



Climate change research priorities for NSW primary industries Discussion paper

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APPENDIX 1: SUMMARY OF CLIMATE CHANGE POLICY INITIATIVES IMPLEMENTED BY THE NSW GOVERNMENT

The NSW Greenhouse Plan

Significant action to reduce greenhouse gas emissions in NSW has been underway for some time. The NSW Greenhouse Plan (2005) replaces the previous Greenhouse Action Plan, released in 1998.

The NSW Greenhouse Plan outlines new and ongoing strategic action to limit greenhouse gas emissions in NSW and achieve key emission reduction targets announced by the Government. Key principles and goals include:

- raising awareness within the broader community
- recognising that climate change is global, long-term and complex
- promoting understanding of the likely impacts on NSW
- identifying strategies for adaptation to the environmental, social and economic impacts of climate change
- limiting the growth of and reducing greenhouse gas emissions
- promoting climate change partnerships through cooperation between government, corporations, and community
- developing and establishing a Kyoto-compliant national emissions trading scheme.

To assist in implementing these key strategic initiatives, the government has established the Greenhouse Innovation Fund, with a total of \$24 million in funding over a four-year period.

New funding initiatives cover five key program areas:

- Climate Change Awareness Program – approximately \$7.5 million (over four years) to raise the community's awareness about the causes and risks of climate change, and about ways in which individuals can reduce their emissions, plan for the future, and adapt to inevitable change. Under this program, NSW DPI conducted two Agriculture Industries and Rural Communities roundtables at Tamworth and Wagga Wagga in November 2006, to raise awareness and to hear of specific research initiatives and farming innovations
- Climate Action Grants Program – \$10 million (over four years) contestable grants available to agencies, industry and individuals, for adaptation technologies and innovative technology development
- Climate Change Impacts and Adaptation Research Program – \$2 million (over four years) to research the likely impacts of climate change on bushfire, water availability, biodiversity, human health and coastal zones in NSW
- Climate Change Adaptation Capacity Building Program – \$2 million (over four years) for capacity building in NSW Government agencies, local government, industry and NGOs, as well as for specific adaptation initiatives in the agricultural sector, and for the development of climate change profiles for catchment areas
- Greenhouse Gas Emission Reduction Projects Program – \$2.3 million for studies and projects on innovation, carbon sequestration, emissions trading and heavy vehicle benchmark rating.

Because greenhouse gas emissions come from almost all sectors of the economy, the NSW Greenhouse Plan takes a multi-sectoral approach, addressing matters including:

- energy generation and energy efficiency
- buildings
- transport

- waste, industrial processes and fugitive emissions
- agriculture, natural resources and land management – agriculture emissions contributed 14% of NSW total emissions in 2002, including emissions from land clearing, soils and livestock. The NSW Government aims to reduce emissions and increase carbon sequestration in these sectors. Key measures include:
 - development of a pilot system to allow a catchment management authority to engage in carbon trading under the NSW Greenhouse Gas Abatement Scheme, and thereby realise the carbon value of revegetation projects
 - strengthening of the Climatology in Agriculture program, to help farmers adapt to climate change and its effect on their business
 - further research on the potential for carbon sequestration through improved soil and vegetation management.

Prior to the release of the NSW Greenhouse Plan, other significant actions were introduced (see below). Most of these continue today.

The NSW Greenhouse Gas Abatement Scheme

New South Wales commenced the world's first mandatory emission trading scheme – the NSW Greenhouse Gas Abatement Scheme (GGAS) – in 2003. The GGAS aims to reduce the greenhouse gas emissions associated with the production and use of electricity, by setting emission reduction targets that must be met by electricity retailers. Targets are met directly, or by buying 'credits', which are created through activities that reduce or offset emissions. The scheme has achieved around 16 million tonnes of greenhouse savings since it started in 2003, and will accrue around 120 million tonnes by 2012. See Appendix 2 for more detail.

Carbon rights legislation

The NSW Government introduced the world's first carbon rights legislation in 1998, recognising carbon sequestration in forests, and allowing the separate ownership, sale, and management of these carbon rights.

Australian Building Greenhouse Rating scheme

NSW initiated this now national voluntary rating scheme in 1999. It enables commercial building owners and tenants across Australia to benchmark and improve the greenhouse performance of their buildings.

The Building Sustainability Index (BASIX)

Since July 2004, new single residential dwellings in NSW must achieve a 40% reduction in water consumption, and, since July 2006, a 40% reduction in greenhouse gas emissions, compared with the average NSW home. Since 1 October 2005, BASIX also applies to multi-unit residential developments. It is estimated that BASIX will save 287 billion litres of water and 9.5 million tonnes of greenhouse emissions over 10 years.

The Native Vegetation Act

The *Native Vegetation Act 2003* provided new protection to prohibit broadscale land clearing, which has historically been a significant contributor to greenhouse gas emissions.

The Energy Savings Fund

This \$200 million fund (\$40 million per year for 5 years) commenced in 2005 to support new energy savings measures and mandate the development of energy savings action plans by high energy users.

APPENDIX 2: EMISSIONS TRADING

Emissions trading creates a market mechanism by which the release of polluting substances incurs a cost, and implementation of abatement measures generates a financial return. Emissions trading has been successfully used to control sulfur dioxide and nitrous oxide emissions in the USA and for water salinity and nutrient management in Australia.

The success of emissions trading in reducing emissions depends on the establishment of a target for emissions at a level that achieves the mitigation required, while sharing liability amongst the emitters, and enforcing compliance. It allows those emitters who can abate or offset their emissions at low cost to trade their extra emission credits with others who can only do so at a high cost, thus achieving an emissions target in the most cost effective way.

A greenhouse gas emissions trading scheme may include credits generated by mitigation activities in the forestry and agriculture sector, such as carbon sequestration in biomass and soil. Inclusion of such projects requires the following issues to be addressed:

- non-permanence – for how long and by what mechanism will the offset be secured? How are risks of carbon loss managed?
- coverage – which carbon pools and GHGs will be included?
- uncertainty – will estimation methods be required to meet a specified level of precision, or will a discount be applied on the basis of uncertainty of the estimate?
- additionality – what test will be applied to demonstrate that credit is given for activities that would otherwise not have occurred?
- leakage – will emissions that are indirectly attributable to the project and occur outside the project boundary be reported?

INTERNATIONAL EMISSIONS TRADING

Kyoto Protocol to the United Nations Framework Convention on Climate Change

The Kyoto Protocol created a market for greenhouse gas mitigation by allowing parties to trade credits in order to meet their targets. Credits can be generated by abatement activities, or by sequestration activities that offset emissions.

The Protocol recognises sequestration activities in the agricultural and forestry sector as legitimate offsets that can contribute to meeting the urgent need to reduce GHG emissions.

The Protocol defines four emission credit units:

- AAUs – assigned amount units, allocated to Annex 1 parties under the Protocol, on the basis of national targets
- CERs – certified emission reduction units, generated by Clean Development Mechanism (CDM) projects, in which developed countries invest in emissions reduction projects in developing countries. In the LULUCF sector, only reforestation and afforestation activities are permitted
- ERUs – emission reduction units, generated by joint implementation (JI) projects between Annex 1 parties
- RMUs – removal units, generated by sequestration activities in Annex 1 countries.

Each of these credit units is tradeable amongst parties to the protocol.

Sequestration projects are subject to strict criteria governing eligibility, estimation and reporting.

To address concerns about permanence of forest offsets under the CDM, reforestation/afforestation projects earn specific credits, known as ‘temporary CER’ (‘tCER’) and ‘long-term CER’ (‘lCER’). A tCER expires at the end of the commitment period subsequent to

the period during which it was issued. In contrast, a ICER expires at the end of the crediting period of the project for which it was issued. The crediting period of the project begins at the start of the project activity, and may continue for a maximum of either 20 or 30 years. In the case of a 20-year project, the crediting period may be renewed twice, which results in an overall duration of up to 60 years. When a tCER or ICER expires, the holder of the certificate must either acquire a new tCER or ICER, or replace it with a permanent credit.

European Emissions Trading Scheme (EU ETS)

The European Union introduced mandatory emissions trading in 2005, to assist the EU countries in meeting their Kyoto Protocol targets. The EU ETS targets those industries that are major point sources of emissions in the EU, which are:

- power generation
- ore processing
- cement, glass and ceramics production
- pulp and paper manufacturing.

The scheme uses a cap and trade approach, whereby each country sets a cap on total emissions, and allocates allowances to the liable parties according to the national allocation plan. The price of allowances increased rapidly to a peak of about €30 per tonne CO₂ in April 2006, but has since crashed to less than a third of that value, as it became clear that the allocation process had provided allowances in excess of requirements.

The EU ETS does not allow agricultural and forestry sequestration activities to generate credits.

California Climate Action Registry (CCAR)

The California Climate Action Registry is a non-profit, voluntary registry that provides a mechanism by which companies can document their annual greenhouse gas emissions inventory. The registry does not engage in trading, but it is anticipated that emissions reductions verified and registered through the CCAR could be traded.

During the first three years of participation, a company is required to report CO₂ emissions only; subsequently, reporting of CH₄, N₂O, HFCs, PFCs, and SF₆ is also required.

The CCAR provides for reporting of greenhouse gas emissions and removals from forestry at both the entity and project levels.

A forest entity may be an individual, a corporation or a government agency that owns at least 100 acres of forest land (tree canopy cover > 10%). Entity-level reporting requires estimation of forest carbon stocks and 'biological emissions', in addition to non-biological emissions.

Forest projects are required to promote and maintain forest types that are native to the project area and to use 'natural forest management' practices. Project-level reporting includes only forest carbon stocks and biological CO₂ emissions (non-CO₂ reporting is optional), for a planned set of activities that remove, reduce or prevent CO₂ emissions to the atmosphere.

Three project types are permitted:

- conservation-based forest management projects, based on management of existing native forests to enhance carbon stocks. Can include commercial harvest and regeneration of native trees
- reforestation projects, based on the restoration of native tree cover on lands that were previously forested, but have been cleared for a minimum of 10 years
- conservation projects, based on specific actions to prevent clearing of native forests.

The forest project must be located in the state of California, use native Californian species, and have been initiated in or after 1990.

All forest projects must demonstrate that the project activity is additional to (i.e. provides sequestration in excess of) the project baseline. The biological baseline for a forest entity or project is the projection of the forest carbon stocks over 100 years, based on the entity's forecast management practices. Determination of the baseline is optional for entity and mandatory for project reporting. Baselines for the three project types are determined by mandatory land-use statutes and regulations, existing practices and/or threats of land-use change.

The forest entity is required to secure the project with a perpetual conservation easement.

The protocols for reporting under the CCAR are based on the World Resources Institute/World Business Council for Sustainable Development (WRI/WBCSD) GHG Protocol. At both entity and project level, reporting of carbon stock in tree biomass, standing dead biomass, and lying dead wood is mandatory. Reporting is optional for herbaceous understorey and shrubs, soil, litter and duff, as well as wood products.

Carbon stock in all but the wood products pool is determined from inventory, based on sample plots and allometrics; carbon stock in wood products is determined from oxidation over service life, based on harvested volume. Inventory plots are to be measured at least every 10 years. Empirical models may be used to project from the last inventory and to develop baselines.

Greenhouse gas emission reductions are determined on an annual basis from changes in inventory, relative to baseline. A decrease in forest carbon stocks between reporting years is deemed an emission, reported in terms of CO₂ equivalent.

For projects, the sampling error at the 90% confidence interval must be less than 20% of the estimate of the mean. Deductions apply to mean estimates of the carbon pools if the sampling error at the 90% confidence interval is 5%–20% of the mean estimate, at the rate of 10%, 20% and 30% deduction for a sampling error of 5.1%–10%, 10.1%–15% and 15.1%–20%, respectively.

Leakage assessment is not required for entity reporting. For projects, activity-shifting leakage that occurs elsewhere within the entity's activities due to the project must be assessed, and reported as an emission. Reporting market leakage is optional.

Non-biological emissions are certified annually; forest carbon stocks and biological emissions are certified every five years. Certification includes direct sampling of a subset of inventory plots, and is undertaken by an approved third-party certifier.

Certified emissions reductions can be created from forest projects, but not at the entity level. (Based on CCAR 2007)

US Regional Greenhouse Gas Initiative (RGGI)

The Regional Greenhouse Gas Initiative is a cooperative effort by eleven Northeastern and Mid-Atlantic US states to develop a regional cap and trade scheme focused on reducing CO₂ emissions from the region's power plants. Electric power generators in participating states maintain current emission levels until 2015, then reduce by 10% by 2019. Early action starts 1 January 2009.

Emissions reductions generated in other sectors will be included as offsets. Eligible projects in the agriculture and forestry sector include afforestation and avoided methane emissions from agricultural manure management operations. Eligible forests are those that are established on sites that have been cleared for at least 10 years, and for which a permanent conservation easement is registered. Carbon stock change in live tree biomass and soil must be reported, while reporting for other vegetation and debris is optional. Credits are based on carbon stock change relative to a baseline, calculated as the C stocks

prior to commencement of the project. Credits are equivalent to CDM ICERs (i.e. issued for up to three consecutive 20-year periods).

Estimates of carbon sequestration must meet a requirement for precision, such that there is 95% confidence that the resulting reported value is within 10% of the true mean. Estimated sequestration will be discounted by 20%, as a risk reduction mechanism. (From RGGI 2006)

Chicago Climate Exchange (CCX)

The Chicago Climate Exchange is the world's first greenhouse gas emission trading system. CCX members make a voluntary (but legally binding) commitment to reduce GHG emissions, by 4% below the 1998–2001 baseline by December 2006, and 6% by 2010. Eligible offset projects in the agricultural and forestry sector include afforestation/ reforestation, agricultural soil carbon offsets, and methane and renewable biomass energy generation.

Forestry projects can include reforestation and forest enrichment, avoided deforestation and urban tree planting, initiated on or after January 1, 1990 on unforested or degraded forest land. Projects must be secured through a permanent conservation easement or similar instrument, and proponents must demonstrate sustainable forest management on all their forestry holdings. Quantification of carbon stock accumulation in small and medium forestation projects is achieved through default tables or inventory. The only carbon pool included is above-ground living biomass.

Agricultural soil carbon offsets can be generated by land managers who commit to continuous conservation for a minimum four-year period, or who have converted cropland to pasture since January 1, 1999. Credits, known as carbon financial instruments (CFIs), are earned at a rate of 0.5 t CO₂ per acre per year for conservation tillage, and rate of 0.75 t CO₂ per acre per year for pasture conversion.

Projects can be undertaken in USA, Canada, Mexico or Brazil. Recently, a group of NSW landholders has successfully negotiated for the inclusion of conservation tillage activities in NSW.

Agricultural methane emission offset credits are issued for GHG emission reductions achieved by agricultural methane collection and combustion systems, such as anaerobic digesters, brought into operation on or after January 1, 1999. Offsets are issued at a rate of 18.25 t CO₂ per t methane combusted.

Credits are subject to verification by independent third-party verifiers.

Prices have generally ranged from US\$1 to \$3.25 per tonne. Average daily trading volume on the CCX is approximately 7000 tonnes.

New South Wales Greenhouse Gas Abatement Scheme

The NSW Greenhouse Gas Abatement Scheme, which commenced on 1 January 2003, aims to reduce greenhouse gas emissions from electricity generation, based on a per capita emissions benchmark. The GGAS imposes mandatory emission limits on all NSW electricity retailers and some large electricity users, known collectively as the 'benchmark participants'. The scheme aims to reduce per capita emissions to 5% below 1990 levels by 2007 through setting a state greenhouse gas 'benchmark', initially at 8.65 t CO₂-e per capita for 2003, declining to 7.27 t CO₂-e in 2007 and continuing at 7.27 t CO₂-e until 2012. The scheme has recently been extended to 2020.

To meet targets, benchmark participants offset excess emissions through surrender of NSW Greenhouse Abatement Certificates (NGACs), which may be created through low emissions intensity electricity generation, demand side abatement, and/or carbon sequestration in eligible forestry activities. Eligible forestry activities are afforestation and reforestation of land that was cleared before 1990 (i.e. 'Kyoto forests'). The forested land

must be in NSW. The definition of 'forest' is that nominated by Australia for use in national inventory reporting under the UNFCCC. The scheme is administered by the Independent Pricing and Regulatory Tribunal of NSW (IPART).

Entities seeking to generate abatement certificates must be accredited as abatement certificate providers. Accreditation involves an assessment of both the eligibility of the project and the capability of the proponent. Five entities are currently accredited to generate certificates from forest projects: Forests NSW, CO₂ Australia, Australian Forest Corporation, Go-Gen Australia and Mallee Carbon.

The regulations governing accounting for forestry activities, described in *Greenhouse Gas Benchmark Rule (Carbon Sequestration)* (NSW Government, 2003), are generally consistent with greenhouse accounting for Article 3.3 of the Kyoto Protocol. While the method of calculating net carbon sequestration is not prescribed, the regulations specify elements that must be included in the calculation. Credit for sequestration activities is based on carbon stock change, and a baseline of zero is assumed. Under the '70% rule', there must be 70% probability that the actual carbon sequestration in any given period exceeds the quantum of carbon sequestration represented by NGACs issued for that period.

To satisfy concerns over the possible reversibility of carbon sequestration, the scheme requires forest growers to demonstrate that the quantity of carbon sequestered by an activity for which NGACs are created will continue to be stored for 100 years. That is, the cumulative number of NGACs created from an eligible forest estate cannot exceed the minimum carbon stocks within the forest estate over the subsequent 100 years. Accredited providers of NGACs must demonstrate adequate measures to control the risks of carbon loss due to fire, pests or disease.

Forest owners must meet strict requirements for the documentation of inventory methods and forest management, as well as record keeping. Regular monitoring is required, and projects are independently verified by registered auditors.

Once accredited as an abatement certificate provider, a forest owner creates NGACs based on stock change in the previous year, and registers these in the web-based scheme registry. Registering NGACs incurs an administrative fee of \$0.15 per NGAC. Trades are arranged directly between benchmark participants and accredited abatement certificate providers or through brokers, and may be spot deals (immediate sale and transfer) or forward contracts. Certificates are electronically transferred, via the registry, to buyers, who then surrender the certificates to meet their targets.

The price of NGACs is related to the penalty for noncompliance; the cost of buying NGACs is considered a business cost for taxation purposes, while a penalty is not. Therefore, the price for NGACs that would be equivalent to paying the penalty is equal to the value of the penalty plus the tax that would be payable. The penalty, which is adjusted annually, is currently \$11.50 per t CO₂-e, giving an equivalent price for NGACs of about \$15 per t CO₂-e.

Of the four abatement certificate providers accredited to create NGACs from forestry projects, Forests NSW was the first entity to complete the audit process and register and trade NGACs. The first trade of forest NGACs took place between Forests NSW and Energy Australia in March 2005. CO₂ Australia has announced agreements with Country Energy and Origin Energy for the future supply of NGACs from oil mallee tree belts being established in the Wagga Wagga region.

Greenhouse Challenge Plus

This program brings together the earlier AGO programs Greenhouse Challenge and Greenhouse Friendly, which are voluntary programs aimed at emissions reduction by industry. Greenhouse Challenge requires participants to report emissions, and to develop and implement emissions reduction action plans. Greenhouse Friendly is a program through which products and services are certified as 'greenhouse friendly', through actions that offset emissions associated with their manufacture/delivery.

Allowable abatement activities under Greenhouse Challenge Plus include forestry offsets. Eligibility of forestry offsets corresponds with Kyoto Protocol Article 3.3, with additional requirements that projects demonstrate financial additionality, and utilise a life cycle perspective, requiring reporting for indirect as well as direct emissions.

Emissions reporting for forestry offsets within AGO programs (including Greenhouse Challenge Plus) is based on the AGO's carbon accounting model, FullCAM, distributed as the National Carbon Accounting Toolbox.

Ad hoc trading

Some bilateral voluntary trading is occurring outside formal schemes, as companies are seeking to meet corporate emission reduction objectives; for example, NGACs created by FNSW have been purchased by IAG and Carbon Planet.

APPENDIX 3: CURRENT NSW DPI CLIMATE CHANGE PROJECTS

NSW DPI has established a climate research unit, a climate risk management team and a range of internal and collaborative initiatives in all NSW DPI divisions, many of which are outlined below. Distributed across the divisions, NSW DPI has considerable research capacity to address many of the climate change issues. Expertise ranges from statistical and biophysical modelling, animal and plant physiology and breeding, to economics.

1. MITIGATION

Through Forests NSW, NSW DPI has undertaken the world's first carbon dioxide emissions trade for carbon sequestration by planted forests, under the NSW Greenhouse Gas Abatement Scheme, and developed sophisticated carbon accounting procedures to support its emissions trading business. Forests NSW is playing a leadership role in forest carbon accounting/trading which should be recognised as bridging technology.

In addition to carbon sequestration (wood is the most carbon-friendly product in the marketplace), trees provide many co-benefits for the environment; they mitigate flooding, reduce erosion, reduce windspeed, improve soils (including carbon levels), improve water quality, enhance biodiversity, and prevent salinity.

NSW DPI is continuing research into carbon storage of wood products in landfill, and working on forest carbon accounting procedures that better reflect the fate of timber products after harvest (the current NSW GGAS excludes the contribution to mitigation of carbon stored in wood products).

- *Greenhouse footprint of wood products*

This research will guide policy and management decisions that will optimise the use of building materials and management of end-of-life options, particularly in light of the threat posed by climate change. The objectives of the project are:

- development of an energy budget for the main types of wood products used in the NSW building sector
- quantification of the greenhouse gas impacts of the various waste disposal options for wood and paper products in NSW
- development of an economic analysis of alternative disposal options for wood and paper (landfill, recycling, bioenergy)
- quantification of the rate and extent of decay of wood and paper products in landfills in NSW and their associated greenhouse gas emissions
- development of data that will inform further development of carbon trading rules in NSW.

NSW DPI is undertaking several projects through which research is being conducted into the potential for low rainfall forestry to deliver carbon sequestration benefits. These projects include the following.

- A pilot project with catchment management authorities (CMAs), funded through the NSW Greenhouse Plan, to develop a system whereby CMAs can act as **carbon pool managers** on behalf of landholders, to facilitate participation in the GGAS carbon trading market, and thereby provide an incentive for revegetation
- *Developing elite trees for economically viable forest plantations in low rainfall sites*
This project aims to develop elite germ plasm (seed and clones) of alternative species of Eucalyptus that have the potential to produce economically viable forest plantations in low rainfall areas, such as the Hunter Valley, South West Slopes and North West Slopes and Plains. Selection of the elite germ plasm will be based on growth, wood density and their ability to sequester carbon.

- *Improving methods to reliably estimate C sequestration by environmental plantings*
NSW DPI is collaborating with Lachlan CMA and CSIRO (ensis) in a Climate Action Grant project to develop a reliable tool for estimating C sequestration by environmental plantings in NSW. Lack of reliable models and inventory methodologies is a major impediment to the incorporation of such plantings into C trading schemes. As a consequence, landholders are denied income that would increase planting rates, with consequent benefits for greenhouse abatement and meeting statewide NRM targets. Activities funded will address technical and management issues, and facilitate landowner participation in the NSW GGAS and potentially in other C trading schemes. Findings will be shared with other CMAs.

As part of the WEST 2000 Plus-initiated Enterprise Based Conservation pilot program, NSW DPI is evaluating the practicality of an incentive system for Western Division graziers that provides financial incentives for maintenance or improvement of ground cover (mostly in the form of grass/shrub litter in summer rainfall areas, or cryptogamic crusts in winter rainfall areas). Such a scheme might be included in a national emissions trading scheme, along with other agricultural offsets.

Management of soil organic carbon

NSW DPI is continuing research into the use of recycled organics in agriculture and forestry as a soil amendment to supply nutrients and sequester carbon, including application in mine site rehabilitation. The department has commenced research into the use of char as a soil amendment to sequester carbon and improve water holding capacity and nutrient cycling.

A program of work is being carried out by NSW DPI and DECC soil scientists, in collaboration with colleagues from other agencies, including CSIRO. DECC and NSW DPI researchers are collaborating with AGO and CSIRO Land and Water to measure:

1. soil C change under tillage systems, looking specifically at the relative effects of combinations of tillage and stubble retention treatments on soil C sequestration
2. soil C changes following revegetation of previous agricultural areas. NSW DPI researchers, with funding from the NSW Climate Action Grants, are investigating the impacts on soil carbon of alternative crop and pasture management systems.

Increasing soil carbon sequestration of NSW agricultural soils by better managing pastures

Pastures are an important component of farming systems in NSW, providing diversity, maintaining soil fertility and, in the case of perennial pastures, reducing dryland salinity risks. However, little information is available on the soil carbon sequestration potential of pastures in farming systems in southern New South Wales. Using soil carbon data from two long-term field experiments (since 1979 and 1992), and regional sites in central and southern NSW, this project aims to quantify such potential. The data will then be used in models to identify the optimal management practices (i.e. pasture types, grazing and nutrient management) required to maximise soil carbon sequestration under different farming systems, soil types and climatic conditions.

Carbon sequestration under summer/winter response cropping in north-western NSW

Soil samples were collected from six cropping and perennial pasture systems over a period of six years (1994–2000) in a replicated field experiment on the Liverpool Plains. The objective is to determine whether the exceptional biomass productivity and hydraulic stability of zero-tillage summer/winter response cropping on the cracking clay soils of north-western NSW translate into net carbon sequestration. Results showed little association between biomass productivity and soil C accumulation; the largest rates were associated with perennial growth (lucerne and grass pastures) and the near-perennial

growth mimicked by very frequent response cropping. Response cropping at this intensity is very unlikely in practice.

Impact of recycled organics on soil carbon

Work by NSW DPI has found that recycled organic amendments, such as green waste derived composts, char and biosolids, have been shown to improve plant growth and many soil chemical and physical properties. While soil organic carbon is maintained or increased through the application of recycled organics, the persistence of the SOC and its longer term nature (determined by the proportion of different organic fractions) has not been investigated. NSW DPI researchers, with funding from the NSW Climate Action Grant, are building on previous work by analysing existing soil samples for organic matter and assessing the labile and recalcitrant fraction. Older sites are also being re-sampled (> 15 years). The objectives are to:

- determine the total, labile and recalcitrant fractions of soil organic matter before and sequentially after amendment with recycled organics
- assess the efficacy of different recycled organics in increasing and maintaining soil carbon stocks over time
- maximise the role of recycled organics in the long-term enhancement of soil carbon.

Soil carbon assessment and rehabilitation: Landholders develop and implement new practices

NSW DPI and Richmond Landcare have gained funding from the NLP Community Support program, for an initial 12 month period, to complete a project with the following objectives:

- to understand the nature of carbon fractions in farming soils under various best management practices in the Northern Rivers
- to measure and account for greenhouse gas emissions (CO₂, N₂O) from farms using existing management practices
- to implement, test, demonstrate and promote a technology (application of biochar) that results in significant carbon gain in soil, while at the same time significantly reducing emissions of N₂O to the atmosphere. This technology holds significant potential for rehabilitation of degraded land, through rapid enhancement of stable and high surface area carbon.

This community project will identify seven farms in the Northern Rivers that are representative of significant agricultural pursuits in the area. In addition, up to three control sites (e.g. native bushland, rainforest) will also be identified and sampled. Of these sites, two will be established as trial sites for the application of black carbon (biochar) to the soil. On-ground activities will include a detailed benchmark assessment and characterisation of soil carbon at the seven sites, and assessment of greenhouse gas emissions from these soils.

Land management to increase soil carbon sequestration in NSW

Changed land use and land management practices have significant potential to sequester carbon in soil. This project aims to:

- develop capacity to use a rapid and cost-effective method for measuring soil C, based on mid-infra red spectroscopy
- assess macro- and micro-scale variability of soil C stocks in diverse landscapes, to aid quantification of soil C stock
- examine the dynamics of soil C sequestration as a result of land management changes, including revegetation, altered crop rotations and grazing management
- examine the ability of organic amendments, particularly bio-char, to increase soil C stocks

- contribute experimental data to calibrate and parameterise the carbon accounting model FullCAM, to improve our capacity to estimate the potential for changed land management to increase soil C stocks, and to provide a calculation tool for emissions trading.

Fluxes of N₂O and CH₄ from forest soils

It is important to understand factors affecting fluxes of the powerful greenhouse gases methane and nitrous oxide, so that they can be accounted accurately, and mitigation measures can be devised. Very few studies on fluxes of N₂O and CH₄ have been undertaken in Australia, and none have been conducted in forests. Because they are affected by soil disturbance, soil temperature and moisture, fertiliser application and N inputs from grazing animals, reforestation is likely to alter the fluxes of these gases.

NSW DPI is collaborating with Ensis, CSIRO L&W and Queensland DNR&M to study N₂O and CH₄ fluxes during pasture–plantation transitions. The project, funded by AGO, will quantify in situ N₂O emission rates and CH₄ fluxes for hardwood and softwood plantations of different ages in climatically different regions of Australia (NSW, Qld, WA). Soil moisture and temperature data, measured concurrently with gas fluxes, investigation of diurnal flux patterns, and laboratory incubations studies, will be used to develop understanding of the processes driving N₂O and methane emissions. The objective of the project is to utilise this knowledge to improve the predictive ability of the FullCAM model for estimating nitrous oxide and methane emissions during the transition from pasture to plantation.

Methane emissions from livestock

NSW DPI is continuing research to:

1. quantify the mitigation arising from selection of beef cattle for improved net feed efficiency in Australia, both at an individual animal level and a national herd level
2. quantify the animal productivity and methane mitigation benefits of modifying gut ecology by eliminating ciliate protozoa from the rumen
3. develop new methodologies for measurement of methane production by ruminant livestock, to estimate the energy expenditure, and potentially the energy efficiency, of cattle.

Bioenergy

The department is actively involved in bioenergy activities, through participation in Bioenergy Australia (the peak government-industry forum) and representing Australia at the International Energy Agency bioenergy forums on ‘Short rotation crops for bioenergy systems’ and ‘Greenhouse gas balances of biomass and bioenergy systems’.

Through the CRC for Future Farm Industries, NSW DPI is working with Victoria, Western Australia and South Australia to investigate the suitability and productive capacity of native woody species for bioenergy production that may be integrated into farming systems in the 300–700 mm rainfall zone.

NSW DPI has formed an alliance with the University of New England, to create the Primary Industries Innovation Centre. Biofuels and biomass energy have been identified as a key future program of this centre, and alliances with industry and researchers are being pursued.

- The department is collaborating with UNE on a project, funded under the NSW Government’s Climate Action Grants program, to examine candidate feedstocks for ligno-cellulosic ethanol production, and thereby identify ‘best bet’ feedstocks with regard to availability, environmental impact, and possible pre-fermentation and fermentation techniques to optimise their use.

In collaboration with Crucible Carbon and the University of Newcastle, NSW DPI is developing the concept of the 'NSW Carbon Pump', aimed at accelerating and scaling up projects for large-scale bioenergy production from novel sources (e.g. algae), and concurrent production of biochar for carbon sequestration in agricultural and mine rehabilitation uses.

Geosequestration (and clean coal technologies)

Through the Government's 'Exploration NSW' and 'New Frontiers' initiatives, NSW DPI is active in identifying potential geological formations for the sequestration of carbon dioxide.

The department is exploring possible involvement in the Coal 21 initiative (a collaboration between the coal and power industries and state and national governments) that aims to reduce or eliminate greenhouse gas emissions from coal-based electricity generation in Australia. The NSW Government is a participant in the Coal 21 National Action Plan, which identifies a number of emerging technologies that hold the key to reducing, or even eliminating, emissions from coal. These include technologies to capture CO₂ emissions from power stations and permanently store them in underground geological structures – a strategy the Action Plan identifies as the pathway to achieving near-zero emissions from coal.

The NSW DPI is working with research groups, such as CSIRO and the CO₂ CRC, in assessing potential storage sites in NSW. Some current projects involving the department include:

- Sydney Basin Reservoir Prediction project, which will develop an understanding of the stratigraphic architecture and provenance of key basin fill sequences, with an emphasis on predicting the distribution and character of saline aquifers suitable for carbon dioxide sequestration
- Darling Basin Reservoir Study, which has similar methodology and objectives to the Sydney Basin Study.

The next stage will be to demonstrate post-combustion carbon capture at a suitable plant.

2. ADAPTATION

NSW DPI has established the climate risk management team to help farmers improve their short-term decision-making in response to seasonal climate variability (e.g. El Niño, SOI). The team also undertakes a broader extension and education role for farmers, on climate change and climate variability.

Land & Water Australia's Managing Climate Variability program funds two projects in NSW DPI aimed at improving seasonal risk management for rangeland graziers, western CMAs and sub-tropical dairies.

- The 'Climate science for better NRM in western NSW' project terminated in May 2007. This project involved collaboration with NSW Department of Natural Resources and Qld Dept of Natural Resources, Mines and Water. It developed refinements to the AussieGRASS spatial growth model for vegetation types in western NSW that will allow more reliable monitoring and forecasting of ground cover at regional scales. This will allow DECC, if requested, to provide a service for CMAs in the Western Division that will monitor a key catchment target and support warnings of possible land degradation events. The project also demonstrated the potential of the PaddockGRASP spatial framework to provide forecasts of forage production and ground cover at paddock scales to support individual property management decisions.
- The 'Seasonal climate forecasts for dairy feed base management' project will terminate in December 2007. This project has identified significant trends since 1957 in a number of key climatic variables related to dairy production. The number of heat stress days has increased from less than 20 to over 30 per annum, and the start of the summer

growth period has moved from mid-November to mid-October, with significant consequences for winter pasture production and feed base management. The project used a combination of simulation modelling and statistical analysis to develop monthly rainfall and pasture growth probabilities for three seasonal forecasting systems, providing a tool to assist dairy producers in assessing seasonal risk in feed base management.

NSW DPI is working with the Bureau of Meteorology to undertake research to downscale global climate models, in order to get a better picture of the impact of climate change on specific NSW primary industries and regions.

The department is continuing to breed and evaluate new plant varieties for agriculture and forestry, to cope with changed climatic conditions (e.g. drier conditions, shorter seasons and increased rainfall intensity).

NSW DPI is developing a range of paper-based and computer packages to help primary producers make better decisions in the face of climate variability.

The department will be holding a joint workshop in late October with the National Insect Pest Initiative on “Climate change and integrated pest management” aimed at identifying necessary modifications to current IPM programs in the face of climate change.

Impacts of climate change on plant growth: Hawkesbury Forest Experiment

The Hawkesbury Forest Experiment has been established at the Richmond campus of the University of Western Sydney (UWS), to investigate the ways in which increased atmospheric CO₂ concentration will affect Australian forests. The experiment brings together an expert team of researchers from the University of Western Sydney; the University of New South Wales; the University of Technology, Sydney; NSW Department of Primary Industries and the Swedish University of Agricultural Sciences, with \$1.2 million funding from the Australian Greenhouse Office.

The project is a carefully integrated program of experimental and modelling approaches. The centrepiece is a field facility with 12 CO₂ and temperature-controlled whole-tree chambers (WTCs), valued at over \$2 million, which have been provided by the Swedish University of Agricultural Sciences. The WTCs can house entire trees up to 10 m tall, and have been used for the last eight years in a boreal Norway spruce forest in northern Sweden.

The broad focus is on developing a predictive understanding of the growth, carbon storage potential and water use of both managed and unmanaged eucalypt forests growing in typical Australian water-limited conditions, and their responses to the rise in CO₂ that will occur during the next 50 years. Potential increases in water use efficiency at high CO₂ are of huge potential importance to Australia, the driest inhabited continent. Consequently, the experiment will include contrasting watering treatments, which will allow researchers to test, for the first time, the effect of elevated CO₂ on the productivity of large woody plants under water limitation.

Long-term predictions of forest responses to climate change cannot be accomplished directly in experiments, and must rely on ecosystem models that incorporate our best understanding of plant eco-physiological responses. The Hawkesbury CO₂ enrichment experiment will guide the development of ecosystem models by testing specific, well-defined hypotheses about the response of water-limited forests to elevated CO₂. The facility could continue to provide valuable information for at least 10 years.

Adaptation risk assessment framework

NSW DPI has been awarded funding to conduct a project to build a Geographic Information System (GIS) based framework for assessing the risk of climate change for agricultural production systems. This framework will provide a tool to assess the impact, vulnerability and potential adaptation options of the range of agricultural systems in NSW.

Climatology in agriculture

- *Climate risk management project*

This project is Action 2.4 of the NSW Greenhouse Plan, and its objective is to strengthen the climatology in agriculture program and develop tools and guidelines for use by farmers and catchment management authorities (CMAs). The project is primarily concerned with raising awareness of climate change and its implications for agriculture, and supporting the development of adaptation strategies for key industries at the regional to local level. Collaboration is key, with technical and scientific input from a wide range of relevant sources, both within DPI and external to it, with partners including CMAs and other state and federal agencies.

A key area of work is the development of a range of climatic indexes, to determine potential future impacts on primary production across NSW. Whilst this work initially only considers the biophysical factors, it provides critical information for evaluating potential economic impacts. Within A&F (EID), some preliminary work has been done on grazing systems (sheep and wool), including impacts on gross margins under certain scenarios. With new regional projections due later this year (expressed as probabilities), greater confidence in scenario planning, climate impact and risk assessment (including economic), and adaptation response is anticipated.

- NSW DPI has informal links with the South-East Australian Climate Initiative (SEACI), a joint project between CSIRO, BoM, Vic DSE and AGO (coordinated by MDBC), which aims to produce better methods and projections for planning water resource management into the future. The SEACI project will be run using a similar model to the Indian Ocean Climate Initiative (IOCI 2002). Significant questions cover amount of rainfall (inter-year variability, decadal trends and climate change), reliability of rainfall, and environmental responses to changing climatic factors. Only a small part of NSW is included in the study area (south of the Lachlan), though all of Victoria and South Australia are included.
- NSW DPI research and extension staff are involved in the work of the CRC for Irrigation Futures, ranging from development of on-farm toolkits and methods for evaporation mitigation through to understanding irrigation in the catchment context (System Harmonisation). Though this research is not directly focused on climate change, the outputs will be important for assisting the irrigation industry in adapting to the changing conditions.
- NSW DPI is collaborating with CSIRO to undertake research into sustainable development of marine and freshwater ecosystems, to ensure that they are ecologically healthy as well as economically productive under the predicted impacts of climate change.

- *Sustainable regional development and strategic options for management of marine uses and industries in NSW*

A five-year project, which commenced in 2005, is undertaking strategic research that will provide the tools and ideas to help planners, decision-makers and the community to understand how we can sustainably develop our regional coastal and marine ecosystems so that they are ecologically healthy as well as economically productive. This challenge will require an integration of likely climate change scenarios, oceanic and estuarine processes, the complex biology and ecology of natural and human-made systems, economic and social development, and systems of human governance.

- The time span for the modelling work in this project is 1950–2030, which captures the historical period of rapid development and environmental change, as well as a manageable projection period of immediate interest to policy matters and aligned with the Australian Greenhouse Office's 2030 predictions of changing rainfall, temperature, sea level and oceanic acidity.

The CSIRO's Atlantis modelling framework is being used to evaluate different management strategies designed to address the likely impacts on fisheries resources of

different environmental scenarios, for an initial study in the Clarence River estuary and for a separate model of the nearshore coastal zone from the Queensland border to the Victorian border. The Atlantis modelling framework is a dynamic, time stepped, biogeochemical model with a coupled physical transport module. Atlantis tracks the nutrient flow through physical, O₂, CO₂, living (multiple) and detrital functional groups in a box model. However, due to the computational limitations in Atlantis, the nearshore model is based on a large spatial scale of the individual boxes. Preliminary outputs from the estuarine model are expected in 2007. The modelling will then be extended to elsewhere along the NSW coast.

- In addition to the mitigation benefits of schemes such as GGAS, sequestration by new forests has an important role as a bridge to a low carbon emission world. New forests can ‘buy time’ for the economy to adapt to low-emission technology. Technology adaptation will take many decades, while a new forest is an economic solution that is available now.
- NSW DPI is undertaking an assessment of its own contributions to greenhouse gases, with a view to developing and implementing policy and practice across a range of operational areas to reduce these contributions in the future.
- The department has undertaken an organisational climate change ‘risk assessment’, to identify those operational areas that are at high risk due to climate change. This assessment will guide organisational adaptation to climate change, and may also identify mechanisms for improving the resilience of primary industries in the face of climate change, which may then be delivered through appropriate extension mechanisms.