Sustaining multiple production systems
1. Forest and fodder trees in multiple use systems in the tropics

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Abstract

The benefits of introducing or maintaining a tree component in land use systems are becoming attractive for land rehabilitation and sustainable production purposes. Increasing evidence supports the view that multiple production systems involving trees have some beneficial economic and environmental consequences in many land use programs throughout Australia.

Coordinated research to support these approaches and to demonstrate their implementation and potential is now needed to complement fragmentary research throughout the country. Government policy towards forestry and agroforestry requires redefinition to provide production incentives to increase the impact of the environmental thrust.

Trees have often been included in farm planning for amenity purposes, particularly around farm houses and buildings but less frequently to provide shade and shelter for animals, crops and pastures or to reduce the harmful effects of rising watertables, especially those containing salt. Advantages and disadvantages of including trees in multiple land use systems are listed and their role and potential discussed. There is considerable potential to expand private timber production in agroforestry systems to offset the very large import bill for timber and forest products.

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Paper presented at the Fourth Australian Conference on Tropical Pastures, held at Toowoomba, Queensland, in November 1990.

Resumen

Los beneficios de introducir o mantener el componente arbóreo en los sistemas de uso de la tierra se están volviendo atractivos para fines de rehabilitación de la misma y para lograr una producción sostenida. Una evidencia creciente apoya la opinión acerca del beneficio económico y las consecuencias medio-ambientales de la inclusión de árboles en los sistemas de producción múltiple en muchos de los programas de uso de la tierra a través de Australia.

Para apoyar este abordaje y demostrar su ejecución y potencial se requiere en la actualidad de una investigación coordinada con el fin de complementar la investigación fraccionada que se tiene a través del país. Las políticas gubernamentales forestales y agro-forestales requieren de una redefinición que proporcione incentivos de producción para incrementar el impacto de las fuerzas conservacionistas del medio-ambiente.

En el pasado, la inclusión de árboles en la planificación de la granja se hacia frecuentemente con fines placenteros, especialmente alrededor de las casas y edificios de las granjas pero menos frecuentemente para proporcionar sombra y abrigo a los animales, a los cultivos y a las pasturas o para reducir los efectos dañinos de la elevación del manto friático, especialmente aquel que contiene sal. Se enlistan las ventajas y desventajas de la inclusión de árboles en las sistemas de uso múltiple de la tierra y se discute su rol y su potencial. Se tiene un potencial considerable para incrementar la producción privada de madera en los sistemas de agro-forestería para balancear el alto pago en la importación de madera y productos forestales.

Introduction

Clearing and thinning of forest communities has been a prime activity of landholders since the beginning of European settlement, particularly in the southern half of the continent. The rationale for this is that trees decrease productivity of

herbage by competition for water, nutrients and light, and the decrease becomes more pronounced as competition increases (Scanlan and Burrows 1990). However this belief has generally extended to the extreme of a few trees per hectare or no trees at all. Some consequences of overclearing have been rural tree decline (Beckmann and Davidson 1990), increasing salinity (Bell 1988; Davidson and Bell 1989) and wind erosion (Davidson 1989b). Tree clearing has not been as extensive in the semi-arid woodlands of northern Australia; however there is an increasing interest in tree eradication (Davidson 1989a; Gillard *et al.* 1989).

Agroforestry has become an important part of a new thrust to develop forms of land use more sustainable than the old destructive techniques widely used in agriculture (Reid and Wilson 1985). Agroforestry is generally considered to be the combination of both agricultural and forestry uses of a piece of land. The definition adopted by the International Council for Research into Agroforestry in Nairobi, Kenya is:

> "a land use that involves deliberate retention, introduction, or mixture of trees or other woody perennials in crop/animal production fields to benefit from the resultant ecological and economic interactions" (MacDicken and Vergara 1990).

Two types of agroforestry systems are considered in this paper — trees on rangelands or pastures (classified as a *silvopastoral* system) and alley cropping (an *agrisilvicultural* system). We also discuss some socio-economic and government policy considerations basic to an understanding of the subject of agroforestry and its acceptance in Australia. Pertinent to this discussion are aspects of trade and the serious imbalance between exports and imports in the timber and forest products sector in comparison with other major primary industry sectors.

Advantages and disadvantages of agroforestry systems

Some potential advantages of agroforestry systems have been reported (Gutteridge 1988; MacDicken and Vergara 1990) and those with some applicability to tropical and sub-tropical Australia include:

(a) Increased space utilization both above and below ground with improved recycling of nutrients and organic matter.
(b) Improved soil chemical, physical and biological characteristics with a reduction in the use of chemical fertilizers and improved infiltration of rainfall.
(c) Higher aggregate biomass production from an agroforestry mixture than from a monoculture.
(d) Reduction in microclimatic extremes.
(e) Reduced soil erosion due to the presence of trees. (However if tree canopies are allowed to become too dense, ground cover will be reduced and erosion may be increased.)

There are some potential disadvantages which must also be considered:

(f) Increased competition for water, nutrients and light, leading to reduced yields of both tree and associate crops.
(g) Damage to tree crop from equipment and livestock.
(h) Allelopathy.
(i) Habitat for pests, especially birds in tree-cereal crop combinations.
(j) Reduction in crop area due to tree rows.
(k) Reduced flexibility of land use due to the presence of trees.
(l) Additional labour requirement for tree management.
(m) Potential weed problem through the spread of tree seed into adjacent crop and pasture components.

Ultimately it will probably be the economic and social advantages which dictate the acceptance or otherwise of agroforestry. Some of the advantages are:

(n) Increased and more diversified income opportunities.
(o) A wider range of products can be harvested from the one piece of land.
(p) Labour requirements may be more evenly distributed throughout the year and there is some potential to increase machinery use.

Some of the disadvantages are:

(q) Agroforestry systems which offer significant financial gains directly from the tree component will largely be limited to the better watered coastal areas.
(r) Gains in the semi-arid regions are more likely to be secondary to wood production through improving animal health, survival and production, and erosion or salinity control.

It is increasingly accepted that the advantages of agroforestry, particularly the environmental aspects, outweigh the disadvantages and that many of the disadvantages can be eliminated or

minimised by manipulating management practices (Reid and Wilson 1985). There is a need to test potentially useful systems, including the role of trees in the rehabilitation of degraded areas, over a wide range of climatic and edaphic conditions. In this assessment the fundamental requirements of being productive, sustainable and adoptive (Raintree 1990) must be taken into account.

Agroforestry for tropical and sub-tropical pastures

Australia has a relatively large percentage of its area within the tropics and subtropics, and determining the means of finding out and maintaining the long-term sustainability of the land and disseminating that information to other countries should be a national responsibility. Both agroforestry categories discussed here are representative of the wide range of practices currently in use in many parts of the world, and an Australian contribution to scientific understanding could lead to improved combinations of components being selected and utilized.

Agroforestry — silvopastoral

Casual observation of animals crowding around a sole tree or the shade of a pole in a paddock during periods of hot sunny weather is sufficient to suggest that some shade is important to the grazing animal. High temperatures can induce conception failure, early embryonic mortality and reduced lamb birth weight in pregnant ewes (Roberts 1984), while low temperatures can cause high mortality in lambs and newly-shorn sheep if the animals have no effective shelter (Bird *et al.* 1984). Young calves, and pregnant and lactating cows, are more susceptible to heat stress than other cattle, but all classes of animals grazed for a greater proportion of the day and made greater weight gains in shaded paddocks compared with unshaded paddocks (Daly 1984). Heat stress was identified as the primary cause of the death of 2400 cattle on a feedlot farm near Texas, Queensland ("*The Courier Mail*", February 13, 1991). Shade significantly increased milk yield of dairy cows from 17.2 to 19.2 kg/cow/day (Davison *et al.* 1988).

Management of woodlands for grazing has been examined by Burrows *et al.* (1988). They recommended that as a general guide, between 10 and 20% of eucalypt woodland or open forest be left as shade in either clumps or strips, but in some situations fewer trees, or no trees, should be removed. Gillard *et al.* (1989) found that clearing trees without pasture improvement was not viable in the semi-arid tropics of Australia, and the best return was from no clearing with fertilized stylo pasture. In better quality coastal forests, Ryan *et al.* (1986) achieved good pasture production rates as well as acceptable tree increments when the tree stand was heavily thinned. Trees and shrubs may also contribute to animal production as browse . Wildin (1990) listed species which could provide fodder for stock throughout the year, but especially during long dry seasons when the quality and quantity of herbaceous species are at their lowest.

Recent evidence suggests that shading may also be beneficial to pasture production and pasture quality. Wilson *et al.* (1990) found a 35% increase in accumulated dry matter of a *Paspalum notatum* pasture under trees compared with an open pasture in south-east Queensland. There was also an increase in the proportion of green leaf, nitrogen and potassium concentration, and moisture content under the trees. These findings support earlier work using artificial shade (Wong and Wilson 1980, and Wilson *et al.* 1986) as well as tree shade (Cameron *et al.* 1989).

In a study with varying densities of *Eucalyptus grandis* (flooded gum), Cameron *et al.* (1989) found pasture production was not depressed at some tree densities. Tree leaf area is likely to be the major factor in competition between trees and pasture for water, nutrients and light, and tree leaf area can be correlated with stem cross sectional area (Shinozaki *et al.* 1964). There is a satisfactory correlation between leaf area and basal area at breast height (1.3 m) for young flooded gum (Rance and Cameron unpublished data). Regressions of the form:

$$\log_{10}(Y) = a + b.X$$

where Y = pasture presentation yield (kg/ha) and X = basal area (m^2/ha), were fitted to data from project STAG (Cameron *et al.* 1989). This yielded values of $a = 4.030$, $b = -0.118$, $r^2 = 0.905$ ($P < 0.001$) for 14 observations of basal area ranging from 3.0 to 18.5 m^2/ha. This agrees with work of Scanlan *et al.* (1990). However, there was no correlation for the 35 observations in which basal area was less than 3.0 m^2/ha. This means

that in project STAG 1140 trees per hectare could be grown without loss in pasture production to age 1.5 year, 595 trees per hectare to 2.0 years, and 305 trees per hectare to 3.0 years (Figure 1). On two occasions, at 2150 stems/ha at age 1.0 year and 1140 stems/ha at age 1.5 year, there were increases in pasture production of about 1 t/ha, before competition with the trees reversed the trend. An initial high tree density appears necessary as the trees at densities of 300 or more stems/ha were of superior stem form and crown shape to those at lower tree densities. Thinning could remove the poorer trees and leave those with good form, taper, crown width and depth. Thinned stems were considered suitable for electric fencing, provided they were given preservative treatment.

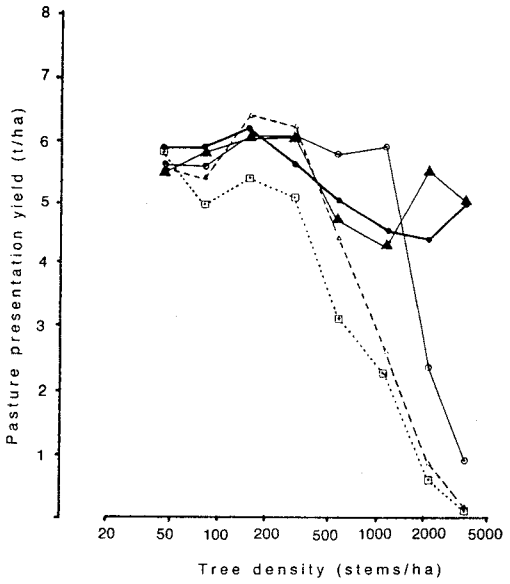

Figure 1. Pasture presentation yield by tree density in south-east Queensland at ages 0.51 (●), 1.03 (Δ), 1.55 ( ), 1.99 (▽) and 3.06 (□) years.

Many of the problems associated with land degradation require remedial action on a regional scale. This recognition has led to coordinated State controlled rehabilitation programs in the south-west and south-east of Australia and a proliferation of land care bodies throughout the country. In some cases belts of trees offer a solution, such as for stabilising land slips on basalt soils in south-east Queensland. On the wettest and most mobile areas any form of tree cover is desirable and thoughts of commercial return would be secondary (Willmott 1984). Similarly, priority should be given to re-establishing forest root networks along cleared stream-bank areas to reduce stream-bank erosion (Cassells 1984). Tree planting is regarded as the most effective means of controlling stream salinity and water quality in south-west Western Australia. The strategy involves a mixture of tree plantings in extensive conventional plantations, wide-spaced plantations with pastures for grazing between trees, and strategic plantings in strips and blocks allowing agriculture to be continued on the unplanted areas (Schofield *et al.* 1990; Water Authority of WA 1989).

Agroforestry — alley cropping

Alley cropping was first developed for the humid tropics as a replacement for the traditional bush fallow "slash and burn" system when sufficient land was not available to allow an adequate fallow period. The restorative power of the bush fallow is linked to the regrowth of deep-rooted trees recycling plant nutrients from below the rooting zone of the undercrop, restoring soil organic matter and suppressing weeds. Alley cropping combines the restorative attributes of the bush fallow with arable cropping so that the two processes occur simultaneously.

Alley cropping systems can be manipulated to minimise disadvantages and consolidate benefits. Maize yields of about 4 t/ha in an alley cropping system with *Leucaena leucocephala* were achieved without nitrogen fertilizer in Nigeria (Kang *et al.* 1981). Similar results were obtained in the Philippines (Dofeliz and Nesbitt 1984), Indonesia (Piggin and Parera 1984), India (Singh *et al.* 1986), Africa (Arap-Sang 1986) and Latin America (Kass and Araya 1987). In these examples, alley cropping offers a permanent, sustainable, low-input form of agriculture, but Steiner (1982) argues that it could be adapted to a higher level of technological input. The biological merits of the system make it appear relevant to current Australian practices which are relatively exploitive and often sacrifice long-term sustainability for short-term gain. The system could be adapted to mechanized farming and have application as wide-spaced rows to prevent wind erosion in cropping areas and to reduce the need for construction of soil conservation banks. Browse species could be lopped when required,

and in mixed cropping and grazing systems tree establishment costs could be offset by sowing a crop between tree rows.

Rachie (1983) detailed important attributes to consider when selecting trees for alley cropping. These are:

(a) Ease of establishment from seeds or cuttings.
(b) Rapid rate of growth.
(c) Ability to withstand frequent lopping.
(d) Nitrogen fixing capacity.
(e) Deep root system with a root distribution different to that of the crop.
(f) Multiple uses such as forage, firewood, fence posts and wood chips.
(g) Ability to withstand environmental stresses such as drought, waterlogging, extremes of pH.
(h) High leaf to stem ratio.
(i) Small leaves or leaflets.
(j) Dry season leaf retention.
(k) Freedom from pests and diseases.

Leucaena leucocephala has most of these attributes (Ssekabembe 1985), and its superiority over other species explains its widespread use (Kang and Reynolds 1986). However its growth is reduced in acid and poorly-drained soils, cooler, high altitudes and subtropical locations (NAS 1984), and by the psyllid *Heteropsylla cubana* (Brewbaker 1986). Further discussion on the role of this species in fodder production systems is addressed by Shelton *et al.* (1991).

Other species which have been used in alley cropping programs include *Gliricidia sepium* (Kass and Araya 1987), *Cassia siamea* (Yamoah *et al.* 1986), *Sesbania sesban* (Yamoah and Getahun 1989) and *Gmelina arborea* (Kang *et al.* 1986). These and other species including *Calliandra calothyrsus*, *Albizia chinensis* and native *Acacia* species may have potential in Australia. Their suitability needs to be examined.

Constraints to the adoption of agroforestry systems

It has been suggested that while agroforestry has an important role in the development of sustainable land use systems in underdeveloped countries, there is little possibility of application to a developed country such as Australia. The Australian lifestyle is remote from the forest, most of our energy needs are derived from fossil fuels and although we make use of the processed products of trees (paper, furniture, building materials), there is generally little appreciation of the role and value of trees in rural production systems. A survey of land users ranked "Sustainable agriculture is an urgent priority" fairly important (1.9 on a scale of 1, extremely important, to 5, unimportant), but "There should be more research into agroforestry" was ranked less important (2.8; CSIRO Division of Tropical Crops and Pastures 1989). Landholders who have shown interest in agroforestry have largely been disillusioned by the total absence of suitable demonstrations of how trees may be incorporated into farming operations and be given a value.

When planning for the future well-being of this country Governments and other funding bodies need to include in their agenda:

(a) The development of techniques which are likely to be productive in the long term and are consistent with the long-term sustainability of the land.
(b) Appropriate rehabilitation of degraded lands and their return to production.
(c) How to pay for (a) and (b).

Socio-economic considerations

Research priorities are rarely directed towards long-term studies and do not attract funding until standard practice fails. By that time, serious losses in production may have occurred, and rehabilitation becomes very costly and beyond the resources of the landholder. The willingness to take new initiatives may also have been lost. Measurement of the interaction of the various components of an agroforestry system presents problems both in time and in procedure. Measurement of tree, pasture, crop or animal production can be relatively straightforward, but long-term changes in other components such as soil properties and site hydrology are more difficult to quantify. Production of components over realistic time scales are also difficult to calculate based on measurements made in the short term. It may also be difficult to equate and collate total production from a system as a whole. Ultimately, economic yields are of critical importance.

The acceptance of agroforestry in the developed world has been slow and in an inverse relationship with the perceived development of a country. Developed countries have adopted monocultural systems over extensive areas for

both agriculture and forestry because it has been economic to do so. Modern economics may countenance such a development, but there is little or no consideration of the long term productivity or sustainability of the system. Maximising immediate returns is considered the correct approach. This may be acceptable and possible over a relatively long term on the very best soils but has been found to be inappropriate on fragile, poor quality soils. Estimates of the area of degraded agricultural and pastoral regions in Australia (Bell 1987) stand as stark evidence of the failure of our stewardship of the land using this approach over the last 50-100 years.

Agroforestry can be considered a potential form of land use in several zones in tropical Australia. On the fringe along the east coast, fertile soils could be used to produce cabinetwoods while the poorer yet still well-watered soils could support a wide range of eucalypt species. The lower rainfall areas further inland could produce durable eucalypt and cypress pine timbers. These products have a continuing and long term market in that region. Clearing programs have operated for decades to eradicate the drier zone *Acacia* species brigalow and gidgee but they still persist. Their timber products have rarely been considered but should be given some attention as the trees have remarkable persistence under difficult conditions and yield durable and very hard timbers. Research programs to examine the potential of these species for fence posts and timber production in this region may help to increase the acceptance of agroforestry in the drier areas of rural Australia.

Government and industry policies

Imports of wood based products into Australia in 1988/89 amounted to $2.172 billion, or 4.6% of total imports (Coopers and Lybrand 1990). Agroforestry could make a considerable contribution to reducing the shortfall in timber products currently available from Australian production. However an initial difficulty for small producers is to gain access to markets, as most tree removals are from public lands or State Forests and smallholders have little chance of negotiating a fair price for their timber. Traditionally, forestry has not been a land use priority for farmers but guidelines on industry organisation and marketing could be developed from the infrastructure existing in other primary industries.

Two contrasting approaches have been used in the development of our primary industry sector. On the one hand, industries such as wool, wheat and meat have had considerable inputs into their production and marketing over many years, farmers and graziers largely make up the total grower system and exports have been a key component of viability. In contrast, Governments have managed and controlled the forestry industry on the basis that long-term planning and investment were necessary. Despite this the industry has been neglected and the need for timber and forest products has grown to such an extent that imports now exceed the value of our meat exports. If forest production was controlled by a large number of small growers then an effective lobby would be established which could respond promptly to market demands. We may then begin to cater for our own timber requirements as the availability of land suitable for growing trees is not a limiting factor in this country. However action, such as taxation reform, needs to be taken to focus attention on the shortfall problem and correct this waste of resources and pressure on our national debt.

A number of schemes have recently been established to address this problem. Bartle (1990) described a pulpwood production "share-farming" scheme introduced for farmers in Western Australia. An investor (the State) underwrites the expected future revenue from plantation establishment on a private farm and after setting aside sufficient funds to cover its costs, pays the farmer the discounted surplus in the form of annual payments. The "Tree Trust" planted 7000ha of *Eucalyptus globulus* in its first two years with emphasis on agroforestry pulpwood cropping systems.

Australia is well placed to carry out research into the possibilities of agroforestry in the tropics and sub-tropics and has a responsibility, as one of the few developed countries in the zone, to do so. Good information has been compiled over many years on the pasture and animal components of grazing systems but little on their interactions with a tree component (Table 1). An understanding of processes in agroforestry would give Australia an opportunity to develop the expertise to provide strategies for management of tropical forests so much in need of rehabilitation. Application of the knowledge in Australia would

be minor in comparison with the technology transfer possible to the zone as a whole.

Table 1. Level of understanding[1] of the various components of grazing systems in tropical and sub-tropical Australia

Grazing system component	Understanding of genetics and breeding	Understanding of nutrition and nutrient cycling	Management of the component as a part of a system
Separately			
Pasture	* * * *	* * * *	* * * *
Animal	* * * *	* * * *	* * * *
Tree	* *	*	* *
Soil	n.a.[2]	* *	* *
Combined			
Pasture/animal	n.a.	* * *	* * *
Animal/tree	n.a.	*	*
Pasture/tree	n.a.	*	*
Pasture/ animal/tree	n.a.	—	—
Pasture/ animal/tree/ soil	n.a.	—	—

[1]Ratings on a scale of nil (—) to maximum (* * * * *)
[2]n.a. = Not applicable

Recently the Federal Government announced a program to establish one billion trees by the turn of the century. The aim was to develop a tree ethic and encourage the community to support the retention, replanting and regeneration of trees. Attention was focussed on environmental needs for trees but there is potential to reinforce this approach with additional economic justification. Perhaps the agency carrying out the program, Greening Australia, could consider providing grants for agroforestry demonstrations which would allow farmers and graziers an opportunity to assess the potential for agroforestry in their region.

Conclusions

Agroforestry is relevant to Australian farming practice. The system makes better use of growth factors, particularly nutrients and moisture in deep soil layers. It reduces the extremes of climate and provides a more equable environment for animals. It permits diversification in terms of both biomass production and economic returns. Agroforestry will have a major role in the rehabilitation of degraded lands and offers a means of replacing imported timber and forest products. With minor modifications it is possible that agroforestry could be used in a wide range of farming areas throughout the country.

There is a need for further research to gain a better understanding of the processes that are operating in the system, particularly competition effects between trees, pastures, crops and grazing animals. Identification of additional tree species suited to agroforestry is important as well as the need to define better management practices to enhance beneficial effects and eliminate negative aspects. In addition, Government policies need revision to provide incentives to farmers to incorporate trees into their production systems.

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