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Planted forest development in Australia and New Zealand: comparative trends and future opportunities

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Abstract

Background: The areas of commercial wood plantations in Australia and New Zealand are 2.01 and 1.71 million hectares respectively, representing the predominant type of planted forest.

Methods: This paper reviews the status of planted forests in Australia and New Zealand and discusses opportunities for further development taking into account economic, social and environmental factors. These factors include regional wood demand and supply conditions, emerging markets for ecosystem services, climate change impacts and social attitudes toward planted forests.

Results: Both countries have followed a similar pattern of state intervention for the development of wood plantations, relying on government ownership and direct incentives such as taxation concessions that have gradually shifted to the use of more indirect policies. The main drivers for wood plantations were as an additional source of wood outside the natural forest, improved productivity and regional development. More recent policy has focused on the privatisation of forest assets and the promotion of ecosystem services such as carbon sequestration. To date, plantings for ecosystem services such as carbon sequestration has been limited.

Conclusions: It is argued that better design of policy settings is needed to capture the carbon abatement benefits and other ecosystem services from planted forests, which may help overcome current investment hurdles. Careful attention will also need to be applied to managing future climate change risks as well as to realising the opportunities from forecast growth in wood and fibre product demand particularly in the Asian region.

Introduction

The Food and Agriculture Organisation (FAO) (2010) defines a planted forest as those forests 'composed of trees established through planting and/or through deliberate seeding of native or introduced species', which includes forest plantations[a] and planted semi-natural[b] forests. Globally, planted forests have increased in area by just over 8% per cent between 2005 and 2010 to a total of 264 Mha (FAO 2010).

Within Oceania, there is approximately 4 Mha of planted forest, with Australia and New Zealand comprising over 92% of this area (Carle and Holgrem 2008). Other countries in the region that have developed a planted forest resource include Fiji and Papua New Guinea. In this paper, planted forest development is discussed with respect to Australia and New Zealand, as the major plantation forested countries in Oceania.

This paper reviews the status of planted forests in Australia and New Zealand and provides a comparative analysis of recent trends and opportunities for their development, taking into account economic, social and environmental factors. These factors include regional wood demand and supply conditions, emerging markets for ecosystem services such as carbon sequestration, climate change impacts and social attitudes toward planted forests. These factors represent a number of challenges

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and opportunities for planted forest development which to date has focused primarily on wood production. It is argued that better design of policy settings is needed to capture the multiple carbon abatement benefits and other ecosystem services from planted forests, which may help overcome current investment hurdles for new wood plantations. The proximity of Australia and New Zealand to Asia is also discussed in terms of forecast growth in regional demand for forest products and implications for plantation development and associated wood processing.

Wood plantations

Planted forests currently play an important role in Australia and New Zealand as a source of wood and fibre supply, partly in response to the declining availability of industrial wood from natural forests. The plantation estates of New Zealand and Australia produce roughly the same volume of logs per annum at 26 million and 27 million cubic metres respectively. In terms of their relative contribution to total annual log supply, wood plantations contribute 99.9% in New Zealand and over 80% in Australia (Australian Bureau of Agricultural and Resource Economics and Sciences (ABARES) 2014; New Zealand Forest Owners Association 2013). This reflects a contraction over time in natural forest availability for wood production and a maturing plantation resource for harvest.

In Australia, the area of commercial wood plantation is just over 2 Mha, with 1.02 Mha of coniferous plantation and 980 000 ha of broadleaved plantation (Gavran et al. 2012). Australia's commercial plantations are located mainly in the north-eastern coastal, south-western, southern and eastern regions of Australia.

The coniferous plantation is dominated by *Pinus radiata* D. Don or radiata pine (75%) and *Pinus elliottii* Engelm. and *Pinus caribaea* Morlet hybrids known as southern pines (15%). Most radiata pine is located in Victoria, New South Wales and Tasmania, and most southern pines are located in south east Queensland. *Pinus pinaster* Aiton, or maritime pine, is the dominant coniferous plantation species in Western Australia. The broadleaved plantation is dominated by *Eucalyptus globulus* Labill. (55%) and *Eucalyptus nitens* H. Deane & Maiden (24%), which are primarily managed for short-rotation pulpwood production.

In the seasonally dry tropical regions of northern Australia, there is also around 10 000 ha of planted African mahogany (*Khaya senegalensis* (Desr.) A.Juss.) which has considerable potential as a high value timber plantation species (Dickinson et al. 2011), as well as over 7 600 ha of Indian sandalwood (*Santalum album* L.) which is used in the global fragrance market.

In New Zealand, there is 1.71 Mha of wood plantation which is dominated by exotic species representing 99% of total planted area, including radiata pine (90%) and *Pseudotsuga menziesii* or Douglas-fir (6%). The remainder of the plantation estate is comprised of a mixture of Cypress species and other exotic softwoods and hardwoods (New Zealand Forest Owners Association 2013).

Historical development

Planted forest development in Australia and New Zealand has followed a similar pattern in terms of direct state intervention for the development of wood plantations over the last 150 years or so, which has gradually shifted to more indirect policies for the improved operation of markets and the promotion of ecosystem services such as carbon sequestration. These policies have resulted in a sizeable wood plantation resource and processing industry, whereby the forest products industry contributes $NZ4.5 billion and $A6.3 billion to national gross domestic product (GDP) in New Zealand and Australia respectively. The primary focus on wood production reflects international trends for planted forests, where it is estimated that 76% of global planted forests have production as their primary goal (FAO 2010).

Stephens and Grist (2014) and Ferguson (2014a) describe early state intervention in Australia for wood plantations via direct government ownership that has shifted to indirect policies such as the Plantations 2020 Vision. The Plantations for Australia: 2020 Vision, launched by the federal and state governments in 1997, aimed to enhance wealth creation and international competitiveness through a notional target of trebling the area of wood plantations to 3 Mha by 2020. This policy has focused on improving competitiveness through research and development, improving information on markets and prices and streamlining planning and regulation.

Large-scale wood plantation development began in the 1960s, through the use of concessional loans from the federal government to the state governments which established and managed the development of long-rotation (e.g. 35 year) coniferous plantation. The major goals of this expansion were to promote regional development and increase wood productivity and self-sufficiency, given the adverse terms of trade in forest products at that time (Ferguson 2014a). These loans led to the establishment of 1 Mha of coniferous plantation for integrated sawlog and pulpwood, used for domestic sawn timber and pulp and paper production (Figure 1). The other major trend that occurred from the 1990s was the emergence of Managed Investment Schemes (MIS) which took advantage of existing taxation incentive provisions and pooled capital from a large number of small investors. This led to the rapid rise of mostly short rotation hardwood (*Eucalyptus* spp.) plantations for woodchip export markets, which increased from a relatively low base to over 800 000 ha by 2012.

However, problems with the structure of the financial arrangements and issues with access to suitable land led to the collapse of many MIS companies, with some areas

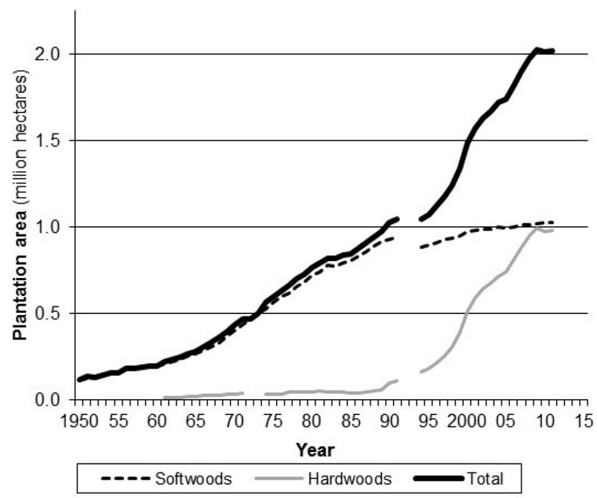

Figure 1 Plantation forest area in Australia, 1950-2011 (*Source*: ABARES.)

planted on uneconomic sites. Following the onset of the Global Financial Crisis in 2007-8 and the collapse of many MIS companies, most of this estate has been acquired by institutional investors. Further rationalisation of the former MIS estate is projected, with some areas not expected to be commercially replanted as a consequence of being established on poor quality sites or other factors such as long distances to markets. Some companies estimate that up to 30% of the former MIS hardwood plantation estate may not be replanted (Ferguson 2014b), with this land being converted back to agriculture following harvest (Stephens and Grist 2014).

Other forests have been planted for ecosystem services such as soil and water conservation, biodiversity and carbon sequestration. There is estimated to be 153 000 ha of non-industrial planted forest in Australia, some of which is used for environmental purposes and farm forestry activities (Montreal Process Implementation Group for Australia and National Forest Inventory Steering Committee 2013). Consultants (URS Forestry 2008) reported 155 000 ha of farm forestry plantings in Australia based on a 2008 survey, which included some large-scale plantings as part of leasehold arrangements with MIS companies. In addition to wood and agricultural productivity benefits (e.g. shade, shelter), a proportion of these plantings is for ecosystem services such as biodiversity and soil conservation, consistent with earlier surveys of farmers undertaking tree planting activities (Wilson et al. 1995).

Similarly, in New Zealand, there was a period of direct state intervention for wood plantation promotion from the 1960s through to the early 1980s. Over this period the plantation forest estate expanded by almost 700 000 ha through a range of programmes, including forestry encouragement grants, low interest loans and taxation deductions of up to 100% of planting costs to support private investment, as well as government planting programmes through the New Zealand Forest Service (Rhodes and Novis 2002, de Fegeley et al. 2011).

Other priorities for planted forests in New Zealand have included land rehabilitation and control of soil and water erosion from previous vegetation clearing for agriculture, particularly on steep slopes. In the Gisborne district of the North Island, for example, there has been a history of planting to combat erosion through Government-owned plantations and grants to private landowners. This has included the East Coast Forestry Project, which has assisted landowners to plant trees since 1992 for multiple goals including erosion control, wood production and employment (Rhodes 2001). Reforestation has been used to improve water quality that declined due to eutrophication from intensive agriculture (Maclaren 1996), and more recently, for the development of a carbon trading scheme.

Ownership trends

A significant feature of the wood plantation estate in Australia has been the shift in ownership from the public sector (i.e. state governments) to the private sector (Figure 2). The harvest and management rights to most of the coniferous plantations were sold in the 2000s to private institutional investors as part of the commercialisation of government owned assets. The management of these plantations is undertaken by timber investment management organisations (TIMOs) on behalf of investors, consistent with recent trends in North America. The other trend has been the acquisition by TIMOs of the hardwood eucalypt plantations formerly owned or managed by the failed MIS companies.

In New Zealand, there is 1.71 Mha of wood plantation. Fifteen companies manage plantation forest in excess of 20 000 ha with the largest being just over 235 000 ha (New Zealand Forest Owners Association 2013). These fifteen companies manage 62% of the plantation estate. Six

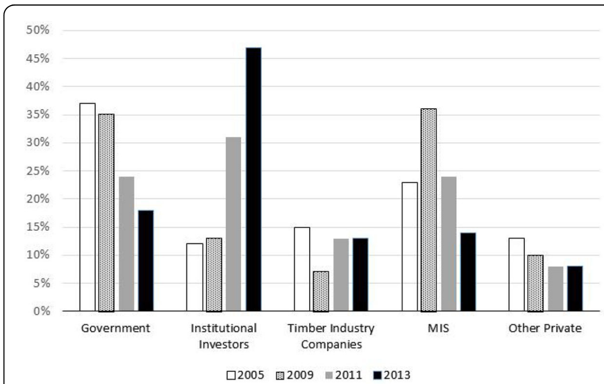

Figure 2 Plantation ownership in Australia (*Source*: ABARES; Australian Forest Products Association).

companies identify themselves as TIMOs, managing 389 000 ha, and 13 companies identify as property management companies managing just over 1 Mha. Maori and the Crown own considerably more land than forest, with Maori leasing 326 000 ha and the Crown leasing 219 000 ha to forest management companies. Another feature of New Zealand's ownership pattern is that 629 000 ha (or just over 37%) is owned by private individuals and landowners with less than 10 000 ha. An increasing proportion of this area will reach harvest age in the next 5 to 10 years.

Regional wood demand and supply

Given their close proximity and on-going forest products trade in Asia, wood demand and supply in the region has a direct influence on profitability and investment in wood plantations in Australia and New Zealand. There is also considerable intra-regional trade between the two countries. Australia is a net importer in forest products of around $2 billion per annum, comprising mostly imports of paper and paperboard from China and sawn timber from New Zealand. Australia has also been a large exporter of hardwood woodchips to Japan and China for pulp and paper production, which has averaged over $A850 million per annum over the past decade. Log exports to China have also increased markedly from 201 000 m^3 in 2002-03 to over 1.2 million m^3 in 2012-13 (ABARES 2014).

New Zealand is a large exporter of forest products, worth around $NZ 4.5 billion in 2012, reflecting the importance of the sector to the national economy at 3.3% of GDP (New Zealand Forest Owners Association 2013). In 2012, the major forest product export partners by value included China ($1.45 billion), Australia ($775 m), Japan ($542 m) and Korea ($392 m).

In terms of demand for forest products, China's influence is increasingly significant for Australia and New Zealand. Over the past few decades, woodchip exports to Japan have been the major market for Australian hardwood plantation pulpwood. However, China's share of woodchip exports value from Australia has grown from less than 1% in 2001-02 to around 20% in 2011-12 (ABARES 2014). There has also been a fundamental shift in overseas market share for New Zealand's forest products, particularly the rise of China to 67% of log and pole exports in 2012. In 2012, China represented 34% of New Zealand's total forest product exports by value, compared to just 4% in 1992 when Australia's share was 34% of forest product exports.

The demand outlook in Asia is influenced by economic growth assumptions and underlying social and environmental policies. Buongiorno et al. (2012) and Indufor (2012) present a range of global demand scenarios in terms of population growth, GDP and adoption of environmental and climate change policies. A consistent trend in these scenarios is the high economic growth in China and India over the next few decades and their forecast position as net forest product importers. The Asia Pacific Forestry Commission (2010) forecast demand for industrial round wood to increase from 317 million m^3 in 2005 to 550 million m^3 in 2020, with East Asia, especially China, accounting for most of this consumption. Similar analysis has shown that growth in construction is expected to be strong in China, the United States and India, with a 70% increase in construction output to $15 trillion worldwide by 2025, including the need for 270 million new homes in China and India by 2015 (Global Construction Perspectives and Oxford Economics 2013).

Global wood pellet production, as a source of fuel for energy, has grown from just less than 2 Mt in 2000 to around 16 Mt in 2010 (Lamers et al. 2012). Global wood pellet demand is expected to grow strongly to around 40-50 Mt per annum by 2020 with Europe accounting for a large share of consumption. The Asian region, which is a much closer market than Europe for Australia and New Zealand, is expected to rise from less than 1 Mt in 2010 to around 10-15 Mt by 2020 (International Energy Agency 2011).

The outlook for Australian and New Zealand wood plantations is also affected by local demand, which is largely influenced by Australian economic activity as a medium sized economy of almost 23 million people (Australian Bureau of Statistics 2014). Recent forecasts of domestic consumption suggest a moderate increase for most forest product categories (Table 1), based on assumed economic growth, rates of household formation, population growth and substitution of forest products in final demand.

The consumption of forest products in New Zealand has similarly remained steady over the past few years, albeit from a smaller population base than Australia (Table 2). As a net exporter of forest products with a relatively small domestic market, growth opportunities primarily lie in the global market.

On the supply side, Carle and Holgrem (2008) undertook a global survey of planted forests in 61 countries and predicted around a one third increase in total area over the next two decades, to reach 345 Mha by 2030 (Table 3). By comparison, Oceania was predicted to have an increase in area of around 11% or 400 000 ha by 2030.

Table 1 Long-term consumption forecasts: Australia

Product	Time period 2010-11 a	2012-13 a	2029-30	2049-50
Sawn wood (Mm^3)	5.0	5.1	6.0	6.5
Wood based panels (Mm^3)	2.0	1.7	3.1	4.3
Paper and paperboard (Mt)	4.0	3.6	5.8	7.1

Source: ABARES (2013, 2014). a = actual consumption. Mm^3 = million cubic metres. Mt = million tonnes.

Table 2 Consumption of forest products: New Zealand

	Year		
Product	**2006**	**2010**	**2014**
Sawn wood (Mm^3)	2.5	1.9	2.2
Wood based panels (Mm^3)	0.7	0.4	0.8
Paper and paperboard (Mt)	0.7	0.9	0.8

Source: Ministry for Primary Industries (2014).

According to Indufor (2012), the total area of industrial forest plantation in the world was 54.3 Mha in 2012 and may increase to 91 Mha by 2050. Indufor (2012) estimated that the area of industrial plantation in Asia and Latin America could double by 2050 with some expansion in Africa and Oceania.

In Australia, a recent survey of plantations and log availability has estimated that the plantation area may remain relatively constant at 2 Mha up to 2019-20 (Gavran et al. 2012). However, log volumes are expected to increase as a result of the maturing resource to average over 29 million m^3 per year in 2015-19 and reach an average annual peak of 33 million m^3 in 2030-34, largely as a result of an increase in hardwood pulpwood with softwood volumes to remain relatively static (Figure 3).

While providing a useful basis for national wood assessments, Ferguson (2014b) has identified some limitations in plantation forecasting in Australia, including the need for more robust sampling for growth and yield and information on replanting assumptions. This is particularly relevant in the case of the rationalisation of the former MIS plantations, with some areas not to be replanted for the reasons identified above.

In New Zealand, the harvest level is around 30 million m^3 of wood from plantations (Ministry for Primary Industries, 2014). Although market conditions eased in 2014, the steady increase in harvest volumes over the past five years is forecast to continue in the coming years to reach around 35 million m^3 by 2022 (Wood Council of New Zealand 2012). Most of this increase is to come from small growers who established forests in the early 1990s and actual harvest levels will depend upon market conditions and the decisions of small-scale owners (Ministry for Primary Industries 2013a).

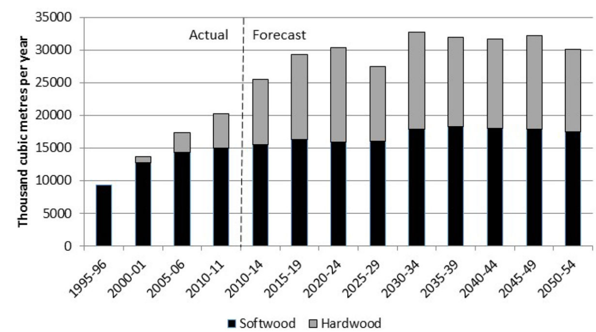

Figure 3 Australian plantation log availability 1990-2050 (***Source:*** Gavran et al. (2012); ABARES (2014)).

Ecosystem services

The predominant purpose of global planted forests has been for wood and fibre production (FAO 2010), which has also been the case in Australia and New Zealand. However, it is expected that the relative importance of planted forests for environmental purposes will increase in the future, given their potential to contribute to a range of ecosystem services such as rehabilitation of degraded sites, protection of soil and water, regulation of watersheds, biodiversity and carbon sequestration (Bahaus et al. 2012). This has been the case in China, for example, which has tripled the area of planted forest between 1990 and 2010 to 60 Mha for the large scale control of desertification (FAO 2010).

Planted forests can have both positive and negative environmental consequences such as the introduction of pests and water-use impacts, but through careful design and planning can help address landscape management issues (Nambiar and Ferguson 2005). When assessing the scope for forest plantings in Australia and New Zealand for ecosystem services, it is important to note the previous environmental degradation of land, water and vegetation, primarily as a result of agricultural development and other settlement patterns since the arrival of Europeans in the late 18th century. In Australia, it is estimated that around 13% or 100 Mha of land has been cleared of native vegetation, mostly eucalypt woodlands, with a further 65% subject to disturbance pressures such as livestock grazing

Table 3 World and Oceania planted forest area, 2005 (actual) and 2030 (forecast)

Year	Region	Softwoods				Hardwoods						Total
		Pinus spp.		Other spp.		*Acacia* spp.		*Eucalyptus* spp.		Other spp.		
2005	Oceania	**Mha**	**%**	**Mha**	**%**	**Mha**	**%**	**Mha**	**%**	**Mha**	**%**	**Mha**
		2.7	68	0.2	5	0.0	0	0.5	13	0.2	5	3.6
	World	73	28	64	25	9	0.3	14	5	100	38	261
2030	Oceania	2.9	69	0.2	5	0.0	0	0.8	19	0.3	7	4.2
	World	94.9	28	83.0	24	9.9	0.3	21.4	6	135.5	39	344.6

Source: Carle & Holgrem (2008). Note: Mha = millions of hectares.

(State of the Environment Committee 2011). This has led to a range of natural-resource management problems, including soil and water erosion, sedimentation, acidification, dry-land salinity and loss of plant and animal diversity.

Plantings for ecosystem services in Australia have evolved from government sponsored schemes (e.g. grants, community education) in the 1980s for land rehabilitation and biodiversity to broader climate change mitigation schemes. Stephens and Grist (2014) identified three distinct trends for ecosystem services plantings, comprising:

- programmes for landscape restoration and farm productivity (1980s);
- greater recognition of biodiversity values and landscape connectivity from revegetation and planted forests (1990s); and
- the emergence of carbon markets for forestry and land sector activities (2000s).

In both Australia and New Zealand, research has found that plantations can provide habitat benefits for a number of species compared to agricultural and pastoral land (Maclaren 1996, Lindenmayer and Hobbs 2004, Kavanaugh et al. 2007, Hock et al. 2009, Baral et al. 2013). There has also been considerable interest in the development of market-based mechanisms to capture ecosystem services such as biodiversity for forest owners. Keenan et al. (2004) identified the early potential for market based mechanisms to encourage small scale private landowners in Australia to deliver environmental services, such as to retain existing forest, establish forests on previously cleared land and integrate trees more fully with farming systems. It was argued that while forest owners can make a profit from the sale of wood and other commercial products, environmental services were not effectively valued or traded as market goods. However, it has been difficult for plantation owners and investors to generally capture the non-market benefits from ecosystem services, given the lack of market development and range of site-specific outcomes and conditions.

In a dry continent such as Australia, it is recognised that plantations, like all forms of agricultural land use, intercept water and that plantations generally use more water than pasture (Zhang et al. 2003). Plantations can also play an important role in improving water quality through reduced use of chemicals and pesticides, reduced erosion and soil salinity and flood control (Zhang et al. 2007). Water policy in Australia has therefore been directed at achieving an appropriate balance between managing the impacts of plantations on both water yield and quality. The interaction of plantations on both these variables is important, as the costs and benefits of reduced run-off and/or lower water tables will depend on the salinity of the groundwater, its potential to contribute to waterlogging or inundation and its potential for productive use (Zhang et al. 2007). In the south-east region of South Australia, for example, groundwater is a highly valued freshwater resource, while in Western Australia there is high saline groundwater and dry-land salinity issues from previous land clearing. At a national level, dry-land salinity is a particularly important water management issue, which arises from the removal of vegetation and rising saline water tables that causes land to be unproductive. The National Land and Water Resources Audit (2001) estimates that 5.7 Mha of land is adversely affected by dry-land salinity which is forecast to increase to 17 Mha by 2050 in the absence of amelioration.

Zhang et al. (2007) suggest that afforestation could play a significant role to reduce dry-land salinity, given the ability of trees to manage recharge through their deep rooting habit and high perennial water use. Considerable work has been undertaken in assessing and trialling salt tolerant tree species to ameliorate dry-land salinity in a range of geographic regions and sites, which can also produce other related benefits such as the harvest of biomass for fodder or bioenergy (Dale and Dieters 2007, Sochaki 2012) and deliver multiple wood, water quality and carbon sequestration benefits (Townsend et al. 2012).

Stephens and Grist (2014) reviewed the market potential for delivering joint wood production and ecosystem services from planted forests in Australia, including biodiversity, water quality and carbon sequestration. They concluded that there was limited scope, at least in the short term, for biodiversity payments given the complexity of capturing the benefits and transaction costs. By comparison, dry-land salinity mitigation was considered important in a regional context where markets do exist at a catchment scale and there is greater market development as part of the national water market for consumptive uses. Carbon markets for sequestration were considered most prospective, given the development of a domestic crediting and verification mechanism and the fungibility of tradable carbon credits.

In New Zealand, Hock et al. (2009) assessed the potential for ecosystem services from planted forests and reached similar conclusions regarding a lack of information and tradable markets for services other than for carbon sequestration. Despite commercial limitations to capturing ecosystem services, Yao et al. (2014) conducted a choice-modelling experiment and found that biodiversity enhancement in large-scale planted forests is valued in the community, and could potentially form part of a suite of future goods and services.

Carbon markets

Planted forests can provide multiple carbon sequestration and fossil fuel displacement benefits, through the carbon stored in forests and harvested wood products, the substitution of more energy-intensive products with wood products and the use of woody biomass for renewable energy (Malsheimer et al. 2011, Lippke et al. 2011, Oliver et al. 2014).

Both New Zealand and Australia have been early movers in terms of the implementation of domestic carbon market based schemes with mixed results in terms of promoting new plantings. In Australia, this has included the New South Wales Greenhouse Gas Reduction Scheme (GGAS) and the Carbon Farming Initiative, the latter which links as a land crediting mechanism to the national Emissions Reduction Fund (ERF). The ERF is a reverse auction market mechanism to buy low-cost emission reduction activities in the Australian economy, with the Australian Government initially allocating $1.55 billion to the Fund over a three year period commencing 1 July 2014 (Commonwealth of Australia 2013).

Mitchell et al. (2012) provided a summary of the evolution of carbon forestry schemes and their uptake in Australia, which has resulted in the establishment of 65 000 ha. The main schemes have generally been aimed at Kyoto Protocol compliant activities, such as afforestation and reforestation activities on cleared agricultural land post-1990. Most carbon plantings have been for not-for-harvest projects, either mixed plantings of eucalypt species, or plantings of mallee eucalypts in low rainfall areas that are multi-branched trees with a height rarely exceeding 6 metres. Overall, the uptake of wood plantations has been minimal given uncertainty in carbon market settings and scheme design issues (Mitchell et al. 2012). These issues have included the treatment of additionality, carbon pools (e.g. inclusion of wood products) and crediting periods (Stephens and Grist 2014). For example, the proposed design of the ERF is to have five-year contracts, which may disadvantage land based sequestration such as forestry projects, which typically have low early growth but higher longer term sequestration rates.

However, given the large area of previously cleared land, there has been strong interest in the potential for sequestration from planted forests under a range of carbon price and land availability scenarios. Several spatial analyses at a national scale have assessed the economic potential for plantations under a carbon market using physiological growth models and agricultural land opportunity costs, with estimates ranging from less than 350 000 ha up to 9 Mha by 2050 (Stephens and Grist 2014). In the absence of a carbon price, Paul et al. (2013) found that establishment of new plantations for wood production on agricultural land was not presently viable in Australia given current costs of establishment. However, on average, for scenarios of hardwoods (*Eucalyptus* spp.) and softwoods (e.g. *Pinus radiata*), a payment of about $A10 and $A30/t CO_2 respectively would make plantation expansion viable assuming a 4% carbon price increase per year, with an initial price above $A20/t CO_2 needed in the majority of scenarios for south-eastern Australia. The scenarios included short- and long-rotation plantations for pulpwood and sawlogs and the crediting of carbon stored in wood products and soils. The findings are consistent with de Fegeley et al. (2011) who suggested that without a carbon price new wood plantations would not be able to meet the investment hurdle rate.

In New Zealand, an emissions trading scheme was introduced in 2009 and forestry was the first sector to be included, generating an initial stimulus of forest plantings for sequestration. In 2011, for example, new forest plantings were almost double the previous year at 12 000 ha (New Zealand Forest Owners Association 2013). However, scheme design issues have since eroded the incentives for planted forests through low domestic carbon prices and high volatility and risk brought about by a series of amendments to the scheme. The depressed New Zealand carbon prices are attributed to the partial sectoral coverage of the scheme and strong linkage to uncapped international carbon trading of Kyoto compliant units, which have also fallen significantly in recent years. Under the New Zealand scheme, any credits are also balanced against any liability from the net release of carbon at harvest.

The ability of a carbon price to drive land use change is also dependent on the agricultural revenues foregone and the objectives of the owner (West et al. 2011). Manley and Maclaren (2009) estimate that a price of $NZ20/t CO_2 could improve the internal rate of return on a typical radiata pine plantation from 5.4% to 11.0% and could stimulate up to 25 000 ha/annum of new planting. In addition, carbon prices can result in modified management practices in new and existing planted forests. Hale et al. (2014) modelled the trade-offs between timber harvest and carbon sequestration and found that while more productive regions of New Zealand such as the Central North Island and Northland have a greater capacity as a carbon sink, it is the less productive regions that have a comparative advantage in carbon sequestration in terms of a lower cost of wood production revenue forgone. Various treatments such as switching from pruning to plant-and-leave or other harvest constraints may be optimal for a range of assumed carbon prices.

Forest management

The legal and institutional policy framework for sustainable forest management in Australia and New Zealand is well described in McDermott et al. (2010) and includes government environmental and planning regulation and codes of forest practice for plantation operations. These codes and regulations prescribe operational practices such as stream buffer areas that cannot be planted, how to build and maintain roads, use of fertilisers and pesticides, erosion control and fire protection requirements. In addition, there is high adoption of voluntary internationally recognised certification schemes for sustainable forest management. In Australia, around three-quarters of production forests are certified under either, or both, the Forest Stewardship Council (FSC) or the Programme for the Endorsement of Forest Certification (PEFC) via the Australian Forestry Standard. Similarly, New Zealand plantation forests began obtaining FSC certification during the mid-1990s and almost 60% of New Zealand's planted forests are certified under FSC.

Climate change impacts

Climate change can have an important impact on planted forest development. Several studies have looked at the possible impacts of climate change on planted forests in Australia and New Zealand (Watt et al. 2008, Battaglia et al. 2009, Booth et al. 2010, Singh et al. 2010, ABARES 2011), including the effects of predicted changes in CO_2 concentration, temperature and rainfall, as well as the threats posed by pests, diseases, weeds, fire and drought.

Climate forecasts vary, but generally predict that New Zealand could be 2°C warmer from 1990 to 2090 and Australia could be warmer by between 0.4 and 2°C by 2030 and between 1 and 6°C by 2070. Variable rainfall trends are also predicted, with the western side of New Zealand's two large islands predicted to have increasing rainfall while the eastern side less (Watt et al. 2008). In Australia, it is predicted that southern Australia will have less rainfall with some increases in northern Australia.

A key consideration is the impact of climate change on forest growth. Plantation growth may increase from rising levels of atmospheric carbon dioxide but may decrease from rising temperature and increased water loss (evapotranspiration). Increased temperature may also increase productivity in some regions and for some species, such as an extended growing season in higher altitude regions and reduced frost. Battaglia et al. (2009) modelled the effects of climate forecasts on plantation productivity in Australia and found a net increase in growth for some major growing regions and for other regions a net decrease. Drought-induced tree mortality was also identified as a significant risk in some drought-prone regions. Watt et al. (2008) identified a general gain in forest growth in New Zealand given relatively high water availability but increased drought risk in some areas.

The other major consideration is the impact of the secondary effects of climate change. In New Zealand, there is forecast to be stronger winds and more high intensity rainfall as well as less risk of fungal disease in drier areas but increased risk from fire and insect attack. Fire risk is also forecast to be significant in Australia. Hennessy et al. (2007) predicted that the frequency of very high and extreme fire danger days in Australia is likely to rise 4-25% by 2020 and 15-70% by 2050. Stephens (2010) has identified that these risks raise significant fire management issues at an individual stand and landscape scale, considering that planted forests occupy less than 2% of the total forest area in Australia of 125 Mha. Cyclones in northern Australia are also predicted to increase in frequency and impact on areas further south of current ranges. Higher susceptibility to pest and disease outbreaks is predicted, resulting from changes in both pathogen vectors and the health of trees influenced by climatic factors, although these factors are the least understood in both Australia and New Zealand (Watt et al. 2008, Singh et al. 2010).

Overall, Australian plantation forests are classified as moderately vulnerable to climate change given that the major commercial species are grown over wide climatic ranges (Booth et al. 2010). It is also recognised that there is large capacity for adaptation. The main management responses are described by Booth et al. (2010), including: spacing and thinning, watering and nutrient regimes, fire management, pest, disease and weed management, use of genotypes and site selection, climate monitoring and establishment practices. Adaptive forest management is regarded as an important tool for plantation managers and the industry has responded in Australia through the development of capacity building tools such as a plantation forest industry climate change adaptation handbook (Stephens et al. 2012).

Social attitudes and land access

Commercial afforestation of agricultural land is often associated with social conflict over the perceived environmental, economic and social impacts of plantations (Schirmer 2007). Planted forest development in Australia and New Zealand has attracted some community concerns, primarily regarding competition for agricultural land, employment impacts and environmental issues. Williams (2008) undertook a survey of community attitudes to wood plantations in Tasmania and the south-western regions of Western Australia and found that respondents tended to value agriculture land use higher than for plantation forestry. Many people believed plantations offered benefits to companies and individuals but only limited regional employment and economic benefits. Similarly, Langer and Barnard (2002) surveyed residents in the Gisborne East Coast region of New Zealand and identified that community concerns about forest expansion included lack of employment generation and the perceived loss of good farming land. These views have been exacerbated in Australia from the collapse of many MIS companies and concerns over the rapid expansion of plantations prior to their collapse and upward pressure on land prices in some areas (Ferguson 2014a). Other issues have included perceptions of naturalness and implications for planted forest management in New Zealand (Fairweather and Swaffield 2003).

Research has shown that plantation forestry can generate a range of employment and economic benefits in Australian regions, particularly through integrated growing, harvesting, transport and processing activities (Bureau of Rural Sciences 2005).

These issues are important as any expansion of the plantation estate will require access to rural land and engagement with landowners and communities. A related issue is the relationship between large-scale and small-scale plantation forestry where the latter are generally viewed more positively (Schirmer 2007). This has led to greater policy recognition of the need for improved relationships between the plantation industry and the rural sector to achieve an appropriate mix of industrial scale and small scale plantings (de Fegely et al. 2011, Ferguson 2014a). To this end, Gordon et al. (2013) assessed the extent of community engagement by the Australian plantation forest industry, and while stakeholders often considered the engagement to be ineffective, measures were identified to enhance relationships with stakeholders and the required skills of forestry professionals.

Discussion

Internationally, the development of wood plantations has struggled to attract large-scale private investment without some form of government intervention or subsidy (Nielson 2007). This is primarily because of the time value of money with high up-front establishment costs and a long period until harvest returns. This, in turn, results in a lower rate of return for plantations compared with other investments excepting where there is other comparative advantage (e.g. high product prices, low transport costs, high yields). This has been the case in Australia, and to some extent New Zealand, where the high opportunity cost of land for agriculture has inhibited new investment without some form of government support. This is reflected in the cumulative plantation forest area in Australia over time (Figure 1), where early direct intervention (i.e. state ownership) and assistance schemes generated significant new plantings from the early 1960s.

However, it is important that development policies are well-targeted to address market failure, minimise distortions and promote the long-term competitiveness of plantations. This is particularly relevant in terms of the potential over-stimulation of the sector through previous subsidy experiences in New Zealand (Rhodes and Novis 2002), and more recent uptake of taxation measures in Australia. In Australia and New Zealand, government support has now transitioned to more indirect enabling policies, with a recent decline in new plantings partly as a consequence of market conditions (Figure 4).

A key trend is the sharp decline in hardwood (i.e. eucalypt) planting rates since 2007 in Australia and plateauing or fall in softwood plantations in both Australia and New Zealand since the 1990s. This will act as a constraint to the processing industry's ambitions to expand the scale of processing to achieve internationally cost-competitive levels using local wood and fibre (de Fegely et al. 2011).

On the export side, plantation owners in Australia and New Zealand have taken advantage of increasing demand for both softwood and hardwood logs and woodchips in China. With respect to the eucalypt plantation resource, Australian producers have experienced a recent upswing in exports to China, although price competitiveness with other emerging regional suppliers such as Vietnam will be important. In June 2014, Vietnam took over from Australia as the world's largest supplier of woodchips to pulp mills in Asia (Pulp and Paper News 2014).

The outlook for plantation forest product exports to Asia from Australia and New Zealand will be influenced by the competitiveness of other major suppliers. The expansion of fast-growing wood plantations (i.e. rotations less than 40 years) in many parts of the world represents a challenge in terms of improved growth (measured as mean annual increment (MAI)) (Table 4) and increased supply. While growth rates in Australia and New Zealand are comparable to many other countries, there can be considerable variation as in the case of Australia (Table 5). Growth rates vary depending on tree species and region, reflecting underlying differences in climatic and edaphic conditions.

However, the long-term sustainability, expansion and productivity of many international wood plantations are uncertain, reflecting underlying environmental and social issues. These issues include population pressure, small land holdings, technology transfer, environmental practices and competition for land and food production (Cossalter and Pye-Smith 2003, Kugelman and Levenstein 2012). The Asia Pacific Forestry Commission (2010) noted that while plantation productivity may increase, this will

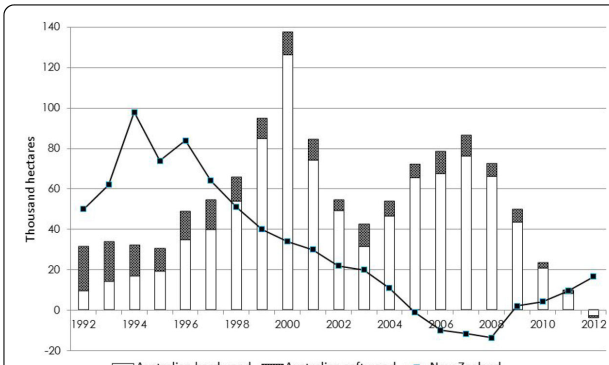

Figure 4 New plantations established in Australia and New Zealand (*Source*: ABARES and New Zealand Forest Owners Association. Note: new plantation areas are net of plantation conversion to other land use).

depend in many countries on improving favourable policy and institutional environments. In the case of South East Asia, for example, Nambiar and Harwood (2014) identify considerable wood plantation potential, but this is dependent upon coordinated research and management for genetic improvement and soil protection.

By comparison, Australia and New Zealand have well developed institutional frameworks, research capacity and environmental policies for sustainable forest management and improved productivity. There has been over 100 years of plantation research and development focusing initially on exotic pines, and there is considerable scope to lift the productivity of the new eucalypt plantation estate in Australia. Genetic improvement and better site matching of species is expected to deliver higher growth for plantation eucalypts over the next rotation, given the rationalization of the former MIS estate in Australia. The New Zealand forest industry science and innovation strategy has also identified a 5 m^3 ha^{-1} $year^{-1}$ increase in productivity by 2025.

The other key issue is what type of wood plantation industry is feasible or desirable in Australia and New Zealand into the future? This is a broader policy issue, reflecting the economics of exporting relatively unprocessed industrial wood versus domestic value adding, which will have implications for future national policy, plantation management and investment. Ferguson (2014a) argues that the Australian plantation industry is at a cross-roads and that a coherent national plantation policy is needed if the Australian government and industry wish to expand the plantation estate to maintain international competitive wood and paper manufacturing and associated rural employment.

Manufacturing costs in Australia and New Zealand can be at the higher end of global benchmarks, factoring in existing scale of facilities, environmental standards, labour and energy. For these reasons, there has been considerable interest in research and innovation into emerging opportunities to value add either low grade logs or under-utilised biomass residues such as for bioenergy, as well as higher value applications for sawn timber and engineered wood products.

Bioenergy offers potential as a new revenue stream that is dependent on renewable energy policy as well as available feedstocks and technology developments (International Energy Agency 2009). The Clean Energy Council (2008) identified there was enough wood waste from forestry and processing activity in Australia to generate up to 3000 Gwh per year or 7% of the national renewable energy target. In New Zealand, over $NZ13 million has been invested into research into converting forestry biomass into liquid biofuels by looking into the commercial viability of establishing a modular test plant to process forest waste into sustainable transport fuel (Ministry for Primary Industries 2013b). These opportunities reflect the growing demand for renewable energy sources and provide a medium to longer term market for the plantation wood industry.

However, it will be equally important that some of the social challenges of plantation development be managed into the future, given previous community concerns over plantation expansion and related socio-economic and environmental impacts. The need for improved community engagement is considered important in gaining wider acceptance from stakeholders (Gordon et al. 2013). Plantation development can occur across a continuum of planting types from monocultures of exotic species to stands of mixed native species; and varying scales from broad scale plantations to small farm woodlots and riparian plantings. The majority of wood plantations in Australia and New Zealand have been large-scale and restricted to a select

Table 4 Selected international growth rates for wood plantations

Species	Mean Annual Increment (m^3 ha^{-1} yr^{-1})	Rotation length (years)	Main countries or regions
Eucalyptus grandis W.Hill ex Maiden and various hybrids	15 - 40	5 - 15	Brazil, South Africa, Uruguay, India, Congo, Zimbabwe
Other tropical eucalypts	10 - 20	5 - 10	China, India, Thailand, Vietnam, Madagascar, Myanmar
Temperate eucalypts	5 - 18	10 - 15	Chile, Portugal, north-west Spain, Argentina, Uruguay, South Africa, Australia
Tropical acacias	15 - 30	7 - 10	Indonesia, China, Malaysia, Vietnam, India, Philippines, Thailand
Caribbean pines	8 - 20	10 - 18	Venezuela
Pinus patula Schiede ex Schltdl. & Cham. and *P. elliotii*	15 - 25	15 - 18	Swaziland
Gmelina arborea Roxb.	12 - 35	12 - 20	Costa Rica, Malaysia, Solomon Islands
Paraserianthes falcataria (L.) Nielsen	15 - 35	12 - 20	Indonesia, Malaysia, Philippines
Poplars	11 - 30	7 - 15	China, India, USA, central and western Europe, Turkey
Pinus radiata *	25 - 30	25	Australia, New Zealand, South Africa, Chile

Source: Cossalter and Pye-Smith (2003), * FAO (2001).

Table 5 Australian regional growth rates for wood plantations

Species	Mean Annual Increment (m^3 ha^{-1} yr^{-1})	Rotation length (years)	Region(s)
Temperate eucalypts (pulpwood)	10 - 19	12 - 25	Tasmania, South Australia, New South Wales, Victoria, Queensland, south-west Western Australia
Temperate eucalypts (sawlog)	20 - 27	14 - 20	Tasmania, South Australia, New South Wales, Victoria, Queensland, south-west Western Australia
Araucaria spp.	15	50	Queensland, northern New South Wales
Pinus radiata	16 - 21	30	Tasmania, Victoria, New South Wales, south-west Western Australia, South Australia
Pinus elliotii and *P. caribaea* hybrids	15 - 18	30	Queensland, northern New South Wales
Eucalyptus nitens	15	15	Tasmania

Source: Gavran et al. (2012).

number of species for high productivity and commercial purposes. Community preferences for more diversified and small-scale plantings may entail changes in planting design and species mix which can have direct impacts on the costs to the forest owner. Managing plantations as part of whole farm plans may assist in this process, although would need to be weighed against the commercial costs and benefits such as higher transaction costs from more dispersed plantation areas.

This leads to the other recent trend of increasing interest in planted forests for ecosystem services. To date, it has been difficult to quantify the extent of these types of plantings as they are undertaken by a range of individuals such as farmers, community based organisations, private businesses, family trusts and local governments. In Australia, there is estimated to be 153 000 ha of non-industrial planted forest.

The outlook for ecosystem services plantings other than for carbon sequestration in Australia and New Zealand is uncertain but likely to increase in conjunction with direct Government programmes, albeit on a small scale, for the amelioration of land degradation. In many cases these programmes are oriented toward revegetation using mixed plantings of endemic native species or natural regeneration. The other major activity is farm forestry activities for wood production, farm productivity and environmental amenity. In these cases, forestry extension is important and investment decisions can be more complex involving lifestyle, income, cash flow and risk choices for the landowner (Schirmer et al. 2000).

In terms of the broad potential for carbon plantings, either as not-for-harvest or joint carbon and wood plantations, it has been shown that prices above \$20/t CO_2 could stimulate new plantation investment in Australia and New Zealand. However, a number of significant impediments are identified in the respective national climate change policy schemes. In the case of Australia and New Zealand, this includes a lack of inclusion of harvested wood products in applicable methods and recognised afforestation activities and in Australia a relatively short contract period for the purchase of emission reductions by the Australian Government. In the case of New Zealand, it is also the partial coverage of the scheme for emitters and uncapped link to international carbon credits that has depressed carbon prices to less than \$3/t CO_2 in recent years. Other issues have included risk and uncertainty through volatility in carbon prices, particularly until underlying national and international carbon regulatory frameworks are fully developed.

Conclusions

Planted forest development in Australia and New Zealand has followed a similar pattern with a strong historical focus on industrial wood plantations. The net outcome from these policies has been the development of a sizeable wood plantation resource and associated downstream processing. However, once governments have transitioned away from direct incentives to an enabling policy environment there has been little new plantation investment.

Concurrently, markets have emerged for some ecosystem services such as landscape restoration, biodiversity and carbon sequestration. Further development and access to these markets may help address some of the investment hurdles for new wood plantations while delivering multiple benefits. There is therefore considerable interest in addressing market failure through the use of emerging markets for the joint production of wood and ecosystem services. A market based solution for ecosystem services in wood plantations has the added potential benefit of increasing economies of scale and competitiveness in wood resource availability and associated downstream processing.

It is argued that more coherent national plantation policies are needed to capture the full range of benefits from wood plantations and other planted forests. In 1997, the Plantations 2020 vision in Australia had a target of trebling the plantation area to 3 million hectares by 2020 to foster economic development. Similarly, the New Zealand government has a target of increasing the planted area by 20 000 hectares per annum, largely to meet climate policy objectives. These goals are unlikely to be met, at least in the short term, given falling rates of new plantings. In fact, there was a net decrease in Australia in the total area of wood plantations by 4 000 ha in 2011-12 (Gavran 2013). In New Zealand, recent surveys have identified deforestation intentions of many landowners, particularly conversion to dairy, over the next few years (Manley 2014). Better design of policy settings, particularly for carbon markets, and policy consistency between land uses, may curb falling rates of new plantings and encourage new plantings to help achieve climate change mitigation and economic development goals.

For existing wood plantations, growing demand in Asia, particularly in China and India, offers significant opportunities for export growth of round wood and woodchips from Australia and New Zealand. This outlook needs to be assessed against the growing supply of forest products from Latin America and Asia, the sustainability of which will depend on underlying policies for environmental management and institutional capacity. There is also potential for growth in bioenergy and other value added products from plantations in Australia and New Zealand over the medium term, either for domestic consumption or export.

In order to fully realise the opportunities for wood plantation development, enhanced community engagement will help address previous concerns regarding the acceptability of plantations in the rural landscape. Close attention will also need to be applied to managing future climate change risks, given forecast changes in temperature and rainfall and secondary effects such as increased pests and diseases or more extreme weather. Climate change forecasts present both risks and opportunities, through predicted increases or decreases in forest growth across regions and other risks posed by drought, fire and wind.

End notes

[a] Forest plantations, a subset of all planted forests, are defined as forests of introduced species and in some cases native species, established through planting or seeding, with few species, even spacing and/or even-aged stands (FAO 2006a).

[b] Semi-natural forests are defined as forests of native species, established through planting, seeding or assisted natural regeneration. This definition includes areas under intensive management where native species are used and deliberate efforts are made to increase/optimise the proportion of desirable species, thus leading to changes in the structure and composition of the forest, with possible presence of naturally regenerated trees from other species than those planted/seeded. This may include areas with naturally regenerated trees of introduced species and areas under intensive management where deliberate efforts, such as thinning or fertilising, are made to improve or optimise desirable functions of the forest (FAO 2006b).

Competing interests
The authors declare that they have no competing interests.

Authors' contributions
David Rhodes and Michael Stephens jointly conceived the review as part of their participation in the Third International Congress on Planted Forests, contributing New Zealand and Australian planted forest perspectives respectively and underlying comparative analyses. Both authors reviewed the literature, drafted the thematic sections and approved the final manuscript.

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