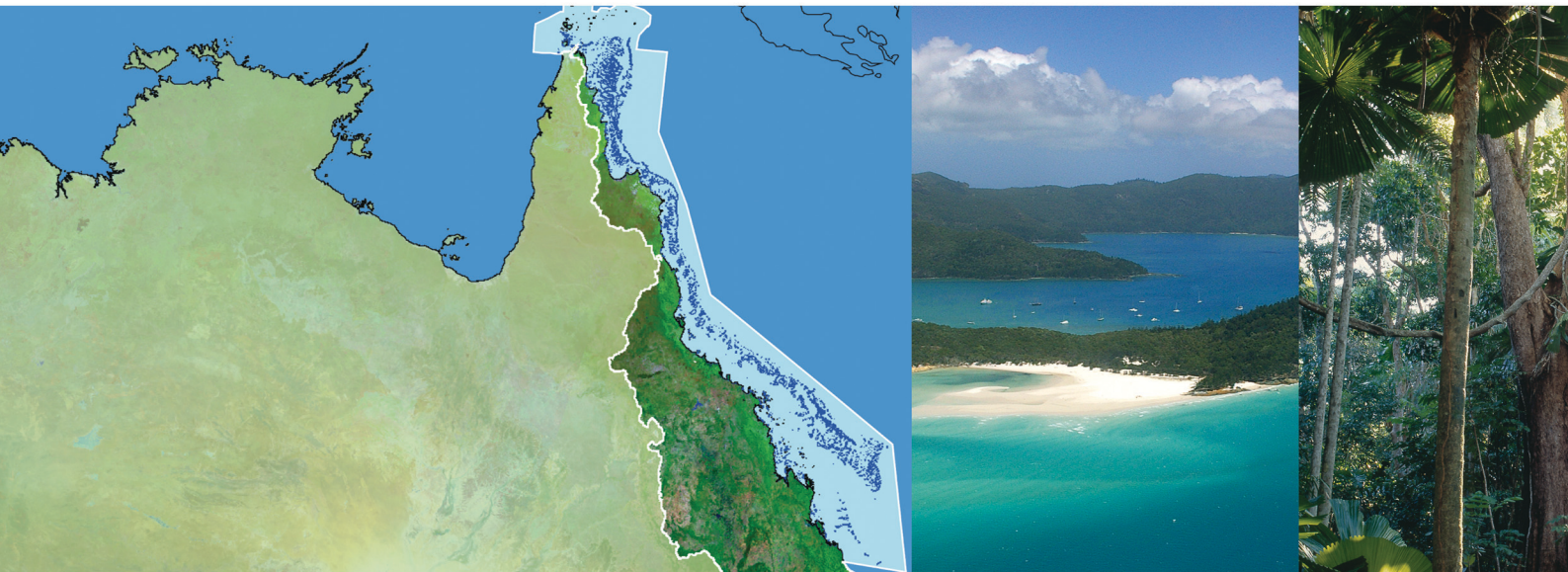


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The management of forests, plantations and remnant vegetation patches for biodiversity conservation

Principles and recommended tree species for revegetation plantings on the Atherton Tablelands, North Queensland

Nick Emtage, John Meadows and John Herbohn



THE UNIVERSITY
OF QUEENSLAND
AUSTRALIA



Australian Government
Department of the Environment,
Water, Heritage and the Arts

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Acronyms Used In This Report

AFFFM	Australian Farm Forestry Financial Model
BMP	Best Management Practices
CRC	Cooperative Research Centre
CRP	Currently Recommended Practices
CRRP	Community Rainforest Reforestation Program
CSIRO	Commonwealth Scientific and Industrial Research Organisation
DLGPSR	Department of Local Government, Planning, Sport and Recreation (Queensland) (now Department of Local Government, Sport and Recreation)
DNRM	Department of Natural Resources and Mines (Queensland) (now Queensland Department of Natural Resources and Water)
DNRW	Department of Natural Resources and Water (Queensland)
DPI	Department of Primary Industries (Queensland) (now Department of Primary Industries and Fisheries)
FNQ	Far North Queensland
FNQ NRM Ltd ...	Far North Queensland Natural Resource Management Limited (now Terrain NRM Limited)
FNQ RPAC	Far North Queensland Regional Planning Advisory Committee
ITC	Integrated Tree Cropping
MIS	Managed Investment Schemes
MTSRF	Marine and Tropical Sciences Research Facility
NRM	Natural Resource Management
OESR	Office of Economic and Statistical Research
QFRI	Queensland Forestry Research Institute
RE	Regional Ecosystem
RIRDC	Rural Industries Research and Development Corporation
TREAT	Trees for the Atherton and Evelyn Tablelands
UFBP	Urban Forest Biodiversity Program
WTMA	Wet Tropics Management Authority

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Introduction

The Wet Tropics bioregion, located on the coast and nearby ranges of far northern Queensland between Ingham and Cooktown, is one of the biodiversity 'hotspots' of the world (Figure 1). Far North Queensland¹ is world renowned for its highly productive ecosystems including a spectacular variety and abundance of forest communities. As noted in the regional strategic plan (FNQ RPAC, 2000, p. 78), 'The Far North Queensland region potentially has the highest level of biodiversity and endemic wildlife species in Australia'. It contains thirty percent of the entire vascular plant diversity of Australia and thirty-two percent of Australia's terrestrial vertebrate fauna in only 0.26% of the continent's area (Williams *et al.* 1996).

The forests in the World Heritage area – mainly on the eastern side of the Atherton Tablelands – and patches of remnant forest within the agricultural landscape provide protected habitat for unique endemic flora and fauna in the region. Just over eighty percent of the bioregion is under wooded vegetation and substantial areas are within the conservation reserve system under World Heritage status. Despite the seemingly large areas of land in conservation reserves, ecologists question whether these areas will be sufficient to sustain biodiversity in the region into the future. The most productive land in terms of the lands' soil types, topography and rainfall has been extensively cleared and developed for agriculture. This land is not only the most productive for agriculture; it also supported the highest levels of biodiversity in the region in the past. The clearing of native vegetation has adversely affected the ecosystems that were specific to these parts of the region. While the land within the World Heritage Area is thought to be in relatively good condition for the conservation of biodiversity, assessment of land outside the reserve system is rated as generally in 'fair' condition and in need of rehabilitation (Weston and Goosem, 2004).

The greatest clearing of native vegetation in Australia has been undertaken for the purpose of expanding agriculture. This has resulted in a 'fragmented landscape', with remnant vegetation in these parts retained in small, isolated patches. The size, shape and isolation of these patches of remnant vegetation leave them susceptible to degradation. Rapidly growing population levels are leading to an intensification of land uses in the region. While broad-scale clearing has reduced in the State following the passing of the *Queensland Vegetation Management Act* (1997) and subsequent amendments, the development of housing and associated infrastructure has the potential to further reduce and degrade remnant vegetation areas.

The responses of communities and government agencies to the degradation of natural vegetation include increasing the areas of land in the public reserve system, the development of plans for natural resource management and urban development, and a range of rehabilitation and revegetation projects by private landholders and community groups. The planning strategies have sought to identify and prioritise parts of the region that are under particular threat and those areas which, if rehabilitated, would provide the most substantial contributions to improving the health of the natural environment. Often the focus is on replanting riparian areas, protecting the edges of remnant patches of vegetation and restoring connectivity between patches. A number of community groups interested in natural resource management are involved in revegetation programs whose purpose is to improve ecosystem functioning. Timber plantations and revegetation programs can have positive and negative effects on the environmental values of a landscape depending on the management practices applied, choice of species, and place in the landscape that is

¹ Far North Queensland (FNQ) is a statistical division within the State of Queensland. The Division includes the newly created Tablelands, Cassowary Coast and Cairns shires.

developed. These revegetation efforts and the rehabilitation of remnant vegetation areas are the focus of this report.

The objectives for this report are to:

- Provide an overview of the current status of biodiversity in the Wet Tropics region;
- Examine the processes affecting biodiversity conservation in the Wet Tropics region;
- Review the outcomes of studies that have investigated the potential biodiversity impacts of revegetation programs;
- Identify design and management principles that can maximise the positive impacts of revegetation programs on biodiversity conservation; and
- Report the results of a study to identify the optimal species to use in revegetation and rehabilitation programs in the Atherton Tablelands sub-region of the Wet Tropics.

Outline of report

The environmental characteristics of the Wet Tropics region and the regulatory environment are first outlined, including the current conservation status of the regional ecosystems, threats to biodiversity conservation, and regional plans to address biodiversity conservation. A number of studies that have examined the environmental impacts of timber plantations on the tablelands are then reviewed, together with research that has examined the biodiversity conservation impacts of plantation development and revegetation programs in other parts of Australia.

The final section of the report presents the results of a survey of foresters and revegetation experts. The survey sought to identify which species would be most suited for use in revegetation programs. The survey examined which tree species could be best used in plantation systems to provide some timber supplies and species that could be used in ecological restoration plantings.

Definitions of Biodiversity and Bioregions

The term biodiversity is in itself a very complex one, and one that is often 'used and abused' (Vercoe, 2001) to cover a very heterogeneous component of the environment. It is commonly interpreted differently by different individuals and, or, professions, often in relation to a specific situation. The term is essentially a conjunct of the two words 'biological' and 'diversity'. A dictionary definition of the root of these two words, 'bio' and 'diverse', respectively equates to 'life', or 'way of life' (Johnston, 1976, p.71), and 'of differing kinds' (Johnston, 1976, p.241). Put simply, biodiversity can be described as the variety of all living things. In 1996, the National Strategy for the Conservation of Australia's Biological Diversity adopted the following definition:

'The variety of life forms: the different plants, animals, and micro-organisms, the genes they contain, and the ecosystems they form. It is usually considered at three levels; genetic diversity, species diversity and ecosystem diversity' (Commonwealth of Australia, 1996).

Other definitions mention that biodiversity also encompasses a combination of the species, genetic and ecosystem elements to form a complex and dynamic web of life providing valued ecosystem functions and services (for example White, 1997; Vercoe, 2001; Paltridge, 2002; Dury *et al.* 2002; Leighton, 2004; Salt *et al.* 2004).

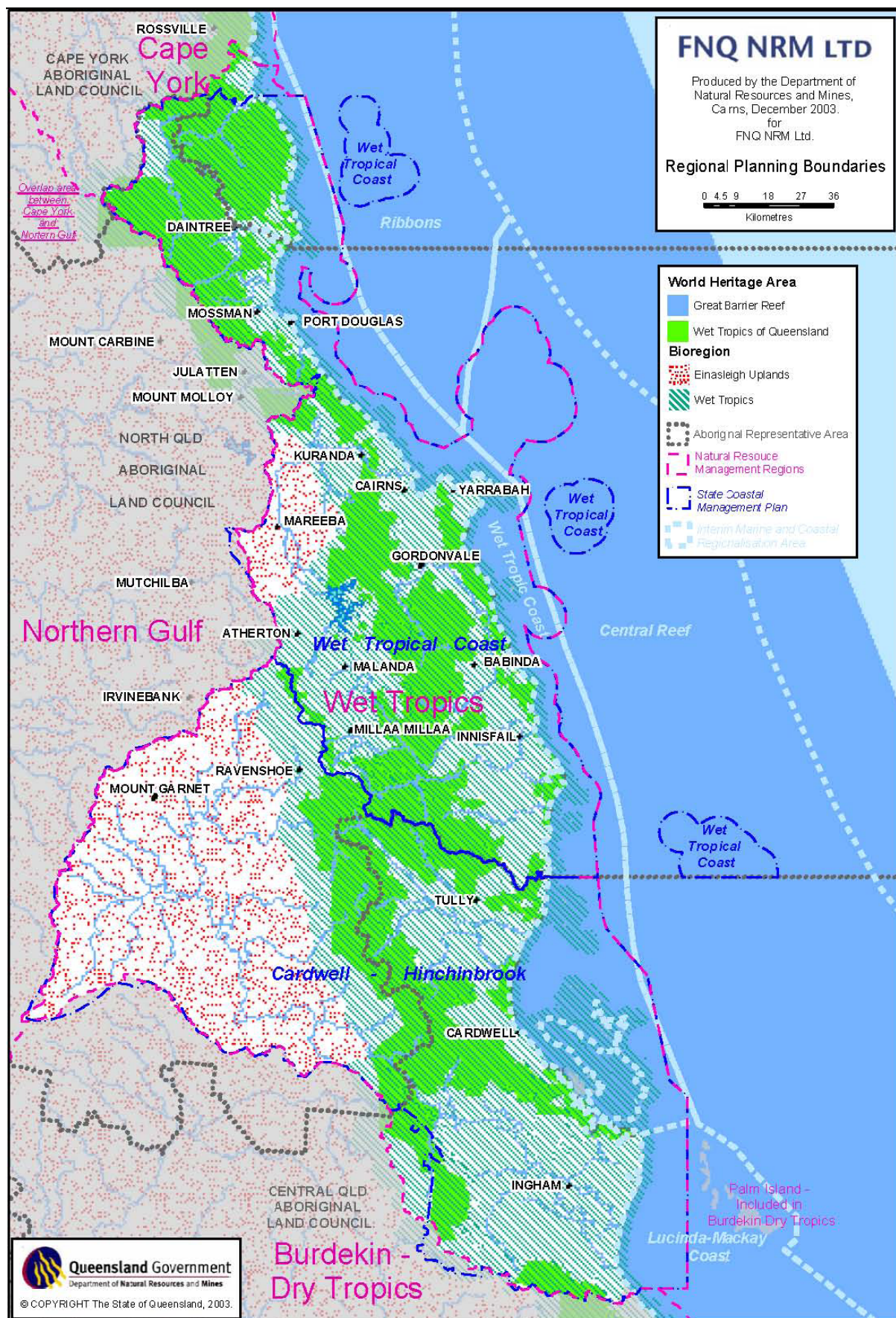


Figure 1: Regional planning boundaries of the Wet Tropics NRM Region.
(Produced by DNRM, Cairns)

Weston and Goosem (2004), citing Sattler and Williams (1999), noted that 'Bioregions represent the primary level of biodiversity classification in Queensland. According to Thackway and Cresswell (1998, p. 27), a bioregion is defined as:

'A complex area (land/sea) composed of a cluster of interacting ecosystems that are repeated in similar form throughout. Region descriptions seek to describe the dominant land/seascape in terms of a hierarchy of interacting biophysical attributes. Bioregions vary in size, with larger regions found where areas have more subdued environmental gradients. These are defined and delineated at the meso-scale (i.e. 100s to 1,000s of km).'

Weston and Goosem (2004) assessed the conservation status of the Wet Tropics region² to develop the regional biodiversity conservation plan. The conservation planning process is based on the units of terrestrial bioregions, a concept of broad landscape patterns that reflect major structural geology, climate, floristic and faunal assemblages (Weston and Goosem, 2004, p. 61). Each bioregion is in turn divided into a number of sub-regions and a series of regional ecosystems are defined to form the scientific basis for conservation planning, biodiversity management and tree clearing guidelines. A regional ecosystem (RE) is defined as a vegetation community consistently associated with a particular combination of geology, landform and soil within a bioregion.

² 'The term 'Wet Tropics' is used variously in the literature in relation to NRM planning and biodiversity conservation. Wet Tropics is the name of a bioregion used to assess the conservation status of regional ecosystems. Wet Tropics is also the name applied to the region for the purpose of NRM planning. It should be noted the Wet Tropics NRM region is not the same as the Wet Tropics bioregion.'

Biodiversity status in Australia and in the Wet Tropics bioregion

The robust and continuing growth of the global population, economy and industrial sectors has had a significant impact upon the natural resource capital of the planet, with its flora, fauna and the ecosystems that support them disappearing at an alarming rate. Added to this is the fact that we still do not know, and likely will never know, how many species actually exist on the planet or the complexity of their interactions within and amongst ecosystems. Scientists have described about 1.8 million species, compared to an estimated 10-100 million that probably exist (Commonwealth of Australia, 1996). One expert in the field has estimated that we could be losing eight species an hour or seventy thousand each year worldwide (Commonwealth of Australia 1996).

Australia is certainly no exception to this sadly common occurrence of declining biodiversity, having lost twenty mammal species, ten species and eleven sub-species of birds, and 97 vascular plants to extinction in little over two hundred years of occupation by Europeans (White, 1997). It is estimated that 43% of the nations' forests, nearly 90% of our temperate woodlands and mallee communities, 75% of our rainforests, and 99% of our temperate lowland grasslands have been cleared and commonly converted to a variety of significantly simplified agricultural systems (Salt *et al.* 2004). Alarming, following on from the 1996 *State of the Environment* Report, the 2001 edition stated that there was little change since 1996, adding that genetic diversity was declining and species diversity was generally deteriorating (Salt *et al.* 2004).

Wooded vegetation covers a little over 81% of the Wet Tropics NRM region. All catchments retain over 50% cover, with most retaining over 70% and the Daintree over 95% (FNQ NRM Ltd and Rainforest CRC, 2004). Weston and Goosem (2004) summarised the biophysical character of the Atherton sub-region as one of plains, low hills and scarps, with predominantly krasnozems derived from basalt parent materials. The major native vegetation types in the region are complex and semi-deciduous mesophyll and notophyll rainforests³; tall open forests of Forest Red Gum (*Eucalyptus tereticornis*); and woodlands dominated by white stringybark (*E. phaeotricha*) and molloy red box (*E. leptophleba*). Weston and Goosem (2004, pp. 74-75) noted that 'a disproportionately large percentage (68%) of the Wet Tropics REs have 'endangered' or 'of concern' conservation status'. These authors listed the following endangered or 'of concern' REs on the Atherton Tablelands:

- Complex mesophyll rainforest on basalt uplands;
- Complex notophyll rainforest on basalt lowlands, foothills and uplands;
- Complex notophyll rainforest on basalt uplands and highlands;
- Forest red gum *Eucalyptus tereticornis*, open forest on basalt uplands and highlands;
- White stringybark *Eucalyptus phaeotricha*, woodlands on basalt uplands and highlands;
- Notophyll rainforest with hoop pine *Araucaria cunninghamii* on granite uplands; and
- Microphyll rainforest with hoop pine *Araucaria cunninghamii* on granite uplands.

The third RE type listed above (i.e. complex notophyll rainforest on basalt uplands and highlands or Mabi Forest, Webb and Tracey type 5b) is listed under the Commonwealth

³ According to the Environmental Protection Agency (Queensland), 'Scientists prefer to classify rainforest on the basis of the leaf size of canopy trees and on the complexity of the forest's structure. Leaves less than 2.5 cm long are termed *nanophyll*; between 2.5-7.5 cm *microphyll*; 7.5-12.5 cm *notophyll*; and 12.5-25 cm *mesophyll*'.

Environment Protection and Biodiversity Conservation Act 1999 as a critically endangered ecological community. It is estimated that of the estimated 19,806 ha of pre-clearing extent of Mabi forest on the Atherton Tableland, only 862 ha or 4.3% remains (Latch, 2006, Figure 2).

According to the Australian Natural Resources Atlas⁴, within the Wet Tropics bioregion ‘...there are 23 endangered and 28 vulnerable regional ecosystems. This equates to approximately 22 and 26 percent respectively of the total number of ecosystems occurring in the bioregion. The most common threatened vegetation types are tropical and sub-tropical rainforest and dry rainforest (43% of the threatened ecosystems) followed by eucalyptus forests with a dense broad-leaved understorey (wet sclerophyll; 16% of the threatened ecosystems). Ecosystems under threat include communities on alluvium and lowland vine forests on basalt. Many of the threatened ecosystems are naturally restricted.’

Catterall and Harrison (2006) estimate that 20% of rainforests that existed in the Wet Tropics region at the time of European settlement have been cleared. Unrestricted broad scale clearing for agricultural expansion has been greatly reduced in Queensland following the introduction of the *Vegetation Management Act* (1997) and subsequent amendments. While vegetation clearing in the region has fallen substantially since the period between 1988 and 1995, some clearing for agriculture still occurs and intensification of land uses resulting from population growth increases the pressures on remnant vegetation areas. As pointed out by Hunt (2004), the inherent productivity of a plantation is largely a function of the climate, aspect and soils at the growing site. The same principle applies to growing any plant, thus it is rationale that farmers have targeted the most productive forest types for conversion to agriculture. As argued by Catterall and Harrison (2006: 2), ‘...within particular subregions and catchments, the effect (of clearing) has been far more extreme than is suggested by these regional averages, because clearing has selectively targeted the most level and fertile areas. Even the World Heritage rainforests are largely confined to steep mountain slopes and relatively infertile soils.’

The decline and loss in biodiversity values is now widely regarded as one of Australia’s, if not the world’s most serious and important environmental problem (Vanclay and Lawrence, 1995; State of the Environment Advisory Council, 1996; Paltridge, 2002; Lindenmayer and Franklin, 2002; Salt *et al.* 2004). Compared to other regions in southern Australia, the Wet Tropics region is still relatively well-vegetated. There are concerns, however, that the fragmentation of habitat in the region will have a detrimental impact on biodiversity conservation in the long term. There is concern about the level of clearing that has been undertaken in particular areas including the Atherton Tablelands. As stated in the FNQ NRM Plan (FNQ NRM Ltd and Rainforest CRC, 2004, p. 23):

‘Clearing has been most severe in the Wet Tropics in the coastal lowlands, along major river valleys and on the basalt soils of the Atherton-Evelyn Tablelands ... In a region like the Wet Tropics, where species are patchily distributed and many have specialised needs, these cumulative effects can have the same effect as broad-scale land clearance in the long term.’

Weston and Goosem (2004, p. 96) further emphasised the cumulative effect that clearing has had on environmental values in the Atherton Tablelands, stating that ‘...in a region like this, where species are patchily distributed and many have specialised needs, this ‘death by a thousand cuts’ can have the same effect as broad-scale land clearance in the long term.’ Weston and Goosem (2004) noted that the most degraded ecosystems in the Wet Tropics are those in the coastal lowlands. The Atherton sub-region is also described as being in need

⁴ The Australian Natural Resources Atlas can be viewed at <http://www.anra.gov.au/topics/vegetation/assessment/qld/ibra-wet-tropics.html>

of rehabilitation to protect its environmental values. As noted in the biodiversity report prepared for the development of the region's NRM plan, the Atherton sub-region is described as a 'very degraded sub-region with intensive effort required to integrate and improve the condition of biodiversity due to the lack of remaining natural areas' (Weston and Goosem, 2004, p. 176).

Habitat loss and ecological degradation

'Habitat' can be defined as the natural home or environment, or range of environments, in which a species of plant or animal can occur, live or grow (Johnson, 1976, p.368; Whittaker *et al.* 1973 cited in Lindenmayer and Franklin, 2002; Goosem and Tucker, 1995). The concept more broadly relates to an area that contains all the resources an organism needs to survive throughout its life cycle – with food and shelter being two important components of an organism's habitat requirements (Salt *et al.* 2004). Availability and quality of suitable habitat has a direct influence upon an organism's ability to survive, reproduce, disperse and persist in the long-term (Lindenmayer and Franklin, 2002) in a particular landscape or region.

The above-mentioned 'environments' are essentially complex ecosystems occurring at a range of spatial scales – from a square meter to a thousand hectares, and from individual trees to large ecological reserves (Lindenmayer and Franklin, 2002). They involve an array of structural, compositional and functional elements that are interwoven to form and support the biodiversity of the planet.

Remnant native vegetation provides habitat for native flora and fauna, and so the clearing and conversion of such vegetation equates to habitat loss or significant simplification. Such losses of complex natural systems destroys habitat for literally thousands of species, simplifies landscape heterogeneity and leads to functional losses and a range of resultant land degradation issues.

Major causes of biodiversity loss and degradation

Threats to biodiversity are ongoing and numerous, and may be described as processes that have a detrimental effect on the survival, abundance, distribution and, or, potential for evolutionary development of a species, community and, or, interaction between these. Overall, habitat loss and degradation are now widely recognised as key drivers of species loss (for example Goosem and Tucker, 1995; White, 1997; Lindenmayer and Franklin, 2002; Salt *et al.* 2004). Inevitably, habitat loss and degradation is related to ecosystem fragmentation, a decline in landscape diversity, structural complexity, and losses to the complex and often unknown relationships and functions at the ecosystem level resulting in negative impacts upon biodiversity.

According to the Australian Natural Resources Atlas, in the Wet Tropics region '...the main threatening processes are broad scale tree clearing, followed by fragmentation of remnants, changed fire regimes, and exotic weeds. The condition of 60% of the threatened regional ecosystems is assessed as declining with 33% of the threatened ecosystems static.' The primary driver of vegetation loss and the decline of biodiversity conservation capacity in the past was broad-scale tree clearing for agricultural expansion. Kanowski *et al.* (2003: 266-7) reported that '...much of the Atherton Tablelands was cleared between 1900 and 1920, although sizeable tracts of rainforest continued to be converted to agriculture until the 1950s. A relatively small area of rainforest on the Tablelands (several hundred hectares) was converted to timber plantations between about 1930 and 1970.'

Some of the pressures on biodiversity are listed in Table 1. Weston and Goosem (2004: 96) reported that '...vegetation clearing is the most significant threat to species and ecosystems in eastern Australia...' and that '...overgrazing, exotic weeds, feral animals and changed fire

regimes are additional key threats to wetlands, riparian zones, threatened species and ecosystems across much of Australia.' Most of the drivers for loss of biodiversity are from population growth and associated land-use pressures. The region has one of the highest population growth rates in Australia. In addition to the extra demand for housing this population growth generates, changing patterns of land tenure (in particular the growth in rural residential subdivisions) creates additional pressure on the rural environment. Climatic variation and change appears to be another driver for loss of biodiversity.

Table 1: Examples of underlying drivers for loss of biodiversity and resultant direct pressures.

Underlying driver	Direct pressures
• Regional population growth • Changes in regional land use • Land tenure patterns • Demand for community infrastructure: - electricity - water supplies - roads - telecommunications • Tourism and recreation • Economic development, world trade and technological advances • Weather and climate change	• Clearing of native habitat • Habitat fragmentation • Altered drainage patterns and flow regimes • Alteration/degradation of habitat: - grazing - altered fire regimes - diseases - pollution • Introduced pest species: - environmental weeds - exotic fauna

Source: Weston and Goosem (2004, p. 95), after WTMA (2002).

In the last two decades population growth in the Wet Tropics region has been among the highest in Australia, with Cairns the fastest growing regional centre outside the south east corner of the state (OESR, 2003). Increasing population levels and the associated development of housing and infrastructure have the capacity to become major drivers of the loss of biodiversity. The parts of the region that are adjacent to the coast are subject to 'sea change' migration, with the hinterlands also attracting many new people to what are termed 'tree change' areas (Burnley and Murphy, 2004). People are attracted to regions with high scenic or amenity values and areas that are reasonably close to large urban centres which provide the potential for employment, and other urban infrastructure and service conveniences. The Wet Tropics region has these characteristics, including close proximity to the coast, high rainfall, spectacular mountain ranges and forests plus the presence of one of Queensland's largest regional centres. A wide range of biophysical or natural resource impacts can and do arise as a direct result of the growth and development pressures and subsequent changing land ownership and uses.

Both public and private lands can be affected by the growth and development occurring in peri-urban and amenity landscapes. New infrastructure (and occasionally housing) developments can consume varying types of public lands, and portions of or whole private properties can be resumed and converted. Parcelisation of private holdings is also common, and all these actions inevitably result in an increasingly fragmented landscape. This incorporates a complex diversity of block sizes; land-uses and associated businesses; socio-economic and cultural backgrounds, values, objectives and demands; and natural resource ownership and function. Overall this fragmentation leads to an array of issues and threats, as well as new opportunities relating to viable rural production and businesses, natural resource and ecological health and integrity, the delivery of ecosystem services generally, and the overarching concept of biodiversity conservation.

Clearing of remnant vegetation is ongoing; for example, ~446,000ha/yr were cleared throughout Queensland during the period 1997-1999 (Queensland Herbarium, 2001), and during the period 1990-1995, for all of Australia, ~292,000ha/yr were cleared for grazing and agriculture, offset by only 83,000ha/yr of on-farm tree planting and plantations (Australian State of the Environment Committee, 2001). Across the State of Queensland clearing rates have fallen to 351,000 ha/yr in 2004-2005 since peaking at a rate of 780,000 ha/yr in 1999-2000 (DNRW, 2007). In Queensland the greatest areas of clearing continue in Western NRM regions including the South West Region (35% of the State's woody vegetation clearing), followed by Fitzroy (14%), the Maranoa Balonne (14%) and Desert Channels (9%) (DNRW, 2007).

While the areas of clearing of woody vegetation in the Wet Tropics NRM region are small in comparison to clearing in the western regions, the Wet Tropics is far smaller in area (2,799,000 ha) than these NRM regions (Fitzroy 17M ha, South West 19M ha). The impacts of clearing in the Wet Tropics can still be severe, however, due to the high levels of biodiversity and restricted ranges of this biodiversity in this region. This means that the effects of clearing in the Wet Tropics are potentially more severe in terms of their impact on Australia's overall biodiversity conservation.

As in the rest of Queensland the rates of clearing in the Wet Tropics documented by the DNRW were highest in the late 1980s and first half of the 1990s. Clearing rates then fell before a second peak in 1999-2000 as landholders anticipated the introduction of a ban on broad-scale clearing of woody vegetation for agriculture in the state. The State Government announced its intention to introduce restrictions on broad scale clearing in 1999 and introduced the measure in 2000.

It is estimated that pastures make up 94% of the replacement land cover following the clearing of woody vegetation throughout Queensland. In the Wet Tropics region it was estimated that approximately 1,000 ha of cleared woody vegetation was replaced by pasture in 2004-2005 (Table 2), representing 56% of the area cleared in the NRM region (Table 3). The pattern of replacement land cover from clearing has changed in the Wet Tropics region over the past twenty years. Prior to 1999 more than half the replacement land cover was agricultural crops and in 2004-2005 this made up only one percent of land cover replacement. Since 1999 the main replacement land cover has been pasture which represents approximately 55% of the total in 2004-2005. Forestry has grown rapidly as a proportion of the replacement land cover since 2001-2002 and now makes up 36% of the replacement land cover type. Clearing of woody vegetation which is replaced by settlement and infrastructure comprise only 7% of the replacement land cover in 2004-2005. As the vegetation cleared for this land use is located near existing settlements where remnant vegetation is already highly fragmented, this clearing is still likely to have a significant impact on biodiversity conservation in these instances.

The pattern of clearing of woody vegetation that is evident across Queensland (i.e. concentrated in the Western regions) is similar to the activity within the Wet Tropics region (Tables 4 and 5).

Table 2: Woody vegetation clearing by replacement land cover in the Wet Tropics NRM region ('000 ha/year).

Period	Pasture	Crop	Forestry	Mining	Infrastructure	Settlement	Total*
1988–1991	1.05	1.973	0.313	0.003	0.31	0.097	3.746
1991–1995	0.221	3.036	0.294	0	0.04	0.048	3.638
1995–1997	0.552	1.885	0.073	0.006	0.105	0.108	2.728
1997–1999	0.689	0.852	0.042	0	0.069	0.027	1.679
1999–2000	2.006	0.21	0.078	0	0.381	0.012	2.687
2000–2001	0.392	0.089	0.051	0	0.103	0.024	0.657
2001–2002	1.286	0.236	0.06	0.023	0.027	0.026	1.659
2002–2003	0.75	0.165	0.191	0.006	0.023	0.02	1.155
2003–2004	0.961	0.002	0.381	0.001	0.044	0.106	1.496
2004–2005	1.011	0.012	0.655	0.004	0.052	0.072	1.806

Source: DNRW 2007.

Table 3: Proportion of area of woody vegetation cleared by replacement land cover in the Wet Tropics NRM region.

Period	Pasture	Crop	Forestry	Mining	Infrastructure	Settlement	Total*
1988–1991	28%	53%	8%	0%	8%	3%	100%
1991–1995	6%	83%	8%	0%	1%	1%	100%
1995–1997	20%	69%	3%	0%	4%	4%	100%
1997–1999	41%	51%	3%	0%	4%	2%	100%
1999–2000	75%	8%	3%	0%	14%	0%	100%
2000–2001	60%	14%	8%	0%	16%	4%	100%
2001–2002	78%	14%	4%	1%	2%	2%	100%
2002–2003	65%	14%	17%	1%	2%	2%	100%
2003–2004	64%	0%	25%	0%	3%	7%	100%
2004–2005	56%	1%	36%	0%	3%	4%	100%

Source: DNRW 2007.

Table 4: Rate of clearing of woody vegetation ('000 ha/year) for various catchments within the Wet Tropics NRM region.

Period	Barron	Daintree	Herbert	Hinchinbrook Island	Mossman	Mulgrave	Murray	North Johnstone	Russell	South Johnstone	Tully	Total
1988–1991	0.407	0.036	1.887	0	0.007	0.061	0.816	0.059	0.065	0.102	0.249	3.709
1991–1995	0.201	0.026	2.269	0	0.009	0.029	0.744	0.039	0.065	0.125	0.13	3.609
1995–1997	0.703	0.029	1.162	0	0.043	0.025	0.404	0.082	0.015	0.076	0.179	2.696
1997–1999	0.36	0.038	0.837	0	0.009	0.015	0.287	0.016	0.023	0.024	0.061	1.639
1999–2000	0.94	0.039	1.357	0	0.037	0.018	0.166	0.034	0.024	0.037	0.031	2.647
2000–2001	0.176	0.007	0.271	0	0.014	0.044	0.037	0.021	0.056	0.019	0.012	0.65
2001–2002	0.223	0.019	1.02	0	0.009	0.024	0.22	0.015	0.06	0.021	0.041	1.639
2002–2003	0.214	0.023	0.457	0	0.026	0.034	0.272	0.029	0.005	0.02	0.073	1.131
2003–2004	0.163	0.002	0.855	0	0.019	0.052	0.347	0.015	0	0.014	0.029	1.496
2004–2005	0.212	0.005	0.881	0	0.018	0.036	0.572	0.029	0	0.027	0.014	1.806

Table 5: Proportion of total clearing woody vegetation in the Wet Tropics NRM region for various catchments (percentage).

Period	Barron	Daintree	Herbert	Hinchinbrook Island	Mossman	Mulgrave	Murray	North Johnstone	Russell	South Johnstone	Tully	Total
1988–1991	11	1	51	0	0	2	22	2	2	3	7	100
1991–1995	6	1	63	0	0	1	21	1	2	3	4	100
1995–1997	26	1	43	0	2	1	15	3	1	3	7	100
1997–1999	22	2	51	0	1	1	18	1	1	1	4	100
1999–2000	36	1	51	0	1	1	6	1	1	1	1	100
2000–2001	27	1	42	0	2	7	6	3	9	3	2	100
2001–2002	14	1	62	0	1	1	13	1	4	1	3	100
2002–2003	19	2	40	0	2	3	24	3	0	2	6	100
2003–2004	11	0	57	0	1	3	23	1	0	1	2	100
2004–2005	12	0	49	0	1	2	32	2	0	1	1	100

Source: DNRW 2007.

In general the largest areas of clearing have been in the Herbert river catchment which has consistently comprised approximately half the overall clearing in the region. The rates of clearing have varied considerably in the Barron and Murray catchments with clearing in the Murray catchment showing the greatest increase in recent years.

Whether acting in an isolated manner or in combination, many of the issues or forces associated with population growth and intensified development activity throughout peri-urban and amenity landscapes do have the potential to significantly threaten a region or localities biological diversity and its on-going conservation. Overall, habitat loss through initial development activities is a clear and major threat throughout these popular landscapes. Subsequent and equally significant on-going degrading threats to remaining natural habitat then often arise with the in-migrations of new residents and their varying lifestyles, values and land-uses.

Forest fragmentation

It is well documented that iconic and ecologically significant trees and remnant vegetation patches of varying sizes are being lost and degraded throughout both urban and rural landscapes. They are effectively being chipped away at through development and decline, resulting in their complete loss from clear-felling operations, or their partial loss and fragmentation into smaller and more isolated patches. They are also rarely adequately replaced or effectively managed to mitigate against degrading influences, ultimately resulting in reduced ecological and natural character values. This needs to be avoided in the landscapes located within important catchments with high biodiversity values which are known for and in many ways are dependent upon their highly scenic outlooks and appealing rural character.

Urban expansion and land development for housing and associated infrastructure and service provision inevitably affects or displaces a region's natural resources, and raises public concern and scrutiny. Native forests and vegetation are very often significant natural features of urban fringe areas, and it is not uncommon for these to be completely consumed through poorly designed and located dense urban sprawl development. In many other cases of extensive 'green-field' development, often very little continuous forest is lost as the sprawl consumes former agricultural, pastoral or other idle lands that were largely cleared of their remnant vegetation long ago.

Throughout the popular peri-urban and amenity regions, past land-use and management activities have resulted in a mosaic of remaining native remnant and regrowth vegetation. This is a landscape that is highly variable in terms of forest types, size, shape, landscape location, patchiness and connectivity, and their ecological integrity and productive potential. The characteristics of the forests that remain are a direct result of past management practices, or lack thereof. Some may have been very well or alternatively quite poorly managed for on-farm or commercial timber supplies, as a grazing and shelter resource for stock, or for recreational pursuits. Other areas may have become degraded from adjacent past agricultural land-uses or other inappropriate activities, or through simply being left entirely unmanaged.

The loss and fragmentation of native forests leads to smaller and more isolated forest patches scattered throughout the landscape. Their reduced size and connectivity with other remaining native forests and vegetation communities reduces their ability to provide the necessary resources, refuge and genetic exchange opportunities, and hence support minimum viable populations of many native flora and fauna species (Meefe and Carrol, n.d.). An extreme example of forest fragmentation is the remnant Mabi forest patches in the Atherton Tablelands region. Latch (2006) reports that 56 patches of Mabi forest have been identified ranging in size from half a hectare to 271 hectares. Fifty-six percent of the entire area of Mabi forest is in two patches of greater than 200ha each in the Wongabel State Forest and the Curtain Fig National Park. Seventy-three percent of all remnant patches of Mabi forest on the Atherton Tablelands are less than five hectares in size. Remnant areas of natural forest in the Wongabel State Forest are fragmented as well due to on-going commercial forestry operations.

Changes to the size and shape of existing forested areas can reduce corridor effectiveness and increases the exposure of core areas to 'edge-effects', which essentially alter environmental conditions and lead to greater susceptibility to natural and man-made disturbances. These edge effects can involve aspects of:

- Soil degradation and erosion;
- Water quality impacts;

- The spread of exotic weeds and pest animals and plants or other non-local natives that thrive in the disturbed environments;
- Exposure to pollutants;
- Disease introductions;
- Greater susceptibility to wind damage;
- Changed microclimatic conditions;
- The inappropriate use and spread of fire; and
- Visitor impacts such as recreational over-use, vandalism and poaching (Commonwealth of Australia, 1996; Burgman and Lindenmayer, 1998; Latch 2006).

More often than not the disturbance agents do not act in isolation, but instead can result in a combined or aggregated effect that has been termed 'hyper-disturbance' (Laurence, 1997), involving the effects of one degrading factor predisposing the environment to further threatening processes and resulting in serious habitat degradation or eventual total habitat loss for resident species. Ecosystem fragmentation and declining landscape diversity and structural complexity, losses of the complex and often unknown relationships and functions at the ecosystem level, and further land and environmental degradation issues are likely to follow. Overall this amounts to cumulative pressures upon biodiversity values and their conservation. The impacts of fragmentation on Mabi forest remnants and dependent flora and fauna species are described in the recovery plan for the ecosystem drafted by Latch (2006).

As development further encroaches into native bushland areas and natural habitat shrinks or is degraded, there are inevitably increased levels of wildlife encounters as they are drawn to urban fringe areas in search of food or refuge. While close proximity to native wildlife is frequently a valued and sought after aspect of relocating to these regions, they can also raise potentially serious issues of public health and safety. Vehicular collisions, and backyard or neighbourhood encounters with potentially dangerous or disease harbouring species are increasingly common.

In North America residents are wary of moose, bears, wolves and coyotes as well as disease carrying ticks associated with deer drawn to lush household lawns. Here there have been increasing demands for the suppression of predatory wildlife to protect residents' pets (Shands, 1991). In South Africa marauding baboons are known to raid houses in search of food, while in an Australian context, snakes are highly feared by most urban migrants and do kill a small number of people each year. There have also been occasional reports of attacks by large kangaroos. Introduced pest species are also common, having detrimental ecological impacts and often presenting risks for residents and their pets and livestock. For example, there are growing concerns about wild deer encounters in some regions, while most common are increasing cases of wild dogs maiming and killing livestock or pets and heightened concerns over the threat these animals pose to humans and especially small children. In the Wet Tropics there was considerable concern expressed about the impacts of Tropical Cyclone *Larry* on the cassowary population. The cyclone caused extensive damage to remnant forests in the Mission Beach area which are home to a large proportion of the remaining cassowary population. Researchers and community members were worried about increased sightings of these large and potentially dangerous birds along roads and in built up areas as they searched for food.

It's not all negative outcomes

While the above described issues are generally regarded as being detrimental or threatening to ecosystem integrity, functioning and related biodiversity, there are also many potential

positive outcomes or opportunities for the environment and on-going sustainable NRM in these changing landscapes.

There may be benefits arising from the reduction in previous extensive agricultural land uses, particularly if these were clearly unsustainable, and generated high levels of animal effluent or made regular use of chemical fertilisers and biocides (Mackenzie *et al.* 2006). A lower rate of industrial scale farming and a shift towards smaller-scale sustainable agricultural practices could significantly reduce topsoil erosion and other soil degradation issues, and polluting run-off, thereby reducing stresses on waterway and catchment values.

Some of the more marginal and often steeper former agricultural land may now support regrowth native vegetation in varying conditions, and this can significantly help to restore a level of forest cover and connectivity across the landscape. The same can be said of strategically located tree planting efforts, and particularly so if they make use of locally occurring native species that can provide additional habitat benefits. A recent study undertaken throughout an exurban region of the United States (Walker *et al.* 2005) has shown that the expansion of rural residential development onto former agricultural lands has widely varying effects, including some significant ecological improvements. These authors found that vegetation cover (and particularly throughout riparian areas) had increased on many properties that had undergone the transition from an agricultural to rural residential land-use. Similar vegetation cover improvements via various planting efforts can be readily observed throughout many of Australia's urbanising landscapes.

While development in these landscapes will inevitably displace and disadvantage many species of native flora and fauna, it can also lead to some new habitat opportunities, particularly for other native wildlife species. The style and intensity of development activities certainly plays a role, with studies from the United States showing that changes in habitat arising from different development patterns will harm some species while favouring others (Irwin *et al.* 2006). An individual property's landscape location will also clearly play a role, but overall in the Australian peri-urban context, lifestyle property developments do provide a range of new 'urbanised habitat' opportunities that many native species – including birds such as an array of honeyeater species and scrub turkeys; possums; and some species of frogs, skinks and geckos for example – are known to take advantage of. While this can delight many newcomer residents, some native species can, however, become pests in these environments (Low, 2001), and sometimes to the detriment of other common or threatened local wildlife.

A wide range of new environmental management opportunities can also potentially arise in these regions, as a direct result of the diverse knowledge, skills, enthusiasm, innovation and strong environmental ethic that can accompany many new 'tree changer' migrants. Some past studies have shown this sector to be better educated than the former farming community, have more disposable financial resources, and a strong concern for the health of the environment (Emtage *et al.* 2001, Hollier *et al.* 2003, 2004a, 2004b; Aslin *et al.* 2004; Aslin, 2006). These characteristics present significant opportunities for extensive and beneficial on-ground NRM activity provided the many other enabling forces now operating in these regions are also successfully tapped in to (Mackenzie *et al.* 2006).

It is often reported that many new rural lifestyle landholders possess a strong environmental stewardship ethic and these landholders may be able to contribute to balancing and reversing forest degradation problems through activities on their small rural holdings. Amongst this sector there are now undoubtedly strong and growing interests in land management practices that can contribute, such as small-scale sustainable agriculture, multi-purpose tree planting, environmental restoration and wildlife preservation actions (Hollier *et al.* 2003; Harrison and Herbohn, 2005; Aslin, 2006). As these regions emerge as 'multi-functional landscapes', a diversity of new horticultural activities and crops are evident and

new urban market opportunities are being developed, small-scale farm forestry systems are increasingly integrated into property and landscape design, and regrowth and remnant vegetation communities are being restored, maintained, enhanced and protected for aesthetic, recreational, habitat and catchment benefits.

Overall, the increasing population, changing demographics and changing ownership and management of a landscape's natural resources can potentially lead to the revitalising of small rural communities following the decline of past extensive industries, the increased adoption of improved land management practices, and assist with the maintenance and regeneration of natural ecosystems. However, such desirable outcomes are far from assured, as these same potentially enabling opportunities mean there are and will remain many on-going significant challenges to promoting and aiding the sound 'multi-purpose' management of the private forests therein. To successfully address these will require adequate and varying NRM and private forest supportive, or communication and assistance measures to be in place.

The importance of active management on private lands

All small native forest owners in these popular landscapes can and do impact on their own and the broader forest's condition. These owners also impact on local and regional biodiversity outcomes through their vegetation management actions or lack thereof. As such, they all play a potentially important contributing role as private native forest managers, being custodians of their forest resources with an accompanying level of social responsibility to maintain and enhance their values, integrity and functioning through the timely application of appropriate forest management actions.

Scientists, academics, all levels of government, and environmental non-government organisations have realised that the public land reserve system is limited in its ability to adequately protect representative native forest communities across the nation (for example Young *et al.* 1996; Lindenmayer and Franklin, 2002; Chudleigh *et al.* 2003; Figgis, 2004). Recent official figures suggest that only around 10% of the Australian landmass is in any kind of formal protected area (Figgis, 2004) and more than half of the country's major biogeographic regions have substantial numbers of ecosystems that are either not represented or are poorly represented in these reserves (Young *et al.* 1996; Figgis, 2004). Privately owned forests are known to cover extensive areas of high conservation value and bioregions not adequately represented in the public reserve system, hence there have been growing calls for more of these areas to be protected (Young *et al.* 1996; Lindenmayer and Franklin, 2002) as a 'critical augmentation' to the public-land protected areas (Figgis, 2004).

In addition to formally 'protecting' privately owned native vegetation communities, other efforts to maintain and enhance these resources outside of the larger 'reserve' system are now seen as essential. Such privately owned holdings and forested areas have been termed 'off-reserve' conservation areas (Burgman and Lindenmayer, 1998) and 'matrix' lands (Lindenmayer and Franklin, 2002), and their importance in overall biodiversity conservation efforts have been described by these authors. Essentially, 'off reserve' native vegetation management and establishment efforts can play four critical roles relating specifically to biodiversity conservation, involving:

- Supporting populations of species;
- Regulating the movement of organisms;
- Buffering sensitive areas and reserves; and
- Maintaining the integrity of aquatic ecosystems (Lindenmayer and Franklin, 2002, p.7).

Furthermore, these authors recommend that more focus be given to management approaches that could be undertaken on these lands, in light of the recognised limitations of the reserve system to provide an effective overall outcome for biodiversity conservation. The 'reserve' and 'matrix' lands are interconnected, leading to the question: 'If the matrix can be affected by what happens in reserves, how much greater is the effect of the matrix on reserves?' (Lindenmayer and Franklin, 2002. p.1).

Researchers have argued that reforestation over a broad section of the landscape is needed (Kanowski *et al.* 2005). As noted in the Far North Queensland Strategic plan (FNQ RPAC, 2000, p. 79):

'...effective management of biodiversity values requires appropriate management and integration of both protected and non-protected areas of high biodiversity value. It is important to pay attention to areas outside the protected area network, as this is where development activity is more prevalent and where the greatest threats to conservation of biodiversity are being experienced.'

Maintaining linkages between natural areas is also important for the long-term viability and evolutionary potential of the region's biodiversity. Small, isolated natural areas are often inadequate in terms of maintenance of ecological processes and long term viability.

The need to strengthen the capacity of the protected area network is also discussed in the FNQ NRM Plan (FNQ NRM Ltd and Rainforest CRC, 2004).

None of the research reviewed for this report provides a specific figure for the area in the landscape that would require protection to ensure the survival of regional ecosystems in the long term. The area is fortunate to have nearly 1M ha of rainforest well protected in the Wet Tropics World Heritage Area. As in other parts of Australia, however, the conservation reserve system is the area of the landscape that was not developed in the past for agriculture. The most fertile soils and flatter parts of the landscape which are the optimal areas for agriculture also potentially have the highest biodiversity conservation values due to their innate productivity, and these areas support different ecosystems than areas of highlands with granite-based soils that predominate in the conservation reserve system (i.e. the regional ecosystems described as endangered or of concern above).

A fundamental component of sustainable natural resource and catchment management is the sound active management of native vegetation communities, including both natural and planted areas. This is so regardless of the specific management objective(s) – be it for timber production, water conservation, a particular species habitat requirements or preferences, or broader environmental and aesthetic values generally. There is growing recognition that healthy native vegetation communities can be considered as important attributes of biodiversity, and also as crude but useful indicators for some characteristics of biodiversity (Freudenberger and Harvey, 2003). Hence there is a growing need to improve the landholders understanding and management activities in relation to this concept – what it encompasses, and what they can do to maintain and enhance its values. The most prudent approach here is to understand and actively apply forest and native vegetation related currently recommended (CRPs) or best management (BMPs) practices. Active forest managers could be defined as those who apply CRPs or BMPs relevant to tree planting, timber harvesting, thinning or other stand improvement activities, wildlife habitat improvement actions, and other practices (such as pruning, pest and weed control, fire management, and on-going monitoring and reporting) implemented to increase the quality and quantity of forest-related products and amenities (Bliss and Martin, 1989).

Failing to implement sound, site-specific active management strategies in a timely manner can exacerbate the degradation of fragmented forests. This can potentially lead to their emergence as environmental or ecological liabilities – becoming overcrowded, full of weeds and pest species, with a heightened susceptibility to dangerous wildfires, and reduced capacity for producing their desired habitat, environmental and amenity services (Sampson, 2001; Kline *et al.* 2004). On-going monitoring and active management of these resources will result in improved maintenance and enhancement outcomes for the particular site and the surrounding landscape.

Even small and micro-scale efforts are vital

Many rural landholdings, and particularly those within new rural residential estate developments will often contain only very small areas of remnant or regrowth native vegetation, or areas suited to native tree planting. While the existing vegetation may often be irregularly dispersed or patchy throughout the landscape, it can still be vitally important both ecologically and aesthetically (for example Brechwoldt, 1986; Freudenberger and Harvey, 2003; Salt *et al.* 2004). For example, it is estimated that 32% of remnant Mabi forest is located on private land. The recovery plan drafted for this ecosystem stresses the importance of improving management of these remnants if the long-term survival of the ecosystem is to be assured (Latch, 2006).

Small remnant and regrowth patches on rural lifestyle properties and throughout ‘estate’ developments may contain significant old-growth habitat trees, riparian communities and other connectivity opportunities, as well as providing ‘site memory’ insights for assisting revegetation works and providing a storehouse of valuable remnant genetic materials. These latter points highlight the importance of the irreplaceability concept of remnant communities or patches (Salt *et al.* 2004), that is, they provide many established and site-specific conservation values that tree planting efforts cannot provide, at least not for decades into the future (Kanowski *et al.* 2005). Even small-scale native vegetation planting efforts can create some form of new habitat (i.e. refuge and resources) or result in improvements to existing habitat and the delivery of ecosystem and biodiversity conservation services (for example, Borsboom *et al.* 2002; Wang *et al.* 2004; Salt *et al.* 2004; Kanowski *et al.* 2005), and particularly so if attention is paid to ecological restoration and structural enhancement principles (Lindenmayer *et al.* 2003; Salt *et al.* 2004). This is also true for efforts to actively protect and manage small patches of existing native vegetation (Lindenmayer and Franklin, 2002).

Vegetation management planning in the Wet Tropics bioregion

The principles of sustainable development underlie the strategy pursued by the FNQ strategic plan, including the protection of the health of the region's natural resources base. Under the regional strategic plan (FNQ RPAC 2000), some areas are regarded as being of regional significance for biodiversity conservation, and several areas are targeted as being high priority for biodiversity conservation and rehabilitation activities. The main priority areas for both conservation of the existing biodiversity and for rehabilitation are the southern Tablelands area around Millaa Millaa, and the Jullaten and Mission Beach areas (Figure 2). This regional plan (FNQ RPAC 2000, p. 100) also notes that '(a)n important component of resource management and resource allocation decisions is the identification of resource availability and development opportunities' and that 'there are a number of areas and resource types where this analysis and mapping has not been carried out.' Some efforts are being made to address this situation. Detailed conservation planning is currently being undertaken in the Mission Beach area by a consortium of researchers and community members. This work is also being supported under Project 4.9.6 (*Strategic Natural Resource Management and land use planning*) of the Marine and Tropical Sciences Research Facility (MTSRF).

The region is undertaking the development of a new regional strategic plan at the time of writing this paper. Under the terms of reference for this planning exercise (DLGPSR 2007), the environmental outcomes sought include recognition of the need to:

Protect and maintain areas of regionally significant biodiversity, including:

- *Ecosystem function, habitat corridors and connectivity;*
- *Waterways and wetlands;*
- *Remnant vegetation;*
- *Endangered, rare and threatened species and their habitat (e.g. cassowary and mahogany glider);*
- *Environmental infrastructure (i.e. critical areas for ecological function and economic value to tourism); and the*
- *Wet Tropics and Great Barrier Reef World Heritage Areas.*

Previous research on biodiversity conservation and restoration in the Atherton Tablelands region

The most extensive and relevant research on the potential environmental impacts of revegetation programs in the Atherton Tablelands region was undertaken by Drs. Carla Catterall, John Kanowski, Grant Wardell-Johnson, Nigel Tucker and others. It should be noted that research into the environmental impacts of plantations is not well developed in terms of the ability to quantify the differences in environmental values from variations in the species composition, plantation management and location of plantations in the landscape (Erskine and Catterall 2004, Emtage 2004, Catterall *et al.* 2005). Catterall and Harrison (2006) reported that efforts to reforest rainforest areas had only begun at any significant scale in the 1990s so that experience with these plantings is limited. Research into these questions is continuing through projects funded by MTSRF and managed by the Reef and Rainforest Research Centre. In the following sections the previous research into the potential contribution to biodiversity conservation of plantations and restoration plantings is reviewed.

Catterall and Harrison (2006) examined rainforest restoration activities and classified these activities into three broad categories, these being the protection of existing vegetation, enhancement of existing vegetation that has been degraded, and reforestation. These authors further split reforestation into three classes, including 'restoration plantings (using a wide variety of species native to the area planted), plantation forestry and vegetation regrowth.

Biodiversity conservation values are best assessed at two scales, being the local or site scale and the broad or landscape scale. Supportive local scale floristic characteristics are important for providing habitat for individuals, while landscape scale distribution of habitat areas determine the ability of populations of species to survive in the long term.

Following their studies of the biodiversity values of various types of revegetation programs and projects, Kanowski *et al.* (2006) have developed some understanding of the principal factors that can affect the outcomes of such programs, as summarised in Table 6. The environmental values, particularly the biodiversity conservation value of a plantation or revegetation planting depend on various factors, including the number and functional variety of planted species, the tree and understorey density, and the landscape context of the planting. In general terms previous research on this topic has revealed that 'restoration' plantings with multiple species provide a faster means to improve biodiversity conservation in an area compared to timber plantations using few species. With biodiversity levels strongly related to structural complexity, it is not surprising that newly established plantings have lower biodiversity conservation values than older plantations. Their findings suggest that important factors include the origin and diversity of the species used in the plantation, the intensity of management practices, and the retention, reestablishment and proximity of native forest areas to the plantation.

The floristic diversity and structural complexity of a plantation has an important bearing on its ability to support fauna (Kanowski *et al.* 2005). When plantations are managed intensively for timber production (i.e. the species not used for timber production are removed), there is less development of floristic diversity and structural complexity and consequently the plantation has a lower value as habitat for native fauna. The biodiversity conservation potential of a plantation can change over time as floristic diversity and structural complexity develop. The development of these characteristics can be accelerated by establishing plantations using multiple species; however, over time even monoculture plantings can develop significant habitat values if they are managed for these values. One important limitation of plantations

for biodiversity conservation is their ability to support fauna species with specialised food and other habitat requirements (Catterall and Harrison 2006).

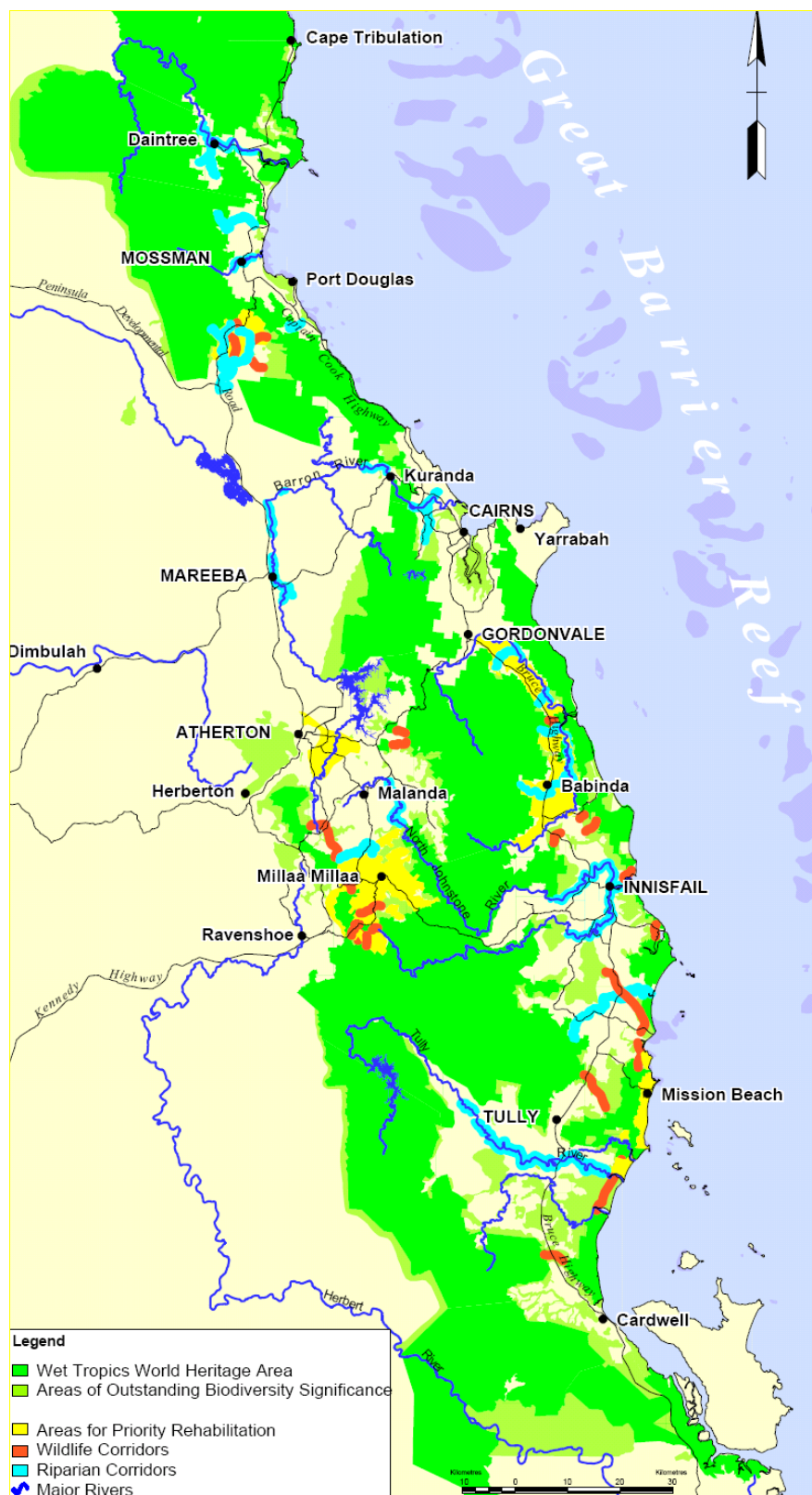


Figure 2: Regional rehabilitation priority areas for biodiversity conservation.

Source: FNQ RPAC (2000, p. 80).

Table 6: Factors affecting the biodiversity associated with plantings.

Site scale					
Presumed biodiversity	Origin of trees used in plantations	No. of species planted at site scale	Stocking rate	Management for timber production ¹	Proximity to native forest
Lower	Exotics	One	Low	Intensive	Isolated
Higher	Local species	Many	High	Limited	Adjacent

Landscape scale			
Presumed biodiversity	No. of species planted at landscape scale	Harvest of coupes	Extent of native forest retained and/ or restored within plantation estate
Lower	One	Uniform	Low
Higher	Many	Staggered	High

Source: Kanowski *et al.* (2006).

The presence of tree species with fleshy fruits plays an important role in attracting seed-dispersing fauna into a planting. The distance from the planting to the nearest source of seeds of understorey species is an important factor in the rate and level of recruitment of various species of trees, shrubs and other plants into a plantation (Keenan *et al.* 1997, McKeena (2001) cited in Wardell-Johnson *et al.* 2005). There is some potential to enrich plantations using understorey plantings (Lamb 1998, Tucker *et al.* 2004) and selective 'weeding', to retain plants that have high biodiversity value and timber quality. The traditional style of timber plantation management emphasises the timber production values where species other than that grown for timber are classified as weeds and removed. While most species used in timber plantations do not have fleshy fruits that are attractive to rainforest fauna, there is potential to include fleshy-fruited species among or adjacent to these plantations. This could immediately increase the habitat value of the plantation plus speed up the recruitment of native rainforest flora.

Research evidence confirms substantial species biodiversity is possible in timber plantations. For example, DPI (1997) reported a total of over 100 species of trees (emergent, canopy and understorey), shrubs, vines, ferns, epiphytes, grasses and herbs in a 56 year old hoop pine plantation at Gadgarra on the Atherton Tablelands. This plantation is located close to remnant forest, however, and was subject to minimal management activity.

The following quote provides a summary of the findings from Kanowski *et al.* (2006). This work suggests that timber plantations and revegetation plantings can have moderately beneficial impacts on biodiversity values in an area when planted in a mosaic pattern in the landscape.

We examine(d) the potential consequences for biodiversity of a number of broadscale plantation scenarios proposed for cleared rainforest landscapes of the Wet Tropics region of north Queensland. Of the scenarios examined, a mosaic of plantations and restoration plantings was considered to have the highest value for rainforest biota. Three scenarios based on plantations of rainforest trees (monocultures of hoop pine, mixed species plantings and a mosaic of monocultures) were considered likely to have similar, moderately positive impacts on biodiversity, while plantations of non-rainforest trees (eucalypts and exotic pines) had the least positive consequences for biodiversity in the region. All scenarios potentially have negative impacts on biodiversity, although these impacts differ somewhat between plantations of rainforest and non-rainforest trees. Plantations of eucalypts and exotic pines are more likely to be weedy than

most other plantation scenarios, while species from plantations of rainforest trees are more likely to invade native forests or, if non-local provenances are used, to carry the risk of genetic introgression to local populations. The risk of genetic introgression is also high for eucalypt plantations into regional eucalypt forests. The ranking of scenarios may vary with landscape forest cover, with scenarios having the most positive consequences (e.g., a mosaic of plantations and restoration plantings) being favoured in heavily cleared areas, and scenarios with few negative consequences (e.g. hoop pine plantations, or a mosaic of hoop pine plantations and restoration plantings) being favoured in well-forested areas. However, plantations of other rainforest trees, or even of exotic pines, may also be acceptable in well-forested areas, provided potential negative impacts on biodiversity are controlled (this may be difficult for some species).

These authors compared the risk of genetic introgression from hoop pine with other rainforest species, concluding that ‘plantations of rainforest trees (other than hoop pine) are more likely to be invasive than eucalypts or exotic pines, if non-local species are used, or to carry the risk of genetic introgression to local populations, if non-local genotypes are used in plantations.’

In regard to the effects of timber plantations on a landscape scale, Kanowski *et al.* (2006) stated that:

In well-forested parts of the Wet Tropics, it may be more important to minimise the potential negative impacts of plantations on native forests (e.g., weeds, invasive species, genetic introgression) than to maximise the positive impacts. On the analysis presented here, a monoculture of hoop pine or a mosaic of hoop pine monocultures and restoration plantings would be favoured over other scenarios in well-forested landscapes. Nevertheless, plantations of other rainforest trees, either as a mosaic of monocultures or mixed species plantations, may also be acceptable in these landscapes provided local species and provenances are used in plantations. In fact, plantations of exotic pines and perhaps other exotic species may also be acceptable in well-forested landscapes in the Wet Tropics, provided plantations are managed to control weeds and plantation species are not invasive (however, many exotic species may be invasive).

At a local scale there are ecological differences between plantations involving exotic pine species and those involving hoop pines which are native to the Atherton Tablelands. Hoop pine plantations do have some habitat value for macrofauna; however, much of the biodiversity conservation value of plantation areas arises from other species (i.e. those not used for timber production) that are recruited into the plantation. The relatively long plantation rotation for hoop pine favours understorey development.

While macrofauna are commonly observed in plantations, including those in the Community Rainforest Reforestation Program, it may be that plantations are less favourable in terms of microfauna. Microfauna are also important for a well-functioning ecosystem, but the observer (unless a scientist) may have little understanding of – or ability to observed changes in – the microfauna population.

Trade-offs between timber production and biodiversity values

Management of plantations will greatly affect the biodiversity value and timber production value of them. Erskine and Catterall (2004) and Catterall *et al.* (2005) discussed the trade-offs between timber production and ecological services from plantations. Their rationale for doing so was that:

- Many private landholders are interested in ecological services from plantations together with timber production;
- Timber supplies from rainforest areas in Australia have diminished sharply following the conservation of rainforests in public ownership in eastern Australia;
- Importing timber from tropical countries raises concerns about the sustainability of these supplies;
- There are relatively few plantations of rainforest species in Australia;
- There is a lack of information about the biodiversity values of timber plantations and a lack of information about the timber values of ecological restoration plantings; and
- There is a need to revegetate significant areas of the landscape outside the conservation reserve system if the future security of endangered ecosystems and particular species is to be ensured.

While the establishment of mixed-species rainforest plantings obviously leads to quicker improvements in local-scale rainforest biodiversity values relative to monoculture plantings, they are generally much more expensive to establish and in some cases offer no prospects of financial returns from timber harvesting. Estimates of the total establishment costs for ecological restoration plantings range from \$20,000 to \$25,000/ha, whereas costs for establishing monoculture plantations range from \$4,000 to \$8,000/ha (Catterall *et al.* 2005; Catterall and Harrison 2006). In other words, given the same budget it would be possible to plant three to six times as much land with monoculture plantings as with ecological restoration plantings.

One problem facing researchers wishing to investigate the trade-offs between timber production and biodiversity values in plantations is the lack of information about these interactions (Emtage, 2004; Erskine and Catterall, 2004). For example, little consensus on timber yield impacts was found in a survey of foresters regarding the effects of mixed-species plantations versus monocultures (Herbohn *et al.* 1999). Of the eleven foresters who were interviewed, five were uncertain about the effects on timber yield of planting mixed species; four thought timber yields would decrease, while two thought the yield from mixed-species plantations would increase relative to that from monoculture plantations. An important characteristic of timber plantations and their ability to provide biodiversity benefits is the rooting depth of the species used. Some foresters believe that when the species used has deep roots it is possible to allow substantial understorey development (after the first five or so years) without significant impacts on the timber production of the plantation. One obvious disadvantage of using timber plantations to provide biodiversity conservation is the disturbance that occurs during harvesting operations. One means of minimising biodiversity and habitat loss at the harvest stage is for harvests to be staggered within a plantation area. This could allow fauna species to migrate to undisturbed areas in the plantation during harvesting. Another alternative harvest management strategy that could be used to minimise disturbance is to apply selective logging whereby only a small proportion of the total stand is harvested at one time. In both these cases the financial viability of the timber plantation enterprise may be adversely affected.

As pointed out by Hunt (2004), the inherent productivity of a plantation is largely a function of the climate, aspect and soils at the growing site. There is always competition for resources (e.g. sunlight, nutrients, moisture) between trees in a plantation, and traditional silvicultural regimes have sought both to reduce the competition encountered by their target (timber producing) species and to manage the growth of the species to maximise growth in the desired areas. Hunt (2004) concluded that it is more useful to assess the biodiversity effects of plantations at the landscape rather than the local scale, and that 'profitability' could be a more useful measure of trade-offs than 'productivity'. With regard to the measure of profitability, Hunt (2004) observed that, were it possible to assign monetary values to

biodiversity, with landholders having access to these payments, then the perceived competition between timber production and biodiversity would decrease. As structural complexity develops over time, timber plantations using long-rotation species have a greater chance of developing attributes supportive of biodiversity conservation if the management of these areas is appropriate.

Design principles to improve biodiversity values of plantations and the landscape

Following a growing research effort towards making plantations, farm forests and farming landscapes more amenable or sympathetic to native biodiversity, there are now a number recognised and scientifically-based management strategies or principles that landholders should consider and apply where relevant, in order to enhance the habitat and biodiversity values of any type and scale of native vegetation establishment and management undertaking. Some notable recent publications on this topic have developed guidelines specifically relevant to softwood plantations (Lindenmayer, 2000), farm forestry plantings (New and England, 2002), and vegetation planning to support wildlife needs at the farm and landscape levels (Bennett *et al.* 2000; Platt, 2002).

Lindenmayer and Franklin (2002) noted that any comprehensive plan for biodiversity conservation requires maintaining habitat across the full range of spatial scales. They have identified five general principles to meet this objective, involving the maintenance of connectivity, landscape heterogeneity, stand structural complexity, and the integrity of aquatic ecosystems; and consideration of the concept of risk-spreading. More recently, a farm forestry focused set of principles has been developed (Salt *et al.* 2004) and these are based on the main elements of vegetation that determine its value for native biodiversity (Race and Freudenberger, 2003). They are further based on years of research by ecologists into the needs and interactions of native animals and plants in the Australian agricultural context (Salt *et al.* 2004), following a thorough review and incorporation of many past studies, including those noted above. The principles are grouped into five themes and build upon Lindenmayer and Franklin's remnant forest focused principles to include consideration of a planting's location (adjacency, connectivity, landscape context and protection of waterways), its configuration (size and shape), composition (species diversity and use of local species), complexity (structure, time and age, patchiness), and its ecological management (simulating natural processes, variability in management actions, monitoring biodiversity and adaptive management) (Salt *et al.* 2004).

Catterall *et al.* (2005, p. 210) listed a number of features of plantations generally associated with higher biodiversity values, including:

- Denser tree spacing;
- More tree species (including fleshy-fruited species);
- Greater variety of life-forms (e.g. shrubs and epiphytes) and age classes;
- Less pruning and less understorey suppression; and
- Greater total area (i.e. size of the area under tree cover or 'patch' size).

The position of the plantation in the landscape in respect to remnant vegetation is an important factor determining the contribution it can make to landscape biodiversity values. Plantations can provide a buffer to help protect small remnant forests from 'edge effects' including dry winds, insecticide spray drift or run-off and invasive weed species (Catterall *et al.* 2005). Previous research on the Atherton Tablelands by Keenan *et al.* (1997) and McKeena (2001) (cited by Wardell-Johnson *et al.* 2005) revealed that recruitment of other plants is most effective within two hundred metres of intact forest areas, and that few rainforest species were recruited to plantations beyond a distance of five hundred metres from intact forest areas.

Another possibility for improving biodiversity benefits at a landscape scale is by integrating mixed native hardwood species on watercourses, steep slopes and road fronts with timber

plantations. Current regulations prohibit cutting of trees in parts of the landscape for a number of reasons. If these areas that cannot be harvested are planted and managed to maximise their biodiversity values then the landscape scale biodiversity values will be improved. The management for biodiversity of areas adjacent to a plantation which is designed to produce timber could speed up development of higher biodiversity values within the plantation itself if this is desired by the plantation manager.

There could be some financial benefit of establishing restoration plantings at the same time as plantings for timber production because there are similar labour and equipment requirements for both types of planting. It is also noted, however, that apart from the higher cost of purchasing plants for more densely planted restoration plantings, one reason that establishing restoration plantings is usually highly expensive is because they are located in parts of the landscape that are more difficult to access.

A report prepared for RIRDC by Lindenmayer (2002) titled *Plantation Design and Biodiversity Conservation* advanced a number of principles to improve the biodiversity status of plantations. While Lindenmayer studied *Pinus radiata* plantations in southern New South Wales and northern Victoria, the principles for improving biodiversity conservation in new plantations are very similar to those of Catterall, Kanowski and others working in tropical and sub-tropical regions. The main three principles to enhance the biodiversity conservation value of timber plantations in northern Victoria and southern NSW identified by Lindenmayer (2002, p.8) include:

1. *Retain native eucalypt forest or woodland remnants within plantation landscapes. Even small remnants of 1-3 ha were found to have important value as habitat for a wide range of species such as birds, mammals, reptiles and other taxa. Moreover, a landscape mosaic comprised of stands of plantation trees and remnant patches of native vegetation will support significantly higher levels of native taxa than plantation landscapes that are monocultures.*
2. *Protect native vegetation along gully lines as these areas can be valuable dispersal routes for some species (e.g. small terrestrial native mammals). These areas are also often quarantined from plantation establishment for quality reasons and they might be useful places to target for native vegetation restoration efforts.*
3. *Take steps to control weed invasion problems (e.g. by pine 'wildlings' and blackberries⁵) within remnants of native vegetation within the plantation estate. This is best achieved in new plantations before the level of weed invasion becomes significant and weed control is still feasible.*

There are also many recognised guidelines relevant to small native gardens, or a 'Backyards for Wildlife' concept (UFBP, 2005), and these are a particularly important consideration for gardens that are adjacent to, or very nearby, natural bushland areas where gardening activities involve a heightened ecological responsibility (Low, 2001). Table 7, adapted from some of the above-noted and other sources, provides a summary of guidelines for enhancing habitat and biodiversity values of any remnant, regrowth and planted farm forest or native garden undertaking.

It must be recognised that there is no singular answer or recommended approach, with the site specific nature of the aims and context of any particular planting or remnant patch management practice determining which factors can or should be adopted. Overall, understanding and applying the relevant principles and practices will greatly help to

⁵ Or lantana in Queensland.

maximise the outcomes of any small or micro-scale effort, and especially when any such efforts are aggregated across property boundaries, or throughout streets, neighbourhoods, estates, sub-catchments, landscapes or regions.

Table 7: Summary of guidelines for enhancing vegetation habitat and biodiversity values.

- Select native species, with a preference for locally occurring native species.
- Remove and avoid the use of exotics and any other known environmental weeds (keeping in mind that even some non-local natives can be environmental weeds), particularly those that produce attractive fruits and berries.
- Use more than one tree species, and diversify the age and structure of the planting via establishing or allowing understorey and mid-level strata development.
- Use plants of different size, shape and form – including canopy trees, understorey trees and shrubs, climbers, scramblers, groundcovers, epiphytes and orchids.
- Use plants with differing foliage size, shape, texture, etc. including sparse, dense and, or, prickly vegetation to provide resting, nesting and shelter opportunities.
- Use plants that possess differing flowering and fruiting phonologies to ensure there will be year-round food sources available.
- Use species hosting nitrogen fixing bacteria, species with a high capacity to host epiphytes, species with distinctive bark or branching habits and species with wildlife-attracting fruits.
- Retain and incorporate existing physical structures – remnant trees and patches, logs, stumps, boulders, windrows, etc.
- Site a planting to complement (expand, protect or connect) existing remnant vegetation and riparian zones, and consider the wider landscape / catchment.
- Incorporate dams, firebreaks and clearings into a planting.
- Use variable spacings between trees and leave gaps and spaces, including during thinning practices.
- Maintain and / or create dead and dying wood – including existing snags, developing decadence in living trees, creating artificial cavities and log (or thinnings and prunings) piles.
- Install nest boxes, native bee hives, bird-perches or baths, or other artificial structures.
- Harvest trees at staggered intervals, maintain part or all of a stand beyond normal economic maturity and permanently retain some older trees – to allow for the presence of older and larger trees (and the chance to develop hollows and other habitat structures) through successive rotations and to add patchiness to the landscape.
- Minimise chemical applications.
- Consider the use of prescribed burning to create a patchy landscape mosaic of areas burnt in different years and / or seasons.
- Introduce or enrich populations of desired animal species.
- Monitor for, and control pests, weeds and plantation or garden escapees.
- Monitor habitat provision and biodiversity, and adjust future management accordingly.

Sources: Blay 1994, Low 2001, Lindenmayer and Franklin 2002, Hobbs *et al.* 2002, Salt *et al.* 2004, UFBP 2005.

Summary of the results of the Delphi Survey of forestry experts in the Atherton Tablelands

With limited information available about the productivity of native tree species, the authors took the opportunity of funding available through the Australian Government's Marine and Tropical Sciences Research Facility (MTSRF) to undertake a survey of forestry experts to gather data about this topic. This work was undertaken in 2006-2007 and builds on similar research undertaken by the authors in 1998 (Herbohn *et al.* 1999) and Russell *et al.* (1993). The results of this survey are presented in the following section.

Rationale for the research

Many people believe there is great potential to grow native Australian rainforest tree species in timber and revegetation plantings. Formal field trials and records for these species are patchy and efforts to collate data from these trials have been poorly supported by research funding organisations for significant periods of time.

In the absence of published quantitative data to help people assess the financial implications of growing native rainforest tree species in plantations, researchers have adapted the Delphi expert survey technique to generate practical information about the performance of the species which can be applied by forestry researchers, practitioners, rural landholders and their advisors.

The research team last undertook a Delphi survey of forestry experts in 1997-1998 using funding from the Rainforest CRC, following similar research by Russell *et al.* (1993). The results of this survey were published in the journal *Australian Forestry* (Herbohn *et al.* 1999) and information about 31 native species was included as data in the Australian Farm Forestry Financial Model (AFFFM). Since that time there has been considerable research activity in the native hardwoods plantation sector in Queensland and northern New South Wales, yet information about the performance of native trees in plantations is still hard to obtain, especially for small-scale growers.

We believed it was critical to update the information about the potential performance of native rainforest timbers in plantations to assist people to make informed decisions about their choice of species and their plantation management. The information will be analysed and published in several formats, including a formal report through the MTSRF, information sheets and articles for timber growers, plus the updated information has been incorporated into the AFFFM software package.

The Delphi Survey process

According to Linstone and Turoff (2002: 12) '...the original justifications for this first Delphi study are still valid for many Delphi applications today, when accurate information is unavailable or expensive to obtain, or evaluation models require subjective inputs to the point where they become the dominating parameters.' Understanding the rotation times and growth performance of potential cabinet timber plantations is central to guiding investment into revegetation using native species in the Wet Tropics region and the information is not available.

In the current study the respondents were sent questionnaires in September 2006. Due to a low response rate the respondents were not sent a summary of the initial findings as discussions indicated they would not change their estimates. The situation they were asked to examine were as follows:

Respondents are asked to provide their estimates of the growth rates and likely rotation times for native species in the following tables.

Please indicate your level of confidence in your ability to provide the estimates by indicating a confidence level for each species estimate on a scale from 1 (not confident) to 5 (very confident).

The following tables contain common species planted under the Community Rainforest Reforestation Program (CRRP) or those identified as being possible species that may be planted in mixed rainforest species plantings similar to those established under the CRRP. Assume that the trees will be planted on relatively fertile basaltic soils near Atherton. Also assume that the rainfall in the area averages 1,500-2,000mm per year. Initial planting density is 660 stems per ha⁻¹ and suitable thinning regimes will be applied.

For each species in the following tables, please provide your best estimate for:

- 1) The expected times to harvest the species (plus the earliest and latest possible times taken until harvest); and
- 2) The expected growth rate per annum (m³ ha⁻¹ yr⁻¹). For these estimates, please assume that the species are grown as a monoculture and also provide an indication of the best and worst growth rates that could be expected.

Data collected by Herbohn *et al.* (1999) is also provided for each species in the tables.

If you believe you do not have sufficient information to make an estimate for a species please mark the appropriate cell 'DK'.

If you believe the species is not suited to the biophysical conditions described above then indicate this by using the letters 'NS' in the appropriate cell.

Results of the survey

Of approximately thirty people who were identified as potentially qualified to undertake the survey, many disqualified themselves on the basis that they had had little involvement in forestry research during the past ten years. The cessation of the CRRP scheme together with major restructuring of the Queensland Forestry Research Institute has severely decreased the number of personnel involved in forestry in the region in the past ten years. This has led to a feeling of abandonment by some of those who have remained, and on-going frustration at the lack of long term vision and institutional support for forestry research in the region and state generally.

Only four people eventually answered the survey. Their responses are summarised in the following tables. Mila Bristow had been involved in forestry research in the region for many years and has recently moved to Gympie to continue work researching timber plantation development. She made a number of important observations and suggestions as to how the process could be improved which are summarised following the results tables.

Table 8: Forecast timber yields for North Queensland cabinet timbers (cubic metres / ha / year).

	Avg-best guess	Avg-highest	Avg-lowest	S.d. best guess	n
<i>Acacia. mangium</i>	15.7	17.3	12.2	6.49	4
<i>Ac. melanoxylon</i>	13.5	15.7	11.7	10.04	3
<i>Agathis robusta</i>	14.6	17.3	12.0	0.80	4
<i>Araucaria cunninghamii</i>	17.7	20.7	14.0	2.65	4
<i>Beilschmieda bancroftii</i>	2.5	5.5	1.0	0.71	2
<i>Blepharocarya involucrigera</i>	6.8	7.7	6.3	3.14	4
<i>Cardwellia sublimis</i>	8.1	9.7	8.3	3.23	4
<i>Castanospermum australe</i>	6.2	7.7	4.7	3.23	4
<i>Cedrela odorata</i>	10.9	13.7	9.3	1.75	4
<i>Ceratopetalum apetalum</i>	4.0	5.0	3.0	0.00	1
<i>Elaeocarpus angustifolius</i>	17.5	20.0	13.0	6.03	4
<i>Endiandra palmerstonii</i>	3.2	4.7	2.7	2.78	2
<i>Eucalyptus camaldensis</i>	14.8	18.3	12.0	4.76	4
<i>E. citriodora</i>	13.3	16.7	11.3	3.51	3
<i>E. cloeziana</i>	16.3	19.3	13.7	3.16	4
<i>E. cloeziana (poles)</i>	16.4	19.3	13.7	3.31	4
<i>E. drepanophylla</i>	9.8	12.3	7.3	2.57	3
<i>E. grandis</i>	19.1	21.7	14.3	5.13	4
<i>E. microcorys</i>	14.7	17.7	12.0	3.06	3
<i>E. pellita (resinifera)</i>	15.3	19.7	12.0	4.73	3
<i>E. tetreticornis</i>	14.3	17.0	12.0	4.35	4
<i>Flindersia australis</i>	8.4	9.0	7.0	2.26	2
<i>Fl. bourjotiana</i>	8.5	10.0	7.0	1.93	4
<i>Fl. brayleana</i>	12.1	14.7	8.0	4.12	4
<i>Fl. iffiana</i>	7.1	8.3	6.5	0.14	2
<i>Fl. pimenteliana</i>	7.2	8.7	5.3	1.72	4
<i>Fl. schotiana</i>	8.8	12.7	7.0	2.17	4
<i>Gmelina fasciculiflora</i>	7.3	9.3	6.0	2.53	3
<i>Grevillia robusta</i>	11.3	16.0	9.7	4.03	4
<i>Melia azedarach</i>	12.4	15.3	9.3	4.10	4
<i>Paraserianthes toona</i>	6.5	7.5	5.5	0.78	2
<i>Toona cilata (australis)</i>	9.3	11.0	3.0	4.99	4

Table 9: Forecast rotation times for various native tree species grown in plantations on the Atherton Tablelands.

	Avg-best guess	S.d. best guess	Avg-shortest	Avg-longest	n
<i>Acacia. mangium</i>	23.6	4.95	18.0	30.0	4
<i>Ac. melanoxylon</i>	25.5	4.27	18.7	31.7	3
<i>Agathis robusta</i>	43.2	5.51	35.0	55.0	4
<i>Araucaria cunninghamii</i>	41.7	6.81	33.3	50.0	4
<i>Beilschmieda bancroftii</i>	100.0	0.00	80.0	120.0	2
<i>Blepharocarya involucrigera</i>	45.3	12.53	38.3	59.0	4
<i>Cardwellia sublimis</i>	58.5	8.50	50.0	76.7	4
<i>Castanospermum australe</i>	64.5	12.69	58.3	83.3	4
<i>Cedrela odorata</i>	29.8	9.50	27.0	37.0	4
<i>Ceratopetalum apetalum</i>	100.0	-	80.0	120.0	1
<i>Elaeocarpus angustifolius</i>	27.8	15.28	22.3	38.3	4
<i>Endiandra palmerstonii</i>	119.0	61.51	101.7	155.0	3
<i>Eucalyptus camalduensis</i>	26.8	2.36	23.3	31.7	4
<i>E. citriodora</i>	30.7	9.02	26.7	35.7	3
<i>E. cloeziana</i>	27.0	8.83	23.0	35.0	4
<i>E. cloeziana (poles)</i>	21.8	4.72	17.3	25.3	4
<i>E. drepanophylla</i>	42.7	8.74	36.0	53.7	3
<i>E. grandis</i>	24.5	7.59	21.7	31.7	4
<i>E. microcorys</i>	28.3	6.51	23.3	33.3	3
<i>E. pellita (resinifera)</i>	25.7	8.14	21.3	31.0	3
<i>E. tetreticornis</i>	27.5	5.57	23.3	33.3	4
<i>Flindersia australis</i>	47.0	9.85	35.0	55.0	3
<i>Fl. bourjotiana</i>	48.5	10.75	41.7	60.0	4
<i>Fl. brayleana</i>	38.5	15.78	32.7	50.0	4
<i>Fl. iffliana</i>	45.5	13.44	37.5	52.5	2
<i>Fl. pimenteliana</i>	50.8	9.43	41.7	61.7	4
<i>Fl. schotiana</i>	41.5	11.36	31.7	53.3	4
<i>Gmelina fasciculiflora</i>	51.0	11.53	43.3	65.0	3
<i>Grevillia robusta</i>	30.5	7.51	26.0	43.3	4
<i>Melia azedarach</i>	25.8	9.43	22.3	30.0	4
<i>Paraserianthes toona</i>	49.7	10.50	45.0	57.3	3
<i>Toona cilata (australis)</i>	45.0	17.32	36.0	61.3	4

Mila Bristow's suggestions

Several forestry research professionals challenged the techniques being used to gather data for the present project. While it was disappointing to not have estimates from these people to include in the process, they raise a number of important and valid points that should be considered. In particular there was some distress in the failure of successive institutions to provide the types of long term support required to establish and maintain 'proper' in ground trials that could deliver the types of data we seek in an objective manner.

Mila Bristow suggests that it is pointless or at least highly inaccurate to try and get estimates on such a large number of relatively unknown species. The results of the assessment of the CRRP plots and other plots in the Wet Tropics revealed three key issues (reported in Bristow *et al.* 2005). First, the majority of species showed highly variable growth rates on the various sites that were assessed. Second, for many of the species there is a lack of replicated plantings, meaning that estimates of the variations in their productivity according to biophysical variability and management activities potentially have very high error rates. Third, there are approximately ten species that have been planted in greater numbers and across a range of sites for which productivity and harvest age estimates could be more reliably estimated.

In the context of redeveloping the regional timber industry based on native tree species, Mila suggested that a number of factors should be considered:

- Species that are planted need to be established at a sufficient scale to support viable management, harvesting, processing and marketing operations.
- Processing and marketing could work most efficiently by concentrating on a small number of products, similar to the concept of Tasmanian and Victorian efforts to bundle several species of hardwoods under one brand name.
- As scale of plantation estates and therefore management and processing is such a critical issue, species are needed that can perform well in a reasonably broad range of climatic and soil conditions
- Developing best practice seed collection, propagation and silvicultural practices can lift timber productivity by 10-20% BUT this is a fairly long and resource intensive process.

Problematic from production point of view is the lack of replicated trials of provenances, soil nutrition, silviculture, etc. With current efforts being put into Teak and Mahogany anyway (by Managed Investment Scheme companies including Integrated Tree Cropping), what other species can be developed in the region as part of a cabinet timber industry? In other words it may be better to offer a short list of species that have been found to work well over a wide range of sites in the Wet Tropics than to ask for estimates on lesser known species. It is unlikely that people's estimates of these species will have changed much in the last five years. We could check with several people who did make estimates in the last survey to gauge whether it is worth revising these.

The trials that do exist (i.e. CRRP plots, QFRI/DPI plots, CSIRO plot) do indicate that several species could be used as the basis for developing cabinet timber plantations (Bristow *et al.* 2005). These native species that grow well across sites include:

- *Eucalyptus pellita* and *E. cloeziana*;
- *Elaeocarpus grandis*;
- *Araucaria cunninghamii*; and
- *Castanospermum austral*.

Species that could be suited for 'niche market' and production of other non-timber values recommended by Bristow *et al.* (2005) include:

- *Flindersia brayleana*, *F. Schottiana*;
- *Acacia mangium*; and
- *Grevillia robusta*.

Mila suggests we target questions around these species and add the following question to the survey to capture species that are of emerging interest: If top species in northern Queensland CRRP were a, b, c, etc, which species would you add to these? These questions will be referred to in future work by the research team.

Top species recommendations

This section of the report presents information provided by Tony Irvine (formerly of CSIRO Atherton) in response to the survey of forestry experts opinions on planting regimes and potential growth rates for plantations of rainforest cabinet species and eucalypts in north Queensland reported in Herbohn *et al.* (1999). Tony worked in the Atherton Tablelands region as a research scientist for more than twenty years and has a strong personal interest in revegetation programs. He was one of the founding members of the community based group *Trees for the Atherton and Evelyn Tablelands* (TREAT) which is still very active today in establishing ecological restoration plantings across the Wet Tropics region. Tony planted several blocks of native trees on his own property near Atherton and has been recording their growth for more than twenty years.

The next section presents the species that Tony recommended for mixed species plantings across a range of site conditions. Following sections detail Tony's recommended species for timber production using native species for specific soil and rainfall combinations.

Explanation of methods used

Species recommendations are for the top species across a variety of biophysical conditions and are based on 22 regimes dealing with lowland to highland, 18 of which are suitable for rainforest plantings, where the rainfall regime is 1,300 to >3,000mm, soils are basaltic, metamorphic, granitic, old beach dunes, beach dunes, colluvial/alluvial, poor drainage good drainage, shallow and deep soils. The top five species were selected in each regime. These species were then ranked for frequency across the system. The species included below reflect these rankings. This can be taken to indicate that a greater variety of habitats suit these species, but pitfalls occur if planted in the wrong habitat. The number in the brackets indicates the number of regimes out of the 18 suited for rainforest in which the species is rated in the top five.

Top species across regimes

Flindersia bourjotiana (11)
Cardwellia sublimis (11)
Flindersia pimenteliana (9)
Agathis robusta (7)
Elaeocarpus angustifolius (7)

Eucalyptus intermedia (16)
E. pellita (9)
E. grandis (8)

Recommendations based on soil and climate combinations

Where:

(F) = Fast growth rate
 (M) = Medium growth rate
 (S) = Slow growth rate
 P = Pioneer species

Basalt 1,800mm to >2,500 mm and shallow soils

Agathis microstachya (F)
Aleurites moluccana (F) P

Alphitonia petrei (F) P
Alstonia scholaris (M)
Argyrodendron peratalum (M)
Argyrodendron trifoliolatum (F)
Cardwelia sublimis (M)
Cinnamomum lanbatii (M)
Cryptocarya oblata (M)
Darlingia ferruginea (F)
Elaeocarpus angustifolius (F)
El. ruminatus (M)
Flindersia acuminata (F)
F. bourjotiana (M)
F. pimenteliana (M)
Geisus biagima (F)
Hylandia dockrillii (M)
Litsea leafeana (M)
Opisthiolepis hetrophylla (M)
Omalanthus novoguineensis (F) P
Mallotus paniculata (F) P
Polyscias murrei (F) P
Polyscias elegans (F) P
Sloanea australis (S)
Sloanea macbrydei
Syzygium gustavoides (M)
Syzygium kuranda (M)
Syzygium papyraceum (M)
Syzygium trachyphloium (M)
Xanthostemon whitei (M)

If basalt is deep, add:

Flindersia brayleyana
Toona cilata

No eucalypts needed, however *E. pellita*, *E. intermedia* and *E. tereticornis* would grow nicely.

Basalt 1,600mm to 1,800mm

Agathis microstachya (F)
Alphitonia petrei
Argyrodendron peratalum (M)
Argyrodendron trifoliolatum (F)
Cryptocarya oblata (M)
Darlingia ferruginea (F)
Elaeocarpus angustifolius (F)
El. ruminatus (M)
Flindersia acuminata (F)
F. bourjotiana (F)
F. pimenteliana (F)
Geisus biagima (F)
Gmelina fasciculiflora (F)
Litsea leafeana (M)
Opisthiolepis hetrophylla (M)
Omalanthus novoguineensis (F)-P
Mallotus paniculata (F) P
Polyscias murrei (F) P

Polyscias elegans (F) P
Prumnopitys amara (S)
Sloanea macbrydei
Syzygium gustavoides (M)
Syzygium kuranda (M)
Xanthostemon whitei (M)

No eucalypts, however if basalt is deep, add *Flindersia brayleyana*.

Basalt 1,300mm to 1,600 mm

Agathis robusta (F)
Aleurites moluccana (F) - P
Alloxylon flammeum (F)
Alstonia scholaris (M)
Argyrodendron peratalum (M)
Argyrodendron trifoliolatum (M)
Celtis paniculata (F)
Cryptocarya hypospodia (M)
Castenospermum australe (S)
Elaeocarpus angustifolius (F)
Euroschinus falcata (M-F)
Flindersia acuminata (F)
Flindersia brayleyana (F)
Flindersia schottiana (F)
Gmelina fasciculiflora (F)
Litsea leafeana (M)
Mallotus molissimus (F) P
Mallotus paniculatus (F) P
Macaranga tanarius (F) P
Melia adzedarach (F) P
Terminalia sericocarpa (M)
Toona cilata (F)
Trema orientalis (F) P
Xanthostemon whitei (S-M)

Two native eucalypts:

Eucalyptus intermedia (F)
Eucalyptus tereticornis (S)

Other eucalypts not native to the area but will grow well include:

Eucalyptus acmenoides (F)
E. pellita (F)
E. reducta (F)
E. resinifera (F)
E. cloeziana (F)
E. torelliana (F)
E. grandis (F)
Lophostomon conferta (F)
Syncarpia glomulifera (M-F)

Basalt 1,100 to 1,300mm

Except in gullies only Eucalypts recommended here.

Local species of eucalypt include:

Eucalyptus leptophleba
E. intermedia
E. clarksoniana
E. platyphylla
E. tereticornis

Non-local species that would grow well in this situation include:

Eucalyptus acmenoides (F)
E. pellita (F)
E. reducta (F)
E. pellita (M)
E. cloeziana (F)
E. citriodora (F)

Basalt 800 to 1,100mm

Local species of eucalypt include:

Eucalyptus leptophleba (S)
E. clarksoniana (S)
E. creba (S)
E. erythrophloia (S)
E. platyphylla (S)
E. tereticornis (S)
E. papuana (S)

Non-local:

Eucalyptus acmenoides (M-F?)
E. reducta (M-F?)
E. cloeziana (F)
E. citriodora (M)

Granite/metamorphic 1,800 to >2,500mm

Acmena divaricata (M)
Agathis atropurpurea (F)
Alphitonia petrei (F) P
Calophyllum costatum (S)
Cardwellia sublimis (F)
Caldcluvia australiensis (F)
Callitris macleayana (M)
Cinnamomum lanbatii (M)
Darlingia darlingiana (F)
Elaeocarpus angustifolius (F)
Flindersia bourjotiana (F)
F. pimenteliana (F)
Musgravea hetrophylla (M)
Omalanthus novoguineensis (F) P
Placospermum coriaceum (M)
Polyscias australiana (F) P
Polyscias murryi (F) P
Syncarpia glomulifera (M)

Syzygium endophloium (M)
Syzygium kuranda (M)
Syzygium papyraceum (M)

Eucalypts:

Eucalyptus pellita (F) at less than 800m altitude

E. grandis (F)

E. intermedia (F)

E. tereticornis (S-F)

Granite/metamorphic 1,600 to 1,800mm

Agathis robusta (F)

Alloxylon wickhamii (M)

Argyrodendron polyandrum (S)

Blepharocarya involucrigera (M)

Buckinghamia celsissima (F)

Caldcluvia australiensis (F)

Calophyllum costatum (S)

Cinnamomum lanbatii (M)

Cryptocarya oblata (M)

Darlingia darlingiana (F)

Elaeocarpus angustifolius (F)

Flindersia bourjotiana (F)

F. pimenteliana (F)

F. brayleyana (F) on granite well drained

F. laevicarpa (F)

Metrosideros queenslandia (M)

Placospermum coriaceum (M)

Prumnopitys amara (S)

Syzygium endophloium (M)

Syzygium johnsonii (M)

Syzygium kuranda (M)

Syzygium wesa (S)

Toona cilata (F)

On well drained granite:

Alphitonia petrei (F) P

Commersonia bartramia (F) P

Omalanthus novoguineensis (F) P

Polyscias australiana (F) P

Polyscias murryi (F) P

Polyscias elegans (F) P

Eucalypts and other sclerophyll species:

Callitris macleayana (M)

E. grandis (F)

E. intermedia (F)

E. reducta (F)

E. resinifera (F)

E. tereticornis (S-F)

Syncarpia glomulifera (M)

Granite/metamorphic 1,300 to 1,600mm

Agathis robusta (F)

Aleurites moluccana (F) P

Alloxylon flammeum (F)

Alphitonia philippinensis (F) P

Argyrodendron peratalum (S)

Blepharocarya involucrigera (M)
Buckinghamia celsissima (F)
Celtis paniculata (F)
Cryptocarya hypospodia (M)
Euroschinus falcata (M-F)
Flindersia acuminata (F)
Flindersia schottiana (F)
Flindersia iffaiiana (F)
Gmelina fasciculiflora (F)
Macaranga tanarius (F) P
Mallotus molissimus (F) P
Omalanthus novoguineensis (F) P
Podocarpus greyi (S)
Polyscias australiana (F) P
Polyscias elegans (F) P
Trema orientalis (F) P

Eucalypts and other sclerophyll species:

Allocuarina torlosa (F)
Eucalyptus acmenoides (F)
E. citriodora (F)
E. cloeziana (F)
E. grandis (F)
E. intermedia (F)
E. reducta (F)
E. resinifera (F)
E. tereticornis (S-F)
Syncarpia glomulifera (M)
Lophostemon conferta in rocky areas

Dry granite metamorphic 800 to 1,300mm

Eucalyptus acmenoides (F)
E. citriodora (F)
E. cloeziana (F)
E. exserta (F) at <1,100mm
E. intermedia (F)
E. moluccana (M)
E. reducta (F)
E. resinifera (F)
E. tereticornis (S-F)
Syncarpia glomulifera (M)

Dry woodland on colluvial and alluvial soils 800 to 1,300mm

Timber species would be completely experimental. Rainfall and substrate may inhibit growth.

Erythrophloeum chlorostachys (S)
Eucalyptus platyphylla (S)
E. creba (S)
E. cullenii (S)
E. leptophleba (S)
E. clarksoniana (S)
E. erythrophloia (S)
E. papuana (S)
E. tessellaris (S)

Tony Irvine's response to Delphi survey, 13 May 2007

Likely tree growth for selected species in a relatively fertile basaltic soil near Atherton (760-800m altitude), with an average annual rainfall regime of 1,500-2,000mm. (The long term average rainfall for Atherton is around 1,420mm per annum). Spacing 1,320 trees per ha (3m x 2.5m). Individual species exceptions to these conditions are indicated besides the species.

Fastest trees to reach 65cm dbh based on most likely estimate

* = species exotic to Far North Queensland

30-55 year group	Age to reach 65cm DBH	Notes
Species name		
<i>Eucalyptus microcorys</i> *	30	1,400-1,500 mm rainfall
<i>Elaeocarpus angustifolius</i>	35	Grow with other dense crown species
<i>Euc. grandis</i>	35	1,400-1,550 mm rainfall
<i>Euc. reducta</i>	35	1,200-1,450 mm rainfall
<i>Neolamarckia cadamba</i>	35	
<i>Terminalia sericocarpa</i>	45	1,400-1,600 mm rainfall
<i>Cardwellia sublimis</i>	50	> = 1,700 mm rainfall
<i>Corymbia citriodora</i>	50	1,200-1,550 mm rainfall
<i>Euc. Cloeziana</i>	50	1,300-1,550 mm rainfall
<i>Flindersia brayleyana</i>	50	
<i>Flindersia acuminata</i>	50	
<i>Toona cilata</i>	50	< 15 years old prone to severe drought
<i>Melia azedarach</i>	50	
<i>Aleurites rockinghamensis</i>	50	
<i>Agathis robusta</i>	55	1,500-1,800 mm rainfall
<i>Flindersia schottiana</i>	55	
<i>Cryptocarya hypospodia</i>	55	
<i>Blepharocarya involucrigeria</i>	55	

60-80 year group	Age to reach 65cm DBH	Notes
Species name		
<i>Flindersia iffaiiana</i>	60	
<i>Flindersia pimenteliana</i>	60	>= 1600 mm rainfall
<i>Celtis paniculata</i>	60	
<i>Dysoxylum mollissimum</i> ssp. <i>Molle</i>	60	
<i>Syzygium kuranda</i>	60	
<i>Eucalyptus tereticornus</i>	65	
<i>Litsea leefeana</i>	65	
<i>Flindersia bourjotiana</i>	66	>= 1600 mm rainfall
<i>Agathis microstachya</i>	70	> 1600 mm rainfall
<i>Darlingia darlingiana</i>	70	
<i>Elaeocarpus bancroftii</i>	70	
<i>Euroschinus falcate</i>	75	
<i>Flindersia australis</i> *	75	
<i>Gmelina fasciculiformis</i>	75	

<i>Syncarpia glomulifera</i>	75	
<i>Eucalyptus acmenoides</i>	75	1100 – 1450 mm rainfall
<i>Sundacarpus amara</i>	75	
<i>Araucaria cunninghamii</i>	80	
<i>Agathis atropurpurea</i>	80	> = 1,700mm rainfall, better 800-1000m alt.
<i>Argyrodendron peralatum</i>	80	

> 80 years based on most likely estimate	Age to reach 65cm DBH	Notes
Species name		
<i>Paraserianthes toona</i>	140	Unsuitable in Atherton, requires <= 450m alt.
<i>Endiandra palmerstonii</i>	150	> = 1,600 mm rainfall
<i>Castanospermum australe</i>	200	Unsuitable in Atherton, requires < =550m alt.

References

- Aslin, H. 2006. *Rural Lifestyle Landholders: Implications for rural policy makers, natural resource managers and communicators*. Science for Decision Makers Series, Bureau of Rural Sciences. Australian Government, Canberra.
- Aslin, H., Kelson, S., Smith, J. and Lesslie, R. 2004. *Peri-Urban Landholders and Biosecurity Issues: A Scoping Study*. Bureau of Rural Sciences. Australian Government, Canberra.
- Australian State of the Environment Committee, 2001. *Australia State of the Environment 2001*. Independent Report to the Commonwealth Minister for the Environment and Heritage. CSIRO Publishing, Canberra. <http://www.ea.gov.au/soe/> (Accessed 12 March 2005).
- Bennett, A., Kimber, S., and Ryan, P. 2000. *Revegetation and Wildlife: A Guide to Enhancing Revegetated Habitats for Wildlife Conservation in Rural Environments*. Bushcare National Projects R&D Program, Research Report No. 2/00. Environment Australia, Canberra..
- Blay, J. 1994. *The Australian Native Plant Gardeners Almanac*. Wildlife Presentations, New South Wales.
- Bliss, J. and Martin, J. 1989. Identifying NIPF Management Motivations with Qualitative Methods. *Forest Science*, Vol. 35, No. 2, pp. 601-622.
- Borsboom, A., Wang, J. Lees, N., Mathieson, M and Hogan, L. 2002. *Measurement and Integration of Fauna Biodiversity Values in Queensland Agroforestry Systems*, RIRDC Publication No. 02/044. Rural Industries Research and Development Corporation, Canberra.
- Brechwoldt, R. 1986. The Value of Remnant Vegetation, In: Distance Education Centre (UQ), 1994. *Rural Nature Conservation – Book of Readings*. University of Queensland, Gatton College, Lawes Campus.
- Bristow, M., Erskine, P., McNamara, S. and Annandale, M. 2005. Species performance and site relationships for rainforest timber species in plantations in the humid tropics of Queensland (In) Erskine, P., Lamb, D. and Bristow, M. (eds.), *Reforestation in the Tropics and Subtropics of Australia*. Rural Industries Research and Development Corporation, Canberra, pp. 84-100.
- Burgman, M. and Lidenmayer, D. 1998. *Conservation Biology for the Australian Environment*, Surrey Beatty and Sons.
- Burnley, I. and Murphy, P. 2004. *Sea Change: Movement from Metropolitan to Arcadian Australia*, University of NSW Press, Sydney.
- Catterall, C.P., Kanowski, J., Lamb, D., Killin, D., Erskine, P. and Wardell-Johnson, G.W. 2005. Trade-offs between timber production and biodiversity in rainforest plantations: Emerging issues and an ecological perspective', Chapter 13 in Erskine, P.D., Lamb, D. and Bristow, M. (eds.), *Reforestation in the Tropics and Subtropics of Australia Using Rainforest Tree Species*, Rural Industries Research and Development Corporation, Canberra.
- Catterall, C. P. and Harrison, D. A. 2006. *Rainforest Restoration Activities in Australia's Tropics and Subtropics*. Cooperative Research Centre for Tropical Rainforest Ecology and Management. Rainforest CRC, Cairns, Australia (94 pp).

Chudleigh, P., Simpson, S., Warburton, Chenoweth, L., Beck, T., and Comerford, E. 2003. *Arrangements to Enhance Effective Use of Incentive Mechanisms in Regional Natural Resource Management: A Scoping Study (AGT13)*. Report to the Social and Institutional Research Program, Land and Water Australia. AgTrans Research, Brisbane.

Commonwealth of Australia, 1996. *National Strategy for the Conservation of Australia's Biological Diversity*, Commonwealth Department of the Environment, Sports and Territories (DEST), Australia.

Department of Local Government, Planning, Sport and Recreation (DLGPSR), 2007. *Terms of Reference FNQ 2025*. May 2007. Brisbane.

Department of Natural Resources and Water (DNRW), 2007. *Land cover change in Queensland 2004–2005: a Statewide Landcover and Trees Study (SLATS) Report*, February 2007. Department of Natural Resources and Water, Brisbane.

Department of Primary Industries (DPI), (1997). *From Reforestation to Rehabilitation: Increasing Biological Diversity in Reforestation Programs, Field Tour Program and Notes*. Department of Primary Industries, Atherton.

Dury, S., Polglase, P and Vercoe, T. 2002. *Greenhouse Resource Kit for Private Forest Growers*. Agriculture, Fisheries and Forestry – Australia (AFFA), Canberra.

Emtage, N., Harrison, S., and Herbohn, J. 2001. Landholder Attitudes to and Participation in Farm Forestry Activities in Sub-Tropical and Tropical Eastern Australia. (In) Harrison, S. and Herbohn, J. (eds) *Sustainable Farm Forestry in the Tropics: Social and Economic Analysis and Policy*. Edward Elgar, Cheltenham, pp. 195-210.

Emtage, N. 2004. The productivity versus biodiversity information vacuum: what do we know and where can we go from here?' (In) Erskine, P. and Catterall, C (eds.), *Production versus Rainforest Biodiversity: Trade-offs or Synergies in Farm Forestry Systems?* Cooperative Research Centre for Tropical Rainforest Ecology and Management. Rainforest CRC, Cairns, pp. 17-19.

Erskine, P. and Catterall, C. (eds.) 2004. *Production versus Rainforest Biodiversity: Trade-offs or Synergies in Farm Forestry Systems?* Cooperative Research Centre for Tropical Rainforest Ecology and Management. Rainforest CRC, Cairns.

Figgis, P. 2004. *Conservation on Private Lands: The Australian Experience*. IUCN, Gland, Switzerland and Cambridge, UK.

FNQ NRM Ltd and Rainforest CRC, 2004. *Sustaining the Wet Tropics: A Regional Plan for Natural Resource Management 2004–2008*, FNQ NRM Ltd, Innisfail.

Far North Queensland Regional Planning Advisory Committee (FNQ RPAC), 2000. *Far North Queensland Regional Plan*. Queensland Department of Communication and Information, Local Government, Planning and Sport, Brisbane.

Freudenberger, D. and Harvey, J. 2003. *Assessing the Benefits of Vegetation Enhancement for Biodiversity: A Draft Framework*, Report for Environment Australia and the Biodiversity Benefits Task Group, CSIRO Sustainable Ecosystems, Canberra.

Goosem, S and Tucker, N. 1995. *Repairing the Rainforest*. Wet Tropics Management Authority, Cairns.

- Harrison, S., and Herbohn, J. 2005. Relationship Between Farm Size and Reforestation Activity: Evidence From Queensland Studies. *Small-Scale Forest Economics, Management and Policy*. 4 (4), pp. 471-484.
- Herbohn, J. L., Harrison, S. R. and Emtage, N. 1999. Potential performance of rainforest and eucalypt cabinet timber species in plantations in North Queensland. *Australian Forestry*, 62(1): 79-87.
- Hobbs, R., Floyd, R., Cunningham, S., Catling, P. and Ive, J. 2002. *Hardwood Plantations: quantifying conservation and environmental service benefits*. RIRDC Publication No. 02/083, Rural Industries Research and Development Corporation, Canberra.
- Hollier, C., Reid, M. and Francis, J. 2003. 'Small and Lifestyle Farmers: Has the Horse Bolted for Biodiversity Gains?' Paper presented at the *Conference on Rural Land-Use Change*. Rutherglen, State of Victoria Department of Primary Industries.
- Hollier, C., Reid, M., and Francis, J. 2004a. Understanding Drivers of Land Use Change Associated With Lifestyle Farms: Background Report 4 (In) J. Crosthwaite, J. Callaghan, Q. Farmer-Bowers, C. Hollier and A. Straker (eds). *Land Use Changes, their Drivers and Impact on Native Biodiversity – Driver Research Phase One: Overview Report*. Department of Sustainability and Environment, Melbourne. CD ROM. <http://www.dse.vic.gov.au>
- Hollier, C., Francis, J., and Reid, M. 2004b. *Rural – Peri-Urban Interface and Extension*, Paper prepared for the National Extension Policy Forum. Department of Primary Industries – Practice Change Research, Rutherglen, Victoria. From www.extensionpolicy.com.au/papers.php?arid=34 Accessed 10 November, 2007.
- Hunt, M. 2004. Biodiversity versus production trade-offs: a production perspective (In) Erskine, P. and Catterall, C. (eds.) *Production versus Rainforest Biodiversity: Trade-offs or Synergies in Farm Forestry Systems?* Cooperative Research Centre for Tropical Rainforest Ecology and Management. Rainforest CRC, Cairns.
- Irwin, E., Bell, K., and Geoghegan, J. 2006. Forecasting Residential Land Use Change (In) Johnston, R. and Swallow, S. (eds) *Economics and Contemporary Land Use Policy: Development and Conservation at the Rural-Urban Fringe*, Chapter 3, pp. 55-82. Resources For The Future (RFF) Press, Washington DC, United States.
- Johnston, G. 1976. *The Australian Pocket Oxford Dictionary*. First Edition, Oxford University Press, Melbourne.
- Kanowski, J., C.P. Catterall, G.W. Wardell-Johnson, H. Proctor and T. Reis 2003. Development of forest structure on cleared rainforest land in eastern Australia under different styles of reforestation. *Forest Ecology and Management* 183 (2003) 265-280.
- Kanowski, J., Catterall, C.P. and Wardell-Johnson, G.W. 2006 Biodiversity Futures Under Alternative Forest Industry Scenarios in North Queensland (In) Harrison, S.R. and Herbohn, J.L. *Sustainable Forest Industry Development in Tropical North Queensland*. Cooperative Research Centre for Tropical Rainforest Ecology and Management. Rainforest CRC, Cairns.
- Kanowski, J., Catterall, C.P., Proctor, H. Reis, T., Tucker, N.I.J. and Wardell-Johnson, G.W. 2005. Biodiversity values of timber plantations and restoration plantings for rainforest fauna in tropical and subtropical Australia, Chapter 12 (In) Erskine, P.D., Lamb, D, Bristow, M. (Eds) *Reforestation in the Tropics and Subtropics of Australia Using Rainforest Tree Species*. RIRDC Publication No 05/087, Rural Industries Research and Development Corporation.

- Keenan, R.J., Lamb, D., Woldring, O., Irvine, A. and Jensen, R. 1997. Restoration of plant biodiversity beneath tropical tree plantations in Northern Australia. *Forest Ecology and Management*, 99(1-2): 117-131.
- Kline, J., Azuma, D., and Alig, R. 2004. Population Growth, Urban Expansion, and Private Forestry in Western Oregon. *Forest Science* 50 (1), pp.33-43.
- Lamb, D. 1998. Large-scale ecological restoration of degraded tropical forest lands: the potential role of timber plantations. *Restoration Ecology* 6(3): 271-279.
- Latch, P. 2006. *Recovery Plan for Mabi Forest*. Report to Department of the Environment and Water Resources, Canberra. Queensland Parks and Wildlife Service, Brisbane. Accessed 16 April 2008: <http://www.environment.gov.au/biodiversity/threatened/publications/pubs/mabi-forest.pdf>
- Laurance, W. 1997. Hyper-Disturbed Parks: edge effects and the ecology of isolated rainforest reserves in Tropical Australia. (In) Laurance, W. and Bierregaard, Jr., R. (eds) *Tropical Forest Remnants: ecology, management and conservation of fragmented communities*. The University of Chicago Press, Chicago, pp.71-83.
- Leighton, S. 2004. Enhancing Biodiversity Value to Farm Forestry. (In) Race, D. (ed) *Integrating Forestry Into Farms, Communities and Catchments*, Conference Program and Proceedings of the Australian Forest Growers Biennial Conference, Ballarat 2004.
- Lindenmayer, D. 2000. *Guidelines for Biodiversity Conservation in New and Existing Softwood Plantations*. RIRDC Short Report #77. Rural Industries Research and Development Corporation. Available from www.rirdc.gov.au/pub/cat/contents.html
- Lindenmayer, D. 2002. *Plantation Design and Biodiversity Conservation*. RIRDC Publication No. 02/019. Rural Industries Research and Development Corporation. RIRDC, Canberra.
- Lindenmayer, D. B. and Franklin, J. F. 2002, *Conserving Forest Biodiversity: A Comprehensive Multi-Scaled Approach*. Island Press, Washington.
- Lindenmayer, D. B., Hobbs, R. J. and Salt, D. 2003, Plantation Forests and Biodiversity Conservation. *Australian Forestry* 66 (1): 62-66.
- Linstone, H. A. and Turoff, M. (2002). *The Delphi Method: Techniques and Applications*. New Jersey Institute of Technology. Accessed October 2006: <http://www.is.njit.edu/pubs/delphibook/>
- Low, T. 2001. *Feral Future: the untold story of Australia's exotic invaders*. Penguin Books, Victoria, Australia.
- Mackenzie, J., Whelan, J., and Oliver, P. 2006. *Reconnecting Fragmented Landscapes: A Scoping Study on Natural Resource and Environmental Management in the Peri-Urban Landscapes of South Eastern Queensland*. Coastal CRC, SEQ Catchments, Brisbane.
- Meefe, G. and Carrol, R. n.d. *Principles of Conservation Biology*. Sinauer Associates Inc., Massachusetts, United States.
- New, B. and England, M. 2002. *Farm Forestry: Designing for Increased Biodiversity*. Primary Industries and Natural Resources, South Australia.

Office of Economic and Statistical Research (OESR) 2003. Queensland's Future Population, Brisbane. Accessed 2 February 2006: <http://www.oesr.qld.gov.au>

Paltridge, N. 2002. *Biodiversity in Agriculture and Farm Forestry*. A report for RIRDC / L&W Australia, FWPRDC, Joint Venture Agroforestry Program. RIRDC Publication No. 02/051. Rural Industries Research and Development Corporation. RIRDC, Canberra.

Platt, S. 2002. *How to Plan Wildlife Landscapes: A Guide for Community Organisations*. Department of Natural Resources and Environment. Melbourne, Victoria.

Queensland Herbarium, 2001. *Remnant Vegetation in Queensland: analysis of pre-clearing remnant 1997-1999*. Regional Ecosystem Information, Toowoong, Queensland.

Race, D. and Freudenberger, D. 2003. *Farm Forestry for Green and Gold: Australian experiences of linking biodiversity to commercial forestry*. Australian National University, Canberra.

Russell, J. S., Cameron, D. M., Whan, I. F., Beech, D. F., Prestwidge, D. B. and Rance, S. J. 1993. Rainforest trees as a new crop for Australia. *Forest Ecology and Management* 60(1): 41-58.

Salt, D., Lindenmayer, D., and Hobbs, R. 2004. *Trees and Biodiversity: A Guide for Australian Farm Forestry*. RIRDC Publication No. 03/047, as part of the JVAP / RIRDC. Rural Industries Research and Development Corporation, Canberra.

Sampson, N. 2001. People, Forests and Forestry: New Dimensions in the 21st Century. Paper presented at *Fragmentation 2000: A conference on sustaining private forests in the 21st century*, Sept.18, 2000, Annapolis, Maryland, United States (www.sampsongroup.com)

Shands, W. 1991. Problems and Prospects at the Urban – Forest Interface: Land-Uses and Expectations are in Transition. *Journal of Forestry* 89 (6), pp.23-26.

State of the Environment Advisory Council, 1996. *1996 State of the Environment Report*, Commonwealth of Australia, Canberra.

Thackway, R. and Cresswell, I. D. (eds.) 1998. *Interim Marine and Coastal Regionalisation for Australia: an Ecosystem-based Classification for Marine and Coastal Environments*. IMCRA Version 3.3. Environment Australia, Canberra.

Tucker, N. I. J. Wardell-Johnson, G. Catterall, C. P. Kanowski, J. 2004. Agroforestry and biodiversity: improving conservation outcomes in tropical northeastern Australia (In) Schroth, G., Fonseca, G. A. B., Harvey, C. A. Gascon, C. Vasconcelos, H. L. and Izac, A-M. N. (eds.) *Agroforestry and Biodiversity Conservation in Tropical Landscapes*. Island Press, Washington, pp. 431-452.

Urban Forest Biodiversity Program (UFBP) 2005. *Introduction to the program, Backyards for Wildlife etc*. Accessed 20 March 2005: <http://www.urbanforest.on.net>

Vanclay, F. and Lawrence, G. 1995. *The Environmental Imperative: Eco-Social Concerns for Australian Agriculture*. Central Queensland University Press, Rockhampton.

Vercoe, T. 2001. Farm Forestry and Biodiversity, Special Liftout No.57 (In) *Australian Forest Grower*, Vol. 24, No.3.

Wang, J., Borsboom, A., and Smith, G. 2004. Flora Diversity of Farm Forestry Plantations in Southeast Queensland. *Ecological Management and Restoration* Vol.5, No.1, pp.43-51.

Walker, P., Marvin, S., and Hurley, P. 2005. Four Legs Good, Two Legs Bad? Re-Examining the Ecology of Rural Residential Growth (In) Anon. (ed). *Emerging Issues along Urban / Rural Interfaces: Linking Science and Society*. Conference Program and Book of Abstracts, Atlanta, Georgia, United States. 13-16 March 2005, p.73.

Wardell-Johnson, G. W., Kanowski, J., Catterall, C. P., Lamb, D. and Piper, S. 2005. Rainforest timber plantations and the restoration of plant biodiversity in tropical and subtropical Australia (In) Erskine, P. D., Lamb, D. and Bristow, M. (eds.) *Reforestation in the Tropics and Subtropics of Australia Using Rainforest Tree Species*. Rural Industries Research and Development Corporation. RIRDC, Canberra.

Weston, N. and Goosem, S. 2004. *Sustaining the Wet Tropics: A Regional Plan for Natural Resource Management. Volume 2A Condition Report: Biodiversity Conservation*. Rainforest CRC and FNQ NRM Ltd, Cairns (211 pp).

White, M. 1997. *Listen Our Land Is Crying. Australia's Environment: Problems and Solutions*, Kangaroo Press, New South Wales.

Williams, S. E., R. G. Pearson, P. J. Walsh (1996). Distributions and biodiversity of the terrestrial vertebrates of Australia's Wet Tropics: a review of current knowledge. *Pacific Conservation Biology* 2:327-362.

Young, M., Gunningham, N., Elix, J., Lambert, J., Howard, B., Grabosky, P., and McCrone, E. 1996. *Reimbursing the Future: An Evaluation of Motivational, Voluntary, Price-Based, Property-Right and Regulatory Incentives for the Conservation of Biodiversity*. CSIRO Division of Wildlife and Ecology, Australian Government Publishing Services, Canberra.

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