Department of **Employment, Economic Development and Innovation**

Productivity tradeoffs and synergies for grazing lands in central Queensland to generate carbon offsets

Project report

December 2009

Commissioned by the Fitzroy Basin Association

Queensland Government

On 26 March 2009, the Department of Primary Industries and Fisheries was amalgamated with other government departments to form the Department of Employment, Economic Development and Innovation.

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by Rebecca Gowen
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Abbreviations

ABARE	Australian Bureau of Agricultural and Resource Economics
AE	Adult equivalent
AFI	Australian Farm Institute
CIE	Centre for International Economics
CO_2^{-e}	Carbon dioxide equivalents
CP	Crude protein
CPRS	Carbon Pollution Reduction Scheme
CSC	Carbon Sequestration Contract
CSIRO	Commonwealth Scientific and Industrial Research Organisation
CQ	Central Queensland
DMD	Dry matter digestibility
EU	European Union
FBA	Fitzroy Basin Association
GNP	Gross National Product
LULUCF	Land Use, Land Use Change & Forestry
NPV	Net present value
QPIF	Queensland Primary Industries and Fisheries
UNFCCC	United Nations Framework Convention on Climate Change

Acknowledgements

The research reported in this paper was fully funded by the Fitzroy Basin Association. The authors gratefully acknowledge the contributions and support from FBA staff and board members.

Executive summary

The project reported here had three key objectives. They were:

- understand the economic implications for central Queensland graziers of participating in a carbon trading scheme,
- measure the likely participation of graziers in an emissions trading scheme under various market design and reporting frameworks and,
- develop a decision analysis tool to assist graziers in calculating the economic tradeoffs of sequestering carbon.

Methodology

An initial desktop study of an enterprise which produced only cattle to one which produced cattle and sequestered carbon was undertaken based on measurements and assumptions from three case study properties in central Queensland. The findings from this analysis were used to inform the design of an experimental auction to test alternative carbon trading scenarios with central Queensland graziers. The experimental auctions were run in seven locations across central Queensland with a range of beef producers, extension officers and consultants. Participants were presented with a scenario in which they had the choice of maintaining current management practices against altering management practices to reduce beef production and enter into a carbon sequestration contract (CSC). They were asked at what price they would enter into a CSC and how that price and likelihood of participating would change under a range of alternative contract conditions.

A number of tools to calculate carbon emissions from agriculture currently exist. For this project the spreadsheet calculator developed by Melbourne University was modified with central Queensland parameters to enable graziers in central Queensland to estimate their on-farm emissions and the potential carbon offsets available in regrowth vegetation. A printed version of the spreadsheets is attached as Appendix C.

Key findings

Initial desk-top modelling over a 20 year time period showed that at a carbon price of $19.60 per tonne CO_2-e graziers would be no better or worse off incorporating biosequestration into their existing production versus continuing to graze. At $25 per tonne over 20 years, a mixed cattle-carbon business would return $90,425 more than a cattle only enterprise. These calculations were based on the assumption that graziers would not be required to account for property emissions, in particular emissions released from routine clearing of regrowth and livestock emissions.

The results of the experimental auctions found significantly higher than breakeven prices for carbon would be required before landholders in central Queensland would offer land as a carbon offset. For brigalow areas the average price demanded was $63 per tonne CO_2-e and on Ironbark areas it was $50 per tonne. The difference in prices is a reflection of perceived risk and the price discovery behaviour of graziers attempting to calculate what a tonne of CO_2-e might be worth versus what it costs them to produce.

Participation rates were influenced by price and also the carbon contract rules. Five rule changes were trialled independently of each other. All were found to have a significant impact on reducing participation and increasing required payment levels.

The original rules were:

- Single page annual reports
- Five-yearly independent audits
- Annual payments
- No requirement to account for on-farm methane emissions.
- 20 year contracts.

The alternative rules trialled were:

- Five page annual report
- Annual independent audit
- Payments made every five years after audit
- Requirement to account for on-farm methane emissions
- 50 year contracts.

Comparison of the desk-top modelling and experimental auctions showed considerable difference between the economically efficient level of carbon offsets from grazing land and the amount graziers would be willing to supply. This is consistent with estimates calculated by the Commonwealth Scientific and Industrial Research Organisation (CSIRO). At a national scale the CSIRO estimated that 75 million tonnes of CO_2^{-e} per year offsets would be available from rangeland sources, a third of which would be in Queensland (CSIRO 2009). Of the total biophysical potential it is estimated that only 6.3 million tonnes would actually be offered as carbon offsets (CSIRO 2009). The magnitude of the differences between potential numbers of offsets and estimates of actual supply highlights the need for further research to understand not only the biophysical potential for carbon offsets but also the economic and social constraints which deter graziers from implementing practices to sequester carbon.

Conclusions and recommendations

The results of this project highlight the lack of knowledge amongst landholders regarding carbon offsets, the likely variation in future supply of offsets, the prices at which offsets may be offered and the sensitivity to trading rules. The lack of knowledge is reflected in the diversity of bid prices received and the difference between bid prices and the breakeven price of carbon calculated in desktop studies, indicating a degree of risk aversion. The risk premium is largely influenced by uncertainty over rules for carbon trading and the concern that rules may change after contracts are signed. Concern has been intensified by the recent experience of many landholders with changes to native vegetation clearing laws.

It is recommended that the focus for future engagement with landholders be on assisting with estimation of on-farm emissions and using the results of this to calibrate emissions calculators for the Fitzroy Basin area. These calculators could then be used to identify carbon exposure reduction strategies for industry and to assist grazing businesses assess how they are likely to be affected by the Carbon Pollution Reduction Scheme (CPRS) or through their participation in a voluntary carbon trading scheme.

Additional work should also focus on further testing of rules relevant to a carbon reporting framework and analysis of the implications of alternative policy structures.

Contents

1 Introduction

In September 2008 the Australian Government announced plans to introduce an emissions trading scheme to be known as the Carbon Pollution Reduction Scheme (CPRS) (Department of Climate Change 2008). The stated aim of the proposed scheme was to reduce carbon emissions and would initially cover the stationary energy, transport, fugitive emissions, industrial processes, waste, and forestry sectors. Initial policy papers proposed that agriculture will initially be exempt from the scheme and a final decision on inclusion will be made in 2013 for implementation in 2015 (Australian Government 2008). This position was revised and the policy at time of publication is that agriculture will be permanently excluded from the CPRS. However, the Australian Government has also indicated that agriculture will need to demonstrate reductions in emissions to meet world best practice standards (Department of Climate Change 2009).

The Fitzroy Basin region in central Queensland supports approximately 3000 grazing businesses running over three million head of cattle. The Fitzroy Basin Association's (FBA) priorities for natural resource management include 'the identification and trial of cost benefit modelling for resource use decisions and development of options and opportunities to increase business resilience'. As part of achieving these priorities the FBA has identified the need to understand the potential opportunities and risks imposed by emission reduction policies on beef producers in the region. The research reported here contributes to improving regional understanding of the opportunities and threats presented by carbon emission reduction schemes and provides guidance on areas of future research.

2 Project aims

The project reported here had three key objectives. They were:

- understand the economic implications for central Queensland graziers of participating in a carbon trading scheme,
- measure the likely participation of graziers in an emissions trading scheme under various market design and reporting frameworks and,
- develop a decision analysis tool to assist graziers in calculating the economic tradeoffs of sequestering carbon.

The results provide information at three levels; for individual graziers, regional natural resource management (NRM) planning and national emissions policy planning. At the property scale a rapid assessment tool has been developed to calculate the economic trade-offs of scenarios for carbon sequestration versus existing enterprises. Producers have been given the opportunity to participate in a mock carbon auction and have experience in calculating the costs and benefits of on-farm carbon sequestration practices. At the regional scale the results provide NRM planners with economic data on the tradeoffs of forgoing production for sequestration and insights in to likely market barriers resulting from CO_2 accounting frameworks. Finally, the results of the experimental auctions provide policy planners at the regional and national level with information about graziers' perceptions towards carbon trading, the likely involvement of agriculture (specifically beef) and the factors which will encourage or discourage participation in a voluntary scheme.

3 Carbon emissions accounting and trading

3.1 The international carbon accounting framework

The international carbon accounting rules are set out in the Kyoto Protocol to the United National Framework Convention on Climate Change (Kyoto Protocol) (UNFCCC 2008). Signatories to the protocol (which Australia ratified on the 3 December 2007 are required to account for the following greenhouse gases: carbon dioxide, methane, nitrous oxide, sulphur hexafluoride, hydrofluorocarbons and perfluorocarbons. Each of these gases has a different global warming potential which is converted to carbon dioxide equivalents (CO_2^{-e}) (UNFCCC 2008). The relative warming potentials of each of the gases is shown in table 1.

Table 1. Greenhouse gases - global warming potential (Department of Climate Change 2009)

Gas	Global warming potential (CO_2^{-e})
Carbon dioxide (CO_2)	1
Methane (CH_4)	21
Nitrous Oxide (N_2O)	310
Sulphur hexafluoride	23 900
Hydrofluorocarbons	140 – 11 700
Perfluorocarbons	6 500 – 9 200

The Kyoto protocol classifies emissions into seven sectors: stationary energy, transport, fugitive emissions, industrial processes, agriculture, waste and land use, land-use change and forestry (LULUCF) (UNFCCC 2008). Australia opted to exclude land-use and land-use change from reporting during the first Kyoto period, 2008–2012. This means that emissions from savannah burning and cultivation are not reported and soil sequestration cannot be counted.

3.2 The Australian carbon pollution reduction scheme

The proposed Australian carbon pollution reduction scheme is due to begin operation in 2011 and covers most major greenhouse gas emitting sectors. The stated aim of the scheme is to reduced emissions by 60 per cent below 2000 levels by the year 2050. The scheme will operate as a 'cap and trade' system in which the government will issue a certain number of emission permits each year. Emitting entities will have to purchase credits equal to their emissions for that year. Firms which can reduce their emissions more cheaply than the cost of buying permits will do so and can also sell spare permits. The market price for a carbon permit (equal to one tonne of carbon dioxide equivalent) will be determined by ordinary forces of supply and demand in the market. Some categories of firms will receive free allocations of permits during the transitional phase of the scheme (Department of Climate Change 2008).

Direct reporting obligations will fall on entities in the stationary energy, transport, fugitive emissions, industrial processes and waste sectors which emit more than 25 000 tonnes of CO_2^{-e} per year. Emissions of all greenhouse gases listed under the Kyoto protocol will be included.The point of obligation for reporting will be dependent on issues such as ease of measurement and transaction costs. This design which applies to approximately 1000 individual entities is estimated to cover approximately seventy five per cent of all Australian emissions (Department of Climate Change 2008).

At the time of publication (December 2009) the CPRS legislation had been presented to the Federal Senate for a second time and was not passed. Indications are that it may be presented for a third time in early 2010. As the proposed legislation currently stands, agriculture has been exempted from the scheme indefinitely. However, the sector will be required to demonstrate reduced emissions and voluntary reporting trials are proposed from 2011 (Department of Climate Change

2009). The Australian Government has also indicated that a system for sequestration credits will be developed to allow offsets from agricultural sources including direct emissions from livestock, manure management, fertiliser use, savanna burning and avoided deforestation (Department of Climate Change 2009).

In addition to these requirements agriculture is likely to experience increases in the costs of inputs including fuel, electricity and fertilizer as major emitters pass on the costs of abatement (Keogh 2007).

3.3 International emissions trading schemes

Several other emissions trading schemes are already operating internationally. These include the European Emissions Trading Scheme which began in 2005. This scheme covers the energy and industrial sectors and currently covers 27 countries in the European Union. The New Zealand Emissions Trading Scheme began in 2008 with the forestry sector (New Zealand Government 2009). By 2013 it will cover all sectors. Japan has a Voluntary Emissions Trading Scheme which also began in 2005 to trial emissions trading, initially between 31 businesses. New Zealand is the only national emissions trading scheme other than Australia which is proposing to include agricultural emissions in a mandatory reporting program (New Zealand Government 2009).

Other trading schemes which are in the planning and development stage include the Canadian scheme which is to be introduced in 2010 (Environment Canada 2009). It will initially cover approximately half of emissions from electricity, oil, gas, iron, steel, cement, chemicals and fertiliser. Emissions reductions targets are to reduce intensity by 18 per cent from 2006 levels by 2010 and an annual two per cent reduction thereafter (Environment Canada 2009). In the United States (the single largest emitter of greenhouse gases) a national emissions trading scheme is currently under consideration by the United States federal government. In the United States, agricultural producers are already provided with incentives to adopt practices such as zero or minimum till cropping which reduce emissions or increase carbon sequestration. These payments are based on broad assumptions about the amount of carbon sequestered by these practices in different locations. The lack of certainty regarding the amount of carbon which is being sequestered under different practise means that carbon purchasers are willing to pay only small amounts per hectare.

3.4 Australian voluntary trading schemes

Within Australia there are several voluntary trading schemes which operate at different levels. One example is 'Carbon Pool' which was a deal in which a large mining company purchased clearing permits from landholders in south-western Queensland to prevent the clearing of mulga lands and received carbon credits in return. Other programs such as 'Greenhouse Friendly' provide accreditation to companies which follow certain practices to reduce their carbon emissions (Department of Climate Change). CarbonLink is a firm which provides carbon accounting and brokering (pooling) of carbon credits, mostly from agricultural sources (CarbonLink 2009).

There are also numerous 'carbon neutral' schemes in which consumers can purchase credits to offset purchases such as airline flights, concert tickets and electricity. All of these programs operate under slightly different rules and assumptions. There is no single regulatory authority to ensure accuracy and validity of measurement or supply from these programs although some have completed independent validation processes. There is no certainty regarding the status of these programs under a compulsory trading scheme.

4 Designing policy solutions

While it appears that agriculture will be permanently exempt from a compulsory emissions trading scheme, indications are that some form of emissions management will be implemented for the sector. Difficulties such as achieving acceptable levels of measurement accuracy, reporting and transactional costs make the inclusion of agriculture under a similar format to the CPRS difficult. This is particularly so for the extensive grazing sector.

There are approximately 60 000 beef producing entities in Australia compared to only 1000 entities required to report under the first stage of the CPRS. These 1000 entities represent those businesses which emit greater than 25 000 tonnes of CO_2^{-e} per year. Applying the same assumptions to agriculture would mean that less than one per cent of Australian agricultural entities would be required to directly report. The farms covered under this threshold represent only two per cent of agricultural emissions (Ford 2009; Tulloh 2009).

The framework used to calculate the current National Greenhouse Gas Inventory (AGO2006) calculates methane emissions from tropical pastures based on factors developed by Kurihara (1999) and Kurihara et al (2006). The calculations are based on standard estimates of liveweight, liveweight gain and dry matter intake for broad classes of cattle. Whilst this method provides a sufficiently accurate estimate for national emissions accounting and Kyoto reporting, it does not take into account the huge variation in seasonal conditions, grazing management and breed which occur in northern Australia. Charmley et al. (2008) found that methane emissions could be reduced by as much as 11 per cent over six years through the use of dry season supplementation. In addition they found that by selecting animals with higher feed utilisation capacity, lifetime methane emissions could be reduced by 13%.

These results provide just two examples of the ways in which individual beef herds may differ in their methane production. Accounting for this variation is important for two reasons, firstly to ensure accuracy in emissions accounting and to measure the success of attempts to reduce emissions but more importantly to provide an incentive for producers to reduce their livestock emissions.

An emissions trading scheme for agriculture, in whatever form it takes will essentially be a case of creating a market for a product which was previously a public good and had no market value. The use of market based instruments to resolve market failures in the area of environmental and natural resource management is a relatively new but not untested system. Previous experience both within Australia and internationally has shown that the specific design details of the scheme will have significant impact on how successful the scheme is.

4.1 Impact of greenhouse gas emissions policy on agriculture

Since the release of the CPRS Green and then White papers many research corporations and industry organisations have commissioned modelling to examine the potential impact of an emissions trading scheme on agriculture. The initial modelling from the Commonwealth Treasury found that the impact on economic growth would be minimal (real GNP per capital growth of 1.1 per cent compared to 1.2 per cent without CPRS) and that agriculture would maintain its comparative advantage in global markets (Treasury 2008). In comparison, modelling which considered specifically the impacts on agriculture at the sector and farm level found significant decreases in profit and production under almost all CPRS scenarios across most industries (CIE 2009; Ford 2009; Keogh 2009; Tulloh 2009).

The results published by ABARE (Ford 2009; Tulloh 2009) were the most positive for agriculture, predicting a three per cent increase in grain profitability and a minimal 1.6 per cent fall in livestock productivity by 2020 (assuming that agriculture becomes a covered sector from 2015). Importantly, ABARE assumed that similar policies including agriculture would be implemented in major international markets within a similar timeframe. However, currently the only other major agricultural producer considering the inclusion of agriculture in an emissions trading scheme is New Zealand. Therefore significant impacts on export market competiveness are likely.

The modelling conducted by ABARE does recognise the fact that the agricultural processing sector will be covered from 2011. This sector is highly trade exposed and therefore likely to pass on only part of their cost increases to the consumer; the remainder will be passed back to agricultural producers. Thus, along with increased prices for inputs including fuel, electricity and fertilizer, agricultural producers will potentially face lower prices for their outputs (Tulloh 2009). Early modelling conducted by the Australian Farm Institute (AFI) based on representative farm financial models found that the beef and sheep industries would experience large declines in returns as measured by the difference in farm cash margins (-6% to -20%). Further modelling conducted by the Centre for International Economics (CIE) for the AFI predicted a 9 per cent fall in gross value of production (GVP) for beef by 2020 and a fall of almost 30 per cent by 2030 (CIE 2009). GVP was also predicted to fall across other major sectors of the agricultural industry with the worst affected being wool (-27.48% by 2030) and sheepmeat (-21.02% by 2030). This modelling was based on an assumption of 100% free allocation of permits in 2015, reducing to zero over a period of ten years.

As noted by AFI in a second report released in September 2009 the results produced by all models are dependent on the assumptions of policy design and carbon price made by each institution (Keogh 2009). While each has striven to make these assumptions based on current government policy and price expectations, significant uncertainty exists around estimates at this stage. As a result ongoing research is required to ensure accurate measurement and monitoring protocols are in place prior to the commencement of any emissions reduction scheme.

4.2 Supply of carbon offsets from Agriculture

Various attempts have been made to estimate the potential supply of carbon credits from agriculture (for example; (Antle et al. 2007; Lawson et al. 2008). Antle et al (2007) used county level data agricultural census data to construct profit functions which were then used to derive soil carbon supply curves based on marginal opportunity costs of carbon sequestration versus current cropping practices. This method found that to accurately model carbon sequestration would require a comprehensive model of land use choices with capacity to account for spatial variation in opportunity costs.

Lawson et al (2008) estimated that at a carbon price of \$29.10 CO_2^{-e} approximately 25 million hectares of land would become economically suitable for afforestration, 40 per cent of which would be in Queensland. Lawson et al (2008) estimated that this area of land would sequester approximately 623 million tonnes of CO_2^{-e} over the period 2007–2050.

These estimates are largely based on biophysical potential and to a lesser degree on economic viability; they do not take into consideration the range of other factors such as social dynamics or biodiversity considerations which may also influence land use decisions. A review of biosequestration options for Queensland found that although there was biophysical potential for up to 225 million tonnes of CO_2-e to be sequestered on rural land annually, the actual potential was likely to be only 10 to 15 per cent of this figure (CSIRO 2009). Figures estimated in CSIRO (2009) also differ significantly from those calculated by the Garnaut Climate Change Review (Garnaut 2008). For example, Garnaut estimated that approximately 286 million tonnes of sequestered CO_2-e per year would be available from rangelands. Estimates contained in the CSIRO report are for only 75 million tonnes of sequestration from rangeland sources, a third of which would be in Queensland. Of this it is estimated that only 6.3 million tonnes would actually be offered as carbon offsets. The magnitude of the differences between these estimates highlights again the need for further research to understand not only the biophysical potential for carbon offsets but also the economic and social potential.

In addition, many of the options for biosequestration proposed by Garnaut (Garnaut 2008, Table 22.2, page 543) are not currently available under the conditions of the Kyoto agreement as signed by Australia. The biggest source Garnaut identified was the rehabilitation of rangelands and mulga country degraded by overgrazing. Australia elected not to sign Article 3.4 of the Kyoto protocol which covers grazing management in the 2008–2012 reporting period (Department of Climate Change 2008). The reason for not including Article 3.4 was concern over the risks of emissions from natural disturbances such as wildfires and droughts (Department of Climate Change 2008).

4.3 Auctions for carbon offsets

Auction mechanisms[1] have previously proven successful in procuring the supply of environmental services in Australia (Stoneham et al. 2003; Rolfe 2008; Windle and Rolfe 2008) and overseas (Cason and Gangadharan 2007). To be successful auctions need to have high numbers of participants who have access to good information regarding the value of the goods to be offered.

Participants in agricultural carbon contracts are likely to be small, less than perfectly informed, have difficulty estimating true opportunity costs and face resource constraints in increasing knowledge and ability to calculate true values. There are potentially many eligible bidders, however insufficient knowledge of the process, long term consequences and distrust of governments are likely to be barriers to participation. The large number of potential bidders supplying relatively small amounts of carbon also results in high transaction costs. To mitigate perceived risks in this environment landholders are likely to overstate costs and offset values which may result in their bids being rejected. Therefore, the efficiency of the final outcome will be dependent on the auction design and how the price discovery process is managed.

A review of auction literature finds that ascending auctions tend to favour advantaged bidders, deter weaker bidders and are often subject to issues of collusion (Klemperer 2002). Alternatively, sealed bid auctions are more likely to attract greater numbers of bidders as 'weaker' firms have a greater chance of winning (Klemperer 2002). However, sealed bid auctions require bidders to have good information about the distribution of their rivals' values to bid intelligently (Klemperer 2002). Given that in the market for agricultural carbon offsets, bidders may not have good information on their own values, there is little chance that they will have good information on rivals' values. This may lead to high levels of over-bidding to compensate for lack of information.

These findings were considered in the design of the experimental auctions.

[1] A process by which private suppliers of a good or service (in this case environmental services) bid for incentives to supply environmental services such as improved water quality. The incentives are awarded to the bids which represent the greatest outcome per dollar invested.

5 Methodology

5.1 Desk-top study

The economic tradeoffs of cattle production versus carbon sequestration was initially calculated using a desk-top benefit cost analysis for a hypothetical grazing enterprise in central Queensland. This analysis assumed that the only costs to a grazier of participating in a voluntary carbon trading scheme were the opportunity costs of foregone cattle production and the only benefits would be payments for carbon offsets. The key assumptions used for this analysis are listed in table 2. For this analysis there was no attempt made to incorporate the effects of transaction costs associated with a carbon reporting framework and perceived risk on the part of landholders.

Table 2. Desk-top study assumptions

Desktop study	Assumptions
Landtype	Poplar box/brigalow
Enterprise description	Trade steers for domestic market
Gross margin	\$168.61/AE[2]
Analysis period	30 years
Discount factor	8%
Carbon price	\$20/tonne CO_2-e

5.2 Experimental auctions

Based on the review of the issues associated with auctions for environmental services it was decided to test landholders' values via an experimental auction. The auction used a sealed bid format which included a general information session on carbon trading policy, risks and opportunities. The aim of this was to provide all participants with the same level of information and improve their chances of providing bids which reflected their true costs.

Participants were drawn from Queensland Primary Industries and Fisheries (QPIF) extension networks, AgForce contacts and FBA sub-regional group contact lists. Workshop locations and participant numbers are shown in table 3.

Table 3. Workshop locations and participant numbers

Location	No. completed bids
Biloela	51
Rockhampton	18
Emerald	47
Springsure	7
Nebo	3

After the overview presentation of the CPRS, the rules of the 'mock' carbon auction were explained to participants. Participants were asked to imagine that the CPRS had been introduced and that agriculture had been included. The auctions were conducted in two stages. The first involved participants being asked to consider four scenarios which included a photo standard, details on land-type, pasture, carrying capacity and condition. Participants were asked to imagine that they owned the paddock as described and to answer questions regarding how they would treat that paddock under current grazing strategies, the payment they would require to implement the rules of the carbon trading scheme and the likelihood that they would participate in the scheme given the rules as stated. The four scenarios were:

- Brigalow high density (tree basal area: 8 m^2/hectare)
- Brigalow low density (tree basal area: 3 m^2/hectare)
- Silver-leaf ironbark high density (tree basal area: 5.3 m^2/hectare)
- Silver-leaf ironbark low density (tree basal area: 2.7 m^2/hectare)

The bid cards and mock auction rules as given to the participants, including the details of each of the above scenarios are included in Appendix A.

The second stage involved asking producers to

[2] AE – Adult equivalent, equates to 400 kg steer, gross margins from Best, (2007)

describe an area on their own property which they would include in a carbon trading scheme. They were asked to list the land-type, pasture and soil types, current grazing enterprise and stocking rate. They were then asked to state the payment they would require to include that area in a carbon trading scheme and the likelihood that they would participate. Participants were then asked to consider a list of alternative trading rules and how the changed rules would affect both their required payment level and the likelihood that they would participate. The list of trading rules under the original scenario and the alternative rules are shown in table 4. Each of the rule changes was to be considered independently. A copy of the worksheet outlining the alternative rules is included in Appendix B.

Table 4. Carbon contract trading rules

Original rule	Alternative rule
1 page annual report	5 page annual report
Independent audit every 5 years	Annual independent audit
Annual payments	Payments made every five years at completion of audit
No requirement to account for methane emissions	Can only sell net carbon after methane emissions accounted for
Contract length 20 years	Contract length 50 years

The experimental auction rules allowed graziers to voluntarily undertake grazing strategies which would sequester additional carbon in return for a specified payment. Under the rules of the auction, areas which were to be used for carbon sequestration could no longer be cleared or treated for regrowth control. Cattle could continue to graze those areas but as woodland thickening occurred it was expected that carrying capacity would be reduced. The rules also stated that participants would need to implement a weed, fire and pest management plan and ensure that the land remained at or above the current land condition score. The most important assumption to note is that there was no requirement for landholders to account for their on farm emissions (including methane and land clearing). This assumption reflects the current policy for most voluntary trading schemes and the difficulty in accurately measuring on-farm emissions.

The trading scheme was designed so that payments would be made on an annual basis at the completion of a simple one page annual report.

5.3 Carbon calculator

A number of tools designed to calculate greenhouse gas emissions from the agricultural industry are already available. A summary list of all those readily available is included in

Table 5 (full details including comments on usability and accuracy are listed in Appendix C). Instead of creating another tool specifically for the Fitzroy Basin it was decided to modify a calculator already available. The spreadsheet created by the University of Melbourne (BeefGreenhouse) was found to be the simplest to use and as it was written in Microsoft Excel it was thought to be the most accessible to the majority of potential users.

BeefGreenhouse was originally developed for Victorian conditions with some allowances for differences in other regions. The calculator consists of two input sheets plus background calculation sheets for methane emissions, energy emissions and vegetative offsets. Emissions are calculated based on the number of livestock carried in each age group, electricity usage and diesel consumption. Standard seasonal livestock weights, daily liveweight gains and pasture quality measures (crude protein and dry matter digestibility) can be modified if actual measures are available for the property under analysis. Carbon offsets are calculated based on the area of trees planted after 1990, the plant species and the average rainfall.

To improve the accuracy of emissions calculations for central Queensland conditions,

Table 5. Farm level carbon calculators

Name	Author	Website
Australian Methodology for the Estimation of GREENHOUSE GAS Emissions and Sinks	AGO	www.climatechange.gov.au
BeefGreenhouse	Richard Eckard, University of Melbourne	www.greenhouse.unimelb.edu.au/site/Tools.htm
CALM (Carbon Accounting for Land Managers)	Country Land and Business Association	http://www.calm.cla.org.uk/
Carbon calculator	Lincoln University – Agribusiness and Economics Research Unit and Agrilink	www.linwww.lincoln.ac.nz/carboncalculator
Carbon calculator	Soil Carbon Center, Kansas State University	http://soilcarboncenter.k-state.edu/
Carbon credit calculator	Bill Smart (Southern Cross PhD student)	http://www.australianforestcorporation.com.au/CO2calc/
Carbon farmer	Hassall and Assoc	
Carbon trading		http://www.carbon.sref.info/estimating/calculator
C-Plan carbon calculator	Drew and Jan Coulter (Scottish Farmers)	www.cplan.org.uk/calculator.asp
Farm carbon–NSW	Agriculture Western Australia	
FarmGAS	Australian Farm Institute	www.farminstitute.org.au
Methane emissions	Soil Carbon Center, Kansas State University	http://soilcarboncenter.k-state.edu/
National Carbon Offset Coalition Inc		http://www.ncoc.us
Northern Australia Methane Estimator	John Rolfe	

the average liveweights, liveweight gains and pasture quality measures were modified based on data from research projects and expert knowledge (MLA 2001; Sullivan 2009). Seasonal liveweights and daily liveweight gains are shown in table 6. Estimates of average crude protein (CP) and dry matter digestibility (DMD) for each season are shown in table 7.

Two tree species relevant to the central Queensland region were also added to the specifications in the calculator. They were brigalow and CQ eucalyptus (combined measurements from poplar box, narrow-leaf and silver leafed ironbarks). These two categories of trees were considered to be representative of a large portion of grazed central Queensland landtypes. The assumed growth rates and carbon contents for these trees are shown in table 8. A complete set of data and calculations from the BeefGreenhouse CQ version is included in Appendix C. The calculator has been calibrated against the FarmGAS calculator developed by the Australian Farm Institute (Australian Farm Institute 2009). A hard-copy version of the calculator is included in Appendix C and a full version is included on the attached CD-ROM.

		Bulls >1	Bulls<1	Steers<1	Cows 1 to 2	Cows >2	Cows<1	Steers>1
Livestock numbers	Spring	10	10	200	200	300	100	100
	Summer	10	10	200	200	300	100	100
	Autumn	10	10	200	200	300	100	100
	Winter	10	10	200	200	300	100	100
	Average	**10**	**10**	**200**	**200**	**300**	**100**	**100**
Liveweight (kg per animal)	Spring	800	100	100	270	490	90	290
	Summer	800	150	150	350	490	140	390
	Autumn	800	220	220	390	520	210	440
	Winter	800	240	240	390	520	230	465
	Average	**800**	**177.5**	**177.5**	**350**	**505**	**167.5**	**396.25**

Table 6. Seasonal liveweights and daily gain for central Queensland (Sullivan 2009)

		Bulls >1	Bulls<1	Steers<1	Cows 1 to 2	Cows >2	Cows<1	Steers>1
Crude protein (%)	Spring	7.25	7.25	7.25	7.25	7.25	7.25	7.25
	Summer	11.09	11.09	11.09	11.09	11.09	11.09	11.09
	Autumn	8	8	8	8	8	8	8
	Winter	4	4	4	4	4	4	4
	Average	**7.585**	**7.585**	**7.585**	**7.585**	**7.585**	**7.585**	**7.585**
DMD (%)	Spring	20	20	20	20	20	20	20
	Summer	40	40	40	40	40	40	40
	Autumn	60	60	60	60	60	60	60
	Winter	90	90	90	90	90	90	90
	Average	**52.5**	**52.5**	**52.5**	**52.5**	**52.5**	**52.5**	**52.5**

Table 7. Crude protein and dry matter digestibility for central Queensland (MLA 2001)

	Rainfall mm/yr	Biomass m³/ha/year from	to	Dry weight tonne/ m³	C content	tCO_2-e/ha from	to
CQ Eucalyptus	700	3.03	3.25	0.63	50%	3.5	3.8
Brigalow	700	1.78	3.28	0.63	50%	0.8	6.1

Table 8. Growth rates and carbon content for CQ tree species (adapted from (Donaghy et al. 2009)

6 Results

6.1 Desk-top study

Table 9 shows the difference in net present value[1] (NPV) between the current cattle enterprise and two carbon sequestration options on a per hectare basis. In the first option all cattle are removed and vegetative thickening for sequestration occurs, in the second only 60 per cent of the cattle are removed to allow for cattle sales and vegetation thickening. Both scenarios return negative results compared to the cattle only enterprise at $10 per tonne CO_2^{-e} but positive results at $25 per tonne CO_2^{-e}.

It is currently proposed that the price of carbon in the first year of the CPRS will be set at $10 per tonne CO_2^{-e} after which it will be allowed to move with market forces and is expected to reach $25 per tonne fairly quickly. Based on this analysis the beef producer would therefore be better remaining a beef only producer in the first years of the CPRS. The initial desk-top calculation on the mixed Brigalow/poplar box landtype showed the breakeven price of carbon to be $19.60 per tonne CO_2^{-e}. This means that at a carbon price of $20 per tonne CO_2^{-e} beef producers would be better off switching to producing carbon rather than cattle (assuming no risk, and no requirement to account for emissions).

Table 9. Net present value differences per hectare

Carbon price ($/tCO$_2^{-e}$)	Discount rate	No cattle	40% cattle
$25	6%	$82	$30
	8%	$66	$79
	10%	$93	$39
$10	6%	–$180	–$131
	8%	–$121	–$90
	10%	–$147	–$108

6.2 Experimental auction – Part I

A total of 126 fully completed bid cards were received from participants at seven workshops held in central Queensland. Bid card sets which were incomplete were not included in the data analysis. Eleven completed bids were also removed from the data set because they contained extreme values. A summary of results from the mock carbon auctions is shown in table 10. The average bid price per hectare across the 115 included bids was $163.61 ($56.79/tCO_2^{-e}). This means that on average, landholders in central Queensland would be willing to participate in a carbon offsets scheme once the carbon price had reached $56 per tonne CO_2^{-e}. However, the average participation rate for brigalow and ironbark areas was well below 100 per cent (48 and 63 per cent respectively). This indicates that there are still a significant number of landholders who would not participate, regardless of price offered.

Figure 1 shows the distribution of bids by dollar amount per hectare of brigalow which producers would require to enter a voluntary carbon trading scheme. Ninety per cent of producers would accept less than $300 per hectare to implement a carbon sequestration contract on brigalow country. If the hectares offered are converted to tonnes of carbon dioxide equivalents, most producers (83%) would enter the scheme at a carbon price of less than $100 per tonne CO_2^{-e} (see figure 2). This is approximately five times the breakeven cost of carbon calculated in the first stage of

Table 10. Mock carbon auction results

	No. observations	Average bid ($) (500 ha)	Average participation	Average $/ha	Average $/tonne
Brigalow	72	$64,545.05	48%	$182.74	$63.43
Ironbark	52	$52,949.42	63%	$144.48	$50.15

[1]Net Present Value is the difference between the costs and benefits of a project discounted to present values terms.

this research. Only 26 per cent of producers would enter the scheme at a carbon price of $20 per tonne.

Similar results were found for Ironbark landtypes (see figures 3 and 4). Ninety two per cent (92%) of producers would enter a carbon trading contract for less than $300 per hectare (equates to $100 per tonne). Interestingly only 15% of landholders would enter the scheme at $20 per tonne, fewer that at the same price on brigalow.

6.3 Experimental auctions – Part II

The second part of the mock auctions was to explore the impact of alternative carbon conditions on bids and participation rates. Figure 5 shows the percentage increase in the level of payment which would be required under alternative contract conditions. Results indicate that if contracts were for 50 years there would be a fifty per cent increase in required payment levels compared to original bids based on a 20 year contract. Increases in administration requirements (5 page report, yearly independent audit; compared to 1 page annual report, independent audit every 5 years) would require a corresponding thirty per cent increase in yearly payments. The increase in administration (measurement and monitoring) costs associated with accounting for methane is reflected in the forty per cent increase in required payment levels under this scenario.

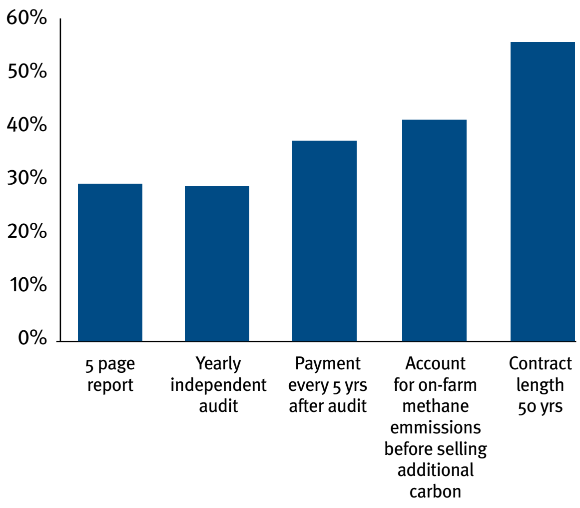

Figure 5. Percentage bid change under alternative rules

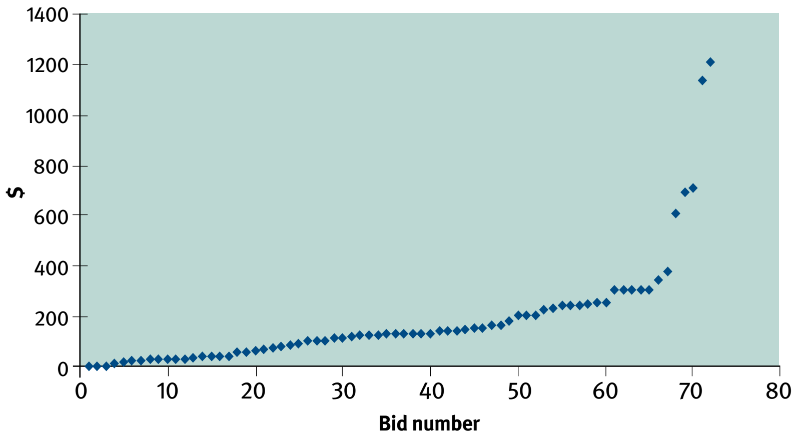

Figure 1. Carbon price per hectare of brigalow

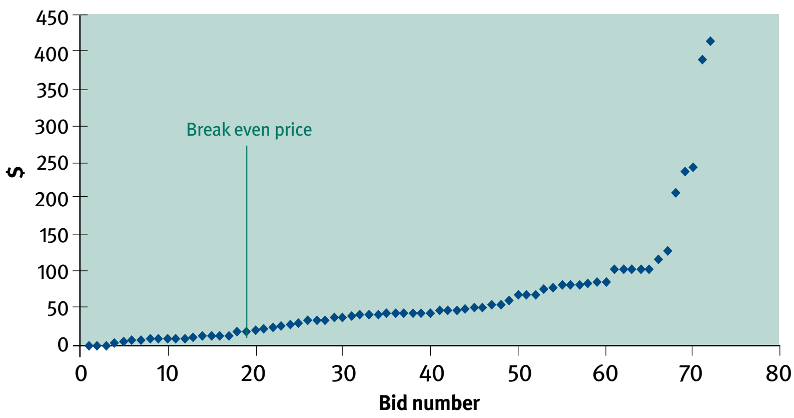

Figure 2. Carbon price per tonne CO_2-e of brigalow

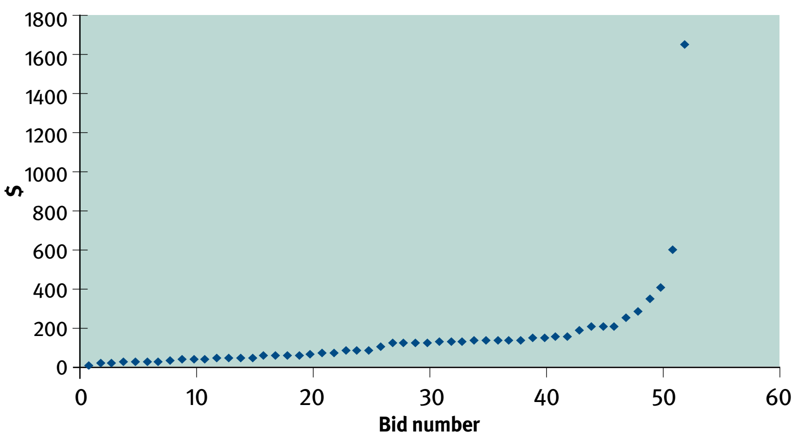

Figure 3. Carbon price per hectare of ironbark

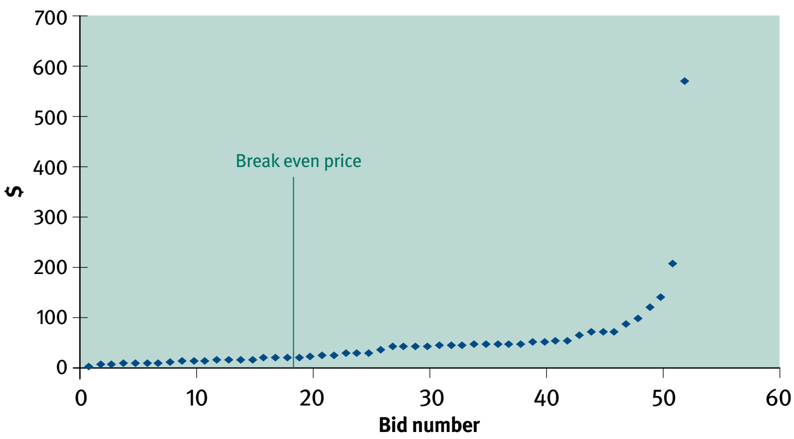

Figure 4. Carbon price per tonne CO_2-e ironbark

Comments recorded by participants at the auction highlighted concerns over the length of the contract, the possibility of rules changing in the future and liabilities associated with losses due to fire, for example:

> *'Reluctant to enter scheme due to threat of fire (having to pay money back); what will happen at completion of contract? Changing government legislation; uncertain where it will end'*

Under all alternative contract conditions tested the rates of participation fell significantly compared to the original conditions. Table 11 shows the percentage of participants with a less than 50 per cent likelihood of participating under each alternative condition. It is significant to note that the inclusion of methane emissions in accounting had the greatest impact on participation; however contract length had the greatest impact on bid levels.

Bid prices for the brigalow and ironbark land-types were analysed using an independent samples t-test. At the 5% level of significance there was found to be a significant difference between the average bid price for brigalow and ironbark areas. This can be partly explained by the difference in opportunity costs (reduction in cattle income) on different land types. It may also be explained by the perception that brigalow land will continue to appreciate in land value. However, there was no difference in bids received for areas of brigalow which could support a higher stocking rate than those which could support only a lower stocking rate.

The results were also analysed using multiple regression analysis to examine any relationships between bid prices and participant characteristics. The regression analysis showed that level of education and brigalow areas were positively and significantly related to bid level. This means that as education levels increase, so do bid levels. It was also found that the larger the area supplied, the higher the bid per hectare demanded.

Participation rate rose with participants' education level but fell for brigalow areas and areas with a higher stocking rate. There was no significant relationship between bid level and stated participation rate which indicates that some landholders would not participate regardless of the level of payment offered.

Table 11. Percentage of participants with a less than 50% likelihood of participating

	Original	5 page report	Yearly independent audit	Payments every 5 yrs after audit	Account for on-farm methane emissions	Contract length 50 yrs
Brigalow	38%	63%	61%	68%	83%	75%
Ironbark	23%	73%	75%	77%	94%	85%

7 Discussion

The results of the initial examination of the economics of carbon sequestration on grazing lands indicated that even at low carbon prices, landholders would benefit from introducing a carbon enterprise into their business, assuming that they do not need to account for on-farm emissions. This economic analysis was extended in a further desk-top study 'The bioeconomic potential for agroforestry in northern cattle grazing systems' (Donaghy et al. 2009). Importantly, neither of these studies considered the risks in participating in a carbon offsets scheme nor includes a penalty for on-farm emissions or emissions from land-clearing. Any future requirement to account for on-farm emissions, including those from land-clearing would change these results significantly.

When the option of including a carbon enterprise into a cattle business was tested with producers in central Queensland several trends emerged. The first is that producers generally had a very low level of understanding of most concepts regarding climate change and emissions trading schemes. As a result many participants found it very difficult to complete the bid sheets. The biggest challenge to producers was to calculate the capital value implications of signing up to long term carbon sequestration contracts. Other factors such as education, land type, location and area offered were found to have an impact on participation and bid price, suggesting that incentives for landholders will vary by more than simply the opportunity cost of a carbon enterprise.

Returns from biosequestration on grazing land are highly sensitive to the carbon price. Initial desktop studies used a base carbon price of \$10 per tonne CO_2^{-e} and conducted sensitivity analyses at \$25 per tonne CO_2^{-e}. Results of the experimental auctions showed that less than 20% of producers indicated that they would enter a voluntary trading scheme at a carbon price of \$10 per tonne CO_2^{-e}. Of those producers who would enter the scheme at this price the average likelihood of participation was less than 50 per cent. These results and the results of testing the sensitivity of producers to alternative conditions suggest that at low carbon prices very few beef producers would be willing to voluntarily change their practices to sequester carbon. This is particularly true given the high degree of uncertainty regarding CPRS rules and implementation at the time of data collection.

Any market design for carbon offsets from grazing land should consider these factors. Also to be considered is the difference between average bid price received in experimental auctions and the breakeven cost of carbon which demonstrates the level of risk premium graziers are incorporating in their bids as a result of uncertainty regarding carbon scheme rules and the likelihood that rules may change in the future. Many landholders are distrustful of the permanency of laws after recent changes to native vegetation clearing laws. This concern may also have an impact on the likelihood of landholders to participate in government run programs. The magnitude of this risk premium is likely to fall if and when an emissions trading scheme is introduced in Australia and the rules of the carbon emissions framework applicable to agriculture are understood by industry.

The scenarios used in the workshops were based on the price which is set for the first year of the proposed CPRS and possible prices in subsequent years. However, there is a great deal of uncertainty regarding the level carbon prices may reach and in what time frame. In addition to uncertainty regarding payments for carbon credits, producers in the experimental auctions expressed significant concerns regarding the ability of current protocols to accurately measure emissions and sequestration, the cost of doing so, liability in the case of fire and the impact of participating in the CPRS on the capital value of their property. In order to achieve even a portion of the estimated potential carbon credits from grazing lands, contracts must be robust, measurement protocols accurate without being expensive and a level of certainty regarding future land use rules must be in place.

8 Conclusions and recommendations

The results of this project highlight a lack of knowledge amongst landholders regarding carbon offsets, the impact of a carbon emission trading scheme on their business and what the long term implications might be. This lack of knowledge is reflected in the diversity of bid prices received and the difference between these bid prices and the breakeven price of carbon calculated in the desktop studies. This risk premium is largely influenced by uncertainty over rules for carbon trading and the concern that rules may change after contracts are signed. This concern has been intensified by the recent experience of many landholders with changes to native vegetation clearing laws.

The economic analysis reported here suggests there is an opportunity to diversify income from grazing businesses depending on the final rules of an emissions trading scheme (ETS). However, participation is likely to remain low in a voluntary system until clarity is received on trading rules and contract frameworks.

This analysis assumed that graziers would not be required to account for emissions from livestock or routine clearing. However, if they were required to account for these emissions, most graziers would be net emitters and therefore worse off under an ETS. Under these conditions it is expected that regrowth clearing in central Queensland would largely cease, woodlands would thicken and livestock numbers would decrease.

It is recommended that the focus for future engagement with landholders be on assisting with estimation of on-farm emissions and sequestration potential and using the results of this to calibrate emissions calculators for the Fitzroy Basin. There should then be a focus on further understanding of how likely accounting and trading rules will affect the ability of landholders in central Queensland to supply carbon offsets. In addition landholders are in need of a reliable source of information on current voluntary carbon trading schemes, how they work, the advantages and disadvantages of each and the prices at which carbon is being traded under different rules.

The structure of the carbon reporting framework used to measure and report carbon emissions from agriculture will determine participation rates and influence bid prices. Additional research is required to test a broader range of reporting framework rules that those reported here.

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Appendix A

Bid card number 1 – Brigalow high density

Tree basal area:	8 m^2 ha
Current stocking rate:	1 AE: 8 ha (20 ac)
Paddock size:	500 ha (total property area: 5000 ha)
Pasture:	buffel
Water points:	1 trough
Fences:	Good condition
Location:	NOT in a priority area

Answer the following questions.

What action you would normally take in a paddock of this condition to continue grazing?
(e.g. blade-plough now, blade-plough in five years, no action)

____

____

How many hectares of this paddock would you include in the CSC? _________________________

How much would you wish to be paid to enter into a carbon sequestration contract (CSC)?
(Under the stated rules) $______________________/yr

How likely is it that you would participate given the stated rules of a CSC? (i.e. 100% - would definitely participate, 0% definitely would **not** participate) ___________________%

The stocking rate you would expect after 20 years (if under a CSC): _________________ha/head

Bid card number 2 – Brigalow low density

Tree basal area:	3 m^2 ha
Current stocking rate:	1 AE: 4 ha (10 ac)
Paddock size:	500 ha (total property area: 5000 ha)
Pasture:	buffel
Water points:	1 trough
Fences:	Good condition
Location:	NOT in a priority area

Answer the following questions.

What action you would normally take in a paddock of this condition to continue grazing? (e.g. blade-plough now, blade-plough in five years, no action)

____

____

How many hectares of this paddock would you include in the CSC? __________________________

How much would you wish to be paid to enter into a carbon sequestration contract (CSC)? (Under the stated rules) $______________________/yr

How likely is it that you would participate given the stated rules of a CSC? (i.e. 100% - would definitely participate, 0% definitely would **not** participate) ___________________%

The stocking rate you would expect after 20 years (if under a CSC): _________________ha/head

Bid card number 3 – Silver-leaf ironbark high density

Tree basal area:	5.3 m^2ha
Current stocking rate:	1 AE: 8 ha (20 ac)
Paddock size:	500 ha (total property area: 5000 ha)
Pasture:	buffel
Water points:	1 trough
Fences:	Good condition
Location:	NOT in a priority area

Answer the following questions.

What action you would normally take in a paddock of this condition to continue grazing? (e.g. blade-plough now, blade-plough in five years, no action)

____

____

How many hectares of this paddock would you include in the CSC? _________________________

How much would you wish to be paid to enter into a carbon sequestration contract (CSC)? (Under the stated rules) $______________________/yr

How likely is it that you would participate given the stated rules of a CSC? (i.e. 100% - would definitely participate, 0% definitely would **not** participate) ___________________%

The stocking rate you would expect after 20 years (if under a CSC): _________________ha/head

Bid card number 4 – Silver-leaf ironbark high density

Tree basal area:	2.7 m^2 ha
Current stocking rate:	1 AE: 8 ha (20 ac)
Paddock size:	500 ha (total property area: 5000 ha)
Pasture:	buffel/natives
Water points:	1 trough
Fences:	Good condition
Location:	NOT in a priority area

Answer the following questions.

What action you would normally take in a paddock of this condition to continue grazing? (e.g. blade-plough now, blade-plough in five years, no action)

____

____

How many hectares of this paddock would you include in the CSC? _________________________

How much would you wish to be paid to enter into a carbon sequestration contract (CSC)? (Under the stated rules) $______________________/yr

How likely is it that you would participate given the stated rules of a CSC? (i.e. 100% - would definitely participate, 0% definitely would **not** participate) ___________________%

The stocking rate you would expect after 20 years (if under a CSC): _________________ha/head

Auction 2 – Individual bid card

Nominate an area on your property, or a property you are familiar with, which you think would be suitable for a carbon sequestration contract. (At least 50 hectares)

Describe the area – it should be a paddock which has the potential for regrowth to occur

Area/paddock size			ha
Vegetation	Brigalow	______	%
	Ironbark	______	%
		______	
Last regrowth control	Pulled	______	Year
	Blade-ploughed	______	Year
	Graslan (or similar)	______	Year
			Year
Soil type		______	%
		______	%
		______	%
			%
Pasture	Buffel	______	%
	Speargrass	______	%
		______	%
			%
Condition	A	______	%
	B	______	%
	C	______	%
	D		%

Current enterprise (e.g. steers, breeders)

____

Current stocking rate _____________________

Expected future stocking rate under a CSC

____

How much would you wish to be paid for this carbon sequestration contract?

$ _________________ /yr

How likely is that you would participate given the stated rules of a CSC (100% - would definitely participate, 0% definitely would **not** participate) ______________%

How much would your bid and likelihood of participation change if the following rules were implemented?

(Assume all other rules remain the same, each possible rule change is independent)

Rule	Bid change (+/- %)	New Participation Rate
Example	double	20%
Yearly report 5 pages		
Yearly independent audit required		
Payments made every five years at completion of independent audit		
Landholders can only sell additional carbon after on-farm methane emissions accounted for.		
Contract length is 50 years		

Please list any other comments you have regarding the potential design of a carbon trading scheme for agriculture.

____

____

____

____

____

Appendix B

Mock auction carbon sequestration rules

Policy terms

– Landholders are not required to account for on-farm emissions, but may sell carbon sequestered on their land.

Under the terms of the Carbon Sequestration Contract the following management actions would be prohibited:

- mechanical clearing e.g. blade-ploughing, pulling, thinning
- chemical clearing e.g. Graslan etc
- stocking rates above current levels

Landholders would also be required to:

- implement a fire prevention plan (including firebreaks, control burning etc)
- implement a weed and pest control plan
- maintain land condition at or above current condition (ABCD framework)
- submit an annual 1-page report on progress/condition of sequestered land (including photo standard)

Contract terms:

- Carbon sequestration contracts will last for 20 years
- At the end of the 20 years the option will be available to renew the contract
- If property is sold the purchaser has the option to continue the contract. If the contract is terminated, the purchaser is responsible for any emissions released as a result of a change in management.

Payment schedule:

- Payments will be made annually at the completion of progress/condition report
- Independent audits will be carried out every five (5) years to ensure contract conditions are met.

Appendix C Farm level carbon calculators

Name	Region	Industry	Author	Date/ version	References	Comments	Website
Australian methodology for the estimation of GREENHOUSE GAS emissions and sinks	Australia	Beef, sheep, pigs, other livestock	AGO	2006		Standards for calculating GREENHOUSE GAS emissions from Australian agriculture	www.climatechange.gov.au
Beef LifeCycle calculator	Canada	Beef		Mar-07		Used with quantification protocol for reducing slaughter age of cattle.	
BeefGreenhouse	Australia	Beef, dairy, cropping	Richard Eckard, University of Melbourne	Version 5	National Greenhouse Gas Inventory Methodology, AGO.	Calculates farm emissions based on energy use, enteric methane and nitrous oxide from soil and animal waste. Also calculates carbon offsets from trees planted after 1990. Developed in Victoria for Victorian conditions. Some options for modifying for other states.	www.greenhouse.unimelb.edu.au/site/Tools.htm
CALM (Carbon accounting for land managers)	UK	Livestock and cropping	Country Land and Business Association	2008	IPCC, UNFCCC, UK GREENHOUSE GAS,	Calculates annual emissions and carbon sequestration for land-based businesses	http://www.calm.cla.org.uk/
Carbon calculator	NZ	Agriculture and horticulture	Lincoln University - Agribusiness and Economics Research Unit and Agrilink		IPCC methodology, NZ Greenhouse Gas Inventory July 2007 default values	Calculates on farm emissions	www.linwww.lincoln.ac.nz/carboncalculator
Carbon calculator	USA	Beef, dairy, pigs, horses	Soil Carbon Center, Kansas State University			Calculates value/amount of carbon, based on 0.5 kg CO_2/ha and $8/t CO_2	http://soilcarboncenter.k-state.edu/
Carbon credit calculator	Australia	Timber for Carbon, cattle	Bill Smart (Southern Cross PhD student)	2007		Calculates the carbon value of timber plantations	http://www.australianforestcorporation.com.au/CO2calc/
Carbon farmer	Any	Timber/ carbon plus agriculture	Hassall and Assoc	1.2		Software that helps users investigate the potential for storing carbon in plantations of trees and entering into a carbon trading market - BCA of alternatives i.e. beef and carbon	

Name	Region	Industry	Author	Date/version	References	Comments	Website
Carbon trading	USA					Calculates carbon stored in different types of forest at different ages	http://www.carbon.sref.info/estimating/calculator
C-Plan carbon calculator	Scotland	Beef, dairy, cropping, sheep, goats, pigs, deer, horses, poultry	Drew and Jan Coulter (Scottish Farmers)	2007	IPCC 2006	Farm level calculator based on IPCC guidelines	www.cplan.org.uk/calculator.asp
Farm carbon–NSW	NSW	Sheep, beef, feedlot	Agriculture Western Australia	1	National Greenhouse Gas Inventory Methodology, AGO.	Estimates farm level emissions using number of head, varied LWG over the year, includes fuel use, burning of crop stubble or pasture, soil disturbance, bush fire	
FarmGAS	Australia	Beef, grain	Australian Farm Institute	2009		Estimates the cost of on-farm emissions under the original CPRS policy	
Methane emissions	USA	Beef, dairy, pigs, horses	Soil Carbon Center, Kansas State University			Calculates methane emissions from livestock	http://soilcarboncenter.k-state.edu/
National Carbon Offset Coalition Inc	USA	Soil, cropping, forest, livestock				Calculates total sequestration for the farm, includes zone and sequestration rate maps	http://www.ncoc.us
Northern Australia methane estimator	Northern Australia	Beef	John Rolfe			Methane emissions calculator	

Appendix D BeefGreenhouse calculator

Sheet 1 – Introduction

The objective of this tool is to facilitate greenhouse gas emission accounting at a farm scale, identify the major sources of emission and explore the impact of changed management options.

By entering in some simple data, which most farmers are likely know, the model presents the user with a greenhouse gas emission profile for their farm. The model also then breaks down these greenhouse gas emissions into the various sources, and where they are coming from on the farm. The user can then conduct some "What if" scenarios, to explore the greenhouse gas impact of changes to farm management. For details on how to operate the model click the HELP box.

The model is based on the Australian National Greenhouse Gas Inventory method, as published on the Australian Greenhouse Office's web site - for more information, click on the link below:

www.greenhouse.gov.au

The three main greenhouse gasses emitted at a farm scale, in order or magnitude, are:

- Methane (CH_4)
- Nitrous oxide (N_2O)
- Carbon dioxide (CO_2)
- Tree Planting and Carbon Sequestration

To read more about these gasses, click on the hyperlinks above.

Methane (CH_4)

"Methane emissions from grazing farms are primarily sourced from:

1. Ruminant digestion (Enteric Methane)

"Enteric methane production is minimised by feeding high quality forages (perennial ryegrass/white clover pasture), particularly where the protein to energy ratio in the ration has been balanced through supplementary feeding strategies (i.e. beef cows in the outback produce more methane than dairy cows in Victoria).
"

"Strategies to reduce enteric methane include:

1. Intensification

Feeding livestock high digestibility feed such as grain or high quality pasture increases milk production per cow and reduces methane emissions per unit of production (i.e. more efficient production).
"

"2. Rumen Modifiers

Monensin is one of the only products shown to be consistently effective in reducing rumen methane emissions, with reductions either only slight to approximately 25 %. However, investigations indicate that the decrease in methane production may be short-lived.
"

"The use of antibiotics in ruminant feeds has recently been reviewed, with the JETACAR report concluding that there is evidence that bacterial resistance in livestock may result in resistance to antibiotics in human medicine. If changes

are made to current registrations it is possible that some antibiotics will no longer be an option to modify methane emissions from ruminants.
"
"3. Dietary Fats
Additions of unsaturated fatty acids to ruminant diets may reduce methane by up to 40% i.e. 7% linseed oil may result in a 37 % reduction in methane emission.
"
"4. Carbohydrate type
The type of carbohydrate fermented in the rumen influences methane production. Beef production systems based on temperate perennial ryegrass/white clovers pasture will produce less methane than beef fed on rangeland.
"
"5. Forage Processing
Grinding and pelleting of forages can markedly decrease methane production. At high intakes, methane loss/unit of diet can be reduced 20-40 %. Increased rate of passage of the ground or pelleted forage is the likely cause of the reduced methane production.
"
"6. Defaunation
In the absence of protozoa, rumen methane emissions are reduced by an average of 20 %, and it is likely that cattle will produce more meat and milk. No commercial defaunating agents are registered in Australia and further research is required to develop these.
"
"7. Acetogens
Acetogens are rumen microbes that convert carbon dioxide (CO2) and hydrogen gas (H2) to acetate, an energy source for the cow, while methanogens form methane, a waste product, from the same basic compounds. Research is underway in New Zealand to investigate the possibility of replacing methanogenic microbes with acetogenic microbes.
"
"8. Vaccination
Methanogens are antigenetically distinct from other organisms in the rumen allowing a vaccination approach to the reduction of methane production by rumen methanogens. The CSIRO is working on a vaccination with on-farm trials currently underway.
"
"Conclusions
Many of the opportunities to reduce methane emissions eg fat supplementation, increased grain feeding, high per animal production etc are not complementary to low cost and extensive grazing systems. If the current industry focus on per hectare production at the expense of high per animal production continues, new technologies to reduce methane emission per animal will be a necessity if Kyoto Targets are to be met. The current technologies which offer the most potential are defaunating agents (including vaccination) and promoting natural populations of ace to genic bacteria in the rumen.

For more information contact the authors or refer to the Australian Greenhouse Office web site."
Nitrous oxide (N2O)

Agricultural N2O emissions sourced primarily from:
- N fertiliser management
- Soil cultivation
- Urinary deposition

And to a lesser extent from:
- Effluent management
- Burning of grassland and agricultural residues (i.e. stubble and trash).

Nitrous oxide emissions from soil, fertiliser and urine are largely a product of denitrification of soil nitrate, with N2O also emitted to a lesser extent during nitrification as well. Denitrification is largely driven by a high labile soil carbon content, available soil nitrate, soil temperature and water filled pore space (as an index of anaerobicity). In other words, denitrification rate, and thus N2O emissions, are maximised in warm and waterlogged soils, with liberal soil nitrate present. However, at this stage, the National Greenhouse Gas Inventory methodology used in this model does not allow us to differentiate between irrigation and dryland grazing at this stage. It is envisaged that this will be included in later updates.

"Best Management Practices are available from that aim to both minimise the environmental impact of, while optimising the economic response to N fertiliser:
"
www.greenhouse.unimelb.edu.au

Carbon dioxide (CO2)

Agriculture as a whole does not contribute significantly to direct CO2 emissions, which would be mainly from electricity use and fossil fuel consumption (diesel), emitting less than 3.6% of national energy sector emissions or between 6 and 9% of farm emissions.

What about planting trees?

To allow users to explore the value of planting trees, an option is included in the model to choose the type of trees and the rainfall zone, with the total carbon removed by trees being subtracted off the farm greenhouse gas emission total. Remember, this is a guide only, as actual tree growth depends on the local growing conditions and the carbon sequestered varies with the age of the plantation. For a more accurate estimation of actual carbon sequestration use the CAMFOR model, available at www.greenhouse.gov.au or refer to a local forestry consultant.

There may well be opportunities to use unproductive or marginal agricultural land for tree planting. In this case, the area could then be used for:

Firewood – if you grow it, you can burn it at no net increase in carbon emission.

Timber – if you use the timber for building or furniture, you may still be able to sell around 1/3 of the carbon credit (i.e. 2/3 of the wood ends up back in the environment through harvesting and milling).

Carbon credit trading – if you locked up the carbon in a forest planted after 1990 and keep it there, you should be able to sell this carbon to someone who plans to increase their carbon emissions, particularly where the cost of cleaning up their emissions directly may be prohibitive. Remember, that once a forest reaches maturity it will decay as fast as it grows and you will need a new area of forest thereafter to continue locking up carbon.

"In high rainfall zones (above 750 mm) Pinus Radiata can sequester between 11 and 25 tonnes CO2 /ha per year, while Eucalyptus nitens (Shinning Gum) can sequester between 18 and 40 tonnes CO2 /ha per year. While pine and eucalypt plantations can sequester significant amounts of carbon, to offset the total emissions from a grazing farm would take about 25% of the farm, assuming a fast growing hardwood in a high rainfall zone. The accounting framework allows you to explore this further for a particular property.

Other sources of information include the AGO's Bush for Greenhouse program (Field Measurement Procedures for Carbon Accounting), and the Greenhouse Challenge Greenhouse Sinks Workbook."

HELP

1. Cells with blue text are for data input
2. Cells with black text cannot be changed as these either report outputs, or are formulas required by the model.
3. If you are unsure of what to enter into a cell, hold your mouse over the small red tag
in the top right hand corner of the cell and a help box will appear.
4. The screen sizes and text have been set for 1024 x 768 resolution. As individual computers have different screen resolutions
if the text on a screen is tool small then adjust the View/Zoom % to suit.
5. When you insert your own data into the model, the annotations on the pie charts will change and may need to be manually moved
in order to be readable. To do this click your mouse on the pie chart and then click on each annotation until just that box is selected.
The annotation can then be moved, using the mouse, to a new location.
6. If you need to unprotect that cells, use Control-U to unprotect and Control-P to protect that sheet.

Sheet 2 – Data input

Beef Grazing - Greenhouse Accounting Tool

State: QLD

Farm Name: Torilla

Herd Information	Bulls >1	Bulls<1	Steers<1	Cows 1 to 2	Cows >2	Cows<1	Steers>1	Units
Livestock Numbers	10	10	200	200	300	100	100	
Liveweight	800	178	178	350	505	168	396	kg LWt
Live weight gain	0.20	0.97	0.97	0.49	0.08	0.94	0.45	kg /day
Crude Protein	7.6	7.6	7.6	7.6	7.6	7.6	7.6	%
DMD	52.5	52.5	52.5	52.5	52.5	52.5	52.5	%

Note: Click on the links above to

Area Improved Pasture	0	ha
Area cropped	0	ha
Nitrogen Fertiliser Pasture	0	
Nitrogen Fertiliser Crops	0	kg N/ year
Annual Diesel Consumption	9000	litres/year
Annual Electricity Use	12774	KWh
Power Source	Black Coal	
Area of Trees Planted after 1990	1	hectares
Type of Trees planted	Low	
Rainfall	Low (<500)	

Note: Enter the farm areas here

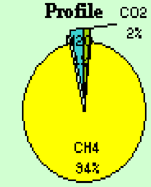
Note: Enter the energy use

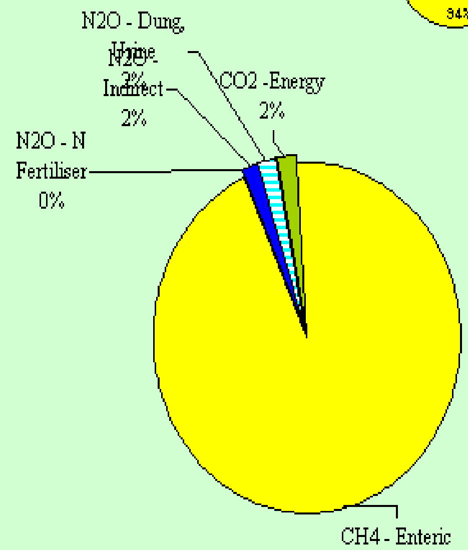
Outputs	t CO2e/farm
CO_2 - Energy	38
CH_4 - Enteric	**1,762**
N_2O - N Fertiliser	0
N_2O - Indirect	33
N_2O - Dung, Urine	35
Tree plantings (after 1990)	-1
Net Farm Emissions	**1,866**

Summary	t CO2e/farm
CO_2	38
CH_4	1,762
N_2O	68

56

Greenhouse Gas Profile





Richard Eckard (2008) Beef Greenhouse Accounting Framework. Updated Nov 2008.
www.greenhouse.unimelb.edu.au/site/Tools.htm

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Victoria The Place To Be

Sheet 3 – Data

Enter your farm data for each animal class and season

Choose your region in Australia

QLD

		Bulls >1	Bulls<1	Steers<1	Cows 1 to 2	Cows >2	Cows<1	Steers>1
Livestock Numbers	Spring	10	10	200	200	300	100	100
	Summer	10	10	200	200	300	100	100
	Autumn	10	10	200	200	300	100	100
	Winter	10	10	200	200	300	100	100
	Average	10	10	200	200	300	100	100
Liveweight (kg per animal)	Spring	800	100	100	270	490	90	290
	Summer	800	150	150	350	490	140	390
	Autumn	800	220	220	390	520	210	440
	Winter	800	240	240	390	520	230	465
	Average	800	177.5	177.5	350	505	167.5	396.25
Live weight gain (kg/day)	Spring	0.3	1.21	1.21	0.43	-0.5	1.17	0.36
	Summer	-0.10	1.21	1.21	0.86	0.20	1.17	0.86
	Autumn	0.50	1.21	1.21	0.42	0.50	1.17	0.42
	Winter	0.10	0.25	0.25	0.25	0.10	0.25	0.16
	average	0.2	0.97	0.97	0.49	0.075	0.94	0.4475
Crude Protein (%)	Spring	7.25	7.25	7.25	7.25	7.25	7.25	7.25
	Summer	11.09	11.09	11.09	11.09	11.09	11.09	11.09
	Autumn	8	8	8	8	8	8	8
	Winter	4	4	4	4	4	4	4
	Average	7.585	7.585	7.585	7.585	7.585	7.585	7.585
DMD (%)	Spring	20	20	20	20	20	20	20
	Summer	40	40	40	40	40	40	40
	Autumn	60	60	60	60	60	60	60
	Winter	90	90	90	90	90	90	90
	Average	52.5	52.5	52.5	52.5	52.5	52.5	52.5

Figures for Liveweight, Liveweight gain, Crude Protein and Dry Matter Digestibility (DMD) are estimates only. If you have more accurate information available, it can be inserted in the green cells.

Sheet 7 – Trees

Carbon sequestration potential of trees

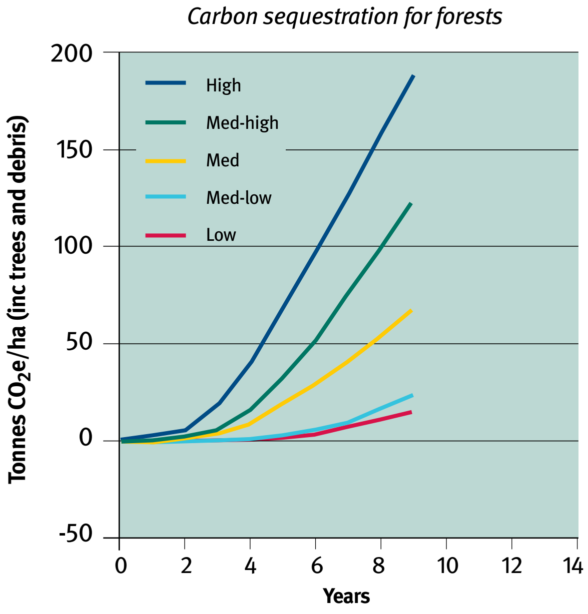
Years	0	1	2	3	4	5	6	7	8	9
High	0	2	5	19	41	68	98	128	159	188
Med-High	0	0	1	5	16	32	52	75	98	122
	0	0	1	5	10	19	29	41	54	68
Med-Low	0	0	0	0	1	3	6	10	16	23
Low	0	0	0	0	1	2	4	7	11	16
Years	10	11	12	13	14	15	16	17	18	19
High	217	244	269	293	316	333	356	374	391	407
Med-High	146	169	191	213	234	254	272	290	306	322
Med	83	99	115	131	147	163	179	196	211	227
Med-Low	32	42	53	65	78	91	104	118	132	146
Low	21	28	35	43	52	60	69	78	87	97
Years	20	21	22	23	24	25	26	27	28	29
High	422	436	449	461	472	482	492	502	510	518
Med-High	337	351	364	377	388	399	410	420	430	439
Med	242	258	273	287	301	316	329	343	356	369
Med-Low	159	173	187	201	214	228	241	254	267	279
Low	106	115	124	133	142	151	160	168	177	185

Counter		Rainfall mm/yr	from m3/ha/yr	to	weight dry-tonne/m3	C content	from t CO2e/ha	to
1	**Softwoods: (select below)**	600	15	30	0.43	50%	11.9	23.9
2	Pinus Radiata - Pine	600	15	30	0.43	50%	11.9	23.9
3	**Hardwood: (select below)**	775	15	32.5	0.63	0.5	17.4825	37.87875
4	Eucalyptus globulus - Blue gum	700	15	35	0.63	50%	17.5	40.8
5	Eucalyptus nitens - Shinning gum	800	15	35	0.63	50%	17.5	40.8
6	Eucalyptus saligna - Sydney blue gum	800	15	30	0.63	50%	17.5	35.0
7	Eucalyptus grandis - Rose gum	800	15	30	0.63	50%	17.5	35.0
8	Comybia maculata - Spotted gum	600	8	20	0.63	50%	9.3	23.3
9	CQ Eucalyptus (poplar box, narrowleaf ironbark, silverleaf ironbark)	700	3	3.25	0.63	50%	3.5	3.8
10	Brigalow	700	1.8	3.28	0.63	50%	0.8	6.1
11	**Speciality Hardwoods (select below)**	530	3	8.8	0.63	0.5	3.5	10.2564
12	Acacia melanoxylon - Blackwood	750	4	10	0.63	50%	4.7	11.7
13	Eucalyptus camaldulensis - River red gum	500	5	10	0.63	50%	5.8	11.7
14	Eucalyptus sideroxylon - Ironbark	500	2	8	0.63	50%	2.3	9.3
15	Eucalyptus cladocalyx - Sugar gum	400	2	8	0.63	50%	2.3	9.3
16	Casuarina cunninghamiana - She oak	500	2	8	0.63	50%	2.3	9.3

Rainfall Selection	t CO2e/ha
High (>700)	FALSE
Med (500 - 700)	FALSE
Low (<500)	0.77

Results

0.8	6.11
	0.77


Carbon sequestration for forests
200
150
100
50
0
-50
High
Med-high
Med
Med-low
Low
0
2
4
6
8
10
12
14
Years
Tonnes CO2e/ha (inc trees and debris)

Definitions

Anaerobic lagoon	Manure in a liquid form is stored in such a way as to create anaerobic conditions. Typically, almost all of the available organic matter of the waste will be converted into methane in the anaerobic situation. In order to prevent emissions escaping into the atmosphere, it is possible to cover these lagoons, collect the methane gas produced and burn it as a renewable fuel.
Dry matter	In this inventory, dry matter refers to plant biomass which has been dried to an oven dry state. Dry material which is only air dry may contain up to 15% moisture.
Enteric fermentation	Refers to the process in animals by which gases, including methane, are produced as a by-product of microbial fermentation associated with digestion of feed. Enteric fermentation occurs in both non-ruminant omnivores (e.g. pigs) and herbivores (e.g. horses), but is pronounced in ruminant animals (e.g. sheep and cattle) where microbial activity in the rumen (fore-stomach) and caecum produces comparatively large quantities of methane.
Feed energy measurements	
Gross energy	Expresses the total energy in the feed consumed by an animal before energy loss through digestion, absorption or excretion. An average value for the gross energy content of feed is 18.4 MJ/kg dry matter.
Digestible energy	Consists of all energy consumed in feed less the energy in the faeces produced from that feed.
Metabolizable energy	Consists of digestible energy less the energy in urine and combustible gases.
Net energy	Consists of metabolizable energy less the energy lost in the generation of heat. Net energy, therefore, represents that portion of ingested energy that actually appears as a product viz. milk, body tissue and/or work
Greenhouse gases	Include carbon dioxide (CO_2), water vapour, methane (CH_4), nitrous oxide (N_2O), oxides of nitrogen (NOx), carbon monoxide (CO), non-methane volatile organic compounds (NMVOC), fluorocarbon (FC) species, and sulphur oxides (SOx).
Liveweight	The estimated weight of an animal at the time of census each year or an estimate of weight by season. For sheep this is considered to be the fleece free weight.
Liveweight gain	An estimate of the expected weight gain of an animal in a particular class of livestock over a season or year, expressed in kilograms per day. Where climatic conditions are particularly harsh and where feed quality is poor, liveweight loss will occur.
Maintenance	The term usually refers to the feed energy required to keep an animal in energy equilibrium i.e. the state in which there is no gain or loss of energy by the body tissues. For the purpose of this inventory energy maintenance is assumed to be equivalent to liveweight maintenance. Manure: Is the animal waste, both faeces and urine, collected from yards and barns. Only the faecal component of manure is capable of producing methane.

Methane Conversion Factor (MCF)	Is defined by the IPCC (1995) as an estimate of the portion of the methane-producing potential of waste that is achieved. MCFs vary according to the negative impact different waste management systems and climatic conditions have on realising this potential, theoretically ranging from 0-100%. Manure managed as a liquid under hot conditions promotes methane formation and emissions and would have a high MCF value. Manure managed as dry material in cold climates does not readily produce methane and consequently has a lower MCF.
Season	Defined in terms of calender seasons Spring - September, October, November. Summer - December, January, February. Autumn - March, April, May. Winter - June, July, August) rather than climatic seasons (i.e. in northern Australia, summer is often defined as January, February and March mirroring the wet season).
Afforestation, reforestation and deforestation	Afforestation is defined as the direct human induced establishment of new forests (trees and woody vegetation) on lands which historically have not contained forests. New forests established by afforestation must cover a minimum area of 1 hectare with a minimum stand width of 10 metres. Potential canopy cover at maturity under current management practices is not less than 20% Reforestation is defined as the direct human induced establishment of forests (trees and woody vegetation) on lands which historically have previously contained forests but which have been converted to some other use. Prior to reforestation, the land must have been under some non-forest use for a period of not less than 5 years. New forests established by reforestation must cover a minimum area of 1 hectare with a minimum stand width of 10 metres. Potential canopy cover at maturity under current management practices is not less than 20%. Confidence level refers to the confidence which can be placed on the estimates of greenhouse gas emissions and associated data. It is described using three tiers: High, Medium and Low. The High confidence level means that the estimate has an associated uncertainty of less that 20% of the value of the estimate. The Medium confidence level means that the estimate has an associated uncertainty of between 20 and 80% of the value of the estimate. The Low confidence level means that the estimate has an associated uncertainty of greater than 80% of the value of the estimate. When an uncertainty is greater than 80%, it is expressed as a multiplicative range, i.e. an uncertainty of a factor of 2 means that the true value is likely to lie somewhere between one half and two times the estimated value. The uncertainty of an estimate is the reciprocal of the confidence of the estimate. e.g. High confidence corresponds to low uncertainty and vice versa.

Sheet 10 – Conversion factors

Conversion factors used

kilo (k) = 103 (thousand)

mega (M) = 106 (million)

giga (G) = 109 (billion)

tera (T) = 1012

peta (P) = 1015

One gigagram (Gg) equals one thousand tonnes, or one kilotonne (kt). One million tonnes or one megatonne (Mt) is equal to one thousand gigagrams. One kilogram per gigajoule (kg/GJ) is equal to one gigagram per petajoule (Gg/PJ).

Conversions

Conversion values adopted in the workbook are:

Energy Content of Feed Dry Matter (SCA 1990) = 18.4 MJ/kg

Energy to Mass Conversion for Methane (Brouwer 1965) = 55.27 MJ/kg CH_4

Density of Methane at 25°C: signified by the symbol (□) = 0.662 kg/m^3

Factor for converting nitrogen into crude protein = 6.25

Sheet 11 – Abbreviations

ABS	Australian Bureau of Statistics
ADC	Australian Dairy Corporation
AIAS	Australian Institute of Agricultural Science
AFIC	Australian Feeds Information Centre
AFRC	Agriculture and Food Research Council
ALFA	Australian Lot Feeders Association
AMLC	Australian Meat and Live-stock Corporation
ARC	Agriculture Research Council
CH_4	Methane
CO	Carbon monoxide
CO_2	Carbon dioxide
CP	Crude protein
CSIRO	Commonwealth Scientific and Industrial Research Organisation
D	Digestibility
DEST	Department of the Environment, Sport and Territories
DM	Dry matter
DMA	Dry matter availability
DMD	Dry matter digestibility
EBG	Empty body gain
EVAO	Estimated value of agricultural operations
FC	Fluorocarbon
GE	Gross energy
IPCC	Intergovernmental Panel on Climate Change
LWG	Liveweight gain
MCF *	Methane conversion factor
N_2O	Nitrous Oxide
NGGI	National Greenhouse Gas Inventory
NMVOC	Non-methane volatile organic compounds
NOx	Nitrogen oxides
OECD	Organisation for Economic Cooperation and Development
SCA	Standing Committee on Agriculture
SOx	Sulphur oxides
SRW	Standard reference weight
VS	Volatile solids
□	Density of methane

*Is defined by the IPCC (1995) as an estimate of the portion of the methane-producing potential of waste that is achieved. Williams (1993) recently measured methane production from dairy cattle manure under field conditions in Australia and found that only about 1% of the methane production potential was achieved. On this basis, MCF values for faeces voided in the field were reduced to 1% from the IPCC (1995, vol. 3) default value of 1.5%.