

Net carbon position of the Queensland beef industry

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Executive summary

The purpose of this technical assessment is to use the Queensland pastoral beef industry at the farm gate level as a case study to determine the 'net carbon' position (i.e. total on-farm emissions minus total sequestration of agriculture) using the latest available data. It assesses the biological process only and, as such, is a scientific approach that does not encompass current international policies. This assessment is not definitive; it is an attempt to help us understand the issue of net carbon position in relation to agriculture.

The Queensland pastoral beef industry at the farm gate level is a useful example because reasonable data are available and livestock emissions are the single largest source of agricultural emissions. In addition, Queensland is the largest beef-producing state in the country. Also, the statewide approach for aggregating the net carbon position at the farm scale 'smooths out' the variations that exist between individual farms.

This assessment is based on existing publically available data. Importantly, while it is consistent with the reporting requirements of the United Nations Framework Convention on Climate Change (UNFCCC), which includes all sources, and sinks applied to all areas, it includes more than Kyoto Protocol-compliant greenhouse gas emissions and sequestration. It provides a more accurate indication of the true situation at the farm gate level, before the policy constraints of current international rules and Australia's National Greenhouse Accounts are applied.

While this assessment specifically focuses on the Queensland pastoral beef industry, the issues it highlights in relation to net carbon position are relevant to other agricultural industries across Australia.

Sources of greenhouse gas emissions from a typical beef enterprise include enteric fermentation in cattle, burning of vegetation (either intentional or accidental), energy use (including electricity and fuel), land clearing, loss of pasture, and declines in soil carbon. Biosequestration in the beef sector occurs through vegetation growth (above and below ground) and by improving soil condition. The difference between the emissions and sequestration is the net carbon position.

We estimated that in 2007, total emissions amounted to 45.9 million tonnes of carbon dioxide equivalent (Mt CO₂-e) and total sequestration was 28.5 Mt CO₂-e. Thus, the net carbon emissions were 17.4 Mt CO₂-e. This figure does not include any change in soil carbon and does not include the full effects of the land clearing legislation and hence there is potential for a positive effect on current net emissions estimates. Assuming a continuation of the existing downward trend in land clearing due to regulatory controls, the net carbon position is estimated to be 1.2 Mt CO₂-e.

In addition, a significant amount of carbon is stored in soil, vegetation and livestock. How these stocks are managed will determine the loss of carbon from those stocks (emissions) and capture of carbon (sequestration). An estimated 22,720 Mt CO₂-e are being managed by the pastoral beef enterprises in Queensland. There are large uncertainties regarding estimates of soil carbon and further research is required to understand the stability and fractions of soil carbon in grazing land and the impacts of different management options.

Key findings

- 1. An estimated 22,720 Mt CO₂-e of carbon stocks are being managed by the pastoral beef grazing industry in Queensland.** While not required to be reported under the current greenhouse gas accounting process, it provides an indication and recognition of the scale of current stocks in the land being managed by graziers and for comparative purposes with the data generated in this assessment.
- 2. Total greenhouse gas emissions from the beef industry (at the farm level) in Queensland are estimated to be 45.9 Mt CO₂-e per year.** The emissions data draws on the most recent tree clearing data from 2006–07, which predates the full implementation of legislative controls on tree clearing in Queensland and includes methane and savanna burning emissions.
- 3. Total biosequestration is 28.5 Mt CO₂-e per year (assuming no change in soil carbon).** Sequestration includes growth of woody vegetation and the carbon in export of livestock taken off the property.
- 4. Net emissions are 17.4 Mt CO₂-e per year (assuming no change in soil carbon).** This is before the full implementation of the legislative controls on tree clearing.

5. Net carbon emissions are estimated to be 1.2 Mt CO₂ per year (effectively carbon neutral) if the remnant clearing rate is assumed to fall 75% from 2006–07 with the full implementation of clearing controls.

6. Soil carbon sequestration potential is significant. While the report excludes current contribution of soil carbon to the ‘net’ position due to insufficient data sets, it does indicate the significant potential gains that could be achieved through improvements in land condition and soil carbon levels and their further impact on the net position of the industry.

For example, this report outlines that moving half of the current C (poor) condition land in Queensland to B (reasonable) condition over a 25-year-period could sequester an additional 190 Mt CO₂-e or 7.6 Mt CO₂-e per annum. There are also multiple benefits of improving land condition, including higher livestock productivity. However, further research is needed to better understand the most effective management options to increase and maintain soil carbon, the impact of disturbances, such as climate variability and future climate change, measuring the changes made, as well as understanding the timescales over which carbon sequestration in soil occurs. Soil carbon sequestration is the subject of ongoing research and is not ready for inclusion in any emissions trading.

Areas of suggested further research

- improved understanding of livestock and energy emissions in different Queensland regions on a per-hectare, per-head and enterprise profitability basis, including the dynamics of livestock methane emissions by seasonal forage quality, land type and animal size/age.
- practical management systems developed and tested to improve land condition and soil carbon stocks across a broad range of soil types and climate zones.
- management systems to minimise emissions per kilogram of beef produced
- understanding the magnitude and impact of grazing management on non-carbon dioxide soil emissions and capture in grazing land
- monitoring and predicting woody vegetation growth of different vegetation types across Queensland regions and rates of decay of cleared woody vegetation, including mulga harvesting for fodder.

While this report examines the issue of net carbon position from a biological or farming systems approach outside of the current international policy framework, the authors acknowledge that policy considerations at the national level do not occur in isolation from international developments.

Introduction

In the agriculture sector, unlike most other sectors of the economy, both natural and induced processes of sequestration and emissions occur as part of a biological production system, which is diverse and covers large areas of the country.

Australia reports annually to the United Nations Framework Convention on Climate Change (UNFCCC) on national greenhouse gas emissions, including those from agriculture and land clearing. The National Carbon Accounting System (NCAS) is an Australia-wide system of accounting for land-based emissions, and is used for the UNFCCC reporting requirements. There are strict guidelines for how emissions and sequestration are reported, including the Kyoto Protocol reporting requirements¹.

A different approach is being pursued in this analysis, which has an industry focus and will include all emissions and sequestration at the enterprise level, whereas NCAS reports on a sectoral basis, separating livestock and savanna burning (reported under 'Agriculture' sector) from vegetation management (reported under 'Land Use, Land Use Change and Forestry (LULUCF)' sector). There are also strict definitions of a forest and human induced change under the international guidelines.

In addition, under Kyoto rules countries' emissions are compared with a 'baseline'; that is the emissions from 1990². In the commitment period (2008-12) countries are required to meet their emissions reduction target which is a percentage of the emissions from that baseline (Australia's is 108% of 1990 emissions). This analysis does not have a baseline, as it is only assessing the emissions and sequestration for 2007.

There have been a limited number of farm-level carbon budget assessments (Bray & Golden 2009) and a supply chain analysis (of the carbon budget of producing a packet of corn chips) (Grant & Beer 2008), but no industry total assessments that can be scaled to various state and regional boundaries. We assessed the carbon budget (net of emissions and sequestration) of the beef industry in Queensland at the state and bioregion scale.

The reported total net emissions attributed to agriculture, forestry and fishing in Queensland was 110.9 Mt CO₂-e in 2007 (DCC 2009b). The beef industry in Queensland is the focus because it is the largest agricultural industry in the state. Queensland accounts for nearly half the beef cattle in Australia, and ruminant emissions make up the largest component (79%) of greenhouse gas emissions from the agricultural sector (DCC 2009a). Emissions from land clearing also make up approximately 27% of Queensland's total emissions (DCC 2009a) and a large proportion (93%) of land clearing is for pastures (NRW 2008). The report provides an initial assessment of the net carbon position of the Queensland beef industry at the farm level (not including transport to market or processing emissions).

Sources of greenhouse gas emissions from a typical beef enterprise include enteric fermentation in cattle, burning of vegetation (either intentional or accidental), energy use (including electricity and fuel), land clearing and loss of pasture, and declines in soil carbon. Biosequestration occurs through vegetation growth (above and below ground) and by improving soil condition. There is a significant amount of carbon stored in soil, vegetation and livestock. How these stocks are managed will determine the loss of carbon from those stocks (emissions) and capture of carbon (sequestration).

¹ Currently under Kyoto Protocol rules (Article 3.3), it is compulsory to report on deforestation, reforestation and afforestation, but under Article 3.4 countries can elect to include emissions and sequestration from forest management, revegetation (for areas that do not meet the requirement of a forest under Article 3.3), cropland management and grazing land management. Australia chose not to participate in any of the Article 3.4 activities for the current commitment period.

² 1990 is the preferred year for the baseline emissions, but not all countries have the data for that year and a slightly different baseline is used.

Relatively good data is available for the Queensland beef industry, including woody vegetation stocks and clearing rates (NRW 2008), cattle numbers (based on an internal analysis of ABS figures; Carter & Stone, pers. comm.) and methane emissions from cattle grazing Queensland diets (Charmley, Stephens & Kennedy 2008). However, data on energy emissions from grazing businesses, impact of managing regrowth and the impact of changing land condition on soil carbon stocks is much less certain. In addition, scaling data down from the Queensland state scale to the regional and business scale, where individual grazing business management decisions can make a real difference to the greenhouse budget of the industry, is another challenge.



Cattle grazing among 20-year-old open brigalow regrowth.

Due to the complexities in measuring emissions and sequestration in primary industries, this is only a first attempt at calculating the net carbon position—a ‘first pass’ analysis—which uses existing information about carbon stocks, emissions and sequestration in the industry. We do not intend this to be a definitive assessment of the net carbon position of beef production in Queensland, but only a starting point for considering the role of agriculture more holistically (by taking into account both emissions and sequestration). It also identifies research and data development that is required in order to more confidently assess the effects of different management options on greenhouse gas emissions and sequestration in the beef industry. This will enable more informed decisions about the most cost-effective way to meet greenhouse goals while still having a profitable and productive beef industry.

The analysis

This analysis attempts to compile available data on each emission and sequestration process and carbon stock that is under the influence of management as part of conducting a beef grazing business in Queensland. This includes livestock methane emissions, property energy emissions, prescribed burning of savannas, woody vegetation management and soil management. The analysis is based on a year (annual time-step). Where time series data were available, we used the data for 2007 (rather than average data), which most closely relates to the current national account data and Statewide Land and Tree Study (SLATS) woody vegetation clearing figures (DCC 2009a; DCC 2009b; NRW 2008).

The actual data, calculations and assumptions used in this analysis are documented, and limitations on the available data and calculations are highlighted. Options for improving the analysis are also proposed (Method 2). We have tested the sensitivity of variation in our selected values in some of the calculations to investigate the expected impact of higher or lower values on Queensland's beef industry greenhouse budget.

The greenhouse gas budget calculations have been divided into nine sections:

- estimation of Queensland's beef grazing area
- livestock methane emissions
- savanna burning
- property and clearing energy emissions
- livestock biomass stock and 'export' from property
- forage and litter biomass
- woody vegetation clearing emissions, woody biomass and thickening
- soil carbon change and soil non-CO₂-e emissions
- Queensland emissions/sequestration summary (see 'Discussion' section).

Estimation of Queensland's beef grazing area

Difficulties exist in estimating the beef grazing area in Queensland and in apportioning management data collected at the state and regional scale (e.g. vegetation clearing and prescribed fire area) to the beef grazing area only. It is difficult to obtain accurate data for the following:

- area of Queensland that is not grazed, including conservation areas (state-managed and privately managed), infrastructure areas (roads, towns, mines etc. that are not grazed), military areas and ungrazed areas on grazing properties (e.g. too rugged, contains poisonous plants, no water)
- grazed area on land whose primary use is another purpose (e.g. forestry, buffer land around heavy industry)
- grazed area of Queensland not used by cattle (e.g. sheep grazing and other grazing livestock such as horses used for recreation and goats)
- how mixed grazing/cropping land is apportioned.

Method 1 (used in this assessment)

Initially, the 'total grazing area' (all grazing livestock) has been calculated for each bioregion by subtracting the 'conservation area' (Sattler & Williams 1999), and land used for other purposes (e.g. infrastructure, cropping, mining, water bodies) from the total land area as calculated by the SLATS 2006–07 assessment report (NRW 2008), Table 10, page 147. Land used for other purposes is assumed to be 14% of land area across all bioregions (Australian Natural Resources Atlas 2001).

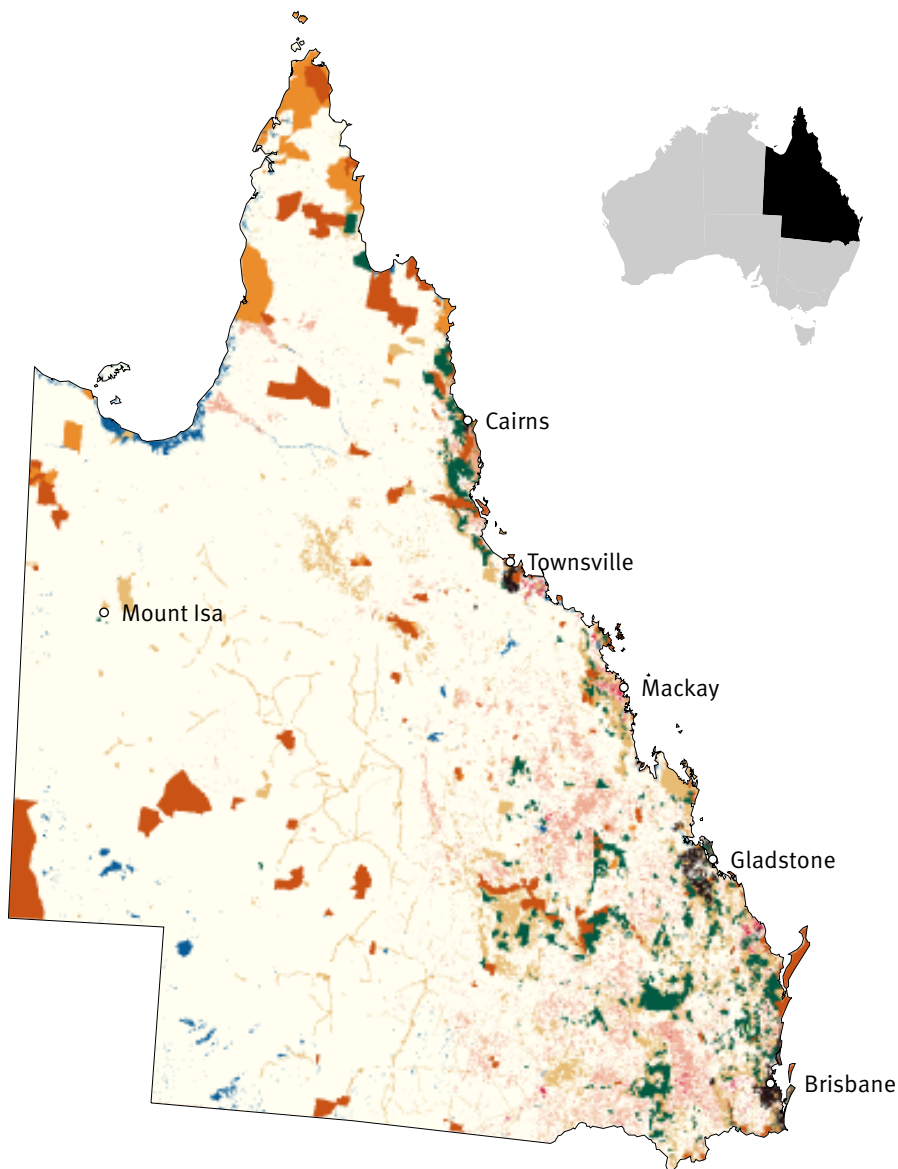
The beef grazing area was then calculated by subtracting an estimated area used for grazing sheep and other livestock (horses used for recreation, goats etc.) from the total grazing area. We assumed the area used for sheep and other grazing stock was 10% in sheep growing bioregions (Mitchell grass, Mulga and New England Tablelands) and 2% in the other regions. The beef grazing area in Queensland using this method was estimated as 135 million hectares (Mha), which is 78% of Queensland.

Method 2 (proposed for future assessment)

An improved estimate of the total grazing area is currently being generated from the Queensland Land Use Mapping Program (QLUMP) (www.nrw.qld.gov.au/science/lump/). An assessment of sheep numbers, together with an estimate of sheep stocking rate, could be used to improve the percentage of each bioregion used exclusively for sheep grazing. Estimating the area used for other livestock may need further consideration but is unlikely to have a major influence on the outcome of this analysis. Conservation areas, urban and infrastructure land use is gradually expanding and taken into account over time.

Land use in Queensland

- | | |
|---|--|
|  Nature conservation |  Dryland agriculture |
|  Other protected areas including indigenous uses |  Irrigated agriculture |
|  Minimal use |  Built environment |
|  Livestock grazing |  Waterbodies not elsewhere classified |
|  Forestry | |



The data set was derived and compiled by the Bureau of Rural Sciences. Land uses were derived using data from the 1997 and 1999 Collaborative Australian Protected Areas Database (Environment Australia), TOPO-250K Version 1 (AUSLIG), the National Forest Inventory 1997 tenure and forest data, Normalised Difference Vegetation Index images (Environment Australia) and AgStats 1996/97 (Australian Bureau of Statistics). Control sites provided by state and territory agencies: NSW Agriculture, Victorian Dept of Natural Resources and Environment, Queensland Dept of Natural Resources and Mines, Primary Industries and Resources SA, Agriculture Western Australia, Tasmanian Dept of Primary Industries, Water and Environment, Northern Territory Dept of Lands, Planning and Environment.

Source: 1996/97 Land Use of Australia Summary and 1996/97 Land Use of Australia, Version 2, National Land and Water Resources Audit

© Commonwealth of Australia 2001

Figure 1. Land use in Queensland (Australian Natural Resources Atlas 2001).

Livestock methane emissions

Methane emissions from beef cattle (enteric fermentation) in Queensland are significant and accounted for a reported 18.8 Mt CO₂-e in 2007 or 11.3% of Queensland's reported greenhouse gas emissions (Department of Climate Change 2009; <http://ageis.climatechange.gov.au/>).

Two significant datasets are required to estimate livestock methane emissions:

1. methane emission per animal, or adult equivalent (AE)
2. number of beef animals.

Significant research is underway to improve the estimation of livestock methane emissions in northern Australia (Charmley, Stephens & Kennedy 2008; Kennedy, Stephens & Charmley 2007; Athol Klieve, pers. comm.). Methane emissions can vary with forage quality ingested, and stocking rates (feed availability and selection ability). Forage quality is difficult to predict in grazing land as it will vary with seasons and recent weather (rainfall, frost). However, animal house studies using northern grazing land forages and modelling case study herd emissions in various northern Australia regions are producing generalised methane emissions factors (Charmley, Stephens & Kennedy 2008; Kennedy, Stephens & Charmley 2007).

This recent research indicates that livestock methane emissions are expected to be 1.0–1.5 t CO₂-e per AE per year (E Charmley, pers. comm.). These simple emissions factors are used in this initial assessment in preference to the more complicated set of equations used in the National Greenhouse Accounts, which require data on dry matter intake, liveweight, liveweight gain, proportion of cows lactating and dry matter digestibility (DCC 2008).

The Australian Bureau of Statistics (ABS) collects and compiles data livestock numbers in Queensland (11,731,000 meat cattle including calves in 2007–08) and for statistical divisions. This equates to 9,384,000 standardised AEs (1 AE is 455 kg liveweight) taking into account the different size classes of cattle (Carter & Stone, pers. comm.). This cattle number also includes approximately 410,000 cattle (assume 410,000 AEs) on feed in feedlots at any one time (ALFA 2009). Apart from concerns with accuracy (i.e. do land managers provide correct data in 'government' surveys?), there is significant difficulty in allocating these numbers to bioregions and other regional divisions.

In general terms, livestock methane emissions are proportional to livestock number. If livestock are removed from certain areas, the livestock methane emissions from those areas will be reduced. However, there is a relationship between livestock grazing and fire; therefore, if livestock are removed, fire frequency and intensity are likely to increase, thus increasing fire emissions and possibly changing woody vegetation carbon stocks and possibly soil carbon stocks.

For the purposes of this analysis cattle in transport for live export or meat processing are deemed to have left the grazing property. They are therefore 'post farm-gate' and are not included in this analysis.



Cattle in northern Australia emit methane at a rate of 1.0–1.5 t CO₂-e per AE per year (E Charmley, pers. comm.).

Data and calculation for livestock methane emissions

Two stages are required to calculate methane emissions:

1. Estimate the number of livestock in AEs (1 AE is 455 kg liveweight) in Queensland and in bioregions.
2. Multiply the number of AEs by an appropriate methane emission factor per AE. In this exercise an emission factor of 1.5 t CO₂-e/AE/year was used.

To estimate the number of livestock in each bioregion Method 1 has been used; however, an improved method is proposed using Method 2.

Method 1 (used in this assessment)

The stocking rate (ha/AE) of each statistical division was calculated from the ABS data: '7121.0 - Agricultural Commodities, Australia, 2007-08' (22/05/2009). These statistical division stocking rates were then 'matched' to the bioregions. The stocking rate for each bioregion was manually adjusted using the experience of the author. The number of beef cattle in each bioregion was then calculated to reflect the local stocking rate, adjusting it if needed to ensure the total number of beef cattle in Queensland matched the ABS data.

Due to possible inaccuracy in the cattle numbers, the relatively small number of cattle in feedlots at any one time (~4% of total herd) and difficulty estimating the percentage of a year that cattle were grazing pasture versus in a feedlot (cattle are often in feedlots for less than three months), we made the conservative decision to not subtract the feedlot cattle numbers from the total cattle number and assumed they were grazing pasture for the full year (no allowance was made for higher emissions of feedlot cattle eating high quality diets or feedlot manure emissions).

To assess the impact of higher or lower cattle numbers on the net carbon position of the beef industry, a sensitivity analysis was conducted that increased or decreased cattle numbers by up to 30%.

Method 2: Improved livestock number using AussieGrass (proposed for future assessment)

The stocking rate in each 5 × 5 km cell in 'grazing land' across Queensland is estimated from the ABS data (all cells within a statistical division have the same stocking rate). The resultant map is then 'cookie-cut' for bioregion and the individual cells are summed to generate a livestock number for each bioregion. A more in-depth analysis of cattle movements to feedlots and impact on the intra-annual pastoral cattle numbers should also be conducted.

Results and discussion for livestock methane emissions

The livestock methane emissions for beef cattle in Queensland are calculated at 14.1 Mt CO₂-e/year (using 1.5 t CO₂-e/AE/year), which is 25% lower than the DCC (2009a) estimate for 2007 (18.8 Mt CO₂-e). This may in part be due to the updated data on methane emissions for northern Australia beef cattle being developed by CSIRO Livestock Industries (E Charmley, pers. comm.) and used in this analysis. Alternatively, the livestock number we have used may be up to 25% lower than that used by DCC (2009a). If 1.0 t CO₂-e/AE/year is used in the calculation, the estimated livestock methane emission reduces proportionally to 9.4 Mt CO₂-e/year.

The impact of variation in beef cattle numbers is shown in Table 1, with methane emission changes proportional to cattle numbers.

As an example of the impact of changing livestock numbers at the regional scale on the greenhouse budget, the livestock number was hypothetically reduced by 30% in the brigalow belt, Wet Tropics, Central Queensland coast, New England Tableland and South East bioregions (perhaps to increase the area of conservation reserves, plant trees or increase ground cover on grazing land). The livestock methane emissions would be reduced in proportion with the livestock number to 11.5 Mt CO₂-e/year. However, the impact of destocking on fire incidence and vegetation stock change should also be considered.

Table 1. Sensitivity analysis of the impact of variation in the number of cattle AEs on the net emissions of the beef grazing industry in Queensland.

Percentage change	Cattle number (million AEs)	Methane emissions (Mt CO ₂ -e)	Net industry emissions (Mt CO ₂ -e)
+30	12.2	18.3	21.4
+20	11.3	17.0	20.1
+10	10.3	15.5	18.8
0	9.4	14.1	17.5
-10	8.5	12.8	16.3
-20	7.5	11.3	14.9
-30	6.6	9.9	13.6

Savanna burning

Savanna burning is a reportable emission in the national inventory; however, it is subject to significant uncertainty, and the National Greenhouse Accounts do not differentiate between anthropogenic fires and wildfires. Issues include:

- Was the fire deliberately planned (prescribed) or 'natural'? How do you deal with accidental fires (e.g. escaped camp fires, welding sparks, car accidents etc.)?
- Would the area burnt by prescribed burn have burnt 'naturally' in any case?
- Should fire suppression with grazing or other management be considered?
- The percentage of fuel burnt is difficult to estimate because it depends on fuel condition (moisture, arrangement) and weather conditions (humidity, temperature and wind speed, time of day).
- How do you estimate the initial biomass of fuel/ forage? At the regional scale, this is often based on modelled pasture growth and an estimation of the forage removed (depends on intensity of grazing).
- Is the burnt area grazing land or ungrazed land? Should burning on conservation land, or remote, rugged, relatively ungrazed ranges, be excluded?

The Department of Climate Change (2009a) calculated an average annual emission of 1.05 Mt CO₂-e/year for 'prescribed burning of savannas' in Queensland between 1990 and 2007 (with a minimum of 0.64 Mt CO₂-e in 1998 and a maximum of 1.49 Mt CO₂-e in 2001). The 2007 emissions from 'prescribed burning of savannas' in Queensland was 1.21 Mt CO₂-e.



Prescribed spring burning in grazing land near Charters Towers in October 1999.

There is an interaction between area burnt and fuel consumed and grazing intensity. More widespread and intense fires are expected if livestock numbers are reduced. These fires also have potential to modify the carbon stocks stored in vegetation and possibly soil.

The area of Queensland burnt each year calculated from the fire scar mapping available on the Firenorth website (www.firenorth.org.au/nafi/app/init.jsp) indicated that 8.76 Mha was burnt in 2007 and 10.26 Mha was burnt in 2008.

Data and calculation for savannah burning

To estimate savanna burning emissions in each bioregion we have initially used Method 1; however, an improved method is proposed using Method 2.

Method 1: Proportion of region burnt (used in this assessment)

The proportion of each region that was burnt was estimated from two sources. It was assumed the percentage of fire was similar for the grazed and ungrazed parts of each bioregion.

Data was extracted (Bastin 2008) on the percentage area burnt (average of five years) for 10 of the 13 bioregions. The percentage area burnt in the three bioregions without data (South East, Wet Tropics and Central Queensland coast) was assumed to be 2%. The proportion of each region burnt was also calculated from fire scar mapping for 2007 and 2008 available from the Firenorth website (www.firenorth.org.au/nafi/app/init.jsp). The area burnt was calculated and multiplied by an emissions factor of 0.1 t CO₂-e/ha/fire (Bray & Golden 2009). This value was calculated using the methodology outlined by the DCC (2008) using a fuel mass of 1.5 t dry matter per hectare (DM/ha).

Method 2 (proposed for future assessment)

Calculate area burnt on beef grazing land from fire scar mapping (e.g. Firenorth website at www.firenorth.org.au/nafi/app/init.jsp or DOLA fire scar data), model forage and litter biomass (e.g. using AussieGrass (Carter et al. 2000)) and possibly apply a variable emissions factor based on seasonal conditions and when most fires occur.

Results and discussion for savanna burning

Using Method 1, the savanna burning emissions for beef grazing land was calculated as 0.79 Mt CO₂-e/year using the Bastin (2008) data, and 0.64 and 0.73 Mt CO₂-e/year using the 2007 and 2008 fire scar mapping respectively.

Increasing the fuel mass to from 1.5 to 2.5 t DM/ha increased the emissions factor to 0.17 t CO₂-e/ha/fire, which increased emissions to 1.09 Mt CO₂-e using the 2007 fire scar data. This is not too different from the DCC's (2009a) estimate for 2007 (1.21 Mt CO₂-e).

The assumption that a similar amount of grazed and ungrazed area is burnt in each bioregion is likely to be incorrect in some bioregions and could have a significant impact on the actual emissions.

Policy discussion regarding 'prescribed' savanna burning versus accidental fires and how these are treated within the National Greenhouse Accounts still requires consideration.

Property energy emissions

Property energy emissions include emissions from the use of fuel (diesel, petrol and LPG) and electricity, along with the energy emissions associated with woody vegetation clearing.

Electricity energy emissions for agriculture, forestry and fishing in Queensland are reported to be relatively low at 0.3 Mt CO₂-e in 2007 (DCC 2009b). Grazing businesses in Queensland would be expected to have a relatively low intensity of energy emissions compared with cropping businesses due to minimal use of irrigation water pumping and cultivation on most properties. However, energy emissions on any individual property are likely to vary greatly due to differences in reliance on water pumping, area of irrigation, area of cultivation and travel distances. For the purposes of this assessment, we include electricity energy emissions in the property greenhouse budget even though the actual emission is generated off-site (often classified as indirect emissions).

Nearly all grazing properties contain one or more residences. It can be argued that the energy use of these residences should be subtracted from the grazing business emissions in line with urban businesses where staff reside off-site. The average household emission in Queensland is 13.77 t CO₂-e per year, comprised of 8.24 t CO₂-e per year for electricity, 4.23 t CO₂-e per year for fuel for 14,800 km (this distance travelled would be very low compared to average household travel distances in regional Queensland) and 1.3 t CO₂-e per year for waste (DPC 2008).

Energy emissions from energy-intensive management options (e.g. woody vegetation clearing) is calculated separately. SLATS provides data on the area of land cleared per year (NRW 2008). Remnant vegetation (previously uncleared vegetation) clearing is declining since the introduction of the *Vegetation Management Act 1999*, and more recently with the introduction of the moratorium on the clearing of regrowth in 2009 (subject to future policy announcements). Therefore, it is important to use the up-to-date clearing area figures.

The other area of uncertainty is the amount of energy emissions generated while clearing vegetation. These are likely to vary widely depending on clearing method. For example, stem injection (“tordoning”) is likely to have relatively low-energy emissions per hectare (although areas are likely to be relatively small), while blade ploughing or pulling and stick raking with large machinery would have relatively high energy emissions per hectare.

Data and calculation for property energy emissions

The data currently used to calculate annual property energy emissions (excluding clearing) is based on the records of one grazing business in the brigalow belt bioregion (0.0088 t CO₂-e/ha/year) (Bray & Golden 2009). Improved data could be generated through on-property surveys in different regions and a specific value calculated for each region (a recent unpublished survey of another nine grazing businesses in Central Queensland had a mean property energy emission of 0.009±0.005 t CO₂-e/ha/year). Currently, the expected energy emissions intensity of each bioregion has been estimated by the author and ranges from 0.3 in low intensity Cape York Peninsula grazing land to 1.0 in brigalow belt grazing land.

General energy emissions for a region (Mt CO₂-e/year) = land area (ha) × regional property energy intensity × property energy emission factor (Mt CO₂-e/ha/year)/1,000,000.

The energy emissions that could be assigned to the residence on grazing properties has been estimated for Queensland. In 2007–08, there were 19,220 businesses that were engaged in grazing; this represents 66% of the 29,121 Queensland agricultural businesses (ABS 2009).

We have assumed there is one residence per business (value can be changed). Issues to consider include:

- Many grazing properties often have more than one residence.
- Many households derive income from working off-farm in other industries (e.g. teaching, mining), with resulting travel emissions being part of household emissions rather than grazing enterprise emissions.
- Mixed enterprise agricultural businesses should have less than one residence apportioned to the grazing part of the business.

The energy emissions for clearing uses the area cleared in hectares (NRW 2008) and multiplies an energy emission per hectare cleared—for example, 0.158 t CO₂-e/ha (Bray & Golden 2009).

Results and discussion for general property energy emissions

The general property energy emissions for Queensland were calculated as 0.87 Mt CO₂-e/year (1.8% of the total emissions). Of this amount, the emissions attributed to households were 0.26 Mt CO₂-e/year.

The energy emissions from clearing for Queensland were calculated as 0.034 Mt CO₂-e/year.

Improved energy emissions data could be generated through on-property surveys in different regions and a specific value calculated for each region (e.g. working with G Bell from AgForward).

Livestock biomass stock and 'export' from property

Grazing land managers are interested in the biomass of their livestock as a carbon stock in their business and in the amount of carbon that is 'exported' off grazing land in Queensland. In 2007–08 the Queensland adult cattle slaughter (grass-fed and finished in feedlots) was 3.59 million head producing 1.04 million tonnes (Mt) of beef and veal (Department of Employment, Economic Development and Innovation 2009), which is equivalent to 0.67 Mt CO₂-e not including other by-products (hides and offal).

The dry matter content of cattle changes with condition score and associated fat content and ranges from 30–50% dry matter (NRC 2000).

Data and calculation for livestock biomass

To calculate livestock biomass (Mt CO₂-e), the livestock number (in AEs) is multiplied by the weight per AE (455 kg), by the percentage of dry matter (40%, condition score 5 (NRC 2000)) and by the percentage of carbon (50%, calculated from NRC (2000) and Blaxter and Rook (1953)).

The livestock biomass 'exported' from the grazing business was calculated by estimating the proportion of AEs that are transferred to feedlots, live export and meat processors each year. The number of AEs transferred for 2007–08 (source: MLA) equalled the number of head exported live (1,782,000 cattle), the number of head in feedlots—assumed on feed for an average three months—(1,438,000 cattle) and the number of grass-fed head slaughtered (total slaughtered minus head in feedlots) (2,155,000 cattle). The number of livestock in each pathway was multiplied by an estimated proportion of an AE (455 kg) at the time of leaving the grazing property (meat processing 1.15, live export 0.65 and feedlot 0.65).

This method indicated that approximately 45% of the annual herd (calculated in AEs) was exported off grazing land each year. Initially, it is assumed that this percentage applies across bioregions. The 45% value can be tested more thoroughly in future analyses by evaluating regional case study herds using Breedcow Dynama herd budgeting software (Holmes 2004).

Results and discussion for livestock biomass

The biomass of the 9.4 million beef cattle in Queensland is 3.13 Mt CO₂-e. Livestock biomass will move in proportion to livestock number (calculated in AEs).

The biomass of the livestock exported off grazing land to meat processors, feedlots and live export was 1.41 Mt CO₂-e. If the dry matter content of cattle was reduced to 35% (condition score 3) from 40%, the biomass of the livestock exported off grazing land would be 1.23 Mt CO₂-e.

Additional searching for slaughter weight and selling weight (live export and feedlot) statistics, ensuring the number of animals slaughtered all originated from Queensland, would improve this calculation. Another approach would be to conduct some regional case studies using Breedcow Dynama herd budgeting software (Holmes 2004).

Forage and litter biomass

Forage biomass is the resource base for livestock grazing. Forage and litter (woody and non-woody derived) biomass is consumed by domestic and native animals, contributes fuel for fires and is also 'cycled' through trampling and decomposition. A proportion of forage and litter biomass produced in any one year can be carried over into subsequent years.

Generally, the forage and litter biomass is expected to range between 0.46 and 9.2 t CO₂-e/ha (0.25 and 5 t biomass/ha) depending on land type, seasonal growth, forage consumed, time since fire and land condition. Without a change in land condition, the forage and litter biomass, although fluctuating, should remain relatively constant over time (apart from the impacts of climate change and carbon dioxide fertilisation). At environmentally sustainable stocking rates, livestock consume about 25–30% of the forage grown in one year.

Litter biomass is composed of forage litter (grass and forb litter) and tree litter. The amount of litter biomass relative to forage biomass can vary greatly, depending on tree cover, time of year (e.g. end of dry season versus mid wet season) and general seasonal conditions (e.g. during drought litter is high relative to forage).

Litter biomass was 70% of the forage biomass based on 16 remnant grazed woodland sites in a range of land condition states in the Burdekin and northern Gulf regions sampled in 2009. However, litter and forage biomass is expected to vary year to year. At 48 remnant grazed woodland sites in the Burdekin catchment assessed during the early 2000s drought, litter biomass was 6 t CO₂-e/ha which was 3 times the forage biomass (Bray et al. 2006). At a Mitchell grassland site in the same study, the litter biomass was 46% of forage biomass.

Data and calculation for forage and litter biomass

To estimate forage and litter biomass in each bioregion we have initially used Method 1; however, an improved method is proposed using Method 2.

Method 1 (used in this assessment)

A standard long-term forage and litter biomass was estimated and assumed for each region over time. The forage biomass for each region in this analysis was visually estimated from the March 2008 total standing dry matter (TSDM) map available on the LongPaddock website at www.longpaddock.qld.gov.au/index.html (the long-term average TSDM map would be preferred).

Litter biomass was assumed to be 70% (can be modified) of the forage biomass. This approach assumes there is no change in land condition over time. The forage and litter biomass will be overestimated in some years and underestimated in other years.

Method 2 (proposed for future assessment)

The AussieGrass modelling framework (5x5 km grid) provides an estimate of:

- annual average TSDM (based on modelled pasture growth, incorporates seasonal conditions and land productivity)
- litter biomass (grass and tree litter)
- proportion of forage consumed by livestock (based on livestock number)
- fire incidence (area burnt)
- proportion of forage carried over between seasons (after a proportion decomposed).

Results and discussion for forage and litter biomass

Using Method 1, the average carbon stocks in forage and litter biomass for Queensland grazing land were estimated at 632 Mt CO₂-e. This value is expected to fluctuate with seasons and may change over time with changes in land condition.

If the litter biomass percentage was increased to 120% of forage biomass or reduced to 40% of forage biomass, the average carbon stocks in forage and litter biomass for Queensland grazing land were 818 Mt CO₂-e or 520 Mt CO₂-e respectively.

To improve this analysis, it may be worth considering applying a different litter biomass percentage and forage biomass estimate for woody and non-woody (remnant and non-remnant) vegetation.

Woody vegetation clearing emissions, woody biomass and thickening

Woody vegetation on grazing land is a significant carbon stock. The clearing of woody vegetation is a significant source of carbon emissions over time as the cleared vegetation decomposes or is burnt.

Following clearing, woody vegetation in most cleared areas subsequently regrows sequestering carbon. In addition, the rates of growth in remnant (uncleared) woodlands and regrowth are variable and the carbon stocks change in response to climate cycles, fire/grazing management and probably some CO₂ fertilisation (Bond & Keeley 2005; Bond & Midgley 2000; Burrows et al. 2002; Fensham & Holman 1999; Gifford & Howden 2001; Henry et al. 2002; Sharp & Whittaker 2003).

Carbon stocks on 60 Mha of grazed remnant eucalypt woodlands in Queensland have been estimated at approximately 9000 Mt CO₂-e with woodland thickening sequestering approximately 128 Mt CO₂-e per year in live trees between 1982 and 2002 (Burrows et al. 2002); however, this sequestration rate has probably slowed with widespread death of trees during the 2001–05 drought (Bray et al. 2007).

Although tree death has occurred, there is not an immediate release of the carbon into the atmosphere; decomposition can take many years, resulting in a significant carbon stock at any one time. The standing dead tree basal area at 48 sites in the Burdekin catchment was 25% of the live tree biomass in 2004 (Bray et al. 2006).



Remnant ironbark grazed woodland in Central Queensland showed thickening of the understorey between 1982 and 2004.



Drought death of remnant mulga woodland south of Cunnamulla between 2000 and 2007.



Clearing of mulga woodland.



Thirty-year-old brigalow regrowth near Wandoan.

The Queensland herbarium has classified Queensland's vegetation into remnant (uncleared) and non-remnant (has been cleared in the past) vegetation, which may or may not be woody.

SLATS has classified Queensland's vegetation at the 25 metre pixel scale into woody (>11% foliage projected cover (FPC), which is approximately 20% canopy cover (Scarath, Armston & Danaher 2008)) and non-woody (<11% FPC). Remnant woodland vegetation will contain a mixture of woody and non-woody pixels. The area of woody and non-woody vegetation and area of clearing for Queensland and each bioregion is publically available (e.g. NRW 2008)

Under Kyoto Protocol rules, land can become 'Kyoto land' if clearing (emissions) occurred since 1990 and thereafter carbon sequestration in regrowing vegetation can be counted. There is difficulty in publically accessing data on areas of 'Kyoto land'.

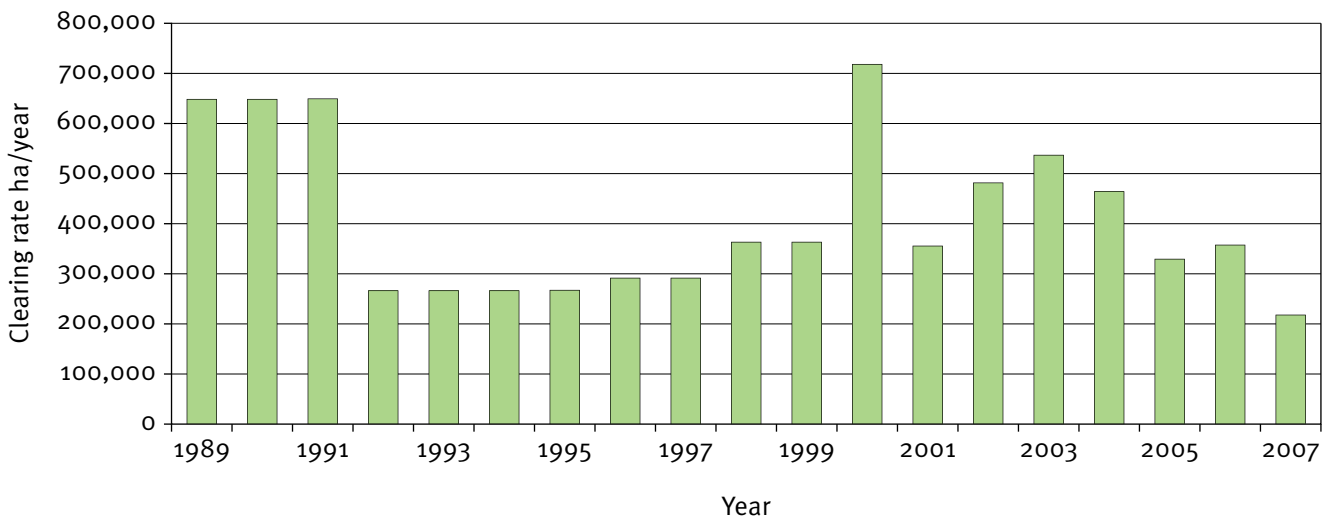


Figure 2. Annual rate of clearing remnant and regrowth woody vegetation in Queensland. Note the trend in decline of clearing since 2003, which coincides with the enactment of vegetation management legislation (NRW 2008).

The rate of clearing has been declining since 2003, which coincides with the enactment of vegetation management legislation (*Vegetation Management Act 1999*). Additionally, the 2006–07 period spans the phase-out of broad-scale remnant clearing, so the clearing rate of remnant vegetation is expected to fall further with the release of the 2008–09 data.

For this regional and state-scale exercise we assume that the carbon in all vegetation cleared will eventually be emitted, but we account for those emissions in the year of clearing. We do not apply a decomposition rate to spread the clearing emissions over future years. In line with this decision, we do not account for clearing debris decomposition emissions from previous clearing events.

Data and calculation for woody vegetation clearing emissions, woody biomass and thickening

To estimate woody vegetation biomass and woody vegetation biomass emissions from clearing in each bioregion we have initially used Method 1; however, an improved method is proposed using Method 2.

Method 1: Clearing emissions (used in this assessment)

The beef grazed area and percentage woody vegetation cover from the SLATS 2006–07 assessment (NRW 2008) was used to calculate area of woody vegetation (remnant and non-remnant >11% FPC, 20% canopy cover) and area of grassland (remnant and non-remnant, includes young regrowth) in each bioregion. The rate of woody vegetation change from the SLATS 2006–07 assessment in each bioregion and the Queensland-wide proportion of clearing that was remnant (55%) was applied to calculate the area of remnant and regrowth clearing for each bioregion.

The above-ground and below-ground biomass of the cleared remnant vegetation was calculated from the area of remnant vegetation cleared for pasture, the average basal area of the cleared remnant vegetation (7.36 m²/ha at 130 cm (NRW 2008)) and the standing biomass allometric (6.286 t biomass/m² at 30 cm (Burrows et al. 2002)). A conversion factor was used to adjust the basal area between 30 and 130 cm height (Krull & Bray 2005). A root:shoot ratio of 0.4 (Zerihun et al. 2006) was used to estimate root biomass. (Burrows et al. 2000) provide an alternative root:shoot ratio of 0.26.

The above-ground and below-ground biomass of the cleared regrowth (non-remnant) for pasture was calculated using the same method as for cleared remnant vegetation; however, the regrowth basal area was assumed to be 5 m²/ha at 130 cm based on the basal area of 20-year-old regrowth (Donaghy et al. 2009) and a regrowth biomass allometric was assumed to be two-thirds of remnant woodland of 4.15 t biomass/m².

The non-woody (<11% FPC) grassland vegetation (remnant and non-remnant) would contain small amounts of woody vegetation (assumed 0.5 m²/ha at 130 cm), that may have been cleared along with the woody vegetation. This emission was not calculated due to the inability to calculate the area of the cleared non-woody grassland vegetation. This area could be estimated using Method 2 below.

The impact of projected changes in remnant and regrowth clearing rates can be tested by specifying the projected clearing rate as a percentage of the 2006–07 clearing rate.

Method 1: Woody vegetation biomass stocks (used in this assessment)

The woody remnant and regrowth area was calculated by subtracting the 2006–07 clearing area for pasture from the 2006 woody vegetation on beef grazed area. We assumed the percentage woody cover for each bioregion was the same as for the beef grazed area. The area of woody remnant and woody regrowth could not be separated which creates a dilemma for assigning the basal area (we have used the remnant value as the woody remnant area would be expected to be much larger than the woody regrowth area in most bioregions) and biomass allometric (we used the remnant value).

The area of non-woody grassland (remnant and non-remnant) was calculated by the difference between the beef grazed area and woody remnant and regrowth area plus the woody vegetation cleared area. Basal area in non-woody grassland was assumed to be 0.5 m²/ha at 130 cm and the regrowth biomass allometric was used.

Method 1: Change in woody remnant and regrowth biomass stock—thickening and thinning (used in this assessment)

The woody remnant and regrowth area was calculated by subtracting the 2006–07 clearing area for pasture from the 2006 woody vegetation on beef grazed area. The woody remnant and regrowth area was multiplied by the basal area change factor of 0.032 m²/ha/year at 130 cm from long term woodland monitoring (Bray et al. 2007) spanning a number of droughts; (Burrows et al. 2002; Fensham, Bray & Fairfax 2007) provide other values) and the remnant stand allometric was applied. This calculation may underestimate the rate of growth of regrowth, which is 0.1 to 0.2 m²/ha/year at 130 cm using the regrowth data in (Donaghy et al. 2009).

The area of non-woody grassland (remnant and non-remnant) was calculated as the difference between the beef grazed area and woody remnant and regrowth area (note the woody vegetation cleared area was not included in this calculation, assumed no growth in year of clearing). The area of non-woody grassland was multiplied by the estimated basal area change in m²/ha/year at 130 cm (0.0032 m²/ha/year at 130 cm was assumed which was 10% of the long term woodland monitoring value (Bray et al. 2007)) and the regrowth stand allometric applied. This calculation may underestimate the rate of growth of young regrowth which is 0.1 to 0.2 m²/ha/year at 130 cm using the regrowth data in Donaghy et al. (2009).

Method 2 (proposed for future assessment)

Method 2 proposes a more in-depth analysis of the SLATS woody cover data, along with the herbarium remnant/non-remnant classification and a classification of Kyoto land (cleared since 1990), to calculate the area and average basal area (using FPC layer) of the following lands used for grazing:

- woody remnant
- cleared woody remnant
- woody non-remnant (regrowth)—pre- and post-1991
- cleared woody non-remnant (regrowth that is re-cleared)—pre- and post-1991
- non-woody remnant grassland
- cleared non-woody remnant grassland
- young non-woody non-remnant (regrowth)—pre- and post-1991
- cleared young non-woody non-remnant (regrowth)—pre- and post-1991.

This detailed separation will provide a much more accurate estimate of carbon stocks and changes, and will enable a more accurate separation of Kyoto and non-Kyoto lands. Further analysis would also be required to separate out sheep and other grazing livestock (could possibly use assumptions from beef grazed area calculation). The basal area estimation for regrowth and non-woody areas will have lower confidence due to less available data, but would still provide an improved starting point than currently available data.



Blade ploughed 20-year-old brigalow regrowth (regrowth clearing) near Wandoan 2008.

Results and discussion for woody vegetation clearing emissions, woody biomass and thickening

The estimated cleared above-ground and below-ground vegetation carbon stocks in 2006–07 was 29.8 Mt CO₂-e, of which 21.8 Mt CO₂-e was from remnant clearing and 8 Mt CO₂-e was from the clearing of regrowth.

For this regional and state-scale exercise we assume that the carbon in all vegetation cleared will eventually be emitted, but account for that in the year of clearing. We do not apply a decomposition rate to spread the clearing emissions over future years. In line with this decision, we do not account for clearing debris decomposition emissions from clearing in previous years.

The full impacts of the phase-out of broad-scale clearing of remnant vegetation will not be known until the next SLATS report is available. The magnitude of future remnant clearing rates is also uncertain. For example, will the decline in remnant clearing rates shown in Figure 3 continue? Due to these uncertainties, we conducted a sensitivity analysis using potential reductions in the remnant clearing rate. The results are provided in Table 2. A 75% reduction in the 2006–07 clearing rate (i.e. a continuation of the recent trend in Figure 3) reduced the net industry emissions to 1.2 Mt CO₂-e per year.

Woody vegetation carbon stock on beef grazing land is large (9420 Mt CO₂-e) with >95% on land classified as woody (>11% FPC) (remnant and regrowth) and the rest on land classified as non-woody (natural grassland, sparse woodland and young regrowth).

The growth in woody vegetation was estimated to be 27.3 Mt CO₂-e/year. This includes the growth of regrowth vegetation and the thickening of remnant vegetation. At this stage, the growth of regrowth on Kyoto land (i.e. land cleared since 1991) has not been calculated separately.

Using these numbers the growth of woody vegetation is almost equal the emissions from clearing and would be expected to be greater than clearing as the clearing of remnant vegetation is phased out.

Standing dead trees, coarse woody debris and land converted to forestry have not been included in this analysis.

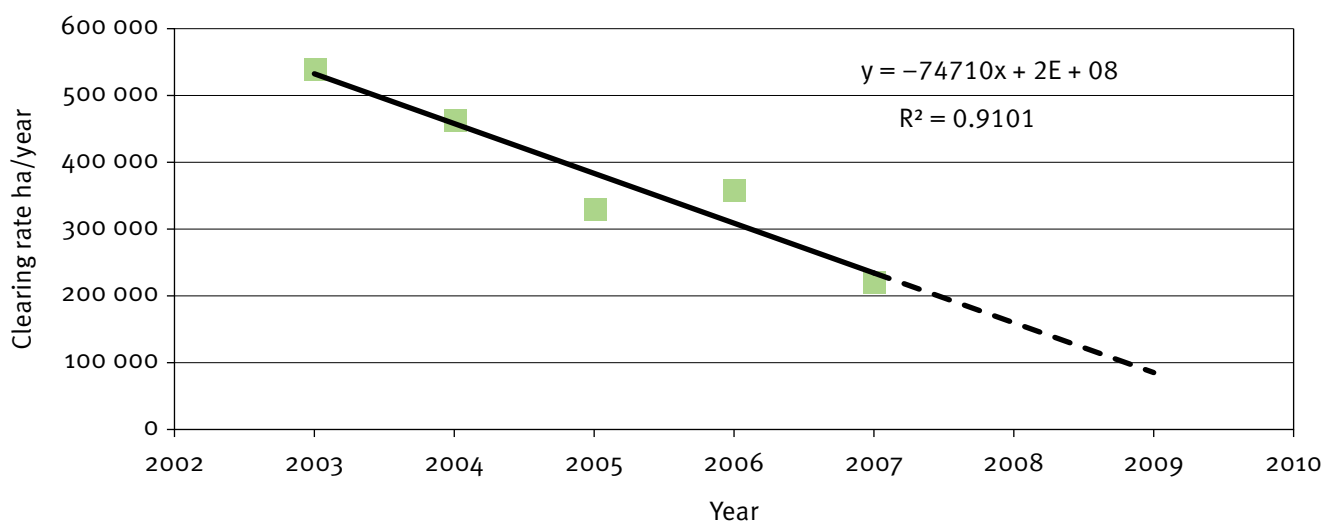


Figure 3. Projected trend in rate (dashed line) of clearing remnant and regrowth woody vegetation in Queensland (NRW 2008).

Table 2. Sensitivity analysis of the impact of reducing the remnant vegetation clearing rate by different amounts (relative to 2006–07 remnant clearing rate) on the net emissions of the beef grazing industry in Queensland.

Percentage reduction	Remnant area cleared (ha)	Net industry emissions (Mt CO ₂ -e)
0	120,077	17.5
10	108,069	15.3
25	90,058	12.1
50	60,039	6.6
75	30,019	1.2
90	12,008	-2.1

Soil carbon

Large uncertainties exist regarding the magnitude, timing and impact of management on soil carbon stocks in Queensland grazing land. Smith (2000) estimated the soil carbon stocks for each bioregion assuming a pre-cleared land condition, providing a background dataset for this analysis.

Ash, Corfield and Ksiksi (2001) reported on the difference in soil carbon in relation to land condition and assessed the impact of perennial grasses on surface soil carbon content (see Figure 4 below). This work can be summarised as ‘the more perennial grass tussocks, the more soil carbon’.

Carter and Fraser (2009) reported on the difference in surface soil carbon between paired grazed and ungrazed (exclosed) areas. The results were variable; however, the soil carbon in most exclosed sites was lower than the grazed sites although a couple of the exclosed sites were higher.

Harms, Dalal and Cramp (2005) assessed soil carbon at cleared and uncleared paired sites. They found that clearing reduced soil carbon slightly, although soil carbon at some sites increased. These results were probably compounded by the grazing management post-clearing.

Work is currently underway to assess soil carbon at 10 paired good and poor land condition sites in the grazing land of Queensland and a further 40 sites are planned (R Dalal, pers. comm.). This new data should provide a much greater understanding of the impact of land management and land condition on soil carbon stocks in grazing land.

After the inherent soil properties and climatic factors, a key driver of soil carbon content is expected to be land condition. Recent, objective data from a statewide assessment of land condition is currently lacking for many regions. Tothill and Gillies (1992) compiled a subjective assessment in the early 1990s and more recently rapid assessment (drive-by assessment) has been conducted in some regions (e.g. (Beutel 2009)).

Soil carbon change in grazing land (not cleared since 1990) is currently not included in the Kyoto Protocol reporting under the National Greenhouse Accounts.

For the purposes of this exercise we assume no change in soil carbon in the emissions calculation; however, we do present a value for soil carbon stock and conduct a hypothetical analysis on the impact of changing land condition on soil carbon stocks and the associated sequestration or emission.

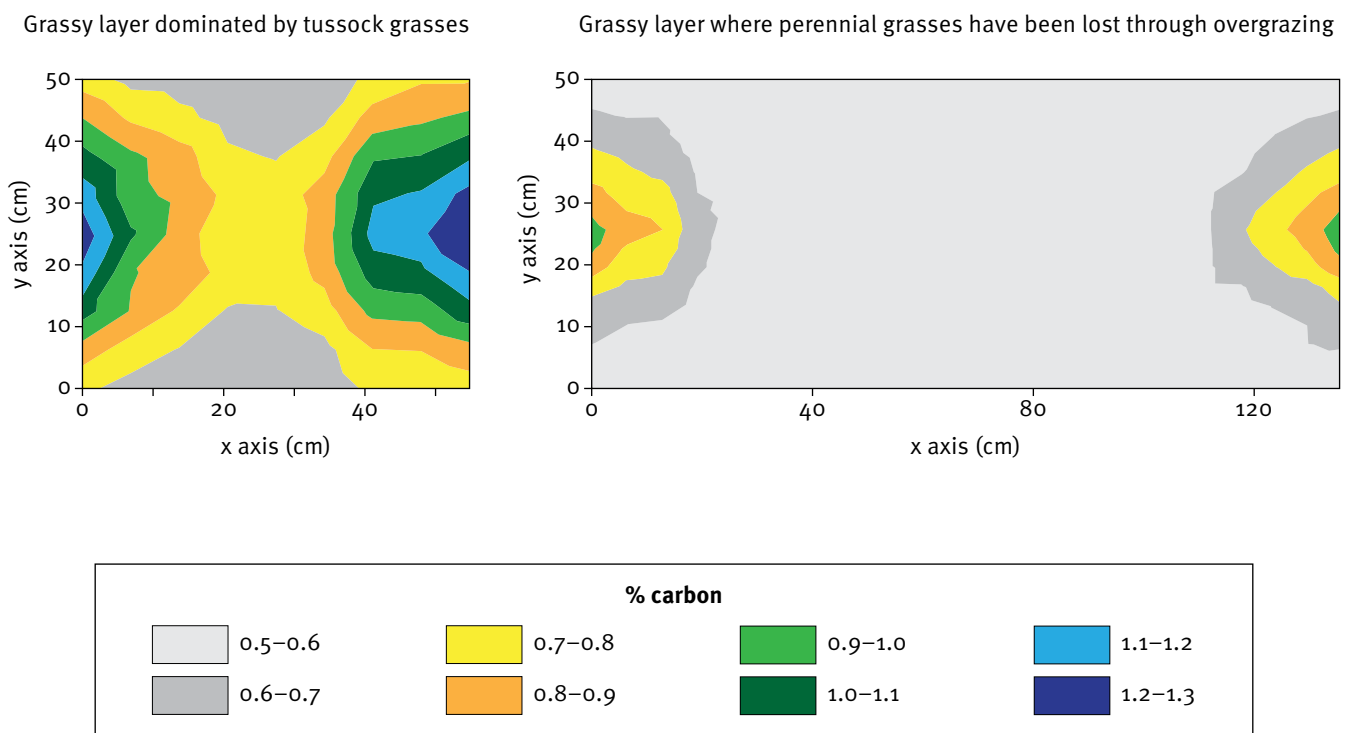


Figure 4. Soil carbon concentration in relation to perennial grass tussock in good condition land (left) and poor condition land (right) (Ash Corfield & Ksiksi 2001).



Collecting soil samples for carbon analysis in red basalt grazing land north of Charters Towers 2009.

Data and calculation for soil carbon

The pre-clear soil carbon stocks for each bioregion (Smith 2000) was used as the base soil carbon dataset. It is assumed that the pre-clear state is equivalent to A-condition (very good condition) as defined by MLA’s ‘Grazing land management’ (GLM) education package and Queensland Primary Industries and Fisheries’ StockTake package (DPI&F 2004). This scheme has four condition levels (A ‘good condition’, B ‘fair condition’, C ‘poor condition’, and D ‘very poor condition’).

To investigate the impact of land condition on soil carbon stocks, the A-condition soil carbon in the soil layers 0–10 cm, 10–20 cm and 20–30 cm was calculated using the metrics from Smith (2000).

The discount (reduction) in soil carbon stock due to poorer land condition was derived from Ash, Howden and McIvor (1995). As this analysis had three land condition levels (A, B and C), we used Table 3 to derive a discount for the GLM land condition levels.

Initially, a standard percentage of area in each land condition was applied across bioregions, which is reasonably consistent with Tothill and Gillies (1992)—A is 30%, B is 35%, C is 30% and D is 5% of land area. It is assumed that a changed land condition only changes the soil carbon in the top 10 cm as deeper carbon is generally old—for example, > 30 years (Krull et al. 2005)—and therefore would be little impacted by management change spanning one or two decades.

The soil carbon stocks in current condition and the difference in soil carbon stocks between current condition and A-condition were calculated.

Results and discussion for soil carbon

Soil carbon stock was calculated at 13,821 Mt CO₂-e if all Queensland’s grazing land was in A-condition. In the current hypothesised land condition, soil carbon stock was calculated at 12,683 Mt CO₂-e with a missing soil carbon stock due to poorer land condition of 1138 Mt CO₂-e.

Initial calculations indicate that if half the land in C-condition could be improved to B-condition, the soil carbon stock, this would increase by 190 Mt CO₂-e. If we assume the improvement could occur linearly over 25 years, this equates to sequestering 7.6 Mt CO₂-e/year. If land condition on grazing land deteriorates, loss of soil carbon would conversely create a significant source of carbon emissions. However, the research to verify that such carbon sequestration in soil is possible has yet to be conducted.

Table 3. Relationship between land condition rating schemes and the relative discount for soil carbon content.

GLM land condition scale	Land condition scale*	Soil carbon discount
A	A	1
B	(A + B)/2	0.85
C	(B + C)/2	0.65
D	C	0.55

* Tothill & Gillies 1992; Ash 1995

Based on these numbers, there is potential scope to manage soil carbon over long periods to offset a proportion of other emissions. However, this potential needs to be quantified through research into the rates and sizes of changes in soil carbon when land condition changes. Regardless of the offsetting potential, higher soil carbon is also likely to generate other productivity benefits through higher rainfall infiltration and associated water availability to forage plants.

It is unknown what the change in soil carbon would be if there were no beef industry; however, a study of paired grazed and enclosed sites in Queensland indicated that the soil carbon may be lower with no grazing (Carter & Fraser 2009).

A review by Gifford and McIvor (2009) describes the lack of information about the carbon sequestration of rangeland soils as 'a massive shortfall of data'. Given the magnitude of the potential sequestration and losses of soil carbon, this is an area in need of further research before the benefits can be confidently described.

Soil non-carbon dioxide emissions and sequestration

Soil non-CO₂-e emissions include primarily soil methane emissions/absorption and nitrous oxide emissions. Nitrous oxide emissions can be significant if fertiliser is applied, particularly in combination with irrigation, and are of particular concern on dairy farms and irrigated agriculture.

There is little nitrogen fertiliser applied to most of Queensland's beef grazing land; therefore, soil non-CO₂ emissions are driven by natural soil biological processes. There is a significant lack of data on soil non-CO₂ emissions in grazing land of Queensland and no information on the response to the grazing land management options (e.g. allowing regrowth to grow, clearing, lowering stocking rates, excluding grazing etc.) or on regional differences. However, Dalal and Allen (2008) in a global review of data from tropical savannas reported a mean sink of -0.02 t CO₂-e/ha for methane, and a mean emission of 0.28 t CO₂-e/ha for nitrous oxide (total emission 0.26 t CO₂-e/ha).

Using these values, a soil non-CO₂ emission of 35.2 Mt CO₂-e/year was calculated for beef grazing land. This value is double the livestock methane emissions. Soil non-CO₂-e emissions are likely to continue even with livestock destocking. The magnitude of soil emissions and the extremely limited dataset for northern Australia highlights the need for more research in this area. The soil non-CO₂-e emissions are presented, but not included, in calculations on Queensland's beef industry emissions.

Soil microbial biomass captures methane from the atmosphere, sequestering these greenhouse gases into the soil (Dalal & Allen 2008). However, the lack of data available for Queensland grazing lands prevents it being included in this analysis. Termite mounds emit methane and the soils surrounding them capture some of this methane (Dalal & Allen 2008). Although recent studies have started to quantify the amount of methane captured, further work is needed to see if microbes in grazing lands also capture some of the methane emitted by cattle (which graze and belch close to the soil surface).

Discussion

An estimated 22,740 Mt CO₂-e of carbon stocks are being managed by the beef grazing industry in Queensland (Figure 5). Total greenhouse gas emissions from the beef industry in Queensland are estimated to be 45.9 Mt CO₂-e per year (includes livestock methane, savanna burning, woody vegetation clearing, property energy emissions and vegetation clearing emissions, but not non-CO₂ soil emissions) (Figure 6). Kyoto Protocol-compliant emissions were 45.0 Mt CO₂-e per year (includes livestock methane, savanna burning, woody vegetation clearing, but not growth of regrowth on 'Kyoto land'). Total biosequestration of 28.5 Mt CO₂-e per year (includes woody vegetation sequestration, livestock biomass turnover/export, but no change in soil carbon)(Figure 6) leaves the Queensland beef industry as a net emitter of 17.4 Mt CO₂-e per year. Vegetation sequestration includes growth from all remnant and regrowth woody vegetation, not just Kyoto protocol-compliant forests as reported in Australia's National Greenhouse Accounts.

However, the net emissions of the Queensland beef industry at the farm scale of 17.4 Mt CO₂-e per year is based on the most current available tree clearing data from 2006–07 which pre dates the full implementation of Queensland broad-scale land clearing controls (which came into effect 1 January 2007). Due to uncertainty of the magnitude of future remnant clearing rates until the next SLATS report, we conducted a sensitivity analysis using a range of potential reductions in the remnant clearing rate (Table 2). In the analysis, a reduction of 75% from the 2006–07 clearing rate reduced the net carbon position of the Queensland beef industry to 1.2 Mt CO₂-e per year (6.6 Mt CO₂-e per year if reduction only 50%). Based on the current trend in the rate of reduction in vegetation clearing (Figure 3), a reduction of 75% is feasible. The conclusion is that Queensland's beef industry is likely to be effectively neutral in its carbon position.

As previously mentioned, the net carbon position of the Queensland beef industry calculations excludes any current contribution from soil carbon due to insufficient data sets; however, significant potential gains could be achieved through improvements in soil carbon levels and their further impact on the 'net' position of the industry. For example, the report outlines that moving half of the current C-condition land to B-condition over a period of 25 years could sequester an additional 190 Mt CO₂-e or 7.6 Mt CO₂-e per annum.

This analysis is based on existing publicly available data and is a first estimation, designed to initiate discussion about assessing the net carbon position of agricultural industries to inform current national and international policy discussions.

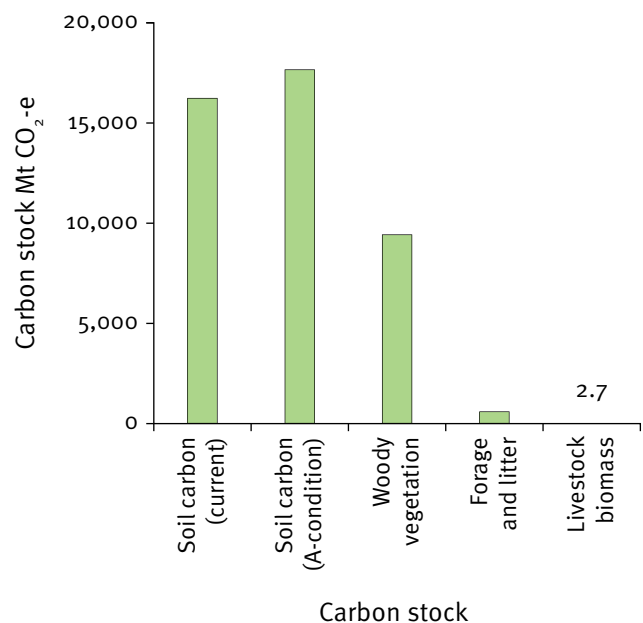


Figure 5. Magnitude of each carbon stock managed as part of the Queensland beef industry.

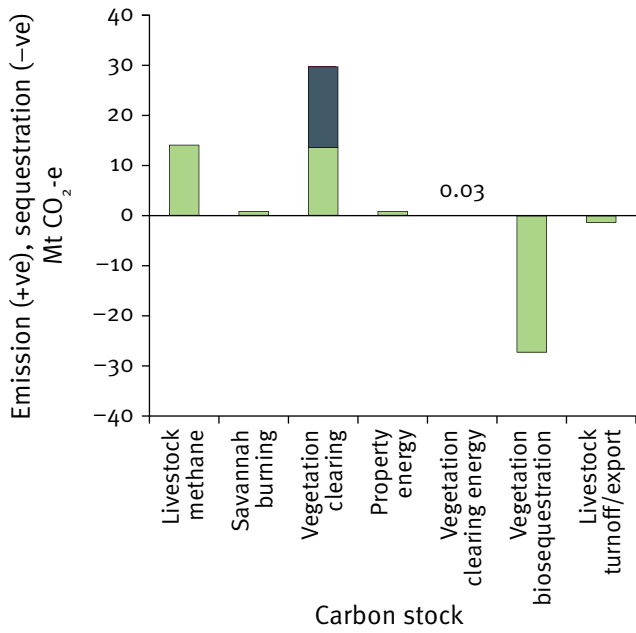


Figure 6. Magnitude of each emission or sequestration (Mt CO₂-e) used to calculate the net carbon position of the Queensland beef industry. For 'vegetation clearing' the full bar (blue and maroon) is the estimated emissions for 2006–07, the 'blue' portion of the bar is the emissions assuming a further 75% reduction in the clearing of remnant vegetation.

Conclusion

If remnant vegetation clearing levels have indeed fallen significantly as the result of legislative controls, the net carbon position of the Queensland beef industry at the farm level is likely to be close to zero. Further, this report highlights the significant unknown contribution of soil carbon and the potential gains in sequestration that could be achieved, in addition to productivity and environmental gains, through the improvement in land condition. This provides an interesting case study of the potential net carbon position of agriculture at the farm level to assist with policy and research discussions around the CPRS and future research in related areas.

The methods used in this analysis provide a framework for assessing the net carbon position of the beef industry, which can be improved as new data becomes available. These methods can also be applied to other agricultural industries.

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