PLANTED FORESTS

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ABSTRACT: New Zealand's 1.72 million hectares of planted forests constitute a productive ecosystem mainly recognised for the provision of wood and fibre. This ecosystem is increasingly being recognised for providing other services such as recreation, climate change mitigation, habitat provision, improved water quality, bioenergy, erosion control, and flood mitigation. This chapter describes several ecosystem services provided by planted forests and reports some of the estimated economic values for these services. Findings from this study suggest that the estimated economic values for emerging services, such as recreation and biodiversity, remain very limited and in many cases out of date. More studies using state-of-the-art methods of economic valuation that account for both time and space are required.

Key words: biodiversity, ecosystem services, *Pinus radiata*, planted forests, recreation.

INTRODUCTION

Planted forests are defined as a type of land use 'composed by trees established through planting or seeding by human intervention' by the Food and Agriculture Organisation (FAO 2012a). They include semi-natural forests with indigenous species and plantation forests with introduced species. Globally, planted forests cover 264 million hectares accounting for 7% of all forests (FAO 2010). Their area expands by an average of approximately 5 million hectares per year (FAO 2012a). They are important sources of forest products (roundwood, fibre, fuelwood, and non-wood forest products) and have recently superseded naturally regenerating forests as the principal source (Evans 2009). Establishment of planted forests provides opportunities for native forests to be managed for uses other than production (FAO 2006). This role is important as natural forests are decreasing in extent through deforestation (mainly in developing countries in the tropics and subtropics) or are designated for conservation or other purposes (mainly in developed countries in temperate zones). Such ecosystem services include carbon sinks, soil and water protection, biodiversity conservation, recreation, and amenity (Carnus et al. 2006; FAO 2012a). This situation holds true for New Zealand in particular. Here almost all harvested timber comes from planted forests containing exotic trees, with less than 0.01% coming from native forests (MPI 2012b). The country's planted forest ecosystem contributes to the conservation of native forests by offsetting pressure on them (UNCED 1992; Dyck 2003; Evans 2009).

New Zealand's planted forests consist mainly of plantations of introduced species with radiata pine (*Pinus radiata*) as the dominant species accounting for 90% of the total area. The remaining exotic species include Douglas-fir (*Pseudotsuga menziesii*), cypress (*Cupressus* spp.) and eucalypts (*Eucalyptus* spp.) (MPI 2012b). New Zealand has a total of 1.72 million hectares of planted forests accounting for approximately 22% of the country's total forest area (MPI 2012b). They help supply the global demand for roundwood, pulp, non-wood products, and other forest products (Bauhus et al. 2010). In 2011, the forest industry exported NZ$4.72 billion worth of forest products making it the country's third largest primary export earner (after dairy products, meat and wool) (MPI 2012d). This ecosystem is also increasingly recognised for providing other services such as climate change mitigation (Adams and Turner 2012), provision of habitats for native species (Jukes et al. 2001; Brockerhoff et al. 2008; Pawson et al. 2010; Yao 2012), recreation (Dhakal et al. 2012), improved water quality (Rivas Palma 2008), avoided erosion (Barry et al. 2012b), and flood mitigation (Dymond et al. 2010).

This chapter provides an overview of ecosystem services provided by New Zealand's planted forests. It aims to describe the contributions of this ecosystem to prosperity and human well-being following an ecosystem approach described in the Millennium Ecosystem Assessment (MEA 2005) and the UK National Ecosystem Assessment (UK NEA 2011). Under this approach, the services provided by the planted forest ecosystem are classified into four key groups of services: provisioning, regulating, cultural and supporting services. Provisioning services include the production of forest products and bioenergy. Regulating services include carbon sequestration and avoided erosion. For cultural services, a compilation of estimates of the social values of recreation and biodiversity in planted forests is provided. For supporting services, the contributions of planted forests to nutrient cycling, soil formation and primary production are discussed. The chapter also presents trends in New Zealand's Emissions Trading Scheme and a mini case study of the value of avoided erosion in New Zealand's future forests.

NEW ZEALAND'S PLANTED FORESTS

Definition

The New Zealand Ministry for Primary Industries (MPI) provides a detailed description of planted forests annually through the National Exotic Forest Description (NEFD) report. The NEFD defines planted production forests as 'an area of trees not less than one hectare in size, planted and managed with the intention of producing wood or wood fibre'. Under the New Zealand Emissions Trading Scheme (ETS), forest land is similarly defined as an area covering at least one hectare of forest species but also has more than 30% tree crown-cover on each hectare, and an average crown-cover width of at least 30 metres. Furthermore, a forest species is a tree species that is capable of reaching at least 5 metres in height at maturity in the place it is located, and cannot be a species grown or managed primarily for fruit and nut production (MAF 2011). Therefore, a planted forest can range from a 1-hectare plot of Douglas-fir in Southland to the 189 000-hectare radiata pine plantation Kaingaroa forest in the central North Island (the largest planted forest in New Zealand).[1]

Distribution of planted forests and key species

As of March 2012, each region in New Zealand had at least 8900 hectares of planted forests (MPI 2012b) (Table 1). This

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TABLE 1 Area of planted forests by region and district (Source: MPI (2012b))

District/Region	Area of planted forest (ha)	Total area of planted forest (%)
Far North District	91 494	
Whangarei District	31 711	
Kaipara District	38 354	
Northland total	161 559	9.4
Auckland City	41 000	
Auckland total	41 000	2.4
Thames-Coromandel District	16 332	
Hauraki District	3255	
Waikato District	18 271	
Matamata-Piako District	1400	
Hamilton City	1	
Waipa District	2709	
Otorohanga District	5057	
South Waikato District	66 622	
Waitomo District	25 651	
Taupo District	169 696	
Waikato District total	308 994	18.0
Tauranga District	110	
Western Bay of Plenty District	23 731	
Rotorua District	51 460	
Kawerau District	34	
Whakatane District	104 348	
Opotiki District	16 631	
Bay of Plenty total	196 314	11.4
Gisborne District	154 289	
Gisborne total	154 289	9.0
Wairoa District	53 890	
Hastings District	60 129	
Napier City	139	
Central Hawke's Bay District	15 428	
Hawke's Bay total	129 586	7.5
New Plymouth District	4008	
Stratford District	6398	
South Taranaki District	9950	
Taranaki total	20 356	1.2
Ruapehu District	46 789	
Wanganui District	28 315	
Rangitikei District	21 911	
Manawatu District	6646	
Palmerston North City	2271	
Horowhenua District	6717	
Tararua District	15 885	
Manawatu-Wanganui total	128 534	7.5
Kapiti Coast District	3664	
Upper Hutt City	6246	
Porirua City	1409	
Wellington City	574	
Lower Hutt City	299	
Masterton District	32 880	
Carterton District	10 341	
South Wairarapa District	8562	
Wellington total	63 975	3.7
North Island total	***1 204 607***	***70.1***
Tasman District	86 386	
Tasman total	86 386	5.0
Nelson City	8969	
Nelson total	8969	0.5
Marlborough District	71 885	
Marlborough total	71 885	4.2
Buller District	3869	
Grey District	13 940	
Westland District	14 657	
West Coast total	32 466	1.9
Kaikoura District	1345	
Hurunui District	40 078	
Waimakariri District	12 458	
Selwyn District	13 863	
Christchurch City	11 495	
Ashburton District	3776	
Mackenzie District	4888	
Timaru District	11 868	
Waimate District	11 629	
Canterbury total	111 400	6.5
Waitaki District	18 129	
Queenstown-Lakes District	757	
Central Otago District	7053	
Dunedin City	14 351	
Clutha District	81 285	
Otago total	121 575	7.1
Southland District	77 121	
Gore District	4404	
Invercargill City	688	
Southland total	82 213	4.8
South Island total	***514 894***	***29.9***
New Zealand total	***1 719 501***	***100.0***

indicates that planted forests are distributed all over the country (Figure 1A and 1B). Seventy percent of the forest areas can be found in the North Island, mostly in the Waikato, Bay of Plenty and Northland regions (Figure 1A). Planted forests in the South Island are more sparsely distributed compared with those in the North Island (Figure 1B). More details of area planted by region and district as well as age class distribution are provided in Table 1.

Radiata pine is by far New Zealand's most widely grown species, accounting for nearly 90% of the total planted area (Table 2). Its popularity is largely because it is perceived as New Zealand's most profitable species and is a reliable crop (MacLaren and Knowles 2005). Radiata pine is typically planted as monocultural stands and is harvested between 26 and 32 years after planting (Dyck 2003; Carnus et al. 2006). As of March 2012, approximately 96% of the planted area of radiata pine consisted of trees under 30 years of age (Table 2). Radiata pine is mainly used as a production forest species but also serves as a shelterbelt

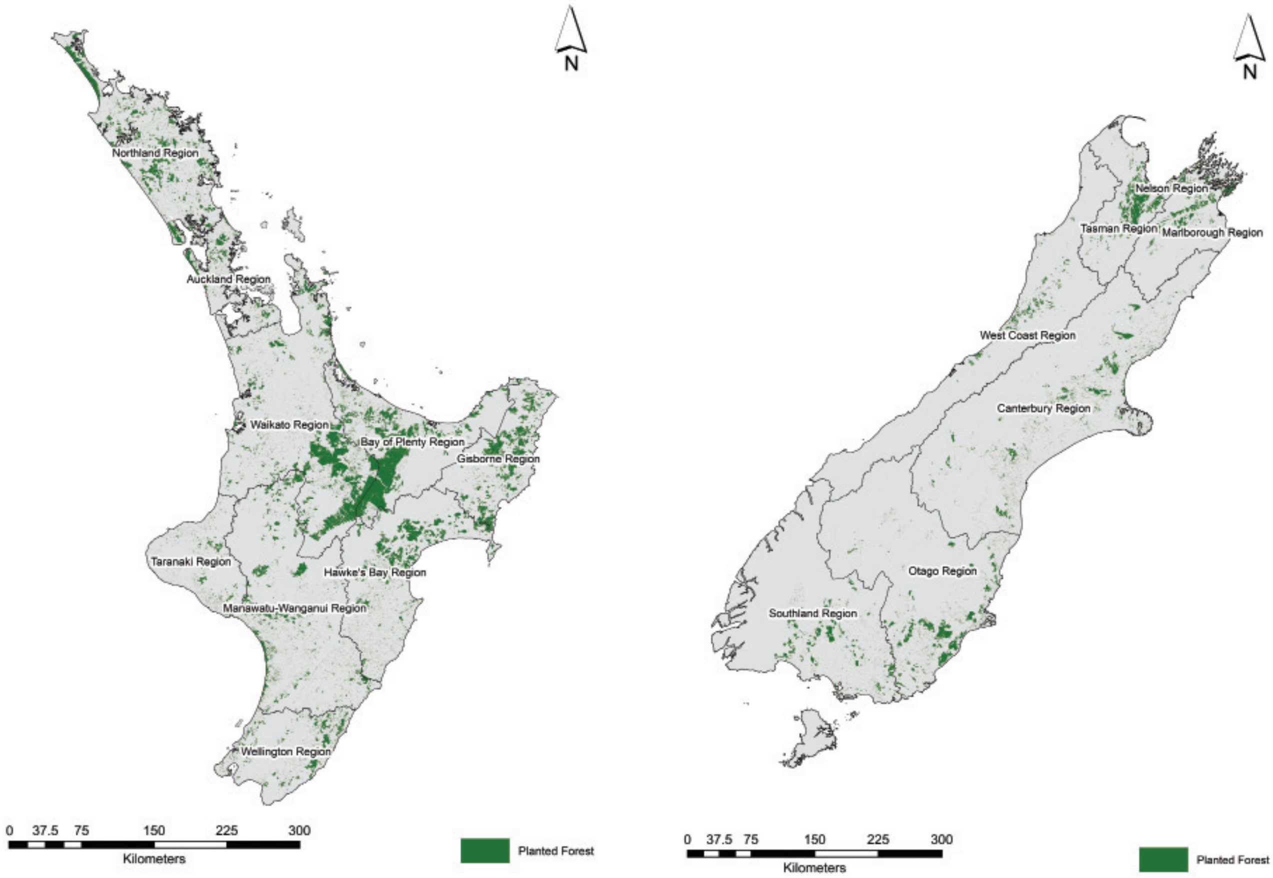

FIGURE 1 Map of the North Island (left) and South Island (right) showing the location of planted forests area by region (produced from Land Cover Database 3 (Source: http://lris.scinfo.org.nz/layers/tag/lcdb3/).

TABLE 2 Area of plantation forests in New Zealand by species and age class, as at 1 April 2012 (Source: MPI (2012b))

	Area planted (ha)											**Total area planted (ha)**	**Total area of planted forest (%)**
Age classes (yrs)	**1–5**	**6–10**	**11–15**	**16–20**	**21–25**	**26–30**	**31–35**	**36–40**	**41–50**	**51–60**	**61–80**		
Species													
Radiata pine	181 754	211 456	308 286	428 975	177 780	177 230	43 419	9682	3224	607	487	1 542 900	89.7
Douglas -fir	6971	17 656	34 648	16 438	6301	8490	8074	4158	4150	701	272	107 859	6.3
Cypresses	1137	2890	2279	1557	340	1108	183	62	163	32	100	851	0.6
Other softwoods	1951	2824	3270	5085	1018	2876	2664	694	1930	633	844	23 789	1.4
Eucalypts	4050	1466	8199	4652	1762	970	871	191	253	84	71	22 569	1.3
Other hardwoods	386	1540	3048	3644	1274	1479	500	184	189	109	180	12 533	0.7
TOTAL	196 249	237 832	359 730	460 351	188 475	192 153	55 711	14 971	9909	2166	1954	1 719 501	100.0

species. Nicholas et al. (MPI 2012b) estimated that the area of radiata pine shelter belts was 50 000 hectares.

Douglas-fir is New Zealand's second most popular planted forest species, accounting for over 6% of the total planted forest area (Table 2). Historically, rotation lengths for this species have been much longer (approximately 70–80 years) than for radiata pine (approximately 30 years) (Maclaren 2009). However, improved silvicultural practices have reduced rotation lengths for Douglas-fir to 45 years or less (MPI 2012b). Approximately 98% of the planted area of Douglas-fir stock is more than 50 years of age (Table 2). Douglas-fir also has advantages over radiata pine in that it is more resistant to windthrow[2] and snow damage and therefore is more suitable in areas with harsh climates (Nicholas et al. 2005; Maclaren 2009). It is also more shade tolerant than radiata pine, and may be an important species for continuous-cover forestry on soils where clear-cut harvesting may have negative environmental impacts on steep slopes and soils that are vulnerable to erosion (Maclaren 1996).

In total, Eucalyptus species are the third most popular planted forest species, consisting of 1.3% of New Zealand's planted forest area (Table 2). Rotation lengths vary according to species and end uses. Rotations will be less than 20 years when grown for pulp wood, so species like *Eucalyptus nitens* may be preferred for such uses because of its high growth rates when young (Nicholas et al. 2005). Age classes under 35 years account for 97% of all eucalyptus plantations (Table 2).

As of 2011, approximately 9 851 hectares (0.6% of forest area) were planted with various species of cypress. The main species grown are *Cupressus lusitanica* and *C. macrocarpa*. These two usually have rotations lengths of 30–40 years. Similar to radiata pine, cypresses can also be used for shelter belts (Nicholas et al. 2005). Other softwoods (1.4%) and hardwoods (0.7%) make up the remainder of planted forest species (Table 2). These include other exotic species like *Sequoia sempervirens* (commonly known as coast redwood), and some natives like *Agathis australis* (kauri) and *Podocarpus totara* (tōtara).

Pruning and thinning regimes

The choice of growing regime depends on a number of factors, such as site characteristics, management and market demand. The choice is also highly influenced by the preferences of investors. The key regime types may be grouped into four broad categories (MPI 2012b), namely pruned or unpruned and with or without production thinning. Table 3 provides an overview of the growing regimes (where known) for the different tree species discussed above and also the area allocated to each regime for each species across New Zealand.

TABLE 3 Approximate composition of current planted forests by management regime

Species	Management regime		Area (ha) per regime in 2012
	Pruned	Thinned for production	
Radiata pine	Yes	Yes	207 000
	Yes	No	692 000
	No	Yes	41 000
	No	No	603 000
Douglas-fir*	No	Yes	108 000
	No	No	
Cypress species	Not known	Not known	10 000
Other exotic softwoods	Not known	Not known	24 000
Eucalyptus species	Not known	Not known	23 000
Other exotic hardwoods	Not known	Not known	13 000
TOTAL AREA			**1 721 000**

Note: The portions of Douglas-fir with and without production thinning are unknown.
Source: MPI (2012b)

The main objective of *pruning* is to increase the proportion of wood ultimately recovered from the log at harvest. Pruning involves the removal of the lower branches of young trees, usually up to a height of 4 metres or more. Radiata pine pruned using various regimes accounts for 53% of the entire planted forests. While pruning regimes provide a higher proportion of a higher grade log in each tree, this comes at an extra cost to the forest grower. Therefore, prices for pruned logs with fixed lengths of clears are the strongest determinant in choices around whether or when to prune (MacLaren and Knowles 2005).

Thinning refers to the selective extraction of trees from the forest before harvest. The need for mutual protection of young trees against exposure means that more trees are planted initially than are required for the final crop. MacLaren and Knowles (2005) suggest that thinning improves the growth rate of remaining trees and reduces the risk of windthrow in the stand. The extracted trees may be left inside the stand or may be removed and sold (known as production thinning). At least one thinning must occur before harvest to ensure the remaining trees grow to an optimal size. This reduces the risk of windthrow to the residual trees, which becomes unacceptable beyond a stand height of 14–18 metres. The timing of the operation is also dependent on whether the thinned trees will be sold. Production thinning requires trees to be large enough and in sufficient quantity (approximately 75–125 m^3 per hectare) to make removal commercially viable. Approximately 84% of the total area currently planted with radiata pine has not been production thinned (Table 3). Thinning is relatively unpopular in New Zealand compared to many other countries (e.g. in Europe). Reasons for this include the often difficult topography on new forest sites, the poor or non-existent markets for stems of small piece-size outside the central North Island, and potential damage to crop trees and land removed from production due to the construction of roads and landings.

ECOSYSTEM SERVICES PROVIDED BY PLANTED FORESTS

The MEA (2005) consider the 10 key ecosystems in the world to be the cultivated, dryland, forest, urban, inland water, coastal, marine, polar, mountain and island ecosystems. Of these, the forest ecosystem provides the highest number of ecosystem services. The forest ecosystem includes New Zealand's planted forests, which provide provisioning, regulating, cultural and supporting services. Figure 2 shows the ecosystem services provided by New Zealand planted forests as adapted from the MEA (2005). The planted forest ecosystem provides a variety of services ranging from those that have market prices and are reflected in the gross domestic product (GDP) (e.g. wood and fibre) to the less tangible ones that are not yet clearly seen in market transactions (e.g. avoided erosion, recreation, water quality). This section presents the four groups of ecosystem services provided by planted forests starting with the more tangible 'provisioning' services by discussing the products, markets and contribution to GDP. This is followed by discussion of the other three services as these are also important to society, but their values remain largely unrecognised. It is hoped that these less tangible services will be better represented in future policies and national accounting systems as they provide a wide range of environmental and social benefits that are increasingly being recognised both locally and globally.

Provisioning services

Provisioning services refer to the products derived from a planted forest ecosystem such as logs, processed wood, fibre and fuel. Forest products directly contribute to GDP (mainly in the form of export earnings and domestic sales) as they have market prices, which may be expressed in dollars per tonne. The forest industry also provides raw materials that can be used to generate heat and power for other primary industries.

Forest products and markets — The main products from New Zealand's planted forests are currently logs, processed wood, pulp, and paper. The log export and wood processing industries source almost all (>99.99%) of their material from planted forests due to the strict planning and permit process associated with harvesting natural forests on private land (Griffiths 2003). Also, no harvesting is allowed on publicly owned natural forests, which accounts for about two-thirds of the natural forest domain (Lee-Jones 2011). Provisional

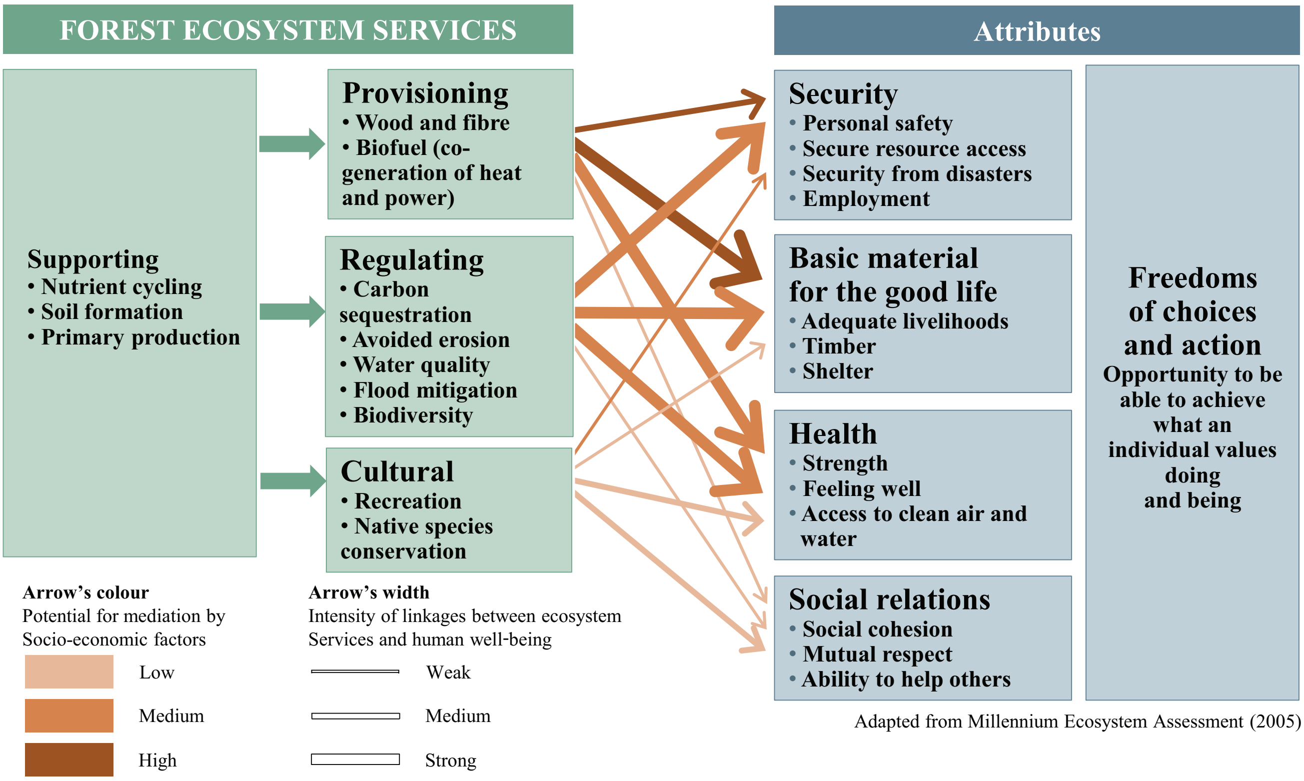

FIGURE 2 Ecosystem services provided by New Zealand's planted forests (adapted from MEA 2005).

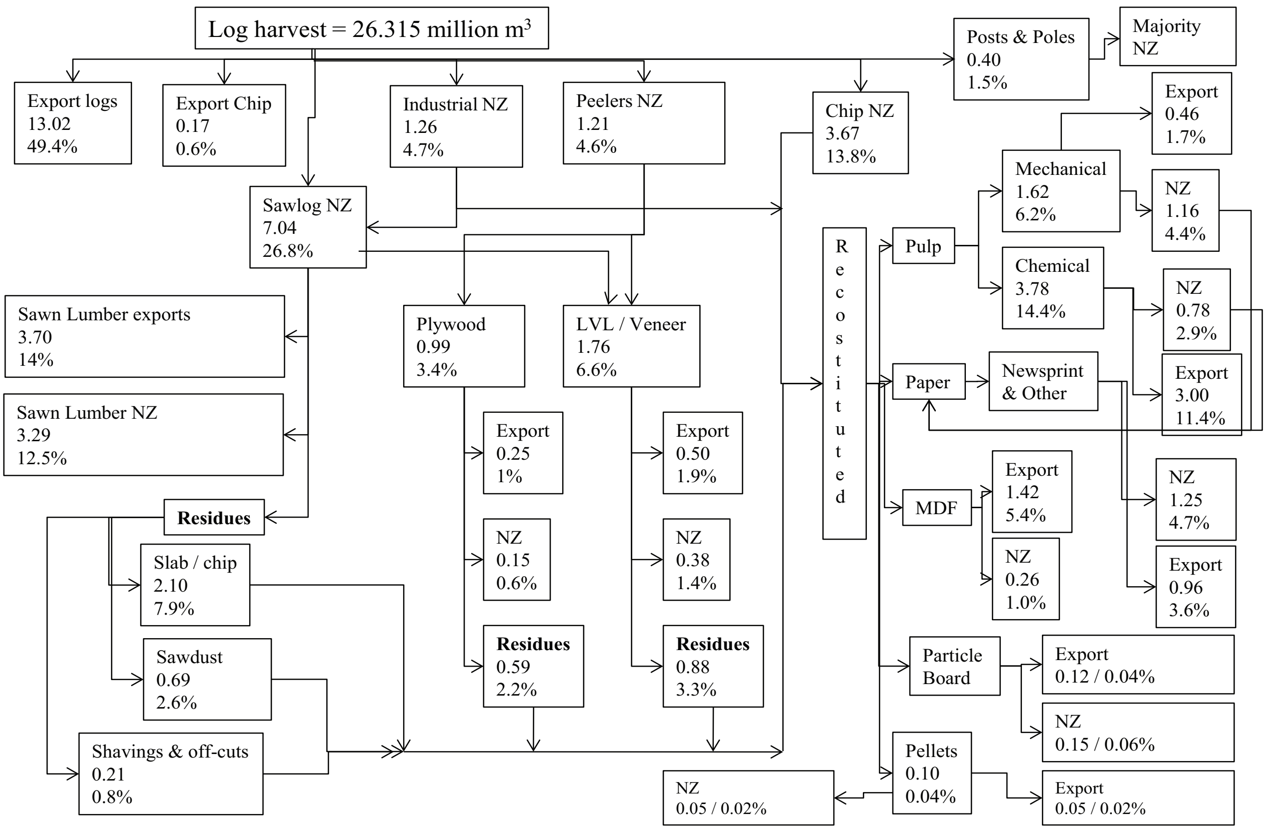

FIGURE 3 New Zealand log harvest – wood flow to products and exports; as log equivalent volumes (all estimates are in million cubic metres), 97.5% balance.

estimates indicate a total of over 26 million cubic metres of roundwood was removed for the year ending September 2011 (MPI 2012c). This wood volume was harvested from 43 300 hectares of planted forest (or 2.5% of the total planted forest area) (MPI 2012c). In 2011, the country provided 1.6% of the world's supply of industrial roundwood (wood that is used for any purpose other than energy). Uses of roundwood include sawlogs, veneer logs, fence posts and telegraph poles) (FAO 2012a). Almost half this total was exported directly either as logs or poles (FAO 2012a) (Figure 3). Asian markets take over 99% of these log exports, with China importing approximately 63% and South Korea 19% (MPI 2012a). A small amount of material was exported as woodchip. The remaining roundwood removals are consumed domestically or converted into various forest products in the country's wood processing industry, for further export and domestic consumption. A detailed breakdown of the wood processing industry in New Zealand and the allocation and reuse volume of New Zealand harvested logs is shown in Figure 3[3].

Sale of roundwood and other forest products contributed about NZ$4.3 billion in annual export earnings, as of June 2012 (MPI 2012a). Revenue from domestic sales of forest products was estimated at around NZ$3.0 billion in 2012 (Horgan 2013). The industry directly employed almost 18 000 people in 2011 (Table 4). Total employment in forest-related activities that year was about 55 600 accounting for 2.3% of the New Zealand labour force (MPI 2012c).

TABLE 4 Employment in forestry and activities associated with the use of wood in New Zealand for the period February 2011 to February 2012

ANZSIC 2006 Code and description of activity	Value
Forestry and logging total	6950
Sawmilling, planning, and other wood milling total	11 005
Paper and paper products total	4950
Wooden furniture manufacturing total	3790
Construction of buildings total	28 940
Forestry first stage processing total	17 955
Total New Zealand industry as at February 2011	1 909 900
Total employed labour force as at March 2011	2 209 900
Total labour force as at March 2011	2 376 700

Note 1: Employee count is a head-count of all salary and wage earners for the February month. The Full Time Employee (FTE) count was discontinued in 2003 and replaced with the "Employee Count" in 2004.
Note 2: ANZSIC 2006 is the abbreviation for Australian and New Zealand Standard Industrial Classification 2006 (Trewin and Pink 2006)
Source: MPI (2012a)

The log export market serves as a valuable outlet for grades not consumed in New Zealand and provides an essential outlet for fluctuations in wood availability when wood processors reach their full capacity. The production of forestry products has fluctuated over the last 50 years (Figure 4A). The proportion of logs exported relative to the amount harvested has increased dramatically over this period (Figure 4B). There has been a gradual increase in the value of log exports over the same period in US dollars, with a sharp increase in value in the last 5 years (Figure 4C[4]). Various products are measured in different units so have been converted to metric tonnes assuming nominal product densities (logs, woodchips, sawn timber, and sleepers are 490 kg m^{-3}; panel products are 700 kg m^{-3}; paper and paperboard are 800 kg m^{-3}; and other products are 650 kg m^{-3}). The world's forest resources are unevenly distributed allowing timber-rich countries, such as New Zealand, to trade with regions experiencing a shortfall in domestic supply. Furthermore, a global decline in supply from naturally grown forests has increased interest in planted forests (Katz 2005). New Zealand has, therefore, been well positioned to take advantage of these opportunities.

In the last decade, increases in New Zealand's log exports have been mostly due to strong demand from Asian markets (GTIS 2013), who buy almost all exported logs. Imposition of a Russian log export tax in 2008 resulted in fewer logs being exported from Russia to China (Lee-Jones 2011). This situation, assisted by competitive pricing of radiata pine logs from New Zealand, expanded the Chinese market to the point where China is the top destination for New Zealand's log exports. This is likely to strengthen in the future as the gap between timber production and demand for wood products in China increases further (Lee-Jones 2011). Export receipts in 2011 for roundwood totalled NZ$1.65 billion (MPI 2012a).

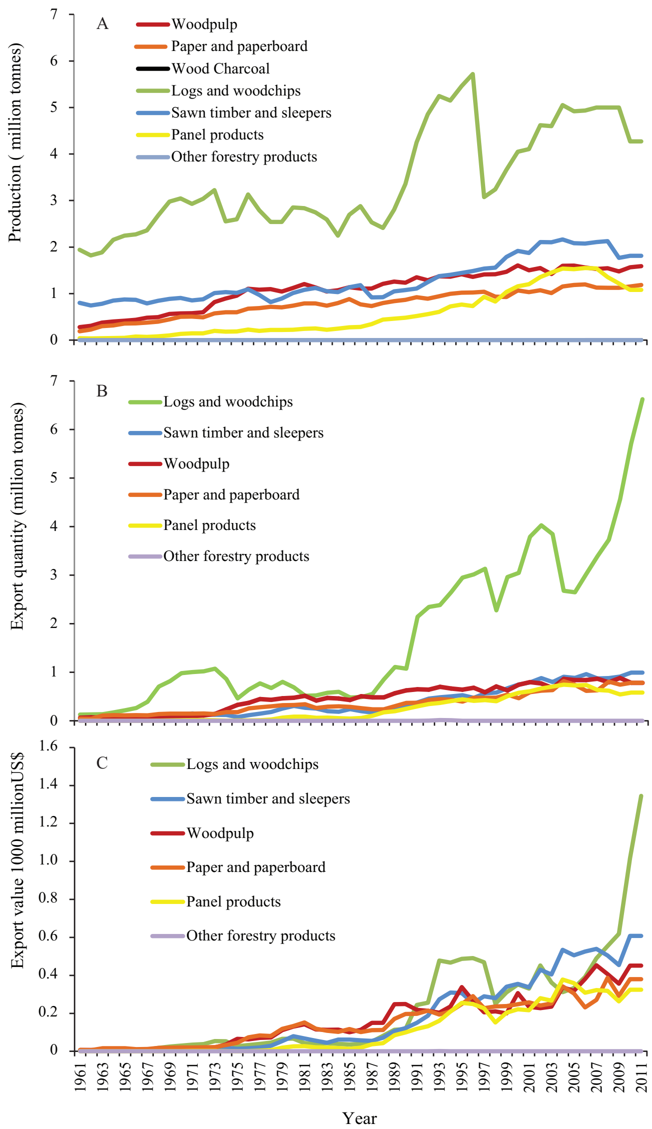

FIGURE 4 Production quantity (A), export quantity (B) and export value (C) of New Zealand forest products from 1961 to 2011 (adapted from FAO 2012).

The sawmilling sector produces sawn timber for export and for the New Zealand construction industry. Stulen (2005) identified six important economic factors for this sector: (1) the expansion in sawn timber export markets from a growing domestic wood supply; (2) lower wood quality from earlier harvesting, (3) advances in sawmilling technology, (4) currency fluctuations, (5) globalisation increasing competitiveness, and (6) changes to market structures.

These factors provide both opportunities and challenges to the sector. Unfortunately, unfavourable changes in currency values and poor wood quality have been major issues for onshore processing that have led to the closure of some sawmills in New Zealand in recent decades. MPI (2012a) reports that in 2011, the largest proportion of sawn timber exports (20%) went to China, with Asia as a whole importing 72%. Australia and the United States were also important export destinations, accounting for 12% and 9%, respectively. Export receipts for the sawn timber, as well as sleepers, were over NZ$750 million (MPI 2012a).

Panel products (such as plywood, fibreboard and other panel products) consist of processed wood material bound together to form sheets. Their properties are closely related to the type and size of wood particles and the types of glue used, as well as how they are manufactured. End uses of panels include furniture, joinery and fitments, cladding, flooring, sheet bracing in walls or ceilings, and concrete shuttering (Warnes 2005). Asia takes 81% of New Zealand's exported panel products. Japan accounts for the majority of these exports at almost 50%, followed by the Philippines at 12% and then China at 10%. The United States and Australia take 5% and 9% respectively (MPI 2012a), but world markets are changing and China has recently become the major net exporter of wood-based panel products globally. In 2008, it was the world's top producer of wood-based panels accounting for 70% of the Asia-Pacific region's (includes New Zealand) production (FAO 2011). In fact, over one-quarter of New Zealand's panel imports came from China in 2011 (GTIS 2013). It is important to note that these figures are not directly comparable as there will be variations in panel properties, wood species used, and log grades traded and manufactured. However, there may be an important opportunity for the New Zealand wood-processing sector to increase the value of its provisioning service from forestry through investment in value added manufacturing like panel products, which in 2011 provided over NZ$480 million in export receipts (MPI 2012a).

In 2011, New Zealand exported over 50% of pulp produced, at approximately 815 000 tonnes (FAO 2012b). Asia-Pacific markets (mostly Japan, China, and South Korea) account for approximately 97% of this volume. The total value of these exports in 2011 was over NZ$610 million (MPI 2012a). Paper and paperboard exports provided over NZ$400 million in the same period, with approximately one-third of exports going to Australia (MPI 2012a). China, the Philippines, and Malaysia account for another third, with the rest of Asia and the United States making up the remainder.

Economic impacts — Figure 5 highlights the importance of forestry to the New Zealand economy. Across the other high income OECD countries, New Zealand is second only to Estonia in terms of the proportion of forestry's contribution to the economy. The estimates refer to the value added coming only from roundwood harvest (World Bank 2013), which therefore does not include the value added from the wood-processing sector. However, the wood-processing sector has the potential to add significant value to each log harvested by focusing on more options for onshore processing (WoodCo 2012) while at the same time providing extra employment domestically.

The value of exports is affected by the strength of the New Zealand dollar. For example, for the year ended September

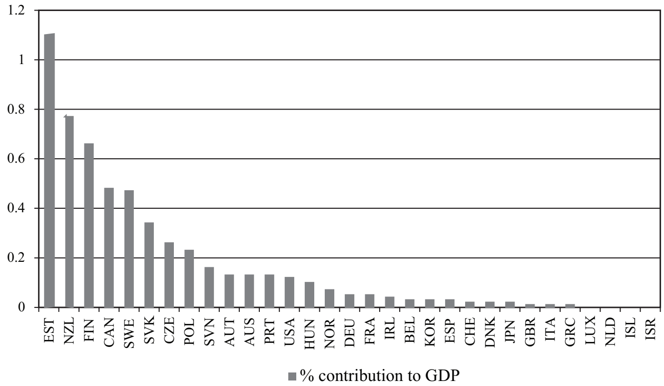

FIGURE 5 Percentage contribution of roundwood harvest to GDP to high income OECD countries (Source: The World Bank 2013).

2011, export returns were up 28% in US dollar terms but only 14% in NZ dollar terms (Lee-Jones 2012).

Regional economies — The forest and logging industries contribute significantly to the economy of the Waikato Region. In 2011, almost 3.8 million cubic metres of logs were harvested in the region, approximately 15.7% of the nation's total harvest in that year. Wood-product manufacturing is also very important to the Waikato regional economy with three major wood and paper manufacturing employers located in this region as at 2010. Employment in this sector is above average relative to the rest of New Zealand. Also, five of the six largest New Zealand forest owners/managers own planted forests in the region (Ashraf and Philips 2012).

The Waikato Region has acknowledged the contribution of natural resources to its economy in the form of ecosystem services. In 1997, the economic worth of ecosystem services was estimated at approximately $9.4 billion, the same as the region's GDP at that time. Forestry[5] contributed almost 20% of this value through climate and erosion control, nutrient cycling, waste treatment, raw material production, and carbon storage (Patterson and Cole 1999).

The Bay of Plenty Region is the country's main wood-processing area and the country's largest sawmill (Waipa) is located within this district. This sawmill was established by the Government in 1939 but has been operated by the private firm Red Stag Timber since 2003. Planted forests cover over 20% of the region. An area of 5.8 million hectares (24.3% of the national total harvest) of the Bay of Plenty was harvested in 2011. In the same year, the Bay of Plenty's forestry sector contributed NZ$88 million to the regional economy (equivalent to 2.3% of the region's total GDP of NZ$3.8 billion). Forestry and logging plus the wood and paper product manufacturing industries provided a larger proportion of GDP to the Bay of Plenty compared with other regions in New Zealand (Infometrics 2012). This region is also home to Scion[6], a leading provider of forest research for the industry.

Bioenergy — The forestry industry contributes to New Zealand's position as a world leader in the co-generation of heat and power from biomass (IEA 2011). Wood waste generated during tree harvesting and sawdust generated during wood processing are used as fuels to produce energy in sawmills, thereby minimising the need for energy from other sources, such as coal. The principal use of this energy at present is for heat in timber-drying kilns. However, opportunities exist for building combined heat and power plants at both saw and pulp mills. In 2011, the total energy derived from wood accounted for approximately 7.4% of the country's primary energy consumption according to the Ministry of Economic Development (MED 2012). Based on these data, the amount of heat generated in the country from bioenergy was approximately 54.4 petajoules in 2011. This quantity is valued at NZ$921 million for that year in biofuel value using an assumed value of NZ$16.9 million per petajoule.

In addition to the wood material that is used for energy, there is a significant resource of in-forest residues created during forest tree harvesting, which are not currently utilised for any purpose. This material consists of stem-wood offcuts and breakage, along with branches. It occurs in a variety of locations, some at roadside and some at the stump. The total amount is in the order of 2–2.5 million cubic metres of wood per annum, with an estimated energy content of 13–17 petajoules, valued at approximately NZ$200 million to NZ$280 million. Adding this value to the biofuel value of NZ$921 million, provided above, shows that bioenergy could potentially provide an overall value in excess of $1 billion.

Furthermore, New Zealand's planted forests are sustainably managed so any fuel derived from them has a very low carbon footprint. The production of logs and associated residues is expected to rise by around 40% over the next 10–15 years (MPI 2012b).

Regulating services

The MEA (2005) defines regulating services as 'the benefits obtained from the regulation of ecosystem processes'. Planted forests provide regulating services such as carbon sequestration, avoided erosion, improved water quality, and flood mitigation (Figure 2). At present only the carbon sequestration service has an economic market.

Carbon sequestration —_According to the Intergovernmental Panel on Climate Change Fourth Assessment Report released in 2007, evidence for warming of the climate system is now unequivocal and there is high confidence that the net effect of human activities since 1750 has been one of warming. Global atmospheric concentrations of carbon dioxide, methane and nitrous oxide have increased markedly as a result of human activities since 1750 and now far exceed pre-industrial values (IPCC 2007).The United Nations Framework Convention on Climate Change (UNFCCC), which was signed in 1992, has the objective of stabilising atmospheric concentrations of greenhouse gases including carbon dioxide. The Kyoto Protocol is part of the Convention and provides for binding commitments to emissions reduction. Deforestation is the second largest anthropogenic source of carbon dioxide emissions to the atmosphere, after fossil-fuel combustion. Conversely, the role of forests in removing carbon dioxide (CO_2) in the atmosphere through photosynthesis and storing it as biomass is acknowledged in the internationally agreed rules for reporting and accounting of greenhouse gas emissions and removals. Planted-forest carbon stocks and sequestration rates have been calculated for New Zealand regularly since 1990 (MfE 2012).

For the purposes of international accounting and reporting under the UNFCCC, New Zealand recognises three categories of forest:

1) Pre-1990 natural forest including successional communities (8.1 million ha)
2) Pre-1990 planted forest (1.4 million ha)
3) Post-1989 natural and planted forests (0.6 million ha).

The latter category is mostly planted forest, with a small amount of regenerating natural forest. Currently the assumption is made that natural-forest carbon stocks are in a steady state at the national level, but estimates of carbon stocks and carbon stock changes are provided by the national greenhouse gas inventory for sub-categories (2) and (3).

The distinction between planted forests established before 1 January 1990 and those established after that date is made to align with international policy (the Kyoto Protocol) and is carried through to domestic policy (the Emissions Trading Scheme, ETS). For the first commitment period of the Kyoto Protocol (2008–2012), accounting for the net emissions from afforestation, reforestation and deforestation since 1 January 1990 is mandatory. Accounting for stock changes in forests that already existed before this date (e.g. due to harvesting and restocking) is optional but total removals from these forests are capped and New Zealand did not elect to account for them. Under the second commitment period (2013–2020), accounting for all managed forests is mandatory but New Zealand has indicated that it will not take on a binding commitment to this part of the agreement.

Reporting of the carbon in harvested wood products is optional under Convention reporting, and estimates were not included in New Zealand's inventory. Accounting for wood products under the Kyoto Protocol is on the basis of an instantaneous emission at the time of harvest for the first commitment period but a first-order-decay approach may be used for the second commitment period.

Estimates of carbon stock and stock change in planted forests are based on estimates of forest area, activity (harvesting, restocking, afforestation and deforestation) and yield tables derived from simulations undertaken using specialised software such as the Forest Carbon Predictor (Beets et al. 2011). This model integrates the 300 Index Growth Model (Kimberley et al. 2005), a wood density model (Beets et al. 2007), a stand tending model (Beets and Kimberley 2011), and the C_Change carbon allocation model (Beets et al. 1999), to enable predictions of carbon stocks and changes in New Zealand's planted forests.

The Forest Carbon Predictor simulates the four biomass pools (above-ground biomass, below-ground biomass, dead wood and litter) and accounts for transfers between them due to factors such as needle fall, pruning and thinning. Estimates of soil carbon are based on IPCC default methodology, and assume that soil carbon will stabilise after 28 years following a land-use change. Data are available from the national inventory report for the period 1990–2010 (MfE 2012) and show that:

- Pre-1990 planted forests sequestered about 29 Mt CO_2 annually in the early 1990s but this declined steadily to less than 7 Mt CO_2 in 2002 and remained low due to the combined effects of deforestation and harvesting.
- Post-1989 forests were initially a small source of carbon as the sequestration by growing trees did not compensate for the emissions from vegetation displaced and soil-carbon losses following the land-use change. Sequestration climbed steadily from the mid-1990s, levelling off at about 18 Mt CO_2 annually from 2005.
- Average sequestration rates per hectare vary over time as the age-class structure of forest changes. For planted forests as a whole the rate has varied from 10 to 19 t CO_2 ha^{-1} since 1990.

Previous modelling work undertaken on a similar basis has considered both a longer time frame and future projections. Results showed the importance of afforestation rate and harvesting rate in determining net emissions. For example, Maclaren et al. (1995) showed that the New Zealand plantation estate was a net source of carbon dioxide in the 1970s, despite an increasing area. This is because the last of the over-mature 'old crop' established in the 1930s was harvested and replanted during this period. Similarly, the post-1989 planted forests that are expected to help New Zealand achieve its targets during the first commitment period are likely to be a net source of carbon from 2020, when the extensive areas planted in the mid-1990s become ready to harvest[7]. Pre-1990 planted forests are expected to be a net source in the short term until harvesting switches to the post-1989 resource.

The duration over which pre-1990 forests are a source is shortened if wood products produced are assumed to decay exponentially rather than being instantly emitted at harvest, since

FIGURE 6 Quarterly carbon price used to calculate New Zealand's Kyoto net position.

short-term net emissions are reduced and long-term emissions are increased (Manley and Maclaren 2010). Gross removals by post-1989 planted forests over the first commitment period were 92 Mt CO_2-equivalent; just over half the 170 Mt CO_2-equivalent emitted by agriculture[8]. Obviously, this proportion will fluctuate over time as the age-class structure of the total forest estate changes, and could increase if more marginal farmland is converted to forest.

The value of carbon sequestration by planted forests can be calculated in a number of ways. The obvious option is to use the market price in the New Zealand Emissions Trading Scheme (ETS). The ETS was designed to cover all sectors and greenhouse gases. Participants who emit greenhouse gases are obliged to surrender emission units, which can be bought on the market in New Zealand or overseas, or from the New Zealand Government at a fixed price of NZ$25. Total emissions are uncapped. Units can be earned through removal activities, including the sequestration of carbon dioxide in forests, embedding of carbon within certain products (e.g. methanol), carbon capture and storage, and the export or destruction of synthetic gases. The demand for units within the ETS is limited for a number of reasons: free allocations of units were made to certain participants (including foresters who may wish to deforest); transition arrangements allowed one emission unit to be surrendered for every two units emitted; and entry of the agriculture sector has been deferred. The ETS is linked to international carbon markets as it allows most Kyoto Protocol emission units to be imported, including Emission Reduction Units (ERUs), Certified Emission Reductions (CERs) and Removal Units (RMUs). The carbon price is therefore set internationally and capped by the New Zealand Government's fixed price. The glut of removal units available on the European market (where their use is restricted) has led to a collapse in the carbon price on the New Zealand market. The carbon price used for calculating New Zealand's net position under the Kyoto Protocol has varied considerably since being introduced. The price per quarter between May 2005 and February 2013 is shown in Figure 6. Using the highest price (NZ$29.24, November 2008), the value of annual sequestration by all planted forests combined has ranged from NZ$600 million to $850 million since 1990. Using the lowest price (NZ$0.19, November 2012) this drops to just NZ$3.9 million to $5.5 million; the equivalent per hectare values are NZ$285–$543 and $1.90–$3.50, respectively. Note, however, that removal units cannot be earned from pre-1990 planted forests in the ETS.

As well as valuing the annual removal of carbon dioxide from the atmosphere by planted forests, it is also possible to value the total carbon held within the forest stock. The carbon stock in planted forests was estimated for 2008 based on a national plot network and reported in the greenhouse-gas inventory (MPI 2012b). The average stock in pre-1990 planted forests was estimated as 124 ± 10 t C ha^{-1} and in post-1989 forest as 88 ± 3 t C ha^{-1} (both at the 95% confidence interval). These estimates exclude soil carbon, which is estimated to be 90 t C ha^{-1}. The value of carbon stored in non-soil pools in planted forests ranges from NZ$148 to NZ$22,749 per hectare, or NZ$0.2 to NZ$25 billion in total using the low and high carbon prices given above. Alternative approaches can be taken to valuing sequestration. Forestry sequestration is not covered by the European ETS, so the British Government guidance on valuing carbon used a base 2010 price of £52 per tonne of CO_2 (about NZ$100) for forestry sequestration for 'social value' (DECC 2010). Carbon could also be valued in terms of the marginal cost of reducing emissions in other sectors in New Zealand (i.e. assuming removal units could not be imported) or by calculating the cost to the economy of unmitigated climate change.

In general, carbon dioxide sequestered in trees and wood products is stored on a temporary basis before being released back to the atmosphere through decay or combustion. Credits may be earned while the trees are growing but a liability is incurred at the time of harvest. The value to the grower in the ETS comes through the use of money in the intervening period and the possibility that the carbon price will be lower when the liability is incurred. The regulatory-service value lies in expanding the carbon stock held in forests by extending forest area and/or stock per hectare. The pool of carbon in forest products can also be expanded and these products may substitute for products with a higher greenhouse gas footprint. Wood can also directly substitute for fossil fuel use.

Avoided erosion — Soils generally perform many regulatory services including flood mitigation, filtering of nutrients, biological control of pests and disease, recycling of wastes and detoxification, and regulation of nitrous oxide (N_2O) and methane (CH_4) emissions (Dominati et al. 2010). Planted forest ecosystems are considered an important resource for protecting many of these services, through avoiding soil erosion (MEA 2005). The total annual cost of soil erosion in New Zealand was estimated at NZ$127 million in 2001 (Krausse et al. 2001), and approximately NZ$200 million in current dollars (Dymond et al. 2011). This estimate outlines the impacts of erosion as those that occur onsite as soil erosion and those that occur offsite as sedimentation. This was expanded more recently to outline the impacts as onsite erosion, sedimentation and flooding (Blaschke et al. 2008). Defining the ecosystem services to be valued according to the relevant temporal and spatial scale (e.g. onsite, offsite) helps to avoid double counting (Fu et al. 2011). However, Krausse et al.'s estimate may be subject to double counting, for instance, it is assumed that estimated costs of erosion are additive. This may affect the accuracy of the total cost of erosion estimated but still may provide an approximation in the order of magnitude for the true cost of soil erosion in New Zealand. Double counting can be avoided by employing measures such as accounting only for the value of the final ecosystem service benefits (Fisher and Turner 2008), employing the appropriate valuation method or combination of methods with consideration of the context (Fu et al. 2011), and differentiating between public and private net benefits to avoid potential double counting across stakeholders of ecosystem service benefits (Pannell 2008).

Various studies have identified the vulnerability of pasture land to landslide erosion compared with that of forested land or scrub, with forests offering the least vulnerability (e.g. Pain and

Stephens 1990; Hicks 1991; Marden and Rowan 1993; Jones et al. 2008). Jones et al. (2008) suggest that planting radiata pine trees can be an effective means of controlling erosion. The economic value of reduced erosion was calculated by Barry et al. (2012b). They found that afforestation using radiata pine trees on marginal lands in New Zealand's Gisborne Region may provide an avoided erosion benefit in excess of NZ$1,000 per hectare into perpetuity. The benefits could be even higher for marginal lands in Gisborne that have steeper slopes.

Improved water quality and flood mitigation — Established planted forests improve the infiltration capacity of compacted soils, which in turn reduce surface runoff. These forests also improve water quality by directly shading streams and lake margins and by reducing nutrient and bacterial inputs as a replacement for agricultural crops or as stream buffers (Dyck 2003). Rivas Palma (2008) found that planted forests in Hawke's Bay are valued by households for their ability to contribute to better water quality. In terms of flood mitigation, Bicknell et al. (2004) estimated that damages due to floods cost New Zealand insurers NZ$247 million between 1995 and 2004, excluding government compensation payments. It is recognised that tree establishment could significantly reduce flooding (Blaschke et al. 2008). Although valuation methods have been developed to estimate values of flood mitigation, to the best of our knowledge, no study yet has estimated the economic value of flood mitigation benefits provided by planted forests.

Cultural services

Cultural services are those non-material benefits obtained from an ecosystem, such as recreation, aesthetic experience, spiritual enrichment, appreciation of biodiversity, and conservation. Several planted forests in New Zealand provide recreational opportunities to the people who visit them, including walking, mountain biking, horse riding, running, and exercising dogs. Cultural services are increasingly recognised as important components of forest ecosystems. For instance, business entities invested in adding new facilities for four-wheel driving and paintballing, and flying-fox adventure in Woodhill forest, a planted forest about 35 minutes by car from Auckland's central business district[9,10,11]. This 12 500-hectare planted forest is also popular for hunting, horse riding and motorcrossing (Te Ara 2012).

Many studies suggest that habitats for threatened native species can be enhanced through forest management (Maunder et al. 2005; Carnus et al. 2006; Seaton et al. 2009). With the formulation of sustainable management guidelines such as those of product certification (e.g. Forest Stewardship Council, FSC), forest managers increasingly recognise the need to conserve indigenous biodiversity. In fact, New Zealand's planted forests provide habitat for at least 118 threatened native species (Brockerhoff et al. 2008; Seaton et al. 2009; Pawson et al. 2010). This is consistent with the findings of numerous studies overseas (Humprey et al. 2003; Carnus et al. 2006). While a planted forest may support fewer native species than a native forest at the same site, Brockerhoff et al. (2008) suggest that planted forests may also replace other human-modified ecosystems (e.g. degraded pasture). Yao (2012) estimated that an average value of $69 per household per year for 5 years was placed on increasing the abundance of threatened native species in planted forests by a sample of New Zealanders responding to a proposed biodiversity enhancement programme in New Zealand's planted forests (see Case 3 in this chapter).

A number of studies that estimated the value of forest ecosystem services in planted or native forests have been undertaken in the last 30 years (Table 5). Some applied a 'revealed preference approach' where value was estimated based on observed behaviour such as cost of travelling and time spent in the forest. Other studies applied the 'stated preference approach' where value is elicited based on a simulated market such as contingent valuation and choice experiment. The recreational values from each study are listed as Willingness to Pay (WTP) estimates in each case.

All WTP values were converted to 2012 New Zealand dollars using the New Zealand Inflation Calculator[12]. Economic valuation techniques are established tools in approximating the value of non-market goods. However, estimated WTP values may depend on how each economic valuation survey was conducted and the econometric models that were used. Estimated WTP values may represent conservative estimates as other factors may not have been accounted for in the valuation process. Therefore, proper care should be undertaken if using these numbers in cost–benefit analysis.

Nine of the 12 studies valued recreation per visit while the remaining three valued additional habitat protection for biodiversity conservation. The three economic valuation studies of individual planted forests (1–3 in Table 5) showed that the value of recreation provided ranges between $34 and $67 per visit in 2012 New Zealand dollars. Yao and Kaval (2010) sampled more than 700 households across New Zealand for willingness to pay for the improved provision of habitat for native species in public forests ($95 per year per household). Kerr (1996) used the contingent valuation method and estimated from a sample of users of the Kaitoke Regional Park that the median willingness to pay for the maintenance of park facilities is about $15 per visit. Beanland (1992) found that households would be willing to pay about $14 per year for biodiversity conservation (via possum control) in Aorangi Awarua native forest park.

Barry et al. (2012a) used continent valuation to estimate the willingness to pay for a possible entrance fee in a new forest park, Tauranga Energy Consumers Trust (TECT) Park in the Bay of Plenty region. Estimated entrance fees for various types of activity per visit were walking ($4), mountain biking ($8), horse riding ($9) and motocross ($19). These recreational activities are only part of the many outdoor recreational pursuits that TECT Park provides for at least nine recreational clubs[13].

In addition to recreation, Table 5 shows studies that value other ecosystem services from planted forests. Yao (2012) estimated the economic value of a proposed biodiversity enhancement programme in New Zealand's planted forests, which is about $69 per household per year for 5 years. Rivas Palma (2008) used choice modelling to estimate the value of improving water quality, quantity and biodiversity in planted forests in Hawke's Bay. The study found that Hawke's Bay households would be willing to pay hundreds of dollars per year for improvement in the provision of those services.

Of the 12 studies listed in Table 5, only five studies were conducted from 2005 onwards while the rest were done in the 1980s and 1990s. There is a distinct lack of recent estimates of economic values of forest ecosystem services. For instance, hunting activities occur in planted forests (e.g. Kaingaroa, Kinleith) and they could either be recreational, subsistence or trophy hunting, hence highly variable in economic value. To the best of our knowledge, no valuation study has been done for hunting in planted forests. In terms of health benefits, Willis and Crabtree (2011) estimated forests in the UK to contribute approximately £1.44 billion in human health benefits, which included reduction in the occurrence of cardiovascular and respiratory

TABLE 5 Comparison of studies calculating the economic value of cultural ecosystem services in New Zealand forests

Study number	Forest(s) studied	Region	Forest type	Forest area (ha)	Ecosystem service	Valuation method used (year valued)
1	Bottle Lake Forest	Canterbury	Exotic planted forest	1200	General recreation	Contingent Valuation (1989)
2	Whakarewarewa Forest	Bay of Plenty	Exotic planted forest	5700	Recreation (walking and mountain biking)	Travel cost (2009)
3	Hanmer Forest	Canterbury	Exotic planted forest	13 000	Recreation	Travel cost (1985)
4	Kaitoke Regional Park	Wellington	Native	2860	General recreation	Contingent valuation (1995)
5	Aorangi Awarua Forest	Wellington	Native	5000	Biodiversity conservation (via possum control)	Contingent valuation (1991)
6	Planted forests	Planted forest areas in all regions	Exotic planted forest	1 720 000	Indigenous biodiversity enhancement	Choice modelling (2010)
7	Kaimanawa and Kaweka Forests Parks	Waikato and Hawke's Bay	Native	140 000	Recreational hunting	Travel cost (1982)
8	Tararua Forest Park	Wellington	Native	116 535	Recreation	Travel cost (1988)
9	Coromandel State Forest Park	Waikato	Exotic planted forest	71 900	Recreation	Travel cost (1982)
10	Native forests on public land	Public land in all regions	Native	8 600 000	Biodiversity	Contingent valuation (2007)
11	Planted forests in Hawke's Bay	Hawke's Bay	Exotic planted forest	128 800	Water quality and quantity, and biodiversity,	Choice modelling (2005)
12	TECT (Tauranga Energy Consumers Trust) all terrain park	Bay of Plenty	Mixture of exotic planted forest and native	1650	Recreation	Contingent valuation (2011)

Study number	Authors (year published)	Willingness to pay (original valuation $)	Willingness to pay (2012 fourth quarter $)	Number of visits for one year (data source)
1	Walker (1992)	$29 per visit	$51 per visit	400 000 (http://www1.ccc.govt.nz/)
2	Dhakal et al. (2012)	$34 per walking visit $49 per mountain biking visit	$36 per walking visit $52 per mountain biking visit	309 000 (APR 2010)
3	Sandrey (1986)	$26 per person per visit	$67 per person per visit	200 000 (DOC 2000)
4	Kerr (1996)	$10.74 per visit	$15.46 per visit	Data not found
5	Beanland (1992)	$8.73 per household per year	$13.86 per household per year	78 075 (Beanland 1992)
6	Yao (2012)	$65 per person per year for 5 years	$69 per person per year for 5 years	Not applicable
7	Sandrey and Simmons (1984)	$27 per person per hunting visit	$92 per person per hunting visit	20 000 (Sandrey and Simmons 1984)
8	Kerr and Manfredo (1988)	$5.13 per person per night	$9.41 per person per night	135 000 (http://www.teara.govt.nz/)
9	Everitt (1983)	$27 per visitor group per year	$92 per visitor group per year	23 639 (Everitt 1983)
10	Yao and Kaval (2010)	$82 per person per year	$95 per person per year	Not applicable
11	Rivas-Palma (2008)	$3.78 for land stabilisation 1% improvement $515.45 for decreasing sediment in water $496.42 for decreasing algae in water −$53.89 for level of water flow	$4.59 for land stabilisation 1% improvement $626.54 for decreasing sediment in water $603.51 for decreasing algae in water −$65.50 for level of water flow	Not applicable
12	Barry et al. (2012a)	$4.14 per walker visit $7.24 per mountain biking visit $8.50 per horse riding visit $17.64 per motocross visit	$4.40 per walker visit $7.70 per mountain biking visit $9.04 per horse riding visit $18.76 per motocross visit	Number of visits still not available according to a TECT Park staff member

diseases and prevention of mental illnesses. These health values have yet to be estimated in New Zealand's forests. Valuation studies should be undertaken so that planners and decision-makers can better account for those services.

Supporting services

These services are basically the biological, chemical and physical processes that underlie the provision of the other three groups of services described above and illustrated in Figure 2. Supporting services indirectly affect society, as their impacts on people occur over a very long time (MEA 2005). Examples of these services provided by planted forests include soil formation, nutrient cycling, water regulation and oxygen production (Quine et al. 2011). Although these services may be quantified and valued, Fisher and Turner (2008) suggest accounting primarily for the values of final ecosystem service benefits to avoid double counting.

MANAGING FOR ECOSYSTEM SERVICES

Planted forests provide multiple ecosystem services. It is difficult to make management decisions that maximise all of them. Some decision-makers tend to put more weight on provisioning than the other three services (Schwenk et al. 2012). Provisioning services provide tangible goods (e.g. wood and fibre) or products that can readily be valued in the short term, while regulating and cultural benefits may be intangible over the same period (Rodríguez et al. 2006). The weight given to provisioning services means that depletion of New Zealand's natural capital is often greater than is socially desirable (Engel et al. 2008). Maximising the synergies between ecosystem services has been one of the key drivers for developing an ecosystem-services approach (Braat and de Groot 2012). Identifying and valuing a range of ecosystem services from different land uses can help guide land-use decision-making towards more sustainable outcomes. For example, the presence of flowering native shrubs may benefit nearby apiarists, and thus some incentive could be necessary for the forest owner to maintain this provision. This type of negotiation between two stakeholders is known in economic theory as Coase bargaining (Coase 1960). However, government intervention may be necessary to encourage ecosystem service provision where benefits become less tangible and more complex, and if there are many stakeholders. Examples of various trade-offs and synergies between three groups of ecosystem services from planted forests is illustrated as a matrix in Table 6 from the three case studies presented later in this section.

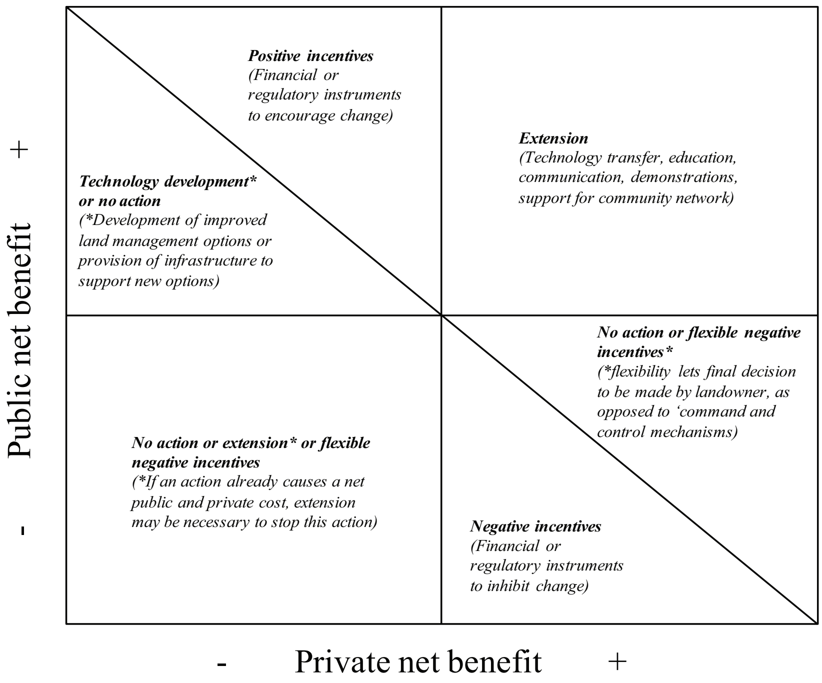

FIGURE 7 Public and private net benefits framework (Source: Pannell 2008).

The level of benefit, the types of services, and the distribution of stakeholders all play a role in deciding suitable policy mechanisms. A framework has been developed that helps policymakers choose between different policy options based on the relative magnitude of public and private net benefits from a land-use change (Pannell 2008, 2009). Figure 7 provides a simplified example of this framework. For example, if afforestation provided a positive private net benefit relative to the previous land use (made more money for the landowner) and a positive public net benefit also (was better for everyone other than the landowner), then the provision of this information may be enough to encourage land use change (top-right quadrant of Figure 7) and would be less expensive than providing a payment to encourage change. On the other hand, where the private net benefit is negative and is outweighed by a positive public net benefit, some sort of payment may be required (top-left quadrant of Figure 7).

Provisioning and regulating services

Planting forests for timber production will sequester carbon and reduce soil erosion, particularly if the land was previously in pasture or bare land. For example, a site in the central North Island can sequester 918 tonnes of carbon dioxide per hectare over a 28-year rotation, including above- and below-ground biomass and the litter layer (Robertson et al. 2004), although this may vary depending on the productivity of the site. The aggregated carbon stock sequestered from New Zealand's planted forests helps to offset New Zealand's greenhouse gas emissions, although this may fluctuate in the short term with the harvesting of trees to produce logs, timber products, paper or fuel. In 2010, net removals from land use, land use change and forestry (LULUCF) decreased by 24% because of increased harvesting of planted forests and low sequestration rates of early plantings on new land relative to the previous land use.

Converting bare land to planted forestry may provide a provisioning service from timber, along with sequestering carbon and reducing sedimentation. However it may also reduce water yield, which can have a negative net benefit on agriculture where there is a demand for irrigation, such as in the tussock grassland in the South Island (Dymond et al. 2011). Sidle et al. (2006) also noted

TABLE 6 Trade-offs and synergies

	Provisioning	Regulating	Cultural
Provisioning		Synergy 1: Afforestation can increase wood supply and carbon storage. It can also reduce soil erosion rates especially on steep areas.	Synergy 2: Forestry operations (e.g. pest control) in existing forests can contribute to the provision of habitats for native birds.
Regulating	Trade-off 1: Planting and harvesting of trees may enhance soil erosion. (Studies on minimising the impacts of harvesting on soil erosion are underway).		Synergy 3: Forests planted in urban areas can assist in flood control and can increase opportunities for recreation.
Cultural	Trade-off 2: Harvesting and planting operations may adversely affect existing habitats for threatened native birds. (Many forest managers now closely coordinate with conservation groups to collect endangered birds before harvesting).	Trade-off 3: Radiata pine forests sequester carbon more efficiently than native species but a landscape of radiata pine may have a low aesthetic value to some people.	

that there is a window of vulnerability between harvesting one crop and replanting the next, which is a high risk period for mass movement erosion, especially if it coincides with an extreme weather event (Phillips et al. 2012). Despite this, there is strong evidence to suggest that planted forests provide reduced sedimentation (Pain and Stephens 1990; Marden and Rowan 1993; Fahey and Marden 2006). To reduce the potential trade-offs between provisioning forest ecosystem services and regulating services, harvesting and replanting must be carefully planned and executed to minimise the impacts of soil erosion and nutrient loss onsite (especially on steep slopes) and sedimentation of waterways. The magnitude of this trade-off may also depend upon the end use of the tree products (including the extent to which these products become an offsite carbon store), and the rate of restoration of forest conditions after felling. The former depends upon markets; the latter on management options, including the scale of the felling intervention, and the manner by which a successor tree crop is established. An example of increased regulation services combined with provisioning services is provided in Case 1.

CASE 1: *Timber, erosion mitigation, and carbon sequestration in the East Coast Region*

The East Coast Region has the two most erodible catchments in New Zealand. The Waiapu and Waiapoa rivers have a combined sediment loss of approximately 50 million tonnes per year (Hicks and Shankar 2003). They are examples of severe ecosystem damage by global standards, despite a relatively low level of floodplain development (Piégay et al. 2006). This case focuses on the area of the catchment (approximately 215 000 ha) that is currently in marginal pastoral agriculture with slight to extreme soil erosion (Watt et al. 2010). An integrated economic model for predicting forestry returns was combined with estimates from the New Zealand Empirical Erosion Model, NZeem (Dymond et al. 2010), to estimate the reduced erosion from afforesting this area; approximately 21 million tonnes of sediment per year, equivalent to 98 tonnes of sediment per hectare per year. Importantly, this estimate is avoided erosion from forestry at full canopy cover and, therefore, does not account for the variation in erosion from various regimes over time. Obviously, there will be disturbance to the soil during harvesting and establishment, when planting for the provisioning service of timber. Also, early forest growth does not provide as much protection as a forest at full canopy. Results from a discounted cash flow analysis with an 8% discount rate show that a typical forestry regime of radiata pine on a 28-year rotation, and using a value of $1 per tonne of sediment (Dymond et al. 2011), would have average timber profits into perpetuity of approximately NZ$1,245 per hectare and an avoided erosion value of approximately NZ$1,017 per hectare. Furthermore, the total carbon stock from this regime would not exceed 1280 tonnes of carbon dioxide per hectare. A similar analysis of a 'plant and leave' regime shows there will subsequently be less erosion, with a present value of approximately NZ$1,114 per hectare and the total carbon stock would accumulate to over 3000 tonnes of carbon dioxide per hectare after 90 years even though there will be no value from timber due to no harvest.

Provisioning and cultural services

The value of cultural services may be positively or negatively affected by production operations. Ideally, these two different services should be jointly managed to provide benefits to both. As mentioned earlier, planted forests in New Zealand provide habitat for at least 118 threatened native species (Pawson et al. 2010). These include iconic species such as the brown kiwi and the bush falcon whose conservation are valued by many New Zealanders (Yao 2012). However, harvesting of these forests may affect the survival of the brown kiwi especially if it was done during the breeding period (Pawson et al. 2010). Use of heavy machinery for forest harvesting and site preparation may also disturb wildlife, at least in the short term (habitat manipulation may actually be beneficial in the medium term) (Quine et al. 2011). The New Zealand Forest Owners Association has formulated management guidelines for planted forests to enhance the awareness of threatened species by managers and owners. These stakeholders are also encouraged to reduce the impact of tree felling and other forest operations to existing threatened species in their respective forests[14]. More than half the area of the planted forest in the country is certified by the Forest Stewardship Council (FSC). Therefore, the majority of planted forests areas comply with FSC Principle 6, which states that forestry management should as much as possible maintain or restore the ecosystem, its biodiversity, resources and landscapes[15]. Many timber companies

CASE 2: *Falcons in Kaingaroa Forest*

Extensive clearance of New Zealand's native forest over the last few centuries has been a major factor in the reduction of falcon populations around the country (Seaton 2007) to the point where this species is threatened with extinction. The 189 000 hectares of planted forest at Kaingaroa, in the central North Island, provides excellent nesting areas and food sources for falcons. The reduced amount of pests (such as stoats, rats, weasels and possums) facilitates safer nesting as falcons nest on the ground. Forest edges, formed in areas between clear-cut and remaining forest stands, provide good habitats for insects and small exotic birds and these areas serve as excellent hunting ground for falcons (Seaton 2007). However, additional activities are still needed to guarantee conservation of the falcon population in the forest. Forest managers can further protect these birds through targeted control of predators, and also reduced impact of harvesting and planting operations in known nesting areas (Maunder 2008).

A survey-based economic valuation study was conducted in 2010 to test if the public would be willing to financially support a proposed falcon conservation programme in Kaingaroa Forest (Yao and Kaval 2010). A survey questionnaire was developed that included contingent valuation questions. About 219 randomly selected individuals across the country provided valid responses to the contingent valuation questions. Results from an econometric analysis of the survey data suggest that a typical respondent would be willing to pay about $14 per year for 5 years to support a proposed programme that would sustain the falcon population in Kaingaroa Forest. This median willingness-to-pay value falls between the bounds of $6 and $20 at the 95% confidence interval based on the econometric estimation by Yao and Kaval (2010).

collaborate with local conservation trusts to protect threatened species in their forests. For example, Kaingaroa Timberlands works with the Wingspan Birds of Prey Trust in Rotorua to facilitate the collection of bush falcons from known locations before harvesting occurs (see Case 2).

There can also be trade-offs between harvesting operations and recreational uses in a forest as access may be restricted for health and safety reasons. Harvesting is likely to produce some changes in the landscape that may rapidly change the aesthetic value of a recreational forest. Good communication between forest users and managers does occur in some cases, such as the Whakarewarewa Forest (Case 3). Users are informed in advance of each scheduled forest operation and usually such operations occur only in small sections of the forest. Therefore, recreation in most parts of the forest continues all year round.

Regulating and cultural services

Radiata pine provides excellent regulating ecosystem services because it is fast growing. However, the value of the cultural services it offers can vary depending on the user. For example, the aesthetic value of a landscape forested with radiata pine may be lower to some people than one with native trees. However, a mountain biker swiftly traversing a track underneath a pine forest would likely be more concerned about the quality of tracks than aesthetic features. The 'willingness to pay' values given in Table 5 for an additional visit to specific forests indicate that the value of a recreational visit to a planted forest is comparable or even higher than that for a native forest. However, estimates in Table 5 are limited only to a few forests and cultural values provided by other key native and planted forests should also be estimated to help improve ecosystem decision-making.

CASE 3: ***Managing the Whakarewarewa Forest for both timber and recreation***

The 5667 hectares of Whakarewarewa Forest are situated about 4 kilometres from the centre of Rotorua, and the public have free access to most parts of the forest for recreation. There were over 300 000 recreational visits, predominantly mountain biking (34%) and walking (29%), in 2009. Other activities included organised bush walks (19%), running/jogging (15%) and horse riding (1%). There are three types of management within this forest: (1) timber production (and partly recreation); (2) recreational forest park; and (3) natural resource conservation.

An APR (2010) survey estimated that there were about 88 500 visits by walkers and another 101 800 visits by mountain bikers to the forest in 2009. Dhakal et al. (2012) studied the value mountain bikers and walkers place on each visit to the forest. They used an economic valuation method called Travel Cost to estimate the recreational use value based on the observed behaviour of a sample of 706 forest visitors (366 walkers and 340 mountain bikers). Results suggest a median willingness to pay of $34 per visit for walkers and $48 for mountain bikers. The economic benefit of the forest for mountain bikers and walkers could be $8 million; $4.9 million from mountain bikers and $3.1 million from walkers.

DISCUSSION

New Zealand's planted forest ecosystem makes a large contribution to the country's economic prosperity, environmental conservation and human well-being. Provisioning services from this ecosystem include production of around 26 million cubic metres of wood. The forest industry significantly contributes to the New Zealand economy with NZ$4.3 billion in export earnings, NZ$3.0 billion in domestic sales of forest products, and employment for 55 600 people in 2011. In addition, co-generation of heat and power from biomass provided biofuel with a value of almost NZ$1 billion (Table 7). Regulating services include carbon sequestration, reduced soil erosion and improved water quality. Assuming a carbon market price of NZ$10 per tonne, the value of carbon credits from planted forests could be approximately NZ$250 million per year. Barry et al. (2013) estimate that the avoided erosion value from the 2.9 million hectares of future forests in the country's marginal agricultural land could be approximately NZ250 million per year. Rivas-Palma (2008) estimates that value of water quality improvement brought about by planted forests in Hawke's Bay could be about NZ29 million per year.

Planted forests also provide cultural services that contribute to the well-being of society especially in forests with high visitation rates. They offer valuable recreational amenities for people and also important habitats to native animals and plants. Table 7 provides estimates of recreational values specific to three iconic planted forests and a value for a proposed biodiversity enhancement programme for all planted forests (Sandrey and Simmons 1984; Walker 1992; Dhakal et al. 2012; Yao 2012). As recreational values are specific to a few forests while the biodiversity programme has not yet been implemented, all the values in Table 7 may not be simply added up given that the estimated values for the provisioning services apply for all existing forests.

TABLE 7 Estimated values of the benefits derived from ecosystem services provided by New Zealand's existing planted forests

Final ecosystem services	In millions of NZ$ (2012$)
Provisioning	
Forest products exports between June 2011 and June 2012	4,278
Domestic sales of forest products in January to December 2012	3,000
Co-generation of heat and power for primary industries in 2011	921
Regulating	
Carbon sequestration (2012 value for post-1989 planted forests assuming $10 per tonne of CO_2	250
Improvement in water quality in Hawke's Bay	29
Avoided erosion in 2.9 million ha of future forests	250
Cultural	
Recreation in Bottle Lake Forest	20
Recreation in Hanmer Forest	37
Recreation in Whakarewarewa Forest	9
Recreation in Whakarewarewa Forest	28

The list of monetary values in Table 7 basically implies that planted forests are more than just forest products with market prices as they also provide environmental and cultural services that have estimated non-market values specific to a very limited number of forests (Hanmer, Bottle Lake, Whakarewarewa) or a region (Hawke's Bay). This chapter shows that regulatory and cultural services are clearly important yet their values remain poorly understood. This lack of understanding means that decision-making processes focus solely on more tangible provisioning services such as export earnings and employment hours. Having robust estimations of the value of regulatory and cultural services, based on empirical data, is likely to improve the likelihood that these data will be included in cost–benefit analyses. More studies using state-of-the-art methods of economic valuation that account for both time and space are required.

In addition, it is important to address common confusion and ambiguity in the use of an ecosystem service approach. Much literature to date has recognised the inherently spatial nature of ecosystem services (Wätzold and Drechsler 2005; Bateman et al. 2011; Dymond et al. 2011) and the reliance of policy on spatially explicit information describing ecosystem services (Maes et al. 2012). And the key issue of double counting and subsequent overestimation of value continues to arise. Future research could focus on separately stacking the final ecosystem service benefits into those that occur for the private stakeholder and those for the public stakeholder. Implementing these values into a policy framework (e.g. Pannell's framework, Figure 7) would help avoid double counting and would target policy to encourage more sustainable land-use decision-making.

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DISCLAIMER

The views and opinions expressed in this book chapter are those of the authors and do not necessarily reflect the views of New Zealand Forest Research Institute Limited (trading as Scion).

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ENDNOTES

1 http://www.kaingaroatimberlands.co.nz/forest.htm
2 Trees uprooted or broken by wind
3 Wood processing is a weight-reducing exercise so data may vary because of difficulties in estimating the conversion of logs into other wood products with precision. Variations in volume and weight metrics used across products are another potential source of error.
4 Figure 4c mainly shows the trend in the value of exports and may not necessarily account for inflation in New Zealand as the two currencies would likely have different inflation rates.
5 This includes both planted and native forests and the proportion of planted forests to this is unknown.
6 Scion has been the trading name of the New Zealand Forest Research Institute since 2005.
7 http://www.mfe.govt.nz/publications/climate/nz-2020-emissions-target/index.html
8 http://www.mfe.govt.nz/issues/climate/greenhouse-gas-emissions/net-position/
9 http://treeadventures.co.nz/gallery.php?fieldset=Branching+Out
10 http://www.ipgnz.co.nz/woodhill-forest-new-opening.html
11 http://www.aucklandnz.com/destinations/woodhill-forest
12 http://www.rbnz.govt.nz/statistics/0135595.html
13 http://www.tectallterrainpark.co.nz/clubs.html?page=0
14 http://rarespecies.nzfoa.org.nz/fauna/forest_birds/forest_birds.htm
15 https://ic.fsc.org/the-ten-principles.103.htm