ESTIMATING CARBON BUDGETS

- *Project Outline* -

Property Carbon Budgeting in Central Queensland Report No. 1

Central Queensland University, Emerald
2001

Rolfe J.

Australian Greenhouse Office
The lead Commonwealth agency on greenhouse matters

Desert Uplands

Centre for Environmental Management

Central Queensland University
Where Students Come First

Stanwell Corporation Limited

Queensland Government

V1002346668

Estimating Carbon Budgets - Project Outline

Report 1 - Property Carbon Budgeting in Central Queensland#

John Rolfe

Centre for Land and Water Resource Management
Central Queensland University
P.O. Box 197
Emerald 4720
Ph 07 4980 7081
Fax 07 4982 2031
Email: j.rolfe@cqu.edu.au

ABSTRACT

The issue of greenhouse gas emissions remains topical in Australia as debate continues over the Kyoto Protocol. The debate is relevant to the grazing industry in the Central Queensland region because properties are both sources and sinks for greenhouse gases. The main sources of emissions are clearing vegetation, cultivating soils, and running beef cattle. The main ways of preventing emissions are to protect remnant vegetation from being cleared. Sinks can generated by allowing regrowth or vegetation thickening to occur.

While there is ongoing work to measure carbon emissions at a national level, there has been little work to estimate emissions and sinks at the property level. This information will be important if landholders were to ever become more responsible for reducing emissions or sequestering carbon. If carbon offsets were ever to become possible for some land management options, then measurement and verification of carbon stocks at the property level will become very important.

A collaborative project has been established to provide some estimates of carbon budgets on grazing properties in the Central Highlands and Desert Uplands regions of Central Queensland. Key funding comes from the Greenhouse Challenge program of the Australian Greenhouse Office. The partners in the project include two of the key stakeholder groups involved in regional planning and natural resource management issues, being the Desert Uplands reg and the Central Highlands Regional Resource Use Planning Project. Other partners in the project include the Stanwell Corporation, Central Queensland University, the Department of Natural Resources and the Department of Primary Industries.

In this preliminary report, an outline of some of the issues involved in the project is presented, together with an overview of the possible ways that might be used to estimate and verify carbon stocks.

Acknowledgement is made of the helpful comments of Rajesh Jalota and Paul Thomas in preparing this report.

1. INTRODUCTION

The issue of greenhouse gas emissions is significant for grazing enterprises in Central Queensland. There are several reasons for this, but the principal one is that many enterprises are significant emitters of greenhouse gases. Emissions come from three main sources. Methane is emitted from cattle and sheep as a natural by-product of the animals digesting grass in the rumen. Fossil fuels such as petrol and diesel release carbon dioxide and other greenhouse gases into the atmosphere. Greenhouse gases are released from the breakdown of timber when vegetation is cleared, and from soils under certain farming or grazing practices[1]. In total across Australia, these operations mean that agriculture is responsible for about one-third of greenhouse gas emissions.

Australia has taken some steps towards accounting for greenhouse gas emissions and reducing the growth in these emissions. A National Greenhouse Gas Inventory (NGGI) has been established to provide estimates of emission levels over time, with scientific work continuing to refine those estimates. The Australian Greenhouse Office has been established, and through the Greenhouse Challenge program, partnership agreements with industry have been sought to reduce emission levels. These voluntary agreements have been effective in reducing the growth in projected emissions in the next decade, but not enough

Australia is a signatory to the Kyoto Protocol, which is an international agreement that limits growth in emissions to the 2008 – 12 period for Australia to 108% of the 1990 levels. While the Kyoto Protocol still has to be ratified to be binding, and there are some uncertainties about whether this step will be formalised, it remains likely that some emission reduction targets will still apply. Significant reductions in emissions would now be necessary to meet the Kyoto target, as emissions in Australia passed that target level in 1996. This means that the search for opportunities to reduce emissions are likely to continue. Agriculture, as a major contributing sector, is likely to become involved in this process.

To date, the focus of the Commonwealth Government, through the Greenhouse Challenge program, has been to search for win-win situations where emission reductions go hand in hand with improved profitability. This can occur in a large manufacturing plant, for example, where improved plant efficiency can cut power usage, therefore saving on costs and greenhouse gas emissions at the same time. Many of the participants in the Greenhouse Challenge program are larger companies that are involved in power generation, transport and manufacturing sectors, where there have been opportunities to find greater efficiencies.

There has been little involvement with agricultural enterprises in the Greenhouse Challenge program. There are a number of good reasons for this. Agriculture is comprised of large numbers of small and medium sized enterprises, in contrast to the small numbers involved in the industrial sectors. This will add substantially to negotiation and transaction costs. As well, many of the emission processes in agriculture are poorly understood, difficult to measure, and highly variable at a property level scale. This raises problems about the identification and verification of possible emission reductions on property. In contrast, reductions are much easier to measure and verify for industries, as it is relatively straightforward to estimate falls in the consumption of items like electricity and fuel.

[1] Carbon is also sequestered on most properties through pasture and vegetation growth, and vegetation thickening. Sequestration and release often occur simultaneously on the same property.

The emphasis on major industrial companies has also occurred because highest rates of growth in emissions are taking place in areas such as power generation and transport. In contrast, emissions from agriculture are only growing slowly. Although the difficulties in involving agriculture have meant that little burden has been placed on enterprises to find emission reductions, this is unlikely to continue. Low returns in some agricultural sectors means that it may be cheaper to reduce emissions in this sector than in others. If Australia has to search harder to find ways of reducing emissions, more attention may be focused on the agricultural sector.

There are three main reasons why agricultural enterprises need to become more involved in the debate. The first is that the industries have some vested interest in seeing Australia meet the Kyoto target. Australian agriculture may be one of the major losers from any future climate changes, and export industries may suffer if there were any international repercussions about Australia not meeting its targets.

The second reason why agriculture should be involved in searching for potential reduction measures is that it may help to avoid the potential use of government penalties or regulations to achieve emission reductions. Because the costs of individual negotiations are going to be high with the agricultural sector, there will always be some argument for direct controls to be used as a way of achieving emission reductions. To counter this, agricultural industries will need demonstrate where some improvements are automatically occurring, and where there are potential for other reductions to be made.

The third reason why agriculture should be involved is that there may some potential for incentives to be paid to reduce emissions or to provide offsets. Under these scenarios, forms of emissions trading or carbon offset trading schemes could mean that industries purchase sequestration benefits from landholders who are able to provide them. Some of the ways that landholders might provide these benefits might be through establishing plantations or reducing the numbers of livestock that are run. While many of the potential ways of reducing emissions may not be cost-effective or easily verifiable, there may be some opportunities for flexible trading mechanisms to be developed.

One of the major components of emissions from agriculture is carbon dioxide emissions relating to vegetation change. This is particularly relevant to the Central Queensland region, because vegetation is often cleared to maximise production. Clearing vegetation allows carbon to be released into the atmosphere, while allowing vegetation to regrow or thicken means that carbon is sequestered. However, little work has been done to estimate emissions at the property level, and identify opportunities for landholders to reduce emissions.

This report is structured as follows. In the next section of the report the potential sources and sinks of carbon on properties in the Central Queensland zone are identified. In section three, issues involved in estimating these influences for a property carbon budget are discussed, and some implications for reducing net carbon emissions are outlined in section four. Conclusions are presented in section five.

2. EMISSIONS FROM THE RURAL SECTOR

In order to assess the Australian position on greenhouse gas emissions, an inventory on national emissions has been developed. This inventory follows the broad guidelines established by the United Nations Framework Convention on Climate Change (FCCC), and includes six groups of gases within emissions. Carbon dioxide is the most prominent greenhouse gas, and accounts for approximately 71% of Australia's emissions. Methane and nitrous oxide are the other important emissions from Australia, accounting for 24% and 5% respectively of emissions. Emissions are usually assessed in tones of carbon dioxide equivalents to reflect a common measuring standard.

The inventory systems also classifies sources of emissions into six broad categories, being:

- Energy
- Industrial processes,
- Solvents and other product use
- Agriculture,
- Land use change
- Forestry and waste.

On an international scale, Australia is a minor contributor, accounting for approximately 1.4% of 38 billion tones of emissions worldwide. On a per capita basis though, Australian emissions are very high, particularly in relation to methane emissions. This is due to a number of factors, including Australia being a highly developed, industrialized country with a small population in large land mass. As well, energy generation in Australia relies predominantly on fossil fuels, with no nuclear generation and limited hydro generation.

A summary of emissions for 1990 and 1995 is set out in Table 2. It is notable that the Energy sector is not only the largest contributor, but is also the sector reporting the highest rate of increase. Although there has been substantial effort put into reducing emissions from this sector with programs such as the Greenhouse Challenge establishing voluntary reduction agreements, and the Commonwealth Government setting minimum levels for power generation from renewable sources, substantial growth is still anticipated to the 2008-12 period. It appears likely that the steps already taken in Australia to reduce emissions levels have lowered the projected increases to the 2008-12 period (from the base 1990 level) from more than 40% down to around 28%.

Agriculture is the next highest emitting sector, with methane emissions from livestock being the major contributor. This is followed by the Land Use Change sector, which is comprised of a number of elements, including forestry. Some land uses (such as clearing vegetation) contribute to emissions, while others (forestry, pasture establishment) act to sequester carbon, and thus are offsets.

It is notable that the combined emissions from the Industrial Processes and Waste sectors were only 5.2% of total emissions. Agriculture and the non-forestry components of land use change contributed 34% of total emissions in 1995. This suggests that the Energy, Agriculture and Land Use Change sectors are the key ones for Australia to focus on if growth in national emissions is to be reduced significantly.

The Land Use Change sector comprises several key areas, as demonstrated in Table 2. One of the most important is Forestry, because this offers an opportunity in Australia (and overseas) for carbon to be sequestered from the atmosphere as forests grow and more areas are planted. However, there are three issues that reduce the appeal of forestry as away to off set green house gas emissions. The first is that if forests are eventually harvested, then quite a high proportion of the biomass may become waste, and return to the atmosphere. The second is that forests are slow to sequester carbon in early growth stages, meaning that there are significant time lags between planting and major sequestration. The third is that establishing forests is expensive, and there are limits on suitable land in high rainfall areas in Australia.

Table 2. Greenhouse Gas Emissions 1990, 1995 and 2010.

Sector	1990	1995	2010	% Change
	(reported)	(reported)	(forecast)	(2010 v 1990)
1. All Energy				37
1A. Energy – fuel combustion	267.3	291.7	373.4	40
1B. Energy – fugitive emissions	26.0	25.6	29.2	12
2. Industrial processes	12.1	9.0	12.1	0
3. Solvents	NRS	NRS	NRS	
4. Agriculture	88.8	87.4	94.9	7
5. Land use change & Forestry				
5A. Forestry	-23.1	-21.1	-32.8	-42
5B and 5C	122.6	84.6	Not predicted	Not predicted
5D	-6.3	-6.5	Not predicted	Not predicted
6. Waste	14.8	16.4	17.2	16
Total without Land use change	**385.9**	**408.9**	**494**	**28**
Total with Land use change	**502.2**	**487.0**	**Not predicted**	**Not predicted**

Units are in million tones of CO_2 equivalent

Source: Australia's Second National Report to UNFCCC, Nov 1997.

NRS = Not Reported Separately (solvent emissions included in other categories)

5B = forestry and grassland conversion

5C = abandonment of managed lands

5D = carbon removal from pasture improvement

The second key area of the Land Use Change category is where carbon is lost from tree clearing, grassland conversion or land management activities. This was a major component of Australia's emissions in 1990 because clearing rates of native vegetation were high at this stage. Gains from regrowth have been offset from the losses from clearing in the inventory. The third key area is where carbon is sequestered from establishing pasture. This is shown to be net gain in the inventory, and reflects the reality that pastures and crops help to sequester carbon.

More information about the key sources and sinks from the Forest and Grassland Conversion sector is contained in Table 3 below. This shows that losses from clearing activities are assumed to occur in three main ways – burning of most of the fallen timber, gradual decay of the remaining fallen timber, and decay of the below – ground biomass (including losses to soil carbon). A major offset to these losses is sequestration from regrowth, which is widespread in cleared areas of Queensland. It is important to note that vegetation thickening, which is also widespread in vegetation communities in Queensland, is not included within the national inventory. The principal reason for the omission is that these changes are not considered to be directly anthropogenic (human induced or controlled).

Table 3: CO_2 - equivalent emissions from Forest and Grassland Conversion sub sector, 1990-1998

Greenhouse Gas Source and Sink Categories	CO_2 - equivalent emissions (Mt) in each year									Change from 1990-1998	
	1990	1991	1992	1993	1994	1995	1996	1997	1998	CO_2-e Mt.	% Change
Emissions (Clearing of vegetation)											
Burning	61.6	32.1	32.1	32.1	32.1	33.5	37.7	37.7	37.6	-24.0	-39.0
Decay of slash	5.8	5.6	5.4	5.2	5.1	5.0	4.9	4.5	4.5	-1.2	-21.6
Below ground	57.6	55.3	52.1	49.2	46.6	44.3	42.7	39.4	39.4	-18.1	-31.5
Total Emissions	124.9	93.0	89.6	86.5	83.8	82.7	85.3	81.5	**81.5**	-43.4	-34.8
Sinks											
Regrowth	21.4	18.7	18.5	18.3	18.1	18.1	18.2	17.5	**17.5**	-3.9	-18.2
Total Sinks	21.4	18.7	18.5	18.3	18.1	18.1	18.2	17.5	17.5	-3.9	-18.2
Net Emissions	103.5	74.2	71.0	68.2	65.6	64.6	65.4	64.0	**64.0**	-39.5	-38.2

From 1990 – 1998, there has been a significant fall in emissions from land clearing, reflecting the slowdown in clearing rates. The sinks resulting from regrowth has also fallen down 18.2% over the same time period. The net effect is that from 1990 to 1998, emissions from land clearing fell from 103.5 Million tones to 64 Million tones, or 38%. However, increased clearing rates in Queensland in 1998-1999 may see the estimated emissions levels rise. The annual rate of broad scale tree clearing in the 1995 –97 was 34,000 hectares per year (including regrowth as well as virgin areas). This rate of tree clearing rose to over 400,000 hectares per annum in the 1998-1999 period, as assessed by the SLATS program in DNR.

The bulk of vegetation clearing in Australia is occurring in Queensland, which means that quite a high proportion of greenhouse emissions from Land Use Change may be coming from Queensland. More than half of the vegetation clearing is occurring within the Brigalow Biogeographic regions (SLATS 1995-97, 1997 – 99). In 1995 –97 the proportion was 56.9%, and in 1997-99 the proportion was 59.1%. This means that individual properties within the Brigalow region where clearing activities are occurring may be quite significant sources of greenhouse gases.

One of the difficulties for landholders in entering the debate over greenhouse gases is that there is little information to translate the national emissions figures (represented in Tables 2 and 3) down to the individual property level. There are currently two major information gaps facing pastoralists in the region. The first is that there is no information available about the quantities of carbon involved in the vegetation and soils on individual properties, and the second, there so little understanding of the effects of the emissions and sequestration of different management and development actions. Most properties in the region have both emission and sequestration impacts, and understanding how these operate, will be important in guiding management decisions. These issues are addressed in the following sections.

3. CARBON POOLS ON PROPERTIES

There are three main pools of carbon on a property that should be accounted for in any carbon budget exercise. These pools relate to vegetation, soils and pastures.

Vegetation.

For vegetation, slightly less than half of the mass of timber is comprised of carbon. Estimates of carbon are thus based on estimating the biomass of vegetation over a given area (usually per hectare), and multiplying by some carbon conversion rate. Vegetation includes trees (living and dead), as well as fallen timber and major debris on the ground. Below - ground biomass is the roots of trees and shrubs, and may be included in the vegetation category.

While the proportion of carbon may vary very slightly between different vegetation types, the major differences relate to the different biomasses that accrue per hectare between these vegetation types. The challenge in estimating carbon stocks therefore is to identify and estimate the areas of different vegetation types on a property, and then estimate the biomass of each vegetation type per hectare. In this way, the biomass of vegetation on a property can be estimated, and then converted into an estimate of carbon.

There is little published data to indicate how much carbon is present in the different vegetation communities in Central Queensland. Techniques have been developed in the forestry industry to use particular tree measurements as an indicator of biomass. The main measure used is the circumference of the tree stem, taken at 0.3 or 1.5 metres above ground level. Circumference measures can be converted in the area of the cross-section of the stem (basal area), and with the height of the tree, be used to estimate biomass quite accurately.

One report for the grazed woodlands of northern Queensland was that the average basal area of all woody plants was $9.62m^2$/ha ($\pm$ 0.95) (Burrows *et al.* 1997). The authors report that the means above ground biomass of Eucalypt trees (the dominant genus type in these woodlands regions) is 4,235 kgs of matter per m^2 of basal area, or approximately 40.74 tonnes/ha[2]. At approximately 46% carbon, the total mass of above carbon is 18.7 tonnes/ha[22].

To this estimate for above – ground carbon in vegetation must be added the below-ground stock (approximately 30% of above-ground stocks to a metre depth). This would bring the total carbon content of vegetation biomass to approximately 24.3 tonnes /ha. For eucalypt communities in the higher rainfall areas closer to the coast, and for the brigalow communities on more fertile soils, the total biomass and carbon per hectare are likely to be much higher. In many parts of the brigalow region, vegetation biomass probably ranges between 100 and 300 tonnes/ hectare. In areas of low shrub or semi-open country, the amount of biomass per hectare would be much lower.

Soils

Soils are likely to be the largest pool of carbon on grazing properties. Carbon exists in soils in three main forms, being organic carbon, active carbon and passive carbon. Organic carbon is closely associated with the richness of soils and the amount of biomass it can support. As a result, the levels of organic carbon can vary widely between different soils, and the different depths within the same soil. Generally, the highest levels of carbon are recorded in the first few centimeters of soil, where the humus layer tends to be rich in organic carbon.

The measurements are taken by taking soil cores with an auger or other instrument, drying the cores in an over to remove moisture, and then analysing the carbon levels in a laboratory. To

[2] Burrows (per comment) reports that estimates of above ground biomass for eucalypts in northern Queensland are being revised upwards, and may be approximately 6 tonnes per m^2 basal area.

assess the carbon in soils on properties accurately, soils need to be classified into different groups, and then sampled to assess the carbon contents for each soil type.

The amount of carbon in soils also varies widely. In the past, most measurements of soil carbon have concentrated on the top ten centimeters, as this is the layer where most variation occurs. However, to estimate carbon pools in soils, it has become more common to sample soils to a depth of 1 or 1.2 metres. In many parts of the brigalow region, soil carbon levels probably average around 80 – 100 tonnes per hectare, but more fertile brigalow soils may have higher levels (Dalal, pers. Comment). In the poorer soils of the Desert Uplands, soil carbon levels may be around 30 or 40 tonnes/hectare.

An example helps to illustrate the reductions in carbon levels that occur with depth[2]. For one soil carbon sample taken to one metre in virgin brigalow scrub in the Central Highlands, the total carbon pool was estimated at 136 tonnes per hectare. 17.3% of that carbon pool was located in the first 10 centimeters, while 21.5% was located in the last 40 centimeters. For each 10 centimeter gradation down into the soil, the levels of carbon were lower.

Pasture

The pool of carbon that is tied up in pasture is much more variable because the stocks of pasture can change so much over each season. Because vegetation and pasture often compete for the same resources, these tend to be an inverse relationship between the amount of vegetation and pasture that can be supported. When vegetation is cleared, the resulting pasture establishment tends to offset some of the carbon lost from the vegetation. For example, a thick stand of high quality buffel grass pasture on Brigalow soils can contain nearly eight tones of dry matter per hectare. When the same pastures are grazed down to almost ground level, the amount of dry matter per hectare may be only 500 kilograms.

Similar relationships hold for pastures in other vegetation communities. High quality natural pastures on eucalypt box country in alluvial type soils might contain up to 5.5 tonnes of dry matter, while natural pastures in ironbark country might contain up to 4.5 of dry matter. Approximately half of the dry matter of pasture may be estimated as carbon.

This means that in a typical case of land development, 40 – 100 tonnes of biomass per hectare might be lost from clearing the timber, but an additional 2 – 4 tonnes of biomass per hectare of pasture will offset this loss. While pastures are an important component of carbon budgets, they would be much harder to include in any agreement about property management. This is because of the natural variation in stocks from decay, grazing and burning.

Changes in carbon pools on properties

The most interest in carbon pools on properties relates to potential changes in those pools. This is because identification of carbon flows may help to identify where losses may be reduced or sequestration rates enhanced. However, the interrelationships between soils, vegetation and pastures mean that changes in carbon stocks are interwoven.

The major flows of carbon on a property can be summarized in the following way.

[2] The unpublished data was provided by Ben Harms of the Department of Natural Resources.

Table 4 Major categories for carbon flows on property.

	Loss or gain?	Comment
Clearing vegetation	Loss	Probably associated with small offsetting gain in pasture production
Regrowth	Gain	Bladeploughing is probably reducing overall pool of regrowth available.
Vegetation thickening	Gain	Probably associated with decline in pasture production, unclear about effects on soil carbon levels.
Cultivating soils	Loss	Mechanical disturbance often reduces soil carbon levels
Degrading soils	Loss	Humus layer often first to be lost
Improved soil production	Gain	Build up of moisture, which is associated with organic carbon.
Increased pasture	Gain	Some grasses deposit significant amounts of carbon in root stocks down to 1 metre
Decreased pasture	Loss	Overgrazing will reduce both above-ground and below-ground biomass.

There are a number of difficulties with estimating many of these categories accurately. These relate to the lack of scientific information, the lack of appropriate baseline data (to relate changes to 1990 base levels), and the difficulty and expense of collecting accurate data. The problems in estimating carbon pools accurately becomes much more acute when the issue becomes one of estimating changes in stocks. This is because changes in stocks (such as levels of carbon in soils) tends to occur slowly over time, and it is difficult to separate out changes and trends from the variations in measurements that always occur.

This measurement problems imply that although there are a large and inter-related set of factors which should be included in carbon budgets at a property level, only a select number of those factors may actually be worthwhile measuring or including in any minimisation or abatement program. For example, it is likely at the property level that vegetation thickening or changes in soil carbon will be difficult to measure directly. For these factors, estimates generated at a regional level may be more appropriate. In relation to vegetation and pastures, it is likely that only the major categories of each will be worthwhile sampling.

Estimating whole-property budgets

To estimate the total impact of a property on greenhouse gas emissions, estimates have to be made in three broad categories. The first are changes to the carbon pools in natural resources, as discussed above. The second are methane emissions from livestock, while the third are releases from burning fossil fuels (eg diesel and petrol).

Methane emissions from livestock are important because these outcomes are interwoven with resource changes that impact on pasture production. When cattle and sheep eat pasture, some of the plant material is transformed into methane gas and released by the animal into the atmosphere. Methane has 21 times the greenhouse effect as carbon dioxide, with the result that domestic animals contribute a significant amount of Australia's greenhouse gas inventory. For example, beef cattle contribute about 7% of total emissions (in terms of carbon dioxide equivalents), with cattle in northern Australia having a larger impact per head than cattle in southern Australia.

Emissions from beef cattle properties in Central Queensland have been estimated by Rolfe and Zeil (2001) and Rolfe (2000). These show that the average specialist beef producer in Queensland with 1,158 cattle would be responsible for approximately 103 tons of methane released into the atmosphere each year. This is equivalent to releasing 2,161 tons of carbon dioxide annually.

Improving the amount of feed available for cattle allows more and/or heavier cattle to be run which leads to an increase in methane emissions. If feed quality can be improved, then the animals make better utilisation of it, and more beef is produced per unit of methane that is released. While it appears difficult for beef producers to reduce methane emissions without reducing cattle numbers, there are opportunities to increase the amount of beef production per unit of methane emitted.

The amount of emissions from fossil fuels from specialist beef producers is small in comparison to the impact of methane emissions. For example, the average specialist beef producer in Queensland produces about 39.5 tons of carbon dioxide from fossil fuels each year. This means that when methane emissions and fossil fuels are considered together, the emissions from cattle account for approximately 95.6% of total emissions.

Changes in carbon stocks on properties may add or subtract from the levels of emissions from fossil fuels and methane. For example, if there was 100 hectares of open eucalypt woodland cleared on a grazing property in one year, there would be approximately 2,430 tons of carbon released, or 8,918 tons of carbon dioxide. The impact of clearing 100 hectares would be more than four times the impact of running more than 1,000 head of cattle for one year.

4. OPTIONS TO REDUCE EMISSIONS

One of the most important issues to consider in light of the Kyoto agreement is the mechanisms by which Australia might meet its emissions target. It is clear that there is likely to be continued substantial growth in the use of fossil fuels within the country. It is also clear that there is limited ability of industry to improve technical efficiencies and meet emission reduction targets in that way. A high level of reduction in energy use in Australia would be problematic because of the associated economic costs.

One of the options to reduce emissions is to vary the rate of reduction across sectors. Here, a slowdown in emissions from sectors such as Agriculture or Land Use Change may be used to compensate for increases in the Energy sector. At current trends it appears that emissions from the Agriculture sector may only rise slightly. There is likely to be an automatic decrease in emissions from land clearing because 1990, the base year chosen by the FCCC, was at a time when clearing rates were high. Clearing rates have been increasing in the late 1990s again, and some of the losses (from remaining logs, roots and soils) occur over subsequent years. This means that current clearing levels will still impact on emissions in 2008-12. However, the tightening of clearing restrictions by the Queensland Government will start to slow the rate of clearing in coming years.

There are two broad groups of reasons why reductions in greenhouse gas emissions from the agriculture sector are of interest. The first broad group relates to reasons that are directly in the best interests of primary producres, commonly called win-win situations. These apply to cases such as the improvement of soils or pasture where the increased levels of carbon stored are also beneficial for production purposes. They also apply to situations where reductions in fossil fuels or other inputs can be made in ways that reduce input costs without sacrificing production outcomes.

The second broad group of reasons relates to situations where it is possible for landholders to reduce the greenhouse gas emissions but only at increased cost or by sacrificing some level of production. In these cases there is no direct incentive for landholders to adopt emission reduction strategies, even though they may be desirable from the viewpoint of society as a whole. In these cases, other mechanisms might be explored to provide more appropriate incentives for landholders.

Currently industries and the Australian government are investing in greenhouse reducing programs by developing renewable energy sources and establishing emission abatement projects. If further reductions in the level of emissions are to be made by industry, this may come at a very high price in terms of lost production and other costs. In contrast, it may be much cheaper to fund reductions in parts of the agricultural sector rather than insist on reductions by each industry group. This argument is the basis for allowing carbon offsets to be used. Improvements in one sector, such as the establishment of a new forest, may be used to count against increased emissions in another sector. If it is cheaper to reduce emissions in agriculture than in industry, it is profitable for industry or the government to provide agriculture with incentives to find emission reduction strategies.

One key area where Australia might search for emission reduction strategies is in reducing rates of broad scale tree clearing. Currently the greenhouse gas emissions from clearing are included within the National Inventory, so reductions in clearing will help Australia to meet emission reduction targets. A key question to address is whether it is more worthwhile to clear vegetation in Central Queensland for production benefits or to retain it for carbon sink purposes.

Rolfe, Bennett and Blamey (2000) compared the value of losses in greenhouse gas emissions to the value of production gains from clearing in the Desert Uplands region in central-western Queensland. They reported that at a carbon price of $10 per tonne of CO_2 equivalent, the losses are approximately $50.50 per hectare. Net production gains are between $12/ha and $28/ha for the eucalypt woodland country, and around S50/ha for the better quality acacia country. The implication is that clearing in the less fertile vegetation areas is not economic once the cost of emissions is taken into account at the price level nominated.

If the benefits from retaining vegetation for carbon sink purposes could be signalled to landholders, then they would automatically change their development strategies. It is likely that some development options are still worthwhile, even when the cost of emissions are factored in. Thus it will be important to develop some flexible process of resource allocation so that optimal strategies can be chosen. One mechanism for this to occur is with carbon offsets. Reducing emissions from land use change has been identified as one preferred option for Australia to meet its Kyoto target (Rossiter and Lambert 1998). Using carbon offset incentives would be one way of signalling to landholders the importance of reducing clearing rates.

There has already been interest from the State and Federal Government in using regulatory measures to reduce tree clearing rates because of the impacts on biodiversity as well as greenhouse gas emissions. The disadvantages with the regulatory approach is that it is politically difficult to impose major restrictions on tree clearing, as well as to have the flexibility to identify further development opportunities. As well, a regulatory approach to reducing greenhouse gas emissions which imposed production losses on the rural sector is not very consistent with the voluntary incentives approach adopted with industry through the Greenhouse Challenge.

There has already been substantial discussion about the development of trade in carbon offsets in Australia (AGO 1999, 2000). Under the Kyoto Protocol, allowance is made for firms to trade carbon credits both nationally and internationally. The intent of allowing credits to be transferred is that it enables the lowest cost solutions to be found. In an industrial setting for example, a power generator might reduce carbon emissions by changing from coal to gas, and sell the resulting carbon credit on to other firms that needed reductions.

There has been interest in the development of forestry in Australia for carbon offset purposes, and proposals to introduce a trading mechanism on the Sydney Futures Exchange have been raised. It is expected that many companies in the industrial and energy sectors would be purchasers of such trades. There has already been a number of preliminary trades taken place (AGO 2000). However, there is still no national emissions trading system that has been approved by the Commonwealth Government, nor is there a consistent legal definition of a carbon credit across the States and Territories.

One of the simpler options for reducing greenhouse gas emissions would be to award some form of carbon offset over vegetation types that were vulnerable to clearing. Landholders might choose not to clear, and thus exercise their carbon offsets. In the more marginal land types, it is likely that the returns from carbon offsets will be more attractive than returns from clearing. Under this scenario, carbon offset trades would operate to automatically reduce clearing rates, and thus reduce the increase in Australian emission levels.

There has been some interest from the Australian Greenhouse Office in offsetting emissions with vegetation retention. The Bush for Greenhouse program is encouraging revegetation initiatives and community awareness to reduce emissions. However, there has been little involvement between the Australian Greenhouse Office and the landholders in Queensland, nor open discussion about how landholders can be encouraged to retain vegetation through the use of carbon credits. The reasons for this are discussed below.

5. CARBON OFFSETS FOR NATIVE VEGETATION?

There appear to be four main barriers to establishing carbon offsets over native vegetation. The first of these is that the international rules for carbon credits that are being designed by the FCCC appear to exclude existing native vegetation. The key terms in the definition are likely to be 'afforestation, reforestation and deforestation', which are all 'actions', whereas preservation of existing forests is more of a static concept. The problem is that Australia has a special condition under the Kyoto Protocol whereby it can count reductions in emissions from tree clearing towards its 2008-12 target, but under the proposed international rules for carbon offsets, it will not be possible to treat them as a carbon offset. While there is a national incentive to reduce tree clearing and the subsequent greenhouse gas emissions, there is no set framework to translate that to individual incentives for landholders.

One solution to this problem is to establish a domestic carbon offset system which encompasses native vegetation. Landholders would be awarded carbon offsets over relevant vegetation, which could then be purchased by companies seeking to reduce emissions. The result would be an automatic adjustment through the market process to balance increases in one or more sectors against reductions in the Land Use sector. The carbon offsets could be traded in the same forum and manner as other carbon offsets, but would not be available for overseas purchasers. They would thus be a 'Grade B' offset, and likely to attract a price discount compared to other carbon offsets.

The second issue is that under the international rules, the maximum that Australia can claim in an annual reduction from land clearing emissions is the level of emissions in 1990. This is currently estimated at 90 million tonnes. Because of the longer term 'leakage' of carbon from previously cleared areas, the amount of emissions that can be effectively reduced by 2008-12 will be a smaller amount than the 90 million tonnes allowed. The implication of this constraint is that any awarding of carbon offset rights over native vegetation has to be selective. It will be ineffective to give every landholder rights over remaining vegetation. It would be better to award carbon offsets in ways that will maximise takeup of the option and minimise clearing rates.

The third issue is that greenhouse gas reduction is a Commonwealth responsibility, while management of natural resources is a State responsibility. The Queensland Government already has a substantial interest in reducing clearing rates in some vegetation types because of concerns about biodiversity loss. There appears to be opportunities to award carbon offsets over vegetation types that are being cleared as a way of reducing clearing rates and meeting biodiversity goals. For the Queensland Government, this may be one way of encouraging retention rates of at least 30% in the "Not of Concern" vegetation types, and reducing clearing rates further in the "Of Concern" vegetation types. Close cooperation between the Commonwealth and the State is necessary here because the Queensland Government is vested with the ownership of vegetation on leasehold land. There will need to be an agreement with the State Government to vest rights in carbon offsets to the landholder so that they can be traded.

The fourth issue is that the number of landholders, and the diversity of clearing activities, makes it difficult to develop close interactions with the Australian Greenhouse Office. One of the advantages of an offset trading system is that it would enable a multitude of landholders to deal with the purchasers of carbon rights, through trading mechanisms such as a futures market. However, there would still be an administrative burden in the process of awarding offset permits. This burden may be reduced or streamlined in a number of ways, including:

- using the Queensland Department of Natural Resources for assessment and monitoring purposes,
- awarding offsets over only a select number of vegetation types,
- establishing a minimum offset level (area of vegetation to be protected?),
- setting some threshhold level of vegetation retention per property, above which the offset might apply,
- linking offset rights with a process of resource monitoring and auditing,
- piggy-backing carbon offsets onto a land stewardship process,
- calling for landholders to tender for carbon offset rights.

It is unlikely that the administrative burden would be much larger than that involved in certifying carbon offsets in the forestry sector. It appears quite feasible that a limited system of carbon offset permits would be very effective in reducing tree clearing rates in Queensland. Apart from the benefits of reducing greenhouse gas emissions, the key advantages would appear to be that:

- it is an opportunity to provide funding to landholders, and would thus be politically acceptable,
- carbon offset funding would come from industry rather than government,
- funding could be associated with a range of landholder responsibilities, including resource management and monitoring,
- funding could be concentrated on key vegetation areas of concern,
- funding could be associated with government incentives for stewardship or biodiversity protection to develop comprehensive incentives for vegetation protection.

6. CONCLUSION

The agricultural sector is a significant contributor to Australia's greenhouse gas emissions. In Queensland, grazing properties contribute by burning fossil fuels, running cattle that release methane into the atmosphere, and impacting on carbon stocks through activities such as clearing. There may some changes in carbon stocks, such as vegetation thickening and soil improvement which help to sequester carbon.

There are two broad ways in which the pastoral industry can become involved with efforts to reduce emissions from grazing properties. The first is to search for win-win situations where opportunities to reduce costs or enhance productivity lead to reductions in emissions. Examples might include opportunities to reduce fuel consumption and the rehabilitation of degraded soils. (In the latter case there may be improvements in both pasture stocks and soil carbon levels). These types of win-win situations can be supported by landholders entering into cooperative agreements with the Greenhouse Challenge program to identify and monitor reduction strategies.

The second broad way of involving the pastoral industry is to look at opportunities to reduce emissions where there may be some loss of production or other costs involved. A typical case is where avoiding the clearing of native vegetation may mean that future beef production is foregone. However, the cost of reducing emissions by actions such as reducing clearing rates may be much lower than in industries such as power generation. Allowing some form of carbon offsets to develop, where landholders receive incentives to reduce carbon emissions, may be a way of achieving emission reduction at lowest cost.

The main focus of this project is to develop carbon budgets for a small sample of properties in the Central Highlands and Desert Uplands regions, and identify where potential exists for reducing carbon emissions or to sequester carbon. Other focuses are to identify measurement and carbon budget protocols, to encourage landholders to enter into emission reduction agreements with the Greenhouse Challenge program, and to promote opportunities for carbon offset programs to develop.

REFERENCES

The Australian Greenhouse Office (AGO), 1999 *National Emissions Trading: establishing the boundaries*, Discussion paper No. 1, Commonwealth of Australia, Canberra.

The Australian Greenhouse Office (AGO), 1999 *National Emissions Trading: designing the market*, Discussion paper No. 4, Commonwealth of Australia, Canberra.

Burrows, W.H., E.R. Anderson, P.V. Back and M.B. Hoffmann. 1997. Regrowth and woody plant thickening/invasion impacts on the land use change and forestry inventory. *Contributory paper for IPCC Workshop on Biomass burning, Land-Use Change and Forestry*, Rockhampton, Australia, September 1997: pp 18.

Rolfe, J.C. and Zeil, V. 2001 *Methane Emissions from Cattle Production in Central Queensland*, report prepared for Meat and Livestock Australia, Sydney.

Rolfe, J.C. 2001 *Some Economics of Reducing Methane Emissions from Cattle Production in Central Queensland*, report prepared for Meat and Livestock Australia, Sydney.

Rossiter, R.D. and Lambert, I.B. (eds) 1998 *Scientific and Technical Opportunities to Reduce Australian Greenhouse Gas Emissions*. Bureau of Resource Sciences, Canberra.