefTalk magazine Autumn / Winter 2013 edition.

- August 2013: A mail out went to 170 mixed farming enterprises in the Maranoa region in August 2013. This included a small handout with information on the Southern FutureBeef Team and current projects, including this project.
- Article "FutureBeef team focus on profits" appeared in the Western Star newspaper's 'Spotlight on Beef' feature in August 2013, which is distributed to over 3500 readers.
- Article on the Southern FutureBeef Team "South-west team here to help" appeared in the Spring 2013 edition of the BeefTalk newsletter (pg 38). This was a handout in the Queensland Country Life and was distributed to over 21 000 readers. It is also in an e-reader format- http://resources.farmonline.com.au/qcl/beeftalk/3dissue/index.html
- Article "Roma officer extends a helping hand" appeared in the Queensland Country Life newspaper in April 2014.
- Article "Ag advisors talk beef over breakfast" appeared in the Bottle Tree Bulletin, February 2015. The Bottle Tree Bulletin is distributed to over 5500 people in the Maranoa region.
- Project report to landholders: Goodwood case study. Ian Houston and David Phelps 2015
- Project report to landholders: Royston case study. Ian Houston and David Phelps 2015
- Project report to landholders: Dunblane case study. Ian Houston and David Phelps 2015
- Project report to landholders: Tarrina case study. Ian Houston and David Phelps 2015

- David Phelps and case study land-holder Rick Britton appeared on ABC TV National News (journalist Peter Lewis) on Friday 14th February, with a audience of approximately 718,000 people (http://www.tvtonight.com.au/2014/02/friday-14-february-2014.html).
- David Phelps was on ABC Western Queensland and the Country Hour on Wednesday 26th March 2014 as a member of an expert panel discussing management options for a looming El Nino over the 2014/15 summer (http://www.abc.net.au/news/2014-03-26/dry-weather-advice-western-qld/5347036). These stories also featured on the ABC website.

Climate Clever Beef webinar series (recorded and available on line):

- Increasing profits and reducing carbon emissions. Peter Whip, Landholder and Climate Change Champion, Longreach. http://www.leadingsheep.com.au/2014/10/increasing-profits-and-reducing-carbon-emissions/

- Storing and measuring soil carbon. Ram Dalal, Senior Principal Scientist at Department of Environment and Resource Management. http://www.leadingsheep.com.au/2014/10/storing-and-measuring-soil-carbon/

- Carbon farming in the grazing lands. Richard Eckard, Director, Primary Industries Climate Challenges Centre, Melbourne. http://www.leadingsheep.com.au/2014/10/carbon-farming-in-the-grazing-lands/

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