CRC for Forestry

Ideas to impact

21 years of forestry innovation

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Ideas to Impact

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CRC AUSTRALIA

Foreword

By Professor Gordon Duff, CEO, Cooperative Research Centre for Forestry

The Cooperative Research Centre (CRC) for Forestry began operating in late 2005 as a 'new from existing' CRC, following the conclusion of operations of the CRC for Sustainable Production Forestry (1997–2005), in turn preceded by the CRC for Temperate Hardwood Forestry (1991–1997). Thus, the successive forestry CRCs are among the longest running in the Australian Government CRC Program. The CRC for Forestry will be wound up during the 2012–2013 financial year, and succeeded by the National Centre for Future Forest Industries.

Over time, the successive CRCs have evolved from a relatively narrow focus on plantation production forestry in temperate Australia, comprising a small number of partners with a majority based in Tasmania, to a broadly based, end user-focused research organisation covering the whole of Australia. In recent years, the CRC has included 31 partners and has delivered research relevant to points ranging along the whole value chain of production forestry including social, environmental and regional–economic considerations.

The CRC for Forestry has been established during a period of significant change and development in the Australian forestry sector. The size of the Australian plantation estate has doubled to 2 million hectares since the CRC for Temperate Hardwood Forestry was established: the increase almost entirely through hardwood plantation establishment. Australian forest industries currently produce a combined annual turnover of $22 billion and employ around 83 000 people directly. Well-managed native forests and plantations provide an additional array of environmental services, including areas of increasing national significance such as biodiversity conservation, carbon sequestration and improved water quality. While these issues were prominent at the time the current CRC was established, they have grown in significance and public profile in recent years, placing even greater national and international significance on the CRC's research outcomes.

The rapid expansion of the plantation estate in Australia since the early 1990s, largely dominated by private sector investment, is beginning to impact significantly on availability of wood from this source, and the harvest is set to accelerate in the next few years. This creates both a challenge and an opportunity for research to contribute to improved risk management, wood quality, harvesting and supply chain efficiency. Demand from the sector for innovation, benchmarking and technology transfer has grown rapidly as more first rotation plantations reach maturity, and the capacity of the CRC to respond has been enthusiastically welcomed by industry partners.

The following pages contain case studies of 13 important CRC innovations. Representing only a small sample of the many outstanding achievements of the three forestry CRCs, they include:

- the Blue gum Productivity Optimisation System, which has helped plantation managers assess the potential performance of plantations on a range of sites
- the portable near-infrared scanner that predicts cheaply and accurately the commercial value of a tree
- new silvicultural options developed for producing plantation sawlogs
- groundbreaking research to help minimise the risks of genetic contamination in native forests from nearby plantations
- tools enabling the industry to meet its obligation to manage community expectations through engagement and consultation.

Each of these significant innovations demonstrates the forestry CRCs' capacity to deliver world-class research outcomes that enhance the industry's profitability and sustainability. More information about these and many other CRC outputs can be found at http://www.crcforestry.com.au/

Research training is arguably the most important legacy of successive CRCs. Since 1991, more than 170 research students have graduated from CRC-supported PhD and Masters by Research programs. Many of these graduates occupy key positions in the Australian forest and wood products sector today, in business, government and academia. In this way, the forestry CRCs have profoundly shaped the capacity of the sector, and have helped position Australia as a world leader in forestry and wood products innovation.

I am proud and privileged to have been associated with this organisation over the past six years. Through the innovations identified in this small volume, and many others besides, the CRC for Forestry and its predecessor organisations have established a legacy that reflects on the hard work, dedication and ingenuity of the many people who have contributed over the past 21 years.

NIR—taking technology to the trees

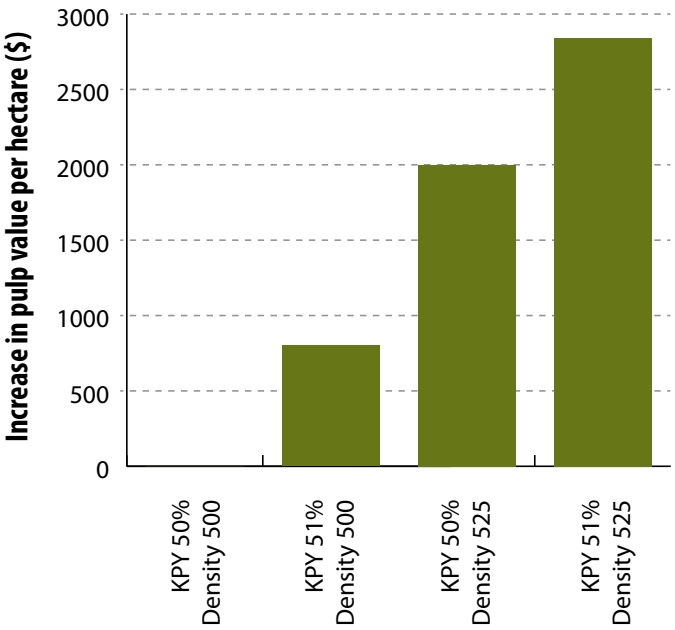
CRC for Forestry research is providing forest managers with a fast, affordable way to measure valuable wood properties.

Measuring internal wood properties is an important activity that helps forest managers gather information about the likely commercial value of a tree. Traditionally, analysing properties such as pulp yield involves expensive and time-consuming laboratory testing; each lab analysis costs around $1000 per sample and requires five kilograms of dry woodchips.

By contrast, using near-infrared (NIR) scanning reduces costs to as little as $2.50 per sample. It also uses much smaller samples extracted from standing trees, making the process easier on the pocket, and on the back!

Portable NIR scanning is an affordable way for forest managers to obtain fast, non-destructive measures of pulp yield in plantation eucalypts. It has been used for some time in agricultural and pharmaceutical industries, but has only recently been adapted for field use in the forestry industry.

CRC for Forestry (CRCF) researcher Dr Geoff Downes and his colleagues have conducted extensive tests using commercially available, hand-held NIR devices such as the Polychromix Phazir™, with assistance from industry partners.



Financial gain from increasing wood value per hectare with a merchantable volume of 200 m³. The first column is the reference. The second column shows gain from a 1% increase in kraft pulp yield (KPY). The third measures gain from an increase in wood density by 25 kg every cubic metre. The fourth column shows gain assuming a 1% increase in KPY and a 25kg increase in wood density.

They have developed calibrations that allow measurement of commercially important wood properties such as cellulose content, Kraft pulp yield and basic density in standing trees cheaply, quickly and using small samples that minimise damage to living trees.

The technology can help forest growers to select the best genotypes for breeding, and to evaluate their forests where they stand to manage the wood to meet customer specifications.

"Increasing Kraft pulp yield by an average of one per cent, in a mill processing four million green tonnes of woodchips per year, represents more than $15 million of extra pulp at current prices," Geoff said.

"This increase could be achieved through breeding and management."

Developing calibrations to measure wood density, moisture content, stiffness and other valuable wood properties can further enhance the benefits of NIR.

"The model is a starting point for the development of a more broadly based calibration, representing more sites and species, which will allow our industry partners to gain experience and confidence in the technology," Geoff said.

Most Australian pulpwood growers currently sell their product as bone dry mass; although some supply Australian pulp mills that place a premium on wood with high percentage pulp yield.

NIR can also be used to estimate cellulose content, which is especially useful for applications such as breeding and detailed resource assessment that require non-destructive determination for many samples.

Cellulose content can be analysed chemically on smaller ground wood meal samples but the cost is around $60 per determination. Pulp yield and cellulose content are very closely correlated, enabling NIR-estimated cellulose content to be used as a proxy for laboratory pulp yield.

Based on extensive testing, the accurate and precise prediction of cellulose content in eucalypt wood meal is now possible, markedly reducing analysis costs and time. CRCF members have been given access to the cellulose calibration and many members have been provided with measurements of cellulose content.

As the CRCF winds up, analytical services using this technology will be available through Forest Quality, a spin-off company emerging from this project.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FastTRUCK—optimising forest transportation

The FastTRUCK software system, developed by CRC for Forestry researchers, provides a way for the industry to improve transport planning and reduce costs.

Transporting wood from coupes to mills costs the Australian forestry industry $1.2 million a day. In order to reduce these costs, CRC for Forestry (CRCF) researchers developed FastTRUCK—a software system that provides a way for the industry to improve transport planning, thereby reducing transport costs by up to 10 per cent.

Initially created to support optimisation of forest transport for in-field chipping, FastTRUCK has now expanded to include log producing operations.

The software enables forestry companies to identify and reduce costs across the entire planning spectrum, by modelling their operations, wood flows and constraints. It can be used for daily dispatching of trucks, from harvest locations to mills; haulage contract design; fleet configuration on a monthly or annual basis; and even enhancing the performance of outsourced dispatching operations.

One of the tool's great strengths is that it can be used to explore tactical 'what-if' scenarios ahead of time. It also makes it easier for managers to dispatch trucks on a daily basis, by providing a plan for operations at the start of the day, while being flexible enough to be revised during the day when requirements or constraints change.

Some of the companies involved in trials of the software are now considering moves to centrally dispatched operations, on the strength of FastTRUCK efficiency gains. Other companies are using the software on a weekly and daily basis for more efficient fleet planning.

Work completed with one company's decentralised truck fleet operation has enabled it to re-engineer its transport haulage contracts, with 20 per cent fewer trucks, while meeting delivery demands more reliably. In another company, preliminary modelling has illustrated that cost savings of around 10 per cent are achievable when the software is used as decision support to human schedulers during planning operations.

The in-field chipping version of the tool was completed in 2010–11 and attracted the interest of companies in both Australia and Europe. As a result of its early success, collaborative support has been provided to help adapt the tool to effectively include biomass as one of the products in the transport optimisation.

Further development of FastTRUCK will continue to make it more broadly applicable for a wider range of operational types and conditions. Having proven the merits of using tailored software to enhance transport operation planning, researchers envisage that the approach is transferable to other industries reliant on trucks as the primary mode of transport.

One of the tool's great strengths is that it can be used to explore tactical 'what-if' scenarios ahead of time. It also makes it easier for managers to dispatch trucks on a daily basis.

Computer on board—getting the most out of forest machinery

Harvesting and haulage are priorities for the forestry industry, as they account for some of the highest costs in the forest supply chain. With onboard computers known to increase productivity, the CRC for Forestry produced a guide to help select and implement onboard systems, offering opportunities for efficiency gains and cost savings.

As forest operations have become increasingly mechanised over recent decades, they have also become more capital-intensive and more complex to manage. International experience in forest harvesting and in related industries has shown significant savings can be made by using onboard computers to get expensive equipment working more effectively. Onboard computers work by identifying inefficiencies and areas for improvement, faster and more accurately than through human observation alone.

However, onboard computers are considerably underutilised in forest machines in Australia, compared with other countries where forestry is a major industry, largely because of a lack of information for machine owners.

The handbook *Enhancing forest machine efficiency: onboard computer selection and implementation guide* was written by CRC for Forestry (CRCF) staff and produced with the support of Forest and Wood Products Australia (FWPA). The guide gives machine owners access to effective information on what computers are available and which are best suited to different operational needs under Australian conditions. It is based on more than a year of testing the range of available onboard computer types in three major field trials, as well as a number of smaller trials and shared international experience.

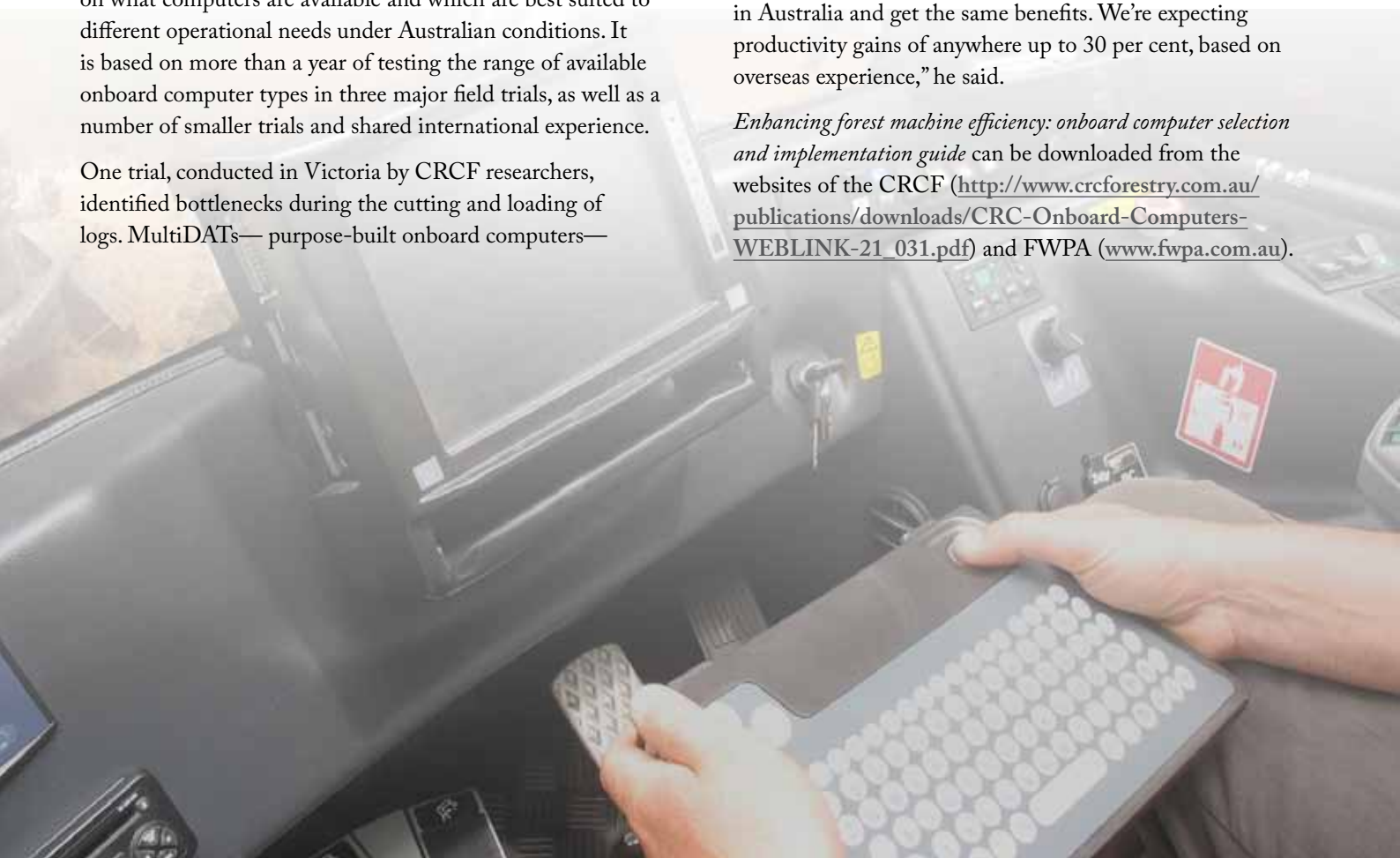
One trial, conducted in Victoria by CRCF researchers, identified bottlenecks during the cutting and loading of logs. MultiDATs— purpose-built onboard computers— were installed and used in a feller-buncher, skidder and an excavator during harvesting in Victoria's Central Highlands. Discussion of the trial results led to two changes: firstly, trucks were loaded completely before load details were recorded, instead of details being taken log by log; secondly and more significantly, responsibility for log loading was shifted to the truck drivers, using a spare excavator that was available during the operation.

This increased the time available to process logs by several hours a day, resulting in a significant increase in log output from the landing and an estimated 30 per cent increase in utilisation of the feller-buncher and skidder. The research shows these changes could result in operational cost savings of an estimated $100 000 a year.

"There has been effective use of onboard computers internationally, but they haven't been used to any great extent in Australia," CRCF researcher Martin Strandgard said.

"We felt we should be able to apply the same technology in Australia and get the same benefits. We're expecting productivity gains of anywhere up to 30 per cent, based on overseas experience," he said.

Enhancing forest machine efficiency: onboard computer selection and implementation guide can be downloaded from the websites of the CRCF (http://www.crcforestry.com.au/publications/downloads/CRC-Onboard-Computers-WEBLINK-21_031.pdf) and FWPA (www.fwpa.com.au).



IPMG—taking the fight to pests

The Industry Pest Management Group has broken new ground in efforts to improve the collection of pest and disease data across the forestry industry.

Initially established in 1998 to support the Western Australian plantation industry, the Industry Pest Management Group (IPMG) became a CRC for Forestry (CRCF) project in 2006. It has since expanded its research and services to other Australian regions and to pests and diseases of a variety of tree species.

CRCF research scientist, Francisco Tovar, says the IPMG provides technical support through an insect and fungal identification service and enhances information sharing and collaboration among its members through workshops and field days.

"We also conduct applied research into alternative pest management methods such as the use of biological controls, biopesticides, silvicultural techniques, varietal selection and improved selective chemical controls," Francisco said.

More recently, the IPMG has embarked on a research strategy to improve the collection, analysis and dissemination of baseline plantation health data. In the past, the lack of these data has impeded sound management decisions and the development of risk-based approaches towards pest management. Robust plantation health data are essential in the face of the increasing risks posed by emerging pests and diseases, declining rotational productivity and climate change.

Recent highlights include the release of:

- **An industry pest information website (2010)**—this website aims to deliver information on plantation pests and diseases in a more timely and accessible way. The website can be found at http://plantationhealth.com.au/index.htm
- **A mobile device software application (2011)**—the application, known as IPMG Plantation Health (IPH), was designed by Francisco in collaboration with Nicolas Garel from the CRC for National Plant Biosecurity. It allows foresters to quickly and accurately record pest and disease outbreak information in the field on their mobile devices. The information can then be uploaded to a database, allowing the industry and researchers to access accurate, auditable and georeferenced data. This could then serve to address any number of biosecurity and plantation health issues.
- **A '*Eucalpytus globulus* pests and diseases field guide'** (to be released later in 2012)—this guide aims to help foresters correctly identify potentially damaging agents at their plantations.

"Overall, the IPMG is involved in a wide number of projects with the broader aim of helping the plantation industry to reduce any losses caused by pests and diseases in an economical yet sustainable manner," Francisco said.

BPOS…is a compelling demonstration of the CRCF's ability to provide world-class decision support tools for industry users, which allow them to enhance their competitive edge in the world market.

BPOS—planning for productivity

A computer-based decision support tool developed by the CRC for Forestry will substantially improve plantation managers' capacity to forecast productivity and evaluate risk across the Australian plantation blue gum estate.

Predicting plantation productivity is a complex task, involving a range of variables including management, local climate and soil quality. During 2010–11, the CRC for Forestry (CRCF) released a new decision support tool to industry partners. The Blue gum Productivity Optimisation System (BPOS) can help forest managers to plan for variations in market settings, climate and site characteristics.

BPOS is a web-based decision support system that synthesises complex growth and nutrition models for blue gum (*Eucalyptus globulus*) in southern Australia. The underlying database is built using CABALA (CArbon BALAnce)—a process-based model for predicting forest productivity, which is designed to support management of plantations and forests.

BPOS combines CABALA outputs generated by an expert user/developer with site-specific information from the forest grower including soils, climate and nutrition. It provides an easy-to-use framework for exploring a range of silvicultural options, such as growth responses to fertiliser application, as well as economic viability modelling.

CRCF Program Manager Dr Don White says BPOS allows users to put in their own data. "BPOS users can run 'what if' scenarios, helping them make decisions about site selection, fertiliser regime and harvest timing, as well as helping them plan for climatic variability, variation in rainfall and for uncertainty about site characteristics," Don said.

The CRCF began road-testing the beta version of BPOS during 2009–10, and it was released to industry partners in June 2011, incorporating feedback from industry users. CRCF partners can access BPOS through a password-protected internet site. The economic and growth information entered by users remains confidential. Availability of the tool via the internet allows new research results to be fed into BPOS continually so that up-to-date research outcomes are readily accessible to end users.

Since its release, BPOS has triggered strong interest from industry partners, and the CRCF has provided ongoing training for forest managers. The tool is a compelling demonstration of the CRCF's ability to provide world-class decision support tools for industry users, which allow them to enhance their competitive edge in the world market.

The initial success of the tool has generated enthusiasm for applying the approach to several other important species and regimes. The development of FPOS (Forest Productivity Optimisation System) has already begun under the auspices of the CRCF. FPOS will extend the BPOS decision support system in several key areas, including five additional species, future climates and different product types. This work is funded by Forest and Wood Products Australia, which has established a steering committee and will manage the product release in 2013.

Variable retention silviculture—maximising biodiversity benefits

Research by the CRC for Forestry on the biodiversity impacts of alternative silvicultural regimes in Tasmanian wet eucalypt forests has led to improvements in operations and coupe design, to maximise biodiversity benefits without compromising silvicultural outcomes.

The design of harvesting systems can be guided by the natural disturbance regime, which in Tasmania's lowland wet eucalypt forests is infrequent, intense wildfire. Clearfell, burn and sow silviculture has been used since the 1960s for harvesting these forests but while this system is practical and effectively regenerates eucalypts in harvested coupes, it is predicted to lead to losses at the coupe level of late successional species (slow-growing, shade-tolerant species with fewer seeds and less seed dispersal) and structures that would survive into stands regenerating after natural wildfire.

The CRC for Forestry (CRCF) has synthesised a decade of studies on the biodiversity impacts of alternative silvicultural regimes in Tasmanian wet eucalypt forests.

The results demonstrate that the variable retention approach is an effective alternative to traditional clearfelling, as it maintains mature forest elements across diverse groups of organisms. In contrast to clearfelling, variable retention has the explicit ecological goal of maintaining some species, habitats and structural legacies from the pre-harvest forest into the harvested and regenerating stand, while meeting timber production objectives and maintaining the social licence to harvest these forests.

Retention forestry is now the global standard for best practice when harvesting native forests. The recognition by industry that biodiversity conservation requires more than a system of reserves has led to the need to consider the outcomes of land management actions, such as timber harvesting, in the matrix land outside reserves. Therefore, variable retention silviculture is being implemented as an alternative to clearfelling in wet old-growth forest on public land (state forest) in Tasmania.

As a result of the CRCF's work, a range of operational measurements has been identified to assess mature forest influence, retention and habitat/connectivity to monitor the success of the operational rollout of variable retention silviculture in Tasmania across more than 50 coupes; these have been used to guide improvements in operations and coupe design.

The CRCF's research also highlighted the value of variable retention as a means of providing a supply of mature trees that produce coarse woody debris—a critical habitat for many forest-dependent species. This research has led to the development of prescriptions for managing coarse woody debris in harvesting operations. These prescriptions are a valuable way of safeguarding biodiversity if proposals to harvest forestry debris for energy come to fruition.

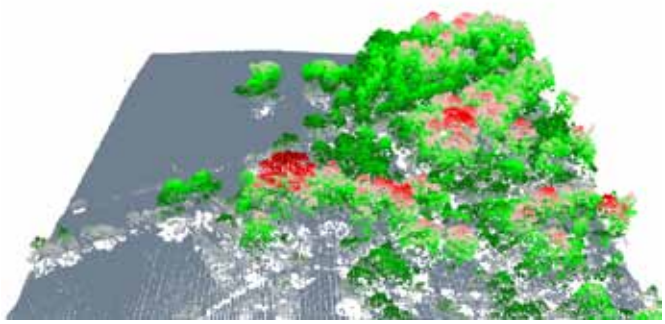
Further demonstrating its commitment to biodiversity through science, the CRC co-invested with the Tasmanian Forest Practices Authority (FPA) in the upgrade of the Threatened Fauna Adviser (TFA).

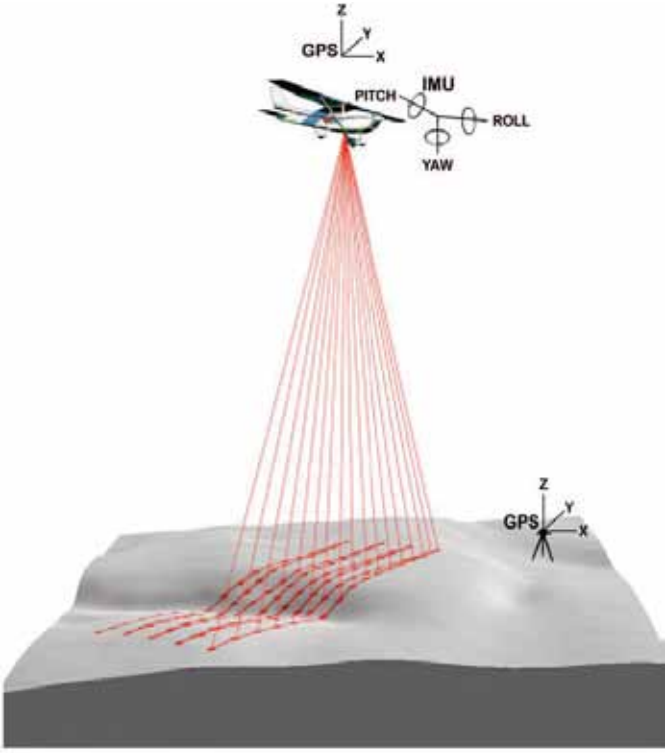
The TFA is a computer-based expert system used in the development of forest practices plans throughout Tasmania. It acts as a conduit, enabling biodiversity research results to be considered during forestry planning decisions. The TFA includes information about various listed forest species, such as the Tasmanian devil and the Lake Fenton trapdoor spider, as well as some grassland and near-coastal species.

Although the TFA delivers mainly operational level management recommendations within the coupe, it also delivers strategic advice on some species. Variable retention has provided the FPA with an alternative tool for threatened species management.

LiDAR—measuring forests remotely

LiDAR is a remote sensing technology with many applications in the management of forests and forested landscapes. The CRC for Forestry has played a leading role in applying LiDAR technology to forest management.





LiDAR (light detection and ranging) uses optical remote-sensing technology that emits and detects returns of high-speed laser pulses, to generate three-dimensional data about objects including terrain or landscape features and vegetation. In forestry, airborne LiDAR technology is widely used to develop reliable maps or models of the terrain beneath the forest (for example, for locating water sources, designing drainage, or planning roads or harvesting). This information has traditionally been based on information obtained in time-consuming and costly surveys, conducted by people on the ground, which provided much less accurate and detailed information.

CRC for Forestry (CRCF) researchers have developed protocols to optimise LiDAR data capture, and methods to allow forest managers to easily and quickly extract and use the relevant parts of the huge amounts of information obtained via this technology. Although the potential for application of LiDAR in forest management is enormous, until recently, it has been limited by the cost of data acquisition and the need for efficient and practical tools for forestry applications.

While the cost of LiDAR is decreasing, it remains significant and it is, therefore, important to make as much use of the data as possible. CRCF researchers have taken a leading role in developing commercial applications of LiDAR in forestry. The CRCF developed ForestSensing4—software that extracts tree metrics (such as height) from LiDAR data. As well as being used by industry partners, the software has been approved for release on the 'Comprehensive R Archive Network'—CRAN. This means that the outputs will continue to be available for improvement and application well beyond the life of the current CRCF.

In 2008, Forestry Tasmania undertook an operational trial to collect airborne LiDAR data over 32 000 hectares. The results provided a persuasive business case that has subsequently led to the acquisition of LiDAR data across most state forests in Tasmania.

The trial led to a major change in the way inventory and mapping of forest operations is undertaken. This, in turn, resulted in improvements in strategic and field planning, as well as enhanced corporate capacity to undertake commercial LiDAR services on behalf of other forestry organisations. The trial identified projected annual savings to forest managers of an estimated $525 000.

This project highlights the importance of successful knowledge transfer, with the CRCF providing a trained researcher to undertake an ongoing role within industry.

Further promising research topics have been identified in areas including:

- LiDAR-derived image classification for forest structure mapping
- cost-effective spot LiDAR data acquisition technologies such as unmanned aerial vehicles
- cost-effective alternatives for subsequent capture of dynamic forest metrics to update LiDAR-derived information.

Forestry Tasmania's estate-wide LiDAR data acquisition and active development of operational LiDAR procedures provide an ideal research opportunity in these areas.

Engaging the community—practical guidance for forest managers

Managing community expectations through engagement and consultation is a key part of modern forest management. To help the industry meet this obligation, the CRC for Forestry has published a handbook offering practical guidance for forest managers on undertaking successful and effective community engagement.

Community engagement (CE) refers to an array of participatory techniques that improve broad engagement in decision-making. CE is an important part of achieving a 'social licence' for forestry activities, and includes processes whereby individuals are given an opportunity to observe or learn about the decision-making process, to input their views, or to play an active role. Increasingly, many stakeholders at a local, regional and national level want to be involved and informed about forestry planning and management. Effective CE can be challenging and the CRC for Forestry's (CRCF) Communities project undertook essential research that led to the development of improved engagement processes.

In 2011, the CRCF published a handbook to help Australian forest managers cultivate the best possible relationship with the communities in which they operate. The *Handbook for operational community engagement within Australian plantation forest management* provides a comprehensive overview of the underlying principles and concepts of CE, as well as practical guidance about how to undertake engagement, using real-world case studies. The handbook provides advice on how to navigate the complexities of working with communities to achieve the 'social licence' required for sustainable forestry activities.

The handbook offers several benefits, including:

- improved understanding and implementation of CE
- encourages improved approaches to CE and helps to redesign communication-based corporate policies and procedures
- improved CE helps to reduce social conflict and promote sustainable forest management practices that suit the community and forest management.

The current regulatory environment and increasing public scrutiny of forest management practices, policies and priorities have helped make CE standard practice for forest managers. The frequency and range of engagement activities required of the modern forest manager make it vital that they have a thorough understanding of CE.

"We recognise that CE can be difficult," said the handbook's lead author, Dr Melanie (Lain) Dare. "This handbook can help forest managers carefully design processes to reduce these difficulties through increased CE awareness and skill levels."

The handbook encourages a holistic approach, focusing on engagement tools and techniques but also on the social principles underlying the engagement process.

"Rather than rely on quick fixes, proper CE design, implementation and follow-up will help improve a forest management organisation's engagement processes as well as its relationships with communities," Lain said.

While the handbook is aimed at commercial plantation forest management, the concepts presented are also relevant for other resource managers and strategic engagement processes.

The handbook can be downloaded from the CRCF website at http://www.crcforestry.com.au/publications/downloads/CRCForestry-CE-FINAL.pdf

The current regulatory environment and increasing public scrutiny of forest management practices, policies and priorities have helped make CE standard practice for forest managers.

MODIS—faster, cheaper forest health surveillance

The CRC for Forestry has developed a remote-sensing product that provides industry partners with free, broad-scale forest health surveillance technologies. A simple user interface facilitates industry uptake and allows forest health to be office-monitored, effectively in real time, increasing monitoring and reducing field costs.

Australian plantation managers have varying approaches to forest surveillance, ranging from systematic helicopter surveys on a three to five year cycle, 'sentinel' plots for early warning of pest and disease outbreaks, or informal observations from field staff. In all cases, there is value to be gained from more targeted deployment of field staff to check 'hot spots' of change.

The CRC for Forestry has developed a remote-sensing product that uses data acquired from the MODIS (MODerate-resolution Imaging Spectroradiometer) satellite to detect changes in forest condition. The Forest Health Surveillance Tool is web-based and comprises BFAST, which detects short-term disturbance events, or 'break points', where rapid change is affecting the health of forests; and the Seasonal Trend Decomposition tool, which provides a picture of long-term trends, without which break points cannot be established.

Forest managers can access the Forest Health Surveillance Tool online and use it to get information about where changes to forest condition have occurred in their estate, allowing further, more detailed investigation and, if warranted, an appropriate management response. The tool provides easy access to satellite images on a weekly or fortnightly basis and delivers optimum deployment of forest health surveillance resources. Among the benefits are reduced staff costs and more effective use of staff time, along with earlier identification of decline events and more successful plantation remediation following decline events.

The Forest Health Surveillance Tool can also help maintain viable industries by providing more sustainable management and can help improve understanding of pest and disease outbreaks, and the impacts of climate, through retrospective analysis of satellite time series.

Annual cost savings to forest managers are estimated at $2 million a year across the national plantation estate. The benefits of early response for long-term plantation productivity are more difficult to quantify but are potentially very large.

…research into…gene flow in Australia constitutes one of the rare exceptions to the general lack of research worldwide into the genetic risks posed by large-scale commercial forestry.

Safeguarding native forests from gene flow

The impact of eucalypt plantations on adjacent native forest of high conservation value is one of the many environmental issues that concerns forest managers. The CRCs for Forestry and Sustainable Production Forestry have been at the forefront of global research into the risks of genetic contamination of native forests by locally exotic plantation species.

Forestry plantations in Australia are often established with locally exotic eucalypt species. For example, the shining gum (*Eucalyptus nitens*) is not native to Tasmania and the blue gum (*Eucalyptus globulus*) is not native to Western Australia or the Green Triangle, but both are widely grown in these areas.

CRC for Forestry (CRCF) research in this field has focused mainly on the flow of pollen from eucalypt plantations to native eucalypts, which can lead to hybridisation and the contamination of the native species' gene pools. As noted in the academic journal *Trends in Ecology and Evolution*, research into such gene flow in Australia constitutes one of the rare exceptions to the general lack of research worldwide into the genetic risks posed by large-scale commercial forestry. A large amount of this Australian effort can be attributed to projects undertaken by the CRCF and the CRC for Sustainable Production Forestry (CRC-SPF).

The focus on pollen follows past research, showing that the distance over which eucalypt seeds are dispersed is relatively restricted, compared with pollen dispersal. This is because most eucalypts do not have specialised mechanisms for seed dispersal, whereas the pollen is actively dispersed by the many mammals, birds and insects that feed from the eucalypt flowers.

Forests have their own natural protective mechanisms against hybridisation. Barriers, such as flowering time differences and cross-incompatibility, reduce the chances of cross-pollination of native species. However, this is not always the case, especially when related species are involved. In Tasmania, the genetic risks are monitored carefully as *E. nitens* plantations now cover more than 200 000 hectares of land. This non-native eucalypt will potentially hybridise with local eucalypt species from the same subgenus.

In a collaborative effort with the Tasmanian Forest Practices Association (FPA) and several forest companies, the CRC-SPF and its successor, the CRCF conducted research over a decade into the probability of gene flow and cross-pollination of plantation eucalypt species with native forest trees.

CRC Program Manager, Professor Brad Potts, has been involved with the genetic-risk assessment since it began in 1999. He describes the effort as "long-term environmental due diligence".

"The consequences won't be determined for generations to come, but our studies have shown that cross-pollination is occurring with some native species," said Brad. "Our focus is on identifying the high conservation value forests most at risk and determining whether hybrids produced will actually survive to reproductive maturity in nature."

Research by the forestry CRCs has shown that the hybrids studied to date in native forests are not as competitive as the native species and have a reduced chance of surviving to reproductive maturity. These inherent barriers can also be supplemented with measures such as buffer zones between plantations and native forests.

The CRCF developed protocols for assessing the genetic risk, which have been incorporated into a risk assessment program overseen by the FPA. Successes include identification of a stand of the rare spinning gum (*Eucalyptus perriniana*) in Tasmania as being at high risk from planned *E. nitens* plantations.

The research has been expanded to include *E. globulus* plantations in Victoria, South Australia and Western Australia, where both hybrids and seed-dispersed wildlings are being studied in a Forest and Wood Products Australia-funded PhD project.

"Our procedures identify and rank risks, and can help forest planners to decide where to locate plantations or determine whether monitoring is required," said Brad.

Due to their high conservation value, rare and threatened eucalypt species are an obvious high priority for assessment.

Using electronic distributional data, the CRCF has now assessed the genetic risk posed to all of Australia's rare eucalypts from industrial eucalypt plantations in Australia. Only three of the 80 rare species of eucalypts in Australia were sufficiently close to plantations to warrant further investigation.

In addition to the risk assessment programs, the CRCF has set up a long-term gene flow monitoring project in the high-risk area identified in Tasmania. Five years of records have been collected to provide baseline data to test risk predictions as the level of flowering increases in the surrounding plantation.

The three successive forestry CRCs have provided world-class research since the early 1990s…this has contributed to the establishment of what is regarded as one of the best tree breeding programs in the world.

Establishing a world-leading tree breeding program

Research by the CRC for Forestry and its predecessors has helped create what is regarded as one of the world's best tree breeding programs.

As Australia makes the transition away from native forest hardwoods to a young plantation-grown resource, the industry faces some notable challenges: among them, how to breed plantation species for high quality timber and paper products while remaining competitive in international markets. The three successive forestry CRCs have provided world-class research since the early 1990s, geared towards breeding the most profitable timber. This has contributed to the establishment of what is regarded as one of the best tree breeding programs in the world.

Under the CRCs for Temperate Hardwood Forestry and Sustainable Production Forestry, researchers worked with the Southern Tree Breeding Association (STBA), to establish its national *Eucalyptus globulus* breeding program.

Their analysis of breeding trials conducted by STBA partners enhanced the efficiency of breeding and helped to ensure that genetic gains were rapidly and efficiently transferred to Australia's expanding plantation estate. This provided the foundation for early work on wood properties for pulpwood and the definition of breeding objectives aimed at maximising profits. The forestry CRCs supported the STBA's development of an industrial-scale genetic evaluation system called TREEPLAN®.

Research by forestry CRCs has improved methods of assessing wood density in breeding programs. Economic analysis of pilodyn pin penetration (an indirect measure of wood density) has shown that using this technique in a breeding program could significantly boost plantation value. Measuring density by taking wood cores has been found to produce similar additional increases in value.

Research was also conducted to identify native forest geographic areas of high genetic value for plantation growers, which led to a classification of natural forest areas, used by STBA members to target seed collection programs for plantation establishment. The classification has been used to improve the prediction of genetic value, and to capture the genetic diversity of this internationally important forest tree gene pool.

As a CRC quantitative geneticist, Dr Greg Dutkowski worked closely with the STBA on analysis of data from breeding trials. He later joined the STBA Board where he continued to provide specialist support, and is now with PlantPlan Genetics, an STBA spin-off company that provides genetic evaluation and advisory services in tree and plant improvement.

"This tree breeding program is very sophisticated because of its solid research base, good analytical techniques, solid economic objectives, and the integration of genetic resources nationwide," said Greg. "This is probably the best *E. globulus* breeding program in the world, and research by the forestry CRCs has been an important factor in its success."

Greg says lessons learnt from the project are being applied to smaller, short-rotation crops such as potatoes.

Managing plantations for sawlog production

As the forestry industry becomes more reliant on plantation-grown resources, the CRC for Forestry and its predecessors have delivered important research outcomes to assist the transition away from native forest hardwoods.

Since European settlement, Australia has relied primarily on its native-forest resources to meet demand for hardwood sawlogs. The 1980s saw the start of concerted campaigns against logging in native forests and the first Commonwealth-funded program in Tasmania to grow sawlogs from temperate eucalypts in plantations. This and two other programs led to the establishment by Forestry Tasmania of a 40 000 hectare plantation sawlog estate, consisting of *Eucalyptus nitens* and *E. globulus*.

More than 20 years later, pressure against harvesting native forests has intensified. Research by the three successive forestry CRCs has justified the initial decision to invest in the development of secure silvicultural systems for replacing at least part of this resource with plantations. CRC for Forestry researchers have also been involved in work on solid wood production from eucalypts in northern New South Wales and southern Queensland, leading efforts to examine the potential to develop silvicultural systems for a range of subtropical species.

Research by the forestry CRCs goes back to the early 1990s, when there was little expertise in managing eucalypt plantation trees for sawlogs. The CRC for Temperate Hardwood Forestry was asked to provide strategic research into how to maximise sawlog yield from plantations.

At that time, the industry was accustomed to using large log sizes. Growing these logs in plantations was a challenge; the industry goal was to produce a 50 centimetre diameter sawlog in about 25 years—around half the time it takes in native forests.

Producing clear or knot-free wood was essential and it was important to make sure the trees grew straight, as happens in densely populated native forests. To realise the required stem size and quality at harvest, it was first necessary to plant at least 1000 stems/ha until a potential sawlog of six metres in length had formed, followed by pruning, then thinning back to a final stocking. The CRC for Temperate Hardwood Forestry's first challenge was to find the most effective way to prune the branches.

To ensure dead knots were not trapped inside the log, living branches had to be pruned, at the risk of removing the trees' potential to grow. CRC researcher Dr Libby Pinkard developed a thorough understanding of how the leaf area and photosynthetic activity of the various parts of the tree crown contribute to growth and how this changes when the trees are pruned. A key finding was that pruning stimulates compensatory responses that enhance the capacity of trees to grow and provide foresters with a mechanism for preventing significant reductions in growth.

The next step was to examine physiological responses to thinning. CRC researcher Dr Jane Medhurst noted the importance of enhanced photosynthetic activity in the lower crowns of retained trees for stimulating growth after thinning. Her findings demonstrated the importance of maximising light interception of individual trees to ensure that high growth rates are maintained until harvest.

The third stage in CRC research showed that nutrient inputs could be used to accelerate growth and clearwood production after pruning. Further research illustrated how pruning, thinning and fertiliser interact to affect growth, structure and resource use of the final-crop trees.

Pruning live branches exposes a potentially large wound that can act as a portal for disease organisms. This can cause stem defects and reduce the commercial properties of trees. Postgraduate studies undertaken by CRC researchers Dr Karen Barry and Dr Alieta Eyles were instrumental in quantifying the potential for decay through pruning wounds and the defence mechanisms trees use to protect themselves. Simple rules emerged such as not pruning large branches, and not worrying too much about what time of the year to prune.

Leaf diseases such as Teratosphaeria (synonymous with Mycosphaerella), which may lead to branch death, can disrupt pruning schedules as well as growth, particularly in *E. globulus* plantations. Dr Libby Pinkard showed that fertiliser application can promote the recovery of crowns following pest attack.

The research effort produced new questions that called for further work in this area. Growing new and fast-growing species delivered wood that required new sawing and drying techniques; the CRC for Forestry has been at the forefront of this research. Other areas needing further research include the effects of relying on a resource sourced from a narrow base that is more susceptible to environmental stress.

As the demand for plantation sawlogs grows, there is clearly a continuing role for scientists to play in increasing wood value and minimising risk.

Education and training—building a stronger industry

The CRC for Forestry and its predecessors have worked closely with industry partners to produce industry-ready graduates, with the right mix of skills to build capacity and sustainability in the industry. The three forestry CRCs have provided support to 175 research students over 21 years, and each student project has made a valuable contribution to the CRCs' overall research objectives.

Through their university participants, the CRC for Forestry (CRCF) and its predecessors have been Australia's major source of postgraduate training for researchers in forestry for more than 20 years. The education and training program has supported 175 research students over the life of all three forestry CRCs, resulting in contributions to a wide variety of research topics, from sociology and forest genetics to engineering and systems modelling.

The forestry CRCs have offered a mix of fully funded Masters and PhD scholarships and top-up scholarships, as well as research funding to support students holding a CRC stipend. Research funding has also been allocated to support other relevant PhD, Masters and Honours projects.

A key focus has been to produce industry-ready graduates, equipped with the right mix of skills, in order to build capacity and sustainability in the industry. Many former students affiliated with the forestry CRCs now hold key positions in industry, regulatory agencies and consultancies, and research positions in Australian universities, CSIRO and other public research agencies.

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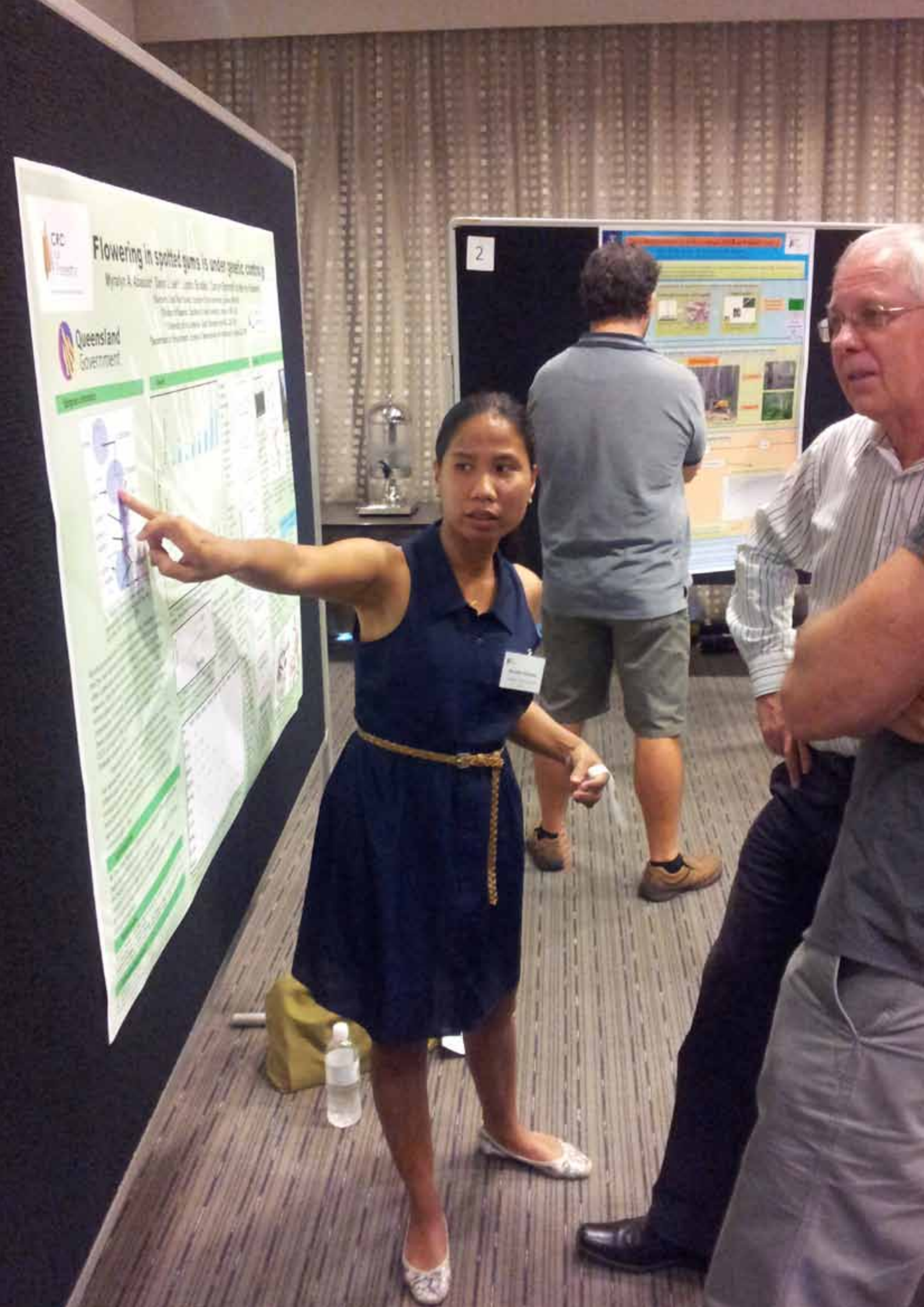
As well as facilitating the academic process within the participant universities, the CRCF has assisted students professionally by helping them build networks with industry partners and peers, as well as with other researchers. Industry partners have been closely involved in students' research projects in a variety of ways, including overseeing program and project activities and formal supervision. They've also played roles in the development and delivery of many courses offered by partner universities. This includes direct roles in the development and delivery of courses (e.g. the Plantations and the Environment course offered by the University of Tasmania to graduate and undergraduate students), or in the delivery of specialist components in the classroom and/or the field (e.g. the Forest Operations course offered by the University of Melbourne).

In conjunction with the CRCF's Annual Science Meetings, students have also participated in professional development workshops to improve their general professional skills.

The CRCF's education and training program has played a fundamental role in supporting the National Forestry Masters Program, in which four of the CRCF's six participating universities were involved. The Masters Program has been developed in conjunction with employers, industry groups and government to provide accessible and practical training to professional foresters and is delivered by five Australian universities. Industry staff and CRCF researchers have participated in and instructed many of the modules and courses offered as part of the Masters Program.

Educational activities of the CRCF have influenced the uptake of new knowledge, products or processes across all programs. The research carried out by students has been designed as an integral part of the overall programs and many students have been closely involved in the adoption processes. A good example is the research work on biodiversity, which was integral to the development of variable retention silviculture management regimes by foresters.


Flowering in spotted gums is under genetic control
Queensland Government
2

An Australian Government Initiative

More information about these initiatives and many other CRC outputs can be found at http://www.crcforestry.com.au/