CSIRO PUBLISHING
The Rangeland Journal, 2016, **38**, 207–218
http://dx.doi.org/10.1071/RJ15124

Overview

Climate Clever Beef: options to improve business performance and reduce greenhouse gas emissions in northern Australia

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Abstract. The Rangeland Journal – Climate Clever Beef special issue examines options for the beef industry in northern Australia to contribute to the reduction in global greenhouse gas (GHG) emissions and to engage in the carbon economy. Relative to its gross value (A$5 billion), the northern beef industry is responsible for a sizable proportion of national reportable GHG emissions (8–10%) through enteric methane, savanna burning, vegetation clearing and land degradation. The industry occupies large areas of land and has the potential to impact the carbon cycle by sequestering carbon or reducing carbon loss. Furthermore, much of the industry is currently not achieving its productivity potential, which suggests that there are opportunities to improve the emissions intensity of beef production. Improving the industry's GHG emissions performance is important for its environmental reputation and may benefit individual businesses through improved production efficiency and revenue from the carbon economy.

The Climate Clever Beef initiative collaborated with beef businesses in six regions across northern Australia to better understand the links between GHG emissions and carbon stocks, land condition, herd productivity and profitability. The current performance of businesses was measured and alternate management options were identified and evaluated. Opportunities to participate in the carbon economy through the Australian Government's Emissions Reduction Fund (ERF) were also assessed.

The initiative achieved significant producer engagement and collaboration resulting in practice change by 78 people from 35 businesses, managing more than 1 272 000 ha and 132 000 cattle. Carbon farming opportunities were identified that could improve both business performance and emissions intensity. However, these opportunities were not without significant risks, trade-offs and limitations particularly in relation to business scale, and uncertainty in carbon price and the response of soil and vegetation carbon sequestration to management.

This paper discusses opportunities for reducing emissions, improving emission intensity and carbon sequestration, and outlines the approach taken to achieve beef business engagement and practice change. The paper concludes with some considerations for policy makers.

Additional keywords: carbon sequestration, grazing, participatory action research, productivity, profitability, rangeland.

Received 15 December 2015, accepted 13 May 2016, published online 23 June 2016

Introduction

This overview paper of The Rangeland Journal – Climate Clever Beef special issue provides a synopsis of options for the beef industry in northern Australia to contribute to the global initiative to reduce greenhouse gas (GHG) emissions and to engage in the carbon economy ('carbon farming'). The papers in the issue present new knowledge based on the modelling of case studies at paddock, whole property and regional scales, and on field studies that examine the relationships between soil and vegetation carbon, grazing and other environmental impacts. Limitations to adoption, incentives (either direct payments through selling carbon credits or through improved profitability) and adoption pathways of new or alternate management practices by beef producers were also examined. The work was, in the most part, conducted under the Climate Clever Beef initiative supported by the Queensland, Northern Territory and Australian Governments together with Meat and Livestock Australia, regional Natural Resource Management (NRM) groups, CSIRO and collaborating beef producers.

The northern Australian beef industry operates in Queensland, the Northern Territory and the northern half of Western Australia (Fig. 1), and is the main agricultural industry with ~15.8 million cattle grazed on 250 million ha (Gleeson *et al*. 2012; MLA 2014; Eady *et al*. 2016). The industry produces about half of the nation's beef turn-off and is estimated to contribute ~A$5 billion (gross value) to the Australian economy (Gleeson *et al*. 2012). Although its contribution to Australia's gross domestic product is relatively small, the industry is the major economic driver for many remote and rural regions due to the lack of other agricultural opportunities and alternate industries.

The grazing industries have attracted community scrutiny for their contribution to Australia's GHG emissions and other environmental impacts such as poor land condition and reef water quality (McAlpine *et al*. 2009; Bartley *et al*. 2014). The net GHG emissions contribution of the northern beef industry is primarily influenced by livestock numbers, with enteric fermentation estimated to contribute ~6% to Australia's reportable GHG emissions under the Kyoto Protocol (DoE 2015). The use of fire across the northern savannas is estimated to contribute an additional 1–3% to Australia's reportable GHG emissions (Whitehead *et al*. 2014), albeit across multiple land uses. Changes in land use including land clearing, cultivation, the use of fossil fuels for essential farm maintenance and transport, and the application of nitrogenous fertilisers in some areas are further contributors to GHG emissions (Bray and Willcocks 2009; Wiedemann *et al*. 2015). However, through management changes, there are opportunities for the northern beef industry to assist Australia in meeting its long-term international emissions-reduction targets.

Grazing of native and naturalised rain-fed pastures under extensive management is the most common production system for the northern beef industry. Average property size is ~24 000 ha (Martin 2015) but can exceed 1 million ha. Under these extensive systems, cattle are typically only mustered once or twice a year due to rainfall seasonality, disparate seasonal growth rates, large property sizes and high mustering costs. These constraints, coupled with long distances to markets (sometimes in excess of 1000 km), generally favour breeding operations turning off relatively young cattle to live export or finished cattle direct to slaughter across the far north (Bortolussi *et al*. 2005). Enterprises that turn over cattle relatively quickly, for example feedlotting, trading and backgrounding[1], are common in the more closely settled regions of central and southern Queensland due to their closer proximity to saleyards, supplementary feed supplies and abattoirs.

In a recent situation analysis of the northern Australia beef industry, nearly half of the beef enterprises were found to be economically unsustainable (McLean *et al*. 2014). These businesses were often over-capitalised, had declining equity, high interest payments and high costs of production leading to low returns on assets. The high rainfall variability, which occurs

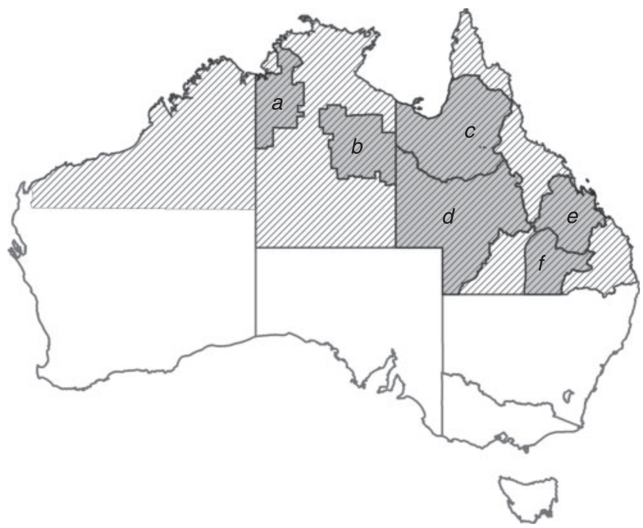

Fig. 1. Map of targeted beef industry regions across northern Australia. (*a*) Victoria River District (VRD) and Douglas Daly, (*b*) Barkly Tableland, (*c*) Queensland Gulf, (*d*) Mitchell Grasslands and Channel Country, (*e*) Fitzroy Basin, and (*f*) Maranoa Balonne region.

in many parts of northern Australia, exposes these businesses to a high level of financial risk. A common management response to this risk is to increase cattle numbers in an attempt to increase output, often beyond levels considered to be environmentally sustainable (Stockwell *et al*. 1991). The subsequent overgrazing of pastures leaves many businesses and the land resource further vulnerable to drought, failed wet seasons and environmental damage (Foran and Stafford Smith 1991; Stockwell *et al*. 1991). The poor financial position of beef enterprises means that alternate management options for profitability or environmental outcomes need to be considered rigorously (Ogilvy *et al*. 2015).

The beef businesses which are performing the best have adequate business scale, lower cost of production, high weaning and branding rates, low adult mortality rates and tend to sell heavier cattle (McGowan *et al*. 2014; McLean *et al*. 2014). Management opportunities to lift livestock productivity, profitability, land condition and beef business resilience in the northern beef industry have been identified via benchmarking analyses (McLean *et al*. 2014), industry reviews (Donaghy *et al*. 2010*b*; Hunt *et al*. 2014; Phelps *et al*. 2014), research projects (e.g. McGowan *et al*. 2014) and commercial case studies (Cullen *et al*. 2013, 2016; Bray *et al*. 2015; Walsh and Cowley 2016). Relevant strategies include increasing weaning rates and reducing mortality rates, improving weight gains, bringing under-utilised land into production and managing costs. On-ground practices to achieve these include developing paddock and water point infrastructure, matching stocking rates to long-term carrying capacity, using genetic and fertility selection, pasture improvement, phosphorus supplementation and feedlot finishing (Bentley *et al*. 2008; Henderson *et al*. 2013; Petty *et al*. 2013; Quigley and Poppi 2013; McGowan *et al*.

[1]The term 'backgrounding' is used to refer to a production system where 'purchased' underweight cattle (the terms 'stocker' or 'grower' are sometimes used) are grown to an optimum weight before entering a feedlot or other system for finishing.

2014). Importantly, many of these practices also improve GHG emissions performance (Kennedy *et al*. 2007; Charmley *et al.* 2008; Rolfe 2010; Page *et al*. 2013). However, adoption of alternative management options has often been constrained by the poor financial position of many grazing businesses, family succession, drought conditions, varying levels of financial literacy, and a lack of confidence and skills to evaluate the risks, costs and benefits of management options relevant to individual businesses (Guerin and Guerin 1994; McLean *et al*. 2014; Rolfe and Gregg 2015; Broad *et al*. 2016; Rolfe *et al*. 2016).

Financial incentives to improve adoption of alternative management options exist through both direct involvement in the carbon market (CSIRO 2012) and through improved management practices which reduce emissions while also offering profitability gains.

Involvement in the carbon market can be through the voluntary market (e.g. Walton *et al*. 2014) or through the Australian Government's Emissions Reduction Fund (ERF) (Australian Government 2014). The ERF was designed to help Australia achieve its international commitment to reduce emissions to 5% below 2000 levels by 2020 (DoE 2016). The ERF provides a financial incentive for participants to register and follow an approved methodology to generate Australian Carbon Credit Units (ACCU), which are purchased by the Australian Government via a reverse auction process (CER 2015). The auction process currently has a minimum bid size of 2000 tonnes of carbon dioxide equivalents (CO_2e) abated or sequestered per annum, on average, for the contracted delivery term (CER 2015). As such, project scale will impact on the ability to participate for many grazing businesses. Current ERF methodologies applicable to the northern beef industry aim to either reduce emissions (e.g. from livestock, savanna burning and land clearing) or increase the sequestration of carbon in vegetation and soil.

Reducing emissions intensity

The current ERF legislation recognises methodologies that deliver reductions in total GHG emissions and/or emissions intensity, thus increasing policy compatibility with the global goal of increasing food production. Reducing total GHG emissions from ruminant livestock generally requires a reduction in livestock numbers and consequently property productivity (Rolfe 2010; Henry *et al*. 2012; Harrison *et al*. 2014). In northern Australia, herd expansion is a high priority because there are still large areas of land that are under-utilised (Bortolussi *et al.* 2005; Petty *et al*. 2013; NT DPIF 2014). The ERF legislation recognises activities that improve emissions intensity (emissions per unit of product) (Australian Government 2014). Thus, producers who are still developing their properties and adopting technologies to increase livestock carrying capacity can participate in the carbon market by simultaneously improving per head productivity (Walsh and Cowley 2016). Practices that improve per head productivity (such as better growth, reproduction and mortality rates) can reduce GHG emissions per kilogram of meat or fibre produced (Hegarty *et al.* 2010; Rolfe 2010; Broad *et al*. 2011; Cullen *et al*. 2013; Harrison *et al*. 2014). These activities are attractive to producers because they improve the profitability of the enterprise (if implemented cost-effectively) and concurrently allow the business to expand. The improvement in the trajectory of total emissions as a result of higher per head productivity is illustrated conceptually in Fig. 2. A key objective of the Climate Clever Beef initiative was the identification of practical opportunities that could increase productivity and profitability while simultaneously reducing GHG emissions intensity.

The Climate Clever Beef initiative

The Climate Clever Beef initiative (Bray *et al*. 2014*b*, 2015) sought to identify and assess regionally relevant, practical management options to reduce GHG emissions, improve GHG emissions intensity or increase carbon sequestration while maintaining or enhancing profitability and land condition. The engagement and participation of beef producers was important to increase the likelihood of adoption of alternate management practices or technologies leading to long-term practice change (Carberry 2001). Prior to the start of the Climate Clever Beef initiative, beef producers across northern Australia perceived 'carbon farming' to be financially unattractive, with uncertainty around the costs and benefits, including price received for ACCU, costs of being involved (e.g. audit costs) and implications for the long-term performance of their business (White 2014). Furthermore, a lack of information and skills in business analysis made it virtually impossible for most beef businesses to evaluate the benefits, costs and trade-offs of 'carbon farming' and the potential implementation of ERF methodologies.

The Climate Clever Beef initiative operated in six regions across northern Australia (Fig. 1) and was unique in that it integrated three key aspects in a regionalised, whole-of -business approach:

(1) Development of a framework to analyse beef businesses and identify options to improve business outcomes (Bray *et al*. 2014*b*).

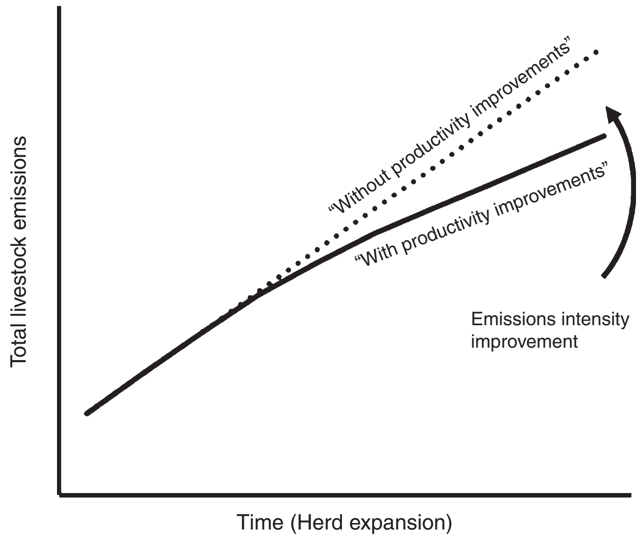

Fig. 2. A conceptual representation of total livestock greenhouse gas emissions increasing proportionally with herd size (dash line) and an alternate trajectory with productivity improvements leading to improvement in emissions intensity and lower total emissions.

(2) Evaluation and demonstration of options through targeted trials, analyses and modelling (Carberry 2001; Nicholson *et al*. 2003).
(3) Facilitation of long-term practice change through the integration of a range of engagement and extension practices (Pannell *et al*. 2006; Pahl 2015).

The Climate Clever Beef framework

The Climate Clever Beef framework (Fig. 3) was developed using the experience and expertise gained in previous projects that included business analysis (e.g. CQBeef, Donaghy *et al.* 2010*b*; $avannaPlan – Beef$ense, Rolfe *et al*. 2016). The framework was used to evaluate and demonstrate the complex benefits or trade-offs of alternate practices on profitability, productivity, land condition, GHG emissions and climate risk. Regional producer champions and collaborating producers from case study properties were engaged as research partners and provided data and insights to maximise regional acceptance (Pahl 2015). Local collaborator property data was preferred over generic industry or regional data as it was expected to greatly improve the likelihood of acceptance and implementation of identified and evaluated alternate practices. The five steps that comprise the Climate Clever Beef framework (Fig. 3) are outlined.

Step 1. Understanding industry and regional drivers

Beef production systems and businesses are influenced by a range of regionally specific factors such as climate, land type, pasture production potential, livestock diet quality and nutrition, location and access to markets. Business drivers, constraints and risks need to be identified for each specific region to understand the environment in which any given business operates. For example, infertile soils and a monsoonal climate with a prolonged dry period in far northern Queensland and the Northern Territory limit livestock growth rates and turn-off of finished stock in the timeframes needed to meet market specifications. The production systems used thus account for this through younger turn-off or transporting cattle for finishing on more fertile country elsewhere. Regional benchmarking, land type and soil fertility mapping, production modelling and agricultural potential reports were useful resources to identify key regional drivers and risk factors (e.g. Bortolussi *et al*. 2005; Jackson *et al*. 2012; McLean *et al*. 2014).

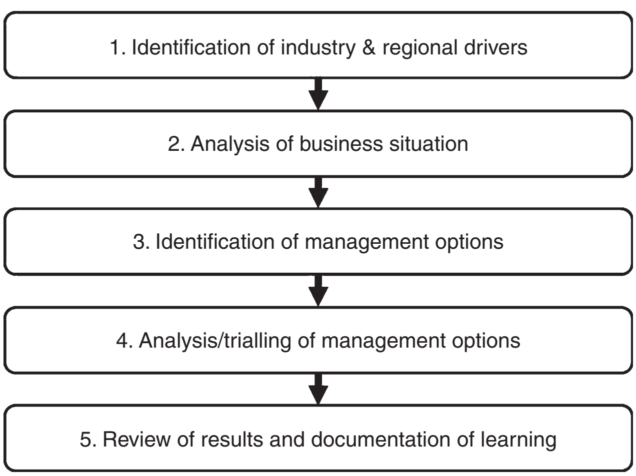

Fig. 3. Climate Clever Beef framework used to systematically assess beef businesses, identify and evaluate alternate management options and review results.

Step 2. Individual business situation analyses

Regional benchmarks, drivers and risk factors were discussed and validated with case-study producers, and the current performance and trends of the individual business were analysed (property benchmarking). The business analysis included documentation of the business drivers and risk factors, and an assessment of productivity, profitability, land condition, GHG emissions (or other environmental imperatives) and the ability of producers to manage climate risk.

Specific tools were used for the situation analyses with tool selection dependent on whether a whole-property systems approach was needed or only one aspect (enterprise) of the business was being targeted. Whole-property benchmarking may use tools such as: The Business Analyser, ProfitProbe™ or other consultant proprietary tools. Other herd modelling tools such as Breedcow and Dynama and the Cashcow Brick may also be appropriate (Holmes 2004; McGowan *et al*. 2014). Supporting grazing enterprises to undertake business analysis training (e.g. Meat and Livestock Australia's BusinessEdge workshop) on an individual or group basis can promote an understanding of the concepts, terms and drivers, and enhances the producers learnings (e.g. Broad *et al*. 2016; Rolfe *et al*. 2016).

Key outputs required include Key Performance Indicators (KPIs) at the whole business level and/or enterprise level. It is desirable that the KPIs are consistently calculated with reported industry, regional and land-type benchmarks (e.g. DPI&F 2007; McGowan *et al*. 2014; McLean *et al*. 2014; Broad *et al*. 2016; Rolfe *et al*. 2016). Using historical records to generate average KPI over several years is desirable due to the variability experienced by beef businesses. As well as objectively measuring current performance, this process provides an objective baseline to measure and evaluate the impact of future practice change on whole business productivity and economic performance. The documentation of known/perceived trends and issues is an important component of the situation analysis and assists in the identification of priority actions.

Business benchmarking can be quite confronting and a significant source of stress for many business owners as the process often identifies aspects of poor performance or weaknesses in the business. Therefore, specialised extension skills (e.g. farm financial counselling), experience and on-going commitment are required to ensure a proper business analysis is conducted, clear explanation of results provided, and the business owner's stress is appropriately managed.

Step 3. Identification of options

Once the status and trends of the business have been captured, strategies to improve the high priority KPI are identified. An understanding of the business owners' future goals, business succession priorities and interests is essential to complete this process. At the overarching business level, there are only three ways in which profitability can be improved:

- increase gross margin (enterprise income minus direct expenses),
- reduce overhead expenses (including finance costs and wages),
- increase turnover.

Historical case studies and research may be useful as a guide for expected responses (e.g. Broad *et al*. 2011; Cullen *et al*. 2013; Walsh and Cowley 2016). During this process the business owner or group will often discuss alternate management options and may request further information to increase their understanding. This provides an extension opportunity to facilitate improved education (e.g. a breeder management field day), which may include participation by other producers in the region.

Step 4. Analyses/trialling of options

The identified management options can be evaluated by desktop analysis, modelling, on-ground trials, or a combination of these methods, to prove the concept and encourage adoption and long-term practice change. The desktop analysis requires collation of relevant information from a range of sources (literature, grazing trials and experts). A comprehensive evaluation of each management change option in terms of productivity, profitability, land condition, GHG emissions (or other environmental imperatives) and potential to manage climate risk is required to capture positive and negative impacts and trade-offs. In some situations simply stating 'the current situation is not expected to change' is sufficient where an intervention has no effect on a particular KPI.

Discounted cash flow analysis and bio-economic modelling to determine the net economic benefits over time and payback periods may be appropriate (e.g. Broad *et al*. 2016; Gowen and Bray 2016; Whish *et al*. 2016). Bio-economic modelling can integrate management practices, livestock, pasture dynamics, tree biomass and soil carbon at the whole property scale and over longer time frames than can be realistically trialled on-farm in a short-term project (e.g. Donaghy *et al*. 2010*a*; Phelps *et al*. 2014; Whish *et al*. 2016).

If analysing options at the enterprise level only (as opposed to whole-farm or multi-farm), the impacts on whole-farm profitability, resources and overhead costs (e.g. labour) still need to be considered. For example, intensively feeding weaners to increase weight gain and reduce age of turn-off may return a positive enterprise gross margin. However, when the cost of capital (e.g. troughs and transport equipment) and labour are considered the impact on whole-farm profitability may be negative.

The desktop analysis may indicate that positive outcomes from implementing the alternate management practice are likely, which could lead to trialling the option at a small scale to reduce risk and increase confidence in application across the property. The analysis may also identify a high risk of negative outcomes which need to be considered.

Step 5. Review of option implementation and learnings

The final step in the process is a review of the outcomes of any management change options that were implemented. Data to be collected are similar to the initial benchmarking undertaken in Step 2. All reported outcomes are compared with the predicted outcomes with reasons for any deviations noted. Questions that should be included in the review include:

(1) What alternate management strategies were implemented?
(2) How successful were the alternate management strategies in progressing towards the intended goal (level of achievement/success)? If not successful, why and how could this be improved?
(3) What is the next priority/target?

Key findings

Improving livestock GHG emissions

Ruminant livestock produce substantial quantities of methane emissions due to their digestion process. The amount of methane emissions per head has been measured in respiratory chambers and is a function of forage intake, which is driven by liveweight, liveweight gain, feed quality and lactation (Kennedy *et al*. 2007; DoE 2015; Charmley *et al*. 2016). Higher forage intake leads to higher emissions. Livestock at maintenance emit methane, but by definition have no associated production. The additional intake above that required for maintenance is associated with liveweight gain or lactation, both of which are directly related to productivity. Therefore, an objective for reducing methane emissions or improving emissions intensity is to maximise the proportion of intake associated with productivity and minimise the proportion of intake associated with maintenance.

A range of management strategies are available to manage this intake-productivity balance with subsequent improvements in herd efficiency, individual animal production and GHG emissions benefits. Additionally, some compounds (synthetic or naturally occurring in some feeds) can reduce the amount of methane per unit of intake (Harrison *et al*. 2015; Herd *et al*. 2015; Charmley *et al*. 2016). Management strategies that improve livestock herd emissions performance include:

- Improving lifetime reproductive efficiency by increasing weaning rates and reducing death rates, leading to more calves in the lifetime of a breeder and its associated emissions. Pregnancy testing can be a powerful tool to evaluate and improve herd reproductive performance and identify unproductive breeders (Charmley *et al*. 2008; Rolfe 2010; Broad *et al*. 2011; Cullen *et al*. 2013, 2016).
- Improving growth rates through supplementation or providing better quality forage (e.g. lower stocking rates enables livestock to select a better quality diet) leading to a higher proportion of intake contributing to production rather than maintenance. The use of improved forages (e.g. legumes or oats) or supplements can improve livestock productivity (Kennedy *et al*. 2007; Charmley *et al*. 2008; Rolfe 2010; Bowen *et al*. 2015; Herd *et al*. 2015).
- Improving genetics and breeding better adapted and productive livestock (Hegarty *et al*. 2007; Cullen *et al*. 2013, 2016; Walsh and Cowley 2016).
- Nitrate supplementation instead of urea supplementation can reduce daily methane emissions (Callaghan *et al*. 2014; Cottle *et al*. 2016).
- The use of some forages such as leucaena not only improves productivity but also contains compounds, which reduce methane emissions relative to intake (Durmic *et al*. 2010; Harrison *et al*. 2015).

Many studies, including those from the Climate Clever Beef Initiative, have concluded that single interventions are unlikely to achieve the desired magnitude of productivity, profitability or emissions improvements (e.g. Bentley *et al*. 2008; Broad *et al*. 2011; Cottle *et al*. 2011; Harrison *et al*. 2014; Bray *et al*. 2015; Wiedemann *et al*. 2015; Cullen *et al*. 2016; Walsh and Cowley 2016). Although a suite of complementary practices is more likely to deliver the highest benefits, the costs of implementation must be carefully considered to ensure that the proposed changes are profitable (Eckard *et al*. 2010; Harrison *et al*. 2014; Ash *et al*. 2015; Ogilvy *et al*. 2015). For example, one case study property in the Queensland Gulf region implemented a range of management changes over 15 years including reducing stocking rates, wet season spelling, pasture improvement, supplementation and feeding of young cattle to meet weight-for-age targets (Broad *et al*. 2011). This suite of practices increased the kilograms of beef sold by 80%, improved land condition, reduced total GHG emissions by 15% and improved emissions intensity by 53% while increasing the gross margin of the beef enterprise by 93%.

Australian beef producers currently have the option to participate in the Australian Government's ERF through two approved livestock methodologies:

- Reducing GHG emissions in beef cattle through feeding nitrate containing supplements, and
- Beef cattle herd management.

Other ERF methodologies are likely to be approved in the future. Both the current methodologies provide opportunities but also have limitations. The 'nitrate methodology', which is being trialled by a large corporate beef producer (Nason 2014), has toxicity and supplement price risks requiring careful management. For most producers, these risks are unlikely to be compensated for adequately through the sale of ACCU (Callaghan *et al*. 2014; Benu *et al*. 2015; Cottle *et al*. 2016). The 'beef cattle herd management' methodology focuses on improving emissions intensity through complementary improvements in productivity (Australian Government 2015*a*). However, the business scale required to generate enough ACCU to participate in the ERF auctions, and the timeframes required to generate enough change in the herd (particularly through genetics) are likely to restrict widespread participation (Bray *et al*. 2015; Cullen *et al*. 2016; Walsh and Cowley 2016).

Increasing carbon stocks in soil and vegetation

The grazing lands of northern Australia inherently contain substantial stocks of carbon in herbaceous vegetation, woody vegetation and soil due to the large land area (Bray and Willcocks 2009; CSIRO 2009; Bray *et al*. 2014*a*; Viscarra Rossel *et al*. 2014). Past management practices such as overgrazing and tree clearing have led to a decline in carbon stocks in some regions (CSIRO 2009). Improving land condition to maximise the growth of herbaceous vegetation or encouraging growth of woody vegetation should lead to higher vegetation carbon stocks and carbon input into the soil (e.g. Ash *et al*. 1995; Holt 1997; Northup *et al*. 1999; Pringle *et al*. 2011). Although management can alter the amount of vegetative matter entering the soil, climate and soil type are the major drivers of soil carbon stocks (Pringle *et al*. 2011; Allen *et al*. 2013; Viscarra Rossel *et al*. 2014; Bray *et al*. 2016), potentially limiting long-term soil carbon sequestration beyond the inherent carbon storage capacity of a regional land type.

Approved ERF sequestration methodologies include carbon sequestration in regrowth, forestry and soil, and carbon retention through avoided deforestation. Other methodologies are likely to be developed in the future. The Climate Clever Beef initiative has found that potential sequestration opportunities need to be evaluated in the whole-farm context with consideration of project risk, project costs, livestock productivity trade-offs and long-term business goals (Gowen and Bray 2016; Whish *et al*. 2016).

Woody and herbaceous vegetation carbon stocks are limited by soil fertility, fire regime (Cowley *et al*. 2014) and water availability, especially during drought periods (Fensham *et al*. 2009; Allen *et al*. 2010). Although management activities that lead to improved land condition would be expected to increase long-term average carbon stocks in soil and herbaceous vegetation (Ash *et al*. 1995; Bray *et al*. 2014*a*; Whish *et al*. 2016), the results from recent soil organic carbon studies using SCaRP-consistent methodology (National Soil Carbon Research Program, Sanderman *et al*. 2011) have shown negligible, inconsistent and contradictory responses to management activities and land condition indicators across different soil types (Bray *et al*. 2010, 2016; Pringle *et al*. 2011; Allen *et al*. 2013, 2014; Pringle *et al*. 2014; Walsh and Shotton 2015). This uncertainty creates a high risk for any soil carbon sequestration project for any particular site, paddock or region. Management practices that can theoretically increase carbon stored in soil and vegetation include:

- Sustainable grazing systems that increase ground cover and forage production (Ash *et al*. 1995; McIvor and Gardener 1995; Hunt *et al*. 2014).
- Rehabilitation of degraded land to increase ground cover and perennial species (Ash and McIvor 1995; McIvor 2001; CSIRO 2009; Scanlan *et al*. 2014).
- Conversion of cropping land to pasture (Conant *et al*. 2001; Guo and Gifford 2002).
- Woody regrowth retention to increase carbon in woody vegetation and potentially soil (Bray and Golden 2009; Dwyer *et al*. 2009; Donaghy *et al*. 2010*a*; Gowen and Bray 2016; Whish *et al*. 2016).
- Woodland thickening as a result of reducing the incidence and extent of late dry season fires in the northern savannas (Crowley *et al*. 2009; Cowley *et al*. 2014).
- Introducing legumes into grass pastures to improve soil fertility or planting high biomass species to increase soil carbon ('t Mannetje 2007; Abberton 2010; Radrizzani *et al*. 2011).

Grazing management strategies that lead to improved land condition, such as pasture spelling or matching stocking rates to long-term carrying capacity (Hunt *et al*. 2014; Harris *et al*. 2015), have the ability to substantially increase the average amount of carbon stored in herbaceous vegetation (Bray *et al*. 2015; Whish *et al*. 2016). This carbon farming practice has significant positive implications for landscape health including increased rainfall infiltration, reduced sediment loss, improved water quality and biodiversity habitat (Bartley *et al*. 2014; Fraser and Stone 2016) and associated benefits for productivity, profitability and reduced drought risk (Scanlan *et al*. 2013, 2014; Hunt *et al*. 2014; O'Reagain *et al*. 2014; Jones *et al*. 2015).

Regrowth of woody vegetation occurs on many properties which were previously mechanically cleared to improve pastoral production particularly in central and southern Queensland (Henry *et al*. 2002). Stopping the re-clearing of regrowth has potential to increase carbon stocks as the woodland regrows and provides other environmental benefits (Dwyer *et al*. 2009; Eyre *et al*. 2009). However, there are trade-offs. Retaining more woody vegetation leads to lower pastoral productivity and livestock carrying capacity (Scanlan 2002; Jobbágy and Jackson 2004; Gowen and Bray 2016; Whish *et al*. 2016). Potentially, planting woody vegetation to increase carbon stocks is possible, but high intra- and inter-annual climate variability means this strategy is expensive and tree establishment is risky (Allen *et al*. 2010; Donaghy *et al*. 2010*a*).

Reducing savanna burning emissions

Savanna burning is a widespread practice across northern Australia and has been used by humans to manipulate the landscape for at least 50 000 years (Roberts *et al*. 1993). There is evidence that the extent, timing and frequency of burning has changed considerably since European settlement in the late 1700s (see Walsh *et al*. 2014). For example, in many parts of northern Australia which receive >1000 mm of rainfall per annum, the size and frequency of catastrophic fires late in the year has increased, particularly on land types and tenures that are not grazed by cattle (Whitehead *et al*. 2014). In contrast, the frequency and extent of burning has decreased on many areas with higher pastoral value (Cowley and Jenner 2015).

Anthropogenic fires contribute between 1% and 3% of Australia's reportable GHG emissions annually (Whitehead *et al*. 2014). There is an approved ERF savanna burning methodology available for High and Low Rainfall Zones. This methodology aims to reduce the extent and frequency of fires, particularly those late in the year when fires burn with high intensity and release more emissions (Australian Government 2015*b*). The viability of a savanna burning project is determined primarily by the recent fire history on the property, in particular the spatial extent, frequency and timing of fires on specified (eligible) vegetation types. The baseline period for the High Rainfall Zone is the 10 years immediately before the commencement of the project and 15 years for the Low Rainfall Zone (Australian Government 2015*b*). It is estimated that proponents will need to correct a poor fire regime on at least 40 000 ha of eligible land in the High Rainfall Zone and 80 000 ha in the Low Rainfall Zone to achieve the minimum ERF bid size of 2000 t CO_2e abatement per annum (CER 2015).

Currently, established savanna burning ERF projects are generating income through the ERF with 7.1 Mt CO_2e of abatement contracted from the first two ERF auctions (CER 2015). Much of this abatement is likely to be on non-pastoral land or marginal grazing land.

For cattle producers, there are some short- and long-term implications to consider before moving towards an early dry season burning regime to generate ACCU. These include impacts on cash-flow from having to move or sell cattle, the management of short-term and long-term forage supplies and the need to manage woodland thickening (Cowley *et al*. 2014).

Integration of extension processes and trialling to facilitate practice change

The Climate Clever Beef initiative between 2012 and 2015 improved knowledge and awareness of beef producers, agency staff, community, agribusiness, rural lenders, academics and policy personnel throughout Australia. Project findings have been communicated to over 2600 people and 1100 businesses via 67 field days and industry events and 90 publications, including case studies, fact sheets, conference papers, newsletter articles and journal papers (Bray *et al*. 2015). Seventy-eight people from 35 businesses, managing more than 1 272 000 ha and 132 000 cattle, demonstrated practice change during the project, by undertaking business analysis and/or changing an aspect of management on their property.

The Climate Clever Beef initiative was a collaborative partnership between government departments, NRM groups, industry organisations and producers. This collaboration was a key project strength and ensured access to a range of expertise. 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.
- Different opportunities could be targeted between regions (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, property development leading to increased herd numbers in the more extensive areas).

The Climate Clever Beef initiative integrated several extension models, which varied slightly on a regional basis. Extension approaches included one-on-one mentoring, group facilitation, regional producer champions, on-farm trials, field days and information provided in the form of fact sheets and case studies. Case studies and fact sheets were useful for producers and policy personnel to understand how management change could impact productivity, profitability and GHG emissions as part of a 'real' grazing business [case studies and fact sheets are available at: https://futurebeef.com.au/knowledge-centre/environmental-management/climate-clever-beef/ (accessed 7 June 2016)].

Using a suite of extension methods as part of a participatory action research model (Carberry 2001; Pannell *et al*. 2006; Pahl 2015), rather than a single extension approach, proved effective at achieving practice change. All approaches included on-farm trials, which served to increase producer confidence in the practices being implemented. A novel approach used within the project was the use of facilitated business analysis to determine current business performance and identify areas of the business requiring attention. This was very effective for engaging producers and generated meaningful data to use when analysing changes to the business (Donaghy *et al*. 2010*b*; Broad *et al*. 2016; Rolfe *et al*. 2016). The trials undertaken in the project were used to demonstrate innovative practices to both the participating producer and those in the wider community. This approach assisted in improving uptake of the practices being trialled by providing a low risk environment to assess impacts of the management practice being analysed (Broad *et al*. 2016).

The most important component of achieving practice change was the ability to develop and maintain trusting relationships with beef producers and colleagues. This was done through the use of one-on-one mentoring with producers, with activities such as business analysis and data collection. Where group work was used, there was also a large individual mentoring component through follow-up visits to each property.

Policy implications

Several carbon farming strategies are available to beef producers in northern Australia to reduce emissions or increase carbon sequestration. Generally, a suite of management changes and tools were required to achieve the desired production, profitability and GHG emissions outcomes. The Climate Clever Beef initiative found there was still much uncertainty and limitations to the profitable generation of ACCU by most farming businesses. Key limitations include, business scale and the number of ACCU, which can be generated to offset project management and auditing costs, and the minimum bid size into the ERF auctions (e.g. Cullen *et al*. 2016; Walsh and Cowley 2016). Undertaking a suite of ERF project activities may be required to increase scale. This will require further on-property research into cost-effective options and rationalisation of ERF compliance costs when undertaking multiply ERF methodologies. Additionally, uncertainty in future ACCU and livestock prices are particularly important when there are trade-offs between livestock production, carbon sequestration (e.g. regrowth retention, Gowen and Bray 2016; Whish *et al*. 2016), increased costs (e.g. nitrate feeding, Cottle *et al*. 2016) or business risk (e.g. increased debt, Rolfe *et al*. 2016).

Despite limitations to accessing carbon income at the individual business scale, a reduction in GHG emissions, improvement in emissions intensity or an increase in carbon sequestration are important from an industry perspective as it demonstrates the northern beef industry is responsibly addressing the GHG emissions issue and improving its environmental performance.

In many cases, the livestock management options identified improved the productivity and profitability of the business even without carbon income (Cullen *et al*. 2013, 2016; Walsh and Cowley 2016). Therefore, if producers are undertaking best livestock management practices, they are likely to be achieving desirable carbon farming outcomes. However, reduction in total GHG emissions was only achieved when stocking rates were decreased. Reduced stocking rates can have a significant impact on business profitability through lower livestock sales even if individual livestock productivity is improved. Where properties are overstocked, reducing stocking rates will be desirable, resulting in lower GHG emissions, better livestock productivity, better land condition and higher herbaceous carbon stocks (e.g. Broad *et al*. 2011; Bray *et al*. 2014*a*). However, where properties are currently understocked and expanding their herds (due to development stage or adoption of technology) total GHG emissions will rise with herd increase. Herd increase is desirable from a global food production perspective, so producers that are expanding their herds should also ensure that the GHG emissions intensity is improved by focusing on cost-effective practices that improve per head productivity.

The retention of regrowth was found to store substantial amounts of carbon in woody vegetation (Gowen and Bray 2016; Whish *et al*. 2016). Additional woody vegetation in some highly cleared landscapes may be desirable for other purposes such as biodiversity (Bowen *et al*. 2009; Eyre *et al*. 2009). However, there was a significant trade-off between regrowth retention and pastoral productivity which needs to be considered in conjunction with long-term business goals, location of regrowth retention to minimise opportunity costs, reduction in future livestock productivity and future land-use options.

Grazing management strategies that lead to improved pasture condition and pasture biomass have the ability to substantially increase the average amount of carbon stored in herbaceous vegetation (Whish *et al*. 2016). This carbon farming practice has significant positive implications for landscape health including reduced off-farm water quality impacts (Bartley *et al*. 2014; Fraser and Stone 2016), long-term business profitability and reduction in drought risk. However, currently, there is no opportunity to generate carbon income due to a lack of an ERF methodology, application of international carbon accounting rules 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 several other Government priorities including reef water quality, drought preparedness, sustainable landscapes, carbon storage and leasehold land condition.

The impact of grazing land management and land condition on soil organic carbon in northern Australia was found to be negligible or inconsistent using SCaRP-consistent methodology across soil types, regions and production systems (Allen *et al*. 2013; Bray *et al*. 2016). We conclude that there is currently limited scope for soil carbon sequestration ERF projects across the majority of northern Australian grazing land due to high project risk and high soil carbon monitoring costs under the current soil carbon ERF methodology. Although consistent and significant changes in soil carbon with land condition were not found, management strategies that aim to increase the carbon stored in soil remain desirable for grazing businesses due to the complementary improvements in pasture quantity and quality which should lead to improved long-term livestock productivity.

To enhance the uptake and participation in carbon farming, an extension and adoption strategy which incorporates business analysis and a range of extension processes is required to facilitate trialling, adoption and long-term practice change. Without this support, uptake of carbon farming practices and specifically undertaking an ERF project by most producers is likely to be minimal as the difficulty in evaluating the alternate options will be a significant barrier for many businesses.

Conclusion

Studies undertaken as part of the Climate Clever Beef initiative successfully identified and evaluated practical carbon farming options for the beef industry in northern Australia. Both opportunities and limitations to the carbon farming options were identified. Inadequate project scale will be a key limitation for most beef producers to participate in the Australian Government's ERF. Undertaking a suite of carbon farming activities may be required to increase scale, which will require further on-property research into cost effective options. To increase producer participation in carbon farming and improve the GHG emissions position of the northern Australian beef industry, an extension and adoption strategy which incorporates whole-farm business analysis will be important to facilitate practice change.

Acknowledgements

The Climate Clever Beef initiative was a collaboration between the Queensland Department of Agriculture and Fisheries, Northern Territory Department of Primary Industry and Fisheries, Australian Government Department of Agriculture and Fisheries – Carbon Farming Futures fund, Queensland Department of Science Information Technology and Innovation and NRM groups including: Northern Gulf Resource Management Group, Desert Channels Queensland, Queensland Murray–Darling Committee and Fitzroy Basin Association. Meat and Livestock Australia was a funding partner in the first phase of the Climate Clever Beef initiative. The project was only possible due to the generous support and collaboration of producers across northern Australia.

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