



Biodiversity in Agriculture and Agroforestry

A Discussion Paper

**A report for the RIRDC/L&W Australia /FWPRDC
Joint Venture Agroforestry Program**

by Nick Paltridge

May 2002

RIRDC Publication 02/051

RIRDC Project No ANU-59A

© 2002 Rural Industries Research and Development Corporation.
All rights reserved.

ISBN 0 642 58450 8
ISSN 1440-6845

Biodiversity in Agriculture and Agroforestry
Publication no 02/051
Project no. ANU-59A

The views expressed and the conclusions reached in this publication are those of the author and not necessarily those of persons consulted. RIRDC shall not be responsible in any way whatsoever to any person who relies in whole or in part on the contents of this report.

This publication is copyright. However, RIRDC encourages wide dissemination of its research, providing the Corporation is clearly acknowledged. For any other enquiries concerning reproduction, contact the Publications Manager on phone 02 6272 3186.

Researcher Contact Details

Nick Paltridge

School of Resources, Environment and Society
Australian National University
Canberra 0200 Australia

Phone: 02 6125 2579
Fax: 02 6125 0746
Email: nick.paltridge@anu.edu.au

In submitting this report, the researcher has agreed to RIRDC publishing this material in its edited form.

RIRDC Contact Details

Rural Industries Research and Development Corporation
Level 1, AMA House
42 Macquarie Street
BARTON ACT 2600
PO Box 4776
KINGSTON ACT 2604

Phone: 02 6272 4539
Fax: 02 6272 5877
Email: rirdc@rirdc.gov.au
Website: <http://www.rirdc.gov.au>

Published in May 2002
Printed on environmentally friendly paper by Canprint

Foreword

In recent years, there has been growing interest in developing agricultural production systems that can be sustained over the longer term. Concurrently, there has been increasing emphasis on farm forestry plantations in Australia, driven by increasing demand for timber, and by environmental imperatives such as the need to better manage water resources and mitigate dryland salinity.

Against this background, the Joint Venture Agroforestry Program has funded a series of projects to investigate potential synergies between farm forestry and biodiversity conservation.

The purpose of this document is to investigate a number of questions relating to biodiversity in agriculture and farm forestry, as background to this broad initiative. The report is based on literature review, interviews and consultation with experts in both academic and commercial sectors. Given the broad subject matter, however, few answers are definitive, and the report is intended primarily as a starting point for further consideration.

RIRDC's involvement in this project and in the Joint Venture Agroforestry Program is part of the Corporation's Agroforestry and Farm Trees R&D Program, which aims to foster integration of sustainable and productive agroforestry within Australian farming systems.

Most of our agroforestry publications, part of our diverse range of over 800 research publications, are available for viewing, downloading or purchasing online through our website:

- download at www.rirdc.gov.au/reports/Index.htm
- purchase at www.rirdc.gov.au/eshop

Peter Core

Managing Director
Rural Industries Research and Development Corporation

Acknowledgements

The author gratefully acknowledges the Joint Venture Agroforestry Program for funding the project, and The School of Resources, Environment and Society at the Australian National University for providing the Visiting Fellowship that made the study possible.

The author is also indebted to the following people for their input during the preparation of the paper:

- Roslyn Prinsley (RIRDC)
- Sarah Bruce (RIRDC)
- Richard Hobbs (Murdoch University)
- David Lindenmayer (Australian National University)
- Peter Kanowski (Australian National University)
- John Field (Australian National University)
- Digby Race (Australian National University)
- Chris McElhinny (Australian National University)
- Peter Dean (Australian National University)
- Jacki Schirmer (Australian National University)
- Mick Tanton (Australian National University)
- David Salt (Australian National University)
- Philippa Rowland (Bureau of Rural Sciences)
- Jim Walcott (Bureau of Rural Sciences)
- Mellissa Wood (Bureau of Rural Sciences)
- Madeleine Baldwin (Bureau of Rural Sciences)
- Phil Pritchard (Bureau of Rural Sciences)
- Denise White (Environment Australia)
- Jeannette Heycox (Environment Australia)
- Jim Donaldson (Environment Australia)
- Lyndel Sutton (Environment Australia)
- Denis Saunders (CSIRO Sustainable Ecosystems)
- David Tongway (CSIRO Sustainable Ecosystems)
- Sue Briggs (CSIRO Sustainable Ecosystems)
- David Freudenberger (CSIRO Sustainable Ecosystems)
- Saul Cunningham (CSIRO Entomology)
- Rob Floyd (CSIRO Entomology)
- Tony Brown (CSIRO Plant Industry)
- Tony Pryor (CSIRO Plant Industry)
- John Passioura (CSIRO Plant Industry)
- John Kirkegaard (CSIRO Plant Industry)
- Mark Peoples (CSIRO Plant Industry)
- Judy West (CSIRO Centre for Plant Biodiversity Research)
- Andrew Young (CSIRO Centre for Plant Biodiversity Research)
- Jeremy Burdon (CSIRO Centre for Plant Biodiversity Research)
- Richard Jefferson (Centre for the Application of Molecular Biology in International Agriculture)
- Jeff Dean (Tasmanian Department of Primary Industries, Water and Environment)
- Rachel Eldridge (Desert Wildlife Services)
- Tony Beck (RG & D Beck & Son)

The report has benefited from comments received from Tony Brown, Andrew Young, Sarah Bruce and Peter Kanowski.

Contents

<i>Foreword</i>	iii
<i>Acknowledgements</i>	iv
<i>Contents</i>	v
<i>Executive Summary</i>	vi
1. Background to Discussion Paper	1
2. Defining Biodiversity	2
2.1 What is biodiversity?	2
2.2 Enacting biodiversity conservation	2
2.3 Biodiversity for the Joint Venture Agroforestry Program	2
3. Arguments for Biodiversity Conservation in Agricultural Landscapes	4
4. Biodiversity Targets in Agricultural Landscapes	6
4.1 Introduction	6
4.2 The ideal situation	6
4.3 Biodiversity for sustainable agricultural production	7
5. Overview of Farm Forestry	9
5.1 Introduction	9
5.2 The Australian plantation estate	9
5.3 Likely composition of future plantings	11
6. Planted Forests and Biodiversity	13
6.1 Introduction	13
6.2 Biodiversity benefits of different plantation types	13
6.3 Increasing biodiversity benefits across the continuum	14
7. Biodiversity Measurement in Tree Plantations	17
7.1 Why measure biodiversity?	17
7.2 What measures could be appropriate?	17
8. Conclusions	19
<i>References</i>	21

Executive Summary

This study investigates a number of questions relating to biodiversity in agriculture, as background to the Joint Venture Agroforestry Program's (JVAP's) broader initiative to look for synergies between farm forestry and biodiversity conservation. Research was conducted over a two month period, through literature search and review, and consultation with experts in academic and commercial sectors.

The paper first discusses the definition of biodiversity. Whilst biodiversity may be readily defined in classical terms, the translation of the word into something meaningful at a practical level is more difficult. It is concluded here that scientists working in the biodiversity field need to be more specific about their objectives, the values they associate with biodiversity, and what they mean by biodiversity in a particular context.

The paper then discusses arguments that relate to biodiversity conservation in agriculture. Whilst there are overwhelmingly powerful cultural, aesthetic and ethical arguments for the conservation of biodiversity, these are not directly relevant to agricultural production. Similarly, arguments relating to the unexploited commercial potential of biodiversity are of little current or likely relevance, in the foreseeable future, to mainstream agriculture in Australia. The most convincing arguments, then, relate to ecosystem function. There is no questioning the fundamental role biodiversity has had in shaping and maintaining the landscape in which we practice agriculture. What remains an open question, however, is the level of biodiversity required to maintain agricultural landscapes in a condition 'fit for the purpose' of agricultural production.

The development of biodiversity targets in the Australian landscape will be crucial to future efforts in nature conservation and sustainable agricultural production, and is of interest to the JVAP. Ideally, sufficient native vegetation and habitat would be restored in the landscape to satisfy all our cultural, aesthetic and ethical aspirations, conserve the commercial potential of biodiversity and restore ecosystem health. It is concluded here that this is unlikely to occur without significant social and economic change. A more realistic approach in the short term will be the development of agricultural systems that incorporate sufficient biodiversity to restore essential ecosystem services without unacceptable impacts on profitability.

To gain some insight into the possible biodiversity benefits of farm forestry, the composition of current and future farm forests is examined. Tree plantations are considered to exist in a continuum, ranging from those planted primarily for commercial return, with little management flexibility, to those planted primarily for land protection, with considerable management flexibility. Whilst a large proportion of current plantings are single species plantings of *Eucalyptus globulus*, *Eucalyptus nitens* and *Pinus* species, with only moderate biodiversity benefit, future plantings for land protection value or non-timber products may offer new opportunities for biodiversity conservation.

Approaches to explore for the enhancement of biodiversity in plantations include changing plantation composition, refining spatial arrangements, and general consideration of the needs of native biota in silvicultural management. The potential gains which may be made vary considerably across the plantation continuum. In some cases, the most important contribution will be the provision of ecosystem services, in particular, restoration of the hydrological balance; in others, substantial biodiversity benefits are likely.

In the interests of promoting biodiversity conservation in general, it will be important for the JVAP to provide clear-cut examples where native biota has proven beneficial to both agricultural and forest production. However, it will be equally important for the JVAP to acknowledge that in many cases the conservation of native biota is primarily a cultural, ethical and aesthetic ideal.

Finally, the paper discusses the need for some form of biodiversity measurement. In the generally simplified environment of a farm forest, relatively simple, taxon-based indicators are likely to be appropriate. The most appropriate indicators will probably vary between sites, however, and depend on subjective rather than objective assessment of what is important.

1. Background to Discussion Paper

This report describes the findings of a two month project funded by the Joint Venture Agroforestry Program (JVAP), with the support of The School of Resources, Environment and Society at the Australian National University, to investigate a number of questions relating to biodiversity in agriculture.

In recent decades, Australian communities have asked questions about how land, vegetation and water resources are managed. One issue the community has focussed on is the future of Australia's biological diversity. In recent years, this has been reflected in growing interest in ensuring production systems are consistent with principles of ecologically sustainable development (Dames and Moore 1999).

Concurrently, there has been increasing emphasis on farm forestry plantations, with an Australian Ministerial Council proposing that the rate of farm forestry plantation be trebled to 80, 000 ha per annum by 2020 (Plantations 2020 Vision Implementation Committee 1997). Due to controls on the clearing of native vegetation, these plantations are likely to be, of necessity, on cleared agricultural land. In addition, increasing emphasis on water resource management and the control of dryland salinity is likely to lead to further tree planting activity, this time with a more environmental focus.

Against this background, the JVAP has funded a series of projects to investigate the potential synergies between expansion in the farm forestry sector and the conservation of Australia's biodiversity. The purpose of this document is to provide background information relevant to this broad initiative.

Specific subjects addressed are as follows:

- Definitions of biodiversity
- Arguments for biodiversity conservation in agricultural landscapes
- Biodiversity targets in agricultural landscapes
- Overview of farm forestry
- Planted forests and biodiversity
- Biodiversity measurement in tree plantations

The information presented was sourced from both the referenced literature, and from interviews with a variety of agricultural scientists, biodiversity researchers and ecologists (see Acknowledgements). Given the time constraint, however, and the broad subject matter, the paper does not represent a comprehensive review of each subject area, and is intended primarily as a starting point for further discussion.

2. Defining Biodiversity

2.1 What is biodiversity?

Biodiversity is a much used and often abused term to cover a component of the environment that is difficult to quantify in terms of economic or social benefit (Vercoe 2001). In classical terms, it is defined as the full variety of life on earth – the different plants, animals and microorganisms, the genes they contain and the ecosystems of which they form part. It is not static, but constantly changing; it is increased by genetic change and evolutionary processes and reduced by processes such as habitat degradation, population decline and extinction (ERIN 1996).

The word biodiversity is, however, often used in different ways, with different people placing different levels of emphasis on genetic- species- and ecosystem-level diversity. In conservation circles, there is distinct bias towards species diversity at the expense of the biodiversity responsible for essential ecosystem services such as hydrological or nutrient cycling. In an attempt to ensure that the ecosystem services provided by biodiversity are not forgotten, some recent definitions emphasise that the interactions between biodiversity and the environment are not merely a consequence of biodiversity, but are components of biodiversity itself (*e.g.*, James and Saunders, 2001).

In its broadest sense, the loss of biodiversity is widely recognised as Australia's most important environmental problem, with species extinctions, the disappearance or decline of whole ecological communities and the degradation of our natural resource base the most obvious symptoms (State of the Environment Advisory Council 1996). In response to this, there is increasing recognition of the importance of biodiversity conservation in the Australian community.

2.2 Enacting biodiversity conservation

The challenge, then, is to translate this concept of biodiversity conservation into something meaningful at a practical level. With biodiversity defined as everything alive, and all processes involving living things, it is often difficult to know what actions are appropriate for its conservation – especially in agricultural landscapes, where primary production is not only an objective, but a demand of wider society. What is biodiversity in a particular landscape?

On a similar theme, Walcott *et al.* (2001) wrote that there is a tendency to promote biodiversity as something that is inherently desirable without describing, among other things, what is meant by the word in a particular context. This situation needs to change before biodiversity can be effectively managed in agricultural systems.

2.3 Biodiversity for the Joint Venture Agroforestry Program

In the context of the JVAP's current efforts to maximise the benefits of farm trees to native biota, it is worth considering how native biota should be defined for the purposes of the Program. Figure 1 illustrates the different components covered by the term biodiversity, at least as defined by Saunders (2000), and the subset of total biodiversity covered by the term native biota.

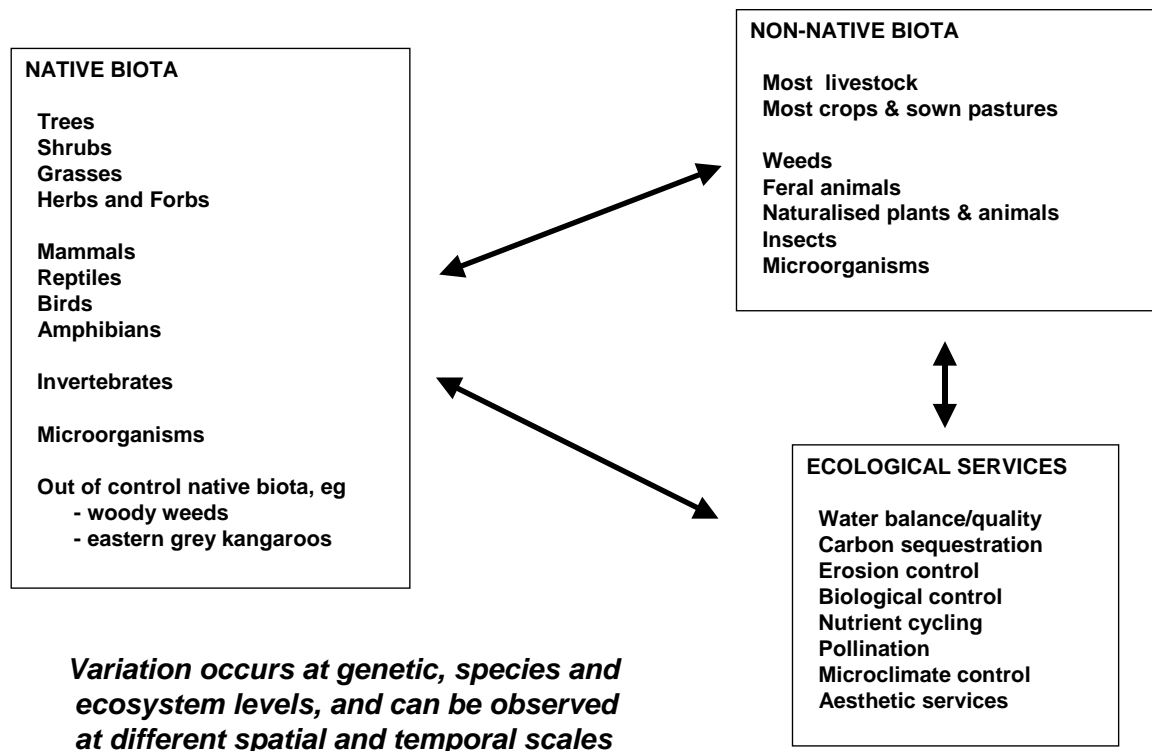


Figure 1. Components of biodiversity. Arrows are an acknowledgment that many components interact.

Several questions remain contentious, and will need to be considered by the JVAP. Firstly, where should emphasis lie - on genetic variety within species, or species diversity, or ecosystem diversity? Are some components of native biota of more value than others? Is an Australian native plant or animal still ‘native biota’ outside its original (pre-1750) range? How do we rank native versus non-native biota? The conservation of native biota can only be achieved if certain ecosystem processes and functions are maintained. Should the contribution farm forestry makes to these processes be considered?

3. Arguments for Biodiversity Conservation in Agricultural Landscapes

Early endeavours to preserve biodiversity were essentially driven by moral, ethical and altruistic motives, and were opposed by developers on economic and commercial grounds. To counter this, the actual and potential economic value of biodiversity began to be emphasised. This led to the development of three main arguments for the conservation of biodiversity (Lefroy 1992).

Firstly, cultural, ethical and aesthetic arguments emphasise that the natural variety of the living world is essential for the emotional, spiritual and intellectual development of the human species (Lefroy 1992). No generation has the right to appropriate the earth's resources solely for their own benefit. This is an important element of the desire many farmers have to leave their land 'in better condition than when they started managing it' (Saunders 2000). Whilst few would refute these arguments, they are not directly relevant to agricultural production, other than to say that in enriching the lives of rural communities, biodiversity contributes to overall community health and therefore production.

Secondly, it is argued that there is a need to maintain genetic- and species-level diversity so that potentially valuable genes and species are not lost to future generations. In the agricultural context, there is no doubt that genetic material of commercial value remains undiscovered, and that as yet unexploited plant and animal species may be important for the development of sustainable farming systems in future. The weakness of the argument, however, is that it only embraces those genes and species with direct commercial potential (Lefroy 1992), and it is hard to see its force in relation to the protection of remnant natural vegetation in agricultural areas in Australia (Passioura 1999).

Thirdly, there are arguments that relate to ecosystem functioning. There is no question that some level of biodiversity has always been fundamental to human existence, providing, over the millennia, healthy, functioning ecosystems – ecosystems that maintain the air we breath, regulate the climate, produce fresh water, form soils, cycle nutrients and dispose of wastes (Saunders 2000). Different components of biodiversity are also responsible for pollinating flowering plants, and for general 'ecosystem resilience'; *i.e.*, the ability to 'bounce back' in some form or other after a disturbance (Lefroy 1992). The loss of biodiversity, then, threatens these essential ecosystem processes, with global climate change, declining water quality, dryland salinity and eroded soils the most obvious symptoms.

Passioura (1999) identified five specific features of natural ecosystems that contribute to landscape and ecosystem stability:

- i) persistent ground cover and minimal disturbance of the soil, minimising erosion
- ii) presence of deep-rooted perennials, enabling the capture of water that has escaped the roots of annual plants during periods in which rainfall exceeds evaporation
- iii) recognition of the mosaic nature of land, so that patches of land are treated according to their particular properties, not according to cadastral boundaries
- iv) seasonal release of nutrients, that match the nutritional demands of plants, ensuring that the leaching of nutrients is minimised

- v) sufficient biodiversity for nutrient turnover, biological control of pests and diseases, and reduction of risk from extremes of the weather.

The over-riding relevance of biodiversity to agriculture, then, is that these five features can only be maintained when a certain level of biodiversity is present in the landscape. Without these features, ecosystems and agro-ecosystems can degrade to the point where they are unsuitable for productive agriculture.

4. Biodiversity Targets in Agricultural Landscapes

4.1 Introduction

In principle, the complex issue of how much biodiversity we should aim to include in our agricultural landscapes can be considered at two levels:

- i) how much biodiversity is required to satisfy our cultural, ethical and aesthetic ambitions for the landscape, and our desire to preserve the economic potential of diverse life forms; and
- ii) how much biodiversity is required to maintain our landscapes in a state fit for continuing agricultural production

The level of emphasis assigned these two questions is likely to differ between people with a production rather than conservation focus. At least over the short to medium term, the answers to these two questions are likely to be different.

4.2 The ideal situation

Ideally, it would be possible to ensure that sufficient native vegetation and habitat is maintained or restored in the landscape to conserve all the current genetic- or species-level variation, enrich our lives culturally and aesthetically, and maintain or restore ecosystem function.

According to James and Saunders (2001), a possible target which could satisfy this goal would be to set aside 30% of the landscape for biodiversity conservation – either through the preservation of native vegetation, or revegetation. This would be the minimum required to ensure no further species loss, and that a moderate level of ecosystem service is retained or restored.

An example of a sustainable landscape design is described by James and Saunders (2001) as one which might contain: 30% of the area permanently covered in native vegetation; 20% covered in deep-rooted trees primarily planted for water-table control and farm forestry income; 30% intensively used for annual crops; and 20% less intensively used for mixed grazing and cropping. According to these authors, however, the correct balance between the different types of land use will be different for different subcatchments. We do not really know what are the most appropriate percentages to achieve ground water control, ecosystem integrity, biodiversity maintenance and healthy, sustainable life-styles (James and Saunders 2001).

How likely is it, then, that landscape designs such as the above will be adopted? In the current social and economic context, it may be unlikely. Most people like to live in cities, and city dwellers exert strong pressure for cheap food. The pressure to produce cheap food is likely to remain immense (Passioura 1999). In this environment, farm designs such as the above may not be economically viable, with farmers forced to pursue short term productivity at the expense of long term sustainability.

That said, the social and political climate is changing. Firstly, there is an extensive legal and policy framework for the protection of biodiversity in Australia (for summary, see Dames and Moore 1999), which means that few landscapes are likely to be cleared to less than 30% native vegetation in future.

In addition, there is increasing recognition of the importance of biodiversity in agricultural landscapes, leading to initiatives such as: The National Objectives and Targets for Biodiversity Conservation 2001 – 2005 (Environment Australia 2001); The Framework for the Development of Terrestrial Biodiversity Targets in the Murray-Darling Basin (James and Saunders 2001); and the Development of National Outcomes and Matters for Targets for Biodiversity Conservation (a current initiative of Environment Australia). Of these, only James and Saunders (2001) nominate any specific targets which could be adopted – all discuss or provide frameworks for target setting – but all stress the importance of revegetation for both environmental and commercial benefits. Initiatives such as these are likely to lead to social and political pressures that encourage the adoption of more sustainable landscape designs.

One stand-out initiative, the so called ‘Bush Tender’ trial, is currently being implemented in Victoria by Victoria’s Department of Natural Resources and Environment (NRE; www.nre.vic.gov.au). In this initiative, landholders establish their own price for the management services they are prepared to offer to improve their native vegetation, and bid to NRE for the right to be paid for those services. Successful landholders receive periodic payments under a three year management agreement. The establishment of conservation as a service the community is prepared to pay for would greatly enhance the prospects for biodiversity conservation on farms.

Another factor likely to favour designs such as that proposed above is the trend towards forestry, with plantations proposed to treble over the next 20 years in response to shortfalls in overall timber production (Plantations 2020 Vision Implementation Committee 1997).

4.3 Biodiversity for sustainable agricultural production

In situations where it is not possible to set aside significant areas of the farming landscape for native vegetation, an alternative approach is to put less emphasis on conservation and more on ensuring land is ‘fit for the purpose’ of agricultural production. In Section 3, it was established that there were five main features of natural ecosystems which relate to biodiversity and could be beneficially applied in agriculture: namely; minimal erosion of soil; balanced hydrology; recognition of the mosaic nature of land; seasonal release of nutrients; and sufficient biodiversity for nutrient turnover, biological control and reduction of risk from extremes of weather (Passioura 1999). In production-oriented circles, primary consideration is given to designing agricultural landscapes and systems that incorporate as many of these features as possible, without unacceptable impacts on productivity (see Main 1999; Passioura 1999).

For some features, this is already practically possible. For example, persistent ground cover may be achieved simply by retaining stubble, and the hydrological balance may be restored by incorporating farm forests or deep-rooted perennials such as lucerne into farming systems. The role of vegetation in fixing atmospheric carbon can be reproduced by plantation forestry; and precision farming holds much promise in ensuring land is treated according to its particular properties, rather than ‘to the fence line’ (Passioura 1999). However, these gains are being made by changes in cultural method, or by slight increases in the diversity of crops grown, rather than by an increase in biodiversity to levels approximating those of natural

ecosystems. Little emphasis is placed on the re-introduction of diverse native vegetation into highly cleared landscapes.

The matching of nutrient release with the demands of crop plants and the restoration of a nutrient cycle would seem irreconcilable with production agriculture, with its seasonal demand for nutrients and emphasis on harvest and export. However, the incorporation of a range of crops in an agricultural system, in particular, legumes, provides one case where some progress towards a nutrient cycle has been made by increasing biodiversity.

The issue of how much biodiversity is required to prevent weed invasion and provide reasonable control of pests and diseases has been discussed (*e.g.*, Main 1999), but draws no definitive conclusion. Certainly, there are cases where beneficial, crop-associated biodiversity has been spectacularly successful in managing harmful biodiversity in agricultural systems (*e.g.*, for the classical biological control of mealy bug in cassava in sub-Saharan Africa; LaSalle 1999). However, the general perception that diverse agroecosystems are less susceptible to pest outbreaks and crop losses is not well supported in the literature (for review, see Wood and Lenne 1999), and a great deal more research is needed to optimise agrobiodiversity for productive agriculture (Lenne and Wood 1999). Main (1999) concludes that intervention by the farmer may always be necessary to control pests and diseases in most cultivated crops.

5. Overview of Farm Forestry

5.1 Introduction

Before considering the possible ways of increasing the benefits of farm forestry to biodiversity conservation, as is an objective of the JVAP, it is important to consider what is meant by the term ‘farm forestry’. This will help clarify what conservation benefits may be realistically attained, and what the most effective approach to its measurement could be.

The present project is part of the JVAP’s broader initiative to explore the extent to which projected expansion in the farm plantation area could bring conservation benefits to biodiversity conservation (see Background). Against this background, it is clear that the focus of the present work should be on trees planted into cleared agricultural land. To gain some insight into the likely composition and distribution of future plantings, it is worth discussing the composition and distribution of current Australian plantations, along with newly developing industries that may contribute to future plantings.

5.2 The Australian plantation estate

The Bureau of Rural Sciences National Forest Inventory (NFI) program was established in 1998, and included a sub-program on the farm forest resource (National Farm Forest Inventory; NFFI), in coordination with the National Plantation Inventory (NPI), to assess the total plantation estate.

For the purposes of the analysis, plantations considered to be ‘farm forests’, and therefore covered by the NFFI, were those plantations ‘owned outright by individuals with a total plantation estate less than 1, 000 ha’. The NPI covered the remainder of plantations, specifically, plantations owned or part-owned by off-farm investors, or plantations of over 1, 000 ha. Figure 2 illustrates the different components of plantation forestry (referred to as a ‘continuum’) which were recognised by the NFI, displayed over a range of scales with a range of expected outcomes. The results of the NFI were delivered in the Plantations of Australia 2001 report (Wood *et al.* 2001), and were also summarised by Stephens *et al.* (2001) of the NFI.

The small grower estate

The NFFI identified 67, 000 ha of small grower plantations, representing 5% of Australia’s plantation resource of 1.5 million ha (see Figure 3).

Hardwood species make up the bulk of small grower plantations, with 33, 500 ha (50%) planted to single species stands, and 8, 200 ha (12%) to mixed species hardwood. *E. globulus* (blue gum; 13, 100 ha) and *E. nitens* (shining gum; 9, 300 ha) make up the bulk of single species plantations. These same two species are also represented among mixed species plantations, along with *E. camaldulensis*, *E. cladocalyx*, *E. saligna*, *Corymbia maculata* and the oil mallee. It is worth noting that *E. globulus* and *E. nitens* are grown almost exclusively for pulpwood, and that *E. globulus*, endemic to Tasmania, tends to dominate hardwood plantations in mainland Australia, whilst *E. nitens*, endemic to Victoria, dominates plantings in Tasmania.

Softwood plantations are dominated by *Pinus radiata*, except in Queensland, where other *Pinus* species predominate.

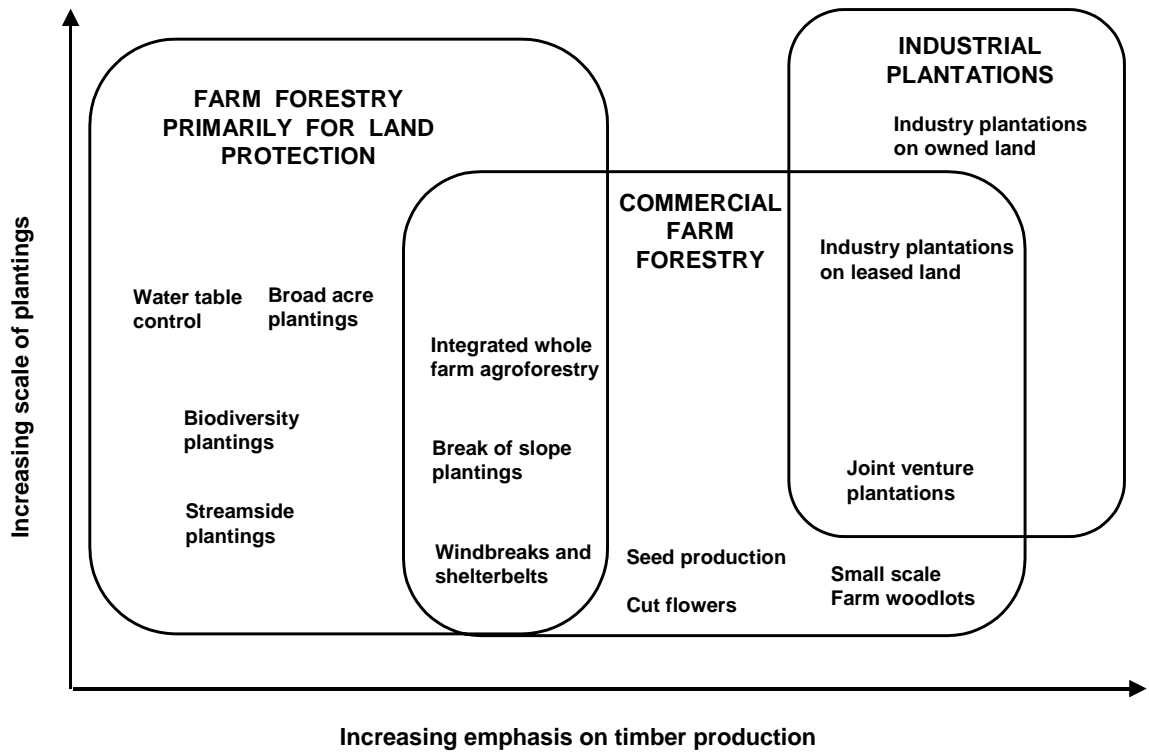


Figure 2 The plantation continuum (modified from Stephens et al. 2001)

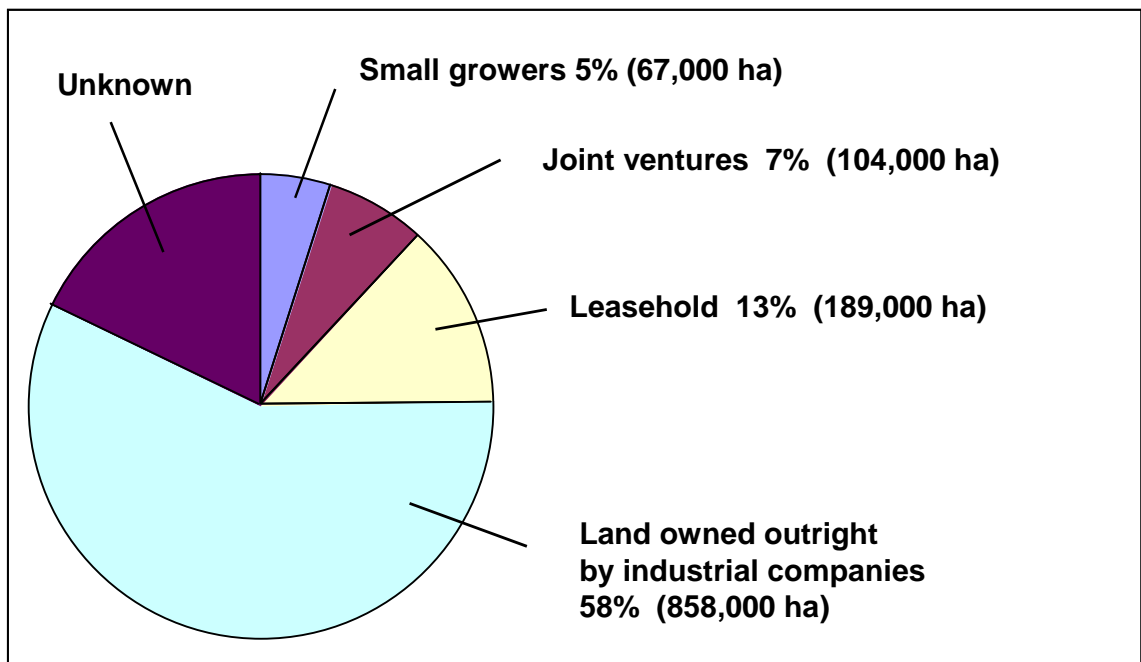


Figure 3 Percent areas of identified sectors in the Australian plantation estate (Wood et al. 2001)

The small grown area of different plantation types is shown in Table 1.

State	Hardwood	Softwood	Mixed plantings	Unknown	Total
VIC	7584	11467	2002	33	21086
TAS	11700	4400	0	0	16100
WA	11542	850	104	0	12,496
NSW	388	3881	2698	915	7862
SA	2021	3367	718	0	6106
QLD	253	378	2660	0	3292
NT	15	0	29	0	44
Total	33504	24343	8190	948	66983

Table 1. Area of small grower plantations (ha) (Stephens *et al.* 2001)

There are marked differences in plantation types between states, with hardwood plantations tending to dominate softwood plantations in Tasmania and Western Australia, softwood plantations dominating hardwood plantations in New South Wales, and mixed plantings dominating single species plantings in Queensland.

More than a third of the current total small grower resource has been planted since 1995, the large majority of which is hardwood. Using data from the Gippsland and Green Triangle regions of Victoria and South Australia, Stephens *et al.* (2001) estimated an average small grower plantation size of approximately 5 ha. Extrapolated across the nation, this suggested approximately 13, 000 landholders contributed to the NFFI.

Joint ventures and leasehold

Thirteen percent (189, 000 ha) of Australia's plantation resource was found to have been established on leased land, where the forest grower (as opposed to the land-owner) has sole primary production and access rights to the trees. A further 7% (104, 000 ha) was found to have been established through joint ventures, where both parties have equity in the product (Figure 3).

A significant proportion of the joint venture and leasehold plantation (approximately 125, 000 ha) has been developed by industrial and/or government parties and does not involve individual farmers. This leaves approximately 170, 000 ha as partnerships involving farmers. Available information suggests that this area is distributed amongst approximately 4, 200 landholders in holdings of 40 ha average size.

Wood *et al.* (2001) do not specify which trees make up the joint venture and leasehold plantations, but it would seem probable that the sector is dominated by single species plantings of *E. globulus* or *E. nitens*. The drive to establish eucalypt plantations in northern New South Wales and Queensland is also likely to mean that a range of sub-tropical eucalypt species will be established in the joint venture and leasehold sector in these states.

5.3 Likely composition of future plantings

Monocultures do represent an efficient and highly productive method of timber production. Obvious advantages include uniformity of product, effective yield, and the fact that major operations such as planting and harvesting need only be conducted once per rotation. The

only disadvantage of the approach is that trees in single species plantations are more susceptible to attack by pests and pathogens than those in more diverse settings. However, the major pest species of practical significance thus far, leaf-eating insects, are able to be practically controlled with insecticidal sprays. Though this is contentious in some areas, the approach is currently commercially effective.

Given the rotation length of decades rather than years, foresters are understandably conservative when it comes to changing their production system, at least in the timber production sector. This, combined with the net advantage of growing in monoculture, means that the timber-oriented plantations of the future are unlikely to vary significantly from those that have been successful in the past; *i.e.*, at least in the short to medium term, they are likely to be dominated by monocultures of *E. globulus* and *E. nitens*, and, to a lesser extent, some *Pinus* species.

In addition to these well-established, timber-oriented industries, however, it is likely that there will be significant expansion in tree plantings for non-timber products in the coming decades. These emerging industries are currently a focus of research in the JVAP and include trees for carbon sequestration, and for products such as wattle seed, charcoal, activated carbon, biofuel and eucalyptus oil (see www.rirdc.gov.au). Such tree crops will probably lead to an expansion of farm forestry into the lower rainfall areas, and generally enhance the diversity of tree crops grown.

Moreover, it is probable that there will be significant expansion in plantings with an environmental focus in future. This will be driven primarily by increasing recognition of the need to restore hydrological balance to the landscape, and by initiatives such as those referred to in Section 4.2. There is likely to be significant flexibility in the way these plantations are designed and managed, and significant potential to design and manage for biodiversity benefit.

6. Planted Forests and Biodiversity

6.1 Introduction

One of the JVAP's stated objectives is to investigate potential synergies between expansion in the farm forestry sector and biodiversity conservation. It is worth considering what those synergies might be, as a starting point for further discussion.

The types of farm forests that offer the most benefits to native biota are probably those that most closely resemble a native forest, offering:

- *In situ/circa situ* conservation of local plant species and genetic material (see Kanowski *et al.* 1997)
- Conservation of animals (mammals, birds, reptiles, amphibians, invertebrates)
- Conservation of microorganisms (above ground/in soil)
- Benefits arising through provision of ecosystem services (water balance/quality, carbon sequestration, erosion control, biological control, nutrient cycling, pollination)

What follows is consideration of the possible contributions different plantation types offer native biota, followed by consideration of ways these might be enhanced.

6.2 Biodiversity benefits of different plantation types

Though forest plantations are said to exist in a continuum, it is probably useful to divide the continuum up into a number of different subsets before looking at possible benefits to native biota. Useful categories could be: i) commercially oriented single species plantings (predominantly *E. globulus*, *E. nitens*, oil mallee or *Pinus* species); ii) commercially oriented mixed species eucalypt plantations; and iii) mixed species plantations established primarily for land protection or conservation value.

Single species plantations

These plantation types dominate small grower plantations established over the past decade. There is little information published on the value of plantation trees for native biota conservation, though this may be a consequence of the fact they are perceived to have little value.

Possible value to native biota is as follows:

- No value in *circa-situ* conservation of plant species
- Limited value as habitat
 - lack of diversity in food and shelter, meaning that only a very limited subset of animals sustained, with greater seasonality in food supply
 - may provide overflow or temporary habitat for animals with core habitat elsewhere (Lindenmayer *et al.* 1999)
 - may connect separate patches of more valuable habitat
 - *Pinus* species likely to be of less value for native biota than eucalypts

- No advantages over other land uses in conservation of soil biota
- Can restore many ecosystem services (*e.g.*, water balance/quality, carbon sequestration, erosion control, nutrient cycling) though not that relate to pollination or biological control, since the lack of habitat diversity brings concomitant decrease in faunal diversity

Mixed eucalypt plantations

- Some potential for *circa-situ* conservation of plant species if locally-derived or rare trees are grown
- Better value as habitat
 - some diversity in structure sustains greater range of animals, with flowering occurring over greater proportion of the year
 - may provide overflow or temporary habitat for animals with core habitat elsewhere
 - may have some value in connecting separate patches of more valuable habitat
- No real advantages over other land uses in conservation of soil biota
- Can restore many ecosystem services (*e.g.*, water balance/quality, carbon sequestration, erosion control, nutrient cycling) and diversity in plantation may help with pollination and biological control as well

Mixed species plantations, primarily for land protection and conservation

Plantations of this type have many of the characteristics of native forests, and thus have potential to offer many of the biodiversity benefits of native forests (as may be the object). *Circa-situ* conservation will be possible if local species and understorey are included, excellent habitat may be provided for local animals and plants (provided the patch is above a certain threshold size), and the patch can have value in connecting remnant vegetation and expanding its effective size. Some soil biota may recover to approximate the soil biota pre-clearing, and many ecosystem services will be restored.

6.3 Increasing biodiversity benefits across the continuum

Changing plantation composition

Given the strong commercial focus of single species plantings, plantation composition is unlikely to be altered unless impacts on production are only marginally negative or net positive. However, in mixed species and land protection plantings, there may be more flexibility.

Possibilities to explore:

- inclusion of understorey species
 - understorey will compete for nutrients and light but bring some production benefits
 - potential to include symbiotants (*e.g.*, acacias for nitrogen fixation; Bauhus *et al.* 2000)
 - enhanced faunal biodiversity
 - *circa-situ* conservation

- resilience
- introduce age structure
 - complicates management
 - better habitat; enhanced faunal diversity
- plant diverse tree species
 - are *E. globulus* and *E. nitens* really so much better?
 - substitute native species for exotics, local for introduced
 - compromises management and production
 - greater resilience
 - enhanced faunal diversity
 - *circa-situ* conservation

Increasing biodiversity benefits by changing spatial arrangements

Across the plantation continuum, there will be many instances where there is little choice in where farm trees can be planted – economic considerations often dictate that trees must be planted on areas of the farm that are difficult to manage or unsuitable for other purposes. However, there will be cases where different designs are possible which are of different value to native biota.

Possibilities to explore:

- size and shape of plantation
 - reduce edge effects
- position in landscape
 - plant near existing remnants
 - connect remnants
 - buffering edge effects in remnant, expanding effective size of remnant, and providing ‘overflow’ habitat for animals

Other general principles

Silvicultural practices will impact significantly on the value of plantations as habitat for animals and microorganisms. Dames and Moore (1999) identified the following additional principles for maximising biodiversity outcomes:

- minimise disturbance through traffic, grazing and fire
- stagger planting and harvest in plantation
- leave prunings, thinnings or trash on the ground where possible (though this does create a fire-hazard)
- avoid excessive use of insecticidal sprays
 - devastating to invertebrates and dependent fauna

One other area to consider might be to introduce or re-introduce the native rhizobia and mycorrhizal fungi that live in association with vegetation in the plantation, both for *circa-situ* conservation and for their value to symbiotic hosts.

Harm minimisation

The potential of tree plantations to adversely affect native biota should not be forgotten, and minimising possible negative impacts could be an important way of maximising net benefits. The following threats need to be considered:

- 'weedy' trees
- habitat for pest and feral animals
- genetic pollution (Potts *et al.* 2001)
 - hybridisation between species
 - introduction of non-endemic races

7. Biodiversity Measurement in Tree Plantations

7.1 Why measure biodiversity?

Some method of assessing biodiversity is essential if approaches are to be developed for its enhancement on farms. It is envisaged that specific objectives may be threefold.

i) Finding out what diversity is supported in a particular landscape or plantation

Since biodiversity varies at genetic-, species- and landscape- levels, across different spatial and temporal scales, it has no absolute measure – what constitutes ‘high’ diversity in one environment may be considered ‘low’ in another – and measurements of biodiversity must normally be made in a comparative sense. However, during plantation design and management, those seeking to maximise biodiversity will still want to know what different life forms are present so that strategies can be developed for biodiversity enhancement.

ii) Following biodiversity in a given plantation over time

Researchers and plantation managers may wish to compare biodiversity levels in a given plantation after different management treatments, to gain insight into the effect of different treatments on biodiversity.

iii) Comparing biodiversity in different plantations

Provided landscape context (*e.g.*, proximity to native vegetation) and patch size are consistent between plantations, informative comparisons may be made of the value of different plantation types or management regimes to native biota. However, comparisons of biodiversity between different plantations will be of limited use where patch size and/or landscape context vary, since these variables will be major determinants of the native biota present.

Whenever the relative value of different patches and plantation designs is under consideration, it must be remembered that biodiversity can be considered over a range of scales, and that a patch of low diversity may represent an important component of diversity at a larger scale.

7.2 What measures could be appropriate?

The different approaches used for the measurement of biodiversity in forest ecosystems have recently been reviewed (Lindenmayer *et al.* 2000). The impracticality of measuring all the different species in a forest is highlighted, and the different indicators that can be used as surrogates for total biodiversity are discussed. These include taxon-based indicators, such as indicator species or species lists, and structure-based indicators such as stand structural complexity and species composition, connectivity and heterogeneity.

For the purposes outlined above, and in the generally simplified environment of a plantation forest, only a subset of these measures are likely to be required.

Since the major benefits offered by plantations to native biota are likely to be improved habitat for birds, mammals, insects and reptiles (see Section 6), it would seem appropriate to target these taxa for measurement. Though it is not easily practicable to conduct complete faunal surveys in native forests, it may well be so in the more simplified environment of a plantation forest. Alternatively, faunal indicator species may be used.

Given the stated objective of the JVAP's current research to enhance the value of plantations to native biota, it is anticipated that only native biota endemic to the area would be valued as components of faunal diversity. The complex question of whether threatened species are given higher 'weighting' during biodiversity measurement than, for example, 'weedy' natives, remains unresolved.

The use of vegetation-based indicators (either taxon-based or of stand structural complexity) is unlikely to be necessary within plantations, where vegetation is both simplified and highly managed.

At scales greater than that of an individual plantation, measurement of connectivity and landscape heterogeneity do begin to be relevant – and contributions plantations make at the landscape level, connecting or buffering remnant vegetation, adding to landscape diversity and contributing ecosystem services are likely to be highly significant. However, these contributions are also likely to be highly site-specific. There is no imminent prospect of methods being developed for their measurement in plantation forestry.

8. Conclusions

Definition of biodiversity

The development of a practical definition of biodiversity that can be applied in more than one context and satisfies a range of people will always be difficult, if not impossible. This is because: a) biodiversity varies enormously across the landscape and can be considered at a number of different scales; and b) because different people tend to use the word biodiversity in different ways, depending on their objectives and the relative value they assign to its different genes, life forms and processes. This has led to a degree of confusion in the agricultural sector as to what it is that constitutes biodiversity.

Whilst these problems relating to definition will not be easily solved, there would seem to be a need for those working in the biodiversity field to be more specific about their objectives, the values they associate with biodiversity, and what they mean by biodiversity in a particular context.

Arguments for biodiversity in agriculture

Though there are overwhelmingly powerful cultural, aesthetic and ethical arguments for the conservation of biodiversity, these are only relevant to agriculture in that much of it exists on agricultural land. Similarly, arguments relating to the unexploited commercial potential of biodiversity have little direct relevance to agriculture, since few if any of the genes and species at risk of disappearance from the Australian landscape are likely to be of practical significance to agriculture.

The most convincing arguments, then, relate to ecosystem function – and the dysfunction that results when biodiversity is removed from the landscape. There is no questioning the fundamental role that biodiversity has had in shaping and maintaining the landscapes in which we practice agriculture. What remains an open question, however, is the level of biodiversity that is required to maintain agricultural landscapes in a condition ‘fit for the purpose’ of agricultural production over the longer term.

Biodiversity targets in agricultural landscapes

Ideally, it would be possible to ensure that sufficient native vegetation and habitat is maintained or restored in the landscape to satisfy all our cultural, aesthetic and ethical aspirations that relate to biodiversity, conserve the commercial potential of biodiversity and restore ecosystem health. It is argued here that this is unlikely to occur without significant social and economic change.

A more realistic approach, and one already being taken in commercially-oriented research quarters, is the development of agricultural systems which incorporate sufficient biodiversity to restore essential ecosystem services without unacceptable impacts on profitability. It is probable that many of the services we associate with sustainable agriculture could be provided by relatively slight increases in biodiversity. Many of the projects currently being developed by the JVAP are consistent with this approach.

Overview of farm forestry

Tree plantations exist in a continuum, ranging from those planted primarily for commercial return, with little management flexibility, to those planted primarily for land protection, with considerable management flexibility.

A large proportion of current farm forestry plantings comprise single species plantings of *E. globulus* and *E. nitens* and, to a lesser extent, *Pinus* species. However, a range of new tree-based industries may lead to changes in the composition and distribution of the Australian plantation estate. In addition, increasing recognition of the importance of trees for their contribution to the hydrological balance, erosion control and conservation is likely to lead to a marked increase in environmental plantings.

Increasing the biodiversity benefits of farm trees

Approaches to explore for the enhancement of biodiversity in plantations include changing plantation composition, refining spatial arrangements, and general consideration of the needs of native biota in silvicultural management.

The potential gains to be made vary considerably across the plantation continuum. In some cases, the most important contribution will be the provision of ecosystem services, in particular, restoration of the hydrological balance; in others, substantial biodiversity benefits are likely.

In the interests of promoting biodiversity conservation in general, it will be important for the JVAP to provide clear-cut examples where native biota has proven beneficial to both agricultural and forest production. However, it will be equally important for the JVAP to acknowledge that in many cases the conservation of native biota is primarily a cultural, ethical and aesthetic ideal, at least in the short to medium term.

Measuring biodiversity

The need for some form of measure of biodiversity is greatest in the research sector, as researchers seek to maximise the benefits of farm trees to native biota. In the generally simplified environment of a farm forest, relatively simple, taxon-based indicators are likely to be appropriate. The most appropriate indicators will probably vary among sites, however, and depend on subjective rather than objective assessment of what is important.

References

- Bauhus, J., Khanna, P.K. and Menden, N. (2000). Aboveground and belowground interactions in mixed plantations of *Eucalyptus globulus* and *Acacia mearnsii*. *Can. J. For. Res.* **30** pp 1886-1894.
- 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 Research and Development Program, Environment Australia, Canberra.
- ERIN (1996). The National Strategy for the Conservation of Australia's Biological Diversity. Environmental Resources Information Network, Commonwealth of Australia, Canberra.
- Environment Australia (2001) The National Objectives and Targets for Biodiversity Conservation 2001 – 2005, Environment Australia, Canberra.
- Dames and Moore NRM and FORTECH (1999). Integrating farm forestry and biodiversity – a discussion paper. RIRDC, Canberra.
- James, C. and Saunders, D. (2001). A framework for terrestrial biodiversity targets in the Murray-Darling Basin – A report for the Murray-Darling Basin Commission. Murray-Darling Basin Commission, Canberra
- Kanowski, P. and Boshier, D. (1997). Conserving the genetic resources of trees *in situ*. In: Plant genetic conservation – the *in situ* approach (eds N. Maxted, B.V. Ford-Lloyd and J.G. Hawkes), Chapman and Hall, London, pp 207-219.
- LaSalle, J. (1999). Insect biodiversity in agroecosystems: function, value and optimisation. In: Agrobiodiversity : characterization, utilization and management (eds D. Wood and J.M. Lenne), CABI Publishing, UK, pp 155-182.
- Lefroy, E.C. (1992). The importance of biodiversity to sustainable agriculture. Land Management Society Newsletter, Winter 1992, Perth, WA.
- Lenne, J.M. and Wood, D. (1999). Optimizing biodiversity for productive agriculture. In: Agrobiodiversity : characterization, utilization and management (eds D. Wood and J.M. Lenne), CABI Publishing, UK, pp 447-470.
- Lindenmayer, D.B., Cunningham, R.B., Pope, M.L. and Donnelly, C. (1999). The response of aboreal marsupials to landscape context: a large scale fragmentation study. *Ecological Applications* **9** (2) pp 594-611.
- Lindenmayer, D.B., Margules, C.R and Botkin, D.B. (2000). Indicators of biodiversity for ecologically sustainable forest management. *Conservation Biology* **14** (4) pp 941-950.
- Main, A.R. (1999). How much biodiversity is enough? *Agroforestry Systems* **45** pp 23-41.
- Passioura, J.B. (1999). Can we bring about a perennially peopled and productive countryside? *Agroforestry Systems* **45** pp 411-421.
- Plantations 2020 Vision Implementation Committee (1997). Plantations for Australia - The 2020 Vision. Department of Primary Industries and Energy, Canberra.

Potts, B.M., Barbour, R.C. and Hingston, A.B. (2001). Genetic Pollution from Farm Forestry. RIRDC, Canberra.

Saunders, D.A. (2000). Biodiversity: What is it and why is it critical to agriculture? In International Landcare 2000 Conference Proceedings. Melbourne pp 213-217.

State of the Environment Advisory Council (1996). Australia: State of the Environment 1996, CSIRO publishing, Collingwood, Victoria.

Stephens, N., Wood, M., Allison, B. and Howell, C. (2001). Farmer and landholder contributions to Australia's commercial plantations. National Forest Inventory, Bureau of Rural Sciences, Canberra.

Walcott, J., Chesson, J. and O'Brien, P. (2001). Indicators of agri-biodiversity: Australia's experience. OECD Expert Meeting on Agri-Biodiversity Indicators, Bureau of Rural Sciences, Canberra.

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

Wood, D. and Lenne, J.M. (1999). Agrobiodiversity and natural biodiversity: some parallels. In: Agrobiodiversity : characterization, utilization and management (eds D. Wood and J.M. Lenne), CABI Publishing, UK, pp 425-445.

Vercoe, T. (2001). Special liftout no. 57: Farm forestry and biodiversity. Australian Forest Grower **24** (3).