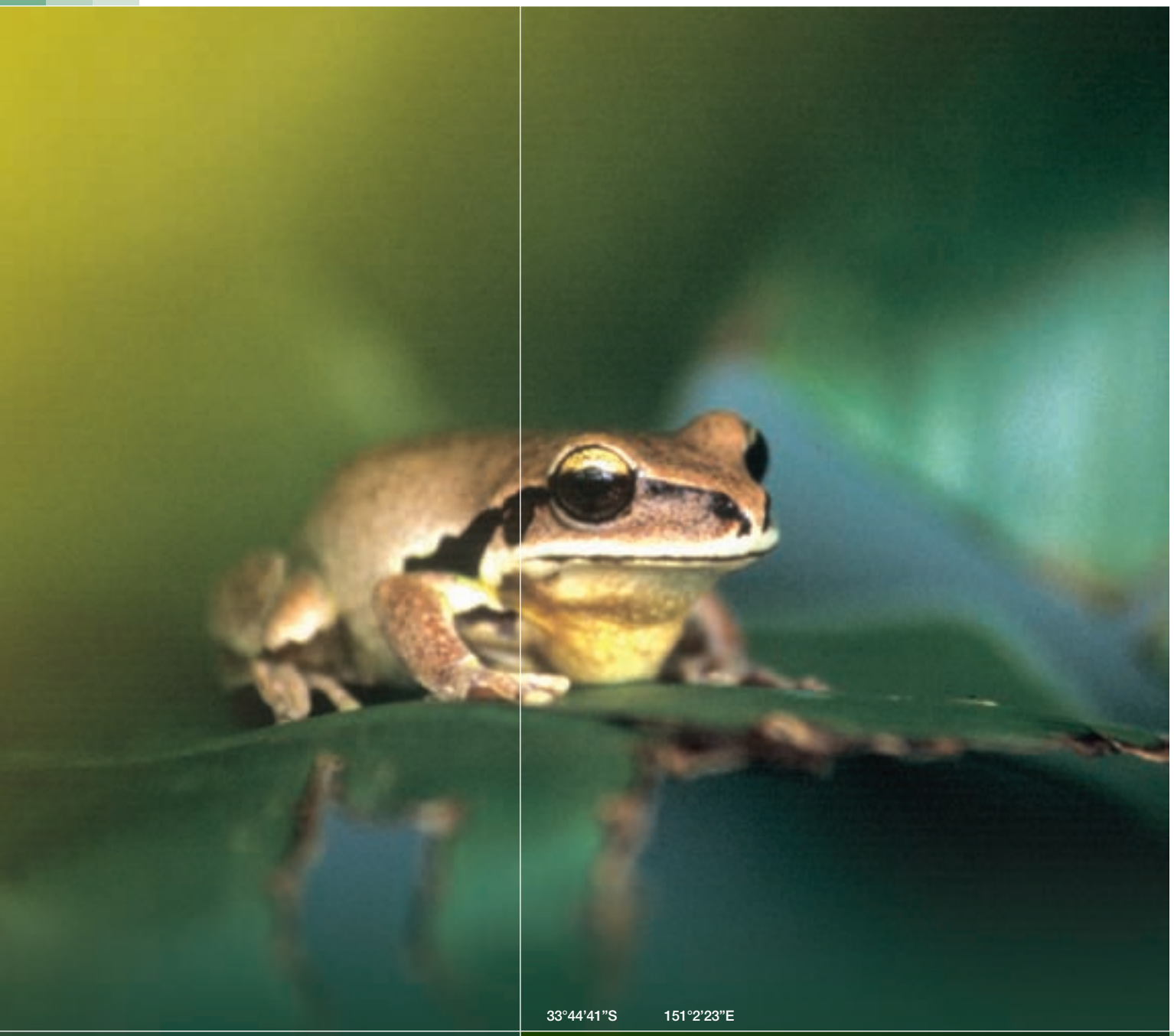

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SCIENCE AND RESEARCH AND FORESTS NSW

Research and Development Annual Report

2006-07

NSW DEPARTMENT OF
PRIMARY INDUSTRIES

Forests NSW is a public trading enterprise within NSW Department of Primary Industries

FORESTS NSW

NSW DEPARTMENT OF PRIMARY INDUSTRIES SCIENCE AND RESEARCH and FORESTS NSW

Research and Development Annual Report 2006–07

Our Mission

Research and development that underpins innovative sustainable forest management systems, adds value to Forests NSW's key objectives and benefits the people of New South Wales

Research and Development Annual Report 2006–07
is a supplement to *Forests NSW's Annual Report*
and the *Social, Environment and Economic Report 2006–07*.

NSW DEPARTMENT OF PRIMARY INDUSTRIES

FORESTS NSW

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Disclaimer

The information contained in this publication is based on knowledge and understanding at the time of writing (November 2007). However, because of advances in knowledge, users are reminded of the need to ensure that information upon which they rely is up to date and to check currency of the information with the appropriate officer of New South Wales Department of Primary Industries or the user's independent adviser.

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Foreword

Forests NSW's research and development objectives are primarily delivered through NSW Department of Primary industries (DPI) Science and Research, as well as units of its own Land Management and Technical Services branch. These groups provide strategic research support to the organisation's operation and service branches.

The NSW DPI Forest Science Centre of Excellence is co-located with Forests NSW, within Cumberland Forest at West Pennant Hills. The Forest Science Centre is home to the Forest Resources Research unit of DPI Science and Research.

The Forest Resources Research unit provides research and development through three program areas: Forest Health Management, Forest Biodiversity and Ecology, and New Forests. The research focus is on providing science-based outcomes for forest resource development and sustainability within NSW. Research in fields that can add value to the commercial services and planted and native forest businesses of Forests NSW remain a priority. The emphasis is on the establishment and product quality of planted forests, and ecologically sustainable management of all forests. Research on the range of important potential benefits to be derived from returning trees to the rural landscape is also an important objective. Benefits include timber, sequestered carbon, enhanced biodiversity and salinity mitigation.

The activities of the Forest Science Centre and of the Land Management and Technical Services water quality monitoring program are reported here.

Robert Eldridge

Research Leader / Centre Director
Forest Resources Research
NSW DPI Science and Research

This Annual Report was compiled by Robert Eldridge

New Forests

Program Leader: Annette Cowie

Aim: A sound scientific basis established for the use of planted forests to benefit the environment.

Objectives:

- Carbon sequestration quantified in managed forests and forest products
- Suitable tree species and management systems available for catchment protection and management
- Ecologically sustainable systems which use forest biomass to generate bioenergy and other value added products

Land management to increase soil carbon sequestration in NSW

A. Cowie

Presently, there is considerable uncertainty about the extent of carbon (C) sequestration possible through improved land use and management practices. The improved land use and management practices with significant potential to sequester soil C may, in future, be recognised as eligible for offsets in the NSW Greenhouse Gas Reduction Scheme or its successor. Providing information on potential C sequestration and developing cost-effective and reliable methods of estimating soil C change will assist NSW landholders to take part in emissions trading. If landholders are informed of how land use practices affect soil carbon, they will be better equipped to enhance the productivity and resilience of agricultural and forestry systems.

This collaborative project between the NSW Department of Primary Industries (NSW DPI) and the Department of Environment and Climate Change (DECC) addresses Action 3.6.5 of the NSW Greenhouse Plan. It focuses on developing cost-effective methods for measuring soil C across diverse landscapes and evaluating a range of management practices with potential to promote soil C sequestration in agricultural, pastoral and forests systems in NSW.

The main aims are to:

- develop a rapid and cost-effective method of measuring C across landscapes
- examine the ability of organic amendments to increase soil C stocks
- examine the dynamics of soil C sequestration as a result of land management changes
- assess macro- and micro-scale variability of soil C stocks in diverse landscapes in order to better measure and monitor soil C condition
- contribute experimental data on the C cycle that will improve our understanding of how land management practices influence soil C stocks

- quantify C sequestration potential under different management options on diverse soil systems
- predict soil C sequestration potential at regional and state levels using the C accounting model
- develop land management guidelines that will facilitate better greenhouse outcomes.

Forest Resources Research is leading a subproject that is assessing biochar (a type of charcoal produced from biomass) as an organic amendment in terms of its ability to enhance C sequestration in soil and reduce the amount of greenhouse gases in the atmosphere.

Because the pyrolysis process produces biochar that is expected to provide long-term carbon sequestration in soil, and also generates renewable bioenergy, it is said to be a “carbon negative” process (it removes more CO2 from the atmosphere than is emitted). To document the extent to which pyrolysis is carbon negative, it is necessary to calculate the whole-of-life greenhouse gas (GHG) balance of the char production and utilisation process, and compare this with conventional practice. In this study we have calculated GHG balance for a range of char feedstocks and two cropping systems. Using published emissions factors, and conservative estimates of biochar-C turnover, we estimated that the reduction in net emissions produced by making and using biochar from dry feedstock was equivalent to 0.5–1.6 times the CO_2e (carbon dioxide equivalent) in the feedstock. Not surprisingly, biochar-C turnover rate (the rate at which the carbon in biochar is returned to the atmosphere as carbon dioxide) was one of the major factors affecting the GHG balance of biochar application to soil. However, this is one of the least well-understood properties of biochar.

Research Scientist Dr Bhupinderpal Singh with a range of biochars stored in sealed buckets. The biochars are being used in a laboratory incubation experiment to study the turnover of various biochars applied to soil.

To address this question, Dr Bhupinderpal Singh has begun a long-term (up to five years) laboratory incubation experiment examining the time it takes for biochar carbon to be decomposed and released from soil. The study is using a novel method that is based on measuring the inherent difference in C isotope content between biochar and soil. The experiment uses biochar produced from a range of feedstocks and under different process conditions. Early results show decomposition of biochar carbon in soil in the first 84 days varied from <0.1 and 4.7 % of biochar-C applied, depending on the char types tested.

Pilot of a catchment management authority participating in the NSW Greenhouse Gas Abatement Scheme

A. Cowie

The NSW Greenhouse Gas Abatement Scheme (GGAS) requires NSW electricity retailers to reduce the per capita greenhouse gas emissions from electricity generation. One way in which they can reduce net emissions is by buying abatement certificates generated through reforestation. This project aims to develop a sequestration pool[1], managed by a catchment management authority (CMA), in order to make it easier for landholders who undertake small-scale reforestation to participate in the scheme.

The objectives are to:

- develop effective and easy-to-use documents, tools and systems to enable carbon sequestration prediction from revegetation activities that meet the needs of the GGAS Rule 5 Carbon Sequestration
- assist one or more CMAs to apply for accreditation as an abatement certificate provider under the NSW GGAS
- pass on the documents, tools and systems to other CMAs interested in seeking accreditation
- recommend institutional improvements where necessary
- extend the capability of current carbon sequestration predictions from CMA revegetation activities.

The preliminary phase of the project evaluated the Murrumbidgee CMA business systems and determined that with only minor changes, many of the requirements of GGAS could be met satisfactorily. Some issues, including the disincentive to landholders created by the requirement for the Restriction on Use to be registered on land title, and the capacity of the CMA as pool manager to meet the requirements of the “100 year rule” (the rule that forests used for sequestering carbon for trading must remain as forests, and the carbon must remain sequestered, for at least the next 100 years), may present barriers.

[1] A ‘sequestration pool’ is a collection of eligible forests that are managed to provide carbon sequestration and controlled by an accredited abatement certificate provider. The eligible forests may be owned by more than one entity.

A business case was developed by the Murrumbidgee CMA to assess the attractiveness of establishing a carbon pool in the Murrumbidgee catchment. This showed that the returns would justify such a venture, but were dependent on the level of interest and uptake demonstrated by landholders. Attracting existing eligible plantings into the pool would be important to provide an immediate source of revenue. It may be more attractive to develop a larger pool based on several CMA areas. Negotiations are underway to establish a consortium of several CMAs and to further investigate the options for CMAs to participate in sequestration pool management under GGAS.

The preliminary phase evaluated two carbon accounting methods (the Carbon Sequestration Predictor and the National Carbon Accounting Toolbox) and concluded that both provided unbiased estimates for plantings of typical dryland eucalypt species over five years old; however, for younger plantings the estimates were inaccurate. Neither model provided a precise measure and the level of uncertainty associated with these methods would result in very conservative estimates for calculation of abatement certificates. Nevertheless, either model may be suitable for use by CMAs, subject to calibration for a wider range of species and planting types, and additional assessment of uncertainty.

While this evaluation showed that both models performed similarly, it should be recognised that the National Carbon Accounting Toolbox model is the subject of considerable investment by the Australian Greenhouse Office, and that on-going development to improve its identified deficiencies is certain. On the other hand, it is much less likely that further development of the Carbon Sequestration Predictor will be undertaken. Furthermore, the more sophisticated nature of the National Carbon Accounting Toolbox in comparison with the Carbon Sequestration Predictor would suggest that the former has the potential to provide superior accuracy and precision.

Understanding the drivers of N_2O and CH_4 emissions during the transition from pasture to plantation forests

Bhupinderpal Singh

This project is part of Greenhouse Action in Regional Australia (GARA), which brings together an expert team of researchers from the NSW DPI, Ensis ACT and WA, CSIRO L&W Adelaide, and Queensland Department of Natural Resources and Water, with more than $250,000 funding for the project from the Australian Greenhouse Office. The main aim of this project is to improve the predictive ability of FullCAM for estimating soil nitrous oxide emissions during the transition from pasture to plantation forests, by quantifying *in situ* nitrous oxide emission rates and their drivers at field sites representing differences in species, age, and growing conditions. This project has been extended to incorporate measures of methane fluxes in order understand processes governing methane uptake and production, and how methane flux is affected by land use change, plantation species, age, and site-specific environmental conditions.

The atmospheric concentration of nitrous oxide and methane is much smaller than that of CO_2. However, the global warming potential of nitrous oxide and methane is 298 times and 25 times, respectively, than that of carbon dioxide (Intergovernmental Panel on Climate Change's Synthesis Report. *Climate Change, 2007*). In Australia, nitrous oxide and methane are the two important non-carbon-dioxide greenhouse gases, contributing 25% of Australia's total greenhouse gas emissions. Thus, in addition to enhancing C sequestration and decreasing carbon dioxide emissions from vegetation and soil, due consideration should be given to understanding and accounting for non-carbon-dioxide gas fluxes, e.g. following changes in land use and management practices. However, there is a paucity of information on the extent of soil nitrous oxide and methane fluxes from Australian plantation systems.

The results from this project will help to improve the predictive capability of FullCAM to describe nitrous oxide fluxes from planted forest systems. We will also achieve a thorough understanding of the rates and drivers of nitrous oxide and methane fluxes, including the effects of species, stand age, and site growing conditions, during the transition from pasture to plantation forests. At this stage, there is a paucity of such information for Australian conditions. With greater knowledge on soil non-carbon-dioxide gas emissions and factors driving these emissions, it would be possible for farm managers, foresters and policy makers to make informed decisions about the greenhouse gas (GHG) implications of land use and management practices that are happening in Australia.

A network of nine contrasting paired pasture-plantation sites has been established across three states in Australia: Western Australia, NSW, and Queensland. Each paired site consists of a forest stand and adjacent pasture. All of the forested sites selected for paired comparison were established on pasture. Features of the paired forest-pasture sites are described in the table below.

Features of paired forest-pasture sites in the FullCAM project

Location	Forest stand age in paired sites	Forest species	Main soil type	Climate
QLD	0.3, 1, 5 years	Spotted gum (Corymbia citriodora)	Red Ferrosol (oxisol)	Sub-tropical
NSW	1, 3, 23 years	Pinus radiata	Red and yellow earths	Temperate
WA	0.5, 2.5, 8.5 years	Blue gum (Eucalyptus globulus)	Duplex	Mediterranean

In NSW, we have established a chronosequence (at one, three and 23 years) of paired pasture–pine plantation sites at Vulcan State Forests in Black Springs (near Oberon, Macquarie Region in NSW).

A chronosequence (at one, three and 23 years) of paired pasture–pine plantation sites established in September 2006 for soil greenhouse gas measurements using closed chambers in Vulcan State Forests in Black Springs, NSW

Sampling showed that soil under both pine plantation and pasture sites are sources of nitrous oxide; however, significant uptake capacity for atmospheric methane was observed in all of the forest sites. Furthermore, a general trend of reduced nitrous oxide emission and increased methane uptake with increasing pine plantation age was observed. Gas fluxes appear to be heavier in rainfall, which is predominantly summer-based in NSW and Queensland, and winter-based in Western Australia. Continued monitoring of all sites during 2007 will determine the nature of trends across an annual climate cycle, and identify the range of soil-related physical and chemical drivers of flux of greenhouse gases under varied conditions during the transition from pasture to plantation forest. Soil incubation studies, to be undertaken during 2007, will also improve process-level understanding of the drivers of nitrous oxide and methane fluxes.

Closed chambers and pine trees at Black Springs in Vulcan State Forest covered with snow at the time of winter gas sampling on 27 June 2007. Closed chambers are used for trapping and sampling gases emitted from the soil.

The role of recycled organics in the increase and nature of long-term soil carbon pools

G Kelly

Loss of soil organic matter is associated with widespread land degradation, resulting in declining plant productivity and increased greenhouse gas emissions. Whilst the application of recycled organics can reverse this decline, understanding the changes in soil organic carbon fractions over time is necessary to determine the long-term role that recycled organics have in mitigating or sequestrating greenhouse gases.

A new two-year project funded from the Climate Actions Grants program was agreed upon in June 2007. The project aims to:

- determine the total, easily decomposed and persistent fractions of soil organic matter before and sequentially after amendment with recycled organics
- assess the effectiveness 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.

The greenhouse footprint of wood products

F Ximenes

> "Australia has an interest, for example, in leading the way in the development of approaches that maximise the potential of carbon sinks to contribute to the abatement task. Current methodologies in international emissions accounting assume that all carbon within a tree is emitted upon harvest. However, carbon remains locked in the timber until it decays. Australia should make it a priority to explore and demonstrate more rigorous methodologies for plantation offsets, which take into account the carbon contained in harvested wood product."
>
> Prime Minister's *Report of the Task Group on Emissions Trading*, Section 6.3.2 Positioning Australia for international developments, page 89.

The NSW Department of Environment, through its Climate Action Program, is funding a project to determine the greenhouse footprint of wood products in NSW. Wood products can significantly extend the greenhouse gas mitigation benefits provided by forests. This project will deliver an energy budget for wood products used for building in NSW and determine the greenhouse impact of waste disposal options.

The research will help those who make policy and management decisions to 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 to:

- develop an energy budget for the main types of wood products used in the NSW building sector

- quantify the greenhouse gas impacts of the various waste disposal options for wood and paper products in NSW
- analyse the economic implications and effects of using alternative disposal options (landfill, recycling, and bioenergy) for wood and paper
- quantify the rate and extent of decay of wood and paper products in landfills in NSW and their associated greenhouse gas emissions
- develop data that will inform further development of carbon trading rules in NSW.

The project began in July 2006 and is expected to run for three years. During the first year the focus was on the energy and landfill components of the project.

Following the identification of suitable sites and agreement with the mills concerned, energy studies were conducted at two large sawmills in NSW (one hardwood and one softwood). The energy studies follow a life cycle analysis approach and involve the quantification of greenhouse emissions associated with harvest, transport of logs to the mill, processing and handling of products and transport to customers. The level of detail and rigour adopted in these studies will result in a comprehensive overview of the greenhouse footprint associated with saw milling activities in NSW.

Senior Research Scientist Dr Annette Cowie and Research Officer Fabiano Ximenes examine wooden material at the Meadowbank landfill excavation.

A landfill excavation was successfully conducted at a site in Meadowbank, Sydney. The site was one of the largest landfills in the Ryde area, operating between the early 1950s until 1968. The site is currently used by the local council as sporting fields. The excavation recovered a wide range of wood products and initial visual assessments indicated they were generally in remarkably good condition. The wood product samples are currently being analysed to determine the extent of any carbon depletion. All wood product samples (384 in total) have been individually measured, labelled, identified to wood type (softwood and hardwood) and photographed. A total of 100 samples (50 softwood and 50 hardwood) have been selected for analysis, which includes moisture content and density, heartwood content, wood identification to species, chemical analyses (cellulose, hemicellulose and lignin) and microscopic examination.

Key sites for hydrology and salinity measurement and model validation

C Barton and H Morgan

This project provides essential data for other current projects under the National Action Plan for Salinity and Water Quality (NAP) and National Heritage Trust (NHT), for example the salinity TOOLS project and Salinity Solutions through Agriculture. It also provides information that will assist relevant stakeholders (policy makers, catchment management authorities (CMAs) and land managers) to make decisions on best land use to minimise the onset and cost of dryland salinity. Data collected will also be used to improve the tree growth models that are required for economic forecasting and estimating of the carbon sequestration potential of tree plantings.

The project is a collaborative effort between NSW DPI, the Department of Environment and Climate Change (DECC) and the University of NSW (UNSW), and is funded under the NAP. The project aims to collect a range of data from a number of sites to quantify the impacts on small subcatchments within the catchment area of various land use options, including tree planting, on water and salt movement. This data will then be used to validate the suite of simulation models currently being developed by DECC that are integral to decision support tools used by CMAs. The models should make it easier to identify areas where land use needs to be changed in order to prevent or reduce salinity. In particular, the project aims to:

- provide the biophysical scientific data to improve our understanding of dryland salinity
- validate existing farm-to-catchment scale water and salt models to enhance confidence in the use of these models, which underpin current decision support tools and state reporting requirements
- provide comprehensive data to enhance the capacity of CMAs, farm advisors and agricultural extension services to deliver meaningful advice to farmers about the land management systems that will best manage salinity
- deliver essential NAP outcomes through the continuation of existing projects that provide detailed investment-decision-support data.

Data collection and analysis has been ongoing at the two field sites operated by the Forests NSW group. One (Paringa) is in the Liverpool plains near Quirindi, where a 10-year-old stand of Ironbarks is being monitored. The other (Baldry) is in the central west between Wellington and Parkes, where a five-year-old 60 ha planting of Spotted Gum and River Red Gum is being investigated.

The continued drought has resulted in high stress levels and a significant number of the Spotted Gum on the drier slopes have been attacked by borer. Lower down the hill the River Red Gum have continued to grow and use water, albeit fairly slowly, and roots have been found in a borehole at a depth of 6 m.

*Technical Officer Brett Wilson holds up roots found at 6 m in a borehole in a river red gum (*Eucalyptus camaldulensis*) stand at the Baldry site.*

Data from the Paringa site was used to test the PERFECT 1D unsaturated zone model. It was discovered that the model did not estimate tree water use well under drier conditions due to the way in which it models deeper soil layers. The growth and water use of the river red gum at the Baldry site were tested against predictions from the 3PG+ model. Growth was predicted well but because of the oversimplified

representation of the soil, water use was not. Other versions of 3PG with more complex soil representations will be tested.

Integrating forestry into salt-source catchments

C Barton

The wider aim of this project is to develop attractive options for farmers that will encourage them to invest in trees for profit and salinity management. The project aims to do this by improving our ability to strategically target land use change for salinity outcomes. In particular, the project will:

- provide data that improves our understanding of growth rates and water use of trees planted in belts on hill slopes
- improve our knowledge of the effects of different spacing and widths of tree belts on water movement down hill slopes in the low rainfall region
- provide comprehensive data to enhance the capacity of CMAs, farm advisors and agricultural extension services to deliver meaningful advice to farmers about the tree planting configurations that will best manage salinity.

The project will bring together economic analyses and biophysical information at farm and subcatchment scales. Core outputs will be quantitative prediction of the impacts of trees on farm profitability and return on investment, and land and water salinity management.

Planting configuration trial

Our component of the project is to investigate the relationships between tree belt width and the pasture belt width on water use and movement down the hill slope. A block of trees (~ 2 ha) was planted in a particular configuration on a property in the Liverpool plains in 2003. This project will monitor the changes in soil moisture across the hill slope in relation to rainfall. The tree growth and water use will also be monitored in order to assess the impact of varying widths of pasture belt and tree belt on tree performance.

The site had previously been instrumented with a network of neutron probe access tubes and good baseline data exist for the soil. Some of the original neutron probe access tubes were damaged or destroyed during tree planting, so new tubes have been installed to ensure good coverage. Tree sapflow instruments have been installed and are being monitored. Tree growth has been measured and will be re-measured at six-monthly intervals.

Commercial and environmental tree use in medium rainfall areas

C. Barton and I Johnson

Trials planted between 2000 and 2003 were designed to provide information about the survival, growth, and form of a number of potentially useful plantation tree species over a range of sites in the medium rainfall (500–700 mm) region of NSW,

and to investigate effects of various silvicultural regimes (establishment techniques, spacing, and thinning) on tree growth and biomass. Many permanent growth plots in older hardwood plantations in the 500–700 mm rainfall zone and in younger (2001–2003) plantings in the 500–700 mm rainfall zone are being maintained and measured periodically.

Species demonstration sites

Results from the Species Demonstration Trials will aid in the production of fact sheets and decision support tools to guide CMAs, extension personnel and landholders in low rainfall areas in selecting best species for establishing plantations on particular site types and for particular purposes (e.g. carbon sequestration, salinity control, commercial returns).

Forty-four sites are considered still viable. The most recent growth and form assessment of all these sites was made in 2005. Height and survival data collected at these sites from 2001 to 2005 was analysed using a mixed effects model. The height of the trees was closely linked to their location and species. Survival data showed significant species and region effects. *Acacia mearnsii, Corymbia maculata, Eucalyptus camaldulensis*, and hybrid clones had the greatest mean height, while *P. pinaster* was very poor. Survival percentage was highest for *E. camaldulensis*, *E. sideroxylon, E. argophloia*, and hybrid clones, and very low for *Pinus pinaster* and *A. mearnsii.* Exploratory analyses using five-year growth data for all sites gave poor correlations with single climatic, geological, and available soil factors. More intensive analysis, including 12 trial sites with more detailed soil data, is underway to explore the effects of these site factors on survival and growth.

Thinning and pruning trials

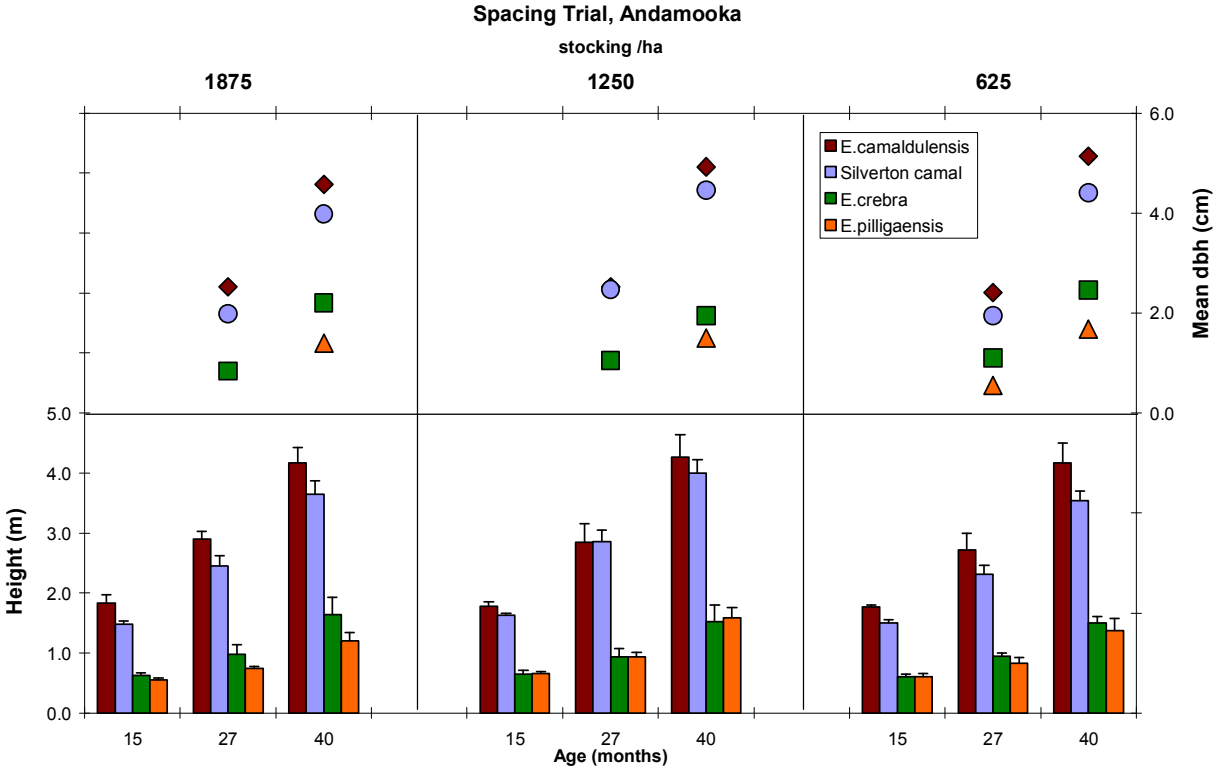
A number of the demonstration trial sites are being used to quantify the effects of a simple commercial thinning and pruning regime on tree growth and development. Such thinning trials should, in time, demonstrate and quantify whether log production from the species tested is likely to be a viable commercial proposition for landholders in low-rainfall zones of NSW. We should be able to evaluate the effectiveness of simple silvicultural management in improving stand log volume and quality, or in enhancing biomass accumulation, compared with the effect of no management (the control plot).

Thinned E. argophloia *plot, Species Demonstration Site N16, October 2006*

Thinned E. sideroxylon *plot, Species Demonstration Site MA11, February 2007 (one year after thinning)*

Technical Officer Jagrutee Parekh stands among recently thinned spotted gum plots at Species Demonstration Site N11, October 2005

Treated plots will be compared with control plots (nil thinning/pruning) in a production study. Fifty-four paired, first thinned/pruned and control plots (matched on pre-treatment survival and growth) have been established in five species over nine sites. Further plots of this type will be established as the trees reach a suitable height for thinning. First thinning aims to retain an equivalent of 500 trees per ha, with pruning to about 3.3 m. These sites will need monitoring over several years to assess the effects of thinning on future growth, biomass, survival, and probably wood production and quality. Occasional plots that have good growth and survival but very poor tree form are being paired for a "survival" trial, with the treated plots thinned only. Six such plots (three pairs) have been included to date.



Height and diameter of trees in the spacing trial at three ages. Height growth has not shown a significant response to spacing but there is an indication in the last set of measurements that stem diameter is decreasing with increased stocking.

Permanent growth plots

Permanent growth plots will provide data for growth over extended periods for species under "real life" plantation conditions, including some species not present in the demonstration trial. The data will be useful for quantifying biomass and carbon sequestration in plantation conditions, and in contributing to development of carbon sequestration tools.

In 2002, 73 permanent growth plots were established in the 450 to 700 mm rainfall zone on 12 private properties from Armidale to Albury. The plots included a range of native tree species aged from five to 14 years old. These plots were re-measured

this year and data analysis is underway to determine growth rates prior to and during the drought.

In early 2007, 47 permanent circular growth plots of trees aged between four and six years were established in 20 mostly small plantation blocks in the Liverpool Plains area. Plot positioning and establishment followed standard Forests NSW inventory methods. Most plots are in blocks of river red gum (*E. camaldulensis*) (11 blocks and 28 plots); the other nine blocks (19 plots) include five other eucalypt species with potential commercial value. The red gum plots are on different topographic positions on both basalt and sedimentary geology. Initial growth measurements were made in May 2007. Plot centres and the locations of their trees are mapped, and access to each plot is documented in detail.

Spacing trial

Spacing and site preparation methods trials will define optimal techniques for successfully establishing tree plantations, perhaps for different purposes, in low rainfall areas. Initial spacing to achieve high biomass may be different from that for commercial production.

A large (7.1 ha) spacing trial was established in May 2003 near Spring Ridge in the Liverpool plains area. Three tree-stocking treatments (1875, 1250 and 625 trees/ha) were applied to four species (*E.camaldulensis, E. camaldulensis* (Silverton), *E.pilligaensis, E. crebra*) planted in four replicates. The trial has been measured annually since planting. No strong pattern has emerged, with tree height growth and diameter unaffected by stocking rate. However there is an indication in the 2006 data that diameters are smaller in more densely stocked plots (see figure above). Measurements in 2007 will determine if this is a developing trend.

Establishment methods

Two trials assessing site preparation methods in areas planted in 2003 with river red gum on sedimentary and basalt sites in the Liverpool Plains were assessed for survival and total height at age 45 months. There is some evidence that deep ripping of the planting site gave substantially greater survival of red gum on a basalt site than shallow ripping and mounding alone (although the shallow ripped site had damage from external factors such as severe drought and cattle). If less intensive site preparation were to result in similar survival and early growth to that from more intensive, expensive methods, it would help reduce plantation costs for growers in drier areas. The planned new site preparation trials should provide us with a fresh chance to study this issue.

Overall mean height at the sedimentary site was much greater than at the basalt site (3.8 m vs 1.4 m), and overall survival was slightly greater at the former, though fairly low at both sites (67.6% and 62.3%). There were no significant differences for mean tree height among site preparation treatments at either site ($p= 0.61$ and 0.33) or for mean treatment survival at the sedimentary site ($p=0.58$). However, on the basalt site, mean survival of trees in the deep ripping treatment was significantly greater than for each of the shallow-ripped, mounded, or ripped and mounded treatments

(p=0.007 to 0.026). Mean survival for deep-ripped plots was 71.9%, compared with the next best (ripped and mounded) at 61.1%. Deep-ripped plots were consistently better for survival than shallow ripped and mounded-only plots.

Sites for two new site preparation plus herbicide trials were selected at coalmines in the upper Hunter Valley. It is proposed that the trials have four preparation treatments that are similar to the older trials, with post-planting herbicide and nil herbicide treatments superimposed, in a row-column design. Site preparation is expected in July–August 2007, when agreements with the mining companies are finalised.

The Hawkesbury Forest Experiment: Impacts of precipitation and CO_2 on trees.

C. Barton

The Hawkesbury Forest Experiment, which is investigating how increased carbon dioxide will affect Australian forests, is at the Richmond campus of the University of Western Sydney (UWS). The results from this research will improve our ability to model and predict the likely effects, in terms of their growth and water use, of climate change on Australian forests. These effects have implications for carbon sequestration and water resources in both native and planted forests.

The project involves two experiments: an elevated carbon dioxide experiment and an irrigation plus fertilisation experiment. The centrepiece of the project is a field facility with twelve carbon dioxide and temperature-controlled whole-tree chambers, valued at over $2 million, which have been provided by the Swedish University of Agricultural Sciences. Six chambers are operated at ambient carbon dioxide concentration and six at ambient plus 240 ppm to simulate the concentration predicted by 2050. Two levels of water availability will be used to investigate the interaction between increased carbon dioxide and water availability. The related irrigation plus fertilisation experiment will investigate the response of a fast growing and a slow growing eucalyptus species to resource limitation.

Reconstruction of the whole tree chambers and installation and testing of control gear and instrumentation has been completed. The irrigation system for the irrigation plus fertilisation experiment has been installed and tested.

Irrigated plot of irrigation x fertilisation experiment at the field site at the University of Western Sydney's Hawkesbury campus. Whole tree chambers can be seen in the background.

Four thousand seedlings of *E. sideroxylon* and *Corymbia maculata* were planted in September 2006. Unfortunately the *C. maculata* were infected with a fungal disease and so were replaced by *E. saligna* seedlings in April 2007. Measurements of growth and physiology will be made on the trees as they grow.

Using wastes to grow commercially viable eucalypt plantations on marginal lands

G Kelly

There are economic and land management advantages in establishing commercially viable hardwood (eucalypt) plantations on marginal and degraded lands. To achieve these advantages, new ways must be found to boost current tree growth in these areas, which typically receive low rainfall. This work will help the Hunter Region, Investment Services, power generators and coalmines determine if trees can be grown at commercially viable rates on buffer and overburden lands (land that lies above the area of economic interest, *e.g.*, the rock and soil that lies above the coal

seam). The results will identify appropriate tree species, particularly where water is likely to be a limiting factor, and determine if amending the soil with organic wastes significantly improves survival and growth.

The project aims to:

- identify the best combination of the abundant local wastes (biosolids, flyash, and greenwaste) for improving commercial hardwood growth on marginal sites
- identify which hardwood species and provenances are appropriate for both marginal and degraded lands where these wastes are being used.

There will be an emphasis on determining treatments that enhance the soil moisture-holding capacity. The trial involves growing six species of eucalypt and eight different treatments, comparing organic wastes with traditional establishment techniques. Tree growth and soil parameters will be monitored for five years.

DPI Science and Research was successful in obtaining funding from the Natural Heritage Trust together with significant collaboration and funding from Macquarie Generation. Planted Forests Division, DPI Science and Research and Hunter Water also contributed funding, to make up a substantial consortium involved in this project.

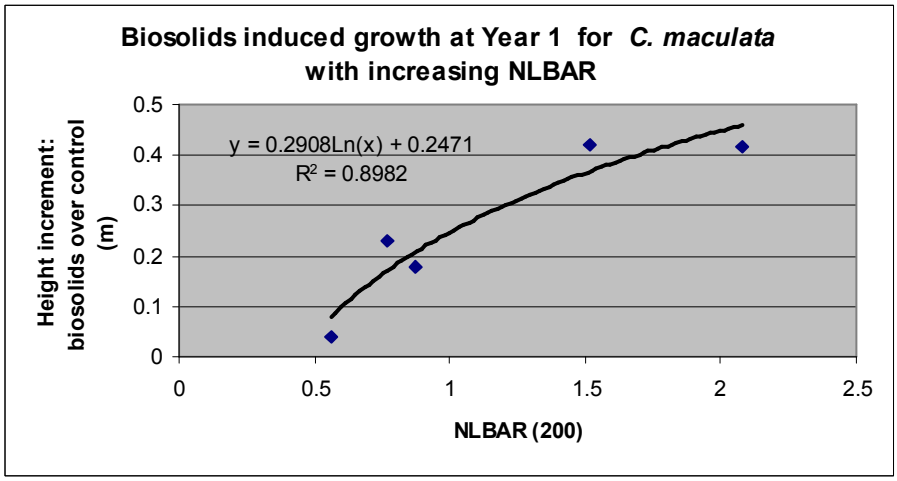
The initial phase of growth soil and foliar assessment is complete. However, the plantation will continue to be monitored, as it is one of the larger and older commercial plantings in the Hunter. Assessments will be made as to the need for early thinning in this dryland area. Further funds will be sought to superimpose a thinning trial on the existing stand.

Data from the Macquarie Generation trial was used in conjunction with that from other Hunter trials to determine the benefits of increasing rates of biosolids application.

Sites varied in location, year of planting and season of planting. To compare sites, the difference in growth between the biosolids and control plots was calculated for each site. This growth increment was then plotted and a curve fitted. All biosolids application rates significantly improved growth for both species tested.

All biosolids application rates (0.5 NLBAR (Nitrogen Limiting Biosolids Application Rate) to 2 NLBAR) improved foliar phosphorus and raised it into the adequate range. However, only applications of 2 NLBAR increased foliar nitrogen to the adequate range.

The magnitude of biosolids-induced growth response (difference between biosolids and control treatments) was much greater on overburden sites than on buffer sites. The beneficial effects of biosolids on *C maculata* become more apparent in later growth (age four and upwards). Whilst tree growth and nutrition is improved by biosolids on all land types, biosolids applications have a better cost/benefit relationship on overburden than on buffer land.



Relationship between biosolids-induced growth (biosolids-control increment) and increasing NLBAR for C. maculata *trees*

These results help to indicate if a commercial hardwood industry is possible in the Hunter Valley and have formed the basis of an initial business plan (developed by Investment Services) involving significant commercial plantings for the region. The plan is currently being reviewed.

Application of recycled organics in mine site rehabilitation

G Kelly

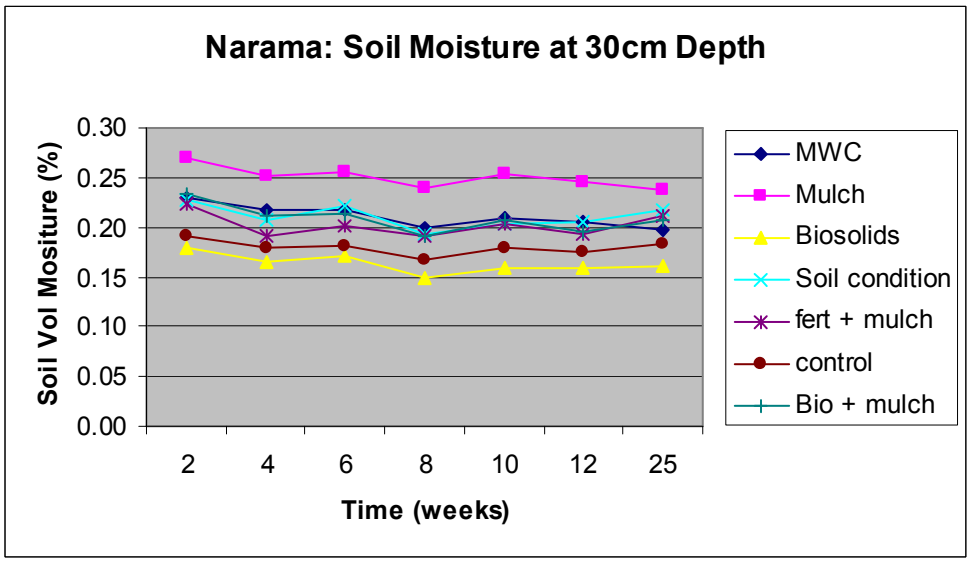
In October 2001, a number of legislative changes to the NSW Government's waste policy and regulatory regime came into effect. This regulation required that all green waste be separated out of the waste stream. The challenge is to find a market for this resource. Mine site rehabilitation potentially presents a significant market opportunity for the recycled organics industry, especially for the lower grades of product.

A 5 ha plantation trial was established on Narama mine in March 2004, using a range of recycled organics as soil amendments. These organics included biosolids, mulch, soil conditioner (made from recycled garden organics) and municipal waste compost (MWC: composted curb-side garbage collection).

The trial has been intensively monitored in its first year of growth. Growth assessment was at three, six, 12, 24 and 36 months. At three years the standout treatments for assisting survival were biosolids plus mulch, mulch, and municipal waste compost. For faster growing species like the eucalypt clone, all recycled organics improved survival outcomes over mineral fertiliser or no fertiliser (the control). In environments where there is little moisture, using mineral fertiliser resulted in less survival than applying nothing at all. Without moisture the fertiliser benefits cannot be maximised and any early growth cannot be maintained.

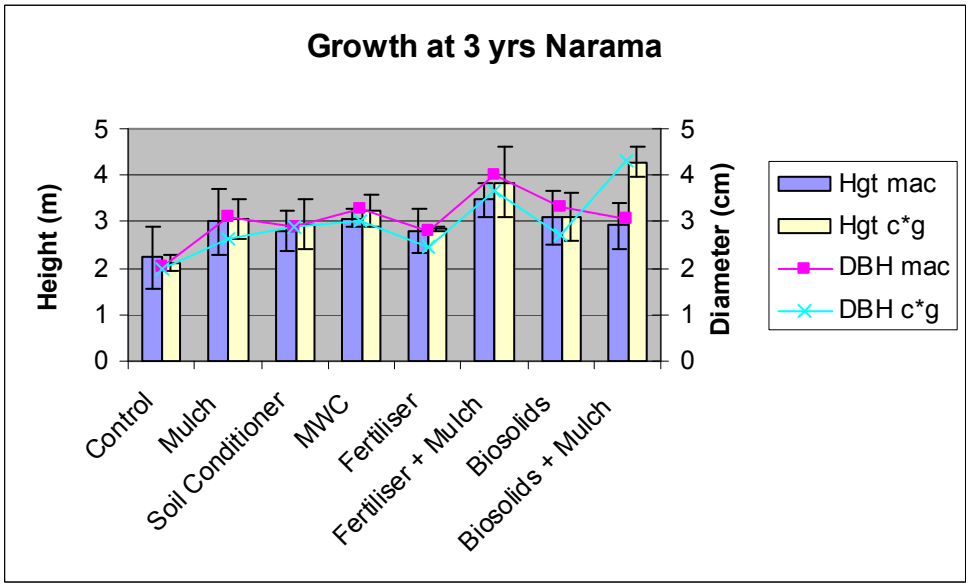
Both amending the soil with recycled organics and applying mulch significantly preserved soil moisture. This is particularly evident in the upper soil profile. The greatest effect of the mulch on soil moisture was seen at 15–30 cm. This is

important, as this is the zone where early root development takes place. At lower depths the impact of the mulch was not significant. All other organic amendments (with the exception of biosolids) increased soil moisture above the level in the control plot.



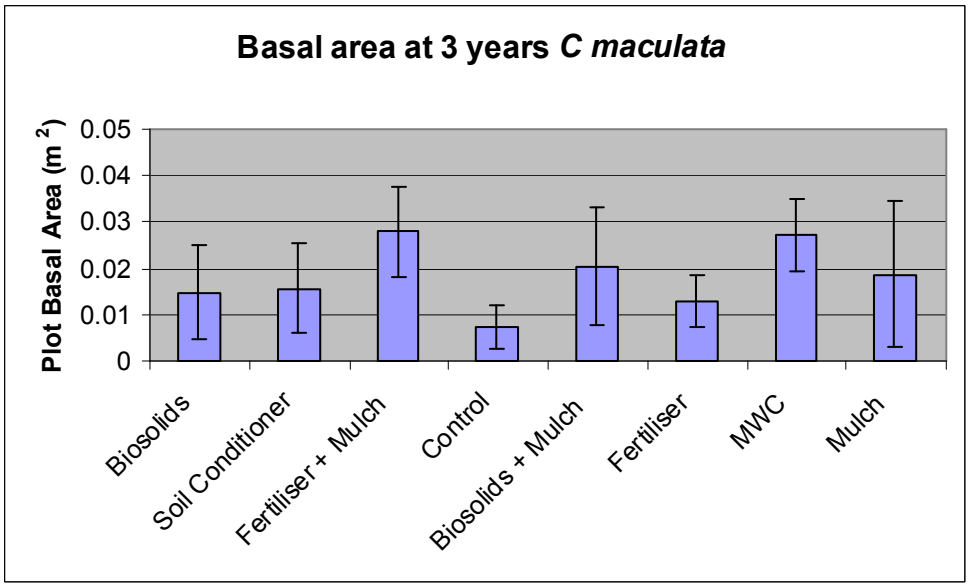
Effect of treatment on soil moisture at 15–30 cm

The incorporation of biosolids as a soil amendment induced significant weed growth—over seven hundred per cent more weed cover than the next highest treatment, fertiliser. The addition of mulch, however, significantly reduced the weed growth in addition to improving soil moisture and moderating soil temperature. These conditions lead to improved tree growth superior to that achieved through the use of biosolids or fertiliser alone.



Effect of different treatments on plantation growth at three years

Basal area is an indication of overall plantation success and site occupancy. Current rehabilitation practices, using chemical fertiliser, yield very little benefit over no treatment (the control)) and significantly less benefit than the use of recycled organics. Judicious combinations of recycled organics can significantly improve the outcomes for plantations on overburden.



Effect of treatment on basal area of C. maculata *at three years*

Recycled organics are proving to be valuable in the early establishment of plantations on mine sites. The trial shows that each recycled organic provides different benefits: biosolids improve growth; mulch suppresses weeds, reduces soil temperature and maintains soil moisture; and soil conditioner and MWC improve survival. Understanding the role of different recycled organics products in maximising the survival and growth of plantation species, allows appropriate combinations of recycled organics to be used to overcome site-specific problems.

Improved spotted gum stock is proving very successful in these trials and has not exhibited the high variation in form normally found within a species. Early growth is superior to that in other spotted gum trials.

Use of soil amendments to maximise forest products on mine lands

G Kelly

The Upper Hunter has approximately 20,000 hectares of marginal or degraded lands. Much of this land is in the buffer zones of mining leases. This research directly addresses the top two key priorities identified by the Upper Hunter Commercial Forests Steering Committee:

- determining timber yields on a range of sites

Research Officer Dr Georgina Kelly with three-year-old E camaldulensis*globulus *hybrid, which showed outstanding growth on the river flat at Coal and Allied's Hunter Valley No 1 mine*

- site preparation techniques using ameliorants (such as biosolids), ripping and mounding.

The research program trials a range of species and soil amendments on a variety of land types (river flats, typical buffer land and mine overburden) and provides recommendations for future plantation establishment. The final growth, soils and foliage measurements were completed in late 2006. A draft final report was sent to the Australian Coal Association Research Program (ACARP) industry monitors in May 2007.

To date the results show:

- The clonal hybrid *E camaldulensis*grandis* has good survival and early growth, though it can be subject to leaf blister sawfly. *E camaldulensis*globulus* is growing particularly well with mean diameters of 6 cm at three years, and individuals reaching 9–10 m in height. At four years spotted gum *(C. maculata*) is beginning to grow more rapidly than the clones. Both the clones and spotted gum are suitable species provided due care is taken with site-specific issues such as frost.
- Amendment of the soil with biosolids and bottom ash achieved significantly greater growth for faster growing hybrids, but was far less effective on the slower growing spotted gum. However, since year four, spotted gum has begun to grow more rapidly and is showing the benefits of treatment with biosolids and bottom ash.
- Biosolids (and biosolids plus bottom ash) produce good tree growth on degraded lands (e.g. mine sites). Biosolids should be used at establishment on overburden sites and can be used as an alternative to inorganic fertiliser when establishing plantations on buffer land.

Bulga mine site plantation trial

G Kelly

In 2000, the then State Forests of NSW established a trial for Tomen Australia Limited on its Bulga Mine to investigate ways of boosting productivity of planted native species on a mine site in the Hunter Valley. Five species and four treatments (including biosolids) were assessed.

At seven years of age the Bulga site is the oldest of our research trials in the Valley. Clonal hybrids were very successful in the early years of all trials in the Hunter Valley. Spotted gum (*C maculata*) was a slow grower with high variability within the species. However, at age six to seven, growth of the clonal hybrids has slowed, particularly in stem diameter. The form remains good and the stands are uniform. Spotted gum is now growing particularly well, though the form is not good and the stands have high variability within them.

Data from this trial and other trials in the Hunter Valley suggest spotted gum is the species of choice in the Hunter, though breeding work to reduce variability and improve form is necessary (and has begun). The clones are a very good alternative for areas subject to frost (e.g. on river flats where the spotted gum have been killed by frost).

The use of biosolids produces good tree growth on degraded lands (e.g. mine sites). Biosolids should be used at establishment on overburden sites and can be used as an alternative to inorganic fertiliser when establishing plantations on buffer land.

Overview of the Bulga plantation trial site

A database of information provided over sufficient time (six years) now exists to indicate some appropriate species for planting in the Hunter Valley. Shortcomings (e.g. within species variability and frost-sensitive sites) have been identified and solutions put in place (genetic improvement or provenance selection for spotted gum and alternative species for frost-prone areas).

Integrated growth and thinning response models for even-aged forests

H Bi

These projects are designed to support and enhance the management and carbon accounting of even-aged forests (forests in which all trees are the same age) managed by Forests NSW. A continuously improved computer application system, *Reden*, that links all biometric equations for individual trees and forest growth models with inventory data and management information for southeast NSW, has been an outstanding outcome from this ongoing effort.

Design and pre-treatment plot measurements have been completed for a long-term thinning experiment in the spotted gum regrowth forests in Currambene State Forest, north of Bateman's Bay and south of Nowra. Thirteen plots have been laid out at the experimental site and measured twice. Treatment will be applied in September 2007.

The large thinning experiment over four sites in the regrowth forests of Eden in the Southern Region has been maintained and re-measured. This ongoing experiment was jointly established by Forests NSW and CSIRO to examine the long-term growth and yield response after thinning in the regrowth forests dominated by *Eucalyptus*

sieberi in southeast NSW. The next round of measurements is scheduled to take place in 2010.

Research work in even-aged blackbutt (*Eucalyptus pilularis*) forests on spatial dependence and individual tree models has led to the publication of two research papers in the journal *Forest Ecology and Management*. The method developed from this work will result in more accurate growth and yield predictions for even-aged forests.

A system of additive equations has been developed to predict aboveground biomass of radiata pine (*Pinus radiata*) plantations. The equation system predicts total biomass as well as component biomass of stem wood, bark, branches and needles using stand attributes that can be easily obtained from forest inventory and growth and yield models.

The potential of *Pinus radiata* for ecological restoration of the Yangtze River catchment in Aba, Sichuan, China—an ACIAR supported project

H. Bi

The overall objective of the project is to assess the potential of *Pinus radiata* for ecological restoration and so help to ensure the future success of the planned expansion of *P. radiata* in Aba. The results will also be valuable to Forests NSW by:

- extending the search for dryland provenances of *P. radiata* for the lower rainfall areas of NSW
- improving assessment of risk of introducing serious pathogens and pests from China
- increasing understanding of how to manage the pathogens and pests of *P. radiata* in diverse environments.

Our work on climate modelling has resulted in the publication of a scientific paper in the international journal *Forest Ecology and Management*. This paper describes a new climatic profile for *P. radiata* and maps areas in southwest China where the species may be suitable for environmental planting on degraded lands to reduce soil erosion. The work will also enhance our understanding of the fundamental climatic niche and the potential geographical range of *P. radiata*.

A draft report assessing forest health risks over the long term for the introduction of *P. radiata* in the dry river valley area has been completed. In this report, the forest health literature on *P. radiata* and other *Pinus* species in China were reviewed to identify both indigenous and exotic pathogens and pests that pose a potential threat to the long-term success of *P. radiata* introduction.

The forest health information from the comprehensive review, field surveys and inspections in 2004–05 and subsequent forest health monitoring was evaluated and analysed to produce a list of indigenous and exotic pathogens and pests that pose a potential. For each pathogen or pest on the list, the likelihood of an attack and the impact of the possible attack over the foreseeable future were rated as low, medium

or high based on the best available information and expert knowledge. Where both the likelihood of an attack and its impact was uncertain, it was marked as a gap of information to be filled by future investigations.

The provenance experiment over three sites along the dry river valley has been maintained and measured. The survival and growth of seedlings were assessed in late 2006. Individual seedlings were coded, tagged and mapped for all three experimental sites.