Plantation forests and biodiversity conservation

D.B. Lindenmayer[1], R.J. Hobbs[2] and D. Salt[1]

[1]Centre for Resource and Environmental Studies, The Australian National University, Canberra, ACT 0200, Australia
Email: davidl@cres.anu.edu.au
[2]School of Environmental Studies, Murdoch University, Murdoch, WA 6150, Australia

Revised manuscript received 6 January 2003

Summary

There are five key reasons why biodiversity conservation should be considered a part of plantation management. (1) The plantation estate is large, and balancing various land management values with wood and pulp production is important when extensive areas of land are involved. (2) The locations and management of new plantations will affect the biota that currently exist in such landscapes. (3) Maintaining some elements of biodiversity within plantations can have benefits for stand productivity and the maintenance of key ecosystem processes such as pest control. (4) The retention (or loss) of biota in plantations is relevant to the formulation of ecological standards and the certification of plantations in many parts of the world. (5) Plantation forestry has a narrow and intensive management focus on producing a forest crop for a limited array of purposes. It will not meet future societal demands for a range of outputs from plantations (in addition to wood and pulp supply), and will not be congruent with the principles of ecological sustainability.

This paper briefly reviews the biodiversity conservation values of Australian plantations. It shows that almost all work in Australian plantations, whether conifer or eucalypt, highlights the importance of landscape heterogeneity and stand structural complexity for enhancing biodiversity. Management of plantations to promote landscape heterogeneity and stand structural complexity and enhance the conservation of biodiversity will, in many cases, involve tradeoffs that will affect wood and pulp production. The extent to which this occurs will depend on the objectives of plantation management and how far they extend towards the more complex plantation forestry models that incorporate social and environmental values. We argue that the widespread adoption of plantation forestry that leads to homogenous stands of extensive monocultures will risk re-creating the array of negative environmental outcomes that have been associated with agriculture in many parts of Australia.

Keywords: forest plantations; biodiversity; wildlife conservation; *Pinus radiata*; *Eucalyptus*; Australia

This paper was presented at a conference, 'Prospects for Australian Forest Plantations 2002', held on 20–21 August 2002 at Canberra, ACT.

Introduction

Plantations of trees (defined here as planted forests of commercially important tree species) cover extensive parts of the earth's surface: 187 million ha in 2000 (FAO 2001). In Australia the plantation estate was estimated to be almost 1.5 million ha in 2000 (Wood *et al*. 2001). The primary aim of almost all plantations is the production of large quantities of wood and fibre (e.g. for timber and paper production). However, there are often important opportunities for biodiversity conservation within plantations (Hartley 2002). In this paper, we explore approaches that promote nature conservation within Australian plantations. We take a hierarchical approach by exploring issues first at the landscape scale and then at the stand level. Our focus is primarily on medium to large plantings (over several hundred to several thousand and tens of thousands of hectares). We have not examined smaller plantings, such as those typically undertaken in agricultural areas by farmers in rural Australia (widely termed 'farm forestry'; *sensu* Race *et al*. 1998). Our literature review indicated that very limited research has been undertaken on small-scale plantings. This is a major area that requires additional research, given that the biodiversity benefits of farm forestry have been widely promoted but remain to be quantified.

A model for biodiversity conservation in plantations

Plantation forestry can be thought of as a continuum extending from simple plantation forestry, as defined by Kanowski (1997), to complex plantation forestry (see Fig. 1). 'Simple plantation forestry' refers to a narrow and intensive management focus on producing a forest crop for a limited array of purposes. Complex plantation forestry, while still having a relatively intensive management regime, attempts to include other land uses and values within plantation boundaries, and aims to produce goods and services in addition to wood products. Kanowski (1997) argued that complex plantation forestry is an important way forward in many situations because society will demand outputs in addition to wood and pulp from plantations, and simple plantation forestry is not congruent with the principles of ecological sustainability. In the medium to long term, simple plantation forestry risks creating environmental problems similar

to those that currently afflict agricultural enterprises in many parts of Australia (Hobbs *et al*. 2002). Indeed, Holling and Meffe (1996) have shown that land use practices that are narrowly focused invariably perform poorly in maintaining key ecological functions.

Background

The biota of conifer plantations

Most studies have found that animal assemblages in conifer plantations are less diverse than those of native forests. Vertebrates such as hollow-using birds and arboreal marsupials as well as nectarivorous, frugivorous, foliage-gleaning and canopy-feeding birds are absent or greatly reduced in abundance in radiata pine plantations. This is most probably because these exotic conifer-dominated stands lack key nesting and foraging resources for these species. While the biota of conifer plantations is depauperate, these areas are not 'biological deserts' because they provide foraging habitat or nesting habitat or both for a range of birds, small mammals and invertebrates. The occurrence of much of the biodiversity found in conifer plantations is strongly related to the mosaic of patches of native forest among them, and the treatment history of planted areas (e.g. thinning regimes and stand ages). These key topics are explored in greater detail in subsequent sections of this paper.

The biota of eucalypt and other types of plantations

Work on biodiversity conservation within eucalypt and other types of plantations has a far shorter history and is much less extensive than the research in radiata pine plantations. Much of the limited work has been recent (e.g. Borsboom *et al.* 2002; Hobbs *et al*. 2002; Klomp and Grabham 2002). Vertebrate and invertebrate assemblages are less diverse than those in native vegetation, largely because of the relative structural simplicity of the plantations (Hobbs *et al*. 2002). Nevertheless, as for pine plantations, bluegum plantations are not 'biological deserts' but provide habitat or resources for a range of species, including a selection of bird species considered to be at conservation risk.

Plantations versus cleared land

Borsboom *et al.* (2002) and Klomp and Grabham (2002) showed that the diversity of birds was higher in planted eucalypt forests than in pastures, although species assemblages were still depauperate in comparison with native woodlands. However, greater species diversity is not always the best outcome for nature conservation. It is often better to use the composition of particular faunal assemblages as a measure. Lindenmayer *et al.* (2001) have found that the species assemblages of newly established plantations are different from (but not necessarily 'better' than) those of semi-cleared grazing lands.

Conserving biodiversity in plantations

Landscape-level issues

We believe there are several key issues associated with the conservation of biodiversity within plantations at the landscape level. These are: (i) the location of plantations; (ii) the role of landscape mosaics created by the retention of eucalypt patches and riparian vegetation within plantations; (iii) the adjacency effects of remnant vegetation next to plantations; (iv) the contribution of harvest scheduling to biodiversity conservation; and (v) the value of landscape restoration.

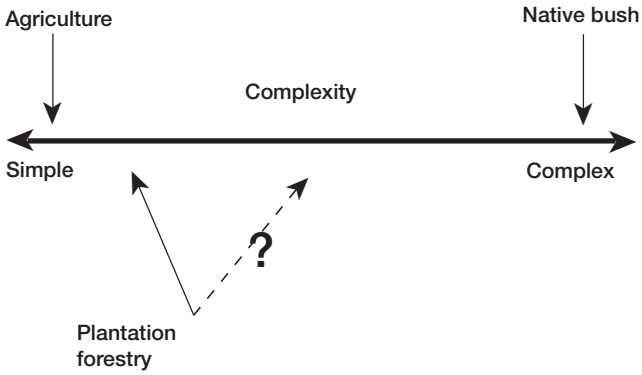

Figure 1. The simple–complex plantation continuum (redrawn from Hobbs *et al*. 2002)

The location of plantations

The pre-existing conservation values of areas where new plantations might be established warrant careful consideration. We believe that clearing native vegetation to establish plantations (e.g. as in Tasmania) is an inappropriate land use practice given the well-documented negative impacts of land clearing. In parts of southern NSW and Victoria, plantation expansion will take place on semi-cleared grazing lands which support patches of remnant native forest and woodland. Even though many remnant patches are small (often less than 3 ha; see Gibbons and Boak 2003), they can have considerable conservation value (Fischer and Lindenmayer 2002).

The role of landscape mosaics created by the retention of eucalypt patches and riparian vegetation within plantations

Many studies have highlighted the value for conservation of maintaining patches of remnant native forest or woodland within plantations (e.g. Friend 1982; Recher *et al.* 1987a). In general, the larger the patches of retained native vegetation within plantations the more the species of vertebrates they support (Lindenmayer *et al.* 1999). However, retained patches do not always have to be large to be useful — areas as small as 0.5–1 ha have been found to be valuable for forest birds, reptiles, frogs and mammals and invertebrates. Riparian vegetation is known to be particularly valuable for native biota within plantations. Other features which can add to landscape heterogeneity and enhance biodiversity conservation include dams and open areas such as clearings and firebreaks.

The adjacency effects of remnant vegetation next to plantations

The greatest diversity and abundance of native animals in plantations occur in stands adjacent to native vegetation (for

example see Friend 1982; Lindenmayer *et al*. 2002). The adjacency of native forest also may assist in the biocontrol of pest invertebrate populations in eucalypt plantations (Strauss 2001). However, there can be some negative impacts of the adjacency of plantations to native forests such as increased browsing damage by native and introduced animals — a phenomenon observed in both eucalypt and conifer plantations (e.g. Barnett *et al.* 1977; Montague 1996; Bulinski 1999).

The contribution of harvest scheduling to biodiversity conservation

There can be positive benefits for biodiversity conservation arising from changes in the spatial and temporal pattern of harvesting in plantation forests. For example, given differences in the biotas of plantations of different ages (see below), maintaining landscapes with a mosaic of stand age classes may increase the biodiversity conservation value of plantations (Gepp 1976). Smith (2000) predicted that the rare Tasmanian carnivorous snail *Tasmaphena lamproides* would be sensitive to aggregated patterns of harvest disturbance and would respond better to a scattered pattern of smaller coupes interspersed among stands of older forest.

The value of landscape restoration

There is scope within some plantations to promote biodiversity conservation through the restoration of targeted areas. Riparian zones, in particular, may be valuable places for such work. Harvesting is often restricted in riparian areas because of water quality and aquatic habitat considerations. Therefore, it is useful to exempt riparian areas from tree planting in new plantations and to allow the regeneration of native vegetation there, or to actively restore native vegetation cover following the final clearfelling operation within already established plantations.

Stand-level issues

A number of matters can be considered in enhancing biodiversity conservation within a plantation program.

The contribution of species mixtures

A diversity of plant species can be positively related to the diversity and abundance of a range of animal taxa. Recher *et al*. (1987b) found that several native species of birds persisted within stands of radiata pine because the presence of scattered regrowth eucalypts created the effect of a mixture of tree species.

Stand age effects on biodiversity

Plantations can have a significant impact on many elements of biodiversity. Borsboom *et al*. (2002) recorded increasing vertebrate species richness with increased stand age in eucalypt (*Eucalyptus cloeziana*) plantations in south-eastern Queensland. Bird species diversity may increase with stand age within conifer plantations. For example, Gepp (1976) attributed such findings to older stands supporting more structurally diverse conditions.

The contribution of biological legacies to species conservation

Biodiversity conservation in plantation forests can be promoted through the retention of elements of the original stand (termed 'biological legacies'; *sensu* Franklin *et al*. 2000) at the time of harvesting. For example, trees retained at the time of regeneration harvesting have been found to be used by many species of birds (Kavanagh and Turner 1994). Bonham *et al*. (2002) emphasised the importance of leaving thinnings and prunings or logging 'waste' to rot on the forest floor to provide habitat for invertebrates in Tasmanian plantation forests. Several of these species of invertebrates would otherwise be sensitive to timber harvesting operations. Windrows of cleared eucalypts left within softwood plantations are useful for many native taxa (e.g. Friend 1982).

Other issues

Pest animals in plantations

Some elements of biodiversity in plantations may have undesirable effects. For example, both Australian conifer and eucalypt plantations are vulnerable to damage caused by native and introduced animals (Bulinski 1999). Radiata pine plantations in Australia support more than 40 species of pest invertebrates and most of these are introduced (Neumann 1979). Strauss (2001) noted that more than 85 invertebrate species are pests of eucalypt plantations in Australia. Most of these are native and have been found on the same tree species or closely-related tree species within stands of native vegetation. She argued that the extent of the pest invertebrate problem in eucalypt plantations was likely to increase in the future as the size of the plantation estate increases and exchanges of animals between regions takes place — highlighting a need for strict quarantine protocols within Australia. Large numbers of introduced animals can occur in plantations, including rodents, the rabbit, the red fox and the feral cat (Hobbs *et al. 2*002).

Genetic pollution

'Genetic pollution' is a potential problem associated with plantations of eucalypts in Australia. That is, there may be genetic invasion from pollen dispersal and subsequent hybridisation between eucalypt tree species used to establish plantations and eucalypts endemic to an area (Potts *et al*. 2001). This may, in turn, alter natural patterns of genetic variability (Strauss 2001).

Tensions between biodiversity conservation and other plantation objectives

Significant tensions exist between management practices to maintain or increase wood and pulp production in plantations, and practices designed to promote biodiversity conservation within plantations (Keenan *et al*. 1997). Some of these tensions are outlined below.

(1) It is generally recognised that more elements of the biota will occur where there are more plant taxa, and this is supported by evidence gathered in Australian studies of plantations.

However, in most commercial plantations emphasis has been placed on the growth of a single tree species — including those that have been subject to considerable genetic modification.

(2) It is well established that there are strong relationships between the structural complexity of forests and the diversity of species (see Lindenmayer and Franklin 2002). However, most silvicultural practices in plantations result in stand simplification. For example, structural complexity (and its associated biodiversity) can be reduced through the removal of windrows to control pest herbivores (le Mar 2000), the application of herbicides to eliminate unwanted or competing plants, and even the application of fertiliser to promote tree growth (Pampolina *et al*. 2002).

(3) Virtually all studies to date have highlighted the conservation value of remnant native vegetation within plantations, even patches that are relatively small (including single large old trees). In addition, many species can use plantations if native vegetation is nearby. However, retaining native vegetation means forgoing plantations on some land — although sometimes these areas are unsuitable for planting (e.g. steep and rocky terrain). In addition, retained vegetation can retard the growth of neighbouring plantation trees (Bi *et al*. 2002).

(4) Retained areas of native vegetation also can create problems for plantation managers through harbouring browsing vertebrates which can inflict serious damage on plantations, particularly at their periphery. Plantations can be a major source of weeds that can erode the habitat quality of neighbouring areas of native vegetation. In eucalypt plantations, planted trees also can be a source of pollen to create new hybrids within adjacent vegetation and, in turn, alter patterns of genetic variability.

Tensions of the four types just described can make it difficult to reconcile many aspects of plantation management and biodiversity conservation. The extent to which forestry practices can be modified to accommodate biodiversity conservation will depend on the flexibility possible within the objectives of plantation management, as well as the degree to which agreements such as the certification of sustainable practices are seriously embraced by state government agencies and private plantation owners. Perhaps the greatest opportunities lie in the establishment of new plantations on semi-cleared grazing lands. In these cases, there will be advantages in articulating plans and visions of what future plantation landscapes might look like, so that values other than wood and pulp production can be embraced. As outlined above, existing remnant vegetation in these areas is extremely important. In addition, there will be a significant conservation role of existing (and restored) riparian native vegetation in these landscapes — a role that need not necessarily have a major negative impact on wood and pulp production, given water quality considerations.

Acknowledgements

The authors thank the Rural Industries Research and Development Corporation and the Joint Venture Agroforestry Program (and particularly Roslyn Prinsley) for funding our work on plantations and biodiversity conservation.

References

Barnett, J.L., How, R.A. and Humpreys, W.F. (1977) Possum damage to pine plantations in north-eastern New South Wales. *Australian Forest Research* **7,** 185–196.

Bi, H., Bruskin, S. and Smith, R.G. (2002) The zone of influence of paddock trees and the consequent loss in volume growth in young *Eucalyptus dunnii* plantations. *Forest Ecology and Management* **165,** 305–315.

Bonham, K.J., Mesibov, R. and Bashford, R. (2002) Diversity and abundance of some ground-dwelling invertebrates in plantation vs. native forests in Tasmania, Australia. *Forest Ecology and Management* **158,** 237–247.

Borsboom, A.C., Wang, J., Lees, N., Mathieson, M. and Hogan, L. (2002) *Measurement and Integration of Fauna Biodiversity Values in Queensland Agroforestry Systems*. A report for the RIRDC/Land and Water Australia/Forest and Wood Products Research and Development Corporation Joint Venture Agroforestry Program. Rural Industries Research and Development Corporation. Publication 02/44. Canberra.

Bulinski, J. (1999) A survey of mammalian browsing damage in Tasmanian eucalypt plantations. *Australian Forestry* **62,** 59–65.

FAO (2001) *State of the World's Forests*. (2001) Food and Agriculture Organization of the United Nations, Rome.

Fischer, J. and Lindenmayer, D.B. (2002) The conservation value of small habitat patches: two case studies on birds from southeastern Australia. *Biological Conservation* **106,** 129–136.

Franklin, J.F., Lindenmayer, D.B., MacMahon, J.A., McKee, A., Magnusson, J., Perry, D.A., Waide, R. and Foster, D.R. (2000) Threads of continuity: ecosystem disturbances, biological legacies and ecosystem recovery. *Conservation Biology in Practice* **1,** 8–16.

Friend, G.R. (1982) Mammal populations in exotic pine plantations and indigenous eucalypt forests in Gippsland, Victoria. *Australian Forestry* **45,** 3–18.

Gepp, B.C. (1976) Bird species distribution and habitat diversity in an exotic forest in South Australia. *Australian Forestry* **39,** 269–287.

Gibbons, P. and Boak, M. (2003) The value of paddock trees for regional conservation in an agricultural landscape. *Ecological Management and Restoration* (in press).

Hartley, M.J. (2002) Rationale and methods for conserving biodiversity in plantation forests. *Forest Ecology and Management* **155,** 81–95.

Hobbs, R.J., Floyd, R., Cunningham, S., Catling, P. and Ive, J. (2002) Hardwood plantations: quantifying conservation and environmental service benefits. Report to the Joint Venture Agroforestry Program, Project CSW-32A. Rural Industries Research and Development Corporation, Canberra.

Holling, C.S. and Meffe, M. (1996) Command and control and the pathology of natural resource management. *Conservation Biology* **10,** 328–337.

Kanowski, P. (1997) Plantation forestry in the 21st century. *Afforestation and Plantation Forestry. Proceedings, XI World Forestry Congress*, 13–22 October 1997, Vol. **3,** Topic 12, pp. 23–33; http://fao.org/montes/foda/wforcong/publi/V3_T12.PDF

Kavanagh, R.P. and Turner, R.J. (1994) Birds in eucalypt plantations: the likely role of retained habitat trees. *Australian Birds* **28,** 32–41.

Keenan, R., Lamb, D., Woldring, O., Irvine, T. and Jensen, R. (1997) Restoration of plant biodiversity beneath tropical tree plantations in northern Australia. *Forest Ecology and Management* **99,** 117–131.

Klomp, N. and Grabham, C. (2002) *A Comparison of the Avifaunal Diversity on Native Hardwood Plantations and Pastureland in North-East Victoria.* Report No. 164, Johnstone Centre, Charles Sturt University, Albury, NSW.

le Mar, K. (2000) Use of the forestry environment by herbivores. *Tasforests* **12,** 169–170.

Lindenmayer, D.B. and Franklin, J.F. (2002) *Conserving Forest Biodiversity: A Comprehensive Multiscaled Approach*. Island Press, Washington, DC.

Lindenmayer, D.B., Cunningham, R.B., Pope, M. and Donnelly, C.F. (1999) The response of arboreal marsupials to landscape context: a large-scale fragmentation study. *Ecological Applications* **9,** 594–611.

Lindenmayer, D.B., Cunningham, R.B., Tribolet, C.R., Donnelly, C.F. and MacGregor, C. (2001) The Nanangroe Landscape Experiment — baseline data for mammals, reptiles and nocturnal birds. *Biological Conservation* **101,** 157–169.

Lindenmayer, D.B., Cunningham, R.B., Donnelly, C.F., Nix, H.A. and Lindenmayer, B.D. (2002) The distribution of birds in a novel landscape context. *Ecological Monographs* **72,** 1–18.

Montague, T. (1996) The extent, timing and economics of browsing damage in eucalypt and pine plantations of Gippsland, Victoria. *Australian Forestry* **59,** 120–129.

Neumann, F.G. (1979) Insect pest management in Australian radiata pine plantations. *Australian Forestry* **42,** 30–38.

Pampolina, N.M., Dell, B. and Malajczuk, N. (2002) Dynamics of ectomycorrhizal fungi in an *Eucalyptus globulus* plantation: effect of phosphorus fertilization. *Forest Ecology and Management* **158,** 291–304.

Potts, B.M., Barbour, R.C. and Hingston, A.B. (2001) *The Risk of Genetic Pollution from Farm Forestry Using Eucalypt Species and Hybrids*. A report for Rural Industries Research and Development Corporation/Land and Water Australia/Forest and Wood Products Research and Development Corporation Joint Venture Agroforestry Program.

Race, D., Guijt, I. and Kanowski, P. (1998) Australian experiences in farm forestry. *Environmental Conservation* **25,** 234–243.

Recher, H.F., Shields, J., Kavanagh, R. and Webb, G. (1987a) Retaining remnant mature forest for nature conservation in New South Wales. In: Saunders, D.A., Arnold, G.W., Burbridge, A.A. and Hopkins, A.J. (eds). *Nature Conservation: The Role of Remnants of Native Vegetation*. Surrey Beatty and Sons, Chipping Norton, pp. 177–194.

Recher, H.F., Davis, W.E. and Holmes, R.T. (1987b) Ecology of brown and striated thornbills in forests of south-eastern New South Wales, with comments on forest management. *Emu* **87,** 1–13.

Smith, R.J. (2000) An investigation into the relationships between anthropogenic forest disturbance patterns, population viability and landscape indices. MSc thesis. Institute of Land and Food Resources, The University of Melbourne, Australia.

Strauss, S.Y. (2001) Benefits and risks of biotic exchange between *Eucalyptus* plantations and native Australian forests. *Austral Ecology* **26,** 447–457.

Wood, M.S., Stephens, N.C., Allison, B.K. and Howell, C.I. (2001) *Plantations of Australia — A Report from the National Plantation Inventory and the National Farm Forest Inventory.* National Forest Inventory, Bureau of Rural Sciences, Canberra.