NSW Department of Primary Industries
Science and Research and Forests NSW

Research and Development
Annual Report 2008-09

NSW DEPARTMENT OF
PRIMARY INDUSTRIES

NSW DEPARTMENT OF PRIMARY INDUSTRIES
SCIENCE AND RESEARCH
and FORESTS NSW

Research and Development
Annual Report 2008–09

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 2008–09
is a supplement to *Forests NSW's Annual Report*
and the *Social, Environment and Economic Report 2008–09*.

NSW DEPARTMENT OF
PRIMARY INDUSTRIES

FORESTS NSW

Published by NSW Department of Primary Industries
Forest Science Centre of Excellence
121–131 Oratava Avenue, West Pennant Hills, NSW 2125
PO Box 100, Beecroft, NSW 2119, Australia
Telephone 02 9872 0111 Facsimile 02 9871 6941
www.dpi.nsw.gov.au/forests

©The State of New South Wales through NSW Department of Primary Industries 2009.

This work is copyright. You may copy, distribute, display, download and otherwise freely deal with this publication for any purpose, provided that you attribute the department as the owner. However, you must obtain permission if you wish to:

- charge others for access to the publication (other than at cost)
- include the publication in advertising or a product for sale
- modify the publication
- re-publish the publication on a website.

You may freely link to the publication on the NSW Department of Primary Industries website.

Published November 2009
ISSN (online): 1834-5557
Author: R. Eldridge (Editor)

Front cover photographs are by Forest Science Centre staff or from the Department of Primary Industries Image Library.
Cover design: Ross Longley

Disclaimer

The information contained in this publication is based on knowledge and understanding at the time of writing (October 2009). 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.

Table of Contents

Foreword

Forests NSW's research and development objectives were primarily delivered through NSW Department of Primary Industries (DPI) Science and Research and through units of its own Land Management and Forest Services branch. DPI Science and Research services are provided, primarily, through the Forest Science Centre, co-located with Forests NSW at West Pennant Hills. Research and technical activities are focused on adding value to the planted forests, commercial services and native forests businesses of Forests NSW as well as the enhancement of forest resource development and sustainability within NSW. Services are provided in three main program areas: Forest Biosecurity and Resource Assessment, Forest Biodiversity and Ecology, and New Forests.

The **New Forests** team delivers research and development of environmental services of forests in the areas of climate change mitigation and land rehabilitation. It develops methods to monitor and predict environmental services and utilises these methods to establish the potential environmental benefits of planted forests and the best management practices to optimise environmental benefits and commercial benefits in low rainfall areas. The team also examines the impacts of climate change on forests and contributes to the development of climate change policy, particularly in relation to bioenergy and greenhouse accounting for emissions trading.

The **Forest Biosecurity and Resource Assessment** team provides research and development of management options to digitally map, quantify and minimise the impact of damaging forest and plantation processes within current commercial, environmental and regulatory frameworks. The team's surveillance activities and diagnostic capabilities enable it to provide routine reports on forest health status and assist it in detecting exotic incursions and potential outbreaks of pests and diseases of forests and timber. The team also carries out research into remote sensing technologies that can accurately and economically assess, for example, forest resource and canopy condition and develop site hazard rating models for managing predicted changes in local climatic conditions.

The **Forest Biodiversity and Ecology** team delivers science and expert advice to underpin management systems for maximising and measuring the ecological sustainability of biodiversity in planted and native forests within the current commercial, environmental and regulatory framework. It provides specialist knowledge of all terrestrial vertebrates and forest plant taxa. The Program has considerable experience and expertise in the design and analysis of multi-factorial experiments, statistical modeling of species distributions and investigations of complex ecosystems. The Program maintains several long-term (> 25 years) operational-scale research experiments dealing with the responses of native fauna and flora to management practices, including the effects of intensive logging and fuel-reduction burning, and the establishment of eucalypt plantations on previously cleared farmland. It also develops appropriate strategies for monitoring the ecological sustainability of forestry operations to meet State Plan targets.

New Forests

Program Leader: Annette Cowie

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

Objectives:

- Quantify the contributions of managed forests and forest products to greenhouse gas mitigation
- Suitable forest management systems available for dryland and degraded environments.

Land management to increase soil carbon sequestration in NSW

Bhupinderpal Singh and A. Cowie

Presently, there is considerable uncertainty about the extent of carbon (C) sequestration potential from improved land use and management practices. The improved land use and management practices with significant potential to sequester soil carbon may, in future, be recognised as eligible for offsets in the NSW Greenhouse Gas Abatement Scheme (GGAS) or its successor. Availability of information on potential C sequestration, and the development of cost-effective and reliable methods of estimating soil C change, will facilitate the participation by NSW landholders in emissions trading. Knowledge of the influence of land use practices on soil carbon will equip landholders to enhance the productivity and resilience of agricultural and forestry systems.

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

Pinus radiata plantation trees at 2, 4, and 24 years of age established on ex-pasture lands in NSW at sites established for measuring soil C stocks as affected by afforestation of pasture lands. Photographs by Cheryl Poon and Bhupinderpal Singh.

The Forest Science Centre is leading the 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, reduce nitrous oxide (N_2O) emissions, improve soil fertility, and deliver life cycle greenhouse gas mitigation benefits.

Our research on biochar shows:

- biochars can reside in soil for between 100 and 2000 years
- biochar application can effectively reduce N_2O emissions and nitrogen (N) leaching from soils and this reduction can be quite significant (up to 94%) for some biochar and soil types
- the biochars tested are a valuable source of important nutrients, contain negligible amounts of non-essential trace elements (lead, arsenic), and do not contain detectable levels of organic contaminants (polycyclic aromatic hydrocarbons, PAHs).

Due to many of these benefits, biochar application has been shown to achieve significant greenhouse gas (GHG) mitigation, as compared to conventional feedstock management practices.

Greenhouse gas balance of biochar application to soil

Using published emissions factors and conservative estimates of biochar-C turnover, net emissions reduction for different char scenarios were estimated to range from 35 to128 kt carbon dioxide equivalent (CO_2e) per 50 kt (dry) feedstock, equivalent to 0.5 to 1.6 times the CO_2e in the feedstock. Not surprisingly, the biochar-C turnover rate was one of the major factors affecting the greenhouse gas balance of biochar application to soil. However, this is one of the least well-understood properties of biochar.

Biochar-carbon stability in soil

The rate of turnover (decomposition) of biochar C is the major determinant of its value in long-term C sequestration in soil. Furthermore, in order for biochar to be accepted by emissions trading schemes, it is fundamental to demonstrate the long-term (>100 years) stability of biochar in soil. A long-term laboratory incubation experiment is examining the time it takes for biochar carbon to be decomposed and released from soil. This experiment uses a novel method that is based on measuring the inherent differences in ^{13}C isotope content between biochar and soil.

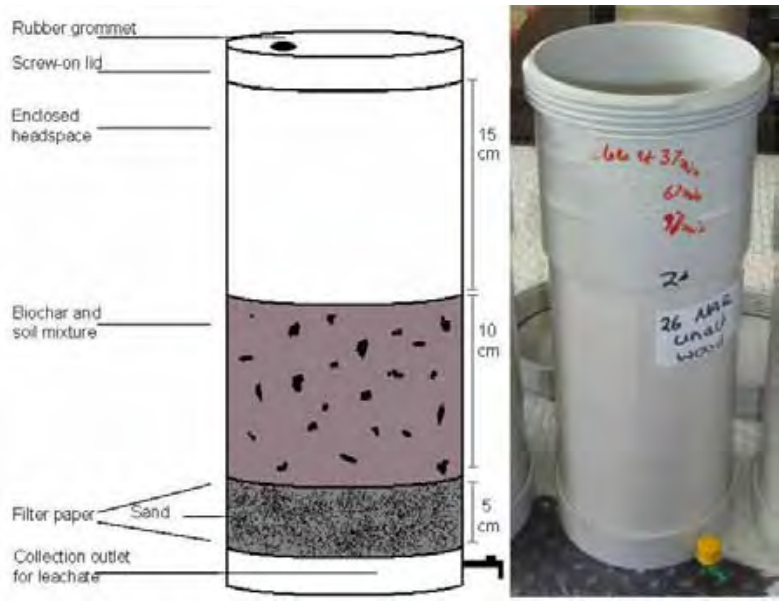
Results show decomposition of biochar C in soil in the first 2 years of incubation varied from 0.26% to 8.7% of biochar-C applied. Microbial biomass was higher in many of the biochar-amended soils. Estimates of mean turnover time of C in different biochars range from 40 to 1200 years. Long-term simulations shows biochar-C can reside for >100 to 2000 years.

The role of biochars in mitigating soil nitrous oxide emissions and reducing nutrient leaching in two soil types

(This project is being carried out in collaboration with Dr Balwant Singh, University of Sydney.)

Biochars are considered to influence soil N cycling processes, including N_2O emissions. However, only a few studies have tested in detail the influence of biochars on soil N_2O emissions, a potent greenhouse gas with warming potential 298 times greater than the equivalent mass of CO_2 in the atmosphere. The influence of four biochars on N_2O emissions

and inorganic N leaching from two contrasting soils at a range of soil moisture levels was studied. Results show that biochar application can be effective in reducing N_2O emissions and ammonium leaching from soils. The most important finding is that after 4 months, all biochars tested, effectively decreased soil N_2O emissions and ammonium leaching by up to 94%, relative to the control.



A drawing and photograph of an experimental column used for measuring soil N_2O emissions and N leaching losses, as affected by biochars. Image by Blake Hatton.

Characterisation and evaluation of biochars as a soil amendment

(This project is being carried out in collaboration with Dr Balwant Singh, University of Sydney)

Biochars are being analysed for a range of chemical and physical properties, and different methods for measuring some of these properties of biochars are being tested to make suggestions about appropriate procedures for the characterisation of biochars. Initial results show large differences in the properties of biochars as affected by the biomass sources, pyrolysis conditions, and laboratory procedures employed for the analyses. Furthermore, data show that the biochars tested are valuable sources of many important nutrients, contain negligible levels of non-essential (e.g. lead (Pb), arsenic (As)) trace elements, and do not contain detectable levels of organic contaminants (e.g. PAH's). It was found that due to the presence of soluble salts, some of the common laboratory procedures may not be suitable for biochar characterisation.

Influence of biochar on the availability of trace elements to maize

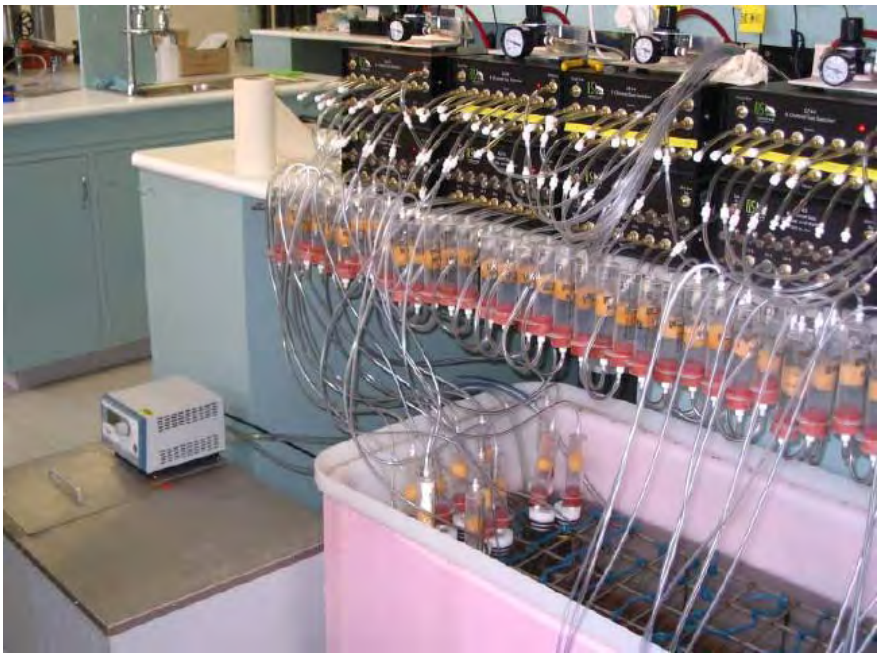
(This work is being carried out by MSc student Tshewang Namgay, University of Sydney, supervised by Dr Balwant Singh and Dr BP Singh)

A pot experiment was conducted to investigate the influence of a biochar on As, cadmium (Cd), copper (Cu), Pb and zinc (Zn) uptake by maize. The main findings of this research are: (a) Biochar application significantly reduced As and Cd toxicity to plants, and (b) Biochar decreased the availability of metals to plants, particularly Cd and Pb.

Soil carbon stocks and dynamics following afforestation of ex-pasture land

(This work is being carried out in collaboration with Prof. Mark Adams and honours student Cheryl Poon, University of NSW)

The few published studies on this topic that exist suggest there can be a significant loss of soil C when pasture sites are reforested, particularly with pine, which could significantly reduce the emissions mitigation value of reforestation. Clearly, in order for plantation forestry to be an attractive emissions mitigation tool, there is urgent need to understand and predict soil carbon stocks and dynamics following afforestation of agricultural lands.



Soil respirometer at the University of Sydney used for measuring soil respiration in “paired” pasture-pine plantation sites in NSW. Photograph by Cheryl Poon.

Our results show that in high rainfall areas, soil carbon is in fact higher (albeit not significantly) in a mature pine plantation site than in the adjacent pasture. This finding is in contrast with the findings of the few published experimental and modelling studies that exist. These studies led to a general view of 15% decline of soil C where pastures are converted to pine plantations. Furthermore, the results show that increased temperature in climate of the future may lead to a positive feedback from CO_2 release from soils under improved pastures and plantations.

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

G Kelly

If the use of recycled organics can be shown to improve soil organic carbon and maintain it over a long period, then more primary producers will be predisposed to using these products over and above greenhouse intensive, and increasingly expensive, chemical fertilisers. This

project builds on previous work by analysing existing soil samples for organic matter and assessing the easily decomposed and persistant fraction in the first 5 years post application. In addition, older sites (>10 years) have been re-sampled, offering the opportunity to assess the nature of the organic fractions in the longer term, and therefore the ongoing potential benefit to greenhouse gas mitigation. Increased use of recycled organics may contribute to soil organic carbon in a more persistent way than other land managment options.

Apart from increasing soil carbon, recycled organics provide many other benefits such as nutrition, soil moisture retention and weed suppression. When recycled organics are being used as a resource they are diverted from landfill, with the resultant economic and environmental benefit. An increased market for recycled organics will generate local and regional business opportunities for the local treatment of appropriate raw material. Quantifying the amount and fraction of the carbon added to the soil by recycled organics will potentially allow landholders to quantify and offset emissions (in covered sectors) or be an offset provider in the Carbon Pollution Reduction Scheme.

As data shows that recycled organics can increase soil carbon, it will become increasingly important to characterise the carbon content of recycled organics and therefore the benefit they may provide. This will assist land managers to select the most appropriate and sustainable fertiliser or soil amendment regime for their industry and site.

Analysis of amended mine site soil showed that all recycled organics tested (greenwaste compost, biosolids and municipal solid waste compost) increased the soil's total organic carbon. The use of chemical fertiliser on this site marginally decreased total organic carbon levels. On a per tonne product C basis, biosolids produced a greater increase in soil total organic carbon on mine overburden than similar amounts of other recycled organic products (municipal solid waste compost and soil conditioner made from green waste). Although less carbon was added in the biosolids, more carbon remained in the soil.

In pine plantations, when biosolids are incorporated into soil, even low rates of application (20 dry t/ha) increase soil total organic carbon and particulate organic carbon relative to the control. This increase is maintained over time.

The greenhouse footprint of wood products

F Ximenes

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 results will inform the development of carbon trading schemes, energy rating systems and waste disposal strategies in NSW.

There is an urgent need to develop appropriate methods and mechanisms for the inclusion of harvested wood products in the framework of the proposed national emissions trading scheme. Further progress has been achieved in this area through collaboration with the Australian Plantation Products and Paper Industry Council (A3P).

Greenhouse footprint of sawn wood production

This project is assessing the energy and greenhouse footprint of six sawmills, one particleboard, one medium density fibreboard (MDF) and one truss and frame manufacturer. The data collected for all mills include the energy used and greenhouse emissions associated with harvest and transport of logs, mill activities and transport of finished products and residues. In this section we report the results of studies conducted at a softwood and plywood mills. A total of 103,378 m^3 of finished sawn product and 26,101 m^3 of finished plywood were manufactured in the 2007–08 financial year.

The kiln drying facility at a softwood mill. Photograph by Fabiano Ximenes.

The energy footprint for the production of finished softwood (80% structural, 20% appearance grade) was 4.4 GJ/m^3. The total energy consumption was 455,001 GJ.

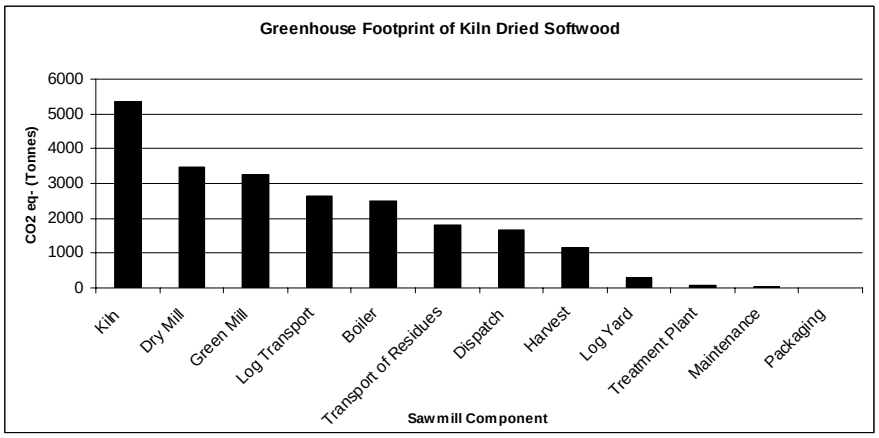
The greenhouse footprint for the production of finished kiln-dried softwood was 0.22 t CO_2-e/m^3. The operation of the kilns produced the biggest greenhouse footprint (see first figure below). The total greenhouse emissions associated with harvesting and transport of logs and mill activities were 22,235 tonnes of CO_2 equivalents.

The energy footprint for the production of finished plywood (100% structural) was 5.7 GJ/m^3. The assessment of the plymill included emissions associated with transportation of the edge sealer and phenol formaldehyde resin required for the production of plywood.

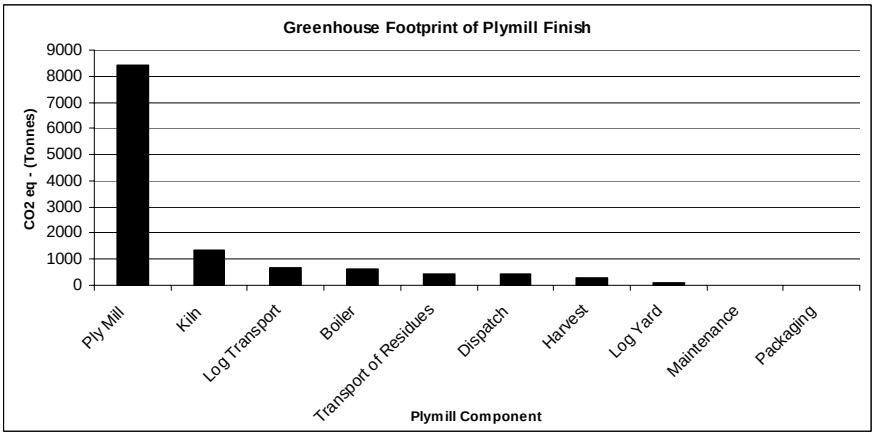
The greenhouse footprint for the production of finished plywood was 0.47 t CO_2-e/m^3. This is consistent with published information and confirms the higher emission-intensity of

production of composite wood products such as plywood compared to the production of kiln-dried sawn wood (more than double in this case). As for kiln-dried sawn wood, the operation of the kilns produced the biggest greenhouse footprint (see second figure below).

The energy intensity results for both the plywood and the finished sawn softwood are similar to those reported in earlier progress reports for a large hardwood mill that was assessed (4.56 GJ/m^3). The greenhouse footprint of the sawn hardwood operation was slightly higher (0.57 t CO_2-e/m^3), reflecting a number of factors such as greater inefficiencies in the hardwood harvest operations (greater distances, less modern harvesting equipment), leading to higher diesel consumption and differences in mill set ups and recoveries between the hardwood and softwood mills.



Greenhouse footprint associated with the production of kiln-dried sawn softwood at a medium mill



Greenhouse footprint associated with the production of plywood.

Data gathering has finished for a typical wall and frame manufacturer in NSW. The energy footprint for the production of wall frames and trusses was 1.22 GJ/m^3. Interestingly the largest contributor to the energy footprint was the use of steel plates and nails in the frames and trusses. The greenhouse footprint for the production of wall frames and trusses was 0.09 t CO_2-e/m^3, with wood transport from the sawmill to Sydney and, once again, steel usage, the main contributors.

Once analysis of the six sawmills studied is complete, the team will prepare a summary report containing the combined results and an estimate for the greenhouse footprint of sawn softwood and hardwood production in New South Wales.

Landfill studies

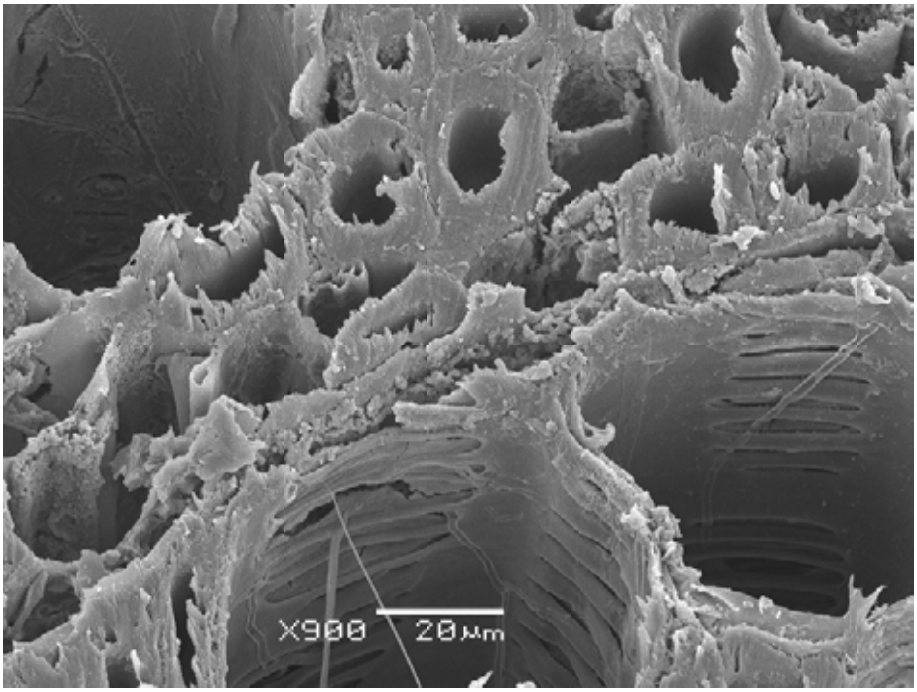
An excavation was successfully conducted at the operational Eastern Creek landfill site in western Sydney. The site is one of the largest landfills in New South Wales, receiving close to 5,000 t of waste per day. Four holes at different areas of the landfill were excavated to a depth of about 10 m using a long-reach excavator. Large volumes of paper and wood products were recovered.

Eastern Creek landfill excavation. Photograph by Fabiano Ximenes.

The age of the waste (dated from newspapers and magazines) varied from 6 to18 years. The pH and temperature of the excavated waste were recorded in the field. The average pH and temperature were 7.3°C and 25.1°C, respectively. The pH was negatively correlated with time of burial—the longer the burial time, the lower the pH.

Paper from 1990, Eastern Creek landfill excavation. Photograph by Fabiano Ximenes

The methodology for the analyses of the samples is being developed and will include measurements of grammage and moisture content, and chemical and microscopic analyses.



Scanning electron micrograph (transverse section) of a coachwood sample from landfill degraded by fungi prior to burial. Micrograph by Fabiano Ximenes.

The analysis of the paper samples recovered from a real-life landfill will be greatly assisted by the results of a research project in collaboration with Morton Barlaz from North Carolina State University. The research aims to determine the maximum potential decomposition of a range of Australian-made paper products under simulated landfill conditions in the laboratory and the results will be used as a benchmark for the analysis of the paper recovered from Eastern Creek. Preliminary results suggest that the extent of decomposition of the range of paper products is lower than currently suggested by the Intergovernmental Panel on Climate Change (IPCC).

Additional work has been carried out in developing appropriate methods for microscopic examination of wood buried in landfills. The outcome confirmed that in the majority of the samples that had been chemically analysed earlier, minimal or no decay was detected, which suggested that no significant decomposition had occurred in the wood samples after 44 years of burial.

Paper and wood samples were collected from the Veolia bioreactor landfill in Woodlawn, NSW, during routine drilling works. Samples from up to 35 m below the surface were recovered and the pH and temperature of the waste were recorded at frequent intervals. These samples represent an important addition to the range of landfill samples already collected, as the effect of management in bioreactor landfills on the extent and rate of decay of paper and wood is currently unknown.

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

A. Cowie, A. Grieve and S. Arnold

Under the NSW Greenhouse Gas Abatement Scheme (GGAS), now known as the Greenhouse Gas Reduction Scheme, parties can become accredited to provide abatement certificates generated through forest carbon sequestration. The intention of this pilot project was to develop tools and systems to enable a Catchment Management Authority (CMA) to apply for accreditation to manage a carbon pool based on its revegetation programs and existing plantings in its catchment.

The project team, led by DPI together with Murrumbidgee CMA staff, comprehensively investigated the feasibility of CMAs becoming involved in carbon trading as pool managers under the NSW Greenhouse Gas Reduction Scheme, using environmental revegetation plantings on private land as the basis for a pool. The main objectives of CMAs engaging in carbon trading were to use the potential income streams arising from the creation and sale of greenhouse abatement certificates either to provide increased incentives to revegetate and maintain land for environmental purposes through additional payments to landholders; or to provide access by CMAs to additional income to facilitate the revegetation required to meet catchment targets. Both these objectives are consistent with the charter and role of CMAs.

This study has concluded that:

- with relatively minor changes and some increases in costs, the business systems of CMAs could support the administrative requirements for accreditation to GGAS although the necessary changes would require a commitment to maintain the revised systems for prolonged periods (more than 100 years)

- suitable service providers are available that could provide support for CMAs in those areas where it may be more appropriate to outsource specific services
- the substantial impacts of legal costs and adverse landholder reaction to the obligatory requirements for registering carbon rights and restrictions on land use on the title may represent a challenge to the viability of a prospective carbon pool
- clear, comprehensive and enforceable contracts will be required setting out mutual obligations by landholders and CMAs for the successful inclusion and maintenance of eligible plantings in the pool
- although a preliminary business case suggested that net incomes to both CMAs and landholders from carbon pool operations would be financially attractive, more refined financial analysis has shown that the net income derived from operating a pool of around 2000 ha across several CMAs would lie in the range $40,000 to $100,000 per annum. Relative to the risks and costs of managing a pool, this level of income is unlikely to attract either landholders or CMAs into such a long-term venture
- the anticipated Australian Carbon Pollution Reduction Scheme (CPRS) may reduce the disincentives to landholder and CMA participation in carbon trading, for example through a more flexible approach to the permanence provisions, or a simpler process for establishing carbon rights and restricting land use on farms. However, the rules of the CPRS are not yet finalised. When the national scheme commences, GGAS will cease, a factor which introduces additional uncertainties around seeking accreditation at the present..

After careful consideration of these findings, the CMA General Managers decided that CMAs should defer applying for accreditation as GGAS pool managers at this time. The project has provided CMA General Managers with the documentation which will be required for application as pool managers under the NSW Greenhouse Gas Reduction Scheme. Similar documentation is likely to be required for the CPRS.

Uncertainty surrounding the transition from GGAS to the anticipated CPRS, has severely reduced demand for credits generated through GGAS and there has been a substantial decrease in their value. While the prospect of the introduction of a national CPRS remains likely, there is little incentive for CMAs to seek accreditation under the NSW GGAS. Whether it is desirable for CMAs to participate in the CPRS will be somewhat unclear until the regulations are released. The CMAs remain interested in the prospect of deriving income from emissions trading based on reforestation offsets. A future decision to seek accreditation as a carbon pool manager under the planned CPRS or a voluntary offsets scheme will depend on the rules and framework for inclusion of reforestation offsets adopted by the scheme. Specifically, the scheme requirements must address the barriers identified in this study, so that inclusion of pools based on large numbers of individual small area sites is a viable prospect.

Key sites for hydrology and salinity measurement and model validation

C Barton and H Morgan

This project provides essential input into other current National Action Plan for Salinity and Water Quality / Natural Heritage Trust (NAP/NHT) project areas (TOOLS II and Salinity Solutions through Agriculture) and provides information to enable relevant stakeholders (policy makers, Catchment Management Authorities and land managers) to make decisions on the best land use to minimise the onset and cost of dryland salinity. Data collected will also be used to improve tree growth models that are required for economic forecasting and estimating the carbon sequestration potential of tree plantings.

The project is a collaborative effort between NSW DPI, the Department of Water and Energy (DWE) and the University of New South Wales. The project aims to collect a range of data from a number of sites to quantify the sub-catchment impacts of various land use options, including tree planting, on water and salt movement. These data are being used to validate a suite of simulation models currently being developed by DWE that are integral to decision support tools used by CMAs.

Measuring growth and water use of *Eucalyptus camaldulensis* at the Baldry site in the Central West. Photograph by Sam Wood.

Data collection and analysis has been ongoing at the two field sites operated by the New Forests Program, one in the Liverpool Plains near Quirindi (Paringa), where a stand of ironbarks established by the landowner in 1996 is being monitored, and one in the central west between Wellington and Parkes (Baldry), where a 60 ha planting of spotted gum and river red gum established by Forest NSW in 2003 is being investigated.

It has become apparent that the rise in dryland salinity in NSW during the 1990s was primarily a result of above average rainfall rather than due to historic removal of trees from the landscape. Since 2000, declining rainfall and the drought has resulted in many occurrences of dryland salinity disappearing. However, data collected at the Baldry site has shown that the trees established on the salt scald did increase the rate of improvement of the saline scald. Furthermore, detailed characterisation of the site has shown that salt is stored in pockets across the landscape rather than in the groundwater and reduction in salinity in the future should be through management of these stores to prevent mobilisation of salt during wetter periods. The advent of the drought has moved the emphasis from salinity amelioration to maintenance of catchment water yields, which reduces the feasibility of broadscale tree plantings as a viable land use option. Targeted tree planting in conjunction with earth works both on discharge areas and around salt stores may be the most effective means of managing the salinity problem when the rains return.

Commercial and environmental tree use in medium rainfall areas

C. Barton and I Johnson

This project consists of a number of research trials established since 2000 to assess the growth, performance and suitable silvicultural regimes for a range of tree species in the lower rainfall areas of NSW (500–700 mm). Older spacing, belt width, establishment, and species demonstration trials (established between 2000 and 2003) are being maintained and periodically assessed, as are permanent growth plots established in 2001 (in various older plantations) and in 2007 (younger plantations in the Gunnedah area).

Species demonstration sites

In 2000, 48 species demonstration sites were established up and down the state in order to compare the growth rates of a number of potentially suitable species across a range of sites. Data from the Species Demonstration Trials will aid in decision support tools to guide Catchment Management Authorities, extension personnel, and landholders in low rainfall areas in selecting suitable species for establishing plantations on particular site types and for commercial or environmental purposes (e.g. carbon sequestration, salinity control, wood production).

Thinning and pruning trials within the species demonstration sites

A number of the replicate plots from the species demonstration plantings have been thinned and pruned as they reached a certain size in order to assess the impact on growth and wood quality. No additional plots were thinned in 2008–09 because suitable plots had been included in the trials by April 2008. In the past 12 months, 215 thinned and control plots were assessed at 1 to 3 years following thinning. At 3 years after thinning, total basal area (BA) for both thinned and control plots was increasing at a similar rate. However, on an individual tree

basis the basal area increment of trees in the thinned plots was almost always greater than for trees in matched control plots. This held true for all diameter classes. The increases tended to be greatest for *E. camaldulensis* and smallest for *E. sideroxylon*. Basal area of individual trees in thinned plots was 30% to 100% greater than for control plot trees

A plot of *Pinus pinaster* near Rylstone that had been thinned and pruned 12 months earlier. Photograph by Ian Johnson.

Permanent growth plots

In the longer term, 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 the development of carbon sequestration tools. They should be measured again within the next 1 to 2 years (4 to 5 years since previous assessments).

Establishment techniques trials

Two trials established in November 2007 were assessed at age 12 months. Overall survival was high (85–86%). At both sites, mean tree height in mounding and deep ripping+mounding plots was significantly greater than from shallow ripping alone.

Rio Tinto plantation establishment trial 12 months after planting—well-established mounded plot (left) compared with adjacent shallow-ripped plot (right). The height stick in the mounded plot is 3 m high. Photograph by Ian Johnson.

Across preparation treatments, post-planting herbicide gave significantly greater height than nil herbicide after planting, although differences were not large. Mounding also gave greater survival at both sites (though only differences between ripping plus mounding and shallow ripping were statistically significant). Shallow ripping resulted in the poorest survival. Differences in survival due to post-planting herbicide were minor at both sites, and only marginally statistically significant at the slower-growing site. To date, the most striking (but not surprising) result, given the clayey soil type in these trials, is that site preparation methods that resulted in more friable soil in which to plant, resulted in increased tree height compared to preparation methods that resulted in “cloddy” soil.

Belt width trial

This trial was established in 2003 to investigate the interaction between width of tree belt and tree belt spacing on water interception down hill slopes in the Liverpool ranges with the aim of providing recommendations for tree planting design to optimise environmental benefits in a salinity prone area.

Tree height and diameters were assessed in October 2008 for the belt width trial. The expected patterns of growth in relation to position from the top of the stand and length of unplanted hill slope above the stand have not emerged. During the drought it is unlikely that enough rain occurred to provide run-on to the stand from the unplanted pasture area above it and trees throughout the stand did become very stressed. Better rainfall in the last few months has reduced stress and trees appear to be recovering. Clearly, the use of belts of trees to intercept lateral flow on hill slopes does depend on there being sufficient rainfall to generate lateral flow and unfortunately this trial has been established just as rainfall moved into a declining phase. When rainfall does return, the stand will be in a good position to respond and provide useful information.

Spacing trial

This trial was established in 2003 to examine the effect of planting density on tree growth in the Liverpool plains region. Four species were planted at three stocking rates: 625, 1250 and

1875 trees per hectare. Height, diameter and survival have been monitored each year. By 2008 the stand basal area is still lowest in widely spaced trees but the gap appears to be closing and individual stem diameter is larger for widely spaced trees. The drought followed by cool, wet weather resulted in a fungal infection that caused widespread defoliation of many trees in the surrounding plantation. Tree health appears to have improved and the trial is still worth monitoring.

Data and information for the National Action Plan for Salinity and Water Quality and the Natural Heritage Trust project

Basic details of location, size, species, age and class and so on have been collected for over 320 plantations and trials of species in the NSW 500–750 mm rainfall zone in order to produce tables and location maps. These data will be placed on the internet as a Department web-book within the next few months. Some extra data are being gathered, particularly on low-rainfall tablelands plantings, to augment information already obtained. Many individuals from several organisations have kindly provided data. Mapping has been carried out by Forests NSW Geographic Information Systems staff.

Species growth data from our species demonstration trials, some silvicultural trials in the Upper Hunter, and permanent growth plots in low rainfall plantations, have been sent for inclusion in the Department's "TreeSmart" database. The data include 1,806 records, incorporating plot growth, location and site data.

DPI Prime Facts are being prepared on farm forestry (commercial), biodiversity, salinity, and carbon sequestration. These present information based on research by DPI, where possible, and from other reports and papers. They are in advanced stages of drafting.

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

C Barton

The Hawkesbury Forest Experiment is established at the Richmond campus of the University of Western Sydney (UWS) to investigate how increasing atmospheric carbon dioxide (CO_2) concentration will affect Australian forests. The project incorporates an elevated CO_2 experiment and an irrigation plus fertilisation experiment. The centre-piece is a field facility with twelve CO_2 and temperature-controlled whole-tree chambers (WTCs) provided by the Swedish University of Agricultural Sciences. The results from this project will improve our ability to model and predict the likely effects of climate change on Australian forests in terms of their growth and water use. These have implications for carbon sequestration and water resources in both native and planted forests.

Whole tree chambers (9 m tall) at the field site at the University of Western Sydney's Hawkesbury campus. Photograph by Craig Barton.

Half of the trees were exposed to a droughting cycle from October 2008 to February 2009. The effects of the treatment started to become apparent in December with lower leaf water potentials, reduced water use and slower growth rates. The whole tree gas exchange has demonstrated a significant increase in instantaneous water use efficiency, which results from a combination of slightly higher photosynthetic rate and lower water loss at elevated CO_2. Due to an almost complete reduction of photosynthetic capacity in trees grown at elevated CO_2, and possible changes in allocation patterns, no enhancement of growth has been observed.

The trees were harvested in April 2009 and analysis of the data is underway.

Use of soil amendments to maximise forest products on mine lands

G Kelly

Since the Kyoto Protocol was first drafted in 1997, many companies have started to investigate the options available to reduce their greenhouse gas emissions and address the threat of climate change. One popular emission reduction strategy involves the establishment of tree plantations to sequester carbon from the atmosphere back into living plant tissue.

Mines have an obligation to rehabilitate after the mining process. Due to the nutrient-poor nature of the unconsolidated overburden, considerable time and money is spent re-

establishing nutrient cycling. Soil amendments such as biosolids are being investigated to determine if they can assist in this process, thus making eucalypt plantations a viable alternative to the traditional use of pasture in rehabilitation.

This research program investigates the role that soil amendments (including biosolids, bottom ash, municipal solid waste compost and greenwaste compost) have on the successful establishment, survival and growth of trees. This includes assessing the impact of fertiliser (organic and inorganic) on tree growth, nutrition and soil nutrition and carbon storage. The carbon sequestration potential, both above and below ground, is being assessed.

Recycled organics are proving to be valuable in the early establishment of plantations on mine sites. Data shows that each recycled organic brings with it its own benefit: biosolids improve growth; mulch suppresses weeds, reduces soil temperature and maintains soil moisture; soil conditioner and municipal waste compost 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.

An application rate of 400 kg available nitrogen/ha is required on the overburden to initiate and maintain growth and adequate foliar nutrition. When this is done, sustainable plantations can be established with a single application of biosolids. This eliminates the need for reapplication of heavy amounts of mineral fertiliser, which is the current practice for at least the first 5 years after rehabilitation. Where a sustainable land use is reached at an early stage (within 5 years), significant financial benefits accrues to the mines.

Improved spotted gum stock is proving very successful in these trials and not exhibiting the high within species variability of growth and form usually found in this species. Early growth is superior to that of other spotted gum trials. It is difficult to predict a mean annual increment (MAI) for young plantations. Some species are slow starters (e.g. *Corymbia maculata*) whilst the clonal material has rapid early growth. In addition, other factors such as changing climatic conditions can play a significant role and there are no older stands with similar planting stock and treatments with which to compare. However, carbon stocks are roughly equivalent to MAI. The best species and treatments returned around 8t $CO_{2\ equiv}$/ha/ yr. This would put best species and treatments from the plantations into the marginal category for conventional commercial forestry. However, taking carbon into account, these conventionally marginal stands may well be commercially viable.

Plantations with very low growth rates (MAI of less than 8 m^3/ha/yr) would not be considered for conventional plantations, but may be considered suitable for other purposes. They have the potential for production of carbon and bio-fuels. This may have particular relevance in the Western and dryland areas, where there is less competition from alternative land uses. Hardwood plantations are favoured as estimates of average annual biomass production, carbon production and CO_2 equivalents are approximately 15% higher for hardwood than for softwood.

Biosolid benefits for plantation pine

G Kelly

Over the last 18 years a series of nine research and 11 demonstration trials (funded by Sydney Water and Forests NSW) has been established to investigate the effects of biosolids on plantation pine.

The older aged stands were targeted to maximise the benefit on merchantable trees. While silvicultural benefits were encouraging, environmental issues were also addressed. Biosolids proved an effective fertiliser in pine, both environmentally and silviculturally. Biosolids increase growth and also provide non-timber benefits (e.g. carbon storage—both above and below ground). Analysis of the carbon sequestration potential of plantations treated with biosolids continues to be assessed.

Technical Officer Paul Brooks sampling soil 17 years after biosolids application to determine the long-term soil carbon benefit. Photograph by Georgina Kelly.

The 18-year-old sites (Belanglo and Penrose) were re-measured to gain further insight into the long-term benefits of biosolids. Just prior to harvest this year, samples were taken (discs and cores) up the tree to determine the impact of biosolids on wood quality. Non-destructive measurements were also taken (Fakopp, pilodyn and Director measurements) to assess a range of wood properties. Early analysis indicates that while the application of biosolids increases growth it does not significantly change wood properties.

The Modulus of Elasticity (MOE, a measure of stiffness) was not significantly different between treatments, though the lowest MOE was for the mineral fertiliser treatment. For the first four logs of the tree (the merchantable timber) the MOE was above 10, placing it in the commercial range. Similarly, the density of the timber was not significantly affected by the application of biosolids.

In short, the increased growth generated by biosolids application was not offset by loss of wood quality. In fact data indicate that mineral fertiliser had more deleterious impacts on wood properties than biosolids (a slow release fertiliser). These results are timely as the cost of mineral fertiliser is rapidly increasing and Forests NSW is re-examining the option of applying biosolids as a fertiliser to the pine estate.

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. Work on biomass estimation for environmental plantings was begun.

Plantation valuation

The forest estates managed by Forests NSW are required to be valued annually by the NSW Auditor General. Dr Bi undertook the task of evaluating the product proportion models currently used by Forests NSW and testing their prediction accuracy. The evaluation focused on the modelling methodology, particularly model specification and parameter estimation, while the test examined both global and local prediction accuracy of the models. To improve prediction accuracy, an alternative set of product proportion models based on a system of additive equations was specified and estimated for each region. The results highlighted the improvement in prediction accuracy that can be gained through improved modelling methods and the requirement for more realistic product volume data to be generated from current cutting strategies.

Radiata pine biomass

Our multidisciplinary research team has made further progress with an externally funded project that is applying LIDAR (light detecting and ranging) technology in forest inventory of *Pinus radiata* plantations. Sampling design, plot establishment, field measurements and preliminary data analysis have been completed. The overall objective of the project is to integrate LIDAR data with forest growth models for rapid, accurate and cost-efficient forest inventory, growth and yield predictions, and biomass and carbon estimation.

Mature radiata pine plantation on the southern tablelands of NSW. Photograph by Georgina Kelly.

A system of additive equations has been modified and refined to predict aboveground biomass of *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. Comparative prediction accuracy of the system has been tested against the conventional method of scaling up in biomass estimation of *P. radiata* plantations. The system of equations has been used by Forests NSW for planning and carbon accounting purposes.

Growth models for native forests

Forests in the Eden area constitute a substantial proportion of the forest estate under the management of the Southern Region. A large thinning experiment over four sites in the regrowth forests of Eden has been maintained. This on-going 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 latest measurement data were screened and entered. The next round of measurements is scheduled to take place in the 2010–11 financial year.

Biomass of environmental plantings

Alternative methods of estimating the biomass of environmental plantings have been compared. This work is a component of the collaborative project led by CSIRO on improving methods to reliably estimate carbon sequestration by environmental plantings. Lachlan Catchment Management Authority is the funding body of the project.

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

H. Bi

Pinus radiata was introduced to the summer rainfall environments of Sichuan Province, China, in the 1990s as a part of an afforestation program for soil and water conservation in the arid and semi-arid river valley area of Aba Prefecture. Through climate matching, a total area of 26,000 ha has been identified as suitable and a further 63,000 ha potentially suitable for environmental plantings of *P. radiata*. The plantations are being established in widely separated small patches of usually only one or two age classes on steep and degraded slopes along the dry Min River valley.

As an important part of the project, a provenance experiment over three sites along the dry river valley was established in 2004 and maintained and measured until late 2007. In May 2008 a devastating earthquake struck northwest Sichuan and the epicentre was located in the study area where our three provenance trials were established. The earthquake triggered large scale landslides that cut off roads, damaged bridges and buried a large number of people and vehicles. The aftershocks also added significantly to the difficulties of carrying out rescue and relief work. Because of their preoccupation with rescue and relief work and the added difficulties from road closures, restrictions and safety hazards, project scientists in China have not be able to perform normal project activities for about a year.

Terracing to allow establishment of a provenance experiment at one of three sites in the Min River valley, Sichuan Province, China. Photograph by Robert Eldridge.

We plan to resume project work in the second half of 2009. It will take several months for us to complete the assessment of the damage to the trials caused by the earthquake, to re-measure the growth of surviving trees, and to process and analyse the data for the final project report.

Forest Biosecurity and Resource Assessment

Program Leader: **Christine Stone**

Aim: Integrated decision support and management systems developed which provide an acceptable level of forest health protection.

Objectives:

- Minimise the introduction or establishment of exotic pests or diseases
- Develop a system of forest health management that evaluates, models and minimises pest and disease impacts on managed forests.

Forest health surveillance

A Carnegie

Surveys by the Forest Health Survey unit identify important pests, diseases, vertebrates, nutrients and weeds that may be limiting to growth and establishment of pine and eucalypt plantations, and that may need further research. Continued forest health surveys are essential to monitor and increase our knowledge of known pests and diseases and the factors influencing development of damaging outbreaks. Regular surveys also increase the probability of early detection of new pests and diseases, including exotic incursions.

Forest Health Reports provide plantation owners and managers with a summary of important pests and diseases in their plantations, with recommendations on remedial or control action where appropriate. In most cases these options are discussed with relevant field staff soon after the survey. Through surveys and research on improving pest and disease management strategies we assist Forests NSW with the task of implementing Ecologically Sustainable Forest Management Plans.

Softwood plantations

Softwoods management can use forest health survey data to: determine correct predictions of pre-harvested wood volume in affected stands; adjust management regimes for "unhealthy" stands (e.g. bring thinning forward in drought affected stands); apply fertilisers or weed control to improve establishment, growth and survival of young trees; control spray for *Dothistroma* needle blight (*Dothistroma septasporum*), and increase trap tree plots in *Sirex* wood wasp (*Sirex noctilio*) infested areas.

Only two Softwood plantation Regions were fully surveyed this year, as requested by Forests NSW: the Hume and Macquarie Regions, which were surveyed in winter 2008. Northern Region softwoods on the northern tablelands were surveyed due to severe *Dothistroma* needle blight. The extent and severity of pests, diseases, vertebrate pests, climatic disorders, nutritional imbalances and weeds limiting growth or affecting survival were mapped and reported.

Sirex wood wasp continues to cause significant tree mortality in several State Forests in the Hume Region, with a slight increase in the area affected from last year. Low parasitism rates were observed in the biological control program over the 2007–2008 season. *Ips* bark

beetles *(Ips grandicollis)* continue to attack *Sirex* trap trees, potentially detrimentally affecting the biological control program. Only low levels of *Sirex* infestation were observed in the Macquarie Region. Recommendations for management of *Sirex* across both Regions included increasing the biological control program in high risk areas.

Tree mortality associated with **drought** (and ***Ips* or *Diplodia pinea* canker**) was significantly reduced in the Hume Region this year compared to 2007–08, with no areas with tree mortality higher than 5%. The area affected was 5,385 ha, compared to over 17,795 ha in 2007–08. Importantly, *Ips* activity was significantly lower than last year. Lower levels of tree mortality were also observed in the Macquarie Region. Few management options are available to reduce tree mortality associated with drought stress. Early thinning of affected stands may reduce further tree mortality by reducing water stress on retained trees. However, research is required to determine whether this is operationally feasible or effective. Another option is to identify high risk sites (such as those with a low water-holding capacity) and plant trees at a lower stocking or prescribe early thinning on these sites. Research within NSW DPI is currently investigating this issue.

Essigella californica (Monterey pine aphid) was again widespread in the Hume Region. The area affected was slightly lower than last year; however, damage observed in September was much more severe than had been observed in previous years, with trees being almost totally defoliated in some areas. Damage from *Essigella* was also widespread throughout the Macquarie Region, occurring in the majority of State Forests. Although the area affected was lower than last year, levels of damage (severity) were higher than last year, with current aphid activity observed in many areas. Forests NSW is currently involved in a national project investigating biological control of *Essigella* (see below under management of *Essigella*).

***Ips* bark beetles** continue to breed and cause damage in the Billo Road Fire area of Buccleuch State Forest. There were moderate numbers of new deaths of trees that had been damaged by fire but not originally killed. We observed *Ips* in many of these trees, indicating that they are continuing to be a good resource for *Ips* to continue to breed and build up their population.

Localised areas of **nutrient deficiencies**, mainly boron deficiency, were identified in several areas in both Regions and recommended for remedial management.

***Dothistroma* needle blight** was severe in several State Forests on the Northern Tablelands. The area of damage was mapped in the Forests NSW helicopter, with maps provided to the Northern Region for control spraying with copper oxychloride fungicide. Approximately 1,800 ha were targeted for control.

Unplanned intervention responses

The Forest Health Survey Unit responded to a range of unplanned requests (including “call outs”) by Planted Forest Operations and Forests NSW Nurseries in response to pest and disease issues throughout the year, providing recommendations on management of problems that included:

- seedling mortality at Blowering Nursery, identified as *Phytophthora cryptogea*
- salvage of fire-damaged trees at Mount David State Forest (potential blue-stain due to bark beetles)

- wind damage to young trees at Bondi State Forest
- renewed Australian Pesticides and Veterinary Medicines Authority (APVMA) permit (PER9817) to control wingless grasshoppers in pine plantations
- mortality of pine grafts at Grafton Nursery, identified as *Phytophthora cinnamomi.*

Pest and disease management

Current pest and disease management strategies were reviewed and management efficiencies identified where appropriate to improve performance. Several research projects are aimed at improving the efficiency and effectiveness of management strategies to reduce the impact of pests and diseases:

Sirex

The effectiveness of the biological control program for this pest is continually monitored by looking at nematode parasitism rates from *Sirex* wasps that emerge from trap tree plots. In recent years this has been sub-optimal, with levels in the Hume Region in recent years being 45–55%, in the Monaro in 2007–08 at 39% (no emergence from 2008–09) and the Macquarie Region at ~60% over the past two emergence seasons. Too few wasps have emerged from trap trees in the Northern Region to provide reliable data. Ideally, parasitism should be closer to 90%. The reason for this reduction in parasitism is being investigated, but could include attack of trap trees by *Ips* bark beetles and sub-optimal timing of nematode inoculation. We have recommended that inoculation of trap tree plots with nematodes occurs from April to May. Due to dry conditions trap trees may be drying out too quickly for the nematodes to effectively migrate throughout the whole tree and infect *Sirex* larvae.

The Forest Health Survey Unit released *Sirex* parasitoides (*Ibalia leucospoides*), which were originally captured from the Hume Region in Nowendoc State Forest to supplement the biological control program.

The APVMA permit to use dicamba (PER10524) to establish trap trees was renewed.

In recent years *Ips* bark beetles have been attacking *Sirex* trap tree plots, potentially reducing the effectiveness of the biological control program. NSW DPI conducted a trial to investigate the potential of pheromones to deter *Ips* from attacking *Sirex* trap tree plots. The trial was funded by the National Sirex Coordination Committee (NSCC), with assistance from the Hume Region. Anti-aggregation pheromones were attached to trap trees in an attempt to deter *Ips* from attacking them before *Sirex* was able to oviposit. Unfortunately, we found no significant effect of the treatment, with the majority of trees attacked by *Ips*. However, we did find that *Sirex* was still able to oviposit in trees attacked by *Ips*. Further research on this problem and fine tuning trap tree establishment techniques is planned, using funding from the NSCC.

Essigella

Forests NSW is part of a national Forests Wood Products Australia (FWPA) project to develop a biological control program for *Essigella*. A parasitic wasp has been imported from the United States, undergone extensive testing in a quarantine facility in South Australia, and is planned for release in winter–spring 2009 following final approval. First releases in Australia are planned for the Hume Region, with data collected during forest health surveys

used to identify high risk sites to target for initial release. Monitoring of the effectiveness of the biological control agent will be conducted in the following years.

A trial has been established in the Hume Region to investigate the potential for remedial fertiliser to reduce the impact of *Essigella* defoliation.

A clone trial in the Hume Region was assessed in 2008, with preliminary identification of clones superior for growth and *Essigella* resistance. Further trials are being identified for assessment in the coming year.

Hardwood plantations

In August 2008, aerial surveys were conducted of a large proportion of the Forests NSW's young hardwood estate in northern NSW. Surveys were also conducted for Dothistroma needle blight in pine plantations and Forest Enterprise Australia's hardwood plantations in the same week. Ground surveys were conducted in October 2008, February 2009 and April and May 2009. The Forest Health Survey unit liaised with the Plantations Forester, as well as Plantation Officers, prior to, during or following surveys. A report containing geographic information system (GIS) maps and management recommendations was sent to the Northern Region following the aerial and October ground surveys, with a report of the 2009 ground surveys still being completed. The main issues are described below.

Bell miner associated dieback (BMAD) was again observed in several plantations on a range of hosts, including *Eucalyptus saligna, E. grandis* and *E. dunnii*. There was little change to the extent and severity of damage from last year. We have also identified areas where active bell miner colonies are adjacent to plantations and, as such, have potential for future BMAD problems. Recommended management of BMAD in young plantations includes continued monitoring of the extent and severity of damage, and of bell miner colonies, and weed control of lantana, which will reduce bell miner habitat.

Cardiaspina psyllids again caused damage to *E. grandis* at one plantation, with the extent of the infestation similar to previous years. Cardiaspina psyllids were observed in many areas on the north coast last year, including in native forest and mature plantations around Coffs Harbour. There are limited management options for this pest.

The **winter bronzing bug**, *Thaumastocoris* sp., was confirmed for the first time attacking eucalypt plantations in NSW during the surveys in October. This insect pest was previously only known from Sydney street trees and an isolated area of plantation in south-east Queensland (a different species has caused extensive damage to eucalypt plantations in South Africa). This tiny bug causes chlorosis of spotted gums (*Corymbia* spp.), resulting in premature defoliation. It was observed during aerial surveys in several localised areas (in total 5 ha) in plantations around Casino and in one plantation west of Port Macquarie during ground surveys in February. Recommended management is to monitor tree recovery in future surveys and for any expansion of the current infestations. The initial outbreaks were identified during the aerial survey and would have been difficult to detect from the ground only. As such, we strongly recommend the continuation of the aerial survey of hardwood plantations.

Damage (yellowing and bronzing) to spotted gum caused by the winter bronzing bug, newly identified in plantations in NSW during forest health surveys in 2008. Photograph by Angus Carnegie.

The winter bronzing bug. Photograph by Angus Carnegie.

Eucalypt sawflies caused extensive and severe defoliation of *E. dunnii* in several plantations in the Bonalbo area in mid to late 2008, with approximately 460 ha affected. We observed small areas (10–20 ha) of defoliation in previous years, but were never able to confirm the causal agent. During the 2008 aerial survey we landed within the plantation and observed sawfly larvae feeding on trees. Few management options are available for this pest and we recommend continued monitoring of the extent and severity of damage and for tree recovery in following surveys.

Severe repeated damage from ***Creiis lituratus psyllids*** has resulted in dead-topping and tree mortality of *E. dunnii* in approximately 153 ha, all in plantations with previous outbreaks. Outbreaks of *Creiis* continue to cause significant problems in younger stands owned or managed by management investment scheme companies in the region. We question the efficacy of chemical control with currently registered insecticides. We have been coordinating a collaborative project through the Subtropical Forest Health Alliance (including private and public growers) investigating new insecticides and delivery mechanisms to control *Creiis* (see below).

Stem borers are a continuing problem in the ageing estate and we have been conducting specific surveys for stem borer damage over the past few years, including identifying the causal agents of damage (various species of cossid moths and longicorn beetles) and associated fungal damage. This forms part of a project on stem degrade focusing on hardwood plantations in subtropical Australia, funded mainly by the Queensland Government (see below).

Forests NSW provides plantation forestry establishment management services to TEPCO Forests Australia Pty Ltd, STMicroelctronics Pty Ltd and AgriWealth Pty Ltd under long-term contracts. The total area of plantation under contract is approximately 14,000 hectares. The plantations are spread over three forestry regions and comprise a mixture of hardwood and softwood species. Forest health assessments are routinely undertaken in a manner that is consistent with those carried out on Forests NSW's own plantation estate. TEPCO Forests Australia Pty Ltd and AgriWealth Pty Ltd plantations were surveyed in 2008–09.

Pest and disease management

Operational pest and disease management advice is provided to Regions on completion of surveys where required, or as requested during an "unplanned intervention response". Examples are provided above, and include continued monitoring of outbreaks or damaged stands and weed control. Current pest and disease management strategies were reviewed and management efficiencies identified where appropriate to improve performance. Several ongoing sub-projects are aimed at improving management strategies for pests and diseases in hardwood plantations.

Pest and disease assessment of tree improvement trials. Assessment of insect damage in an *E. dunnii* provenance and family trial were carried out. Future assessments are planned. No other trials were identified for assessment in 2008–09.

Impact of stem defect agents on wood quality in subtropical hardwood plantations. This is a multi-agency (growers and research providers) project which is funded largely by the Queensland Government's Plantation Hardwoods Research Fund. The main aims are to identify the major factors that determine a plantation's (or tree's) susceptibility to stem

degrade, quantify the economic impact of degrade on solid wood crops, and develop prescriptions and tools to reduce the impact of stem defect agents in current and new plantings. The Forest Health Survey unit is involved through provision of forest health data and expertise and assisting in quantifying the impact of stem degrade via destructive sampling and sawmilling studies.

Improved management of *Creiis* psyllids. *Creiis* is still the single major health threat to profitable *E. dunnii* plantations in northern NSW. Current insecticide control has proven sub-optimal. Through the Subtropical Forest Health Alliance we are assisting in testing and trialling new chemicals and application techniques, with registration of a new insecticide imminent. The APVMA permit to control *Creiis* with dimethoate was renewed (PER11322).

New and emerging pest and disease threats. A major benefit of surveillance by trained experts is that new and emerging threats are identified early. In recent years we have identified several eucalypt leaf spot fungi new to science, as well as the first outbreak of the winter bronzing bug in plantations in NSW.

Remote assessment and spatial modelling of native forest dieback in NSW

C Stone

Throughout coastal south-eastern Australia, Bell Miner Associated Dieback (BMAD) refers to a form of canopy decline observed in eucalypt crowns occupied by colonies of bell miners (*Manorina melanophrys* (Latham)). While the total extent of BMAD is unknown, numerous observations and local surveys indicate that the problem is spreading. In October 2008 *Forest eucalypt dieback associated with over-abundant psyllids and bell miner* was gazetted as a “Key Threatening Process” after a formal determination by the NSW Scientific Committee (see http:www.environment.nsw.gov.au/committee/ListOfScientificCommitteeDeterminations.htm). As a consequence of this decision, formal strategies for managing BMAD will need to be developed and implemented. Accurately mapping the location of bell miner colonies and identifying forest stands susceptible to this form of dieback is essential to implementation of recommended management strategies.

Research begun in 2004 was supported by the BMAD Working Group and recommended by the Northern Rivers Catchment Management Board for Natural Heritage Trust funding. The second phase of this project was based in the Watagans, and conducted at the Jilliby Study Site. Several agencies utilised the study site and associated plots (e.g. DPI Forest Science Centre, Forests NSW Native Forests Operations, Department of Environment and Climate Change - National Parks and Wildlife; NSW Rural Fire Service and the University of NSW). Data collected from these plots was shared with the NSW Rural Fire Service as part of a related spatial project investigating the remote assessment of fire fuel loads.

The overall aim of this project was to identify the acquisition, processing and modelling specifications of cost-effective imagery that will enable the accurate classification of canopy health in native eucalypt forests, using BMAD as a case study. The study has demonstrated that through the fusion of lidar and multi-spectral satellite imagery, it is possible to apply a modelling system that accurately maps the current and potential distribution of BMAD. This information is essential for the planning and implementation of BMAD management

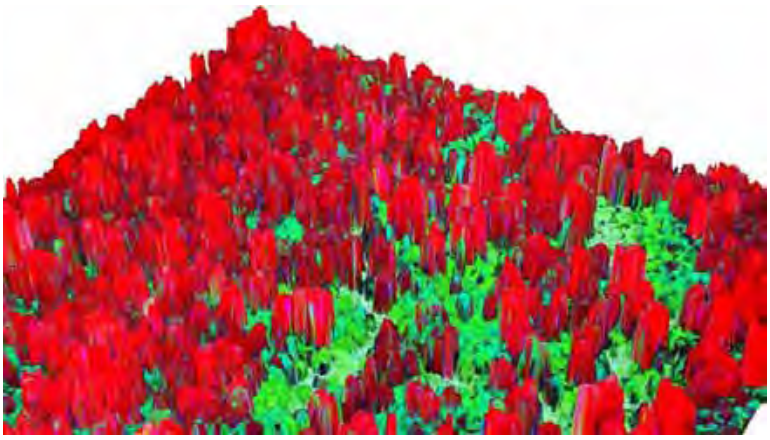
strategies. It is recommended that managers of native forests known to have BMAD formalise their priorities with respect to the application of remote sensing technology for forest assessment and monitoring. This approach requires commitment to investing not only in the acquisition of remotely sensed imagery but also in the technical expertise and facilities required for handling and analysing such spatial data. Cost efficiencies arise from larger-scale projects (> 100,000 ha) and these often occur from cost-sharing collaboration on multi-functional projects involving clusters of forests. For example, the acquisition of lidar for both water catchment management and canopy health assessment.

Key stand floristic, structural, silvicultural, edaphic, topographic and climatic factors

Analysis of the ground-based plot data revealed that in the Jilliby study area, the presence of bell miners was significantly associated with unhealthy eucalypt crowns. The plot results also demonstrated a strong association between forest structure (an open sclerophyll canopy over a dense lower storey) and the presence of bell miners. The density of understorey was significantly correlated with fire frequency. We recommended that, based on these results, the prevention or subsequent removal of a dense lower understorey would make a forest less at risk from bell miner colonisation. Silvicultural practices that promote rapid overstorey regrowth and canopy closure would be a viable option for managing canopy decline associated with bell miners. From the Jilliby plot data we also found that soil landscape type was not significantly associated with bell miner colonisation but that topographic Wetness Index, however, was selected in a final logistic regression model. Bell miner colonies were absent from dry sites. Although there were significant differences in the ranking of crown condition between eucalypt species, tree species was not selected in the final model.

Spatial predictive models for bell miner associated dieback

In collaboration with Dr Andrew Haywood (Victorian Department of Sustainability and Environment), a modelling system for mapping the actual and potential distribution of native forest colonised by bell miners, and hence susceptible to BMAD, was developed.



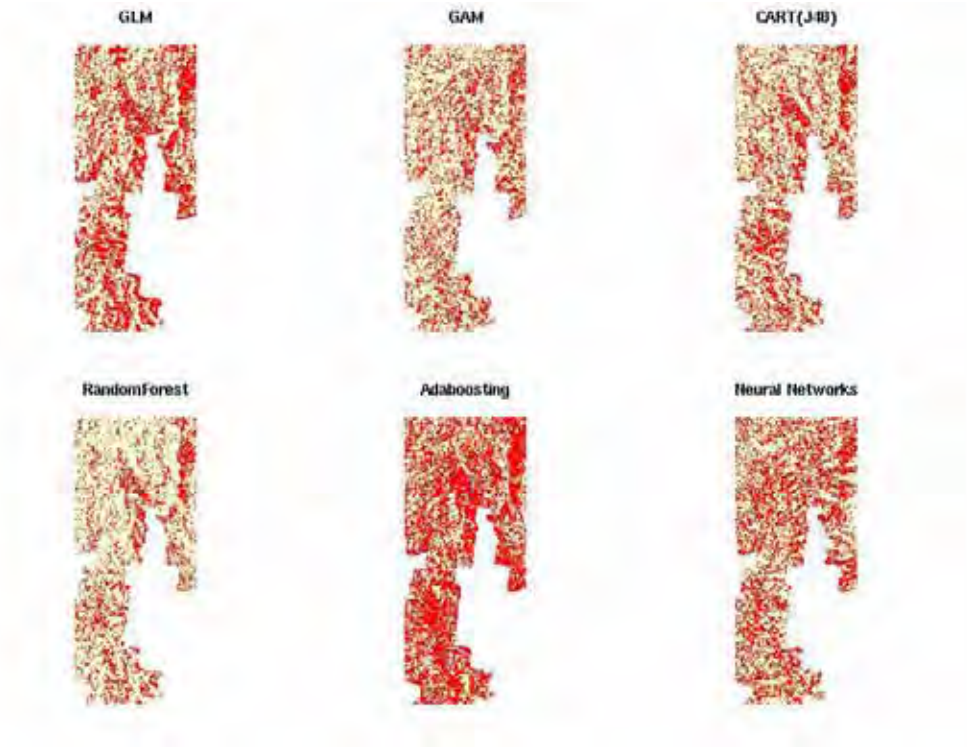
Lidar image distinguishing vegetation classes within Eucalypt regrowth. Image by Russell Turner.

The field training data was split into a model building data set and a validation data set. Six modelling techniques (Logistic Regression, Generalized Additive Models, Tree-Based Classification, Random Forest, and Boosting of Trees and Neural Networks) were integrated with Airborne Laser Scanner (lidar) and SPOT5 data and topographic variables.

For the Jilliby study site, the most accurate algorithm for predicting the distribution of bell miner colonies was Random Forests

High-resolution, geo-referenced digital maps that accurately classify the extent of BMAD within the study area

A comparison of the predicted presence and absence of bell miners as an indicator of eucalypt forests susceptible to BMAD in the Jilliby Catchment Study Area produced by the six models is illustrated below. A comparison of the six maps reveals areas of commonality with respect to the predicted presence of bell miners. These areas should be given priority when planning follow up, ground based assessment required for amelioration activities. These maps identify both stands which were actually colonised by bell miners and stands which are susceptible to colonisation by bell miners. These two classes can be separated by either ground based visitation or the subsequent acquisition of high resolution, hyperspectral remotely sensed imagery which has the discriminative power to detect unhealthy eucalypt crowns in complex native forest.



An illustrated comparison of the predicted presence or absence of bell miners as an indicator of eucalypt forests susceptible to BMAD in the Jilliby Catchment Study Area produced by six models. Images by Christine Stone and Andrew Haywood.

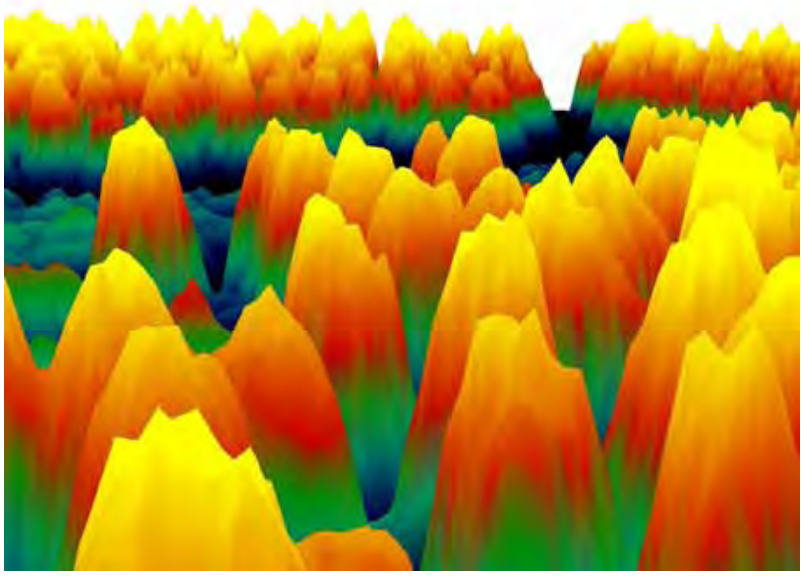
The modelling system developed for the production of the maps in the figure above was applied at a resolution of 10 m within the Jilliby catchment study area. However, this study confirmed the high quantitative capacity of airborne Lidar (at a point density of 2 pulses/m^2) to accurately measure forest stand structure. Using the Lidar dataset, Dr Russell Turner (DPI, Science & Research, Forest Health) produced high resolution canopy height and understorey volume surfaces and accurately determined overstorey cover. We found significant relationships between a lidar-derived vegetation structural index (plot area covered by eucalypt overstorey or 'volume' of understorey up to 10 m height), eucalypt crown condition and the presence of bell miners.

Cooperative Research Centre for Forestry—the Green Hills State Forest Project

C. Stone

NSW DPI is a Supporting Partner of the Cooperative Research Centre (CRC) for Forestry. The Forest Health Management Program is making a significant in-kind contribution to the collaborative Research Program 1, "Managing and monitoring for growth and health" and, in particular, Project 1.2.2, "Measuring and managing forest health". A key multi-focus study site for Program 1 is located in Green Hills State Forest, near Batlow, NSW.

The health component of this project is based on the exotic pine aphid *Essigella californica,* which is now considered a key pest of *Pinus radiata* in SE Australia. By May 2007, however, tree deaths associated with the drought and the introduced bark beetle *Ips grandicollis* were becoming a significant health issue in the northern section of Green Hills and this tree mortality has been included in the remote and ground-based assessment program.



Green Hill State Forest pine plantation as a three-dimensional Lidar-derived canopy height model. Image by Russell Turner.

This project will quantify the capacity of emerging technologies such as satellite and airborne sensors to effectively assess a range of important biophysical attributes related to the health and condition of *Pinus radiata* plantations. Change detection metrics have been developed through temporal analysis of imagery over northern Green Hills acquired by the MODIS satellite sensor. The MODIS sensor acquires imagery over Australia daily but at a coarse resolution of between 250 and 1000 m and is available free of charge. This analysis will be used to develop an extensive "first pass" monitoring system for detecting vegetative changes in the plantations. Unexplained trends (e.g. not due to the regular patterns of seasonal phenology or silvicultural operations) would be identified. These areas would then be targeted for more detailed investigation through field surveys of finer spatial resolution imagery.

The Green Hills project provides an opportunity for Forests NSW to review the advantages of acquiring this spatially explicit information, information that can be more accurate and cost-effective than existing conventional methods of inventory and forest health assessment.

Six major field campaigns in which tree and plot data related to tree growth and health were collected (between September 2006 and May 2009) have now been completed. The final field campaign is scheduled for September 2009. Imagery from the following satellite and airborne sensors has also been acquired over the study site: MODIS, Quickbird, Hyperion, Landsat and ADS40 digital camera imagery. These imagery datasets represent a wide range of spatial, spectral and temporal resolutions. Four aerial sketch mapping surveys have also been completed over the study site. In addition, insect population monitoring of the *Essigella* pine aphid was carried out over the period November 2006 to May 2008.

Diaeretus essigellae, an exotic biological control agent for the pine aphid, has been brought into Australia and tested for host specificity. It is hoped that the approval process for release will be finalised by September 2009 and a limited number of the parasitoid wasps released into Green Hills State Forest. The survival and efficacy of this biological control agent will be followed during the remaining term of the forestry CRC.

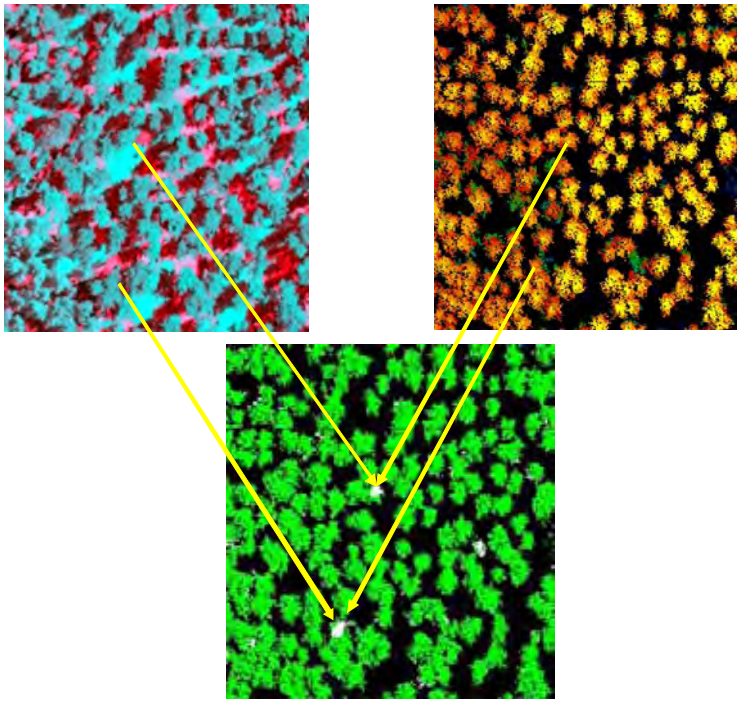
A total census of dying or recently killed trees enables us to accurately quantify the impact of damaging agents and processes. Experience gained from the Green Hills project will enable us to provide the guidelines and specifications required for the acquisition of imagery from a range of remote sensors. Recommendations related to the integration of remotely acquired digital imagery into existing spatial data management systems and stand based growth models as well as emerging process-based models will also be an important outcome. In addition, this project will enable the Forest Health Surveillance Unit to calibrate their aerial sketch mapping methodology.

High resolution remote sensing of the Green Hills State Forest

C. Stone

This 2-year research project, developed during 2008, resulted in a contract with Forests & Wood Products Australia, which was signed in October 2008. The project will receive $125,215 from FWPA, as well as significant in-kind contributions from Forests NSW and NSW DPI's Forest Health Program. The project will harness the benefits of high resolution lidar and multispectral imagery through the modification and customisation of existing

methodologies and software systems and provide recommendations for its specific implementation. Relevant information and software tools already available, or close to commercialisation, will be evaluated and the outcomes collated.



Illustrating the 'semi-supervised' identification of individual dead crowns in a 20-year-old, unthinned stand of *Pinus radiata* using lidar height thresholding and spectral variation from digital camera CIR data. Accurate image co-registration of the two digital images is essential but difficult to achieve if the lidar and camera imagery is acquired separately. Images by Russell Turner.

The rapid advancement in the capacity and affordability of remote sensing technologies has resulted in a paradigm shift in the approach taken to assess plantation inventory. Conventional ground-based inventory methods are labour intensive and based on a small survey of plots while high spatial resolution digital imagery enables a total census of plot and tree-scale attributes. Adoption of this technology will supply benefits through a reduced reliance on conventional field-based inventory assessments and more cost-effective estimates of inventory attributes. The likely significant cost differential between lidar and conventional inventory approaches will enable forest managers to undertake more frequent large-scale strategic inventories as well as monitor forest growth and productivity.

The procedures developed in this project will enable the integration of this technology into ground-based, lidar canopy and stem profiling, GPS linked harvest operations and the adoption of process based modelling for productivity estimates and carbon accounting.

Exotic timber insects

M Horwood and R. Eldridge

The Forest Science Centre (FSC) identifies forest and timber insects for members of the general public, businesses and other government agencies. One aspect of the identification service that provides a major economic benefit to the community is the identification of suspected exotic timber insects.

This year one of the samples, sent to the FSC for identification by members of the pest control industry, contained the exotic West Indian drywood termite *Cryptotermes brevis*. The infestation was investigated and a site visit conducted to determine the extent of the infestation. The infestation was confined to a single door that was fumigated with assistance from the Australian Quarantine and Inspection Service (AQIS).

Another important aspect of the exotic insect incursion management activities of the FSC is the identification of suspected exotic termites for AQIS. These are suspected border intercepts or material collected by AQIS Officers participating in the Northern Area Quarantine Surveys (NAQS). During 2008–09, 16 samples were identified on behalf of AQIS.

Termite and Power Pole Evaluation Research Project

M Horwood

Each year the Australian power supply industry spends millions of dollars protecting wood poles from subterranean termite attack and replacing poles damaged by termites. Concerns within the industry about the efficacy of the chemicals used for controlling termites and a desire to optimise treatment practices led to an investigation known as the Termite and Power Pole Research (TAPPER) trial. The Electricity Association of NSW and the Forest and Wood Products Research and Development Corporation provided the necessary funding for the trial and Forests NSW undertook the research in collaboration with EnergyAustralia, CountryEnergy and Integral Energy. Work commenced in 2000.

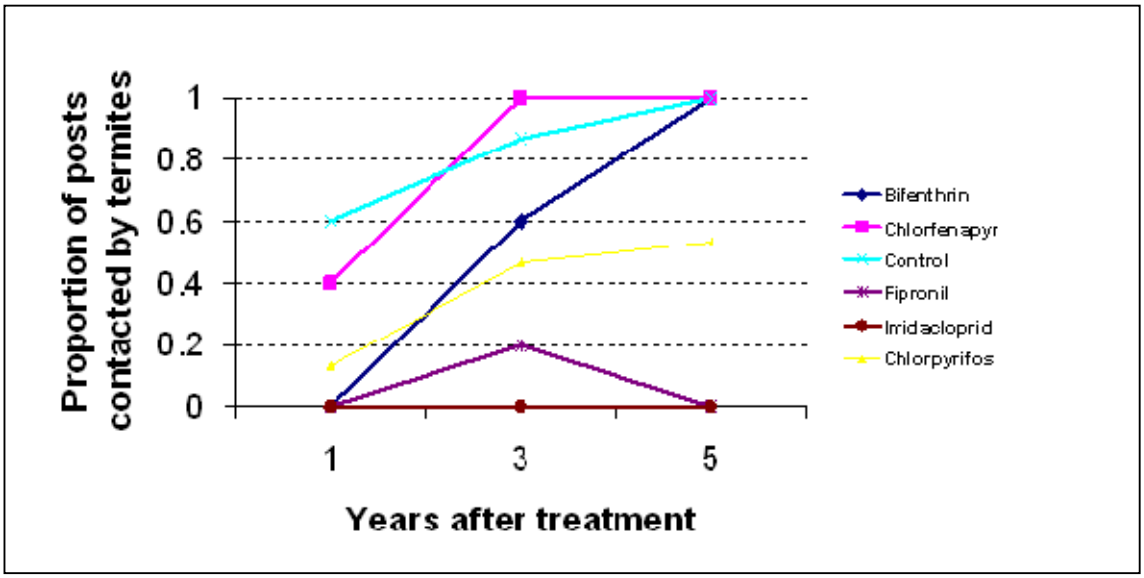
To achieve the study objectives, two trials were established:

- a service trial conducted over 7 years to evaluate the performance of termiticidal treatments including dusts, chemical soil barriers, a residual timber fumigant and baits for eradicating termite infestations from infested in-service power poles. Three smaller trials were run in conjunction with the Service Trial
- a field trial lasting up to 20 years to evaluate chemical soil barriers and a physical barrier for protecting new poles from termite attack.

All service trial treatments achieved significant reductions in termite infestation. As the trial progressed, poles became reinfested by termites. By the fifth year after treatment poles treated with chemical soil barriers had the lowest probability of infestation, followed by poles treated with fumigant. Poles treated with dusts were the least well protected from termite attack 5 years after treatment.

The field trial was established in 2002 in a State Forest near Narrandera in south-western NSW. Five years after the establishment of the field trial, all full barrier systems were unpenetrated by termites. Partial barriers of fipronil and imidacloprid were 100% effective after 5 years (see figure below). The year seven inspection is scheduled for 2009.

Arrangements for this inspection (including funding) will be negotiated with the electricity supply industry.



Incidence of termite attack on posts with partial termiticidal barrier and control treatments.

Several network operators have altered their termite treatment practices to take on board the findings of this research. Expectations are high that these changes will result in significant progress towards Objective Two: reducing the cost to the power supply industry of termite damage and treatment.

National Plant Pest Indicator Species Surveillance Program

D. Kent

The primary objective of the National Plant Pest Indicator Species Surveillance (NPPIS) program for 2008–09 was the collection of data on the presence or absence of pests already present in Australia as indicator species for environmental change. It is envisaged that this surveillance will provide data on the current distribution and abundance of targeted pest species and provide a baseline for monitoring future changes. These data will also contribute to the development of models of spread and habitat suitability in the context of environment change (i.e. climate and land use).

The main activities scheduled to be undertaken during the year are described below.

Urban forest trees survey: Urban amenity trees, including *Platanus* spp. trees, within Sydney and regional council areas were surveyed for *Corythucha ciliata* Sycamore Lace Bug.

The sycamore lace bug adult *Corythucha ciliata* (Say); length 3 mm. Photograph by Peter Gillespie.

Forest and timber pests: In conjunction with the Australian Quarantine Inspection Service (AQIS), the NPPIS is developing a profile of Quarantine Approved premises (QAP) within the Sydney Basin which import products at risk from a range of forest and timber beetles and woodwasps. The pilot study proposal to undertake surveillance of these profiled QAP and surrounding urban areas has been put on hold. As a result this trapping phase of the program was delayed and will now commence in the second half of 2009.

Bark beetles: Distribution data on the exotic softwood bark beetles, *Ips grandicollis*, *Hylastes ater* and *Hylurgus ligniperda* in NSW softwood plantation areas were extracted from the DPI insect collection database. These data were by-catch from the 2006–07 *Sirex* monitoring program.

Forest Science Centre collections

D. Kent

The Science and Research Collections based at the Forest Science Centre provide invaluable identification and reference resources for current research projects and forest health surveillance. The insect and disease collections are also a repository of biosecurity comparative material relating to potential exotic plant pests affecting both forestry and timber products.

The Forestry Commission of NSW Insect collection (FCNI) is a collection of over 50,000 Australian and exotic forest and forest product insect specimens. The Forestry Disease Herbarium is a collection of approximately 3,500 tree and timber fungal specimens and fungal fruiting bodies and approximately 1500 fungal cultures. The third and last collection is the Forestry Commission of NSW Wood collection, which contains approximately 30,000 wood samples of Australian and overseas material, a voucher herbarium collection and a comprehensive microscope slide collection. All three collections have now been gazetted under the *Agricultural Scientific Collections Trust Act NSW* (1983). This achievement recognises the collections as valuable forestry resources and supports the long-term maintenance, improvement and management of all three collections.

The FCNI collection provides the basis for an important identification service to the NSW Department of Primary Industries, including Forests NSW staff, other government agencies (including Australian Quarantine Inspection Service), the pest control industry and the general public. The FCNI has been improved for future maintenance and management with the adoption of Biolink, a database specifically designed for collections. Over 50% of the collection is on Biolink and is also available to all contributing Australian Plant Pest Database (APPD) organisations, including Plant Health Australia and Biosecurity Australia, on-line via the APPD website.

The FCNI was recently re-registered as a scientific organisation for non-commercial loan, donation or exchange of scientific specimens of native Australian species between Australian and overseas institutions by the Department of the Environment, Water, Heritage and the Arts. The collection retains its original registration number: AU021. The FCNI still maintains an active membership in the Council of Heads of Australian Entomological Collections (CHAEC) and supplies an annual report on collection activities. Membership of CHAEC allows the collection manager to keep abreast of current collection maintenance developments and electronic data capture innovations.

The pathology collection at the Forestry Disease Herbarium performs the same important identification service as the insect collection and is electronically databased into the KE Texpress data management system. Several isotype collections of recently described eucalypt foliar fungi are lodged in the Forestry Disease Herbarium.

Of the three collections, only the Forestry Commission of NSW wood collection has not been regularly used. Access is currently difficult due to storage issues. The microscope slide collection is currently on long-term loan to an ex-Forests NSW wood anatomist and is safely housed on the south coast of NSW.

Forest Biodiversity and Ecology

Program Leader: **Rod Kavanagh**

Aim: A scientific basis for maximising biodiversity values in managed forests.

Objectives:

- Enhance understanding of managed forest ecosystems
- Develop integrated landscape models of wildlife habitat and timber production
- Develop species monitoring programs to enable assessments of progress in meeting NSW State Plan biodiversity targets
- Evaluate the role of eucalypt plantations for restoring biodiversity in rural landscapes.

Ecology of birds and non-flying mammals in managed forests

R Kavanagh and M Stanton

Prey availability may limit barking owl population density

The barking owl, *Ninox connivens*, a threatened species throughout southern Australia, maintains a large robust population in the Pilliga forests of northern New South Wales. Breeding pairs in this population occupy large home ranges of up to 2000 ha.

Principal Research Scientist Rod Kavanagh releases a barking owl in the Pilliga State Forest. Photograph by Matthew Stanton

Nest sites and roost sites do not appear limiting for the owls in these forests so an investigation was made of barking owl diet and prey availability. Barking owls preyed on over 40 species of birds, the Sugar Glider, insectivorous bats and insects, with most prey items taken from the air or in trees and few prey items taken on the ground. Preliminary results for prey availability show that while all prey groups are widely distributed throughout the Pilliga forests, the distribution of the owls was strongly correlated with prey biomass. Spatial variability in prey biomass, particularly birds, provided the best explanation for barking owl distribution. The available prey biomass, including birds and small to medium-sized mammals, appeared to be limiting barking owl population density and distribution within the relatively marginal habitat provided by the Pilliga forests. Prime habitat for barking owls elsewhere in NSW has been cleared for grazing and cropping.

Biodiversity monitoring

Biodiversity monitoring at multiple scales is needed for reporting status and trends in ecological sustainability, and to assess progress towards the achievement of State Plan Biodiversity Targets. Decisions about the allocation of sampling effort at each monitoring point, regardless of its location, involve trade-offs between the time-cost of surveys and the power of the monitoring design to detect changes in species presence or abundance.

There is a need to determine the optimal sampling effort for landscape monitoring programs for forest birds and other taxonomic groups. We recorded 100 forest bird species at 81 points during a pilot monitoring program in the Pilliga forests of north-western NSW. Simulations using a sub-sampling method were made to determine the variation in bird species richness according to sampling plot size, number of sampling plots at each location, and number of visits to each plot. The time required for each sampling option was recorded. We found that it was feasible to reliably record (i.e. with 90% confidence) about 30% of the forest avifauna in standardised species monitoring programs. These species were representative of a number of ecological guilds and included some listed as “threatened”.

Plot size, number of plots and number of visits all had important influences on species richness and species detectability. Optimal sampling effort was determined by the capacity to sample more than one location per day. This required visits to fewer plots at each location and, accordingly, resulted in fewer species detected with high levels of confidence. Our maximum sampling effort was insufficient to record all species known to be present, due mainly to the highly skewed nature of bird species distributions; additional visits or targeted research on selected priority species may be required. A statewide (national) grid offers potential as a framework for unbiased sampling of “resource condition” for species and habitat surrogates, and also a solid platform from which to assess changes over time.

Remote sensing of habitat surrogates

The capacity to recognise and identify important features of habitat for animals by using a range of new remote sensing technologies is in its infancy. However, both satellite and aircraft-borne methods offer huge potential for regular, cost-effective assessment of changes in forest stand conditions across large areas and, eventually, of changes in the availability of habitat for many species. In collaboration with the University of Queensland, we developed methods for mapping isolated trees and patches of forest and woodland in agricultural landscapes from satellite imagery (multispectral Landsat 7 and SPOT 5) using a combination

of the normalized difference vegetation index (NDVI), spatial filtering and threshold values. We then calculated various discrete and continuous landscape metrics based on the tree and forest mapping and assessed their importance in explaining spatial patterns of bird species richness. Data for bird species collected at each of 120 sites in the Albury region were used in the analysis. A high level of accuracy (80–90%) was achieved in deriving a layer of trees represented as point objects in areas with low–medium tree cover. The remotely sensed percentage of tree cover at spatial extents of 3–28 ha around sites was found to explain almost 50% of the variability in overall bird species richness and 60% of the variability in woodland-dependent bird species richness. The work provides a novel remote sensing and spatial ecology approach to investigating the ecological importance of small and isolated landscape features such as paddock trees, for bird species richness. This approach could be used for more extensive assessment of avian habitat quality from high spatial resolution images across a range of human-modified landscapes.

Long-term ecological research sites

R Kavanagh, M Stanton and T Penman

Bird populations at the Banksia Road, Eden, alternate coupe logging study were assessed in spring 2008, 32 years after project establishment. Progress results from this study were published in 1985 and 2003. The most recent data have yet to be analysed and reported.

Bird populations at the Eden Burning Study Area were also assessed in spring 2008, 22 years after project establishment. Progress results from this study have been reported at major ecological conferences. A major analysis of the combined data across all years is currently underway.

Populations of arboreal marsupials within the Waratah Creek experimental logging area, near Bombala, were assessed in autumn 2009, 28 years after project establishment. Progress results from this study were published in 1998 and 2004, but many other papers on aspects of the ecology of these species have been published. The most recent data have yet to be analysed and reported.

Impact of forest management practices on plant species diversity

R Kavanagh and T Penman

This project examines the effects of the two primary forest disturbances, fire and logging, on both understorey and overstorey vegetation. Data have been collected within the Eden Burning Study Area over a 20-year period. Funding has been provided by the Bushfire CRC to analyse and publish the results of this study.

Prescribed burning and logging operations affect understorey plants differently. However, the typically patchy nature of these management procedures, at least in the dry sclerophyll forests in south-eastern NSW, means that some refuges are likely to be available for species that are more sensitive to fire and logging. Extending the study to other forest types such as the north coast of NSW will extend our understanding to different forest types and allow for more broadscale approaches to be developed.

A hazard reduction burning operation in a native forest environment. Photograph by Trent Penman

Analysis of existing data indicates that the effects of timber harvesting on floral diversity are relatively short lived (less than 15 years) and the predicted detrimental impacts of frequent prescribed fire were not realised. The lower than predicted impacts are thought to be a function of the heterogeneity of disturbances at the site and the low intensity of these disturbances.

The major unexpected result was that the diversity of sites changed over time independently of management regime. This was considered to represent a natural response to increasing time since wildfire. These results have been verified independently using similar data collected from another long-term study and reference site in the region, the Forests NSW Yambulla Hydrology Research Catchments, and additional sites from an ongoing collaboration with the NSW Department of Environment and Climate Change.

Soil seed bank

To examine the ability of the plant communities to recover if wildfire occurred in the area, we conducted a soil seed bank study. This work was initiated under a Bushfire CRC student summer scholarship and completed under funding from the Bushfire CRC and Forests NSW. Results of the soil seed bank indicate that the forest management practices are having “hidden” impacts on these communities through modifications to the soil seed bank. Timber harvesting increased the diversity and abundance of seeds within the seed bank, while frequent burning had the opposite result.

Biodiversity in eucalypt plantations established on farms for wood production and to reduce salinity

R Kavanagh, B Law and F Lemckert

This “biodiversity in plantations” project builds upon existing knowledge from a large number of sites planted for environmental benefits in the Albury-Wodonga region and extends the geographical relevance of the work to include the Liverpool Plains region near Gunnedah.

Sugar gliders utilised nest boxes soon after installation during the Liverpool Plains Study. Photograph by Matthew Stanton.

A detailed investigation into how plantations are used by bats on the Liverpool Plains was undertaken by radio-tracking a number of species on two adjacent properties (Paringa and Connamara) near Quirindi. In February 2008, 10 bats were radio-tracked and in September 2008, a further eight bats were radio-tracked, altogether comprising four species. We used manual observations and deployed remote data loggers to measure the percentage of time spent by bats in plantations during night-time foraging. Day time roosts were also located and these were always in mature trees, usually in hollows, in remnant vegetation. These data are now in the process of being analysed and give us a better understanding of the way bats

use plantations. Koalas have also been recorded foraging in several of the young eucalypt plantations in this study. Two adult males were fitted with GPS data loggers to record their fine-scale use of habitat. These data showed that the Koalas frequently used these plantations for both diurnal shelter and foraging, but also made extensive use of remnant trees and woodland in the landscape. These animals frequently moved across cleared areas to reach preferred foraging locations.

Goonoo Lands Fox Project

R Kavanagh and A Towerton

This project aims to improve the effectiveness of fox control operations through an understanding of fox movements and habitat preferences in a forested area northeast of Dubbo, NSW. Extensive radio-tracking work has been completed. Remote cameras are being tested as a means of assessing changes in fox numbers before and after baiting operations. Bait spacing experiments are currently underway to test the effectiveness of reduced bait density in order to increase the spatial coverage of bait placement.

Bat ecology in managed forests

B Law

The improving knowledge of forest bat ecology is allowing predictions to be made about changes in bat communities resulting from changes in forest management practices and will be integral to demonstrating ecological sustainability.

Technical Officer Alison Towerton with a yellow-bellied sheath-tailed bat captured in the Pilliga State Forest. Photograph by Brad Law.

Response of bats to disturbance

Bats in the Karuah Research Area

An 11th consecutive annual banding of bats was conducted in March 2009, with 143 banded and 68 recaptured from previous years. Analysis of these data will provide the first estimates of bat population sizes and survival rates in forests, enabling comparison between regrowth and unlogged catchments. Thinning of regrowth catchments began in 2009, allowing the experiment to move into its next phase, which will compare the extensive pre-thinning data on bat populations with post-thinning data in years to come.

Bat monitoring—ongoing

The **Large-footed Myotis**, a water-way dependent bat, has been banded over 12 consecutive years at Kerewong State Forest. The main study colony has not been relocated since the bridge housing the roosting bats collapsed in 2006. A second colony at Kippara SF is continuing to be monitored annually, with 17 bats banded and 11 recaptured from previous years. A total of 125 bats and 59 recaptures have accumulated since annual banding began at this location in 2001.

Monitoring also continued, at key subterranean roost sites, of **eastern horseshoe** and **eastern bent-wing bats**, using an infra-red gate and data-logger. In December 2008, the 8th annual population census was carried out at Ourimbah bat cave on the central coast (the largest known roost of Horseshoe bats in Australia). An uncorrected count of 3,524 bats for one night was made as they exited their cave. Continued monitoring of these important bat populations will allow Forests NSW to track the changing status of these bats and especially to assess changes due to forest management practices imposed on the surrounding environment. No count was done at Mumbulla Mine in 2008.

Bats in river red gum forests

Acoustic surveys of bats were required as part of the Riverina Environmental Impact Study. To efficiently and objectively analyse the thousands of calls collected by this survey, we developed an automated identification key to bat calls of the Riverina area. This involved trapping bats in River Red Gum forests, recording their acoustic calls upon release and thus establishing a reference library of calls. The calls were then statistically analysed to differentiate species and the results were incorporated into the automated identification software. Over 40,000 calls collected by the survey were subsequently analysed, with the results delivered to Native Forests, Western Region.

A typical bat survey night in the “office” (Pilliga State Forest) with Principal Research Scientist Brad Law and Technical Officer Mark Chidel. Photograph by Alison Towerton.

Habitat requirements of threatened bats

*The **greater long-eared bat** in Pilliga forests.* The study investigating the habitat requirements of this threatened species continued, with additional radio-tracking in spring 2008. The greater long-eared bat is strongly associated with cypress forests and the Pilliga forests represent core habitat, in that the greatest number of captures have occurred in this area. Although the bat’s distribution is reasonably well known, little is known of its ecology and the impact of timber harvesting. The results will also be relevant to the southern cypress forests and the Riverina’s river red gum forests. The aim of the study is to investigate roost selection, because roosts in tree hollows are typically the most critical resource for insectivorous bats. Maternity roost selection was investigated in November 2008, with 13 individuals radio-tracked. At this stage the data collection is not complete and data that have been collected have not been statistically analysed. A preliminary inspection of the data suggests that bats in both seasons commonly roosted in dead trees, most commonly in ironbarks, but also in cypress and buloke. It is notable that tree roosts often had a relatively small diameter (< 50 cm dbh). Based on these preliminary results, small, dead trees will deserve greater attention by forest managers in cypress forests. Information on foraging movements was also collected.

A roost tree of a greater long-eared bat found by radio-tracking in the Pilliga State Forest. Photograph by Alison Towerton.

Ecology of pygmy possums in managed forests

B Law

This project is investigating the ecology of the eastern pygmy possum and the impact on the species of logging in forests to provide a scientific underpinning for management of the species. The pre-logging phase was completed at MacPherson State Forest in April 2007 and, after discussions and field inspections with the Department of Environment and Climate Change, logging of the site began in April 2009. Logging is expected to be completed by August 2009 and the post-logging phase of the possum study will begin in 2010.

Managing frogs and reptiles in the forest environment

F Lemckert

Current protective strategies for frogs in selectively logged forests appear to be adequate to protect the target species, based mainly on the ability of frogs to tolerate disturbance to their non-breeding habitats. Most species in eastern New South Wales have enough records in the reserve system to suggest that they are in a good position for their long-term conservation. The effect that climate change may have on this does, however, need to be factored in.

Current monitoring approaches using only relatively few sites are unlikely to detect anything but major changes in frog numbers. Increased replication of monitoring sites is required, including the current program for the northern corroboree frogs, if changes are to be detected in relatively short (1–2 years) periods of time. Site occupancy modelling can provide a more

sensitive means of detecting population changes with minimal survey effort, but its effectiveness depends on the species. Work on the development of effective monitoring programs for frogs is being conducted with Research Scientist Dr Trent Penman.

The ongoing wetter conditions have demonstrated that the frog populations have not suffered severely from the extended drought. Threatened species such as the heath frog and red-crowned toadlet remain in good numbers in the Watagan Mountains. The long-term work on frog monitoring and habitat relationships has culminated in the completion of Frank Lemckert's PhD thesis on the subject (University of Newcastle). The final chapter is a summary of the findings and how they relate to current frog management strategies, concluding that frogs in selectively logged forests appear well capable of surviving under the current regime.

The red-crowned toadlet, one of several threatened species found in the forests of the Hunter Region. Photograph by Mark Chidel.

Work in collaboration with the Federal Department of Environment, Water, Heritage and Arts (DEWHA) has been published on the patterns of frog records in Australia relative to reserves. This work provides specific information on the status and rarity of Australia's frogs, and particularly those in south-eastern Australia. It demonstrated that forest frogs in SE Australia have relatively high levels of reservation and occur in numerous reserves and hence are likely to be well protected under the current system. This work has been favourably received by DEWHA and the Biodiversity and Ecology Program has been engaged to prepare a similar report for a range of other species and groups. A preliminary report including all of the terrestrial vertebrates, butterflies, huntsmen and wolf spiders and dragonflies has also been provided. The final report will be completed by August 2009.

National recovery plan—giant burrowing frog

F Lemckert

The giant burrowing frog (*Heleioporus australiacus*) recovery plan was completed for the Department of Environment and Climate Change. The plan has been passed on to the federal government and should soon be submitted for public comment.

A giant burrowing frog, the subject of a national recovery plan. Photograph by Frank Lemckert.

Giant burrowing frogs can be managed in south-eastern NSW through a diverse strategy that encompasses all land tenures. A local management plan has been developed in the Eden Region to manage this species in light of the research work and recommendations of the plan. Fire is no longer automatically excluded from areas where this species is known, which has been extended to locations on the central coast.

Recommendations have been made to further determine whether there are two species within this group rather than one. Further funding to complete the picture on the genetics of this species is being investigated. This is unlikely to alter any current management strategies.

Wildlife schools

F Lemckert

Senior Research Scientist Frank Lemckert enthrals attendees at the Dorrigo Wildlife School with his stories of epic struggles against tusked frogs. Photograph by Traecey Brassil.

Wildlife schools open to Forest NSW and staff from other agencies provide continuing training in the skills needed to carry out pre-logging survey programs as efficiently as possible. As well, these training sessions promote communication and understanding between Forests NSW and other agencies regarding current forest practices and management knowledge. The opportunity to provide training for staff from the regulatory agency enhances efficient communication and collaboration with Forests NSW.

A golden-crowned snake seen during nocturnal surveys at the most recent wildlife school in Dorrigo. Photograph by Frank Lemckert.

Two “Frog, Bat and Reptile” survey, identification and management courses were run during the year: one at Dorrigo and the other at Kioloa. The courses were attended by Forests NSW staff, Department of Environment and Climate Change staff, members of the Commonwealth Department of the Environment, Water, Heritage and the Arts and a large number of consultants.

Mr Lemckert provided an invited lecture at the annual Animal Care and Ethics Committee members’ conference in April, providing a talk on the wildlife school program. Following from this, a course is being planned in conjunction with the Animal Welfare Unit to demonstrate wildlife survey techniques to members of Animal Care and Ethics Committees. Several members of different Sydney-based committees have expressed interest in attending this course.

A red-bellied black snake, a snake commonly seen during reptile surveys. Photograph by Frank Lemckert.

Published Papers, Reports and Presentations

1. Andersen A.N., **Penman T.D.**, Debas N. and Houadria M. 2009. Ant community responses to experimental fire and logging in a eucalypt forest of south-eastern Australia. *Forest Ecology and Management* **258**: 188–197.
2. Angel, P.L., Nicholas, J.D., **Stone, C.** 2008. Biology of *Creiis lituratus* Frogatt (Hemiptera: Psyllidae), pest on *Eucalyptus dunnii* Maiden in plantations: morphology, life cycle and parasitism. *Australian Forestry* **71**(**4**): 311–316.
3. Barber, P.A., **Carnegie, A.J.**, Burgess, T. I. & Keane, P. K. 2008. Mycosphaerella leaf diseases in *Eucalyptus globulus* plantations and adjacent native forest in the Green Triangle region of Australia. *Australasian Plant Pathology* **37**: 472–481.
4. Barry, K.M., Newnham, G. and **Stone, C.** 2009. Estimation of chlorophyll content in *Eucalyptus globulus* foliage with the leaf reflectance model PROSPECT. *Agricultural and Forest Meteorology*. **149**: 1209–1213.
5. Bridges, R.G. 2009. Effects of logging and burning regimes on overstorey species of dry sclerophyll forest in south eastern NSW. Initial results (1986–2001) from Eden Burning Study Area. *Research Paper No. 42. NSW Department of Primary Industries*: 161pp.
6. **Carnegie A.J.** 2008. A decade of forest health surveillance in Australia: an overview. *Australian Forestry* **71**: 161–163.
7. **Carnegie, A.J.**, **Bi, H**., **Arnold, S.**, Li, Y. and D. Binns. 2009. Distribution, host preference, and impact of parasitic mistletoes (Loranthaceae) in eucalypt plantations in New South Wales, Australia. *Can. J. Bot.* **87**(**1**): 49–63.
8. **Carnegie, A.J.**, Cant, R.G. and **Eldridge, R.H.** 2008. Forest health surveillance in New South Wales, Australia. *Australian Forestry* **71**: 164–176.
9. **Carnegie, A.**, Lawson, S., Smith, T., Pegg, G., **Stone, C.** and McDonald, J. 2008. *Healthy hardwoods—a field guide to pests, diseases and nutritional disorders in subtropical hardwoods*. Forest & Wood Products Australia, Victoria.
10. Cherubini, F., Bird, N.D., **Cowie, A.**, Jungmeier, G., Schlamadinger, B. and Woess-Gallasch, S. 2009. Energy- and greenhouse gas-based LCA of biofuel and bioenergy systems: Key issues, ranges and recommendations. *Resources Conservation & Recycling*. **53**(**8**):434–447.
11. Fischer, J., Stott, J., **Law, B.**, Adams, M. and Forrester, R. 2009. Designing effective habitat studies: quantifying multiple sources of variability in bat activity. *Acta Chiropterologica* **11**: 127–37.
12. Gaunt, J. and **Cowie, A.** 2009. Biochar, greenhouse gas accounting and emissions trading. In: Lehmann J., Stephen J. (eds) *Biochar for environmental management: science and technology*. Earthscan Publ., London, pp. 318–340.
13. Gillespie, G., Roberston, P., Hines, H., **Lemckert, F.** and Hero, J-M. 2008. *Heleioporus australiacus*. Pp 422 In: *Threatened amphibians of the world*. S. N. Stuart, M. Hoffman, J.

S., Chanson, N. A. Cox, R. J. Berridge, P. J. Ramani and B. E. Young (Eds). Lynx Edicions, Barcelona, Spain.

14. Henery, M.L., **Stone, C.** and Foley W.J. 2009. Differential defoliation of *Eucalyptus grandis* arises from indiscriminate oviposition and differential larval survival. *Agricultural and Forest Entomology* **11**: 107–114.

15. Henery, M. L., Walis, I. R., **Stone, C.** and Foley, W. J. 2008. Methyl jasmonate does not induce changes in *Eucalyptus grandis* leaves that alter the effect of constitutive defences on larvae of a specialist herbivore. *Oecologia* **156**: 847–859.

16. Hero, J-M., Gillespie, G., Cogger, H., **Lemckert, F.**, and Roberston, P. 2008. *Litoria aurea;* In: *Threatened amphibians of the world*. S. N. Stuart, M. Hoffman, J. S., Chanson, N. A. Cox, R. J. Berridge, P. J. Ramani and B. E. Young (Eds). Lynx Edicions, Barcelona, Spain, p. 256.

17. Hero, J-M., Gillespie, G., **Lemckert, F.**, Roberston, P. and Littlejohn, M. 2008. *Litoria booroolongensis.;*In: *Threatened amphibians of the world*. S. N. Stuart, M. Hoffman, J. S., Chanson, N. A. Cox, R. J. Berridge, P. J. Ramani and B. E. Young (Eds). Lynx Edicions, Barcelona, Spain, p. 256.

18. Hero, J-M., Gillespie, G., **Lemckert, F.**, Littlejohn, M., Roberston, P., Brereton, R. and Brown, P. 2008. *Litoria raniformis* In: *Threatened amphibians of the world*. S. N. Stuart, M. Hoffman, J. S., Chanson, N. A. Cox, R. J. Berridge, P. J. Ramani and B. E. Young (Eds). Lynx Edicions, Barcelona, Spain, p. 260.

19. Hero, J-M., Gillespie, G., Robertson, P., Littlejohni, M. and **Lemckert, F.** 2008. *Litoria spenceri*. In: *Threatened amphibians of the world*. S. N. Stuart, M. Hoffman, J. S., Chanson, N. A. Cox, R. J. Berridge, P. J. Ramani and B. E. Young (Eds). Lynx Edicions, Barcelona, Spain, p. 261.

20. Hero, J-M., Hines, H., Meyer, E., **Lemckert, F.**, Newell, D. and Clarke, J. 2008. *Litoria brevipalamta*. In: *Threatened amphibians of the world*. S. N. Stuart, M. Hoffman, J. S., Chanson, N. A. Cox, R. J. Berridge, P. J. Ramani and B. E. Young (Eds). Lynx Edicions, Barcelona, Spain, p. 257.

21. Hero, J-M., Hines, H., **Lemckert, F.**, and Roberston, P. 2008. *Litoria castanea*. In: *Threatened amphibians of the world*. S. N. Stuart, M. Hoffman, J. S., Chanson, N. A. Cox, R. J. Berridge, P. J. Ramani and B. E. Young (Eds). Lynx Edicions, Barcelona, Spain, p. 257.

22. Hero, J-M., Hines, H. and **Lemckert, F.** 2008. *Litoria piperata*. In: *Threatened amphibians of the world*. S. N. Stuart, M. Hoffman, J. S., Chanson, N. A. Cox, R. J. Berridge, P. J. Ramani and B. E. Young (Eds). Lynx Edicions, Barcelona, Spain, p. 260.

23. Hero, J-M., **Lemckert, F.**, Gillespie, G., Roberston, P. and Littlejohn, M. 2008. *Heleioporus australiacus*. In: *Threatened amphibians of the world*. S. N. Stuart, M. Hoffman, J. S., Chanson, N. A. Cox, R. J. Berridge, P. J. Ramani and B. E. Young (Eds). Lynx Edicions, Barcelona, Spain, p. 421.

24. Hero, J-M., Gillespie, G., Roberston, P. and **Lemckert, F.** 2008. *Pseudophryne corroboree*. In: *Threatened amphibians of the world*. S. N. Stuart, M. Hoffman, J. S.,

Chanson, N. A. Cox, R. J. Berridge, P. J. Ramani and B. E. Young (Eds). Lynx Edicions, Barcelona, Spain, p. 463.

25. Hero, J-M., Gillespie, G., Roberston, P., **Lemckert, F.** and Littlejohn, M. 2008. *Pseudophryne pengilley*. In: *Threatened amphibians of the world*. S. N. Stuart, M. Hoffman, J. S., Chanson, N. A. Cox, R. J. Berridge, P. J. Ramani and B. E. Young (Eds). Lynx Edicions, Barcelona, Spain, p. 464.
26. Hero, J-M., **Lemckert, F.**, Roberston, P., Cogger, H. and Littlejohn, M. 2008. *Pseudophryne australis*. In: *Threatened amphibians of the world*. S. N. Stuart, M. Hoffman, J. S., Chanson, N. A. Cox, R. J. Berridge, P. J. Ramani and B. E. Young (Eds). Lynx Edicions, Barcelona, Spain, p. 463.
27. Hero, J-M., Richards, S., Alford, R., Allison, A., Bishop, P., Gunther, R., Iskandar, D., Kraus, F., **Lemckert**, **F.**, Menzies, J., Roberts, D. and Tyler, M. 2008. Amphibians of the Australasian Realm. In: *Threatened amphibians of the world*. S. N. Stuart, M. Hoffman, J.S., Chanson, N.A. Cox, R.J. Berridge, P.J. Ramani and B.E. Young (Eds). Lynx Edicions, Barcelona, Spain, pp. 65–73.
28. Hunter, G.C., Crous, P.W., **Carnegie, A. J.**, and Wingfield, M. J. 2009. *Teratosphaeria nubilosa*, a serious leaf disease pathogen of *Eucalyptus* spp. in native and introduced areas. *Molecular Plant Pathology* **10**(**1**): 1-14.
29. Kapambwe M., **Ximenes F.A.,** Keenan R and Vinden P. 2009. Dynamics of carbon stocks in timber in australian residential housing. Prepared for Forest & Wood Products Australia. Project No: PN07.1058, May 2009. Available online at: http://www.fwpa.com.au/Resources/RD/Reports/PN07.1058dynamics_carbon_stocks.pdf?pn=PNA016-0708
30. **Kavanagh, R.** and **Stanton, M.** 2009. Conserving barking owls in the pilliga forests. *Wingspan* **19(2)**, 28–30.
31. **Kent, D.S.** 2008. Distribution and host plant records of *Austroplatypus incompertus* (Schedl) (Coleoptera: Curculionidae: Platypodinae). *Australian Entomologist* **35**(**1**): 1–6.
32. **Kent, D.S.** 2008. The mycangia of the ambrosia beetle, *Austroplatypus incompertus* (Schedl) (Coleoptera: Curculionidae: Platypodinae). *Australian Journal of Entomology* **47**: 9–12.
33. **Law, B.** and **Chidel, M.** 2008. Quantifying the canopy nectar resource and the impact of logging and climate in spotted gum *Corymbia maculata* forests. *Austral Ecology* **33**: 999–1014.
34. **Law, B.**, **Chidel, M.** and Spark, P. 2008. Long range movement of a banded Eastern Falsistrelle *Falsistrellus tasmaniensis. Australasian Bat Society News* **31**: 19–21.
35. **Lemckert, F.** 2008. Observations of above ground calling by the giant burrowing frog (*Heleioporus australiacus*). *Herpetofauna* **38**: 123.
36. **Lemckert, F.**, Rosauer D. and Slatyer, C. 2009. A comparison of Australia's anuran records against the reserve system. *Biodiversity and Conservation* **18**: 1233–1246.
37. Levin, N., McAlpine, C., Phinn, S., Price, B., Pullar, D., **Kavanagh, R.** and **Law B.** 2009. Mapping forest patches and scattered trees from SPOT images and testing their

ecological importance for woodland birds in a fragmented agricultural landscape. *International Journal of Remote Sensing* **30**: 3147–69.

38. McMurtrie, R.E., Norby, R.J., Medlyn, B.E., Dewar, R.C., Pepper, D.A., Reich, P.B. and **Barton, C.V.M.** 2008. Why is plant-growth response to elevated CO_2 amplified when water is limiting, but reduced when nitrogen is limiting? A growth-optimisation hypothesis. *Functional Plant Biology* **35**(**6**): 521–534.
39. Pegg, G.S., O'Dwyer, C., **Carnegie, A.J.**, Burgess, T.I., Wingfield, M.J. and Drenth, A. 2008. *Quambalaria* species associated with plantation and native eucalypts in Australia. *Plant Pathology* **57**: 702–714.
40. Pegg, G.S., Webb, R., **Carnegie, A.J.**, Wingfield, M. J. and Drenth, A. 2009. Infection process of *Quambalaria* spp. on *Corymbia* and *Eucalyptus* species. *Plant Pathology* **58**(**4**): 642–654.
41. **Penman T.D.** 2009. Book review: Community bushfire safety. *Austral Ecology* **34**: 357–357.
42. **Penman T.D.**, Binns D.L. and **Kavanagh R.P.** 2009. Patch-occupancy modelling as a method for monitoring changes in forest floristics: A case study in south-eastern Australia. *Conservation Biology* **23**: 740–749.
43. **Penman T.D.**, Binns D.L., **Shiels R.J., Allen R.M.** and Plummer S.H. 2008. Germination responses of a dry sclerophyll forest soil stored seed bank to fire related cues. *Cunninghamia* **10**: 547–555.
44. **Penman T.D.** and **Lemckert F.L.** 2008. Monitoring the green and golden bell frog: Current problems and an alternative approach. *Australian Zoologist* **34**: 373–378.
45. **Penman T.D.**, **Lemckert F.L.** and Mahony M.J. 2008. Applied conservation management of a threatened forest dependent frog, *Heleioporus australiacus*. *Endangered Species Research* **5**:45–53.
46. **Penman T.D.**, **Lemckert F.L.** and Mahony M.J. 2008. Spatial ecology of the giant burrowing frog (*Heleioporus australiacus*): implications for conservation prescriptions. *Australian Journal of Zoology* **56**: 179–186.
47. **Penman T.D.**, Muir G.W., Magarey E.R. and Burns E.L. 2008. Impact of a chytrid related mortality event on a population of the green and golden bell frog, *Litoria aurea*. *Australian Zoologist* **34**: 314–318.
48. **Penman T.D.** and **Towerton A.L.** 2008. Are soil temperatures during autumn prescribed burning sufficient to trigger germination in fire responsive species? *International Journal of Wildland Fire* **17**: 572–578.
49. Phillott, A.D., Skerratt, L.F., McDonald, K.R., **Lemckert, F.L.**, Hines, H.B., Clarke, J.M., Alford, R.A. & Speare, R. 2008. Toe clipping of anurans for mark-recapture studies: Acceptable if justified. That's what we said! *Herpetological Review* **39**: 149–150.
50. Roff, A., **Turner, R.**, **Stone, C.**, Mitchell, A. and Taylor, G.R. 2008. Hyperspectral remote sensing of vegetation. In: *Methodology manual—imaging spectrometry for natural resources management*. Editors: Mitchell, A. and Taylor, G.R. Cooperative Research Centre for Spatial Information, Melbourne. Pp. 153–210.

51. Slade, C. and **Law, B.** 2008. An experimental test of gating derelict mines to conserve bat roost habitat in south eastern Australia. *Acta Chiropterologica* **10**: 367–376.

52. Smith, S. M., Beattie, A. J., **Kent D.S.** and Stow A. J. 2009. Ploidy of the eusocial beetle *Austroplatypus incompertus* (Schedl) (Coleoptera: Curculionidae) and implications for the evolution of eusociality. *Insectes Sociaux* **56(3)**: 285–288.

53. **Stone, C.**, **Kathuria, A.**, **Carney, C.** and Hunter, J. 2008. Forest canopy health and stand structure associated with bell miners (*Manorina melanophrys*) on the central coast of New South Wales. *Australian Forestry* **71**(**4**): 294–302**.**

54. **Stone, C.**, **Turner R.**, and Verbesselt J. 2008. Integrating plantation health surveillance and wood resource inventory systems using remote sensing. *Australian Forestry* **71**: 245–253.

55. Turner, J., Lambert, M., **Bi, H.** and Jurskis, V. 2008. Long term accumulation of nitrogen in soils of dry mixed eucalypt forest in the absence of fire. *Forest Ecology and Management* **256**: 1133–1143**.**

56. van der Merwe, M.M., **Walker, J**., Ericson, L. and Burdon, J.J. 2008. Coevolution with higher taxonomic host groups within the *Puccinia*/*Uromyces* rust lineage obscured by host jumps. *Mycological Research* **112**: 1387–1408.

57. Van Zwieten, L., **Bhupinderpal-Singh**, Joseph, S., Kimber, S., **Cowie, A.** and Chan, Y. 2009. Biochar reduces emissions of non-CO2 greenhouse gases from soil. In: Lehmann J., Stephen J. (eds), *Biochar for Environmental Management: Science and Technology* . Earthscan Publ., London, pp. 227–249.

58. Van Zwieten L., Kimber, S., Morris, S., Chan, Y.K., Downie, A., Rust, J., Joseph, S., and **Cowie, A.** 2009. Effects of biochar from slow pyrolysis of papermill waste on agronomic performance and soil fertility. *Plant and Soil* doi: 10.1007/s11104-009-0050-x.

59. **Walker, J.**, Shivas, R.G. 2009. *Bibulocystis gloriosa* sp. nov. (*Pucciniales*) on *Caesalpinia scortechinii* in Queensland, with comments on *Spumula caesalpiniae*. *Australasian Plant Pathology* **38**: 29–35.

60. **Ximenes F.A.** and Gardner W.D. 2008. The fate of carbon following the harvest of five commercial forest species in Australia. Proceedings of the Technical Session “Woody biomass utilization: challenges and opportunities”. Forests Products Society 60th International Convention, Newport Beach, California, USA.

Other reports

1. **Carney, C.**, Worsley, P. and **Stone, C.** 2009. *Investigation of object-based image analysis software packages for the delineation of individual tree crowns.* NSW DPI Science & Research Report*.* 32pp.

2. Chan, K.Y., **Cowie, A.**, **Kelly, G.**, **Singh, B.P.** and Slavich, P. 2008. Scoping paper: Soil organic carbon sequestration potential for agriculture in NSW. NSW DPI Science & Research Technical paper.

3. **Eldridge, R.** 2008. *Research and Development Annual Report 2007–08* (Ed.). NSW Department of Primary Industries, Science and Research and Forests NSW. 65pp.

4. **Horwood, M. A.** 2009. Final Report. A trial of baits for controlling termites in power poles. Report prepared for the Energy Networks Association. Power Poles and Crossarms Committee, March 2009.
5. **Kathuria, A.** 2008. Analysis of Audit Data-2008 for Valuation of NSW Conifer Forests: Report submitted to Forest NSW. April 2008, 9pp.
6. **Kent, D.S.** 2008. Psyllids in vegetable crops. *NSW Vegetable IPM Newsletter*, Issue 5 – ISSN 1833-007X, pages 4–6, April 2008, 6 pp.
7. Luo, Q., **Kathuria, A.** and Liu, D. 2009. Sensitivity analysis of NSW wheat cropping to climate change. Proceedings of Greenhouse 2009: Climate Change and Resources. Perth, Australia 23–26, March 2009.
8. Rančić, A., Salas, G., **Kathuria, A.**, Acworth, I., Johnston, W., Smithson, A. and Beale G. 2009. Climatic influence on shallow fractured-rock groundwater systems in the Murray–Darling Basin, NSW. Published by Department of Environment and Climate Change NSW. Available at: http://www.environment.nsw.gov.au/resources/salinity/09108GroundwaterMDB.pdf
9. **Turner, R.** and **Kathuria, A.** 2008. Forest health assessment with satellite multi-spectral imagery in the Gunbower-Koondrook-Perricoota Icon Site (GKPIS) Technical Report, March 2008, 34pp.
10. **Ximenes F.A.,** Kapambwe M. and Keenan R. 2008. Timber use in residential construction and demolition. *BEDP Environment Design Guide*, November, PRO36, 9p. Available at: http://www.environmentdesignguide.net.au/

Conference presentations

1. **Barton, C.V.M.**, Adams, M., Amiji, B., Conroy, J., Duursma, R., Eamus, D., Ellsworth, D., Linder, S., Medlyn, B., Parsby, J., Tissue, D. and McMurtrie, R. 2008. “Hawkesbury Forest Experiment: How will climate change affect Australia’s Forests”. Climate Action Grant Stakeholders Workshop, University of Western Sydney, Oct 2008.
2. **Barton, C.V.M.**, Adams, M., Amiji, B., Conroy, J., Duursma, R., Eamus, D., Ellsworth, D., Linder, S., Löw, M., Medlyn, B., Parsby, J., Tissue, D. and McMurtrie, R. 2008. “Hawkesbury Forest Experiment: Investigating the impacts of impacts of climate change on Australia’s forests”. Ecological Society of Australia, Sydney, Oct 2008.
3. **Barton, C.V.M.**, Littleboy, M. and Mitchell, D. 2009. “Quantifying sub-catchment impacts of tree planting on water yield and quality – Little River”. Knowledge transfer workshop NSW State Level Activity. Sydney, May 2009.
4. **Barton, C.V.M.**, Adams, M., Amiji, B., Conroy, J., Duursma, R., Eamus, D., Ellsworth, D., Linder, S., Löw, M., Medlyn, B., Parsby, J., Tissue, D. and McMurtrie, R. 2009. “Hawkesbury Forest Experiment: Implications of climate change for water use of Australia’s forests”. Forestry and Forest Products Committee, Research Working Group 3 Land and Water Resources, Workshop, Canberra, May 2009.
5. Blundell, A., Clulow, S., Peters, K. and **Kavanagh, R.** 2008. “Distribution, habitat usage and observed behaviour of a southern resident population of the Eastern Grass Owl *Tyto*

longimembris near Newcastle, New South Wales". Australasian Raptor Association National Conference, Coffs Harbour, August 2008.

6. **Cowie, A.** 2008. Invited speaker: "Emissions trading: Opportunities and challenges for forestry". Asia Pacific Forest Industries Climate Change Conference, Sydney, August 2008.
7. **Cowie, A.** 2008. Invited keynote speaker: "Measuring carbon neutrality: *Is my bioenergy system carbon neutral?"* Woodfuel supply chain – sharing the experience. Workshop organised by IEA Bioenergy and the UK Forestry Commission, University of Warwick, September 2008.
8. **Cowie, A.** 2008. Invited speaker: "Soil carbon trading: Lessons learned from forestry". Carbon farming workshop on soil carbon trading, Orange, NSW, September 2008.
9. **Cowie, A.** 2008. Invited keynote speaker: "Science in the marketplace: GHG accounting for emissions trading". Science of forest carbon management conference, organised by the University of Toronto and Pollution Probe, Toronto, Canada, December 2008.
10. **Cowie, A.** 2008. Invited speaker: "Is bioenergy as an effective greenhouse mitigation option?" Realising sustainable bioenergy opportunities for Australia, 2008. Bioenergy Australia conference, Melbourne, 8–10 December 2008.
11. **Cowie, A.** 2009. "Climate change mitigation benefits of biochar as a soil amendment". Digging the dirt on biochar. An online media briefing at http://www.aussmc.org/biochar.php, 4 March 2009.
12. **Cowie, A.** 2009. Invited speaker: "Emissions trading: opportunities and issues for agriculture". Weather, climate and agriculture forum, Lismore, March 2009.
13. **Cowie, A.** 2009. "Direct effects of bioenergy systems on soil carbon". IEA Bioenergy Task 38 workshop. Land use changes due to bioenergy: quantifying and managing climate change and other environmental impacts. Helsinki, 30 March – 1 April 2009.
14. **Cowie, A.** 2009. Invited speaker: "Carbon sequestration: Mitigation opportunities for agriculture". Agriculture Uncovered" workshop. Sydney, 28 April 2009.
15. **Cowie, A.** 2009. "Climate change mitigation benefits of biochar as a soil amendment". Asia Pacific Biochar Conference, Gold Coast, 17–20 May 2009.
16. Clulow, S., Peters, K., Blundell, A. and **Kavanagh, R.** 2008. "Diet of a permanently resident (non-nomadic) population of the Eastern Grass Owl *Tyto longimembris* on the mid-north coast of New South Wales and its relation to seasonality and prey availability". Poster presentation at the Australasian Raptor Association National Conference, Coffs Harbour, August 2008.
17. **Kathuria A.** and **Stone C.** 2008. "Developing an optimal sampling design for pine plantations health data". Poster presented at the Australia Statistical Conference 2008, Melbourne, 30 June – 3 July 2008.
18. **Kavanagh, R.** and **Stanton, M.** 2008. "Population density of barking owls in the Pilliga forests". Australasian Raptor Association National Conference, Coffs Harbour, August 2008.

19. **Kavanagh, R., Stanton, M.** and Johnson-Walker, C. 2008. “Home-range of the Masked Owl on the north coast of NSW”. Poster presentation at the Australasian Raptor Association National Conference, Coffs Harbour, August 2008.
20. **Kavanagh, R., Stanton, M.** and Johnson-Walker, C. 2008. “Diet of the Masked Owl on the north coast of NSW”. Poster presentation at the Australasian Raptor Association National Conference, Coffs Harbour, NSW, August 2008.
21. **Kent, D.S.** and Pilkington L. 2008. “*Orius gracilis* (Hemiptera: Anthocoridae), a potential biocontrol agent for greenhouses in Australia”. Poster presented at the International Organization for Biological Control of Noxious Animals and Plants, Asia and the Pacific Regional Section, Australian and New Zealand Biocontrol Conference. 10th – 14th February 2008, Sydney.
22. **Kent D.S.** and Taylor G. A. 2008. “Not in my back yard! A new species of *Acizzia* Crawford (Hemiptera: Psyllidae) damaging eggplant, *Solanum melongena* L. (Solanaceae) in eastern Australia”. Oral presentation at the 39th Annual General Meeting and Scientific Conference of the Australian Entomological Society. 28th September – 1st October 2008, Orange Agricultural Institute, Orange, NSW.
23. **Law, B.** 2008. “Effects of logging on nectar production”. Annual conference of NSW Apiary Association, Port Stephens, NSW.
24. **Lemckert, F.** and Mahony, M. 2008. “The relationships between habitat and pond use by frogs in NSW”. Spoken presentation in the Herpetological Conservation and Biology Symposium of the 6th World Congress of Herpetology. Manaus, Brazil.
25. **Lemckert, F.** and Brassil, T. 2008. “Improving tree plantings as habitat for reptiles”. Poster presentation at the 6th World Congress of Herpetology. Manaus, Brazil.
26. **Lemckert, F.** 2009. Wildlife Training Schools. Spoken presentation at the 2009 NSW Animal Care and Ethics Committees Annual Conference. North Sydney.
27. **Penman T.**, Christie F., Andersen A., Bradstock R., Cary G., Henderson M., Price O., Tran C., Wardle G., Williams D. and York A. 2008. “Prescribed burning: How can it work to conserve the things we value?” Australasian Fire Association Council annual conference, September 2008, Adelaide.
28. **Penman T.** and Towerton A. 2008. “Soil temperatures during autumn prescribed burns: Are they sufficient to trigger germination in fire responsive species? ” Australasian Fire Association Council annual conference, September 2008, Adelaide.
29. **Penman T.**, Christie F. and Hendersen M. 2008. “Fire and ecology in a changing climate – putting the theory into practice”. Ecological Society of Australia. University of Sydney, December 2008, Sydney.
30. **Penman, T**, Binns D. and **Kavanagh R**. 2009. “Managing fire and biodiversity in dry sclerophyll forests”. NSW Nature Conservation Council Bushfire Conference, June 2008, Sydney.
31. Smith, S. M., Beattie, A. J. **Kent D.S.** and Stowe A. J. 2008. “Ploidy in the eusocial beetle, 2N or not 2N”. Poster presented at the XXIII International Congress of Entomology, July 2008, Durban, South Africa.

32. **Stanton, M.** and **Kavanagh, R.** 2008. “Prey availability may limit barking owl population density”. Australasian Raptor Association National Conference, Coffs Harbour, August 2008.

33. **Stone, C.** and **Turner, R.** 2009. “Estimating tree mortality in *Pinus radiata* plantations from *Ips grandicollis* using high resolution imagery”. International Forest Biosecurity Conference, March 16–20 2009, Rotorua, New Zealand.

34. Todd, M., Munks, S., Hindell, M., Bowman, D., Richardson, A, Bell, P., **Kavanagh, R.** and Taylor, I. 2008. “Habitat use and ecology of the Tasmanian Masked Owl”. Poster presentation at the Australasian Raptor Association National Conference, August 2008, Coffs Harbour, NSW.

35. Verbesselt, J., Culvenor, D., **Carnegie, A.**, **Stone, C.**, Opie, K. & Sims, N. 2008. “Assessing severity of tree mortality in *Pinus radiata* plantations with MODIS time series and aerial survey data”. 14th Annual Australasian Remote Sensing & Photogrammetry Conference, 29 Sept – 30 Oct 2008, Darwin.

36. Verbesselt, J., Newnham, G., Robinson, A., **Stone, C.** and Culvenor, D. 2009. “Using MODIS satellite time-series to detect and forecast changes in forests”. International Unionn of Forest Research Organizations Conference: extending forest inventory and monitoring. May 19-22 2009, Quebec City, Canada.

37. Verbesselt, J., **Stone, C.,** Sims, N., Opie, K., Newham, G. and Culvenor, D. 2008. “Monitoring health of pine plantations by trend and seasonal analysis of MODIS time-series”. 2008 IEEE International and Remote Sensing Symposium. July 6–11, Boston, Massachusetts, USA. Published Proceedings Paper #3986.

38. **Ximenes F.A.** 2008. “Carbon in forest products: market opportunity”. Australian Forest Growers Conference. October 2008, Albury, NSW..

39. **Ximenes F.A.** 2008. “The decomposition of wood products buried for 44 years in a landfill in Sydney, Australia”. Intercontinental Landfill Research Symposium, September 2008, Copper Mountain, Colorado, USA.

40. **Ximenes F.A.** 2008. “Carbon storage in forest products”. Asia-Pacific Forest Industries Climate Change Conference, August 2008, Sydney.

41. **Ximenes F.A.** 2009. “Issues associated with paper disposal in landfills”. Presentation given to the Paper Round Board Meeting, March 2009, Sydney.

42. **Ximenes F.A.** 2009. “Carbon in timber: recent research”. Carbon in timber within a national emissions trading scheme discussion workshop. February 2009, Sydney, NSW, Australia.

43. **Ximenes F.A.** 2009. “The greenhouse implications of using wood products and alternative building materials in the construction of two popular house designs in Sydney”. Sixth Australian Conference on Life Cycle Assessment. February 2009, Melbourne.

Staff List and Location (30 June 2009)

Forest Science Centre

121–131 Oratava Avenue, West Pennant Hills, NSW 2125

PO Box 100, Beecroft, NSW 2119

Telephone 02 9872 0111

Facsimile 02 9871 6941

Anuj	Mr	Narendra	Librarian	9872 0110
Barton	Dr	Craig	Research Scientist, New Forests	9872 0199
Bi	Dr	Huiquan	Principal Research Scientist, New Forests	9872 0168
Brassil	Ms	Traecey	Technical Officer, Forest Biodiversity	9872 0194
Brooks	Mr	Paul	Technical Officer, New Forests	9872 0181
Carnegie	Dr	Angus	Senior Research Scientist, Forest Health	9872 0131
Carney	Ms	Catherine	Technical Officer, Scientific Services	9872 0196
Chidel	Mr	Mark	Technical Officer, Forest Biodiversity	9872 0169
Coburn	Ms	Rebecca	Technical Officer, New Forests	9872 0585
Cowie	**Dr**	**Annette**	**Program Leader, Senior Research Scientist, New Forests**	
Eldridge	**Mr**	**Robert**	**Research Leader, Director, Forest Science Centre**	**9872 0126**
Fortunaso	Ms	Kora	Research Officer, New Forests	
Giles	Mr	David	Technical Officer, New Forests	9872 0141

Horwood	Mr	Martin	Research Officer, Forest Health Management	9872 0149
Johnson	Mr	Christopher	Research Officer, New Forests	
Johnson	Mr	Ian	Research Officer, New Forests	9872 0161
Kathuria	Dr	Amrit	Biometrician, Scientific Services	9872 0146
Kavanagh	**Dr**	**Rod**	**Program Leader, Principal Research Scientist, Forest Biodiversity**	**9872 0160**
Kelly	Dr	Georgina	Research Officer, New Forests	9872 0151
Kent	Dr	Debbie	Project Officer, Forest Health Management	9872 0133
Law	Dr	Brad	Principal Research Scientist, Forest Biodiversity	9872 0162
Lemckert	Mr	Frank	Senior Research Scientist, Forest Biodiversity	9872 0159
Morgan	Dr	Huw	Research Officer, New Forests	
Parekh	Ms	Jagrutee	Technical Officer, New Forests	9872 0140
Penman	Dr	Trent	Research Scientist, Forest Biodiversity	9872 0157
Poon	Ms	Cheryl	Technical Officer, New Forests	9872 0230
Sandhu	Ms	Kamaljeet	Technical Officer, New Forests	9872 0103
Seslija	Ms	Jovanka	Library Technician	9872 0109
Sims	Ms	Kerrie	Technical Officer, Forest Health Management	9872 0167
Singh	Dr	Bhupinderpal	Research Scientist, New Forests	9872 0148
Stanton	Mr	Matthew	Technical Officer, Forest Biodiversity	9872 0182

Stone	**Dr**	**Christine**	**Program Leader, Principal Research Scientist, Forest Health Management**	**9872 0132**
Tornquist	Mr	Steve	Technical Officer, Scientific Services	9872 0158
Towerton	Ms	Alison	Technical Officer, Scientific Services	
Ximenes	Mr	Fabiano	Research Officer, New Forests	9872 0143

Southern Research

13B Bass Street, Eden, NSW 2551

PO Box 273, Eden, NSW 2551

Telephone 02 6496 1500

Facsimile 02 6496 3258

Allen	Ms	Ruth	Field Worker, Forest Biodiversity	6496 1500
Shiels	Mr	Roy	Forest Assistant, Forest Biodiversity	6496 1500

List of Shortened Forms used in the Report

A3P	Australian Plantation and Paper Products and Paper Industry Council
ACIAR	Australian Centre for International Agricultural Research
APPD	Australian Plant Pest Database
As	arsenic
BA	basal area
BMAD	bell miner associated dieback
C	carbon
Cd	cadmium
CMA	Catchment Management Authorities
CO_2	carbon dioxide
CO_2e	carbon dioxide equivalent
CPRS	Carbon Pollution Reduction Scheme
CRC	Cooperative Research Centre
DECC	Department of Environment and Climate Change
DPI	NSW Department of Primary Industries
DWE	NSW Department of Water and Energy
FHSU	Forest Health Survey Unit
FCNI	Forestry Commission of NSW Insect Collection
GGAS	NSW Greenhouse Gas Abatement Scheme
GHG	greenhouse gas
GIS	geographic information system
IPCC	Intergovernmental Panel on Climate Change
LIDAR	light detecting and ranging
MDF	medium density fibreboard
N	Nitrogen
NAP	National Action Plan for Salinity and Water Quality
NHT	National Heritage Trust
N_2O	nitrous oxide
NSCC	National Sirex Coordination Committee.
PAHs	polycyclic aromatic hydrocarbons
Pb	lead
Zn	zinc

Forest Science Centre

121–131 Oratava Avenue, West Pennant Hills NSW 2125
PO Box 100, Beecroft NSW 2119 Australia

Telephone **02 9872 0111** Facsimile 02 9871 6941

www.dpi.nsw.gov.au/forests