ARTICLES

Studying interactions between pastures and *Pinus radiata* in Canterbury's subhumid temperate environment – the first two years

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An agroforestry experiment, established in 1990, was designed to study both the potential of a range of pastures for growing under Pinus radiata in a dryland Canterbury climate and the competitive processes between the trees and pasture. The main trial consists of five pasture treatments plus a bare ground control (no competition to the trees). Within these main plots are subplots of five tree types of radiata pine; four are tissue culture clones and the fifth is a GF 14 seedlot of "850" selections. Trees were planted at 1.4 by 7 m spacing. A second part of the trial consists of pasture treatments without trees. Until sheep are introduced at age three the pasture is being cut for silage.

After two growing seasons both lucerne and phalaris with clovers were causing a marked reduction to tree height and diameter growth. Pine N and K foliar levels were lower in these plots while Mg was increased. There were no statistical interactions between pasture and tree type for growth or nutrients, suggesting that specific breeds of radiata pine are unlikely to help overcome competitive effects from pasture.

At age two years the experiment has also shown that seedlings are more prone to toppling and have more malformation than the trees derived from tissue culture. While the larger trees within a tree type are more liable to topple, the fastest growing genotype from tissue culture had almost no toppling, indicating that there is also a clonal effect not related to growth rate.

Detailed process studies have begun. A better understanding of these and relative pasture/tree performance should assist the design of appropriate silvo-pastoral systems for subhumid climatic zones.

Background

The growing of widely-spaced radiata pine trees on improved pasture in New Zealand is an option many farmers are considering for a variety of reasons such as shelter, diversification, or controlling erosion (Maclaren 1988; Fairweather 1992). In some circumstances the result has been greater overall productivity.

Excellent work on some aspects of management, silviculture and pastures has been undertaken by farmers and research organisations. This has led to a considerable body of experience and to the development of two agroforestry models to evaluate the economics of this land-use option (Knowles 1988; Knowles *et al* 1991).

However, less is known about contrasting pasture types, how these perform under trees, or how standard ryegrass/clover pasture performs under trees in the Canterbury climate which is drier than that of the central North Island where most studies have been concentrated.

Nor do we know a great deal about competition processes between radiata pine and pasture in an agroforestry situation. At Rangiora studies in four-year-old radiata pine and a ryegrass/cocksfoot/white clover pasture mixture suggested that moisture was the main factor involved (Clinton and Mead 1990). More recent work on pumice soils has suggested that Mg uptake can be restricted by pasture (Payn 1991). There have also been a number of studies on the competition between weed species and radiata pine grown in industrial plantations (Boomsma and Hunter 1990) and some have specifically considered the control of herbaceous weeds and grasses (e.g. Balneaves 1982; Squire 1977). In dryland climates of Australia the results have generally emphasised the importance of moisture stress (Nambiar and Zed 1980; Sands and Nambiar 1984) and sometimes competition for nitrogen, particularly where fertilisers have been applied (Squire 1977; Squire *et al* 1987). In one interesting study Waring and Snowdon (1985) found that clover grown with closely spaced *P. radiata* was initially a vigorous competitor particularly during low rainfall periods. However, in the long term when the clover had been completely suppressed and its nutrients released, pine growth was greater than in the non-clover treatment.

Ong (1991) reviewed competition processes in agroforestry in the tropics, partly drawing on inter-cropping examples. His review highlighted how it was possible to design systems to obtain greater productivity based on understanding the competition between trees and agricultural crops for light, water and nutrients. We would argue that a similar understanding is required for radiata pine. Furthermore, by including a range of tree types in this experiment we hoped to explore the possibility of breeding specific lines of radiata pine that would be better as a pasture overstorey. Monitoring of processes would be also facilitated by controlling the genetic variation.

The trial described here is a joint venture between Lincoln University and the School of Forestry, University of Canterbury. A number of Lincoln University Departments are involved in this interdisciplinary research, including Plant Science, Soil Science and Animal Science.

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Trial objectives

The experiment has a number of objectives, the main ones being:

1. to study the competition for water, nutrients, shelter, light, and space between radiata pine and a range of pasture mixtures;
2. to determine if different pine tree genotypes/propagation methods behave the same with respect to pasture competition;
3. to determine the most appropriate pasture to use in silvo-pastoral systems in subhumid, temperate climates.

This report of the first two years' results concentrates on tree and pasture growth, including information on tree malformation and toppling as influenced by treatments and tree type.

Methods

Site

The trial is located 2 km from Lincoln University on a site which in the season prior to planting had been planted in vining peas. The soil is classified as a Templeton silt loam and consists of 1 to 2 m of fine alluvial sediments over gravels. It is medium to free-draining with a moderate capacity to hold moisture. The site has only slight changes in topography, but there is variation in depth to the underlying gravels.

The climate at the site is described as temperate and subhumid. The nearest permanent climate station is 2 km away at Lincoln. The long-term rainfall average is 666 mm, generally being well distributed through the year, but with considerable variability from one season to the next. For example, in the first two growing seasons of the trial (June to May) the annual rainfall was 712.0 and 524.8 mm, respectively; moreover there were five months in 1991 – 92 where the rainfall was less or equal to half the long-term monthly average. Summer droughts are common. Long-term climate data show that raised open pan evaporation exceeds rainfall for eight months of the year, from September through to April. The average annual evaporation is about double the rainfall.

Mean annual temperature averages 11.4 °C, with mean monthly temperatures falling below 10 °C from May to September and with December to February having mean annual temperatures over 15 °C. Ground frosts are recorded on 90 days per year, on average.

The predominant wind is a cool sea breeze from the north-east, but the site is exposed to cold, often moist south-west gales and hot dry north-west fohn winds. The latter are most frequent in the spring and summer and often aggravate any drought. Mean daily windrun averages 279 km and is generally somewhat lower between May and August.

Experiment

The experiment is in two parts. Part A, which covers a total of 5.2 ha, is a split-plot, randomised block design with three replications. The six main plot treatments are various pasture combinations aimed at providing a range of competitive situations under the trees (Table 1). They range from bare ground through to lucerne which was included as it was expected to be a severe competitor. Sub-plot treatments within these main plots compare five different tree types of radiata pine (Table 1). Four of these are clones produced by tissue culture by Tasman Forestry Ltd at Te Teko. The fifth is a seedlot of low genetic improvement. In the remainder of the paper we refer to these tree types as "seedlings" or by clone number.

The seedlings were from seed collected from an open-pollinated seed orchard of "850" parents (see Shelbourne 1986 for information on the various radiata pine selections). They are classified as having a growth and form rating (GF) of 14 (Vincent 1987). Three of the four tissue culture clones (set 38) are half-sib crosses of clone 55 from the "850" tree selections. It is expected that these will have a GF 15 rating (J. Gleed *pers comm*). Set 38 was four years from seed when planted. The fourth tissue culture clone (11/8) was from a full sib cross of clones 7 (female) and 292 (male) from the "875" series and is expected to have a GF rating of about 16/17. This tissue culture line was six years from seed when planted and has higher than average wood density (J. Gleed *pers comm*).

The gross area of each plot is 42.0 x 46.2 m (0.194 ha). Within each plot there are six rows of trees with the trees planted at 1.4 m within the row and 7 m between rows. The subplots of tree types are six rows of five trees running across the main plots. The outer rows are buffer rows, so that at establishment there were groups of 20 trees of the same tree type within the central measurement area of the subplots. Three rows of trees were planted at either end of the main plots to act as a buffer with the adjoining main plot; in addition a tree was omitted between pasture treatments to allow for a fence to be erected. Thus no measurement tree is within 5.6 m of a different pasture treatment. This should be an adequate buffer as Clinton and Mead (1990) found that on a similar soil type radiata pine roots seldom extended beyond 2 m at age five years.

Trees were planted at 1000 stems/ha, the initial close spacing along the rows being chosen to ensure a full stocking and to allow destructive sampling in the first four-five years of the trial. The proposed final crop stocking will be 200 stems/ha.

The trees were planted in July 1990. All trees were flown down from Te Teko and were planted on the same day. Care was taken to block out the possible effects due to different tree planters. One-third of the green foliage was buried at planting.

Tree rows were ripped to a depth of 50 cm prior to planting and were strip sprayed (1 m wide) with hexazinone at 2.5 kg a.i. ha^{-1} in the springs of 1990 and 1991. This was to ensure good tree establishment. The bare ground plots have been kept weed free by spraying with hexazinone and glyphosate as required.

The trees were measured for diameter (at 5 cm above the soil

TABLE 1: Treatments in part A of the agroforestry trial at Lincoln University.

Main plot treatments: Sowing rates (kg/ha) in brackets.

1. Bare ground
2. Maru phalaris (8) + clovers
3. Wana cocksfoot (10) + clovers
4. Yatsyn perennial ryegrass (13) + clovers
5. WL320 lucerne (8)
6. Weeds (Yatsyn perennial ryegrass)

Notes:

Clovers = Pawera red (6), Huia white (2) and Woogenellup subterranean (10).

Treatment 6 was originally sown in Maku lotus, which did not establish. It was resown in Yatsyn ryegrass in autumn 1992 to give a minus legume pasture treatment. For the purpose of the result presented here the treatment is essentially one of volunteer weeds dominated by wireweed *(Polygonum aviculare)*.

The treatment replacing bare ground in the open pasture is Roa tall fescue.

Sub-plot treatments

Clone 1	–	Set 38/6	half sib of "850" clone 55
Clone 2	–	Set 38/203	half sib of "850" clone 55
Clone 3	–	Set 11/8	full sib of "875" clones 7 x 292
Clone 4	–	Set 38/9	half sib of "850" clone 55
Seedlings	–	"850" open pollinated seed (GF 14)	

surface) and height at planting and at age one and two years. Malformation of each tree was also recorded. Some toppling of the trees occurred in southerly storms over the second winter; so in August 1992 the angle of toppled trees was measured.

In March 1992 (autumn of the second growing season) foliage was collected from each tree type and pasture treatment and analysed for N, P, K, and Mg (see Nicholson 1984 for methods). The needles were taken from 2nd order branches in the upper crown from each sub-plot tree and bulked prior to analysis.

The pastures were sown in the spring of 1990. The autumn fallowed land was cultivated before planting the trees and again in late September. This produced a fine firm seed bed and pasture mixtures (see Table 1 for details) were drilled on September 28 and October 2, 1990. Main plots will be fenced in winter 1993 and grazing with sheep will commence in the spring.

Part B of the trial to the east of Block A, covers 1 ha, has three replicates of the pasture mixtures but no trees. There is no bare ground treatment in this part of the experiment, and a sixth pasture treatment is included (but not reported here). Plots are 27.5 m by 18 m or 0.05 ha.

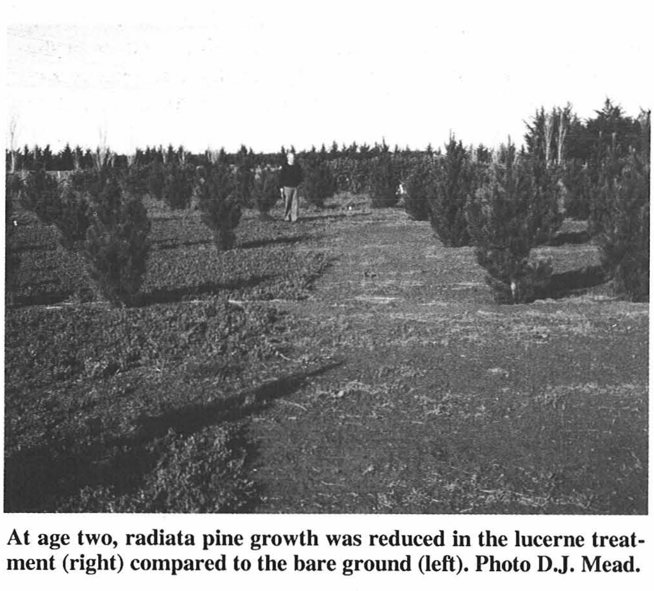
The pasture was cut for silage on four occasions in the first two growing seasons. The dry weight of the pasture was measured by sampling measured lengths from the mown swath, weighing fresh in the field and subsampling for dry matter content and botanical composition.

Data were statistically analysed using the appropriate split-plot model. The Tukey multiple range test (5% level) was used to compare differences between pastures or tree types.

Results to age two years

The results of the statistical tests on tree growth showed that the interaction between understorey treatments and the pine tree types was not significant ($p > 0.3$). Statistical differences between understorey treatments were not apparent at the end of the first year, but they were highly significant ($p < 0.001$) at the end of the second year (Figures 1 and 2). The most marked reduction in tree growth due to pasture competition was in the phalaris + clover and lucerne treatments (Photo below). These resulted in a 25% reduction in height growth and a 45% reduction in the diameter at the base of the stem.

The tree types also differed significantly ($p < 0.001$) with one clone being consistently better in height and diameter than the others (Figures 3 and 4). The seedlings were of similar height to the slowest-growing clone but in terms of diameter they were similar to the fastest-growing clone.



At age two, radiata pine growth was reduced in the lucerne treatment (right) compared to the bare ground (left). Photo D.J. Mead.

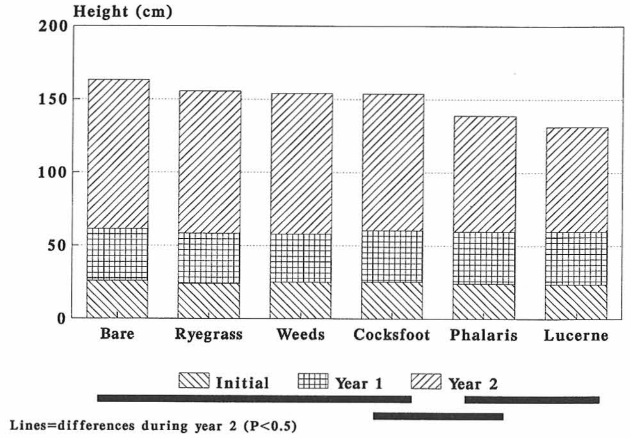


Fig. 1. Influence of pasture treatments on mean tree heights (cm) over the first two years.

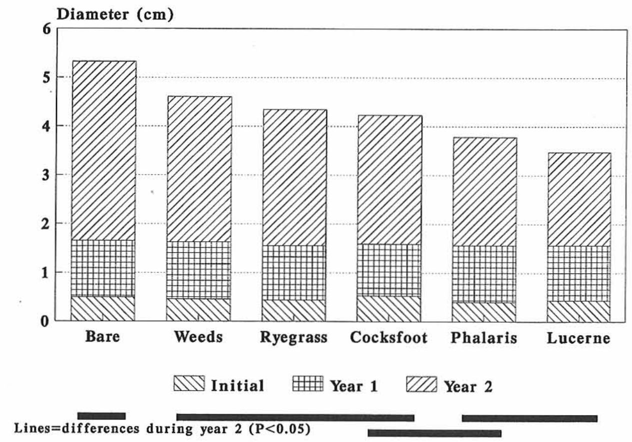


Fig. 2. Influence of pasture treatments on mean tree basal diameter (cm) over the first two years.

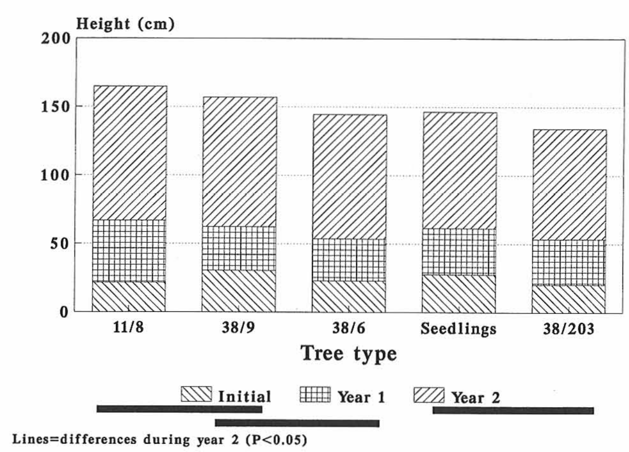


Fig. 3. Influence of radiata pine tree type on mean tree heights (cm) over the first two years.

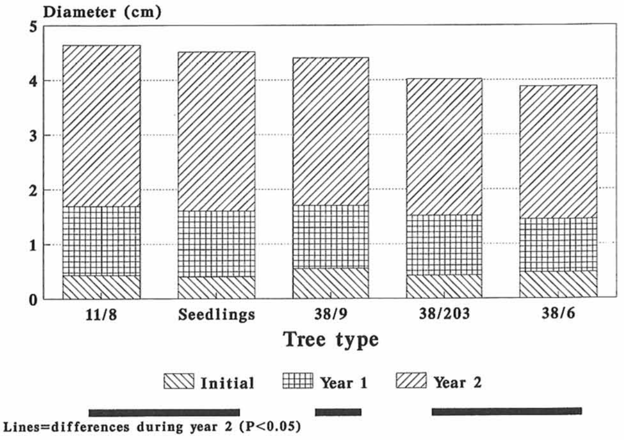


Fig. 4. Influence of radiata pine tree type on mean tree basal diameter (cm) over the first two years.

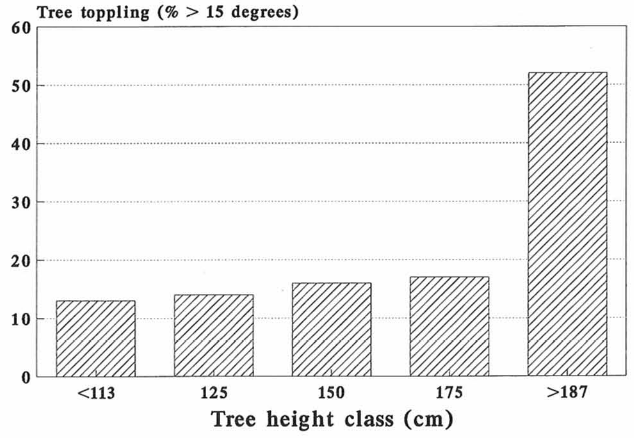


Fig. 6. Influence of tree height in the seedlings on the frequency of trees with a lean > 15° following storms in the winter of their second year.

Tree toppling greater than 15°, a useful criterion related to subsequent stem deformation, was influenced both by understorey treatment and tree types (both $p < 0.001$). The interaction between the two was significant at $p = 0.044$, largely as a result of one clone (11/8) being almost free of toppling (0-5%) except on the bare ground treatment where over 10% of the trees had toppled. This may be compared to the seedlings where the degree of toppling ranged from 56% to 68% in the pasture treatments but was 87% in the bare ground treatment. On average, 58, 36, 30, 21, 19 and 15% of the trees had a lean greater than 15° in the bare ground, ryegrass, weeds, cocksfoot, lucerne and phalaris treatments, respectively. Differences between tree types were even more marked (Figure 5). The seedlings showed the highest level of toppling with 65% of them having more than a 15° lean. In contrast the fastest-growing clone had almost no toppling. This clone was four years from seed. That the fastest-growing trees were more stable was most unexpected; this has not been reported before. However within the seedlings the tallest trees proved to be the most susceptible to toppling (Figure 6). Mason (1985) has reported that larger trees in a stand topple more frequently.

Malformation was also much greater in the seedlings than the tissue culture clones (Figure 7). Similar results have been

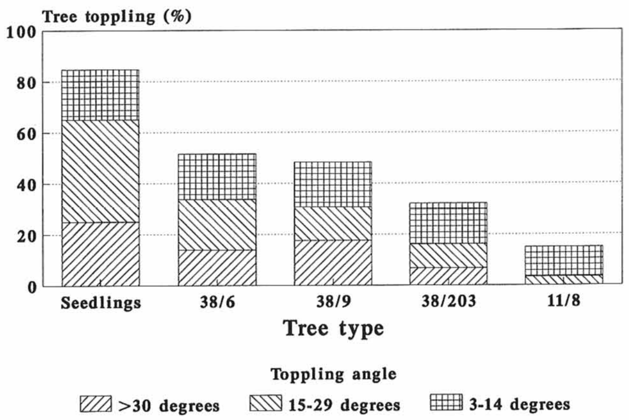


Fig. 5. Tree toppling frequency at age two years as influenced by radiata pine tree type. The multiple range test on trees with a lean > 15° showed all tree types were significantly different except 38/6 and 38/9.

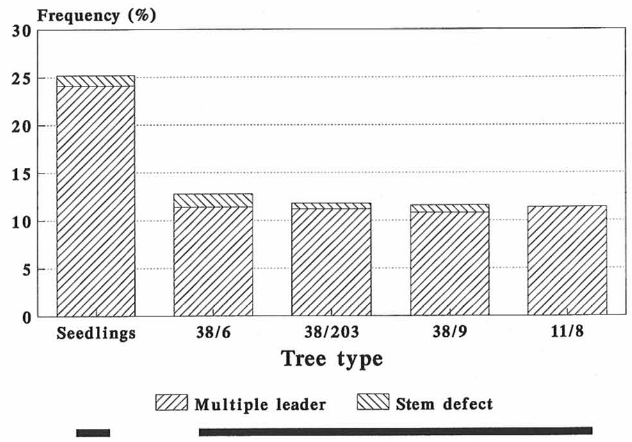


Fig. 7. Tree malformation in the seedlings and tissue culture clones of *Pinus radiata* at two years of age.

reported for cuttings by Menzies and Klomp (1986).

Foliage samples collected from the trees in the autumn of 1992 show that the more severe pasture competitors were associated with lower N and K concentrations (Table 2). However, Mg levels followed the opposite trend, being highest in the lucerne and phalaris/clover pasture treatments. Phosphorus levels were not influenced by the ground cover treatments but some levels were marginal.

There were distinct clonal differences in foliage concentrations, but the interaction between tree type and ground cover was not statistically significant. One clone (set 11/8) was distinctly low in Mg.

Total dry matter of pasture did not differ greatly between the various treatments (Figure 8). The effects of the trees on pasture were unimportant at this early stage of the experiment.

Conclusions

The early results of this trial have shown:

1. Height and diameter growth began to be influenced by the understorey pastures in the second year. The best growth at age two was in the bare-ground control and the most competitive treatments were lucerne and the phalaris/clover mixture.

2. The radiata pine tree types differed in height and diameter growth in both 1991 and 1992. However the interaction between tree type and understorey was not statistically significant.
3. The frequency of toppling, which occurred in March 1992, was highest in the seedlings and almost non-existent in the fastest growing clone. The high amount of toppling in the seedlings may have been related to their bushy form.
4. Within the seedlings (and perhaps within the other clones) the largest trees were most susceptible to toppling.
5. The seedlings showed more stem and leader defects than the plants propagated by tissue culture, probably because of the effects of physiological aging during the tissue culturing process.
6. Total dry matter production in the various pastures from sowing in spring 1990 to February 1992 was similar at 13 tonnes per hectare.

The results show that there are distinct advantages in using tissue cultured stock when trees are planted at wide spacing on fertile sites. The clones had less malformation and were less susceptible to toppling.

The lack of a significant understorey/treatment interaction could also be important, as it indicates that tree breeding may not help overcome competition problems. However longer-term results and further study of competition processes are required to confirm this.

It is perhaps too early to conclude which is the most desirable pasture to use under widely-spaced trees in the subhumid Canterbury climate. However, it is apparent that lucerne and phalaris should be avoided if the owner wishes to have the best radiata pine growth. The 1 m wide sprayed strip was only adequate in preventing competition from these two pastures for the first growing season while the pastures were being established.

Detailed research is continuing in this experiment and it is expected that the results will clarify some of the competition processes. This should assist in the design of sound silvo-pastoral systems.

Acknowledgements

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TABLE 2: The effects of ground cover and tree type on radiata pine foliage nutrient concentrations – samples collected in March 1992. Treatments or tree type followed by the same level do not differ at the 5% test level using the Tukey test.

Ground cover treatments	N	P	K	Mg
		% d.m.		
Bare ground	1.77a	0.130a	1.02a	0.096d
Weeds	1.67abc	0.123a	0.93ab	0.102cd
Ryegr./clover	1.73ab	0.138a	0.92ab	0.108bc
Cocksfoot/cl.	1.61bc	0.132a	0.91ab	0.110bc
Phalaris/cl.	1.58c	0.133a	0.80b	0.123a
Lucerne	1.42d	0.135a	0.86b	0.113b
Tree type				
Set 38/6	1.69a	0.128bc	0.86c	0.105c
Set 38/203	1.58bc	0.132abc	0.82c	0.123a
Set 11/8	1.56c	0.137a	1.03a	0.120a
Set 38/9	1.65ab	0.126c	0.86c	0.084d
Seedlings	1.67a	0.136ab	0.95b	0.112b

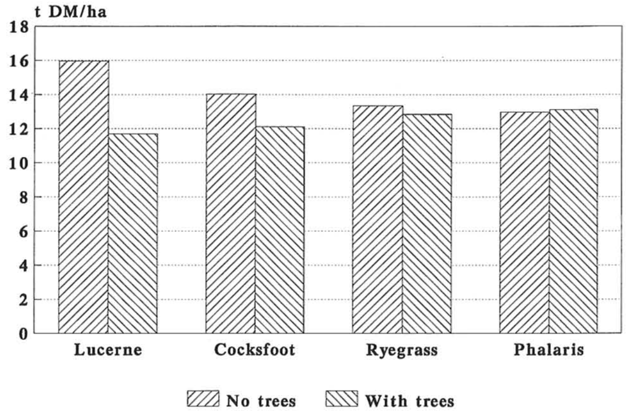

Fig. 8. Total pasture dry matter production (t/ha) during the first two years of the agroforestry experiment. Note that production from the treatments with trees is expressed on a total area basis, not on the 86% of the area occupied by pasture strips.

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Philippines Forestry – Bukidnon Forests Inc.

Peter D. Clark

Abstract

Bukidnon Forests Incorporated manages a reforestation project of the Government of Philippines, assisted by New Zealand. The project has been allocated 25,000 hectares of denuded grasslands, of which 2500 hectares has been planted to date. Early opposition to the project has been replaced by widespread public support as success in reforestation becomes evident. Natural forest resources in the Philippines have disappeared at an alarming rate over the last 40 years, with little plantation forest established to meet the basic needs of the population for wood products. This project represents a serious attempt to address the need for regional nuclei forest estates, using large areas of degraded lands which have low agricultural value and low occupancy.

Bukidnon Forests Incorporated (BFI) is one of New Zealand's largest foreign aid forestry sector programmes. Initiated by President Cory Aquino and Prime Minister David Lange in 1986, the project commenced on the ground in February 1989. New Zealand has been contributing around $1.1 million per annum in a mix of cash and technical assistance.

The project covers 25,000 ha of denuded grasslands in Bukidnon Province located in the southern Philippines island of Mindanao. This will be sufficient, when combined with private sector plantings, to support an integrated forest industry of sawmilling and either Medium Density Fibreboard or CTMP pulp production.

The land was allocated for reforestation because of its low occupancy and low agricultural value. Steep topography and compact, sometimes shallow, soils make reforestation technically difficult and commercial forestry marginal at best. However, the site typifies many hundreds of thousands of hectares of similarly denuded lands throughout the Philippines and other parts of S.E. Asia. Rising populations are putting increasing pressure on good land for agriculture. Small private woodlots and village scale forestry can do much to supply fuelwood and local timber requirements. However, it is the view expressed in the Philippines Master Plan for Forestry Development that any serious attempt to substitute natural forest hardwood timber with plantation grown timber, on a national scale, should include the setting up of large nuclei forest estates. These can support modern nurseries, attention to correct species and provenances, as well as training, research and extension programmes that are so essential for small-scale social forestry to work. Large nuclei estates will also give the private sector confidence to invest in modern processing.

Denuded hill country typical of that being planted by BIPP.

In its early stages the project was treated with scepticism and caution by local politicians and religious leaders, and outright opposition by some land and human rights activists. Such opposition all but disappeared after the first year of field operations when it became clear that BFI was serious about reforesting otherwise totally unproductive land. The project now enjoys widespread support at national government, local government and local community levels, except in a few instances of localised tension.

The Philippines Government, through the Department of Environment and Natural Resources (DENR), has addressed early organisational problems. The project has become a government-owned corporation with its own Board of Directors and decentralised management.

It is envisioned that once a sizeable plantation forest has been established, and is approaching maturity, the Government will dispose of some or all of its shareholding in BFI to the private sector.

The Philippines Government has recognised the serious state of the national forest resource and is determined to promote plantation forestry. From a forest cover of 17 million hectares in 1934, when the population was 15 million, only 6.1 million hectares of forest cover remains. Of this less than 1.0 million hectares is old growth dipterocarp forest.

The forest industry has traditionally been based on harvesting old growth dipterocarp forest, with virtually no plantation forest harvesting. A recent decision to restrict logging to second-growth forest will, if enforced, reduce the size of the forest processing industry in the Philippines, as most second-growth forests are carrying little merchantable timber that could be eco-

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