THE CHANGING FOCUS OF PASTORAL AGROFORESTRY IN TEMPERATE ZONES

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ABSTRACT

The emphasis for pastoral agroforestry in temperate zones over the past two decades has been to develop an integrated pastoral/forestry production system with the aim of better financial returns overall than for either system alone. Research programmes were established to quantify this and provide information for future planning. The information gathered encompassed a wide spectrum; tree establishment, tree growth and quality, pasture production, livestock performance, soil and plant nutrient status, microclimate, tree species and spacing and ecological aspects. Results from countries in the temperate zones have shown that agricultural productivity declines as tree age and stocking increased, irrespective of tree species. Sophisticated interactive models have been developed in several countries to predict tree growth, understorey pasture production, livestock grazing returns, identify marketing strategies and financial implications of planting trees on farms. The economics, at least under the price regimes of the last 20 years, have been dominated by returns from trees. In temperate zones where trees grow fast, there is a preference to develop single discipline regimes. The grazing component of agroforestry is financially relatively less important than it was in the 1970's and 1980's. Concern for environmental and sustainability issues, e.g. erosion control, soil fertility, biodiversity, landscape values and animal welfare is again driving the interest in combined land use and the role of integrated tree/pasture systems. The focus now for research in temperate zones is 'fine tuning' agroforestry management systems based on the earlier results. The challenge for our grassland farmers and researchers is to demonstrate the potential benefits of agroforestry systems to the pastoral industry and land use planners; to protect the environment with sustainable methodology and to be financially viable.

KEYWORDS

Pasture, livestock, trees, economics, sustainability, interactions, agroforestry.

INTRODUCTION

The inclusion of Agroforestry as a theme at this Congress is recognition of this science and land use as an important contribution to the grasslands of the world. The science of agroforestry and its multi-disciplinary approach has brought together a comprehensive range of scientists. There have been excellent reviews of world and temperate agroforestry systems at international conferences and in publications over the past decade (Gold & Hanover, 1987; Carruthers, 1990; Sibbald & Sinclair, 1990; Knowles, 1991; Nair, 1991; Bird et al., 1992; Prinsley, 1992; Williams & Gordon, 1992; Buck, 1995; Mead, 1995; and Sanchez, 1995).

The application of agroforestry varies between countries, i.e. from farmer and forest company plantings in countries with deregulated economies to State tree planting programmes and Government subsidised schemes. The needs and directions for agroforestry research have generally been well defined by scientists but these programmes have often been compromised or subsequently abandoned because of conflicting policy or funding priorities. This has tended to be a greater problem in larger countries where the co-ordination and maintenance of such long term programmes requires considerable foresight, liaison and persistence by dedicated individuals. The general understanding of agroforestry is changing as people acknowledge the wide ranging implication and long term effects of it on our land.

HISTORICAL PERSPECTIVES

Silvopastoral agroforestry systems in the temperate zones have been researched intensively for only two decades (Gold & Hanover, 1987). The fundamental reasons for research in each country have been similar, i.e. the increasing importance and value of timber, the declining financial returns from livestock and a desire to find alternative forms of land use for environmental reasons.

In New Zealand there was a shortage of traditional land for both intensive agricultural or forestry use and at the same time developments in plantation forestry with "direct sawlog" regimes for *Pinus radiata* (Fenton & Sutton, 1968). Consequently, Forest Companies bought many marginal pastoral farms which were then planted in pine trees. Intermediate grazing with sheep and cattle was used as an opportune way of utilising the understorey pasture and maintaining some cash flow (Knowles, 1972). The subsequent interest in silvopastoral systems encouraged a combined research programme on *Pinus radiata* between the New Zealand agricultural and forest research organisations.

This programme, which encompassed four large scale projects in both North and South Island locations, is still active and the same projects are nearing tree crop maturity. These agroforestry research projects are based around the management of the tree crop, production of timber and agricultural products, and a study of the effects of trees on a range of biological and productive parameters. That these projects have survived is a reflection of the persistence (and dedication) of research personnel, the recognised increasing value of long term projects and financial support from both the Government and the forest industry.

More recently, new agroforestry process studies have commenced at Lincoln University, Canterbury (Mead et al., 1993) and alternative tree-pasture associations for hill country farming environments in the North Island (Thorrold et al., 1997). Shelterbelt management systems received some research attention in the 1970's and 1980's and a co-ordinated programme commenced in 1991. Reviews of the timber production aspects of shelterbelts have been undertaken by Chavasse (1982) and Tombleson (1993) and an excellent review on the role of shelterbelts in protecting livestock has been published by Gregory (1995). Forest grazing, where the understorey in plantation forests is grazed by cattle and sheep, has been practised over the past 25 years. Forest grazing was primarily seen as a weed control measure, but the introduction of forage legume species has improved the nutritional value of the understorey (Knowles, 1991).

The present application of agroforestry in New Zealand is mainly with farmers and investment companies who are currently planting woodlots, at a rate of 60-100,000 ha per year.

The Australian interest in agroforestry commenced for many of the same reasons (Moore & Bird, 1997) but without the competition by forest companies for farmland. Agroforestry was seen as having the potential to diversify farmer incomes, provide landcare benefits and produce much of the nation's future timber requirements. Long term research projects were initiated in Western Australia (Anderson & Batini, 1983). Similar parameters were measured to those in New Zealand but climatic variations encouraged a range of other studies such as the use of pine needles for sheep feed in times of drought (Anderson, 1985). In Victoria and New South Wales, co-ordinated silvopastoral agroforestry studies commenced in the 1980's and these projects now form the basis of an interdisciplinary agroforestry research programme (Kellas et al., 1995; Bird et al., 1995). Non-production values of trees, such as their role in reducing ground water salinity are now a focus of their research programme (Institute of Foresters of Australia, 1989). The adoption of agroforestry practises is increasing through "trees-on-farm" schemes throughout temperate Australia.

In the United Kingdom, a resurgence of interest in agroforestry became evident in the 1980's as a result of the need to find alternative forms of land use. This interest was driven by mounting agricultural surpluses in the European community, a dwindling supply of quality timber and growing environmental concerns (Sibbald & Sinclair, 1990). The agroforestry research programme came under the stewardship of the UK Discussion Forum; an informal group of scientists who set up a national network of silvopastoral experiments. Much of the research has involved detailed studies of ecological and physical processes. More recently, this network has been incorporated into a European pastoral agroforestry project, co-ordinated from France.

Pastoral agroforestry in North America has had a chequered history over the past two decades (Gold & Hanover, 1987; Schultz et al., 1995). Individual experiments in southern and northwest USA have highlighted multi-use management systems and the need to balance forage availability with animal performance when grazing under plantations. The use of animals has primarily been an alternative to chemical control for weeds and fire hazard vegetation. In the vast rangelands of America, cattle have been used extensively in plantations.

The Canadian agroforestry experience has primarily been with grazing sheep and cattle in rangeland situations to control competing vegetation and reduce fire hazards. Forest grazing in Canada is a controversial topic associated with negative aspects of forest degradation due to overgrazing. Large scale operational trials have commenced in British Columbia using sheep to control weeds in new plantations (Ellen, 1992). Field shelterbelts are a feature of the Canadian prairies but their use as livestock windbreaks is primarily to improve animal health, survivability and increase feed efficiency rather than in a silvopastoral context. Silvopastoral research in Canada is considered to be at an embryonic stage of development (Williams et al., 1997).

In several other temperate regions, silvopastoral systems have been practised for many years, predominantly as subsistence farming. This is particularly so in the temperate areas of China (Hsiung et al., 1995), India (Khosla and Kaushal, 1992) and South America (Gutmanis pers comm). Innovative agroforestry projects have more recently been conducted in China and India, but few on silvopastoral systems. In temperate South America, pastoral agroforestry is at an early stage of development.

RESEARCH RESULTS

This section outlines the results from pastoral research projects in temperate zones, with particular reference to New Zealand.

In New Zealand, where pasture productivity has been measured over a 20 year period from four agroforestry trials planted in *Pinus radiata*, there was declining production relative to open pasture (no trees) as tree stocking and tree age increased (Figure 1). At tree stockings of 200 and 400 stems per hectare (sph), this decline was associated with canopy closure and shading. This rate of decline varied primarily due to latitude induced climatic and tree growth conditions such that pasture was still available in the South Island trial, at 400 sph, for six years longer than in the North Island trial, 900km to the north (Cossens & Hawke, unpubl.). At a lower tree stocking of 100 sph, there was some pasture production through to tree age 24 years, although pasture species had changed (Hawke & Gillingham, 1997) from an initial ryegrass/white clover based sward, to native grass *(Microleana stiploides)* after 24 years.

In the main agroforestry trial at Tikitere in the central North Island, livestock performance was monitored before canopy closure occurred. As expected, livestock carrying capacity declined as pasture production decreased. Livestock performance trials showed that young sheep gained weight satisfactorily under low tree stocking regimes of 50 and 100 sph, providing that adequate fresh grass was available. Under higher tree stockings, it was difficult to grow a sufficient quantity of nutritious grass to adequately feed livestock (Hawke et al., 1993).

Recent studies on soil chemical and microbial changes during tree growth have reported decreased soil pH, soil organic phosphorus and microbiological activity with increasing tree stocking (Hawke and O'Connor, 1993 and Perrott et al., 1996).

In other New Zealand studies, Pollock et al. (1994) reported reductions in pasture production from a three year stand of 1000 sph *Pinus radiata*, compared with open pasture. Gilchrist et al. (1993) measured pasture production at a range of distances from the trunks of poplars, willows and eucalypts over a three year period. They reported depressed pasture yields close to the trunks. A recent project investigating tree/pasture associations is reporting reduced pasture yields with increasing stockings of 7 year old acacia trees (*A. melanoxylon*), although the rate of decline with tree size is less than that measured for *Pinus radiata*, (Thorrold et al., 1997).

Data from the main long term agroforestry trials and measurements from farm woodlots in the New Zealand North Island were used to develop a predictive relationship (Percival & Knowles, 1988). Analysis showed a curvilinear relationship between relative pasture production and the tree crop, dependent on the sum of the crown lengths per hectare and mean crown length per tree. This relationship which is about to be updated, incorporating data from other trials both in New Zealand and Australia, will strengthen the model.

The Australian evidence is illustrated by data from Western Australia and Victoria. Anderson & Moore, (1987) and Anderson et al. (1988) reported similar pasture production early in the tree rotation under a range of *Pinus radiata* tree stockings, but there was a significant reduction by tree age 7 with the higher tree stockings. This reduction became more pronounced by tree age 20 at a lower tree stocking (Table 1). In Victoria, Kellas et al. (1995) also measured reductions by tree age 7 at the higher tree stocking (Table 1). In Western Australia, Anderson & Batini, (1984) measured pasture in a mid-rotation of *Pinus pinaster* and reported reductions at 90 sph by tree age 18. Trials that included eucalypts (*E. camaldulensis*) also grew less grass with increasing tree stocking (Moore & Bird, 1997).

In Britain, an experiment measuring pasture production in boxes situated beneath Sitka spruce (*Picea sitchensis*) tree canopies reported overall reductions in growth rates at the lower tree spacing configurations (Table 2; Sibbald et al., 1991).

The evidence from North America suggests that where interactions have been measured, forage yield decreased with reduced light availability (Lewis, 1983). In summary, the collective evidence from research conducted under a range of tree species throughout the temperate zones clearly demonstrates that pasture yields decline with increasing tree stocking and age. The relationship between tree species varies due to a range of factors, e.g. light transmission, nitrogen cycling and moisture use.

IMPLICATIONS OF RESEARCH RESULTS

Under a predicted future climate of increasing economic and environmental pressures, land use will change over substantial areas of the temperate zone, particularly in industrialised nations (Williams et al., 1997; Schultz, 1995; Moore & Bird, 1997). The increasing importance of plantation forestry for supplying world timber requirements means that more temperate grasslands are likely to be planted in trees. The build up in soil fertility of grasslands, usually over many years, from added fertiliser and animal recycling of nutrients is a bonus for tree growth (West et al., 1982).

The implications of this, as shown by studies in New Zealand are that higher tree stockings can be supported and trees can use the extra fertility by growing more timber per hectare. In this situation increased competition between trees also restricts branch growth which adds value to timber grades above the pruned butt log (Maclaren, 1993). This increased timber yield is at the expense of pasture growth. The associated earlier canopy closure and direct competition between trees and pasture for available light results in a more rapid loss of grazing.

Relatively widely spaced conifers have been found to have several drawbacks. They produce extra large butt logs which current machinery is not designed to handle, large branching which reduces timber quality and marketing flexibility, under-utilisation of the land and the likelihood of more wind damage. The benefits to farmers of wide spacing are a cash flow from livestock sales well into the tree rotation, and some shelter. However, reduced fodder quantity and quality late in the rotation make matching of feed supplies with animal requirements quite difficult.

In both New Zealand and Australia, the pasture on most agroforestry areas is not used to its potential. It is usually regarded as run-off pasture for dry stock and is therefore not grazed to its full advantage. Lax grazing may also be necessary to prevent stock damage to the trees early in the rotation. The cost of providing adequate fencing and water supply is often not justified with the reduced financial returns from sheep and cattle livestock sales. The introduction of a legume into forest floor situations, e.g. ‘Maku’ lotus (*Lotus uliginosus*), can benefit timber growth and provide a supply of quality forage for cattle (West et al., 1991). However, again the cost and maintenance of fencing and water supplies and the risk of cattle rustling has resulted in the potential benefits of this type of agroforestry not being achieved.

The research and experience with *Pinus radiata* agroforestry in New Zealand show two clear results. The first is that wide spacing produces unsatisfactory timber returns. The second is that even at low tree spacings, maximum grazing returns are unlikely to be obtained because the management requirements cannot be financially justified. Both of these factors point to a move to higher tree stockings being planted on farmland in future - a trend that has already commenced with farmer woodlots and investment companies. As a result of purely financial considerations, the original agroforestry concept would appear to have a limited future in association with *Pinus radiata* in New Zealand.

The New Zealand experience has been almost entirely with *Pinus radiata*: When results are available from research with other tree species, there may be opportunities and positive encouragement to consider pastoral agroforestry with lower tree stockings. The utilisation of high value timber crops and the maintenance of pastoral activity are possible outcomes of present research studies.

In other temperate zones, it appears that the implementation of research results and the adoption of agroforestry is very dependent on tree planting schemes and subsidies. Tree rotations are very long term in many countries, so apart from Australia and New Zealand, research results have been slow to be put into practice.

FUTURE LAND USE DIRECTIONS

The priorities for future land use will be dictated by the balance between economic and sustainability issues.

In New Zealand, a small country of 26.8m ha, the face of the landscape is changing quickly, primarily due to commercial priorities. Whole farms in selected areas are being purchased by forest companies and investor groups. Forest companies may choose to sub-divide off the best pastoral areas of a farm as rural lifestyle units or for intensive agriculture, e.g. as grazing for dairy cattle. These opportunities benefit the community by retaining rural services. However, investment groups are usually funded by a wide range of people, usually for superannuation purposes. Their primary interests are to obtain the best returns as soon as possible. This usually means planting of the whole farm area with a fast growing tree species (e.g. *Pinus radiata*), keeping maintenance costs as low as possible and aiming for a projected harvest date of 28 years. Grazing is incidental, depending on the scale of the operation as it often complicates management and involves fencing, water supplies and stock handling facilities.

While forest companies and investment groups are planting trees on large blocks of ex farmland, there is another movement which is also resulting in increased plantings on farms. This consists of farmers, who are realising that forestry is a profitable venture, which they should be involved in. Consequently more farmers are planting parts of their farm in trees as a means of both diversifying income and prolonging the financial viability of their total farm operation. The goals that farmers have for land use management are broadening to include sustainability issues, e.g. soil erosion control, riparian plantings, biodiversity and water quality (Maclaren, 1996).

There are predictions that the rate of planting *Pinus radiata* trees onto pasture in New Zealand will continue at the present level for several years (cited in Maclaren, 1996). Inevitably, much of this planting will be on marginal country. While it is hoped that farmers will be the driving force behind this planting boom, foreign investment will increase. This does have repercussions in land ownership issues. Erosion control rates very highly as a reason for planting trees (Wedderburn, pers comm) and the use of hard wood alternative species is likely to increase.

The associated potential benefits for animal shelter, increased fodder dry matter supply, soil water quality and aesthetic appearance are all factors that are encouraging a new interest in tree pasture relationships, especially in the higher rainfall hill country pastoral regions of New Zealand.

Longer tree rotations in northern temperate zones result in areas being committed to one land use for long periods of time, denying options for alternative uses and landscape designs. However, in these same North American and European zones, the emphasis on environmental considerations is relatively greater than in the southern hemisphere countries and is causing political pressure for changes to traditional land use patterns (Acworth & Hutton, 1993).

In New Zealand, the recent Resource Management Act (1991) has accelerated the move towards developing sustainable management systems. Sustainable land use planning technology is being used to evaluate and develop tree planting strategies (Taranaki Regional Council, 1992). Computer based modelling systems such as STANDPAK (Forest Research Institute, 1993) analyse the outcomes of a range of options; labour requirements, livestock numbers, annual cashflow and wood volumes at harvest. These systems can be extended to include social aspects, conservation issues and agroforestry estate management (Knowles, 1993).

The challenge is to develop methods for landscape design where high quality pasture is maintained and utilised, in balance with tree species that are both effective and economically worthwhile and where this management technology is rapidly and widely spread to all interested land users.

The major direct costs of establishing and maintaining pastoral agroforestry are the purchase of tree seedlings and herbicide, and the tree planting and management costs. The effect of these can be reduced by planting only small areas annually and/or establishing joint venture partnerships with other investors or a forest company. Indirect costs include the loss of grazing, shading, and the possible increase in weeds. The net effects of these depends largely on how production in the non forested areas can be increased, especially in the later years of a tree rotation when available grazing within the planted areas is reduced to near zero.

Shelterbelt systems offer major contributions to both the timber and pastoral industries providing that they are properly designed and managed. By managed, it is meant that shelterbelt design, tree species, orientation of the belt, pasture and livestock management are all considered. The interactions between shelter, pasture and livestock appear to be more complicated than in evenly spaced agroforestry designs (Gillingham & Hawke, 1997). The increasing worldwide concerns for domestic animal welfare suggest that farm shelter, particularly in countries where animals are outdoors all year round, is likely to be a greater priority in the future, with an associated increase in appropriate shelter plantings.

Forest grazing is unlikely to achieve its potential in New Zealand because of the poor economic returns from livestock farming and the cost of management. However, in North America, this form of agroforestry is historically popular and will continue to be so (Pearson, 1991).

High value edible and shade tolerant crops such as ginseng (*Panax ginseng*) and mushrooms are being grown in association with tree crops in New Zealand (Follett et al., 1994). Leaders in this field are the U.S.A. and China where a range of crops are grown (Williams, et al., 1997 and Hsuing, 1995).

FUTURE POLICY, RESEARCH AND TECHNOLOGY TRANSFER DIRECTIONS

There is good evidence, particularly from the U.S.A., that policies are being prepared which could provide support for agroforestry research and development (Schultz et al., 1995). The extent to which these policies will result in action depends very much on the initiatives shown by the scientific institutions and the support funding available. Initiatives such as the Stewardship Incentives Programme (1991) and the Association for Temperate Agroforestry appear to offer more effective co-ordination of pastoral agroforestry.

In Europe, a pastoral agroforestry research network is the main avenue for applying technology (Sibbald, pers comm); it has support from the E.C. and a co-ordinated programme gives fresh impetus to agroforestry. British researchers will continue to focus on below and above ground interactions and the results used to develop ecological and financial models (Acworth and Hutton, 1993). In France, there is likely to be continued emphasis on the effectiveness of tree shelters in establishing agroforestry (Dupraz and Baldy, 1993).

Technology changes in Australia have paralleled many of the New Zealand experiences. Computer models such as FARMTREE (Loane, 1991) have been developed to help extension officers evaluate returns from agroforestry. New research projects are planned in consultation with landcare groups and farmers. Technical development will concentrate on improving the viability of agroforestry linked with the need to protect soils and water from further degradation.

Technology transfer is arguably the domain of the consultant rather than the researcher. However, consultants are generally discipline specific and an understanding of all the issues relevant to agroforestry is rarely present. In New Zealand many agricultural consultants have not appreciated the value of trees for asset growth and landscape enhancement and similarly forest consultant knowledge of agriculture varies greatly. Despite these limitations, a deregulated market has resulted in 60-100,000 ha of trees being planted on pastoral land each year (Knowles, 1993). The New Zealand Farm Forestry Association represents private growers and its membership is growing rapidly. Regular field days organised by farmers in New Zealand and Australia have been successful in promoting agroforestry and are likely to continue to provide the main venue for technology transfer to the agroforestry end users. These farmer groups provide a model which could be more actively developed in other temperate countries to improve the standard of agroforestry production systems.

In New Zealand, future agroforestry research is likely to be focussed more on tree species other than *Pinus radiata* which may be more compatible with long term pasture use and also provide valuable timber at wide spacings. In addition second rotation crops on previous pastoral land will require research to measure the long term effects of agroforestry on below and above ground interactions and also the implications of re-conversion back to farmland.

CONCLUSIONS

Pastoral agroforestry research programmes have provided a considerable amount of information, much of it quantifying the effects of trees in a range of situations. The results have given a picture of competition effects, management requirements and an understanding of the dynamic and often complex interactions taking place.

Traditional land uses and changing political agendas have determined agroforestry progress in northern hemisphere temperate zones. In southern hemisphere temperate zones, the economics of planting trees on pasture are clearly defining the direction in which we are heading.

Indiscriminate planting of trees over the pastoral landscape will certainly increase the timber resource, but in my opinion it may do little to promote a balanced land use. On the other hand, jealous protection of our grasslands may not be in the best interests of sustainable and profitable land use. Strategic planning, the use of interactive models and a multi disciplinary approach to agroforestry science is vital to optimise and promote the changes that are occurring. The sooner all these facets are integrated in a district, state or even national management plan, the sooner we will achieve the goal we should be seeking — a sustainable environment. We need a better understanding of the land user and his goals. Pastoral agroforestry in temperate regions has considerable benefits to offer — timber, livestock production, erosion control, conservation, landscape variety, salinity amelioration to name a few. The talents and experience we individually and collectively have should be harnessed to promote what could be the dominant pastoral land use of the future — agroforestry.

ACKNOWLEDGEMENT
The author thanks Dr A. Gillingham, Dr B. Thorrold and Mr J. Tombleson for manuscript comments and suggestions.

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Figure 1
The effects of stocking and age of Radiata pine on relative pasture dry matter production at the North Island (NI) and South Island (SI) agroforestry trials, New Zealand (sph = stems per hectare)

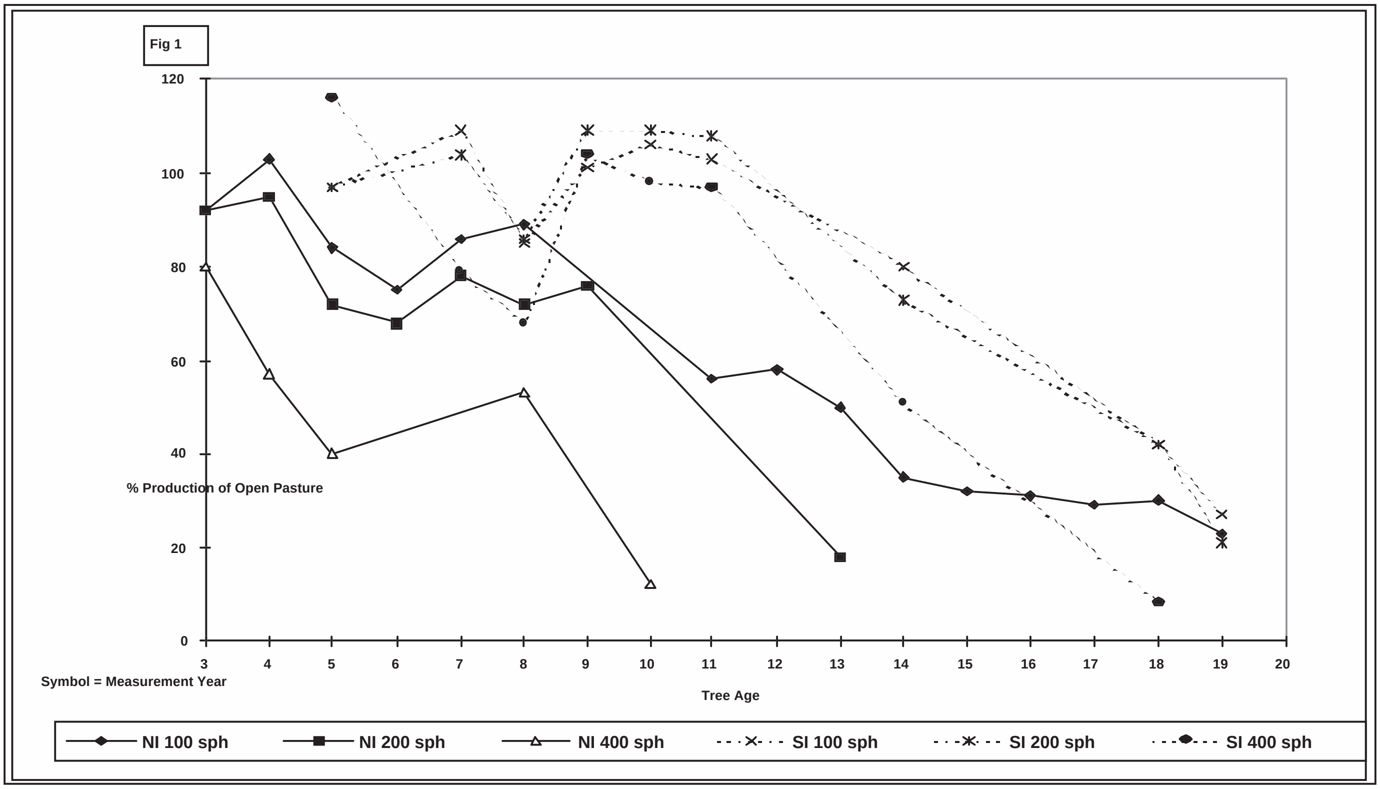

Table 1
Relative pasture dry matter production from Australian *Pinus radiata* agroforestry trials. At the Western Australia site, results are relative to open pasture production = 100%. At the Hamilton and Branxholme sites, results are relative to areas with 35sph = 100%

Location	Western Australia[1]				Hamilton, Victoria[2]				Branxholme, Victoria[2]			
	Tree Stocking (trees/ha)											
	70	100	150	300	60	90	130	225	60	90	130	225
Tree Age — 7 years	-	87	-	76	92	95	87	79	78	86	92	67
Tree Age — 20 years	67	-	39	-	-	-	-	-	-	-	-	-

1 From Anderson et al., 1988
2 From Kellas et al., 1995

Table 2
Relative pasture dry matter production from a Sitka spruce agroforestry trial[1] at Glentress Forest, Scotland.

	Dry matter production (as % of open pasture)		
Tree (trees/ha) stocking	156	278	625
Tree height 3m	80	84	56
Tree height 5m	80	72	10
Tree height[2] 8m	91	77	17

1 from Sibbald et al., 1991
2 pruned to 1.5m height