Outback carbon

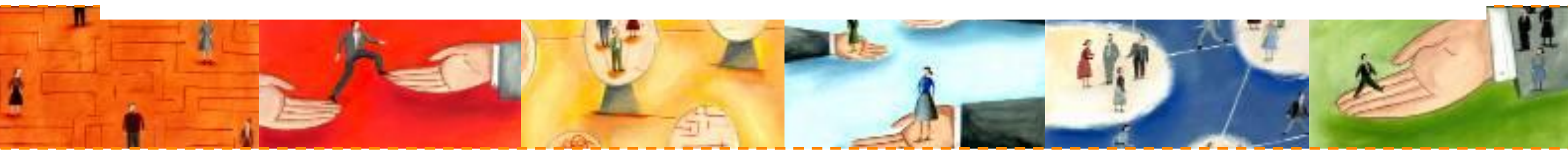
An assessment of carbon storage, sequestration and greenhouse gas emissions in remote Australia

July 2010

A report by The Nous Group to:

The Pew Environment Group-Australia and The Nature Conservancy

Wild Australia is a joint project of the Pew Environment Group and The Nature Conservancy that works to protect large tracts of Australia's unique terrestrial and marine environment. www.WildAustralia.org



THINKING DOING LEADING

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1.1 Key findings

This report demonstrates that protecting and sequestering carbon in the Australian 'outback' provides cheap options to help Australia make deep and early cuts to the nations projected emissions.

The outback land management practices analysed in this report have the potential to provide early and achievable greenhouse gas (GHG) reductions:

- **9.79 billion tonnes of carbon** is stored in the Australian outback, with an estimated additional **1.08 billion tonnes of carbon** that can be stored there
- A total potential saving of approximately **1,300 Mt CO_2-*e*[1]** can be achieved by 2050, with a **4% reduction** in business-as-usual emissions by **2020**, and a **5% reduction by 2030**
- the economic cost of implementation is in most cases **lower than that of many of the industrial sector emissions reductions** that are targeted by the Australian Government's proposed Carbon Pollution Reduction Scheme (CPRS) (most of these land management practices **cost less than the estimated carbon price** in the Australian emissions trading scheme or currently being discussed as interim pricing arrangements, apart from grazing management), with feral pest management identified as a 'no regrets' initiative.

Australia is in a unique position: our vast carbon stores in the outback provide an opportunity to utilise a readily available climate mitigation strategy. Australia is therefore well placed to develop a comprehensive and balanced policy framework for climate change that:

- **Harnesses existing mitigation potential** that does not rely upon huge technological advances, is able to be quickly implemented, and has, over millennia, proven itself an effective climate mitigation tool
- Takes advantage of a **cost effective** method of carbon abatement
- Encompasses **good risk management** by ensuring that all facets of climate mitigation are equally addressed.

To capitalise on the opportunity for abatement present in the outback, Australia's Governments must establish the right policy setting to encourage uptake of the land management practices outlined in this report. The first key steps are:

- Arguing for a comprehensive **international policy framework** under the United Nations Framework Convention on Climate Change (UNFCCC) that fully recognises terrestrial carbon
- Clarifying and reforming where necessary domestic legislative and policy frameworks to allow landholders and local communities including Indigenous communities to share equitably and sustainably in the benefits of income streams which may derive from

[1] Note that the total abatement from these five initiatives cannot be calculated by simply summing their individual abatement (due to issues of complementarity and interference that have not been considered). As such, this total figure should be considered approximate.

protection of existing outback carbon banks and further sequestration of terrestrial carbon

- Developing more robust monitoring and **carbon accounting** methods to properly measure the mitigation contribution of terrestrial carbon.
- Investing in further **research and development** to more thoroughly assess the environmental and economic benefits of changed land management practices

1.2 Overview

Tackling the challenge of climate change requires a comprehensive approach by communities and governments – encompassing businesses, the wider economy and individuals. To achieve the necessary cuts to GHG emissions, we must seize all viable opportunities to mitigate emissions and store carbon.

So far the primary focus for emissions reductions within Australia and globally has been the energy, transport and the major industrial emitters. The rationale behind this is clear: the energy sector alone constitutes the vast majority of Australian greenhouse gas emissions – 75% in 2007.[2]

A recent study by the World Bank argues that a comprehensive strategy to mitigate climate change needs to rest on a balanced approach to the three fundamental pillars of climate policy:[3]

1. **Mitigation:** reductions in emissions (primarily from industry), driven by economic policy and incentives, promotion of energy efficiency and encouragement of low-emissions energy measures;
2. **Adaptation:** implementation of adaptation measures to reduce the vulnerability of landscapes, communities and industries;
3. **Ecosystem-based approaches:** preserving natural ecosystems and native habitats to protect biodiversity, reduce emissions and increase carbon storage through "green carbon".[4]

Currently, Australia's climate policy concentrates on the first two pillars – the economic settings for key industries through the CPRS, and the development of adaptation strategies.

Nature, the third pillar of climate change mitigation policy, has so far been largely overlooked in Australia. According to the World Bank 'ecosystem-based strategies can offer cost-effective, proven and sustainable solutions contributing to, and complementing, other national and regional adaptation strategies.'[5] While some important studies have recently been advanced here in Australia, – for example, the Garnaut Review,[6] a study on carbon

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[2] Framework convention on climate change – secretariat *Summary of GHG emissions for Australia*. Available at http://unfccc.int/files/ghg_emissions_data/application/pdf/aus_ghg_profile.pdf. Accessed 10/5/2009

[3] Environment Department, The World Bank (2009) *Convenient Solutions to an Inconvenient Truth: Ecosystem-based Approaches to Climate Change*, The World Bank, Washington, p. 8

[4] "Green carbon" is carbon that is sequestered through plant photosynthesis and stored in native forests undisturbed by land clearing and other intensive human land use activities. See Mackey et al, *Green Carbon: The Role of Natural Forests in Carbon Storage*, ANU, Canberra, p. 11.

[5] Environment Department, The World Bank (2009) *Convenient solutions to an inconvenient truth: ecosystem-based approaches to climate change*. June 2009.

[6] Garnaut, R. (2008) *The Garnaut Climate Change Review,* Final Report, Cambridge University Press, Port Melbourne.

storage potential of Australia's south-eastern forests by ANU,[7] and the CSIRO's recent report on the greenhouse gas mitigation potential in rural landscapes[8] – the opportunity for climate mitigation through the protection and restoration of nature has not been fully explored by policy makers.

Nature has the potential to make a significant contribution to Australia's climate change mitigation effort, strengthening and adding to the current focus. This project is about understanding and quantifying these opportunities for carbon storage and emissions reduction in our natural landscapes.

The focus of this project is the vast expanses of the Australian outback – an area which makes up approximately 80% of the continental landmass,[9] and offers a unique and biologically diverse landscape that is synonymous with the Australian cultural identity. The delicate ecosystems of the outback sit directly in the path of the potentially severe effects of climate change, with rapid and volatile changes in weather patterns, yet its enormous potential for carbon abatement is frequently forgotten when we consider climate mitigation solutions.

Australia's outback possesses a huge carbon store – approximately 9.79 billion tonnes are sequestered in the 'green carbon' of its natural ecosystems.[10] Although much of outback Australia is arid or semi-arid – with a relatively low potential for carbon storage per hectare – the vast areas involved lead to significant greenhouse gas abatement potential. Through improved land management practices in the outback, it is estimated that by 2020, a 4% reduction of projected Australia-wide business-as-usual emissions can be captured, with a 5% reduction achievable by 2030.

To take advantage of the environmental, economic and social benefits available in the outback, Governments and the community need to act to encourage adoption of these practices. We must:

- *Protect* the existing carbon stores in the outback
- *Reduce* greenhouse gas emissions by making changes to outback land management practices
- *Capitalise* on the overall cost effectiveness of the land management practices.

To assist policy-makers and the community make an assessment of the environmental and economic value of changed land management practices in the Australian outback, Pew Environment Group (Pew) and The Nature Conservancy (TNC) engaged The Nous Group to conduct an evaluation of the carbon abatement potential in this often overlooked landscape.

[7] Mackey, B., Keith, H., Berry, S., Lindenmayer, D., (2008) *Green Carbon: The Role of Natural Forests in Carbon Storage*, ANU, Canberra.

[8] CSIRO(2009) *An Analysis of Greenhouse Gas Mitigation and Carbon Sequestration Opportunities from Rural Land Use*, edited by Sandra Eady, Mike Grundy, Michael Battaglia and Brian Keating, CSIRO, St Lucia, Queensland.

[9] Department of the Water, Heritage and the Arts (2009) *Outback Australia – the rangelands*. Available at www.environment.gov.au/land/rangelands/index.html. Accessed 20 November 2009.

[10] Green carbon is carbon sequestered from the atmosphere from plants and stored in natural forests. Mackey, B., Keith, H., Berry, S., Lindenmayer, D., (2008) *Green Carbon: The Role of Natural Forests in Carbon Storage*, ANU, Canberra. p. 11.

This work is based on a study of carbon stocks undertaken by the Queensland Herbarium[11] which provided base data for this project, and also draws on existing research to estimate:

- current carbon stocks
- greenhouse gas mitigation potential in the outback
- the economic cost of a range of changed land management practices.

The results of the study are summarised below.

There is a vast carbon store in outback Australia.

The Queensland Herbarium's study estimated that a total of **9.79 billion tonnes of carbon** is stored in the vegetation of the Australian outback. This storage can be considered both an asset (as the vegetation has absorbed vast amounts of carbon) and a liability (degradation or destruction of this landscape could lead to greenhouse gas emissions of up to 50 times Australia's entire annual emissions).[12]

Through good land management practices (particularly by significantly reducing land clearing and vegetation regrowth) there is the potential to increase these carbon stores by re-absorbing carbon dioxide from the atmosphere. The Queensland Herbarium estimates that technically, an additional **1.08 billion tonnes of carbon** can be stored in the outback.

Improved land management practices have the potential to achieve 5% reduction in atmospheric greenhouse gases (GHGs) by 2030.

The Nous Group has studied a series of proposed land management practices in 'outback' Australia[13] and identified the potential for significant greenhouse gas reduction. Five land management practices were quantified, though other potential options have been proposed that could not be quantified due to the need for further research in these areas. The land management practices are listed below, with more detail on each provided in the **Background** section.

- Reducing land clearing
- Vegetation regrowth
- Grazing management
- Fire management
- Feral pest management.

These land management practices can significantly reduce atmospheric greenhouse gas emissions through re-absorption of atmospheric carbon dioxide and conversion into biomass, as well as a reduction in the emissions of other greenhouse gases (methane and nitrous oxide). These reductions are outlined in **Table 1**.

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[11] The Queensland Herbarium ("the Herbarium") is the centre for research and information on the Queensland flora, vegetation and plant communities. The Herbarium is a part of the Queensland Department of Environment and Resource Management. More information is available at http://www.derm.qld.gov.au/wildlife-ecosystems/plants/queensland_herbarium/

[12] Australia's national emissions from all sources were 597 million tonnes in 2007 (see Department of Climate Change*National Greenhouse Gas Inventory*. Available at http://www.ageis.greenhouse.gov.au/. Accessed 14 October 2009).

[13] See **Section 2.2** for the definition of the geographic region studied.

	Reducing land clearing	Vegetation regrowth	Fire management	Feral pest management	Grazing management	Total
Total reduction to 2050	425	287	230	184	206	**1,332**
Annual reduction at 2020	11	5	5	4	0	**26**
Annual reduction at 2030	11	9	7	6	8	**40**

Table 1 - Overall reduction in GHG due to changed land management practices (Mt CO_2-e)[14]

By applying changes to these five land management practices, there is a total potential saving of approximately 1,300 Mt CO_2-*e* by 2050.[15] This is equivalent to the carbon dioxide saved by taking 7.5 million average cars off the road.[16] The modelling also indicates early and deep cuts in emissions across the five practices – with a 26 Mt CO_2-*e* reduction in emissions by 2020. These figures translate to a 4% reduction in business-as-usual emissions by 2020, and 5% by 2030.

The figures developed accord with similar estimates provided by Garnaut and CSIRO in related studies.

Emissions reductions resulting from changed land management practices are cost effective.

While there is now emerging evidence on the vast abatement potential of remote Australia, there has been little work to date on assessing their economic viability. Nous has developed whole-of-life economic cost estimates for each option, providing a means for comparison with the carbon cost of other abatement options (such as energy and manufacturing efficiency). The results are summarised in **Table 2** below.

	Reducing land clearing	Vegetation regrowth	Fire management	Feral pest management	Grazing management
Cumulative carbon cost to 2050 (NPV / total abatement)	$11.19	$17.54	$7.47	-$2.43	$101.09
Carbon cost at 2020 (cost at 2020 / abatement)	$7.95	$17.95	$12.50	-$3.95	N/A
Carbon cost at 2030 (cost at 2020 / abatement)	$18.79	$22.92	$12.50	-$3.14	$416.44

Table 2 - Carbon costs of the land management practices

[14] These estimates have been developed based on the best currently available data and accord with estimates, such as those produced by The Garnaut Review and CSIRO. Future research is likely to provide additional data and understanding of issues such as regional variation that will allow the development of more accurate estimates.

[15] 1,300 MT CO_2-*e* is an approximate figure based on summing the contribution of each of the land management practices. Due to issues of complementarity and interference (that have not been considered) the total abatement from these five initiatives cannot be calculated by simply summing their individual abatement (due to the complementarity and interference between initiatives that has not been considered) and this figure should be considered as an estimate only.

[16] The average car emits approximately 4.3 t of carbon dioxide per year. See Greenfleet *Car offsets* https://secure.greenfleet.com.au/treetotaller/order_simple_individual.aspx

As most of these costs are less than the estimated carbon price in the Australian emissions trading scheme (apart from grazing management),[17] the emissions cuts from land management make economic sense.[18] The land management practices studied can be divided into three broad categories:

- **'No regrets' initiative (feral pest management):** Feral pest management is a 'no regrets' initiative leading to net economic gain (because of productivity gains in the grazing industry)
- **Low cost initiatives (reducing land clearing, vegetation regrowth and fire management):** These initiatives all have a carbon cost of \$10 - \$20 per t CO_2-*e*. The initiatives are less expensive per tonne of greenhouse gas abatement than the current proposed carbon price.
- **Potentially high cost initiative (grazing management):** There are various methods of grazing management that have been proposed. Some diminish industry productivity – though there is the potential for 'win-win' initiatives that can reduce emissions and increase productivity. More research is required into optimal grazing management methods.

Emissions reductions are achievable, but we must take the vital next steps to make them happen

This report finds that the carbon abatement potential of the outback is significant and cost effective; however, this abatement is contingent on Australia's Governments creating the right policy settings to encourage uptake of the five land management practices outlined in this study. Some key first steps in this process will be:

- Arguing for a comprehensive **international policy framework** under the United Nations Framework Convention on Climate Change (UNFCCC) that fully recognises terrestrial carbon
- Developing more robust monitoring and **carbon accounting** methods to properly measure the mitigation contribution of terrestrial carbon
- Further **research and development** to more thoroughly assess the environmental and economic benefits of changed land management practices.

[17] Under the Carbon Pollution Reduction Scheme Bill 2009, an initial carbon price cap of \$40 per tCO_2-*e* has been proposed, with an increase of 5% per annum. The actual price will vary depending on the target level of abatement, but is estimated to be \$23 and \$32 (in 2008 dollars) at scheme commencement for the 5% and 15% targets respectively. (See Australian Government (2008) *Carbon Pollution Reduction Scheme: Australia's low pollution future* p. 4-25.)

[18] Although Nous studied weed management and biochar qualitatively, more research is required for accurate quantification of economic impacts.

2 Background: land management and the role of terrestrial carbon in climate change mitigation

2.1 Terrestrial carbon and climate mitigation

Over the past decade, there has been increasing public concern about the significant economic and environmental impact of climate change on Australians into the future.[19] Climate change and the resulting issues facing Australia are central to all future policy and thinking about environmental, social and economic development.

To address the climate challenge, thus far much of the attention has been centred on technology and people. However, there is growing international awareness of the role that nature can play in greenhouse gas abatement. The abatement potential of nature lies with the carbon that is sequestered through plant photosynthesis and stored in native ecosystems.[20] Internationally, this carbon is widely known as terrestrial carbon;[21] in Australia, it has been coined ‘green carbon’.[22]

In considering climate change mitigation strategies, the World Bank and United Nations Environment Program released two important studies that highlight:

1. Why nature is crucial to a holistic and comprehensive policy for tackling the climate challenge, and
2. How proper management of terrestrial carbon in nature can significantly mitigate greenhouse gas emissions.

These international reports are supported by Australian studies that identify the great potential for carbon abatement within our own natural habitats.

The World Bank

The World Bank’s report, *Convenient Solutions to an Inconvenient Truth*, emphasises the importance of protecting natural ecosystems and habitats such as wetlands, forests and oceans, as a key aspect of tackling the climate change challenge.[23] In this report, The World Bank advocates a three pillared approach to climate policy:

1. **Mitigation:** reductions in emissions (primarily from industry), driven by economic policy and incentives, promotion of energy efficiency and encouragement of low-emissions energy measures;

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[19] There are a variety of definitions of ‘climate change.’ This report defines climate change according to the United Nations Framework Convention on Climate Change (UNFCCC) definition (as outlined in the *Garnaut Climate Change Review*), which defines ‘climate change’ specifically as an anthropogenic phenomenon. Garnaut, R., (2008). *The Garnaut Climate Change Review: Final Report,* Cambridge University Press, Port Melbourne, p. 27.

[20] Mackey et al, Green Carbon: The Role of Natural Forests in Carbon Storage, ANU, Canberra, p. 11.

[21] See www.terrestrialcarbon.org . Accessed 8 November 2009.

[22] The most notable use of the term ‘green carbon’ is in Mackey et al, *Green Carbon: The Role of Natural Forests in Carbon Storage*, ANU, Canberra,

[23] The World Bank Environment Department, (2009) *Convenient Solutions to an Inconvenient Truth: Ecosystem-Based Approaches to Climate Change*, The World Bank, Washington.

2. **Adaptation:** adoption of adaptation measures to reduce the vulnerability of landscapes, communities and industries;
3. **Ecosystem-based approaches:** preserving natural ecosystems and native habitats to protect biodiversity, reduce emissions and increase carbon storage through terrestrial carbon.[24]

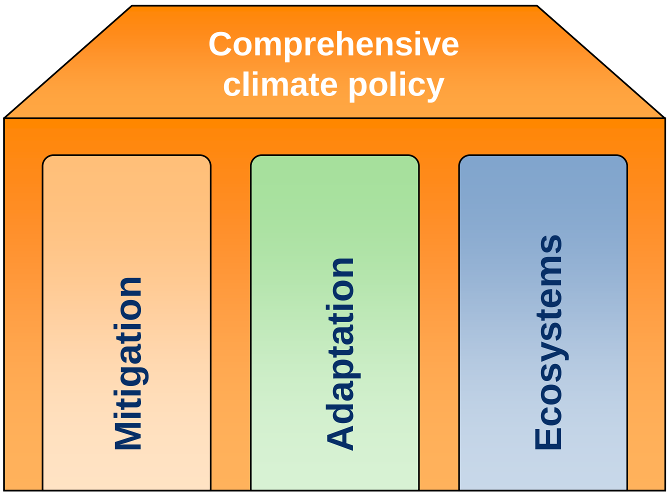

Figure 1 The World Bank's three pillars of comprehensive climate policy

Using terrestrial carbon in ecosystems in mitigating climate change therefore requires a dual faceted management process of habitats, involving:

- Protection of remaining natural habitats to preserve existing stores of terrestrial carbon
- Restoration of impacted natural habitats to increase carbon stores.

Currently, public debate on Australia's climate policy has focused on the first two pillars: the role of terrestrial carbon and natural ecosystems is not well understood.

The United Nations

Similar to the World Bank report, the United Nations Environment Program (UNEP) recently published *The Natural Fix?*, advocating the use of nature as an existing and proven method of carbon abatement, rather than solely relying on the emergence of technology to solve worsening climate problems.[25] The report outlines the importance of management of carbon in existing ecosystems to harness the climate mitigation potential of the Earth's natural carbon cycle. This report also highlights that reliance on management of fossil fuels and carbon capture technologies will not be sufficient to address the climate challenge.

Australian studies, including reports by CSIRO and ANU

The most notable of these recent Australian studies are CSIRO's *An Analysis of Greenhouse Gas Mitigation and Carbon Sequestration Opportunities from Rural Land Use* and Mackey, Keith, Berry and Lindenmayer's (ANU) *Green Carbon* reports.

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[24] "Green carbon" is carbon that is sequestered through plant photosynthesis and stored in native forests undisturbed by land clearing and other intensive human land use activities. . See Mackey et al, *Green Carbon: The Role of Natural Forests in Carbon Storage*, ANU, Canberra, p. 11.

[25] Trumper, K., Bertzky, M., Dickson, B., van der Heijden, G., Jenkins, M., Manning, P. (2009). *The Natural Fix? The role of ecosystems in climate mitigation. A UNEP rapid response assessment*. United Nations Environment Programme, UNEP-WCMC, Cambridge, UK.

Mackey, Keith, Berry and Lindenmayer examine the sequestration potential of carbon-rich forests in Australia's south-east, concluding that:

1. Green carbon is essential to tackling the climate challenge
2. Australia's wealth of carbon stocks is far larger than is recognised
3. Harnessing the mitigation potential of Australia's rich reserves of green carbon relies upon reducing land clearing in natural forests and allowing regrowth of disturbed forests.[26]

CSIRO's lengthy study on the carbon abatement potential of rural landscapes identifies the opportunity to sequester large amounts of carbon in rural landscapes, and reduce emissions through reformed rural land management practices. This report posits that proper management of terrestrial carbon and land use emissions will play a pivotal role in GHG abatement over the next 50 years.[27]

Both of these studies emphasise improving carbon accounting and monitoring as essential to taking the next steps in encompassing natural landscapes in climate policy.

Beyond just carbon

In all of the studies examined here, protecting biodiversity is outlined as an essential part of the ability of natural ecosystems to mitigate climate change.

Biodiversity – the variation of all life forms, including the ecosystems in which they reside – is acknowledged as essential to supporting all life on Earth by contributing to healthier environments.[28] Biodiversity adds value to climate change mitigation by increasing:

- **An ecosystem's carbon carrying capacity:** Scientific research suggests that biodiversity increases an ecosystem's ability to sequester carbon in comparison with growing monoculture plantations to maturity on the same site.[29]
- **Ecosystem resilience:** an ecosystem with multiple species that perform similar functions is able to better cope with environmental pressures – particularly anthropogenic pressures.[30]
- **Permanence of carbon storage:** Biodiversity is thought to help ecosystems retain carbon in stores – for example, in the soil by providing ecosystem stability.[31]

Aside from the ecological imperative, the importance of preserving biodiversity is often not clearly understood as it is difficult to quantify, particularly in an economic sense. Recent

[26] Mackey, B., Keith, H., Berry, S., Lindenmayer, D., (2008) *Green Carbon: The Role of Natural Forests in Carbon Storage*, ANU, Canberra.

[27] CSIRO (2009.) *An Analysis of Greenhouse Gas Mitigation and Carbon Sequestration Opportunities from Rural Land Use,* edited by Sandra Eady, Mike Grundy, Michael Battaglia and Brian Keating, CSIRO, St Lucia, Queensland.

[28] National Biodiversity Strategy Review Task Group (2009), *Australia's Biodiversity Conservation Strategy 2010-2020, Consultation Draft,* Australian Government, Department of the Environment, Water, Heritage and the Arts, Canberra, p. 5.

[29] Blakers, M. (2008). *Biocarbon, biodiversity and climate change: A REDD Plus scheme for Australia*, Green Institute Working Paper 3, Green Institute, Hobart, p. 2. See also, The World Bank Environment Department, (2009) *Convenient Solutions to an Inconvenient Truth: Ecosystem-Based Approaches to Climate Change*, The World Bank, Washington.

[30] Ibid, p.1.

[31] Ibid, p. 2.

studies have taken steps towards identifying methodologies for providing a value to biodiversity,[32] although the actual economic value remains qualitative at this stage.

As a signatory to the Convention on Biological Diversity, Australia has committed to seek to halt the loss of biodiversity.

2.2 The task undertaken by The Nous Group

Many of the activities excluded from Australia's commitment to the Kyoto Protocol under Article 3.4 are prevalent in Australia's remote areas, which consist primarily of grazed rangelands. Australia's 'outback'[33] accounts for approximately three-quarters of the continent's landmass.

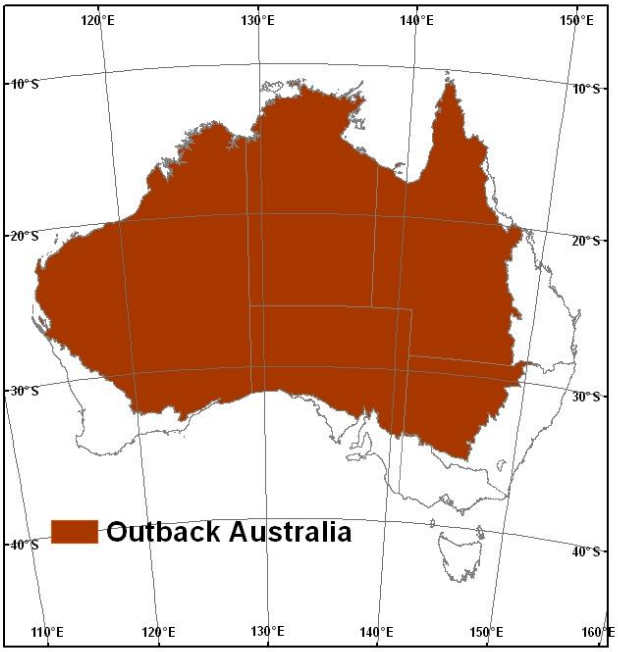

Figure 2 The 'ACRIS Rangelands' definition of the Australian outback

The Pew Environment Group (Pew) and The Nature Conservancy (TNC) have noted that little accounting has been undertaken in regard to native vegetation in the 'outback' natural landscapes of Australia, the semi-arid rangelands and arid deserts of central, southern and western Australia, and the tropical savannas of northern Australia.

The potential to reduce greenhouse gas emissions in the Australian outback and increase sequestration by changing management practices (often offering additional environmental benefits such as improving habitat for threatened species) has not been quantified, and there is a risk that changes of management practice may be overlooked in the development of measures to reduce emissions.

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[32] Biological Diversity Advisory Committee, Department of Environment and Heritage (2005) *Making Economic Valuation Work for Biodiversity Conservation*, Australian Government, Land and Water, Canberra. See also, *The Economics of Ecosystem and Biodiversity study*, http://www.teebweb.org

[33] The analysis provided here identifies Australia's outback as Australia's rangelands as defined by the Australian Collaborative Rangelands Information System (ACRIS). See www.environment.gov.au/land/rangelands/index.html .

Pew and TNC engaged The Nous Group (Nous) to assess the greenhouse gas emissions and sequestration potential in the Australian outback. In this project Nous estimated carbon stores in the outback (based on work completed by the Queensland Herbarium), and assessed the potential and cost-effectiveness of reducing greenhouse gas (GHG) through changed land management practices in the Australian outback.

The land management practices outlined in this project are:

- Reducing land clearing (excluding regrowth)
- Vegetation regrowth
- Fire management
- Feral pest management
- Grazing management

These land management practices are described briefly below.

2.3 Land management practices modelled

Reducing land clearing (excluding regrowth)

This initiative involves the reduction of deforestation of "mature" vegetation to sustain existing carbon stores in the outback, and prevent greenhouse gas emissions from reduction in stored biomass.[34]

In Australia, land clearing (deforestation) accounts for approximately 13% of greenhouse gas emissions (77Mt in 2007).[35] We have the world's fifth highest rate of land clearing, with the highest rate in the developed world. In Australia's outback, 4% of the land area has been cleared, primarily in the denser vegetation communities.[36] There is a large potential to reduce Australia's total greenhouse gas emissions by reducing clearing of mature vegetation, particularly in carbon-rich woodlands and savannas.

Reducing land clearing of mature vegetation (remaining pre-settlement vegetation) will help to preserve the vast existing stores of carbon in the outback, and prevent the release of large amounts of greenhouse gases into the atmosphere.

Currently, there are two significant Australian examples of Government legislated reduction in land clearing:

- Queensland's cessation of broadscale clearing of remnant vegetation in 31 December 2006 and further, the introduction of regulated regrowth vegetation codes (in October 2009): around 1 million ha of 'high value regrowth vegetation' in Queensland – encompassing areas with the potential to contribute to Australia's obligations under the

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[34] In this project, "mature" vegetation is defined according to the Queensland Government's definition of "remnant" vegetation where a) 50% of the predominant canopy cover that would exist b) 70% of the height of the predominant canopy that would exist, and c) the same floristic species that would exist if the vegetation community was undisturbed. See Queensland Government, Department of Environment and Resource Management, www.nrw.qld.gov.au/vegetation/bioregions.html . Accessed 30/09/2009.

[35] Department of Climate Change *National Greenhouse Gas Inventory*, www.ageis.greenhouse.gov.au. Accessed 20 September 2009.

[36] Data provided by The Queensland Herbarium

Kyoto protocol[37] – is regulated and cannot be cleared, unless an exemption or development permit is granted[38]

- Land clearing restrictions in certain areas of the Daly River catchment in the Northern Territory (see **Outback Example 1**).

Outback example 1: Land clearing in the Daly River catchment, Northern Territory

Land clearing in the Daly River Catchment in the Northern Territory has been a source of significant tension between conservationists and development interests since the 1960s. Beginning in Kakadu National Park and Katherine Gorge, the Daly River flows 500 kilometres to the Timor Sea. The Daly River catchment includes a number of sensitive wetlands, billabongs and floodplains; its land cover is primarily native forest and woodlands that are home to a diverse range of native birds and animals.

Much of the land clearing occurring in the Northern Territory has occurred in the Daly River catchment, to support agricultural development (including irrigation and sowing exotic pasture). So far, approximately 260,000 ha of the Daly River Catchment have been cleared, which accounts for approximately 5% of the total area and 10% of the smaller Daly Basin Bioregion.[39]

A recent study by the Environment Centre Northern Territory (ECNT) and WWF estimates that emissions from land clearing in the Daly River Catchment range from 85 to 120 t CO_2-e per hectare in the south of the catchment where it is driest, to between 210 to 240 t CO_2-*e* per hectare in the Douglas\Daly and lower Daly regions.[40]

ENCT and WWF estimate that with economic incentives, preserving the Daly River Catchment will be more economically viable than clearing it. That is, if a carbon cost of $20 per tonne for emitting greenhouse gases from land clearing were imposed on landholders, the cost of land clearing in the Daly River would range from $1700 per hectare in the woodlands on the Sturt Plateau, to approximately $4800 per hectare of land clearing in open forest and woodland of the Douglas\Daly and lower Daly regions.[41]

Vegetation regrowth

This initiative allows regrowth of native vegetation in land previously cleared of mature native vegetation, thereby creating carbon sinks that sequester carbon from the atmosphere.

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[37] The definition of 'high value regrowth vegetation' is restricted to vegetation that has not been clearing since 31 December 1989, aligning the definition to the stored carbon included under the Kyoto protocol.

[38] Department of Environment and Resource Management (2009) *Regrowth vegetation code: on freehold and Indigenous land and leasehold land for agriculture and grazing – version 1.* The Queensland Government.

[39] Rob Law and Stuart Blanch (2009) *Estimated Greenhouse Gas Emissions from Land Clearing in the Daly River Catchment Northern Territory, Australia,* Environment Centre Northern Territory, Darwin, p. 15.

[40] *Ibid.* p. 14.

[41] *Ibid.* p. 4.

This land management practice is also known as carbon accumulation through ecosystem recovery (CATER), and is championed as an effective way to address both carbon abatement and biodiversity.[42]

In Queensland alone, approximately 40% of native vegetation cleared annually is classified as regrowth vegetation. Regrowth is native vegetation that has been previously cleared, and is now potentially regrowing back into native habitat. As a consequence of re-clearing of regenerating native vegetation, greenhouse gases are released into the atmosphere and the carbon sequestration potential of the regrowing native vegetation is voided.

In October 2009, Queensland introduced legislation regulating clearing of high value regrowth vegetation (including regrowth along watercourses in the Great Barrier Reef catchment). However, some of the protected regrowth falls outside the bounds of the 'outback' (see **Outback Example 2**).

In this initiative, protection of regrowth vegetation is extended across the outback to reduce broad-scale clearing of regrowing vegetation and allowing native flora to continue to regenerate in those previously cleared ecosystems. Allowing native vegetation to regrow results in two main carbon impacts:

- Increase in carbon sequestration through growing native vegetation, which absorbs and stores carbon during regrowth
- Prevention of potential greenhouse gas emissions resulting from the process of land clearing.

Regrowth is most valuable in regions that can be rehabilitated into high biomass vegetation types, such as tall trees and shrubs. Ensuring carbon sequestration is most effective in regrowth vegetation will also require management of fire regimes and other factors to ensure the proper recovery and longer term maintenance of optimal carbon storage.

Outback example 2: Protecting regenerative native vegetation in Queensland

In October 2009, the Queensland Government introduced *The Regrowth Vegetation Code*[43] which provides ongoing regulation of the clearing of high value regrowth vegetation, which includes endangered ecosystems as well as ecosystems that can be used to store carbon under Australia's Kyoto obligations.

The purpose of the legislation is to address the historic increases in the rate of clearing of 'high value' regenerating native vegetation in Queensland, to repair landscapes damaged by the original clearing of mature vegetation and subsequent re-clearing or regrowing vegetation.

By introducing the restrictions, the Queensland Government will protect approximately one million hectares of regrowth and a total of 2.3 million hectares became subject to minimum standards and best land management practice.

[42] Fensham, R.J., Guymer, G.P., (2009) *Carbon accumulation through ecosystem recovery Environmental Science & Policy* 12, pp. 367-72.

[43] Department of Environment and Resource Management (2009) *Regrowth vegetation code: on freehold and Indigenous land and leasehold land for agriculture and grazing – version 1.* The Queensland Government.

Fire management

Fire management involves changing burning practices to reduce the release of greenhouse gases. Improved fire management can lead to significant greenhouse savings, as well as generating ancillary environmental and social benefits.

A savanna is a grassland ecosystem with scattered trees or shrubs, and occurs in abundance in the Northern parts of Australia, covering about 25% of the Australian continent.[44] In an average burning year, 210,000 km^2 of the Northern Territory's tropical savannas region is affected by fire.[45] Rapid growth during the rainy season, followed by hot dry weather creates optimal conditions for large scale fire. Burning in these areas creates a significant and steady volume of greenhouse gases, however the carbon sequestration qualities of subsequent plant growth offsets this to an extent. Methane and nitrous oxide are also released by the fires, both of which are not recaptured as effectively via sequestration and are absorbed into the atmosphere. These two gases both have particularly large global warming potentials.

Savanna burning is a significant source of greenhouse gases, accounting for between 1 and 3% of Australian GHG emissions.[46] Between 1990 and 2006 there was a 73.7% increase in emissions from prescribed burning[47] of savannas on a national basis.[48] These emissions estimates include the methane and nitrous oxides emitted – the carbon dioxide is excluded as it is assumed to be later re-absorbed during regrowth.[49] In addition, current fire regimes strongly impact regional biodiversity, human health and social and community values.[50]

Studies have shown that planned, early, dry season fires emit less greenhouse gases per area affected than the more intense, late, dry season fires.[51] The application of strategic scientific management of the savanna fires can ensure that the net effect of the emissions is as small as possible. Climate change has the potential to exacerbate fire activity, magnifying the impact of such initiatives. While pilot projects (such as the Western Arnhem Land Fire Abatement Project) have demonstrated significant GHG reductions, the potential for such models to be applied in other, drier areas is less developed and requires further research. CSIRO Sustainable Ecosystems in conjunction with other partners is currently investigating this issue.

[44] Purdon, P (2007) *A Northern Perspective: Savanna Management' for 'Climate change land management, agriculture and forestry workshop* on 17 August 2007, Melbourne.

[45] Council of Australian Governments *National Inquiry on Bushfire Mitigation and Management* cited in Russel-Smith, J et al (2009) *Culture, Ecology and economy of fire management in North Australian Savannas*. CSIRO Publishing. P. 2

[46] Department of Climate Change (2007) *National Greenhouse Gas Inventory.* Available at http://www.ageis.greenhouse.gov.au/. Accessed 20 November 2009.

[47] Prescribed burning in the context of the Australian savannas, is the deliberate lighting of fires in the dry season in order to reduce the area of stronger, late dry season fires

[48] UNFCCC (2008) *Report of the individual review of the greenhouse gas inventory of Australia submitted in 2008*. p. 13

[49] While the Intergovernmental Panel on Climate Change makes this assumption, there is currently debate over its validity. There is a need for more research in this area. See Russel-Smith, J et al (2009) *Culture, Ecology and economy of fire management in North Australian Savannas*. CSIRO Publishing. P. 27

[50] Russel-Smith, J et al (2009) *Culture, Ecology and economy of fire management in North Australian Savannas*. CSIRO Publishing. P. 2.

[51] Purdon, P (2007) *A Northern Perspective: Savanna Management.* Department of Natural Resources, Environment and Arts.

Outback example 3: The Western Arnhem Land Fire Abatement (WALFA) Project[52]

Indigenous Ranger groups in the Northern Territory are implementing strategic fire management across 28,000 km^2 of Western Arnhem land. As well as significant greenhouse gas savings and better environmental outcomes, the initiative also brings broader opportunities for the local indigenous community.

The project has been achieved through a partnership between the Aboriginal Traditional Owners and Indigenous ranger groups, Darwin Liquefied Natural Gas (DLNG), the Northern Territory Government and the Northern Land Council. It offsets emissions from an LNG plant at Wickham Point in Darwin.

Based on traditional aboriginal fire management practices, greenhouse reductions are achieved through burning patchy fires and fire breaks in the early, cooler part of the dry season to prevent wildfires occurring in the hotter parts of the year. The project has averaged 122,000 tonnes of CO_2-*e* savings per year.

The changed practices are funded by Darwin LNG (at a cost of around $1 million per year – equating to less than $10 per tCO_2-*e*), and bring additional opportunities to the region including new jobs, networks and educational opportunities. In addition, it helps to conserve the environmental and cultural values of the environmentally-significant Western Arnhem Plateau.

Feral pest management

Pest animals can produce significant volumes of methane through enteric fermentation and the loss of plant biomass. Significant greenhouse gas savings can be achieved by removing them from the landscape.

Many species of pests which inhabit the rangelands emit methane into the atmosphere though enteric fermentation in their digestive systems and also impact on plant biomass (they degrade the landscape by damaging, disturbing and eating soil and vegetation). The removal of these animals will result in a reduction of methane emissions and preserve carbon stocks in biomass. As well as their environmental and social impacts, feral pests have been estimated to have an annual economic cost of $719.7 million as a result of control costs (such as baiting, fencing, shooting and research into management practices); production losses (as a result of predation on young stock, crop damage and competition for feed); as well as public research and management costs.[53]

Climate change may exacerbate this problem. Warming trends could lead pests to extend their habitat southwards.[54] Disturbed habitats (such as those impacted by extreme weather events) may be more easily colonised by pest animals. With greater climatic variation, strategic pest management will become more important.[55]

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[52] See CSIRO Tropical Savannas *The West Arnham Land Fire Abatement Project (WALFA)*. http://savanna.cdu.edu.au/information/arnhem_fire_project.html. Accessed 1/7/09.

[53] Drucker, A.G. (2008) *Economics of camel control in the central region of the Northern Territory*. Desert Knowledge CRC. P. I.

[54] National Agriculture and Climate Change Action Plan (2008) *Communicating climate change: climate change impacts on pest animals and weeds*

[55] *Ibid.*

One recent example of a feral pest management initiative is the camel culling program initiated by the Federal Government.

Outback example 4: camel culling programs

The Federal Government has committed $19 million to fund a camel culling program in Northern and Western Australia.

There are currently nearly one million camels in outback Australia. An introduced pest, their numbers have swelled dramatically – by an estimated 11% per year – due to having no local predators.

Regarded as one of Australia's worst feral pests, camels cause damage to infrastructure and trample habitats, as well as releasing vast amounts of methane from enteric fermentation.[56]

Camels are estimated to have an economic cost of $0.2 million per year as a result of their control costs and impacts on production.[57] Research by the Desert Knowledge CRC has shown that reducing their population by 75% will lead to a total present economic benefit of $88 million over 12 years.[58]

Helicopters are used to cull camels in remote parts of central Australia.

Grazing management

Research is underway to investigate the possibility of modifying traditional agricultural production techniques to improve their impacts on GHG emissions and soil stored carbon. One major opportunity in this area is the possibility of reducing emissions from enteric fermentation, which are a major pollutant.

Grazing management involves manipulating animal grazing to balance the supply of forage needed by animals (for production) with the animal, plant, land or economic impacts. Grazing management can contribute to reducing greenhouse emissions by: (1) reducing direct emissions (particularly methane) from the animals themselves; and (2) by maximising the carbon stored in vegetation where they graze through a range of management practices.

1. **Direct emissions:** The ability of ruminant livestock such as cattle to consume coarse plant material that humans cannot is due to their unique digestive system. The digestive system, known as enteric fermentation, breaks down and ferments the plant material into a product that can be used as energy. A by-product of this process is methane which is released into the atmosphere, registering a dietary loss but also a significant

[56] On average, camels release approximately 0.97 tonnes of CO_2 equivalents per year, though there will be variation between animals. See Department of the Environment, Water, Heritage and the Arts (2009) *Camel fact sheet*. Available at http://www.environment.gov.au/biodiversity/invasive/publications/camel-factsheet.html. Accessed 16 April 2010.

[57] McLeod, R and Norris, A (2004) *Counting the cost: impact of invasive species in Australia, 2004*. Pest Animals Control CRC. p. 1.

[58] Drucker, A.G. (2008) *Economics of camel control in the central region of the Northern Territory*. Desert Knowledge CRC. P. VI.

greenhouse gas contribution.[59] These emissions could potentially be reduced by actions including:[60]

- changes in pasture management and feeding practices (generally, the higher the diet quality, the lower the emissions per unit of intake)
- manipulating the digestive process to reduce methane production (possibly through vaccines, anti-microbials, selective breeding and/or genetic improvement)

2. **Impact on biomass:** Grazing animals can degrade the landscape and reduce the levels of stored carbon. There are several management practices livestock producers can implement on the farm to help preserve and increase carbon stocks, including:
   - Balancing livestock demands and the available forage supply to encourage the biomass to remain in its most productive phase
   - Spreading the grazing 'load' over the landscape (using fencing, artificial watering points, or other techniques)
   - Providing effective rest periods and managing grazing in a way that in harmony with the requirements of the species of plant being grazing.

Outback example 5: Wambiana study of grazing management regimes[61]

Two scientists from the Queensland Department of Primary Industries and Fisheries have conducted an eight-year trial to investigate the impacts of a variety of different grazing management strategies on the land, the cattle and the people. This provides a long-term, whole-of property snapshot of the whole grazing system's response to management actions.

The trial has shown that sustainability and profitability can go hand-in-hand in Australia's northern savannas. Good management practices can lead to better quality of animals, shorter turn-off times, reduced costs and higher rainfall use efficiency. In contrast, heavy stocking performed well initially but land condition declined and the stock numbers could not easily be maintained.

The project will develop best practices and guidelines for graziers.

2.3.1 Land management practices not modelled

Various additional land management practices have been proposed that may be applicable in the Australian outback, but additional research is required in order to quantify these. While these may be viable actions, Nous has not modelled these in this analysis due to a lack of data. Notable proposed practices that have not been modelled include:

[59] Global Climate Change and Environmental Stewardship by Ruminant Livestock Producers (1998)

[60] Commonwealth Science and Industrial Research Organisation (2009) *An analysis of greenhouse gas mitigation and carbon Biosequestration opportunities from rural land use*. p. 39

[61] Tropical Savannas CRC *Wambiana: the big picture on grazing*. http://savanna.cdu.edu.au/publications/savanna_links_issue33.html?tid=250863. Accessed 19/10/09.

- **Invasive weed management:** The invasion of non-native weed species threatening the biodiversity of flora and fauna in native eco-systems of the outback, and potentially impacting the carbon sequestration potential of outback Australian ecosystems.[62]
- **Biochar:** Biochar has been recently discussed in scientific circles and the media as a major step toward an effective carbon abatement solution as it has carbon negative sequestration potential. This means that, overall; biochar removes more carbon from the atmosphere than it produces in the carbon cycle. [63]

2.4 Methodology

Nous assessed the environmental impact of these initiatives on greenhouse levels as well as the economic viability of their implementation. This analysis was performed through assessing:

1. **Reference case carbon stocks and emissions:** Estimating the current carbon stocks and emissions from outback Australia under the impact of expected business-as-usual changes
2. **Modelling emissions changes:** Calculating the impact of proposed changed land management practices on reference-case carbon stocks and emissions
3. **Cost analysis:** Developing a whole-of-life economic cost for each of these practices.

The key data source for estimation of carbon stocks is the Queensland Herbarium's study estimating the biomass in outback Australia's vegetation communities. This study delineates biomass into its *potential* (theoretical levels after regrowth and revegetation) and *current*[64] (actual levels based on historical clearing) components. The biomass values were used to establish the current carbon stock in outback Australia.

Nous research has identified that carbon sequestration and abatement potential varies across landscapes and regions of the outback. The initiatives modelled in this project reflect *overall* outback abatement potential.

Nous modelling has been informed by input from subject-matter experts (listed in **Appendix C**), and a wide range of studies. Nous has developed the model from the best available data, as of the date of publication.[65]

2.5 Report structure

This report was commissioned to assist policy makers and the community make an assessment of the environmental and economic value of changed land management practices in the Australia outback.

The report sections to follow outline:

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[62] B.A. Bradley and R.A. Houghton, et al. 'Invasive grass reduce aboveground carbon stocks in shrublands of Western US' in *Global Change Biology* 12 (2006), pp. 1815-22.

[63] *An Analysis of Greenhouse Gas Mitigation and Carbon Sequestration Opportunities from Rural Land Use*, edited by Sandra Eady, Mike Grundy, Michael Battaglia and Brian Keating, CSIRO, St Lucia, pp. 143-44.

[64] Current biomass is defined as 2001 remnant vegetation based on the VAST 2004 classification

[65] While the report presents preliminary findings with the best available data, we recognise the need for further research in this field.

- Carbon abatement potential in Australia's outback through changed land management practices that preserve existing stores of carbon, sequester carbon and reduce greenhouse gas emissions
- Potential cost of abatement expressed through a marginal abatement cost curve
- Implications of large carbon abatement potential in the outback on Australian climate policy.

3 Results: The carbon abatement potential of Australia's outback

Outback Australia can play a pivotal role in the Australian climate change mitigation effort by preventing emissions of greenhouse gases and removing carbon dioxide from the atmosphere. An enormous amount of carbon – nearly 9.79 billion tonnes of carbon – is stored in the Australian outback. This project has identified the potential for abatement of approximately 1,300 Mt CO_2-*e* in remote Australia through application of changed land management practices.

This benefit is a combination of *protecting* existing stores of biomass, and *reducing* emissions by sequestering carbon plant biomass, as well as *reducing* emissions of nitrous oxide and methane. The modelling also demonstrates that these land management practices are, in most cases, cost effective.

3.1 A vast carbon store in outback Australia

Carbon is an essential component of soils and vegetation and is absorbed into plant matter through photosynthesis. Outback Australia is dry and sparsely vegetated, and thus has low carbon storage per hectare. However, the sheer size of Australia's outback has led it to amass vast carbon stores. A study by the Queensland Herbarium for this project has shown that almost 10 billion tonnes of carbon is stored in the Australian outback (more detail on the Queensland Herbarium study is provided in **Appendix B**). Protecting these areas from degradation and destruction has the potential to preserve this current carbon storage. If poorly managed, this carbon store has the potential to release substantial amounts of sequestered carbon.

3.1.1 Storing carbon within biomass

Plants, through the process of photosynthesis, convert atmospheric carbon dioxide into the sugars that they need for energy and growth. This chemical reaction is essential for life on earth: we depend on it as a source of energy directly and in our food. It may also prove a valuable weapon in the fight to reduce atmospheric greenhouse gas levels.

The carbon absorbed from atmospheric carbon dioxide is stored within the plant matter in the tree – it has been estimated that 50% of a tree's weight is carbon.[66] When the tree dies and decays, part of this carbon will be transformed into soil organic matter – which is 57% carbon.[67]

Forests that are increasing in density or area will be a net carbon sink (absorb more carbon than they emit). In essence, carbon dioxide is withdrawn from the atmosphere and converted into vegetative matter. On a global scale, this effect is massive: it has been

[66] Gifford, R. (2000) 'Carbon Content of Woody Roots: Revised Analysis and a Comparison with Woody Shoot Components' in *National Carbon Accounting System Technical Report No. 7 (Revision 1).* Australian Greenhouse Office, Canberra.

[67] Sundermeier, A et al (2009) *Soil carbon sequestration – Fundamentals*. Ohio State University, Food Agricultural and Biological Engineering. http://ohioline.osu.edu/aex-fact/pdf/0510.pdf. Accessed 20/10/2009.

estimated that photosynthetic organisms (including both trees and bacteria) convert around 100,000 Mt of carbon into biomass per year.[68]

This process is particularly valuable for climate change mitigation efforts as it provides a mechanism to re-absorb historic emissions. The world has already embarked on a high-emissions trajectory and opportunities to sequester atmospheric carbon dioxide will be increasingly valuable in preventing dangerous impacts from climate change.

Climate change may actually prove to enhance this effect. Higher concentrations of carbon dioxide in the atmosphere can make plants grow more rapidly and thus sequester more carbon. One study of tropical forests showed that the African, Asian and South American tropical forests had absorbed about 18% of all carbon dioxide added by tropical forests.[69]

Figure 3 provides an overview of the carbon cycle and the process of carbon storage in biomass.

[68] Field, CB et al (July 1998) 'Primary production of the biosphere: integrating terrestrial and oceanic components' in *Science* (journal), **281**, (5374). p. 237–40.

[69] ScienceDaily (2009) *One-fifth of Fossil-fuel emissions absorbed by threatened forests* http://www.sciencedaily.com/releases/2009/02/090218135031.htm. Accessed 20/10/2009

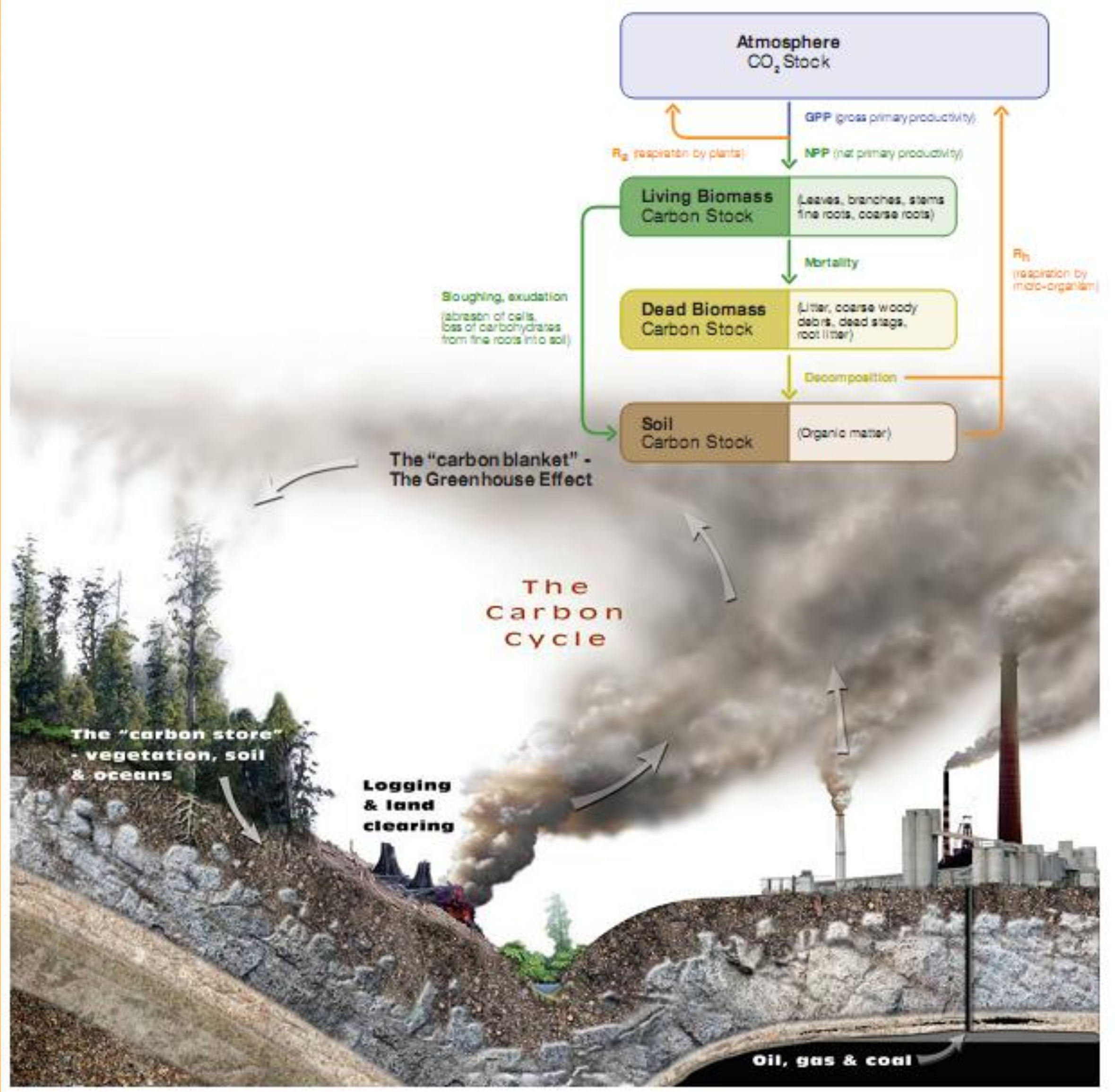

Figure 3 - the carbon cycle and carbon storage in biomass[70]

3.1.2 Carbon storage distribution

The Queensland Herbarium study splits vegetation into vegetation type, based on the tallest stratum growth form (TSGF) as used in the Carnahan classification system. The study contrasts *actual* carbon stocks (as a result of historic clearing) with the *potential* increase in stocks (through vegetation regrowth).

Of the calculated stored biomass, medium woodland-forests, low woodland-forests and tall shrublands represent approximately 77% of the biomass, and have the highest additional

[70] Reproduced, with permission, from The Wilderness Society (2009) *Green carbon in the Great Western Woodlands: a global opportunity*. p. 4

storage potential. **Figure 4** shows actual levels of carbon storage in 2001, with the potential for additional storage.

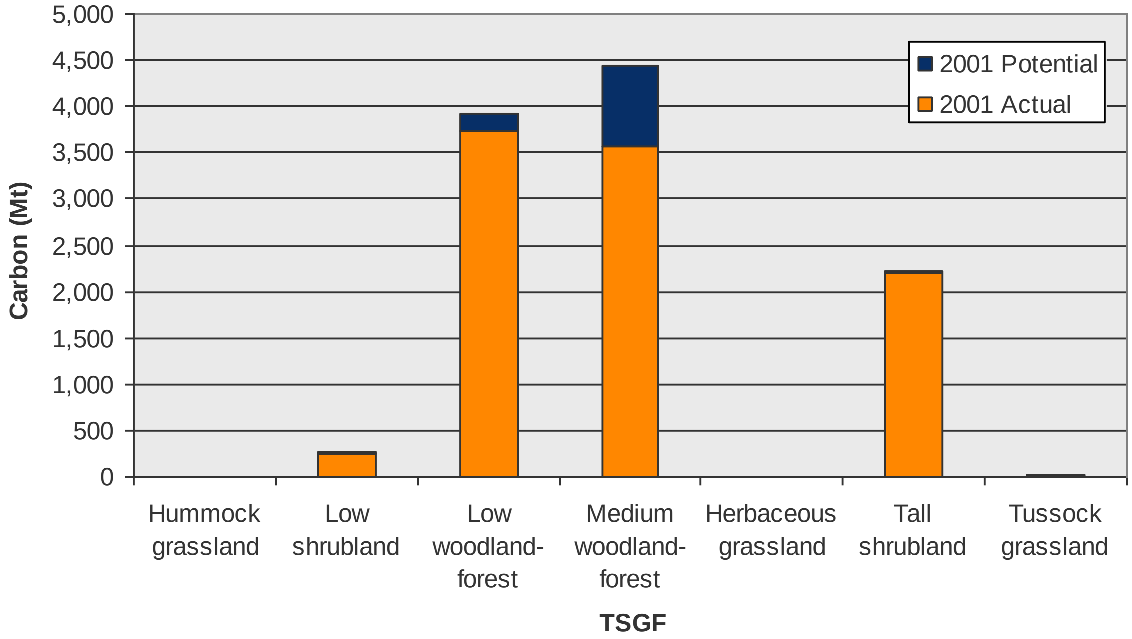

Figure 4 – Carbon levels for each vegetation type

3.1.3 Above and below ground biomass

The Queensland Herbarium's analysis distinguishes between above and below ground[71] biomass. Approximately 84% of biomass stocks are above ground.

[71] Below ground estimates exclude soil carbon.

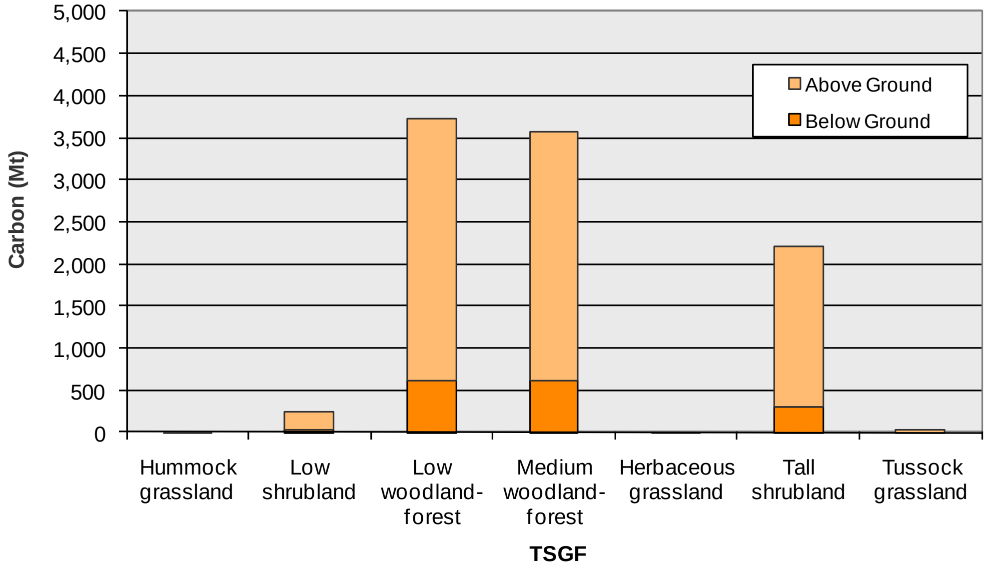

Figure 5 – Above and below ground carbon (excluding soil carbon) stores by vegetation type

3.1.4 Projections over time

Nous has produced projections which account for the various factors that impact on carbon storage and shown that under current conditions the carbon stock is relatively stable, with a very slight increase over time.

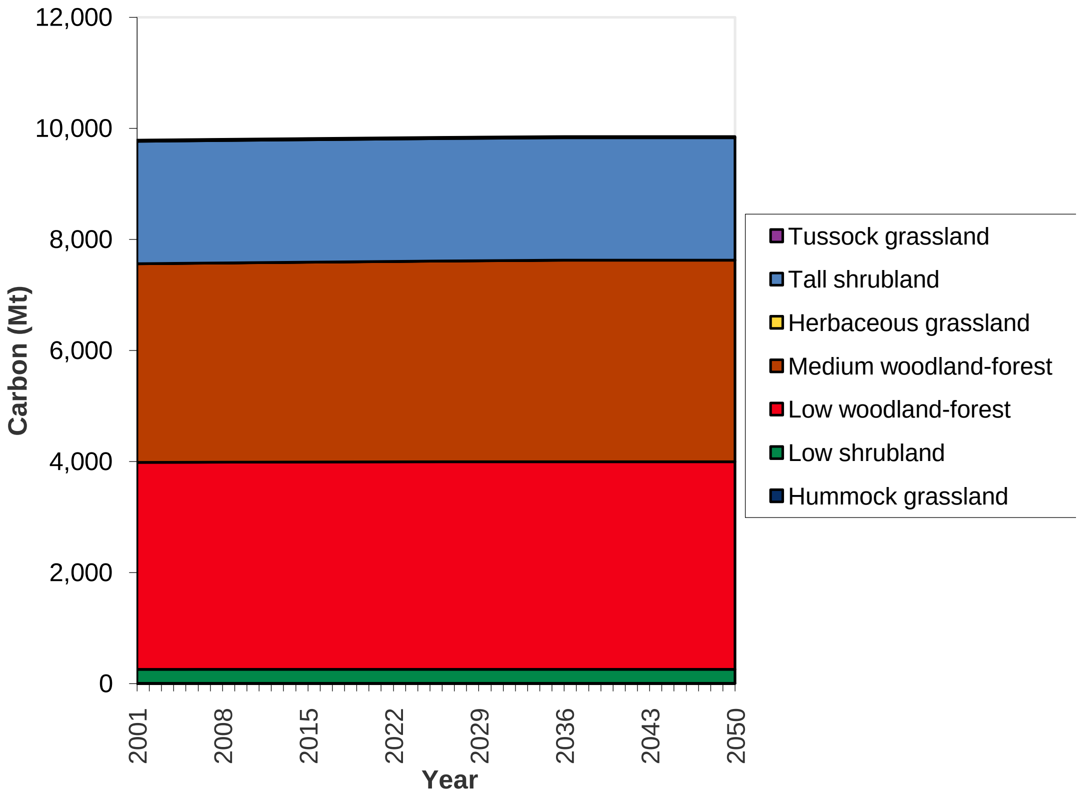

Figure 6 – Total carbon stock levels in the Australian Outback

3.1.5 Carbon stocks under the Kyoto protocol

Much of the native vegetation in the large expanses of Australia's outback is classified as non-compliant within the definition of forest under the Kyoto protocol ("Kyoto non-compliant").

The Kyoto Protocol allows developed countries to discount their greenhouse gas emissions by including specific Land Use, Land Use Change and Forestry Activities (LULUCF), including specific cases of afforestation, reforestation and deforestation activity since 1990. This activity is restricted to 'Kyoto forest', which is defined in the Marrakesh Accords.[72] This definition excludes approximately 7.4 billion tonnes of biomass in the Australian outback, or 3.7 billion tonnes of carbon. For inclusion under the protocol, carbon stocks must be stored in Kyoto forest, and must also meet additional criteria including having been cleared prior to 1989. The definition of "Kyoto-compliance" is restrictive – excluding the bulk of the potential storage in remote Australia – and was developed in response to technical constraints and

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[72] 'Kyoto Forest' is a minimum area of land of 0.05-1.0 hectares with tree crown cover (or equivalent stocking level) of more than 10-30 per cent with trees with the potential to reach a minimum height of 2-5 metres at maturity in situ. A forest may consist either of closed forest formations where trees of various storeys and undergrowth cover a high portion of the ground open forest. Young natural stands and all plantations which have yet to reach a crown density of 10-30 per cent or tree height of 2-5 metres are included under forest, as are areas normally forming part of the forest area which are temporarily unstocked as a result of human intervention such as harvesting or natural causes but which are expected to revert to forest.' European Environmental Agency *Environmental Terminology Discovery Service'*. http://glossary.eea.europa.eu/EEAGlossary/K/Kyoto_forest. Accessed 30/9/2009.

what was politically possible and strategic at the time, rather than facilitating maximal greenhouse gas abatement.

Improvements in measuring and monitoring techniques may allow the extension of the definition of forest under international agreements to include a greater percentage of carbon stocks, and fully recognise the potential for carbon storage in the Australian outback.

3.2 Potential for significant reduction in GHG emissions through improved land management practices

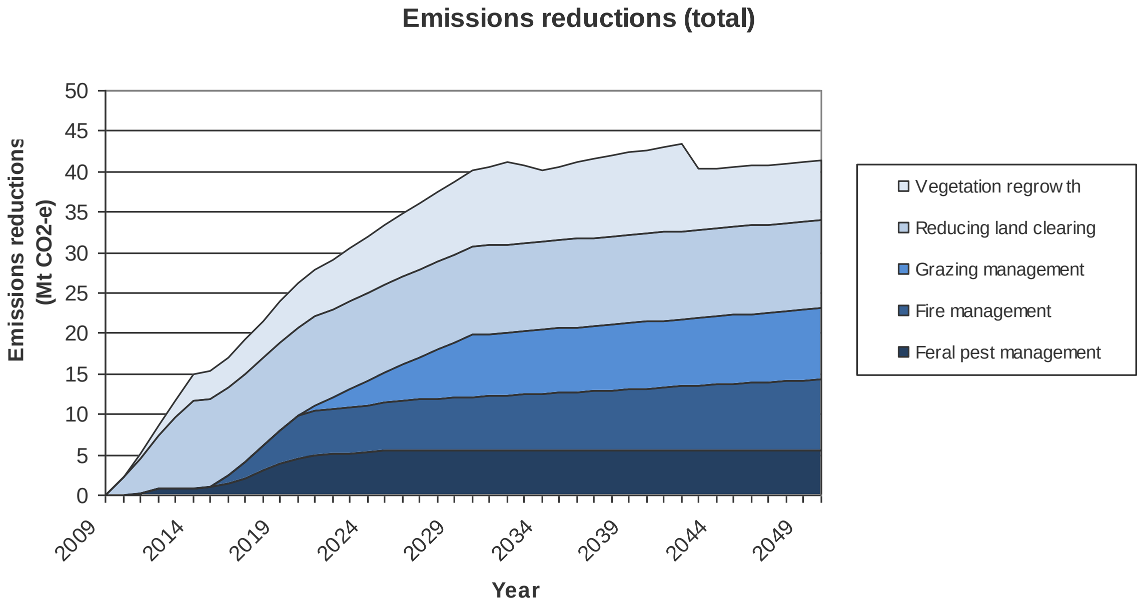
The Nous Group modelled the potential of five land management activities to contribute to GHG abatement. These initiatives can reduce GHGs through two mechanisms:

1. **Increasing carbon stocks**: Action can be taken to preserve and add to the levels of carbon stored in biomass in the Australian outback. Even small changes in the carbon levels can have dramatic implications due to the large areas involved
2. **Reducing current emissions of other related greenhouse gases**: Other greenhouse (particularly methane and nitrous oxide) are released from various anthropogenic and natural processes in the outback. As nitrous oxides and methane have a severe impact on climate (with a heat trapping capacity of 298 and 25 times that of CO_2 respectively),[73] their inclusion is necessary for accurate estimation of overall GHG change.

Both of these GHG sources are significant and were considered separately in this analysis. For example, land clearing primarily impacts on biomass levels, as woody mass is permanently removed. In contrast, fire management leads to a temporary loss of biomass (which is recovered over the long-term due to regrowth), but emits large amounts of nitrous oxide and methane.

The total emissions reduction from each of the land management practices (including both of these components) is shown in **Figure 7**.

[73] This is the global warming potential at 100 years (see Forster, P., (2007) 'Changes in Atmospheric Constituents and in Radiative Forcing' in *Climate Change 2007:The Physical Science Basis*. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press. p. 212)



	Reducing land clearing	Vegetation regrowth	Grazing management	Fire management	Feral pest management	Total
Total reduction to 2050	425	287	206	230	184	**1,332**
Annual reduction at 2020	11	5	0	5	4	**26**
Annual reduction at 2030	11	9	8	7	6	**40**

Figure 7 - Overall GHG reductions through land management activities (Mt CO_2-e)[74]

All of the land management practices investigated lead to significant GHG reductions over the term of the study. Reducing land clearing offers the greatest opportunity for emissions reductions, indicating that the Queensland ban on most land clearing activity (of mature vegetation) should be extended to other states. These results also clearly demonstrate the need for additional research prior to implementing many proposed grazing management activities – these are only likely to become effective at around 2020.

The emissions reductions from each initiative cannot be directly summed: there are complementarities and interferences between the initiatives which have not been accounted for. Therefore, while the total figures provided are only approximate, they do provide an indication of the magnitude of potential abatement that can be achieved.

The total abatement of approximately 1,300 Mt CO_2-*e* is a significant sum – similar in scale to the abatement identified in a previous study of the potential for emissions reductions across the Western Australian economy.[75] This is equivalent to the carbon dioxide saved by taking 7.5 million average cars off the road. [76] The annual abatement at 2020 and 2030 are

[74] Note that component figures may not add up exactly to totals due to rounding

[75] The Nous Group (2008) 'Assessment of greenhouse gas abatement potential and cost in key sectors of the Western Australian economy'

[76] The average car emits approximately 4.3 t of carbon dioxide per year. See Greenfleet *Car offsets* https://secure.greenfleet.com.au/treetotaller/order_simple_individual.aspx

approximately 4% and 5% respectively of projected Australia-wide business-as-usual emissions.[77]

There are several previous studies which have estimated the potential for abatement from changed land management, notably *The Garnaut Review* and CSIRO's report *An Analysis of Greenhouse Gas Mitigation and Carbon Biosequestration Opportunities from Rural Land Use.* This Nous study was performed in parallel with parts of the latter study, building on it by assessing additional land management practices and providing an economic assessment to determine the cost-effectiveness of each initiative. **Table 3** provides a comparison of the figures calculated in this analysis to those developed by Garnaut and CSIRO. Note that these are not directly comparable, as the region under consideration in this report, the Australian outback, does not correspond exactly to the Australia-wide estimates provided by Garnaut and CSIRO.

	Nous			Garnaut	CSIRO
Initiative	**Total abatement to 2050**	**Annual abatement at 2020**	**Annual abatement at 2030**	**Annual abatement**	**Annual abatement**
Reducing land clearing	424.9	10.9	10.9	63	38
Vegetation regrowth	287.3	5.4	9.4		
Fire management	229.9	5.4	6.5	5	13
Feral pest management	183.7	4.4	5.6	Not included	Not included
Grazing management	206.5	0.0	7.7	16	11

Table 3 - Comparison of abatement calculations across various studies (Mt CO_2-e)

The sections below outline the approach and results used in estimating these two types of GHG sources.

3.2.1 Storage in biomass

Plant matter contains carbon which is released into the atmosphere as carbon dioxide on combustion. Dry wood is approximately 50% carbon by weight.[78] Changed land management practices have the potential to preserve and restore carbon stored in plant matter through vegetation growth and thickening. Nous calculated this impact, by using data provided by the Queensland Herbarium (see **Appendix A** for an outline of the methodology used). Demonstrating the results from this analysis, **Figure 8** shows the potential to modify carbon storage in biomass through changed land management practices.

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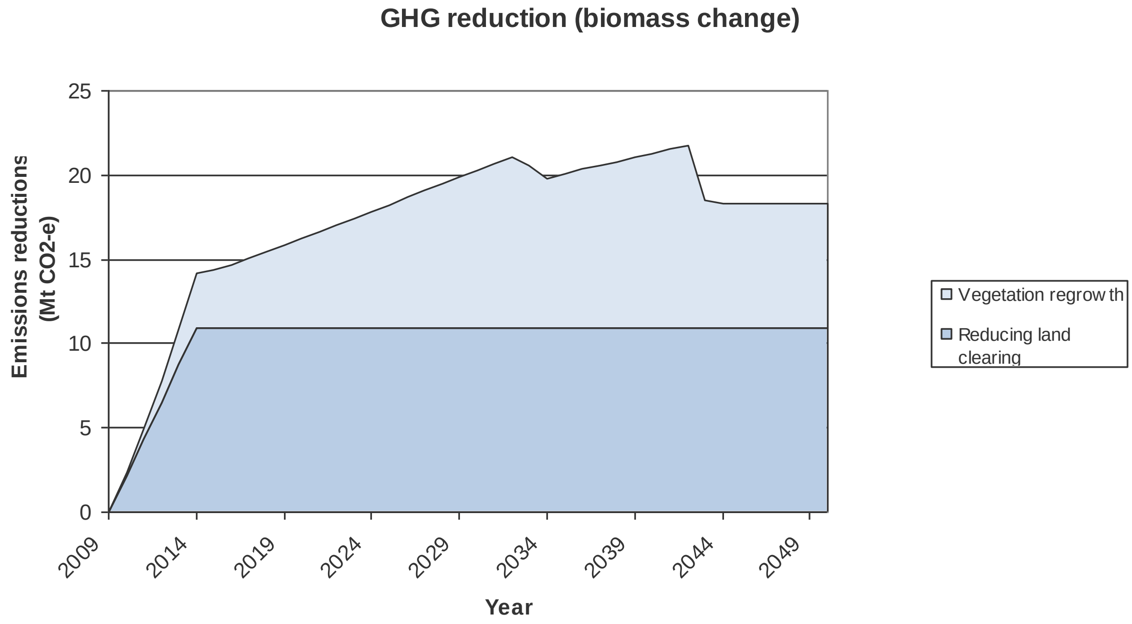
[77] Garnaut, R. (2008) *The Garnaut Climate Change Review,* Final Report, Cambridge University Press, Port Melbourne. p. 284.

[78] Smith, JE, Heath, LS and Jenkins, JC (2002) *Forest volume-to-biomass models and estimates of mass for live and standing dead trees of US forests*. United States Department of Agriculture. p. 1.



	Reducing land clearing	Vegetation regrowth	Total
Total reduction to 2050	425	287	712
Annual reduction at 2020	11	5	16
Annual reduction at 2030	11	9	20

Figure 8 - GHG reduction from changes in biomass stock (Mt CO_2-e)

Action that controls land clearing and allows previously cleared native vegetation to regrow offers significant opportunities to increase or retain carbon storage in biomass. As a comparison, this additional biomass storage is equivalent to the carbon storage that would be achieved by between 5 and 15 carbon capture and storage systems that could sequester CO_2 emissions from coal-fired energy generation.[79]

As regrowth rates are dependant on the species and type of vegetation, there is volatility in the rate of carbon sequestered through regrowth.

3.2.2 Abatement of other gases

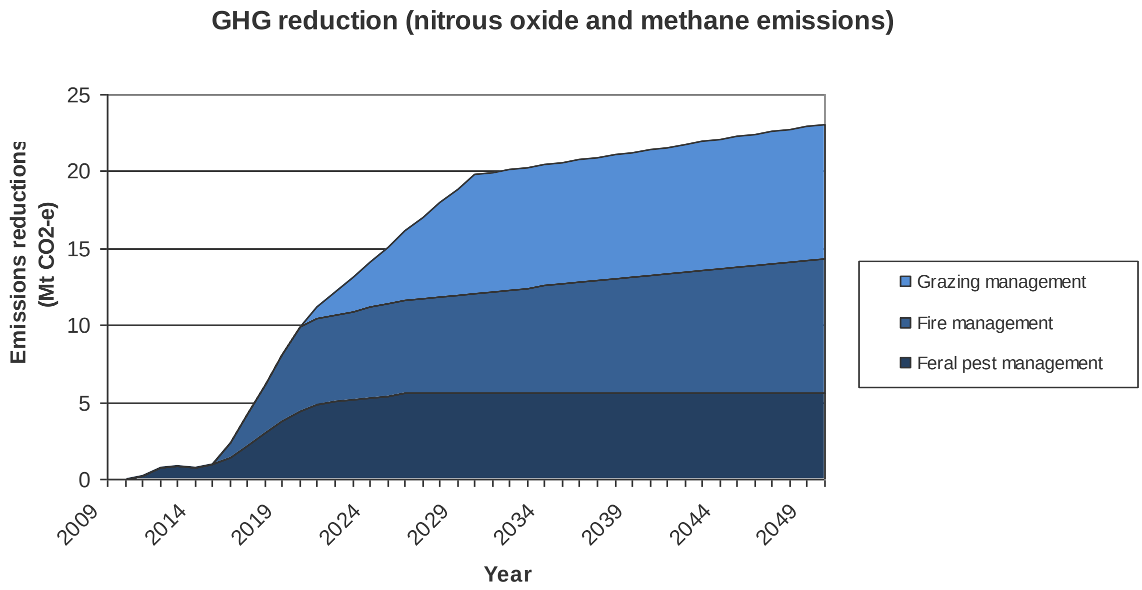
While CO_2 forms the vast majority of Australia's emissions (74% of total emissions in 2007),[80] methane and nitrous oxide emissions (at 20% and 4% respectively) are also significant GHG sources, particularly in the land use change and forestry and agriculture

[79] CCS systems each store approximately 1-5 Mt CO_2--*e* per year. See Intergovernmental Panel on Climate Change (2005) *Special Report: Carbon Dioxide Capture and Storage: Summary for Policymakers*. p. 12.

[80] Department of Climate Change *National Greenhouse Gas Inventory 2007*. http://www.ageis.greenhouse.gov.au (Accessed 25 September 2009)

sectors. These gases have significant heat trapping ability, with a global warming impact many times worse than that of carbon dioxide.[81]

For some of the studied initiatives – grazing management, fire management and feral pest management – the prime GHG impact is through reductions in nitrous oxide and methane emissions. These resulted in the emissions reductions as shown in the Figure below:



	Feral pest management	Fire management	Grazing management	Total
Total reduction to 2050	184	230	206	620
Annual reduction at 2020	4	5	10	10
Annual reduction at 2030	6	7	20	20

Figure 9 - GHG reduction from nitrous oxide and methane emissions (Mt CO_2-*e*)

All three land management practices can lead to significant emissions reductions. The total potential reduction is 23 Mt CO_2-*e* at 2050.

There are significant differences between the implementation time period for these three initiatives. Pest management can be implemented rapidly and immediately via deploying culling programs. Both fire management and grazing management face significant R&D barriers and are likely to only become viable at a much later stage.

3.3 Overall, the land management practices are cost effective

The CPRS Bill (2009) proposes the establishment of a cap and trade emissions trading scheme in Australia. This would introduce a carbon price of $40 in 2010-11, with growth of

[81] The global warming potential after 100 years for methane and nitrous oxide is 25 and 298 respectively. (see Forster, P., (2007) 'Changes in Atmospheric Constituents and in Radiative Forcing' in *Climate Change 2007:The Physical Science Basis*. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press. p. 212)

5% per annum.[82] The majority of the land management practices identified in this report have a carbon cost less than that of the carbon trajectory proposed in the CPRS Bill (2009). This report confirms that changes to land management present cost effective carbon storage and sequestration options that can assist Australia make deep cuts to national emissions.

The land management practices identified in this report fall into three categories:

- **'No regrets' initiative:** Pest management is a 'no regrets' initiative leading to economic gain (because of productivity gains in the grazing industry) – independently of any carbon incentives
- **Low cost initiatives:** The reducing land clearing, vegetation regrowth and fire management initiatives all have a carbon cost of $10 - $20 per t$CO_2$-*e*. These initiatives would not be economically viable unless incentives were developed, but are less than the proposed CPRS carbon price. If linked to Australia's emissions cap they would reduce the total economic cost of emissions reductions
- **Potentially high cost initiative:** There are various methods of grazing management that have been proposed. Some have the potential to diminish industry productivity – though there is the potential for 'win-win' initiatives that can reduce emissions and increase productivity. More research is required into optimal grazing management methods.

These assessments of cost-effectiveness were established through developing whole-of-life economic costs for each of the studied initiatives. By combining these cost assessments with the impacts on GHGs, Nous developed a marginal abatement cost curve (MACC). This tool provides a mechanism for combining environmental and economic impact in order to assess the cost effectiveness of the land management practices as GHG abatement measures. More detail about the methodology used and key assumptions is provided in **Appendix A.**

[82] Department of Climate Change (2009) *Summary: key changes to the carbon pollution reduction scheme legislation'* p. 5.

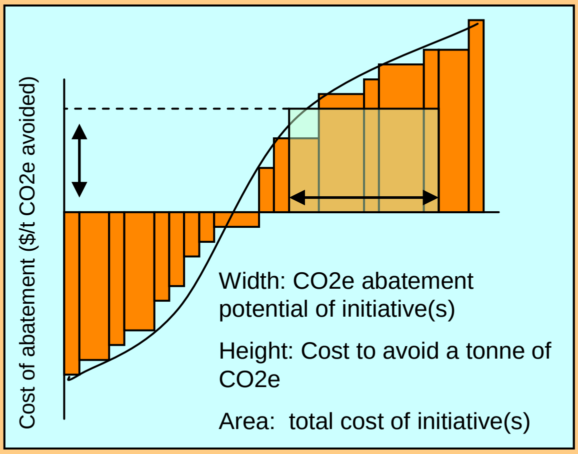
What is a marginal abatement cost curve?

The marginal abatement cost curve is an evidence-based tool which is valuable for assessing the potential and cost-effectiveness of greenhouse gas abatement. It is derived by calculating the change in emissions and carbon storage relative to a reference case (representing the emissions profiles and carbon stock absent any extraordinary effort to abate), and the cost of the changed management practice relative to the reference case.

Construction of the marginal cost abatement curve involves assessing individual initiatives for their abatement potential and cost, and arranging these initiatives in graphical format from least cost to highest cost order. Importantly, the profile of initiatives considered is crucial: invoking some abatement options will impact the abatement potential and costs of others.

Estimating the cost of abatement: The costs considered in the construction of a marginal abatement cost curve are derived from a comparison of costs incurred under abatement initiatives and those incurred under the reference case. For a given initiative, the cost of abatement is the annual additional cost (including depreciation of capital expenses) less potential cost savings (for example, from averted damage to grazing output) compared to the reference case. This means that costs can be negative if the cost savings are considerable compared to the reference case alternative. Opportunity costs associated with productivity losses or foregone alternative investments have been included where appropriate.

The following figure shows a stylised representation of the marginal abatement cost curve:



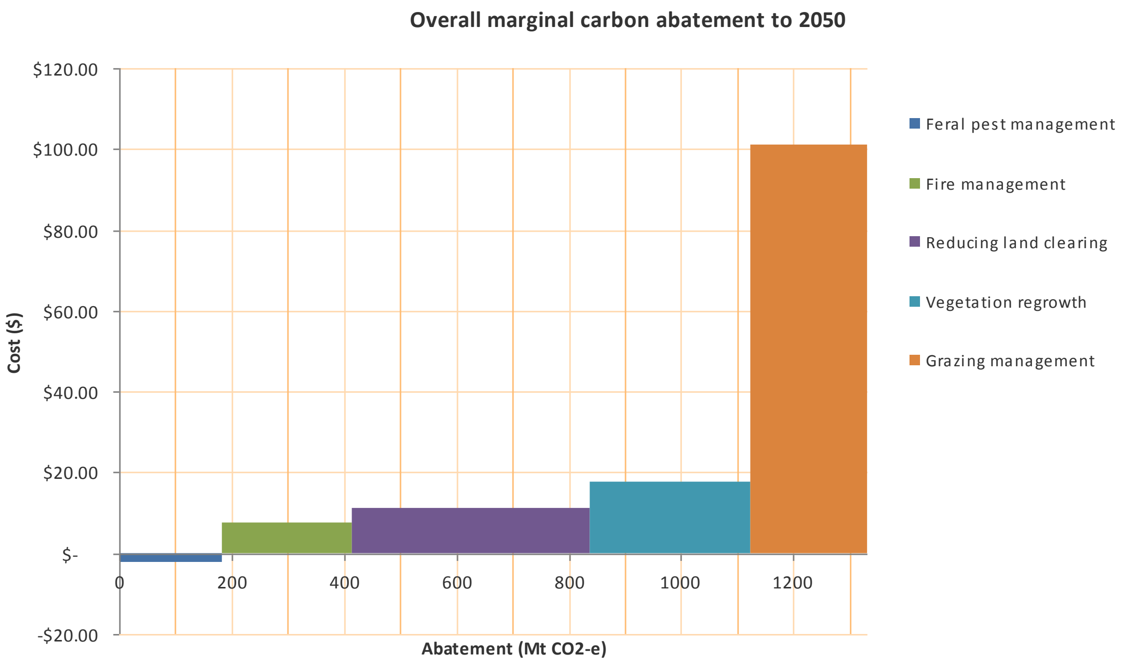
Initiatives that extend below the *x*-axis result in a net economic benefit (that is, a negative cost). Those above the *x*-axis result in a net economic cost. The curve yields insights for policy makers in measuring the economic costs of abatement. For example, by reading off the *x*- and *y*-axes, policy makers can measure the per unit abatement costs associated with given abatement targets. These curves also provide guidance as to the type of initiatives that would be 'triggered' by a carbon price under an appropriately constructed emissions trading scheme, at the same time highlighting the areas beyond an emission trading scheme's reach.

Table 4: Marginal abatement cost curve description

Nous has produced two types of MACC curves, which are both valuable for different purposes:

1. **Overall MACC to 2050**: This provides a whole-of-life assessment of the GHG change and cost of each of the practices. In order to incorporate the time-value of money, costs are aggregated using a Net Present Value. The whole-of-life approach is valuable for decision-makers in assessing the overall feasibility of initiatives; the measures include both short-term implementation barriers as well as long-term trends
2. **MACC at 2020 (and 2030):** These two graphs provide a snapshot of the emissions at 2020 (and 2030), and are useful for analysing the potential for emissions reductions at these times.

3.3.1 Overall carbon abatement cost curve to 2050

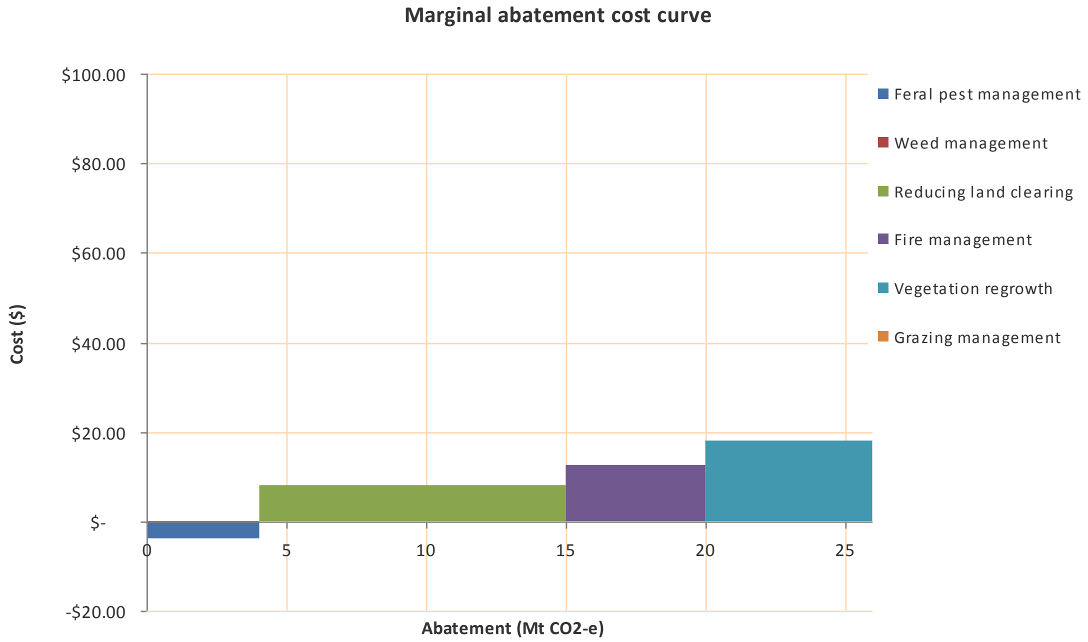


Initiative	Total abatement to 2050 (Mt CO_2-e)	NPV Cost / unit abatement (2009 $)
Reducing land clearing	425	$11.19
Vegetation regrowth	287	$17.54
Fire management	230	$7.47
Feral pest management	184	-$2.43
Grazing management	206	$101.09

Figure 10 - overall carbon abatement cost curve to 2050

These overall cost estimates demonstrate the potential for significant abatement at low cost. Approximately 1,100 Mt CO_2-*e* would be viable at a carbon cost less than the proposed carbon price. Some proposed grazing management strategies would generate productivity losses for industry and are therefore high cost, though other techniques are ‘win-win’: leading to productivity gains as well as emissions reductions.

3.3.2 2020 carbon abatement cost curve



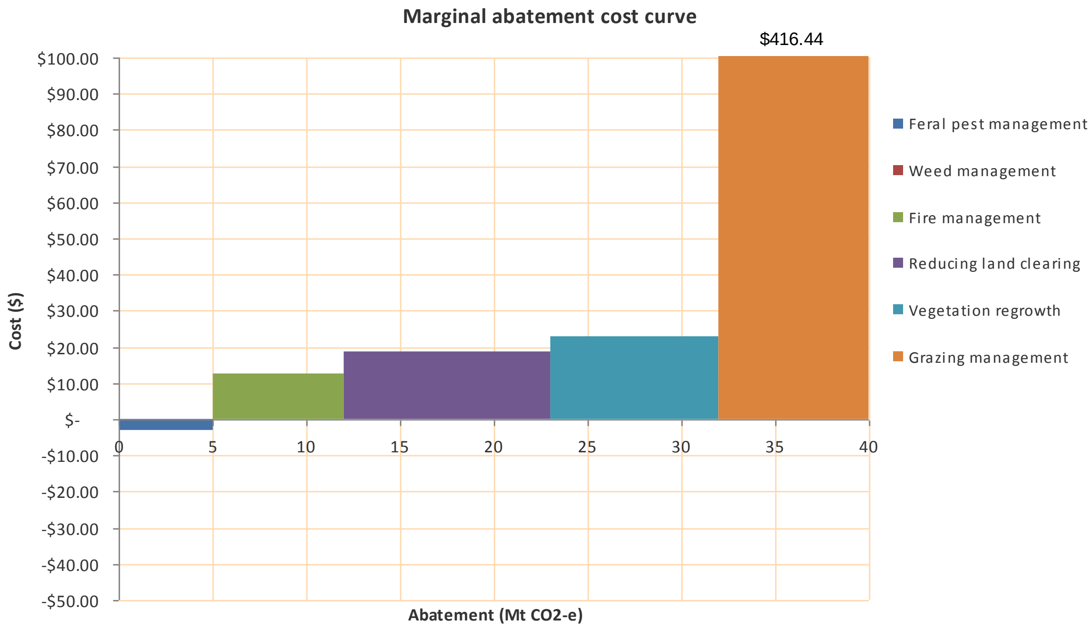
Initiative	Annual abatement at 2020 ($Mt CO_2$-e)	Cost at 2020 / unit abatement (2009 $)
Reducing land clearing	10.89	$7.95
Vegetation regrowth	5.35	$17.95
Fire management	5.44	$12.50
Feral pest management	4.44	-$3.95
Grazing management	0.00	N/A

Figure 11 - 2020 carbon abatement cost curve

Approximately 26 Mt CO_2-*e* of abatement has been identified at 2020, with a carbon cost of less than $20 / t CO_2-*e*.

By 2020 the reducing land clearing, vegetation regrowth, fire management and feral pest management initiatives could be fully operational. It has been assumed that grazing management methods, such as reduction of enteric fermentation using bio-agents, are not yet operational due to research barriers to implementation of these techniques.

3.3.3 2030 carbon abatement cost curve



Initiative	Abatement at 2030 ($Mt\ CO_2$-e)	Cost at 2030 / unit abatement (2009 $)
Reducing land clearing	10.89	$18.79
Vegetation regrowth	9.31	$23.22
Fire management	6.53	$12.50
Feral pest management	5.58	-$3.14
Grazing management	7.67	$416.44

Figure 12 - 2030 marginal abatement cost curve

Approximately 40 Mt CO_2-*e* of abatement has been identified at 2030.

Grazing management may have a high cost at this time, due to the large potential opportunity costs from lost productivity. The actual cost will be dependent on the particular grazing management techniques and technologies used and available.

3.3.4 Comparison with other studies

The table below provides a comparison of these values with values reported in other sources. While there are differences in scope between the Nous study and other past studies, the results are broadly in agreement.

Initiative	Nous			Other source		
	NPV Cost / total abatement (2009 $ / t CO2-e)	Annual Cost / abatement at 2020 (2009 $ / t CO2-e)	Annual Cost / abatement at 2030 (2009 $ / t CO2-e)	Reference value ($ / t CO_2-e)	Source	Rationale for difference
Reducing land clearing	$11.19	$7.95	$18.79	$50.00 at 2020 (in 2007 $)	McKinsey[83]	McKinsey is whole of Australia, and include high yield agricultural and forestry land. Opportunity cost for rangelands is much less per ha.
Vegetation regrowth	$17.54	$17.95	$23.22	$35.00 at 2020 (in 2007 $)	McKinsey[84]	McKinsey report only includes reforestation and afforestation, and specifies tree planting, which signifies greater cost.
Fire management	$7.47	$12.50	$12.50	$10-$15 currently	Garnaut[85]	Estimates from pilot WALFA project.
Feral pest management	-$2.43	-$3.95	-$3.14	About -$120 for camel control	Desert knowledge CRC[86]	High economic impact from various species. CRC study focuses on NT only.
Grazing management	$101.09	N/A	$416.44	$1,000 in 2007$	Nous / SKM[87]	High opportunity cost due to potential productivity losses. Covers WA only.

Table 5 - Comparison of Nous results with other studies

[83] McKinsey (2008) *An Australian cost curve for greenhouse gas abatement*. p. 14

[84] *Ibid*. p. 14

[85] Garnaut Climate Change Review *Abating greenhouse gas emissions through strategic management of savanna fires: opportunities and challenges – Northern Territory*. p. 3.

[86] Long term control costs for camels are approximately an annualised present cost of approximately $600,000 per year, with emissions of 5,000 MT CO_2-*e*. (see Drucker, AG (2008) *Economics of camel control in the central region of the Northern Territory*, Desert Knowledge CRC. For data on other species, see Mcleod, R (2004) *Counting the cost: impact of invasive animals in Australia* CRC for pest animal control).

[87] The Nous Group (2008) *Assessment of greenhouse gas abatement potential and cost in key sectors if the Western Australian economy*

4 Harnessing the abatement potential of the outback

This report has demonstrated that improved land management practices in Australia's outback can produce significant, achievable and cost effective GHG abatement.

4.1 A cheap opportunity for quick and deep cuts to Australia's projected emissions

The outback land management practices analysed have the potential to provide early and achievable GHG reductions. This report finds:

- **9.79 billion tonnes of carbon** is stored in the Australian outback, and an estimated additional **1.08 billion tonnes of carbon** that can be stored in the outback
- A total potential saving of approximately **1,300 Mt CO_2-e**[88] can be achieved by 2050, with a **4% reduction** in business-as-usual emissions by **2020**, and **5% reduction by 2030**
- the economic cost of implementation is in most cases **lower than that of many of the industrial sector emissions reductions** that are targeted by the CPRS (most of these land management practices **cost less than the estimated carbon price** in the Australian emissions trading scheme, apart from grazing management), with feral pest management identified as a 'no regrets' initiative.

4.2 Harnessing the outback's carbon potential

Australia is in a unique position: our vast carbon stores in the outback provide an opportunity to utilise a readily available climate mitigation strategy. Australia is therefore well placed to develop a comprehensive and balanced policy framework for climate change that:

- **Harnesses existing mitigation potential** that does not rely upon huge technological advances, is able to be quickly implemented, and is has, over millennia, proven itself an effective climate mitigation tool
- Takes advantage of a **cost effective** method of carbon abatement
- Encompasses **good risk management** by ensuring that all facets of climate mitigation are equally addressed.

To capitalise on the opportunity for abatement present in the outback, Australia's Governments must establish the right policy setting to encourage uptake of the land management practices outlined in this report. The first key steps are:

- Arguing for a comprehensive **international policy framework** under the United Nations Framework Convention on Climate Change (UNFCCC) that fully recognises terrestrial carbon

[88] Note that the total abatement from these five initiatives cannot be calculated by simply summing their individual abatement (due to issues of complementarity and interference that have not been considered). As such, this total figure should be considered approximate.

- Clarifying and reforming where necessary domestic legislative and policy frameworks to allow landholders and local communities including Indigenous communities to **share equitably and sustainably** in the benefits of income streams which may derive from protection of existing outback carbon banks and further sequestration of outback carbon.
- Developing more robust monitoring and **carbon accounting** methods to properly measure the mitigation contribution of terrestrial carbon.
- Investing in further **research and development** to more thoroughly assess the environmental and economic benefits of changed land management practices.

Appendix A Methodology for assessing GHG reduction and cost

In this project Nous assessed the potential and cost-effectiveness of reducing GHG through changed land management practices in the Australian outback. This analysis was performed through assessing:

1. **Reference case carbon stocks and emissions:** estimating the current carbon stocks and emissions from outback Australia under the impact of expected changes.
2. **Modelling emissions changes:** calculating the impact of proposed changed land management practices on reference-case carbon stocks and emissions.
3. **Cost analysis:** developing a whole-of-life economic cost for each of these practices.
4. **Policy implications:** discussing the impact of these practices under various proposed greenhouse gas accounting provisions.

An overview of this methodology is depicted in the diagram below, and is described more fully in the proceeding sections.

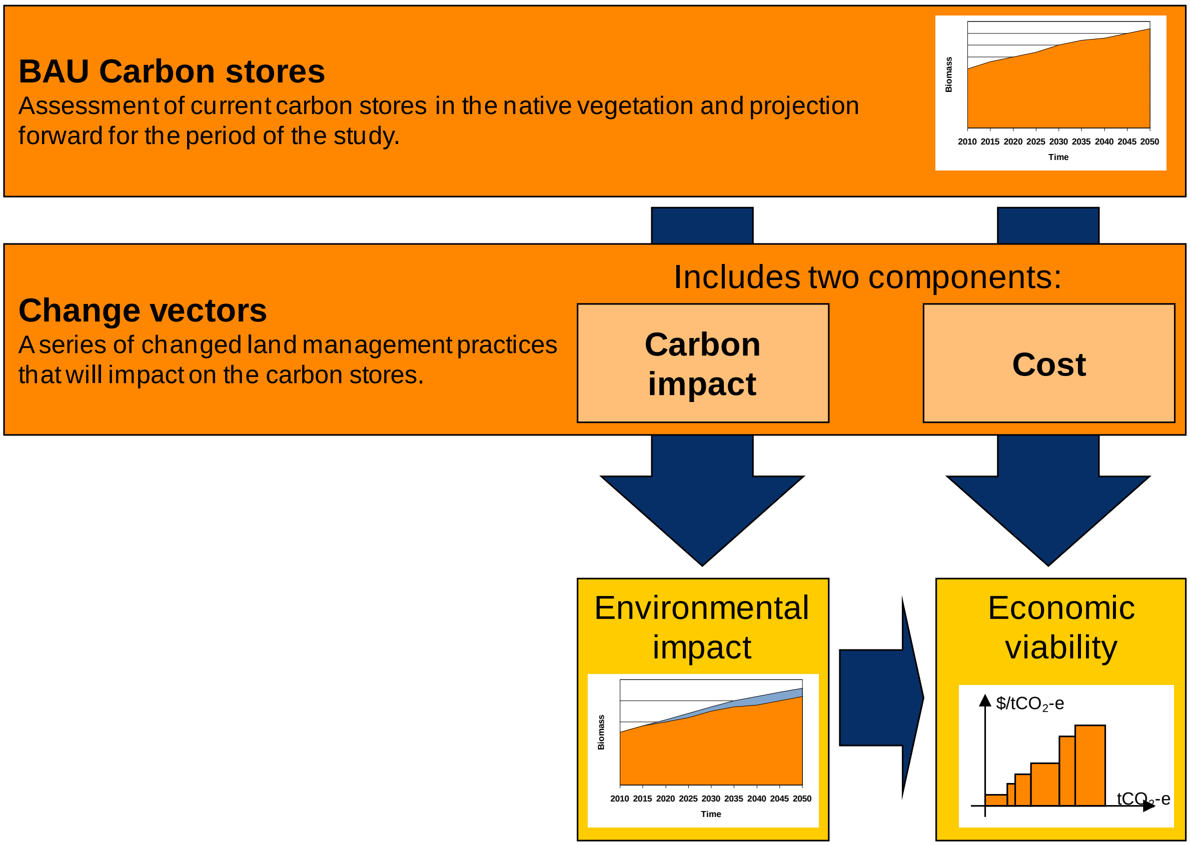


Figure 13 – Overview of methodology for assessing environmental impact and economic viability

The modelling included assessments of the impact of the initiatives on both carbon stocks as well as emissions of other gases. These two effects are both significant from an emissions perspective and vary in relative severity between the various land management practices studied.

The emissions impact was calculated by projecting historic emissions using regression analysis (based on reporting in the National Greenhouse Gas Inventory). These reference case emissions were then adjusted based on the impact of the initiative in order to estimate the emissions change.

The carbon stock impact was calculated using a model of carbon dynamics for each land area. The model was based on 2001 data provided by the Queensland Herbarium which was projected forward to 2050 by adjusting for the various factors which will change carbon stocks in this period. The model incorporates both changes in the geographic distribution of vegetation types (such as land clearing) as well as changes in carbon density (such as regrowth). **Figure 14** provides an overview of this approach.

	# Ha	x	Carbon/Ha	=	Carbon stock
BAU	Current land mapping and known changes		Current carbon density		Existing carbon stock
+/-					
Change (vectors)	Optimal region for application and change; or scope of region transforming vegetation type		Change in biomass storage		Carbon flow (proportional to emissions)
=					
Predicted	Predicted land mapping		Predicted carbon density		Final carbon stock

Figure 14 - Overview of the carbon stocks/flows model

A.1 Reference case carbon stocks and emissions

The reference case provides a base-line for assessing the impact of the land management practices studied. Base case projections were developed for carbon stocks and flows in outback Australia, as well as the expected trajectories of methane and nitrous oxide from various land management activities. Nous' modelling and sensitivity analysis identified that the reference case is a stable base from which to model the emission changes from proposed land management practices.

In this analysis the various vegetation types and areas were aggregated into Tallest Stratum Growth Form (TSGF) groupings, with consideration of clearance levels, TSGF areas, biomass for the given areas and status under the Kyoto protocol.

To match the proposed interventions, the base case's timeline was set from 2001[89] to 2050. As this is a long range forecast, it can be expected that the levels of accuracy will diminish for later years – though sensitivity analysis indicates relatively low error margins.

These 2001 levels were then projected forward by accounting for the impact of the key drivers of change, as identified through an issues tree. **Figure 15** below provides a simplified overview of this process (note that carbon stock levels can be calculated from biomass levels):

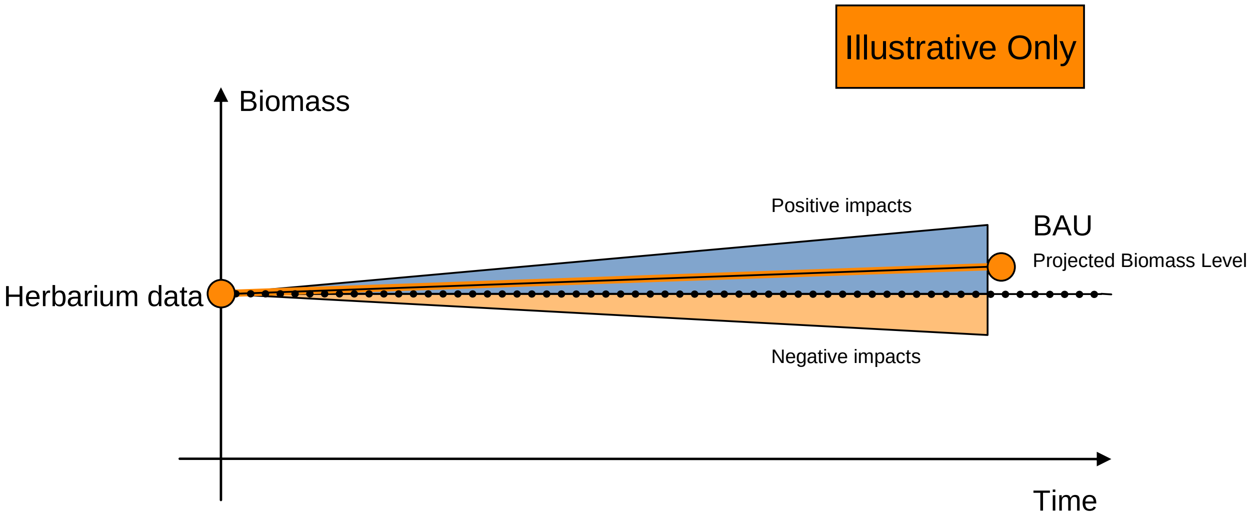


Figure 15 – Stylised overview of construction of reference case

A.1.1 Issue tree

Nous began its analysis by mapping out an issue tree of all major natural and anthropogenic factors, which would affect current carbon stocks over time (see **Figure 16**).

[89] The reference case was based on 2001 carbon stocks provided by the Queensland Herbarium (see Appendix A for an overview of the results and methodology from the Queensland Herbarium's study).

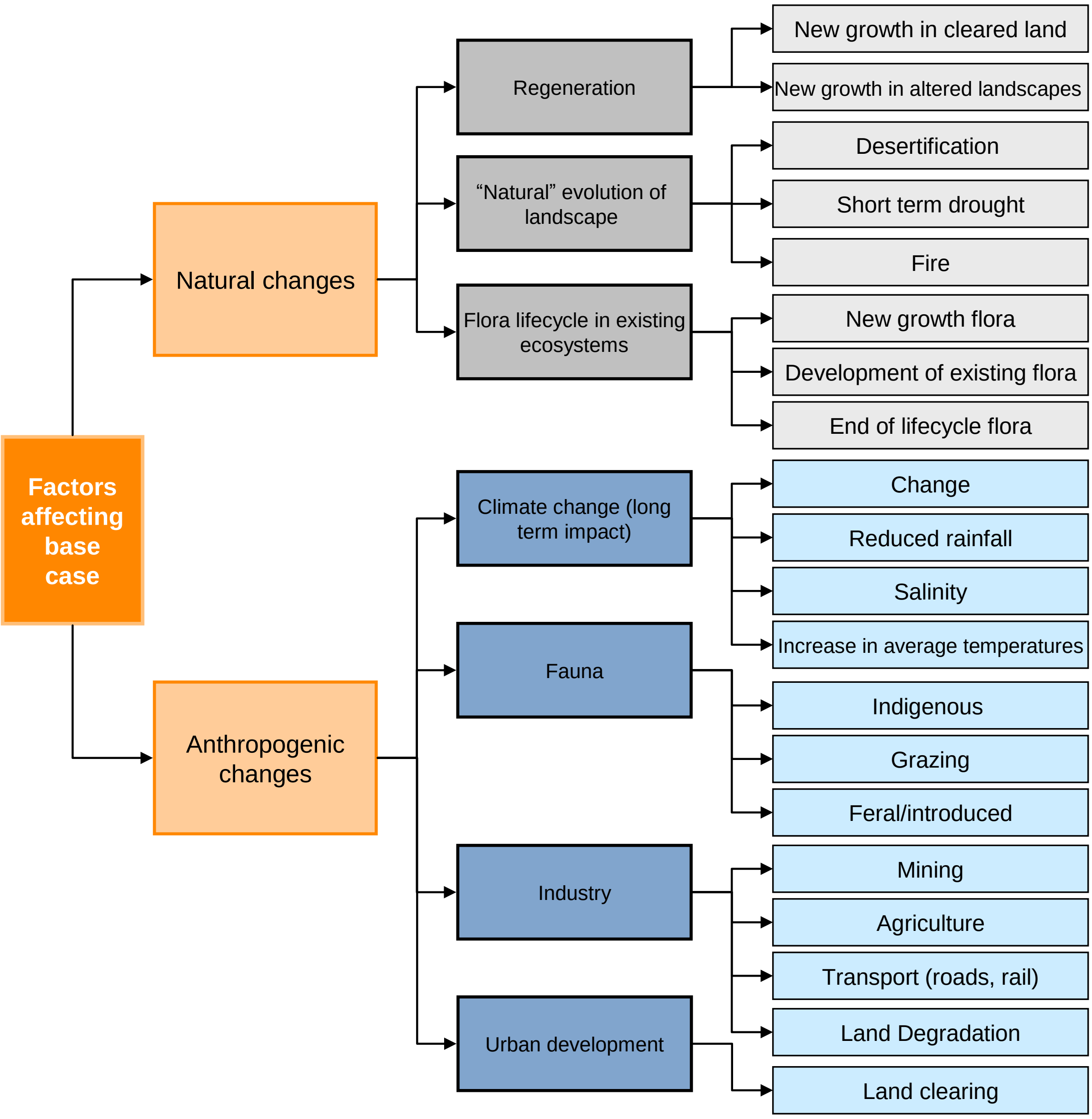


Figure 16 – Issues which may affect the base case

Nous performed extensive desktop research and consultation with experts to determine which set of these factors should be included within the model. The analysis focussed on those factors that were considered by experts to be the key drivers of change in existing carbon stocks. Eliminated factors included those that:

- Did not impact or have a negligible impact on carbon stocks
- Led to cyclical changes but did not impact mean carbon levels (these would cancel out over time)
- Impacted positively and negatively different geographic regions, but would not impact on overall carbon stocks
- Were considered by experts to be tenuous, unmeasurable or improbable
- Were not quantifiable and independent of the land management activities proposed.

From this analysis it became apparent that only two factors are relevant to the land management changes proposed in this report – namely reducing land clearing and facilitating regrowth. These factors are modelled in terms of biomass stock. Note that other important implications of these trends (such as biodiversity) were not quantified, but are discussed further in **Section 2 above**. The following sections describe the modelling assumptions and process used for these two key factors.

A.1.2 Reducing land clearing

Nous modelled the impact on biomass areas and volumes caused by land clearing and re-clearing. This model provides a useful baseline for consideration of the impact of policy and economic drivers that would affect future land clearing rates.

By combining data from several sources,[90] Nous projected the land clearance for each year until 2050. Nous then modelled the complex relationship between land clearance and the reduction of biomass stocks, which it then used to project the biomass levels. The model included consideration that:

- land clearing occurs in areas where there is both dense and sparse biomass levels
- land clearing affects multiple vegetation types
- land clearing affects both regrowth and mature vegetation
- land clearance permits are recorded differently among the different states
- different vegetation types have different biomass levels
- illegal land clearance is inconsistently accounted for in clearance estimates by each state.

A.1.3 Vegetation regrowth

The regrowth model takes into consideration:

- the **natural regrowth rate** of vegetation in wet and dry climates, and the proportion of the Australian outback that is wet and dry
- the impact of **regrowth clearing** as a retardant to regrowth levels and
- the limits to regrowth by **anthropogenic factors** (e.g., vegetation cannot regrow if freehold buildings have been constructed on the property, or if there are other factors using the land or keeping it cleared).

The anthropogenic factor essentially is “how much land is available for regrowth to occur?” and the first two factors are “how fast will the regrowth occur?”

Of these three factors the most important factor is the anthropogenic influence. This sets the cap for regrowth—as even in the worst case scenario among the other factors almost all vegetation types will regrow to a mature state within a 40-year timeframe.

Based on consultation with experts, consideration of current cleared land land-use (e.g., grazing and land which has been built over), and the incentives of land owners to maintain their cleared land to avoid application for clearance permits, Nous created a robust model to blend both “rate” and “amount” regrowth factors.

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[90] Australian Bureau of Statistics (2006), ‘The Natural Landscape’ In *Measures of Australia’s* (1370.0) pp.98-120; The National Greenhous Gas Inventory; The SLATS Report (2007).

A.1.4 Outcomes and analysis

With the impacts of land clearance and regrowth taken into consideration, there is a less than 1% upward shift in the carbon stock levels between 2001 and 2050 as shown in **Figure 17**.

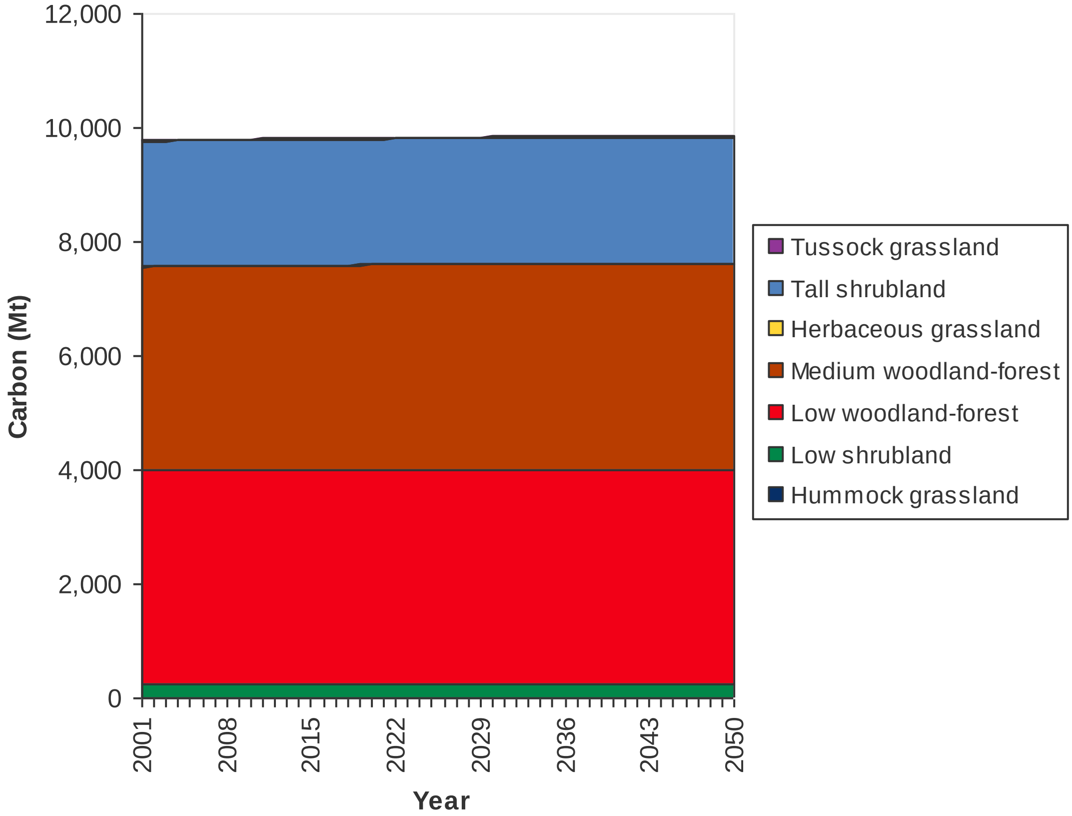

Figure 17 – Carbon stock projection for base case

Figure 18 shows that the majority of carbon stocks in the Australian outback are held in medium woodland-forests, low woodland-forests and tall shrubland (in order of magnitude). Together these TSGFs represent approximately 94% of the total carbon stock. These three TSGFs also represent the greatest potential for regrowth.

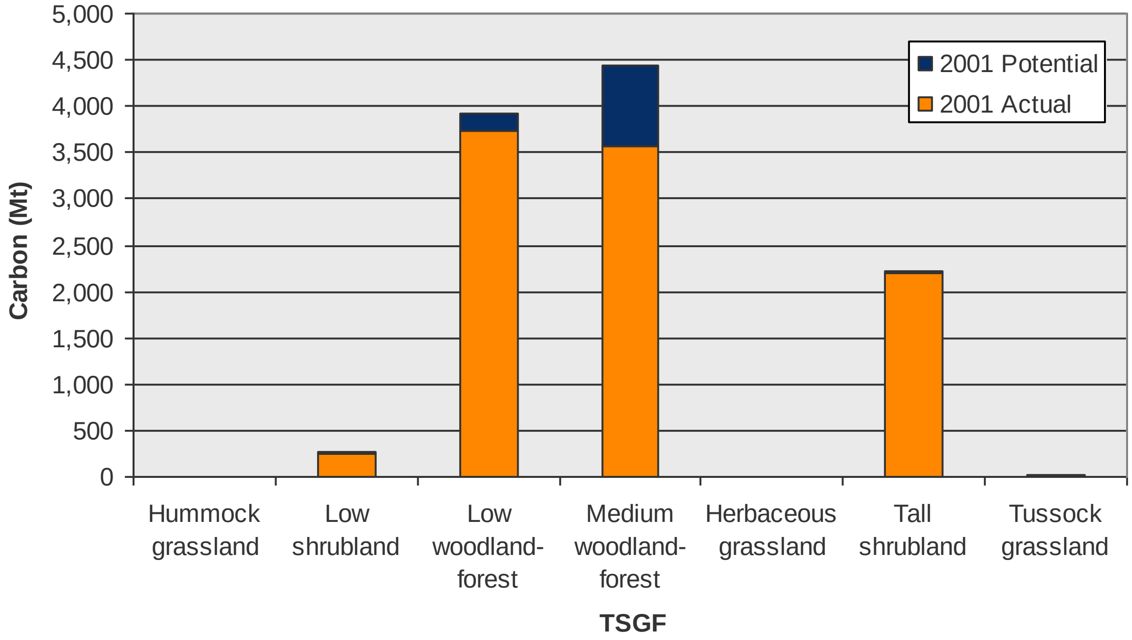

Figure 18 – Carbon stocks actual and potential

Table 6 is the summary of the base case model. It indicates the biomass levels and expresses the amount of tCO_2-*e* currently sequestered in outback biomass.

	Carbon stocks (Mt)	Emissions equivalent (Mt CO_2-e)
Total actual carbon stocks (2001)	9,788	35,861
Total actual carbon stocks projected at 2050	9,852	36,097
Total potential carbon stocks (2001)	10,864	39,805
Additional theoretical potential sequestration	1,077	3,945

Table 6 - Summary carbon stock and CO_2-*e* sequestered.

A.1.5 Sensitivity analysis

Nous performed sensitivity analysis to test the model by creating a “better” and “worse” case scenario, where:

- In the **better case scenario**, land-clearing levels are halved, and regrowth potential is increased so that regrowth will happen on 50% more land.
- In the **worse case scenario,** land-clearing quotas are doubled and regrowth potential is considered at about half the amount modelled in the base case.

Figure 19 below indicates the outcome of the analysis.

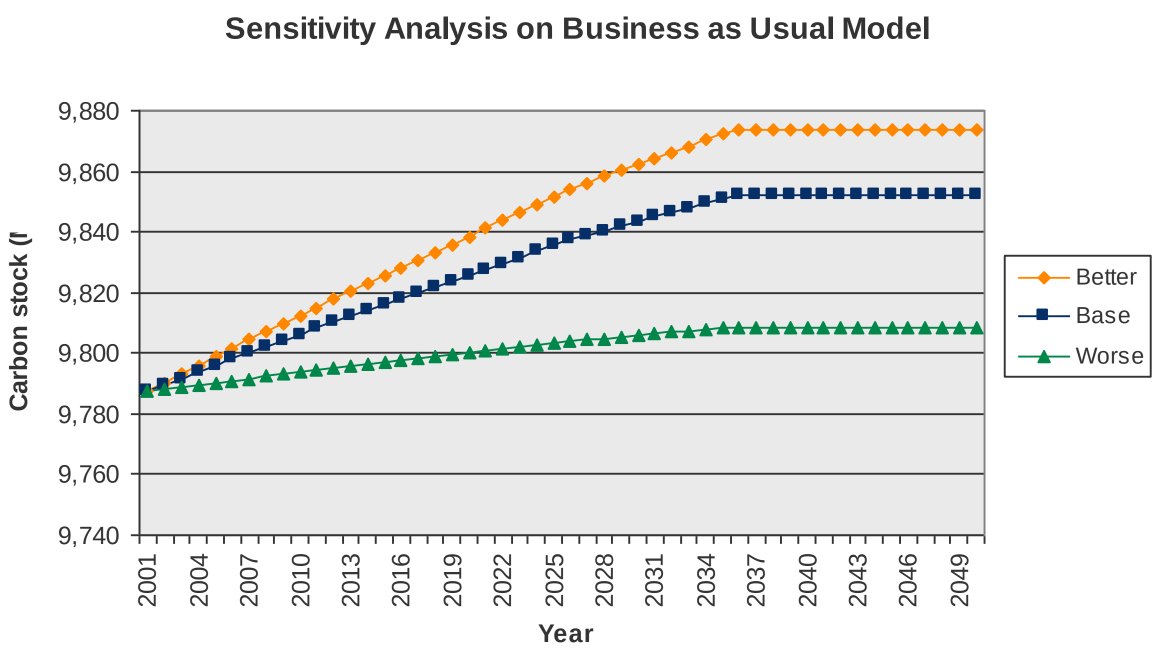

Figure 19 – Sensitivity Analysis for Base Case model

The sensitivity analysis indicates that the overall amount of outback carbon stock is likely to increase by 0.22% – 0.88% over the next 50 years.

The low difference between the better and worse case scenarios suggest that the model is quite precise and stable. This ensures that the emission changes proposed by the initiative analysis below will be meaningful in both “negative” and “positive” states of the world.

A.2 Modelling emission changes

Emissions changes were modelled by estimating the impact of the land management practice on business as usual carbon stocks and emissions. This involved desktop research and consultation with stakeholders and experts to understand both the technical abatement potential associated with each initiative as well as the likely rate of take-up in the Australian outback. A complete list of contributors is provided in **Appendix C**.

Based on this research, models for each initiative were developed. Each initiative was modelled using a different methodology, to provide a nuanced assessment of emissions reduction potential:

- The **reducing land clearing** model calculated the transformation in vegetation cover that is occurring and its impact on carbon stores.
- The **regrowth** model assessed a particular area of vegetation and used regrowth rates to assess the potential for additional carbon storage.
- The **feral pest management** initiative included estimates of population dynamics for each major species of feral pest in order to calculate their emissions. Emissions were calculated by estimating the change in population that could be achieved.
- The **fire management model** used regression analysis to project methane and nitrous oxide emissions and then estimated the impact of changed management practices.

- The **grazing management** initiative used regression analysis to project methane emissions from grazing, and estimated the impact of changed management practices on emissions.

In order to provide consistency between these models, a common set of parameters was used to quantify the impact of the changed management practices. These were:

- **Start date:** the year at which the initiative is modelled as commencing to have an impact; the choice of this year is conditioned by a range of considerations including ease of implementation and availability of technology.
- **Ramp-up time:** represents the time taken (in years) for the initiative to reach its full impact. Values selected for this parameter are conditioned by judgements around market penetration and stakeholder compliance.
- **Change:** the impact of introduction of the initiative. This included consideration of both the 'technical potential' (best-case steady-state abatement potential from an ideal implementation) as well as 'take-up' (the impact of implementation issues, contextual factors and other limitations). The form of this parameter varied by initiative.

A.3 Cost analysis

Each initiative has been costed to assess the lifetime economy-wide cost of the intervention. By costing the initiatives the viability of the initiatives under proposed carbon trajectories could be analysed.

The costs were assessed through three components in order to assess the lifetime cost and cost variability of the initiative:

- **Establishment cost:** the cost to bring the management action to the implementation phase, including R&D and commercialisation costs. Sunk and committed costs have not been included in the establishment cost as they are not relevant to the decision making process.
- **Implementation cost:** for setup of the management action (including procuring materials, training, etc). Where appropriate, opportunity costs were included in this component (such as foregone production due to changes in grazing stocking rates or tree harvesting). Risk management costs were also included.
- **Ongoing cost:** the long term ongoing cost for operation and monitoring and the long-term monitoring cost.

These three components of cost were developed by drawing on the wealth of studies of the financial and economic viability of management options. A key source was analysis published by DEWHA: *Assessing financial and environmental impacts of management options: managing for biodiversity in the rangelands*.[91] Other initiatives drew on financial analysis performed by CSIRO and the various cooperative research centres (CRCs). Nous also contacted experts for each initiative who provided further data and estimates.

Some costs are one-off and independent of area, while others are dependent on the scope and extent of the initiative. The expected area of coverage was developed for each initiative to reflect the area most likely to benefit from or implement each initiative. This was

[91] MacLeod, J and McIvor, J (2004) *Assessing financial and environmental impacts of management options*. CSIRO Sustainable Systems.

developed through discussion with expert advisors in reference to data on geographic distribution and effectiveness. For example, fire management is thought to have less economic benefit in drier areas due to the dynamics of fuel and carbon sequestration potential. The costing was then developed for the various growth forms in each of these regions.

The carbon price trajectory was developed by reference to the current price and trajectory prescribed in the *Carbon Pollution Reduction Scheme Bill (2009)*.[92]

A discount rate of 2% was used in line with the Garnaut and Stern Reviews.[93] This rate reflects a near-zero pure rate of time preference (so as to avoid a 'tyranny of the present') and a marginal elasticity of utility with respect to consumption of between 1.3-2.6% (to reflect the higher quality-of-life of future generations).

[92] Department of Climate Change (2009) *Summary: Key changes to the Carbon Pollution Reduction Scheme Legislation*.

[93] The average discount rate was used from Garnaut, R., (2008) *The Garnaut Climate Change Review: Final Report,* Cambridge University Press, Port Melbourne.

Appendix B The Queensland Herbarium study: Carbon storage in outback Australia

B.1 Overview

The study provides an estimation of the potential above ground carbon stored in outback Australia's vegetation communities of 9.79 billion tonnes. This study delineates carbon storage into its *potential* (theoretical levels after regrowth and revegetation) and *current*[94] (actual levels based on historical clearing) components. Carbon storage is calculated through estimations of biomass levels.[95]

The key findings of this study are:

- Outback Australia's[96] above and below ground carbon (excluding soil carbon) totalled 9.79 billion tonnes (see **Figure 20**).[97]
- There is ~9.1 billion tonnes of above ground carbon within outback Australia before clearing. This comprises ~8.2 billion tonnes in the present mature-growth areas, and a further ~0.9 billion tonnes that was present and potentially could be recovered within the regrowth areas of outback Australia.
- Below ground carbon (excluding soil carbon) in mature ('remnant') areas is estimated at 1.5 billion tonnes with the potential for 0.17 billion tonnes in regrowth ('non-remnant') areas.

The Figure below depicts the distribution of stored carbon across outback Australia.

[94] Current biomass is defined as 2001 remnant vegetation based on the VAST 2004 classification

[95] Biomass has been estimated to consist of approximately 50% carbon by mass. (see Gifford, R. (2000) 'Carbon Content of Woody Roots: Revised Analysis and a Comparison with Woody Shoot Components' in *National Carbon Accounting System Technical Report No. 7 (Revision 1)*. Australian Greenhouse Office, Canberra.)

[96] The definition of 'Outback Australia' used in this report is based on the ACRIS definition (see **Figure 21**)

[97] Note that soil carbon has not been accounted for in this study.

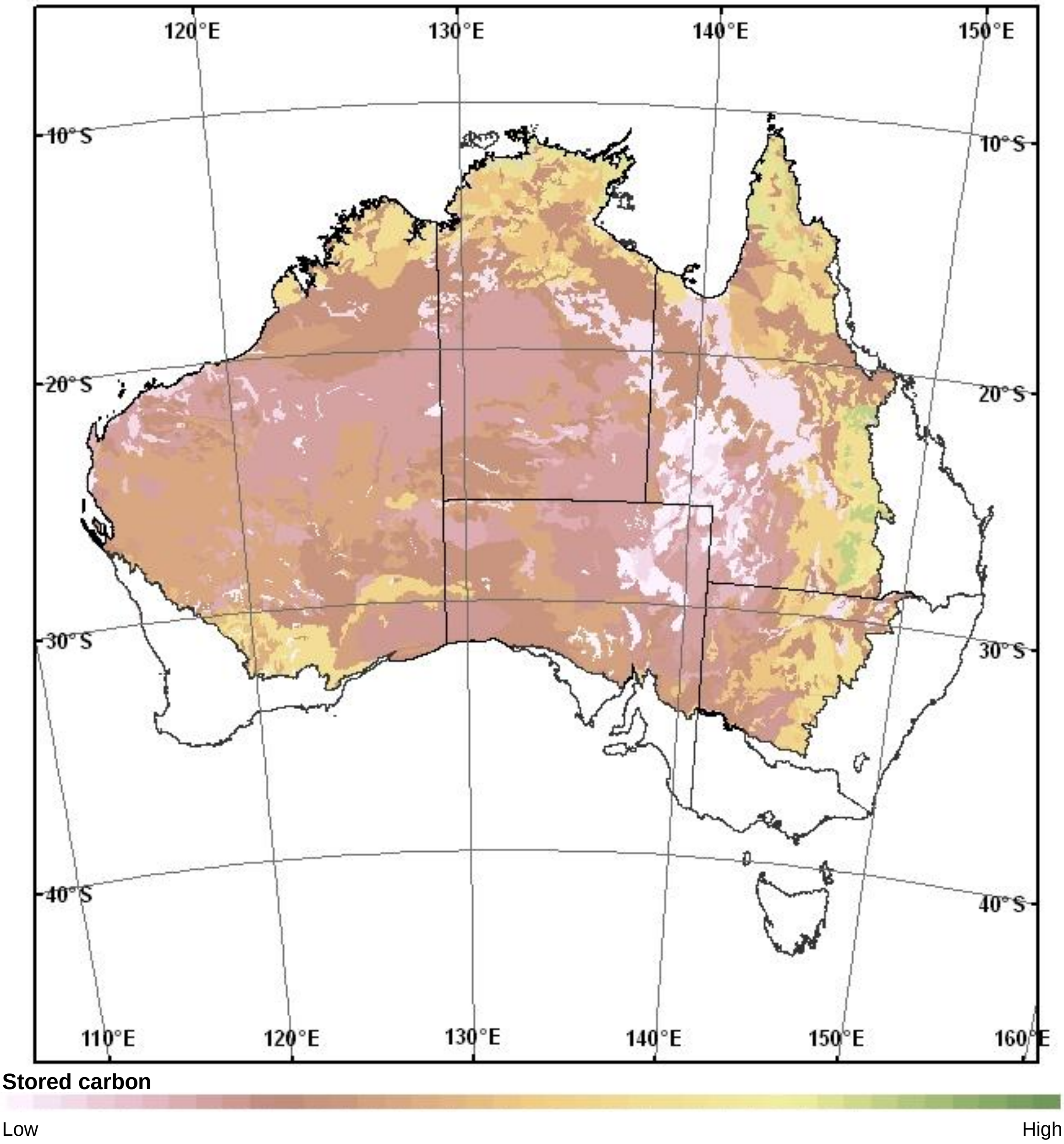

Figure 20 – Distribution of above and below ground biomass in Australia's outback

B.2 Methodology

The potential and current carbon for above and below ground live and dead biomass in outback Australia (ACRIS) was estimated using Carnahan's pre-clearing coverage and the 2001 VAST coverage (2004). This analysis provides details for outback Australia as well as for each State and Territory.

The discussion below outlines some key methodological considerations incorporated into this study.

B.2.1 Area definition

The analysis provides details for outback Australia as defined by ACRIS for Australia's rangelands (see **Figure 2** for a definition of the region under consideration) and is further analysed within this area for each State and Territory.

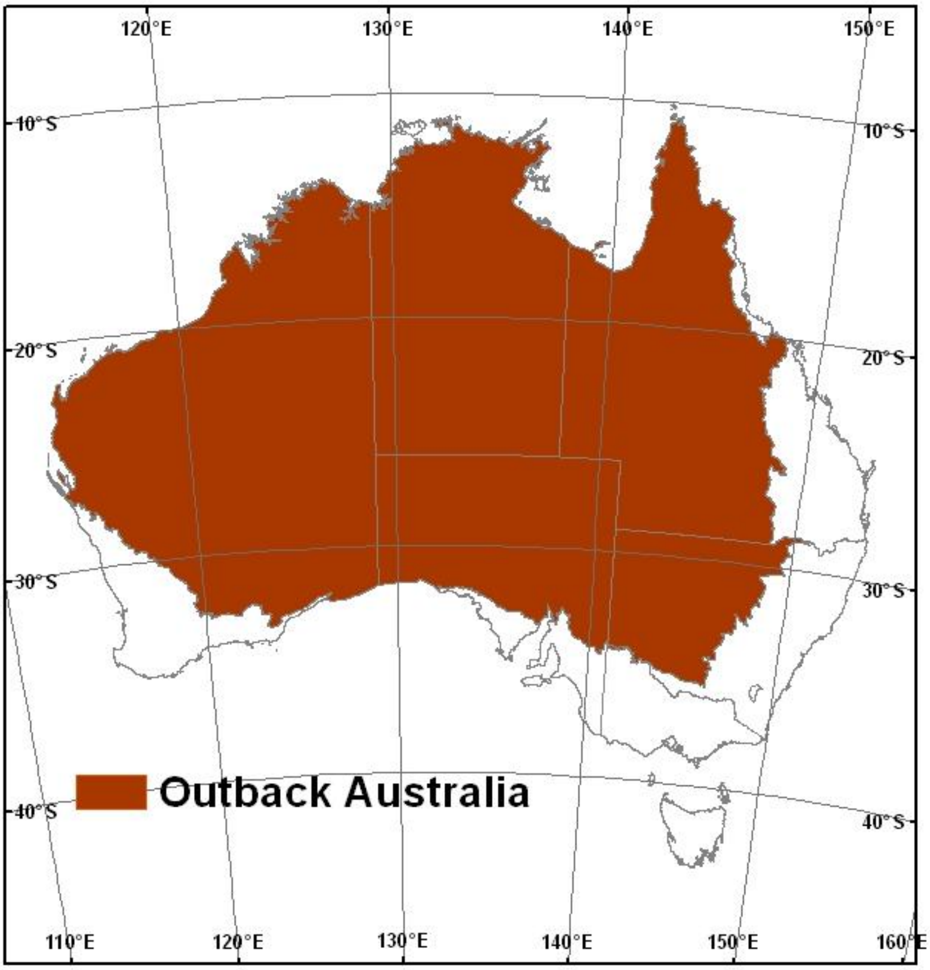

Figure 21 - The 'ACRIS Rangelands' definition of the Australian outback

B.2.2 Vegetation classification

The Carnahan (1990) classification of vegetation provides a logical structural and floristic approach based on growth form, foliage cover and species dominance. Although this is at a large (1:5M) scale, it provides a uniform classification for Australia vegetation (see **Figure**

22). This study has used the tallest stratum attributes (growth form, species dominance and foliage cover) to estimate the biomass (dry weight). The estimates were applied to above ground biomass including: woody (live), herbaceous, litter, debris and standing dead. Root biomass (dry weight) was also estimated.

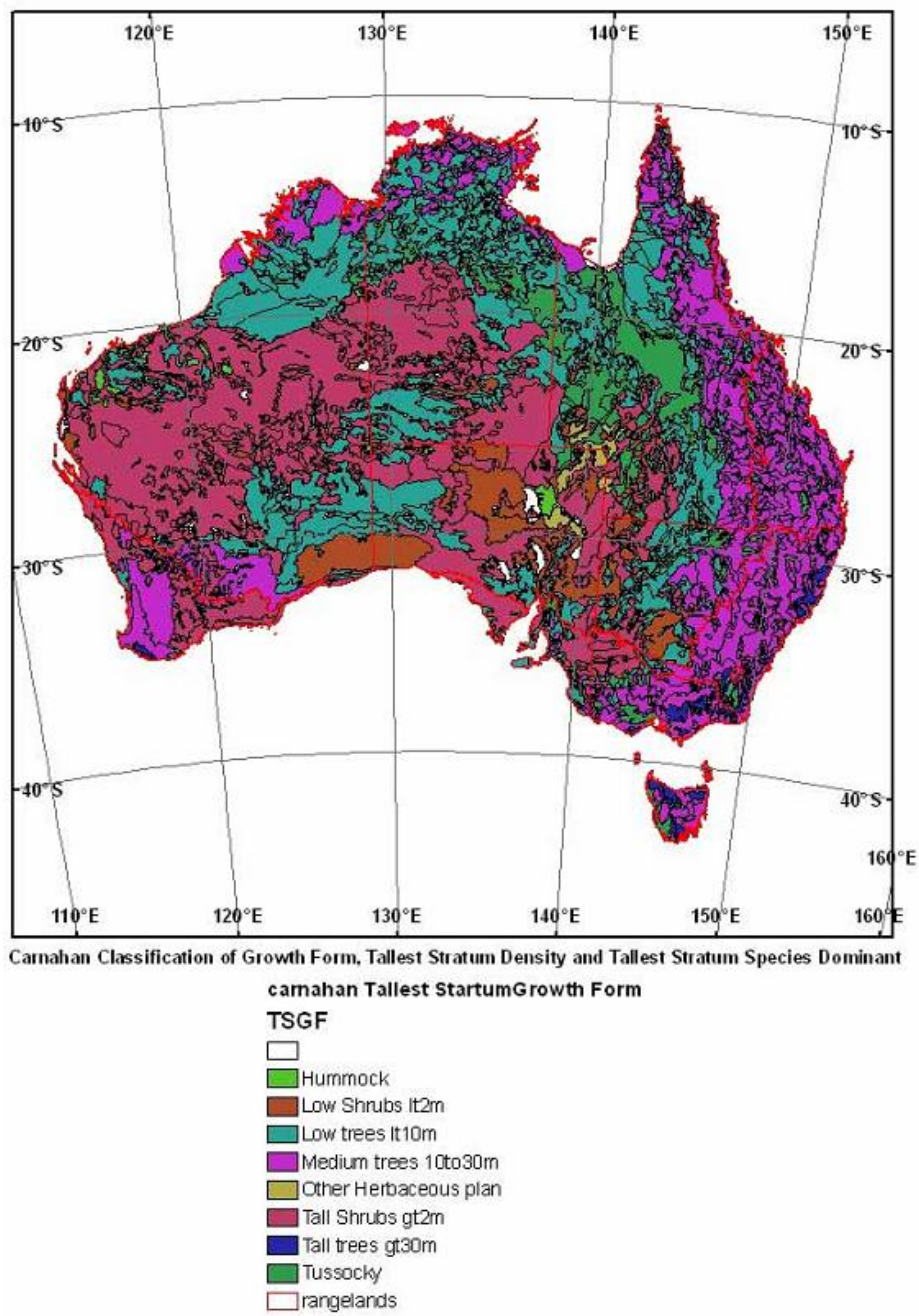

Figure 22 – Distribution of vegetation across Australia based on the Carnahan classification

B.2.3 Biomass estimation

Assigning above ground live biomass values to the mapping units was guided by estimates from the literature, but it was not possible to apply these estimates directly because they are sufficiently variable and patchy that the estimates would not have been logical in relation to the structural mapping units. Thus estimates were assigned so that there was a progression of biomass increasing logically from low to tall height classes and from open to dense cover classes. It is recognised that a single estimate for some widespread units will not sufficiently capture the known variability.

Estimates of the proportion of live above ground biomass represented by root biomass, standing dead wood and coarse woody debris were also guided by the literature but applied after expert consideration across the units. Different proportions for standing dead wood and coarse woody debris were applied for ecosystems subject to regular fire and those where fire is rare.

The biomass estimates for each component (live woody, herbaceous, litter, debris, dead standing and roots) was linked to the classified Carnahan Pre-clearing Digital Coverage Maps (**Figure 22**). This enabled formulation of maps showing the distribution of biomass components (live woody, herbaceous, litter, debris, dead standing and roots) in outback Australia (**Figure 20**).

Based on current estimates from scientific literature, below ground biomass is assumed at 43% of above ground live biomass.

The estimates for all components across all mapping units are provided and these can be adapted in the future as better information becomes available.

B.2.4 Assessing effects of burning on biomass of woody debris

The vegetation mapping units were designated into two groups: regularly burnt and rarely burnt. The assumption is that dead wood is a substantially higher proportion in the drier outback vegetation mapping units where fires are rare in comparison to mapping units where fires are frequent. In mapping units rarely burnt, coarse woody debris was estimated as 45% of live above ground woody biomass. In mapping units experiencing frequent fires, biomass was estimated at 5% of live above ground woody growth.

B.3 Discussion

B.3.1 Comparison with other studies

This study estimates outback Australia's total *live and dead* above ground biomass (dry weight) for the pre-cleared landscape to be 18.28 billion tonnes. Using very different methodologies, Berry and Roderick (2006)[98] estimate outback Australia's *live* above ground biomass as 18.04 billion tonnes. This comparison suggests that estimates from this study are conservative.

B.3.2 Clearing regrowth

The focus of this study was outback Australia and the cleared landscape was only assessed in relation to its potential to re-sequester carbon (as reflected by the estimates of

[98] Berry S.L. and Roderick M.L, (2006) 'Changing Australian vegetation from 1788 to 1988: Effects of CO_2 and land use change' in *Australian Journal of Botany*. **54**, pp. 325-328

biomass in those landscapes before clearing). The cleared portion of the outback Australia is 4% of the total (623.2 Million ha).

B.4 Further work

Further groundwork, including the assessment of the actual biomass of different species across different vegetation communities within different bioregions, will be an essential requirement to further improve biomass estimates.[99] The data that this would provide could be used to calibrate spatial mapping products that will give greater accuracy than the Carnahan classification for assessing biomass.

In Queensland, detailed Regional Ecosystem mapping can provide an improved delineation for biomass association,[100] which may provide enhanced biomass calibration and estimates. This may be performed using techniques including Landsat, SPOT, LIDAR and ALOS Radar.[101]

[99] Fensham RJ, Fairfax RJ (2003) 'Assessing woody vegetation cover change in north-west Australian savanna using aerial photography.' In *International Journal of Wildland Fire*, **12**, pp, 359–367.

[100] Wilson, B. A., Neldner, V.J. and A. Accad, A. (2002). 'The extent and status of remnant vegetation in Queensland and its implications for statewide vegetation management and legislation' in *The Rangeland Journal*, **24**. pp. 6-35

[101] Lucas, R.M., Lee, A.C., Bunting, P.J., 2008. 'Retrieving forest biomass through integration of CASI and LiDAR data' in *International Journal of Remote Sensing*. **29**, pp. 1553–1577.

Appendix C Expert contributors

C.1 Project contributors

The following experts contributed in various ways to this project, including

- Providing research advice
- Corroborating results
- Providing 'best estimate' advice
- Attending a 'strawman' workshop
- Providing expert review of the final report..

Contributor	Position/Organisation
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Dr Andrew Ash	Director, Climate Adaptation Flagship, CSIRO
Dr Barry Traill	Director, Wild Australia Program, Pew Environment Group
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Associate Professor Bob Beeton	School of Integrative Systems, University of Queensland
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Ian Porter	CEO, Alternative Technology Association
Justin McCaul	Northern Australia Program, ACF

Lindsay Hesketh	Healthy Country Campaigner, ACF
Dr Michael Looker	The Nature Conservancy
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Simon O'Connor	Economic Advisor, ACF
Tim Danaher	Environment NSW
Tim Low	Invasive Species Council
Dr Tony Grice	Sustainable Ecosystems, CSIRO

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Appendix E Glossary and acronyms[102]

ACF: The Australian Conservation Foundation

Abatement: Reducing the degree or intensity of greenhouse-gas emissions.

Afforestation: Planting of new forests on lands that have not been recently forested.

Ancillary Benefits: Complementary benefits of a climate policy including improvements in local air quality and reduced reliance of imported fossil fuels.

Anthropogenic Emissions: Emissions of greenhouse gasses resulting from human activities.

Article 3.4, Kyoto Protocol: includes an accounting framework for forestry emissions. Australia, however, has elected to opt out of this Article, which concerns post-1990 land use other than afforestation, reforestation or deforestation. Under Article 3.4, committing countries use land management activities to estimate carbon stocks at 1990, and changes in those stocks since 1990.

Baselines: The baseline estimates of population, GDP, energy use and hence resultant greenhouse gas emissions without climate policies, determine how big a reduction is required, and also what the impacts of climate change without policy will be.

Biochar: is charcoal created by pyrolysis of biomass. The resulting charcoal-like material is a form of sequestration or atmospheric carbon capture and storage.

Biomass: Biological material derived from living, or recently living organisms.

Biodiversity: The variety of organisms found within a specified geographic region.

Carbon Dioxide (CO_2): CO_2 is a colourless, odourless, non-poisonous gas that is a normal part of the ambient air. Of the six greenhouse gases normally targeted, CO_2 contributes the most to human-induced global warming. Human activities such as fossil fuel combustion and deforestation have increased atmospheric concentrations of CO_2 by approximately 30 percent since the industrial revolution. CO_2 is the standard used to determine the "global warming potentials" (GWPs) of other gases. CO_2 has been assigned a 100-year GWP of 1 (i.e., the warming effects over a 100-year time frame relative to other gases).

Carbon Dioxide Equivalent (CO_2e): Carbon Dioxide Equivalent (CO_2e). The emissions of a gas, by weight, multiplied by its global warming potential.

Carbon Pollution Reduction Scheme (CPRS): is a cap-and-trade system of emissions trading for anthropogenic greenhouse gases, due to be introduced in Australia in 2010.

Carbon Sequestration: see Sequestration

Carbon Sinks: Processes that remove more carbon dioxide from the atmosphere than they release. Both the terrestrial biosphere and oceans can act as carbon sinks.

Carnahan Classification: The Carnahan (1990) classification of vegetation provides a logical structural and floristic approach based on growth form, foliage cover and species dominance. Although this is at a large (1:5M) scale, it provides a uniform classification for Australia vegetation. This study has used the tallest stratum attributes (growth form, species dominance and foliage cover) to estimate the biomass (dry weight).

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[102] Many of these are drawn from The Pew Center on Global Climate Change 'Glossary'. http://www.pewclimate.org/global-warming-basics/full_glossary. Accessed 20/10/2009.

Climate: The long-term average weather of a region including typical weather patterns, the frequency and intensity of storms, cold spells, and heat waves. Climate is not the same as weather.

Climate Change: Refers to changes in long-term trends in the average climate, such as changes in average temperatures. In UNFCC usage, climate change refers to a change in climate that is attributable directly or indirectly to human activity that alters atmospheric composition.

CSIRO: Australia's Commonwealth Scientific and Industrial Research Organisation

Desertification: Land degradation in arid and dry sub-humid areas resulting primarily from natural activities and influenced by climatic variations.

Discounting: The process that reduces future costs and benefits to reflect the time value of money and the common preference of consumption now rather than later.

Ecosystem: A community of organisms and its physical environment.

Emissions: The release of substances (e.g., greenhouse gases) into the atmosphere.

Emissions Cap: A mandated restraint in a scheduled timeframe that puts a "ceiling" on the total amount of anthropogenic greenhouse gas emissions that can be released into the atmosphere. This can be measured as gross emissions or as net emissions (emissions minus gases that are sequestered).

Emissions Trading: A market mechanism that allows emitters (countries, companies or facilities) to buy emissions from or sell emissions to other emitters. Emissions trading is expected to bring down the costs of meeting emission targets by allowing those who can achieve reductions less expensively to sell excess reductions (e.g. reductions in excess of those required under some regulation) to those for whom achieving reductions is more costly.

Emissions Trading Scheme (ETS): is an administrative approach used to control pollution by providing economic incentives for achieving reductions in the emissions of pollutants. It is sometimes called cap-and-trade.

Garnaut Review, The: A 30 September 2008, report by Professor Ross Garnaut, commissioned by the Australian Government to examine the impacts of climate change on the Australian economy, and recommend medium to long-term policies and policy frameworks to improve the prospects for sustainable prosperity.

GDP: Gross Domestic Product, a measure of overall economic activity.

Global Warming: The progressive gradual rise of the Earth's average surface temperature thought to be caused in part by increased concentrations of GHGs in the atmosphere.

Global Warming Potential (GWP): A system of multipliers devised to enable warming effects of different gases to be compared. The cumulative warming effect, over a specified time period, of an emission of a mass unit of CO_2 is assigned the value of 1. Effects of emissions of a mass unit of non-CO_2 greenhouse gases are estimated as multiples. For example, over the next 100 years, a gram of methane (CH_4) in the atmosphere is currently estimated as having 23 times the warming effect as a gram of carbon dioxide; methane's 100-year GWP is thus 23. Estimates of GWP vary depending on the time-scale considered (e.g., 20-, 50-, or 100-year GWP), because the effects of some GHGs are more persistent than others.

Greenhouse Effect: The insulating effect of atmospheric greenhouse gases (e.g., water vapour, carbon dioxide, methane, etc.) that keeps the Earth's temperature warmer than it would be otherwise.

Greenhouse Gas (GHG): Any gas that contributes to the "greenhouse effect."

Kyoto Protocol: An international agreement adopted in December 1997 in Kyoto, Japan. The Protocol sets binding emission targets for developed countries that would reduce their emissions on average 5.2 percent below 1990 levels.

Land Use, Land-Use Change and Forestry (LULUCF): Land uses and land-use changes can act either as sinks or as emission sources. It is estimated that approximately one-fifth of global emissions result from LULUCF activities. The Kyoto Protocol allows Parties to receive emissions credit for certain LULUCF activities that reduce net emissions.

MACC: Marginal Abatement Cost Curve. A full description is provided on page 35.

Market Benefits: Benefits of a climate policy that can be measured in terms of avoided market impacts such as changes in resource productivity (e.g., lower agricultural yields, scarcer water resources) and damages to human-built environment (e.g., coastal flooding due to sea-level rise).

Methane (CH_4): CH_4 is among the six greenhouse gases to be curbed under the Kyoto Protocol. Atmospheric CH_4 is produced by natural processes, but there are also substantial emissions from human activities such as landfills, livestock and livestock wastes, natural gas and petroleum systems, coalmines, rice fields, and wastewater treatment. CH_4 has a relatively short atmospheric lifetime of approximately 10 years, but its 100-year GWP is currently estimated to be approximately 23 times that of CO_2.

Nitrous Oxide (N_2O): N_2O is among the six greenhouse gases to be curbed under the Kyoto Protocol. N_2O is produced by natural processes, but there are also substantial emissions from human activities such as agriculture and fossil fuel combustion. The atmospheric lifetime of N_2O is approximately 100 years, and its 100-year GWP is currently estimated to be 296 times that of CO_2.

ppm or ppb: Abbreviations for “parts per million” and “parts per billion,” respectively - the units in which concentrations of greenhouse gases are commonly presented. For example, since the pre-industrial era, atmospheric concentrations of carbon dioxide have increased from 270 ppm to 370 ppm.

Reforestation: Replanting of forests on lands that have recently been harvested.

Renewable Energy: Energy obtained from sources such as geothermal, wind, photovoltaic, solar, and biomass.

Sequestration: Opportunities to remove atmospheric CO_2, either through biological processes (e.g. plants and trees), or geological processes through storage of CO_2 in underground reservoirs.

Sinks: Any process, activity or mechanism that results in the net removal of greenhouse gases, aerosols, or precursors of greenhouse gases from the atmosphere.

Source: Any process or activity that results in the net release of greenhouse gases, aerosols, or precursors of greenhouse gases into the atmosphere.

TNC: The Nature Conservancy

TSGF: Tallest Stratum Growth Form, see Carnahan Classification above.

UN Framework Convention on Climate Change (UNFCCC): A treaty signed at the 1992 Earth Summit in Rio de Janeiro that calls for the "stabilization of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system." The treaty includes a non-binding call for developed countries to return their emissions to 1990 levels by the year 2000. The treaty took effect in March 1994 upon ratification by more than 50 countries. The United States was the first industrialized nation to ratify the Convention.