WORKSHOP PROCEEDINGS

Production Versus Rainforest Biodiversity: Trade-offs or Synergies in Farm Forestry Systems?

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Rainforest CRC

Cooperative Research Centre for Tropical Rainforest Ecology and Management

PRODUCTION VERSUS RAINFOREST BIODIVERSITY: TRADE-OFFS OR SYNERGIES IN FARM FORESTRY SYSTEMS?

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Edited by
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COLOUR PLATES

PREFACE

These are the proceedings of a workshop discussing production and biodiversity trade-offs in farm forestry systems on former rainforest areas of tropical and sub-tropical Australia. The workshop was held in Cairns, Queensland in November 2003 as part of the 10th Annual Conference of the Rainforest CRC.

The multiple goals of farm forestry make the trade-offs between productivity and biodiversity a difficult balancing act and the primary purpose of this workshop was to allow speakers to share their experience and/or research findings in tropical and sub-tropical rainforest regions of Australia.

Relevant questions we asked attendees to consider included:

- What does 'biodiversity' mean?
- What is production trying to maximise?
- What are (or should be) the objectives of farm forestry systems?
- What mechanisms would help landholders include greater levels of biodiversity in their plantations?
- Does it make sense to combine production and biodiversity goals? In what circumstances?
- What can be achieved through site versus landscape design?
- What are the important knowledge gaps?

The organising committee for this workshop comprised:

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Production of this volume has been possible because of the efforts of many people, including the organising committee, staff of the Rainforest CRC (Jann O'Keefe, workshop organisation; Shannon Hogan, typescript), and those who participated in the workshop discussions, thereby contributing important points to the Synthesis Chapter.

SUMMARY

In former rainforest areas of Australia tree-planting has served various purposes, and different people have planted trees in different ways. For example, Queensland Department of Primary Industries (Forestry) planted large areas of monoculture hoop pine with the intention of producing a return for treasury investment dollars. At the other extreme are the dense and diverse plantings that aim to restore rainforest biodiversity to a site, for example those undertaken by community-based organisations and recently funded by the national Natural Heritage Trust scheme.

There is increasing interest in forms of reforestation that might in some way blend the outcomes of timber production and biodiversity. Rural landowners often establish small-scale farm forestry plots with mixed goals, however, such plantings also run the risk failing to achieve these goals. The future may bring novel combinations of reforestation with industrial projects (for example, to provide economic benefits associated with eco-accreditation, carbon credits or biodiversity credits).

This volume addresses the opportunities and limits to combining timber production and biodiversity goals in tropical and sub-tropical rainforest landscapes. It provides diverse perspectives and opinions from researchers, managers and landholders. It draws on past experience with farm forestry systems, but also considers future scenarios and challenges.

Plate 1: Pasture used for dairy farming (photo: John Kanowski).

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DIVERSITY AND PRODUCTION IN TROPICAL REFORESTATION

Peter D. Erskine

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PERSPECTIVES

Most tropical rainforest landscapes have been significantly altered by human activities. How people view these landscapes depends upon both their own experience and their belief system. To people who are intensively producing tropical agricultural crops such as sugarcane or bananas for their livelihood, desirable landscapes are those which maximise production and financial returns, using well-established methods that they understand. On the other hand, conservationists would view these same landscapes as being degraded and heavily fragmented, containing low levels of forest biodiversity and in need of extensive reforestation. Other members of society have views which lie somewhere between these two perspectives, but in recent decades there has been a transformation of community views towards more 'natural' landscapes (O'Hara 2001). This paper considers how the wider community view has impacted on the management of tropical forest landscapes and what types of reforestation can provide both economic and biodiversity outcomes.

THE WET TROPICS

In the Wet Tropics region of Australia, some major agricultural activities (particularly dairy and sugar production) are in decline due to changes in national and international trade. Tourism is now the major industry in the region with tourists generally visiting to experience the World Heritage listed Great Barrier Reef and the Wet Tropics rainforest. The World Heritage listing of the rainforests lead to the decline of the timber processing industry in the region and although an attempt was made to create a sustainable plantation industry through the Community Rainforest Reforestation Program (CRRP), generally it appears to have failed to achieve that goal.

TYPES OF REFORESTATION

Throughout all levels of government and much of the community it has been recognised that forest clearing has led to a range of problems, including loss of biodiversity and the degradation of waterways. A variety of community groups acted on these concerns and with government assistance, estimated to be between $27 to $48 million, they attempted to re-establish over three thousand hectares of forests in the region (Erskine 2002). Of these plantings, habitat restoration has had the best biodiversity outcomes of the different reforestation styles in the short term (Kanowski *et al.* 2004), but the cost of this type of planting has limited the amount of area that has been rehabilitated (Erskine 2002). Furthermore, there are no direct financial outcomes for this type of reforestation (see Table 1).

An alternative type of reforestation with mixed species plantings, such as those conducted by the CRRP, should in the longer term provide moderate levels of financial returns and moderate increases in biodiversity. Alternatively, hoop pine monocultures have been established on State owned land to provide a relatively healthy financial return for the Government. Over the longer term these plantations will lack the canopy diversity of the other types of reforestation and therefore will be likely to have relatively poor levels of

biodiversity (Table 1). Because of growing public aversion to plantation monocultures, the dual potential of mixed species plantations providing biodiversity and economic outcomes offers a reforestation technique that could cover large areas.

Table 1: Types, costs and predicted long term outcomes of different types of reforestation conducted in the Wet Tropics (adapted from Erskine 2002).

Style of Reforestation	Organisations*	Approximate Cost per Hectare	Financial Outcomes	Biodiversity Outcomes
Habitat restoration	WTTPS	$15,000–$80,000	None	Good
CTR/TREAT	CTR/TREAT	$25,000		
Mixed species cabinet timber	CRRP	$5,000–$10,000	Moderate	Moderate
Hoop pine monoculture	QDPI-Forestry	$5,000	Good	Poor

*Community Rainforest Reforestation Program (CRRP), Wet Tropics Tree Planting Scheme (WTTPS), Centre for Tropical Rehabilitation (CTR), Trees for the Evelyn and Atherton Tablelands (TREAT), Queensland Department of Primary Industries (QDPI).

WHY MIXTURES?

Theoretically, mixed species plantations should be capable of higher productivity than monocultures because they may reduce between-tree competition, improve nutrition and reduce insect and disease problems. Growth data from CRRP plantations comparing species grown in monocultures and mixtures (Table 2) demonstrate that average tree volumes are 18% to 60% greater when grown in mixtures. Although the CRRP was not designed as an experimental system, and there were a range of planting densities and a diversity of species surrounding target species in Table 2, this data provides evidence of early production benefits from mixtures in the CRRP.

Table 2: Comparison of the average tree volume at age eight years for three species growing in CRRP monocultures and mixtures, on basaltic soils.

Species	Average Tree Volume (cm^3)	
	In monoculture	In mixture
Agathis robusta	135	217
Araucaria cunninghamii	541	640
Eucalyptus pellita	980	1379

This does not necessarily mean that mixtures are always better than monocultures. Mixtures of randomly chosen tree species are unlikely to be successful in the longer term as one species may become dominant and inhibit other species. There are several silvicultural problems to be solved before a multi-species plantation system can be designed. The first is to identify which species are likely to form complementary mixtures and which species should not be grown together. Species compatibility in mixtures has begun to be examined by the Rainforest CRC project *Revegetation Techniques*, and we are provisionally able to suggest 'best bet' species groups for certain environmental conditions (Lamb *et al.* in press, Bristow *et al.* in press). Furthermore, management prescriptions for different species

combinations to maximise production are being developed (Keenan *et al.* in press), and recommendations for plantation design and management to balance diversity and production suggested (Catterall *et al.* in press a). In the longer term there is still a need for:

- further research on species complementarity;
- the domestication of native rainforest species;
- tree species combinations and plantation designs that significantly increase forest biodiversity; and
- the contribution of plantation mixtures to landscape functioning.

THE ON-SITE AND OFF-SITE BIODIVERSITY AND CARBON BENEFITS OF MONOCULTURE *ARAUCARIA CUNNINGHAMII* PLANTATIONS IN THE WET TROPICS

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ECONOMICS AND THE ENVIRONMENT

Today, society values both economic stability and environmental health. It could be stated that the economic gains of the past 150 years in the industrialised world often created environmental harm, and that the two objectives were mutually exclusive. The situation is changing. Increasing numbers of corporate bodies are adopting triple bottom line accounting practices, and western governments are creating markets for carbon credits, and are demanding better environmental performance from industry and the community in general. Regarding forestry, Australia is making the transition from harvesting native forests to establishing a plantation resource. However, although Australia has locked up its own native forests in the name of biodiversity conservation, we continue to import timber produced in other countries with poorer environmental records than our own. And in terms of financing long-rotation forestry timber species, even the 'greenest' ethical investment fund is not interested in projects that have more than a fifteen year horizon for returns on investment.

ARAUCARIA: DOMESTICATION OF A RAINFOREST TIMBER TREE IN THE WET TROPICS

Araucaria cunninghamii (henceforth referred to as araucaria) is a native Queensland species with wide distribution from Papua New Guinea to northern New South Wales (Gould 2000). In Queensland's Wet Tropics region, there are small populations on the Gillies Highway, and in the Tully Falls and Hann Tableland areas. In the region, radiocarbon dating of pollen records from Lynch's Crater indicate that forests with araucaria tree species were more prominent on the Atherton Tablelands about 40,000 to 75,000 years ago, when the annual rainfall was about 1400 millimetres – much less than the present levels of 2200 millimetres per year – leading some authors to suggest that the introduction of fire management by Aborigines, along with climate change, may have combined to reduce the species' natural distribution and assisted the development of dry sclerophyll forests, as araucaria is fire sensitive (Singh *et al.* 1981).

A little-known fact is that, long before the Community Rainforest Reforestation Program of the 1990s, attempts were made at trialling native species in plantations. In 1928 and 1929, sixty-five species were trialled at Gadgarra State Forest, with the most promising species being araucaria, kauri pine (*Agathis robusta*), various eucalypt species, red mahogany (*Eucalyptus resinifera)*, tallowwood (*E. microcorys*), spotted gum (*E. maculata*), forest red gum (*E. tereticornis*), and a number of rainforest species including southern silky oak (*Grevillea robusta*), Queensland maple (*Flindersia brayleyana*), maple silkwood (*F. pimenteliana*), northern silky oak (*Cardwellia sublimis*), Mexican cedar (*Cedrela mexicana*) and west Indian cedar (*Cedrela odorata*) (Queensland Forest Service 1928, 1929).

Research in the 1950s narrowed down the best species for planting on rainforest or open

forest types on the volcanic soils of the southern Atherton Tablelands to three species: kauri pine, Queensland maple and araucaria (Queensland Forest Service 1953). Kauri pine had slow growth, and Queensland maple was soon dropped from the focus list as it lacked straight timber 'form' and suppressed surrounding trees when open-planted in mixtures with araucaria. It was believed that Queensland maple and other rainforest or broadleaved hardwood species developed large and spreading crowns in open situations and required a nurse crop. They were therefore often underplanted in existing natural stands or plantations of araucaria. Although the Queensland maple grew well when under-planted after the first thinning of araucaria, this research practice was deemed to be not commercially viable when applied operationally. Increasingly, after the 1960s, research work focussed on improving the productivity of araucaria and PCH (*Pinus caribaea var. hondurensis*) plantations (Queensland Forest Service 1965).

MONOCULTURES OF ARAUCARIA MAXIMISE PRODUCTIVITY

At an expected growth rate (mean annual increment, or MAI) of fifteen cubic metres per hectare per year, the productivity of mature (40 to 45 years) araucaria plantations established on ex-pasture lands would be six hundred cubic metres per hectare, and this could be obtained with a high final stocking of 400 to 450 stems per hectare. An additional five thousand hectares of araucaria established in the next five to ten years with this productivity would yield approximately three million cubic metres of roundwood (logs) by about 2050 to 2055. At a conservative average stumpage price of $60 per cubic metre, this resource would be worth $180 million in today's dollars even before processing in a sawmill, and would have cost about $25 to $30 million to establish and manage over the period. Investment for carbon credits may be available from regional power companies.

Some authors have suggested that plantations containing two or more species will almost certainly be more difficult to manage than traditional monocultures, and the biodiversity gains from these simple mixtures may be relatively modest, and that biodiversity enhancement is best done at the landscape scale (Lamb and Keenan 2000). By spatially separating the two opposing objectives of wood production and biodiversity, a 'win-win' outcome is more likely. Waterways can be re-planted and retained with biodiversity species, and commercial plantations can be established, managed and harvested commercially. Without a market to pay for the ecosystem services that are provided by mixed species plantations, the dilemma is that private forest owners would have to pay for providing biodiversity benefits and would lose revenue to benefit the broader community.

Araucaria has been grown in several mixed-species designs over time but has never achieved the yield of monocultures. Furthermore, these designs have generated problems at harvesting time, due to the necessity for several harvesting cycles and problems associated with controlling damage to the residual stand. Monocultures of araucaria are preferred from a production and industry development perspective for several reasons. Monocultures maximise the economic returns from commercial wood production on the limited remaining available areas of productive land, and also maximise carbon sequestration and potential sales of carbon credits to global investors. The ability of 40 to 45 year old araucaria plantations to yield 600 to 800 cubic metres per hectare means that it is likely to be a saleable carbon sink and, relative to other lower yielding native species options, more cleared land can be left available for other land uses, including biodiversity plantings.

THE BIODIVERSITY BENEFITS OF ARAUCARIA PLANTATIONS

Pine plantations are often considered 'biological deserts', but this is not true of araucaria plantations established in Queensland (Huth *et al.* 2001). Plantations of native conifers such as araucaria could be designed to complement the natural terrain of the southern Atherton

Tablelands landscape and have some potential to enhance biodiversity and remnant vegetation by providing an environment for shade-tolerant understorey species to germinate from surrounding areas of remnant native vegetation. Older (more than fifty years) first rotation stands of araucaria established on the Atherton Tablelands can develop a diverse rainforest understorey over time (Tucker *et al.* 2004).

It has been suggested that araucaria plantations could be used to rehabilitate degraded rainforest lands (Keenan *et al.* 1997), because they can be established at lower cost than other reforestation methods. Araucaria plantations established close to areas of remnant rainforest have been shown to increase biodiversity relative to a baseline of cleared agricultural land (Keenan *et al.* 1997, Stork *et al.* 1998), although this is unlikely to occur for plantations isolated from rainforest, or for wide-spaced plantations with a grassy inter-row. If second rotation plantations develop a lantana-dominated understorey, due to reduced thinning or lower stocking rates, research also suggests that they may not support as many rainforest specialists as the current crop of old plantations (Kanowski *et al.* 2004).

GLOBAL CONSERVATION OUTCOMES IN PROFIT-DRIVEN PROJECTS

Monocultures of araucaria can still contribute to global conservation. The conifer family Araucariaceae consists of three genera and forty species, and has a highly restricted present day distribution, unlike in the past (University of Bonn 2003). The genus *Araucaria* is represented by fossil material in both hemispheres as early as the Jurassic, while *Agathis* is only known from the Southern Hemisphere beginning in the Cretaceous. Locations in Australia, New Zealand, and many parts of Malaysia have been logged, and many of the species are threatened or endangered. The rare and endangered Wollemi pine is a member of the Araucariaceae. Aboriginals or Traditional Owners often ate the nuts of some species, including bunya pine, for food. By planting the full range of Araucariaceae species and provenances, it could be possible to contribute to the conservation of global Araucariaceae genetic diversity and seed sources. For example, a small portion of the plantations (say 1% to 2%) could be reserved for this conservation purpose and not harvested. Specific funding support from either philanthropic individuals or non-government organisations (NGOs) or environmental groups would most likely be required for this aspect of the project.

Harrison *et al.* (2000) examine aspects of timber production and biodiversity trade-offs in plantation forestry in more detail.

BIODIVERSITY AND TIMBER PRODUCTION: TRADE-OFFS AND SYNERGIES IN RAINFOREST PLANTATIONS FROM A WILDLIFE ECOLOGY VIEWPOINT

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AN ENVIRONMENTAL PERSPECTIVE ON TIMBER PLANTATIONS

During the past two centuries there have been large shifts in attitudes to Australian rainforest timbers and their source forests: from felling native forests towards growing plantations; from viewing forests and plantations as mainly providers of timber to viewing them as sources of multiple benefits (timber, biodiversity, carbon sequestration, catchment protection, others); and from timber plantations being developed mainly by government on public land towards those established by private citizens or companies on freehold land. Intact rainforests, which were once viewed as either a source of timber or a source of fertile land for agriculture, are now widely recognised for their environmental and social values; as places of beauty and grandeur that are especially rich in species of flora and fauna, and which play a role in local and global climate regulation.

In recent decades, various government initiatives have either severely restricted or ended timber harvesting in sub-tropical and tropical Australian rainforests, and hence most future supplies of locally-sourced rainforest timber must be obtained from other areas, such as timber plantations. Timber plantations based on native plant species, and established on land formerly cleared for agriculture, may also have a potential to restore some level of biodiversity to this land, and to provide other environmental benefits.

However, plantations that are designed and managed to optimise economic returns from timber sales may have a limited ability to provide the habitat structure and resources needed by many of the flora and fauna species that are characteristic of intact rainforest. How much contribution can timber plantations really make to sustainable regional biodiversity? To answer this question requires scientific research based on methods that allow quantitative measurement of biodiversity values, used to compare measured biodiversity outcomes across a spectrum of different plantation styles.

MEASURING BIODIVERSITY VALUES IN RAINFOREST PLANTATIONS

The biodiversity characteristics of a range of different types of rainforest plantations have been compared within the Rainforest CRC project *Quantifying the Biodiversity Values of Reforestation* (QBVR) (see Kanowski *et al.* 2003, 2004; Catterall *et al.* in press a, b, Wardell-Johnson *et al.* 2001, 2004).

We have measured a range of different aspects of 'rainforest biodiversity value' (including birds, reptiles, insects, plants, physical structure, aspects of decomposition and predation), in the subtropics (Lismore to Imbil region) and tropics (Atherton Tablelands) of eastern

Australia. In each region, we used replicated reference sites of pasture and intact rainforest to provide a benchmark for assessing biodiversity development in different types of plantation (Figure 1; mono-species hoop pine plantations, mixed species cabinet timber plots, and complex species-rich ecological restoration plantings).

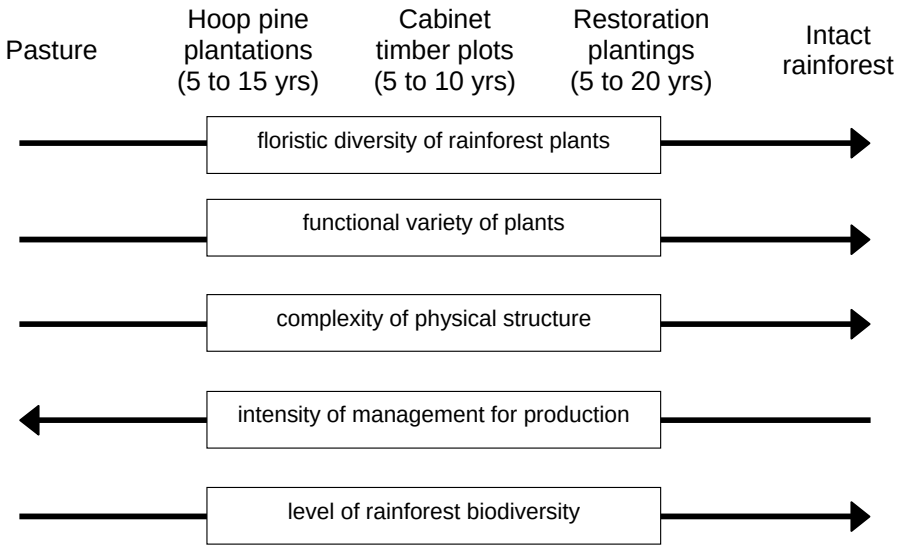

Figure 1: Common styles of timber plantation in rainforest landscapes, and factors associated with their differing values as wildlife habitat (results of the QBVR project).

At around ten years after planting, all forms of replanted forest supported substantially more rainforest species than did grazed pasture, but substantially fewer than found in intact rainforest. However, both the hoop pine plantations and mixed cabinet-timber plots supported less rainforest biodiversity than did the ecological restoration plantings. This difference was associated with a greater structural complexity, closer spacing of stems, greater understorey development, and greater variety of plant life-forms in the restoration plantings.

WHAT AFFECTS BIODIVERSITY VALUES OF PLANTATIONS?

Key factors likely to affect the biodiversity values of rainforest plantations are:

- plantation styles (as above, e.g. structural complexity, understorey, special habitat features including ground litter and debris, fruiting trees, standing dead wood);
- timber harvest cycles (there is little information on biodiversity trajectories past ten years, aspects of rainforest biodiversity may take many decades to develop); and
- patch area (very small patches of a few hectares may be unlikely to support rainforest biota unless they are adjacent to intact rainforest).

Improved outcomes for wildlife biodiversity in timber plantations require suitable:

- plantation design and management (e.g. provision/retention of habitat features, incorporation of fleshy-fruited tree species);
- spatial configurations of plantations (e.g. interspersing timber plantations with restoration

plantings that are large, and/or connected to other habitat areas); and

- rotation lengths (longer, asychronous).

These and related issues are discussed in the references cited above (see also Catterall 2000, Tucker *et al.* 2004).

BUILDING A BETTER KNOWLEDGE BASE

To improve knowledge for decision-making, we need more:

- site-based measurements of both production and biodiversity values on the same sites, across a range of differently designed and managed plantation projects; and
- experimental plantings (mixed goals, long-term investment).

It should ultimately be possible to develop a portfolio of differing guidelines for plantations with different aims (e.g. pure profit, pure diversity, small plot aiming for some timber but also maximising biodiversity outcomes, large plot aimed largely at timber but with a biodiversity component). This will enable landholders to more effectively choose a style of plantation design and management to suit their particular goals.

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BIODIVERSITY VERSUS PRODUCTION TRADE-OFFS: A PRODUCTION PERSPECTIVE

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The consideration of multiple forest values and products is critical to the future of production forestry, both in planted and less intensively managed systems. I will make only five points that I believe are important to consider during a debate about productivity and biodiversity trade-offs in such managed forest systems.

1. In forested systems that are managed primarily for timber production, there is a dearth of data to indicate that there is an advantage in a polyculture over a monoculture, in terms of production in primary crop species and the associated forest products arising from it. Importantly, this is a very active field of research, there are numerous investigations now being undertaken, and it is quite probable that such systems will be described quantitatively in the future.

2. There are good reasons for this when the physics and physiology of production are considered in some detail. A tree physiologist (such as I) may define a forest as "a terrestrial interface that transfers energy and mass, that is carbon and water, between the atmosphere and the soil". This is not a widely held definition, particularly within a forum interested in biodiversity issues, but it has the advantage of helping focus the mind on reasons why trees may grow better in a polyculture as opposed to a monoculture, or vice versa, and how biodiversity may affect this. In any system there is competition among organisms for limited resources and it is the relative success of this competition among species and individuals that determines their various rates of productivity.

3. Productivity may indeed be the wrong entity to measure in comparison to, or as a trade-off for, biodiversity. Profitability may be of more use. This is because productivity is not something we have a great deal of control over (at a fundamental level), but with profitability we have much more flexibility. This point is made on the basis of physics being beyond human control but economics being something inherently manipulable. Society can create demand, can change supply, can assign value where there was none previously – but cannot affect the physical rules governing the forest system. For example, it is not possible to change the solar radiation flux on the top of the canopy; nor the conversion efficiency of the C3 photosynthetic system. But it is possible to assign a dollar value to biodiversity. Thus when profitability (rather than purely productivity) is the quantity of interest, there is inherently more opportunity to exert control over the system and shape management to achieve policy goals.

4. Explicit consideration of scale is of fundamental importance to any such discussion and much recent debate on the topic has failed to be useful due to an absence of this. There is a great deal of focus on small-scale variation in productivity and biodiversity. In a natural resource management context, management at a landscape scale or a catchment scale makes a great deal more sense than management (for broad objectives such as biodiversity or profitability) on a hectare basis. Many more opportunities rather than conflicts become apparent once the appropriate scale has been identified.

5. From a research perspective, many of the same questions need to be asked to address both production and biodiversity issues – thus putative trade-offs between biodiversity and

production are more matters of policy rather than scientific research. It is much better that science organisations focus on the processes that underlie variation in biodiversity, resource allocation, timber quality etc so that outcomes can be quantified in a way that permits social scientists and policy makers to assign dollar values that reflect the priorities of the society for whom they are being managed. These priorities and policy objectives will change over time, the underpinning science will not.

GROWING TREES FOR PROFIT

Errol Wiles

Landholder and Tree Grower, Babinda

INTRODUCTION

I grow trees, and without the slightest shame, I grow them for profit. But then those of you who grow trees also grow them for profit. Your profit may be expressed in currency other than dollars, but it is profit! Do not then despise those of us who seek a dollar profit.

Now, what is biodiversity? Why should we seek to maximise biodiversity? How many billions of species have been and gone? Try to imagine the unimaginable billions of species between the slime from your pond, to your coconut palms, to your elephants, to your human beings and so forth. There must be unimaginable billions – been and gone. How are our lives affected by the loss? Is it loss of these species? What is sustainable? Is George Street, Sydney sustainable? Why is the sustainability of my rainforest more essential than that of Collins Street, Melbourne?

I see a lot of us discussing these questions, sometimes to the accompaniment of hand waving. The problem is that no one is speaking the same language. One person speaks in Albanian, another Swahili, Gaelic, Hungarian, and yes there is the odd English word. Our most pressing need is for definitions and terms upon which we can agree. I listened to the talks this morning and, although I have a fair and reasonable command of English, I assure you a great deal of it went over my head. We need to define our terms in language upon which we can all agree.

GROWING TREES FOR NATIVE BIODIVERSITY

I grow trees. I am entirely in tune with the idea of the need on my place to maximise the biodiversity that applies with my tree-growing. That is why I walk along and pick through the cassowary scats that have been dropped on my place, examine the seeds, clean them off so that I can properly identify them, and then replant them down along the creeks. I do it, but I exclude the ones that I don't want replanted, for example pond apple, or *Annona glabra*, and others that I don't want because the cassowary is quite indiscriminate in the things that it eats. I don't want all of them, but I do try to maximise native biodiversity. My plantings are such that they are not in monocultural situations, but I would like you to examine the thought that a rainforest tree in its full majesty and glory occupies a space half the size of this room, and upon that space it is a monoculture. There might be one entirely different in the other half of the room, but it also is a monoculture. So what is monoculture? Every single tree is a monoculture, however many of them you put mixed up in various combinations.

HYPOCRISY

The important thing about this whole issue is that Australia is approaching an annual deficit of $3 billion in forest products. We import our timber needs from wonderful places renowned for their biodiversity and 'care' of the environment such as Papua New Guinea, Malaysia, the Pacific Islands, Africa, Central and South America. Even the Brazilians have locked up their forests in the Amazon because of the way they have been pillaged and robbed. Some 70% of the plantations of the world are mythical or just some paper entry somewhere. They don't exist, but we are clean and green, aren't we? We are clean and green, and we import our

timbers from places that have no idea at all about what biodiversity maximisation is, or what looking after the environment is. We are clean and green in this country! We are hypocrites! The fourth abandonment of a proposal to build a paper mill in Tasmania has seen the expansion of Indonesian mills to fill that void. These almost certainly do not have to meet the environmental standards that an Australian mill would do. A substantial part of the raw-material needs for those Indonesian mills has been sourced from Australia. We're clean and green!

Look, I can carry on and give you examples one after another. The point is, we live in one world, and the backyard from which we are importing that $3 billion of foreign product is my backyard. We don't have a great big wall up there that says "Well, you've damaged your atmosphere and your water. You keep it." It touches me too. The world is getting smaller and smaller, and we continue to import too much at peanut prices, to the extent that millers will offer $45 per cubic metre for exquisite north Queensland cabinet timbers. Not while I am living – I will cut them down and burn them! And we should all do the same thing. And yes, I get rather passionate about this, you might observe, because I have put a lot of effort and work and thought and planning into this whole scheme. I have made 783 mistakes in the ten years I have been working on this. I am young enough to make another 783 mistakes, but I have learned from my mistakes. I made those mistakes because the research wasn't there, because the advice wasn't available to me, so I had to make it on my own. But now I know, and it will be a very, very brave man who will come onto my place and tell me what I can and cannot do on my freehold land.

And about the little problem of not harvesting on river banks and creek banks. Let me point out to you that in the Russell catchment, where in 1999 I measured 7.53 metres of rain, I saw a tree of such mass that it slumped on the river bank vertically, that is it went straight down. It exposed five metres of raw bank to the space, and fifteen minutes later, the entire bank went. How much smarter it would have been to take out that damn tree before it reached such a mass that became dangerous to the integrity of the bank. Do you see? Everything that lives dies, unfortunately including me. Use the tree, use it discreetly, and replant it or let it replant itself, but let's get on with it!

THE PRODUCTIVITY VERSUS BIODIVERSITY INFORMATION VACUUM: WHAT DO WE KNOW AND WHERE CAN WE GO FROM HERE?

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INTRODUCTION

Examination of the relationship between productivity and biodiversity, the potential trade-offs that may occur when designing and managing planted trees, is an important task. Our research into landholders' tree planting and management attitudes and behaviour in former 'rainforest' country has shown that landholders are interested in both the biodiversity conservation and the production attributes of tree plantations (Emtage *et al.* 2001). They are experimenting on their own, and also looking for researchers to provide guidance on the questions of plantation design and management to help them achieve their objectives. What I will argue today is that we are not yet in a position to provide them with clear answers.

The work of Catterall and others (Catterall *et al.* in press a) has given us some insight into the implications for biodiversity of various plantation types and management options. However, our research that has examined the financial implications of tree planting and management on private lands has shown that we are lacking in terms of having access to information needed to assess the productivity and biodiversity implications of varying the species used and management applied to tree plantations (Emtage *et al.* 1999). I believe that some of this information exists, but it is not available to the public, or else is in an unprocessed form that is of little use at present. I further believe that if we are to get the information we need to inform the productivity versus biodiversity debate, we will have to be persistent, and we need to cooperate.

WHAT DO WE KNOW ABOUT THE PRODUCTIVITY OF AUSTRALIAN NATIVE TREES?

A number of studies have examined the productivity of plantations using rainforest tree species (Russell *et al.* 1993, Herbohn *et al.* 1999), however we lack crucial information about the effects of variations in plantation design and management on the volume and quality of timber produced, not to mention information about the response of most native tree species to environmental variables like climate and soils.

These studies have sought to overcome the lack of published information about the growth rates and harvest ages of cabinet timber species by using surveys of forestry experts. Herbohn *et al.* (1999) surveyed eleven foresters and researchers with experience in growing rainforest trees in plantations to gather information about the likely growth rates and harvest ages of 32 tree species that had been used in the CRRP program (Herbohn *et al.* 1999). They were also asked which species should or should not be grown together, and about the effects on productivity (in this case growth rates), and management implications of using mixed rather than single species plantations.

The responses of the forestry experts to questions about the relative ease of management and timber yields of multiple species plantations relative to single species plantations were mixed, particularly in terms of their opinions about the effects on yields (Table 1). There was

reasonable consensus that mixed species plantations are relatively more difficult to manage (Table 2).

Table 1: Changes in timber yields using mixed species rather than single species.

Yield of mixed sp. plantings relative to single sp.	Frequency
Uncertain	5
Decrease	4
Increase	2
No change	0

Table 2: Relative difficulty of plantation management using mixed species plantations rather than single species plantations.

Difficulty of plantation management using mixed species plantations rather than single species	Frequency
Harder to manage	7
The same	3
Uncertain	1
Easier to manage	0

So, after we gathered and examined some expert opinions about the trade-offs between increasing the biodiversity of plantations and the productivity of the plantations what did it tell us? It told us the management of mixed species plantations is more akin to an art than a science at this point. Given the lack of consensus among the experts and lack of detail in the information we gathered, the information about interactions between species was not sufficient to allow us to incorporate it into our financial analyses of plantations.

WHAT DO WE NEED TO KNOW ABOUT THE PRODUCTIVITY OF AUSTRALIAN NATIVE TREES?

There is little published, processed information about the productivity and biodiversity of mixed species plantations in Australia, but there are a number of databases that do have relevant information. These include work by the State government agencies associated with forestry in Queensland such as Department of Primary Industries (Forestry) (DPIF) and the Queensland Forestry Research Institute. I believe that the DPIF currently maintains the Treedat database. Another database is the Sub-Tropical Site Management database, a project begun by researchers at Southern Cross University in Lismore and being managed, the last time I heard, by the Sub-Tropical Farm Forestry Association. CSIRO also has a tree performance database that is a subset of the original Treedat system.

It is fantastic that effort has been made by many people to develop these databases. Unfortunately, the information in them is not yet helping us in this discussion. I am aware that some of the organisations maintaining these databases have struggled in the past to secure on-going funding to update and analyse the data. Yet the start has been already made, much data is contained, data that could allow us to take the guesswork out of designing and maintaining multiple species plantations. There is the opportunity to take multiple species plantations beyond an ‘art form’, beautiful as that is, and into the realm of science. We are fortunate that researchers and the organisations they have been associated with, have established a beautiful crop of information that is growing towards maturity. We may have the chance to harvest this data, but there seems to be a risk that the crop could die due to lack of management. This has already happened on numerous occasions in early field trials of mixed species and cabinet timber plantations. The enthusiasm and vision of researchers has, too often, led to the establishment of field trials that have subsequently been neglected and become virtually useless through lack of long-term support by the agencies that

established the trials.

Growing trees is a long-term activity. Obtaining experimental data about the effects of tree management, plantation design, climatic impacts and site species matching takes a long time. I believe that all of us who are interested in these issues need to support these efforts to maintain and use the databases. Is there an organisation with the capacity and long-term vision to keep up the data collection, combine the existing databases, and make them available for research activities? The agency that came to mind was the newly formed Australian Tropical Forestry Institute, but I don't mind who it is. All I know is that we need the information, and to get it we need long-term commitment.

SYNTHESIS

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OVERVIEW OF WORKSHOP

Researchers, government department staff involved in tree planting, restoration practitioners and members of the public gathered for this workshop. Participants were affiliated with various institutions within and outside the Rainforest CRC, and represented interests from both tropical and sub-tropical Australia. Six speakers gave their perspectives on the trade-offs and synergies between biodiversity and productivity in a plantation environment.

Peter Erskine spoke of diversity and production in tropical reforestation. He outlined contrasting viewpoints on how much tree cover is desirable in a landscape, and described the high costs associated with restoring biodiverse rainforest, compared with the cost of establishing timber plantations. He outlined reasons why mixed-species plantations may perform better than monocultures for both production and biodiversity, and described research on species compatibility in mixtures. He also highlighted knowledge gaps relating to tree species' growth performance, domestication, and the design of plantations to improve biodiversity outcomes.

Daryl Killin spoke of the on-site and off-site biodiversity and carbon benefits of monoculture hoop pine plantations. He described the unique qualities of hoop pine, and of the family Araucariaceae, and the benefits of long-term research on hoop pine for the silviculture of the species. He also considered the potential benefits of a substantial hoop pine plantation resource, and the opportunity to gain ‘win-win’ outcomes by establishing mixed-goal plantations which contain spatially distinct areas of monoculture and biodiversity plantings.

Carla Catterall spoke of trade-offs and synergies in biodiversity and timber production from a wildlife ecology viewpoint. She introduced her presentation with a historical overview of the shifts in attitudes to Australian rainforest timbers and their forests: from felling native forests towards growing plantations; from viewing forests and plantations as mainly providers of timber to viewing them as sources of multiple benefits; and from timber plantations being developed mainly by government on public land towards those established by private citizens or companies on freehold land. She outlined factors likely to affect the biodiversity values of rainforest plantations (plantation styles, timber harvest cycles and patch area), and then suggested issues needing consideration if improved outcomes for wildlife biodiversity in timber plantations are to be achieved (plantation design and management, spatial configurations of plantations and rotation lengths).

Mark Hunt spoke about productivity and profitability. He argued that a consideration of multiple forest values and products is critical to the future of production forestry. He pointed out that the productivity data are limited with respect to whether or not polycultures offer advantages over monocultures. However, he also argued that it is better to be thinking about profitability than productivity because there is some capacity to control profitability through economic management (e.g. by manipulating value, supply or demand), while productivity is more associated with inherent site quality (e.g. soil fertility and moisture), and hence largely beyond management control. He, like other speakers, emphasised issues of scale. He

concluded by calling for improved scientific understanding of the factors which affect both biodiversity and production, to provide policy makers with the independent information that they need in order to arrive at sound decisions, given particular societal values.

Errol Wiles provided a spirited argument concerning the economics of tree-growing from a private grower's perspective (tree growers are interested in biodiversity but also seek to survive). He also argued that Australians concerned with conservation issues should be ashamed of the continued importation of unsustainably harvested rainforest timbers from other tropical countries with low environmental standards. This has the effect of lowering timber prices in Australia to a level where it is uneconomical to grow (for timber) local indigenous timber species in an environmentally sound manner.

Nick Emtage argued that research has shown that landholders are interested in both the biodiversity conservation and the production attributes of tree plantations. However, the information required for decision-making on production/ biodiversity trade-offs is not readily available. He also suggested that some of this information will take a long time to collect and synthesise. While there are some existing databases containing useful information on tree growth, much of which has not been analysed, these are at risk due to shifting organisational priorities. Hence there is a need for a responsible body with the capacity and long term vision to maintain the data collection, combine the existing databases, and make them available for research activities and for tree planters.

Spirited discussion followed the six presentations. Questions generally focussed on the themes of trade-offs or synergies, biodiversity values, landscape and scale issues, research requirements and policy and management interactions. The following account describes the issues identified during the discussion, by drawing on our record of the questions and answers. In doing so, we have also incorporated our own perspectives on these issues.

TRADE-OFFS OR SYNERGIES?

Biodiversity and productivity trade-offs can be considered as a wicked problem (Rittel and Webber 1973). That is, there is no correct answer to a question of optimal or appropriate trade-offs between biodiversity and productivity, but rather a negotiation by participating parties. Particular answers will vary depending on situations and individuals and societal needs at a particular time. Regardless, there is currently only limited synthesised information available on production/ biodiversity trade-offs to inform plantation design and management, even where a particular approach or outcome is desired.

There are many reasons for the limited state of information, including the complexity and timescale of the research required and the limited previous attempts to quantify the various factors involved (see Bradshaw 1992). Nevertheless, workshop participants expressed their concern about the lack of available synthesised information concerning synergies and trade-offs. Synergies between biodiversity and productivity (or profitability) are only beginning to be explored. In fact, it could be argued that we are not yet even at the point of fully identifying key research questions concerning this theme. It is also likely that we need both science and policy changes to promote synergies between biodiversity and production.

Workshop participants generally agreed that we need to be seeking synergies rather than focussing only on trade-offs, because there are so many areas where growing trees can promote biodiversity and where biodiversity can promote productivity. We need to be seeking these synergies in policy, research and management without making the mistake of assuming either that growing trees is automatically good for biodiversity (see Catterall *et al.* in press a, Kanowski *et al.* in press, Wardell-Johnson *et al.* in press) or that increasing productivity automatically must lead to biodiversity loss.

SCALE AND LANDSCAPE

The issues of scale and context are important in any discussion of biodiversity and productivity trade-offs in plantation forestry, as multiple-use landscapes are spatial patchworks (e.g. of pasture, native forest, cropland, and tree plantations). The size, timing and desirable or appropriate pattern of reforestation are also likely to vary between landscapes. For example, in regard to context, it may be appropriate to increase levels of timber production on cleared farmland (provided they do not have adverse off-site effects) in regions that already include an acceptable percent cover of native forest (e.g. 30%, see below). However, in regions whose percent native forest cover has fallen below this threshold, it may be important to plan to include a substantial component of biodiversity in the plantation scheme. In regard to scale, what may be appropriate for a given landholder may not be appropriate for the region as a whole.

There is some potential divergence of individual and social value systems as to the 'optimal mix' of plantations and other land cover types in the landscape, and the 'optimal mix' might vary at different scales (e.g. landholder versus landscape). The area of degraded or abandoned agricultural land provides one estimate of the area, which would optimally be reforested (various estimates are available: e.g. Kent and Tanzer (1983) suggested forty thousand hectares on the Atherton Tableland). However, the focus on degraded land for reforestation reflects an attempt to avoid conflict between different value systems, as degraded land may not be optimal for plantations from a production viewpoint. On the other hand, agricultural enterprises may be abandoned because of shifts in global, national or local economics and public policy. Recent examples include dairy deregulation at the Australia-wide scal,e which has been associated with a decrease in land used for cattle grazing, and trends in worldwide sugar prices which, at the time of writing, were making cane growing uneconomical for many farms. Former dairy and cane growing properties are likely to be suitable for growing rainforest trees, if species are selected to match site conditions.

Another estimate of the amount of revegetation needed could perhaps be derived from the 30% rule of thumb, i.e. under the *Queensland Vegetation Management Act* (1999, amended 2004) forest cover should not be reduced below 30% of its pre-clearing extent. There is an argument for landscapes cleared below this level to be revegetated to at least 30% cover (see, e.g. Kanowski *et al.* in press). Thus, landscapes could be targeted for funding and incentives on this basis.

There is a level of synergy between production and biodiversity requirements in terms of scale. For example, in former rainforest landscapes in tropical and sub-tropical Australia, most reforestation for farm forestry or ecological restoration has been conducted on a small scale (most plots less than five hectares: Catterall *et al.* in press b). However, participants argued that relatively large plots (more than twenty hectares) are needed for viable farm forestry, while it also appears that rainforest plots need to be larger than five to ten hectares to support many specialist rainforest vertebrates. Furthermore, it is likely that large areas of revegetation are needed to have biodiversity and production benefits at a landscape scale.

BIODIVERSITY VALUES AND ENVIRONMENTAL SERVICES OF PLANTATIONS

If we revise our thinking of the value of plantations towards profitability and away from a narrow preoccupation with timber productivity, an opportunity is provided to focus on the range of potential 'products' generated by plantations (e.g. ecosystem services, carbon credits, recreational opportunities) that are currently not given status in many financial models.

Some forest growers, government departments and, increasingly, consumers care about the biodiversity values of plantations. Further, taxpayers, who care about biodiversity often subsidise forestry projects. An argument was presented that if taxpayers care about biodiversity, they should be prepared to pay for the biodiversity values they want from plantations. However, to the extent that production is enhanced by biodiversity, there may not be a need to compensate landholders for managing plantations for biodiversity. For example, it may be possible to reduce fertiliser requirements in mixed species plantations, and hence produce less nitrogenous pollutants, if mixed species are better at capturing nutrients than monocultures, and/ or they include nitrogen-fixing species. On the other hand, if biodiversity is also further enhanced by maintaining very close tree spacing, a forest understorey, and by including non-timber species such as *Ficus* species, and if these lead to reduced profitability, then community-funded incentive payments may be appropriate.

It is likely that markets for environmental services will develop in Australia (e.g. Binning *et al.* 2002), in which case people (or society as a whole) who want biodiversity values in plantations may be able to pay for them. Certification is one route by which landholders might be compensated for managing plantations for biodiversity values (assuming certified products can be marketed at a premium). However, the information that might be required to certify plantations for their biodiversity values is still being developed (see, e.g. Catterall *et al.* in press a).

POLICY AND MANAGEMENT INTERACTIONS AND HARVEST SECURITY

Some would argue that, because large areas of remnant rainforest have been conserved in Australia (e.g. the Wet Tropics World Heritage Area, the Central Eastern Rainforest Reserves World Heritage Area), landholders in former rainforest landscapes should be able to grow trees as a monoculture, like a crop, if they want to, without concern for their potential biodiversity values. However, this approach would ignore both the potential and immediate (e.g. pest control) economic value of biodiversity in plantations, as well as landscape-scale issues (such as the existence of many threatened species outside of these or other nature reserves, and the role of forest cover in regulating ecosystem processes such as climate, water runoff, and infiltration of rainfall). There are also differences in temporal and spatial scale between timber plantations and annual crops, which render comparisons between the two inappropriate.

Many landholders feel threatened by the potential value of their plantations for biodiversity because they believe they may be prevented from harvesting biodiverse plantations. However, most governments have made provision for landholders to register plantations for future harvest. In general, harvest security is likely to increase with the amount of forest cover. Thus, it is more likely to be an issue where little forest cover remains. For example, there is currently some controversy over the clear felling of the old, relatively diverse plantations at Wongabel on the Atherton Tablelands, where the surrounding forest type (5b or Mabi forest) is listed as endangered. Nevertheless, if plantations were to be resumed or protected from harvest, the impacts on industries and communities would need to be considered, and due compensation payable.

Whatever the value of plantations to biodiversity, there is obviously a loss of much of that biodiversity during the harvesting of plantations. It may be possible to use silvicultural solutions (e.g. selective or small-patch logging rather than large-scale clear felling) in dealing with aspects of these kinds of trade-off between biodiversity and productivity (e.g. Lamb 1998; Catterall *et al.* in press a). These issues of potential conflict also raise questions that can be answered through a combination of new types of plantation trials, research and monitoring.

There have been several policy changes concerning forest management in Australia in recent decades, including a shift from logging native forest to plantation development (Catterall *et al.* in press a). Early plantation establishment was carried out through the clearing of native forests, leading to overall increases in productivity, but at the expense of biodiversity. These plantations have usually increased in biodiversity value with time (depending on factors such as management, site properties, and distance to native forest; Catterall *et al*. in press b, Kanowski *et al.* in press). Whether or not overall biodiversity is maintained or decreased in these forest/ plantation mosaics will depend in part on the scale and pattern of the final mix of forest, plantation and other land cover types. For example, forest surrounding plantations (such as scrub breaks and remnants) often includes substantial biodiversity.

More recently, timber production is increasingly sought from plantations on cleared private land, where production of timber will be associated with at least some increase in forest biodiversity. In this case the shift from timber production in diverse native forests to timber production from relatively low diversity plantations leads to a net positive outcome for biodiversity, even though it remains well short of a restoration of the pre-clearing biodiversity. Landscape management is now increasingly focussed on the positive interactions of biodiversity and productivity at a range of spatial and temporal scales. Plantations are increasingly fulfilling multiple roles, including process roles such as that of supporting a diverse functional ecosystem.

CONCLUSION

The promotion of synergies between biodiversity and production or profitability in forest plantations is an area that needs further attention from researchers. Practitioners will also make an essential contribution to developing new approaches, through experiments with different forest designs. Adaptive management, which brings together practitioners and researchers in the monitoring and interpretation of the outcomes of such trials, is also important if the lessons from them are to aid the design of future plantations, established by different proponents. This workshop has clearly demonstrated the need for researchers and practitioners involved in plantation forests to work together to achieve the mix of production, profit and biodiversity that will serve individuals and society well into the future.

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