

Blue Gum Timberbelt

Design for Alley Farming

**A report for the RIRDC/LWRRDC/FWPRDC
Joint Venture Agroforestry Program**

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November 2000

RIRDC Publication No 00/154
RIRDC Project No DAW-70A

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ISBN 0 642 58184 3
ISSN 1440-6845

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Published in November 2000
Printed on environmentally friendly paper by Canprint

Foreword

This report investigates alley farming by presenting observed effects on production in the competition zone between short rotation Tasmanian blue gum (*Eucalyptus globulus*) and pastures. It documents the extent of pasture growth suppression by adjoining blue gums, and reveals a significant boost in production of edge trees. This information is integrated into an economic model of the alley farming system for the purpose of estimating profitability of a range of design options.

This project was funded by the Joint Venture Agroforestry Program - a program of three R&D corporations - RIRDC, LWRRDC and FWPRDC which are funded principally by the Federal Government. The project is an addition to RIRDC's diverse range of over 600 research publications and forms part of our Agroforestry and Farm Forestry R&D program, which aims to integrate sustainable and productive agroforestry within Australian farming systems.

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Peter Core

Managing Director
Rural Industries Research and Development Corporation

Acknowledgments

Phil Scott, formerly of Agriculture WA, was one of the originators of this project. His contribution up to the submission presentation to RIRDC was invaluable. Without doubt the success of this 3-year project is a result of the positive contributions by the 17 farmers who willingly supplied their land, time, knowledge and energy. Collectively they are to be congratulated for their ‘job well done’. Competent technical pasture skills by Mark Dixon, Quentin Albertsen and Max Bourne were also much appreciated. Jane Speijers and Jason Bolland professionally undertook the pasture statistical analyses.

Terry Reilly described the soils at each site. Steve Ward interpreted the soil descriptions. River Richards and Glenn Batty provided valuable support in recording soil and tree parameters. Beth Reid and Matt Williams performed statistical analyses of the tree data. We are grateful for their valuable assistance and advice.

We are also grateful for the assistance provided by Phil Durrell of Bunnings TreeFarms in quantifying the typical costs, performance and logistics of harvesting operations.

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Executive Summary

The objective of this project was to measure the production effects at the interface between plantings of Tasmanian blue gums grown for pulpwood, and pasture, and then build these into an economic model which would help farmers to recognise the profitability of blue gum alley farming and to optimise the design of their own alley farming projects. This should give farmers greater confidence to invest in what is a relatively new but profitable land use in southern Australia.

Background

Tasmanian blue gum is being extensively planted across parts of southern Australia for the production of pulpwood. Plantings in 1999 exceeded 50,000 hectares nationally, because this crop is often more profitable than grazing, especially with the taxation advantages it offers to investors. The apparent extra volume of edge trees and the anticipated shelter and hydrological benefits of these trees had suggested that blue gums in an alley farming layout would be even more profitable than plantations.

Alley farming also offers the prospect of farmers remaining in working occupation of their land pursuing traditional enterprises, rather than move off the farm to make way for fence-to-fence industrial plantations.

Agriculture Western Australia and the Department of Conservation and Land Management together possess the skills to measure, analyse and model these effects, and have access to a wide range of sites because the blue gum pulpwood industry had already begun to establish itself in south western Australia. The area of blue gum plantations in Western Australia has grown from 42,000 hectares to 130,000 hectares in the five planting seasons since this project was first proposed.

Research

Thirty sites were selected for the establishment of plots in the trees and pasture respectively. The sites were spread over a wide area of the higher rainfall agricultural zone, most receiving more than 600 mm annually during the project. Mean annual rainfall ranged from 463 mm to 1079 mm at the sites selected for the three years of the project.

Pasture yield was measured each year by periodical cuts at a set distances from the edge trees, in order to define the extent of pasture lost due to the competition from trees. These results were then expressed as the equivalent width of pasture lost.

Tree height and diameter were measured for each of the outside three rows, for three consecutive years. Tree volume was calculated from these measurements. Harvest volume estimates were limited to six sites because these were the only trees at or close to harvest age.

A spreadsheet model (BLUEBELTS) was adapted to calculate the profitability of a blue gum alley farming project. Pasture loss distance and the extra volume of edge trees, expressed as a percentage of inside-row trees, were included in the model using the means of plot data. The model was also modified to reflect the effects of design on tree harvesting costs, and to incorporate the option of pruning edge trees to avoid the extra costs of hand felling and debarking occasioned by heavy branches on these trees.

Outcomes

Pasture loss distance clearly increases with the age of the trees. There is typically a loss of almost 10 metres of total annual pasture production in the year in which the tree crop reaches 10 years of age, which is the usual age at harvest. This is more pronounced at the start of the season. Autumn pasture loss distance was estimated at close to 12 metres for the year in which trees reach 10 years of age.

The project confirmed that edge tree volume is substantially greater than the volume of inside row trees. The edge effect does not extend into the plantation beyond the outside row. The effect is highly variable, but the cause of this variation could not be established due to the low number of sites with trees of harvestable age.

Economic modelling showed that narrow tree belts are more profitable than wide belts provided the total volume of wood produced is sufficient to make cost-effective use of conventional harvesting equipment. Modelling also indicated the ‘window’ of situations in which alley farming is likely to be superior to either grazing alone or pure plantation. These relate to the relative returns of blue gums and grazing, which in turn depend on site quality, mill door price and distance to the mill.

Implications

Farmers in the high rainfall zone can have confidence that pasture loss distance is much less than one tree height during the first rotation of a blue gum pulpwood crop, and that edge trees produce more wood than inside trees. However, the variability of the observed edge tree advantage limits the predictive value of this project for design of alley farming projects. It was surmised that the effect might be inversely proportional to the quality of the site for blue gums, which is now understood to be a function mainly of rainfall, soil depth and soil fertility. Further research is warranted to relate the size of the edge effect to readily measurable site characteristics.

The project outcome is encouraging to farmers who find that they need to plant trees in a dispersed arrangement on a substantial part of their farms to improve catchment water balance and reduce the impact of salinity and wind on the sustainability of their farming system.

The results of the project are also encouraging for tree growers who are increasingly interested in producing solid wood products from widely spaced eucalyptus.

1. Introduction

Alley farming is a form of agroforestry involving trees or shrubs in belts with bays in between for grazing or cropping (Stirzaker and Lefroy 1997). It has evolved in Australia in parallel with, but independently from, similar developments elsewhere in the world, particularly in Africa and in tropical regions (Ong 1994). In Australia the development has been largely driven by farmers in response to land degradation such as salinity, waterlogging, wind erosion, soil acidification and loss of nutrients. Alley farming is also seen as having the potential to diversify farm income (from tree products such as timber), to assist in the development of new industries based on tree products, to aid nature conservation and to provide shelter for crops, pastures and animals (Bird et al. 1992). Distributing trees in the landscape in belts is a way of dispersing them to maximise water use while permitting use of agriculture machinery in the alleys.

Lefroy and Scott (1994) suggest that one of the requirements of a successful alley farming system is that the tree/shrub component is able to compensate for the land taken out of agricultural production. Compensation can be achieved by the trees producing a saleable product (e.g. timber), by increasing the production of agricultural activities in some way (e.g. through shelter or by lowering watertables) or by a combination of both. Recent economic modelling by Abadi and Lefroy (unpublished) suggested that there is an economic incentive for widespread adoption of alley farming if the tree/shrub species used provides a direct commercial return or an indirect benefit to agricultural production through shelter.

The potential to use *Eucalyptus globulus* (Tasmanian blue gum) in alley farming has received considerable interest, particularly in southwestern Australia, since the early 1990s. Tasmanian blue gum is being extensively planted across parts of southern Australia for the production of pulpwood. By the end of 1998 more than 130,000 ha of blue gum had been planted in Western Australia alone (AGWEST/CALM, 1999 a). For many farmers the opportunity to receive an annual payment from a forestry company for land planted to blue gums is attractive given the current low returns from many traditional agricultural activities. Many farmers also see blue gums as providing landcare benefits such as shelter and control of watertables.

In this context farmers are asking questions such as; “where should blue gums be planted to provide the greatest benefits to the farm overall”? “What arrangement of blue gums will produce the best outcome”? “Would an alley farming layout be a practical and economic design and if so how wide should the tree belts and pasture/crop alleys be”?

This project aims to answer these questions about the design of alley farming with blue gums by developing an understanding of the interaction between blue gums and pasture. The project complements other research projects investigating aspects of trees in agriculture. These projects include ‘The Strategic Agroforestry Systems Project’, ‘The National Windbreak Project’, ‘The Sustainable Production of Blue gums Project’ (all funded by RIRDC), ‘South West Land Resource Interpretation’ (funded by the National Landcare Program) and ‘The Effect of Trees on Waterlogging and Crop Production on a Duplex Soil’ (funded by the Grains Research and Development Corporation).

2. Objectives

The project has three objectives:

1. To collect data on wood and pasture production from the interface between plantings of Tasmanian blue gum and pasture for a range of tree orientations, tree ages and rainfall zones.
2. To use this information to model the interface relationships and develop an objective basis upon which layouts of blue gums in alleys can be designed.
3. To assess the prospects for high rainfall alley farming and actively encourage farmers to adopt alley farming using economically optimal designs.

3. Methodology

3.1 Site selection

Approximately 60 blue gum farm plantations were assessed for their suitability for the project. The selection criteria covered location, pasture and tree components. Specifically it included rainfall, soil type, topography, pasture vigour, pasture age (pasture/crop rotation), botanical composition, grazing stock type (sheep/cattle), tree vigour, tree age, tree orientation, tree planting layout (treebelt/plantation), number of rows in treebelt, suitability of pasture on either side of treebelt, distance between treeline and perimeter fence, width of perimeter firebreak etc.

Thirty sites, which met the criteria, were selected. Two additional 10 year old tree sites were selected after the second year of the project to provide more data on the distance the 'edge effect' extends into a blue gum plantation. Both these sites were located in the high rainfall zone (Witchcliffe 1100 mm and Ruabon 840 mm annual rainfall). No pasture measurements were recorded at either of these two sites during the project period.

As the occurrence of blue gum alley farming (belts of blue gum trees separated by alleys of pasture) is very limited the sites for the tree plots were largely selected from the edges of plantations. However, sites 11, 12, 25 and 26 were in classical alley farming configurations. At most sites (except sites 25, 26) the trees had been fenced at planting time to exclude grazing stock. These fences extended from between 1 and 4 m out from the edge rows of trees. In addition, at most sites a 2 m firebreak had been established external to the fence.

3.2 Site description

Site location, tree age (planting year), number of tree rows/belt, distance from treeline to fence and N, S, E or W orientation of pastures are detailed in Appendix 1. Actual rainfall for 1996 to 1998 is detailed by site in Appendix 2.

At each site, soil profiles to 2 m depth were described with respect to depth of major horizons, texture, colour, pH, salinity (where a watertable was encountered) and root impeding subsoils or hardpans (McDonald *et al.* 1990). See Appendix 3.

Soil samples (to 10 cm depth) were collected from each site for nutrient analysis (N, P, K, pH, total soluble salts and organic C). This technique involved bulking 80 'pogo' samples per site collected uniformly across the three outside rows of trees. See Appendix 4.

3.3 Pasture plot establishment

At sites 1 to 28, during February, March and April 1996 (before the opening rains), the trial pasture area adjacent to the trial tree plot (width approximately 80 m and extending 60 m out into the paddock) were fenced to exclude stock. Where possible these fences were connected to the farm electric grid network. These fences were removed at the conclusion of the 3 year project period.

From preliminary observations there was clear evidence of retarded pasture growth up to approximately 10 m out from the trees into the open paddock but no indication of any pasture loss at a distance greater than 20 m. Therefore, transects at 0, 1, 2, 5, 10, 20 and 50 m out from and parallel to the edge row of trees into the paddock were established. These distances were chosen to define the interface competition zone.

At the remaining two sites (29 and 30) 1 m by 1 m weldmesh pasture cages were positioned at the same transect distances. All the weldmesh cages were removed at the conclusion of the 3 year project period.

At all fenced sites the farmer was encouraged to manage the pasture trial area in the same way as the surrounding paddock, especially with respect to maintaining soil fertility.

3.4 Pasture measurement

In the 3 year project period (1996 to 1998) pasture yields were measured at each of the established 0, 1, 2, 5, 10, 20 and 50 m transects at approximately monthly intervals throughout each growing season. In 1996 only, the fenced plots (sites 1 to 28) were grazed after each yield measurement. The residual pasture yield after grazing was also measured. At some sites and in some months it was impractical for the farmer to graze after

each yield measurement. Consequently, in 1997 and 1998 this grazing requirement was replaced by mowing. The residual pasture yield after mowing was also measured.

At sites 29 and 30 the pasture yields of the transect swards under weldmesh cages were measured by mowing (i.e. cut, carry, oven dry and weigh) each year.

The cumulative seasonal pasture yield, 'open paddock' yield plateau and the pasture loss distance for each measured site in 1996, 1997 and 1998 are detailed in Appendix 5, 6 and 7 resp.

The 'open paddock' total seasonal yield plateau of all sites together with the number of yield measurements in each of the 3 years are summarised in Appendix 8.

Botanical composition of the pasture swards along the assessment transects were visually rated at approximately 6 weeks after germination and again in spring.

Three sites were not measured for pasture yield in 1996. Site 3 was discarded because of wind blown material from an overgrazed paddock nearby. Up to 20 cm of this eroded material was deposited at and around the treeline of the pegged and fenced experimental site. As a consequence the 0, 1, 2, 5 and parts of the 10 m transects were atypical of normal non-eroded paddocks. This site was terminated in the 1996 winter before any pasture measurements were undertaken. No additional tree measurements were made.

Measurement at site 13 was difficult because of low pasture density as a consequence of the paddock having been cropped in 1994 and 1995. Pasture management in 1996 therefore focused on promoting legume growth and seed production for natural regeneration. In 1997 and 1998 pasture yield measurements were satisfactorily undertaken.

At site 14 cattle invaded the fenced plot area on 3 occasions during winter despite all endeavours to exclude them. As a consequence pasture yield data for 1996 was too incomplete and therefore not used in any overall analyses. In 1997 and 1998 pasture yield measurements were satisfactorily undertaken.

In late spring 1996 the pasture on sites 9 and 10 were unintentionally and severely overgrazed. This resulted in very low subclover and annual ryegrass seed production for natural regeneration. Consequently it was necessary to reseed these two sites at the break of season in 1997. Re-establishment was satisfactory at both sites and pasture yield measurements were subsequently undertaken.

Site 27 was unavailable for seasonal pasture measurements in 1997 when the farm was sold and the pasture trial paddock area planted to grapevines. However, tree measurements continued.

In 1998 an additional 3 sites were not measured for pasture yield.

- 1) site 1 was lost when the pasture trial paddock area was planted to plantation bluegums
 - 2) site 8 was lost when the pasture trial paddock area was cultivated and sown to a grazing oat hay crop
 - 3) at site 21 the middle tree plot replication was removed as it was directly under a high voltage power line
- Tree measurements continued at sites 1 and 8.

3.5 Calculation of pasture loss width

Data on pasture yields were plotted against distance from the treeline. In all cases the yield response curve approximated a Mitscherlich function. From each of these response curves the individual pasture yield loss was calculated and statistically analysed to assess the effects of treebelt orientation, tree age and rainfall on the level of pasture yield loss due to treebelts.

A typical example is the 1996 total seasonal pasture yields at site 8 detailed in Table 1. Here the yield response curve has clearly plateaued at the 20 and 50 m transects. At these distances the yield is considered to be the practical 'open paddock' yield, and that the treebelt has reduced the yields at the closer distances.

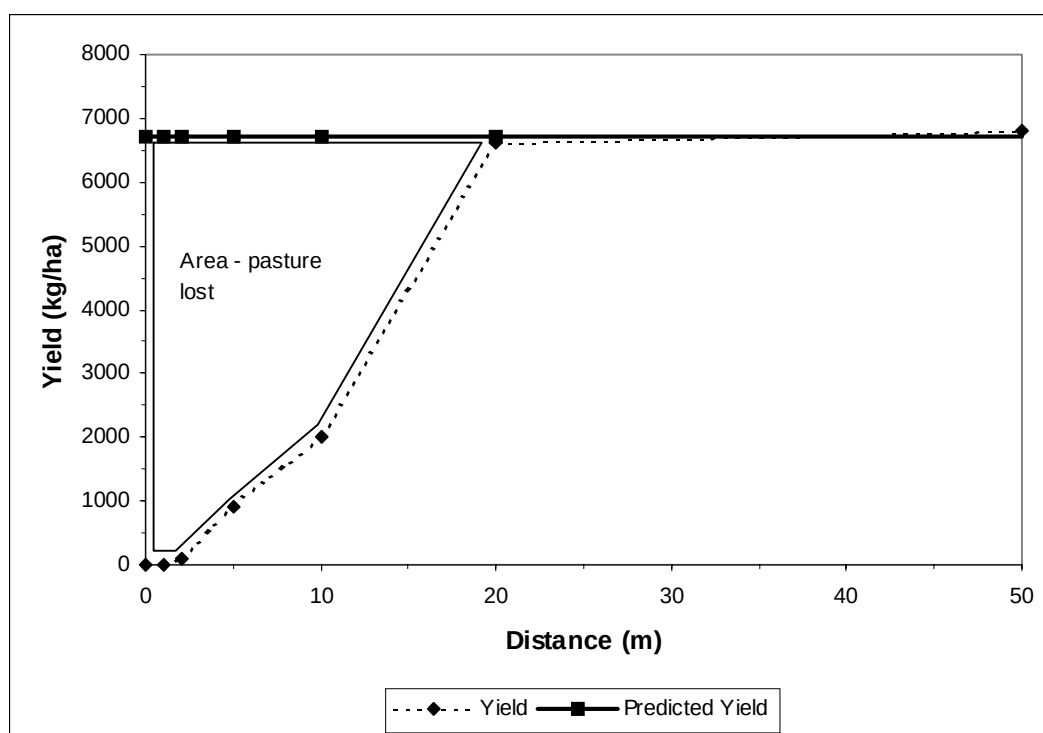
This practical 'open paddock' yield is the average of the yields at which it is assumed the yield has plateaued. Thus a new (corrected) set of yield values is calculated, whereby the last two (in this example) yield recordings are replaced by their average. The predicted yield can then be assumed to be at the level of this plateau, i.e. this is the yield that would have been present at all distances had the treebelt not been in place. In situations where the yield is seen to plateau before the 20 m transect the average is calculated over the required number of distances.

Table 1. 1996 total seasonal pasture yield plateau at site 8.

Distance (m)	Yield (kg/ha)	Corrected yield (kg/ha)	Predicted yield (kg/ha)
0	0	0	6715
1	0	0	6715
2	80	80	6715
5	920	920	6715
10	2010	2010	6715
20	6630	6715	6715
50	6800	6715	6715

From the corrected yields it is possible to calculate the lost yield by estimating the area between the curve of actual yield (shown in by the dotted line in Figure 1) and the predicted yield. From this estimate of the lost yield the *loss distance (m)* can be calculated. This value is taken to be the distance at which loss of pasture would have stopped had the loss been uniform over distance.

Figure 1. 1996 Total seasonal pasture yield data (site 8).



For example, in Table 1 the lost yield is calculated as 81,810 kg metres per hectare. If the loss is assumed to be uniform over distance then the loss distance (m) is calculated as the lost yield (area) divided by the predicted yield, to give $81,810/6,715 = 12.18$ metres. When calculating the loss distance (m) it is assumed that the area between the actual yield and the predicted yield will be rectangular in shape.

The cumulative seasonal pasture yield, 'open paddock' yield plateau and the pasture loss distance for each measured site in 1996, 1997 and 1998 are detailed in Appendix 5, 6 and 7 resp. The autumn and total seasonal pasture loss distance for each site in each year is summarised in Appendix 9.

3.6 Regression analyses of pasture loss with data

The response variable of interest in the statistical analysis is the pasture loss distance. The orientation (O) of the pasture in relation to the tree belt (i.e. pastures on the north, south, east, or west side of the trees), the age (T) of the trees in the tree belt, the monthly site rainfall combined with site location (L) were recorded and were used in the analysis to explain the differences in the pasture loss distance (m) between sites.

It must be noted that the complete pasture yield measurement data set and all pasture loss distance data has been used in the regression analyses. The data set has not had any abnormally high or low value outliers selectively modified or deleted.

A total of 8 regression analyses were undertaken on the complete pasture yield data set. Regression analyses were undertaken for the combined 1996 to 1998 (i.e. ‘all years’) data in addition to the 3 individual years (i.e. 1996, 1997 and 1998). Furthermore, the analyses were repeated for both the total seasonal and the autumn yield data set. The autumn pasture data was analysed separately because it is well recognised by competent graziers that the economic value of available feed for grazing is appreciably higher in the autumn/winter period than during the relatively abundant spring flush season. The autumn data set was defined when the new season’s (i.e. up to the end of July) pasture yield >500kg/ha in the 20 and 50 m transects (i.e. in the practical ‘open paddock’). This was considered to be approximately equivalent to the farmer’s first grazing rotation option.

In the early stage of the analysis the linear response of pasture loss distance (m) to site rainfall was examined. However, more significant results were found using the two rainfall categories (R) of High and Low (>750 mm, <750 mm of rain resp). Consequently, site rainfall was not used as such in the final analysis.

Additionally, as it was hypothesized that the growth of pastures close to the southern side of a tree belt would be constrained by lower light and temperatures relative to pasture swards growing on the north, east or west sides of a tree belt, a further factor (S), was added to the analysis to extract this effect prior to testing whether or not differences existed between the orientations.

The age of the trees in the tree belt (T) was calculated by subtracting the tree planting year from the pasture yield year of measurement. These ages were then grouped to be used as a factor in the analysis. Seven groupings were used.

The number of pasture yield measurements in each year and tree age category is detailed in Table 2.

Table 2. Numbers of pasture yield measurements in each year by tree age category.

Tree age category (years)	Autumn				Total season			
	1996	1997	1998	total	1996	1997	1998	total
1	4	0	0	4	4	0	0	4
2	2	4	0	6	2	4	0	6
3	2	2	3	7	2	2	3	7
4	7	4	2	13	7	4	2	13
5	6	7	4	17	6	7	4	17
6	1	6	6	13	2	6	6	14
<6	4	5	8	17	4	5	10	19

Regression analysis of the combined 1996 to 1998 (‘all years’) total seasonal pasture data was used to investigate the relationship between the pasture loss distance (m) and the explanatory variables. A preliminary investigation showed significant effects due to site location (L), which included factors such as soil type, environment, topography and farm management skills. This term was always included last in any model so that any known environmental effects associated were removed first and the site location effect represents other unknown effects.

The initial model used in the analysis contained the main effects of Year (of pasture measurement), South, Orientation, Tree age and Rain, followed by the interactions of South by Orientation, Age by Rain and Year by Age. As stated above the main effect of site Location was included last in the model.

A similar analysis of the combined 1996 to 1998 (ie ‘all years’) autumn data was also undertaken.

3.7 Tree plot establishment

At each project site 3 tree measurement plots were established over a distance of approximately 50 metres along the tree belt. Plots were established in well stocked sections and spanned the outside 3 rows. Plot size was approximately 8 trees x 3 rows or 0.02 ha, which ensured that each plot contained at least 24 trees. Plot area was measured and 1.3m steel posts were placed on the tree line to permanently mark the plot boundaries.

For the purpose of discussion, row 1 is the outside row of the tree belt and row 3 is the inner row.

3.8 Tree measurement

Tree height and diameter at breast height over bark (DBHOB) were measured for all trees in plots. Trees were measured in March each year for the 3 years of the project. From these parameters, mean height, mean DBHOB, mean tree volume, mean total volume per ha and tree density were calculated. This data is detailed in Appendix 10.

3.9 Tree data analysis

Of the 32 project sites, 6 were old enough to provide estimates of wood production at harvestable age. Wood production at harvestable age (about 10 years for most sites) is the critical production figure, because it is used to calculate income to the grower. The other 26 sites were too young to provide useful data on wood production but had a crucial role in the pasture production component of the project.

Of the 6 sites suitable for assessing wood production, four (29 to 32 inclusively) had trees of a harvestable age (9.7 years) and actual wood production (m^3/ha) was calculated. At the other two sites (27 and 28) tree age was 8.7 years and wood volume at 9.7 years was estimated by calculating mean annual volume increment and projecting growth forward. Tree volume in all cases was calculated using the cone formula, as this has proved to be a reasonable approximation.

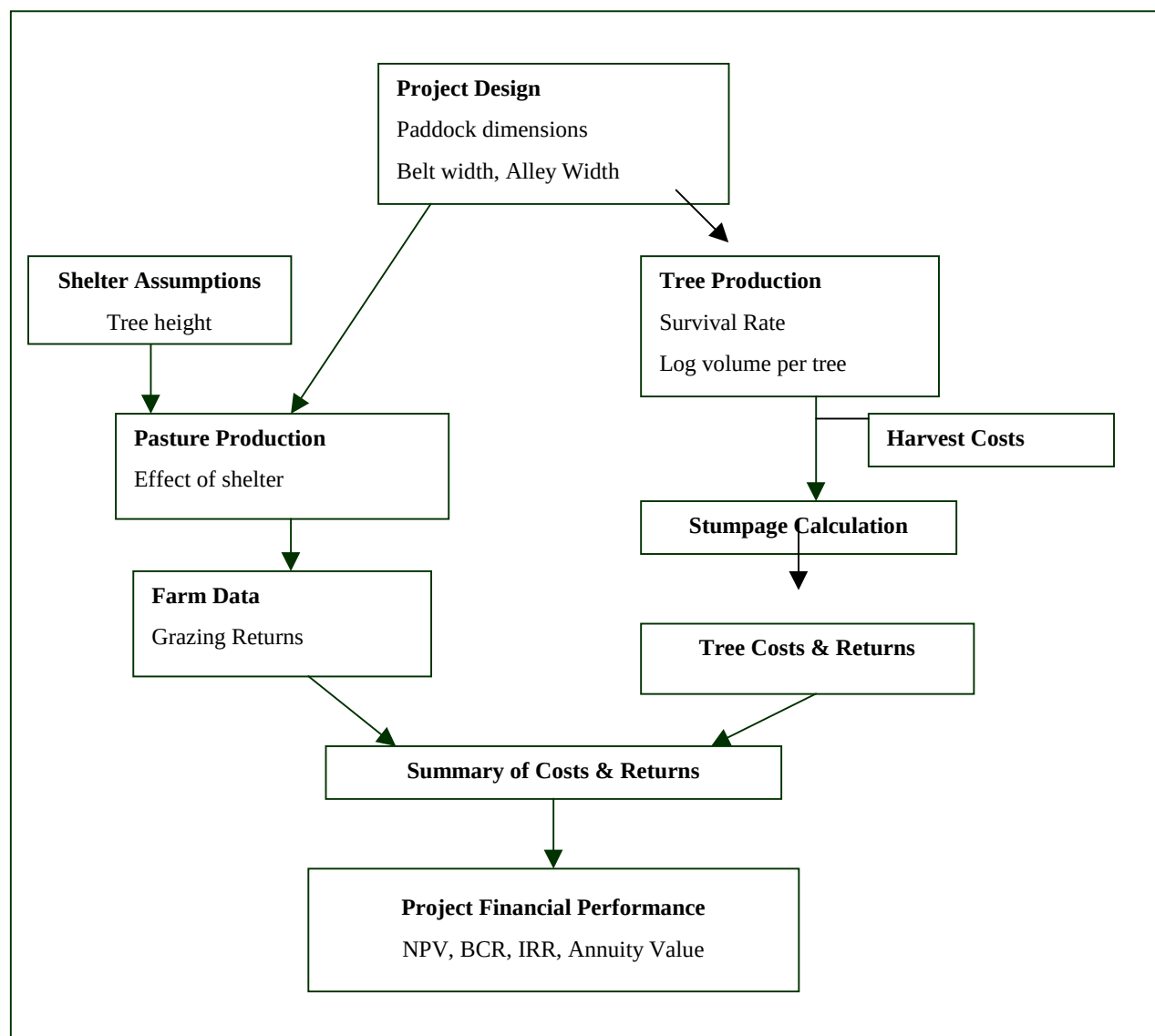
3.10 Modelling framework

Optimising the design of blue gum alley farming is defined as finding the combination of belt width, alley width and orientation which maximises profit for a given set of prices and costs. This requires a quantitative model incorporating the interactions between trees and pasture and also between design variables and operational costs for a given project. A spreadsheet model was adapted to calculate the profitability of a blue gum alley farming project.

BLUEBELTS was used as the basis for this model, as it had been developed for the purpose of estimating profitability of a blue gum alley-farming project, incorporating estimated shelter and hydrological benefits (Eckersley 1994). The main components of the model, and the links between them, are depicted diagrammatically in Figure 2.

The model expresses profit as Net Present Value (NPV), Benefit Cost Ratio (BCR) and Internal Rate of Return (IRR). These terms are explained well in the book 'Design principles for farm forestry' (RIRDC 1997). NPV is the net total of all returns minus all costs for the project, discounted to the starting year of the project to reflect the time value of money. NPV is a useful measure for comparing alternative designs in the absence of any serious capital constraint. Alternative project designs may be ranked in a different order when compared on the basis of BCR or IRR rather than NPV. IRR is a preferred measure when capital is the limiting resource.

Figure 2. Framework for economic modelling of blue gum alley farming system.



In BLUEBELTS, shelter effects on agriculture are expressed as expected changes relative to ‘open paddock yield’, this being the ‘theoretical’ zone which is beyond the influence of trees. In this blue gum alley farming project it was recognised that it would not be possible to measure the ‘theoretical open paddock yield’, due to the relatively short distances between one tree/pasture interface and the next. On the farms where sites were available, there was not sufficient width of pastured area on the same soil type. These distances were therefore too narrow to leave any pasture completely free from the theoretical shelter effect of trees.

In this project pasture yields were found to be very similar at distances greater than 20 m from the edge tree line. It was decided to use the arithmetic mean of the 20 and 50 m transects yields as a proxy for the theoretical open paddock yield. The model was altered to incorporate the effective pasture loss as measured at the experimental sites, relative to open paddock yield, and expressed as the width (in metres) of the strip of land from which there was effectively no pasture production. Spring and autumn-winter pasture values were integrated to give a single measure of loss for each year of tree age, averaged across all sites. The method of integration is described in section 3.11.

It is also acknowledged that edge-row trees usually develop large limbs of a size that interfere with standard harvesting operations. It was therefore necessary to develop a mechanism in the model that would reflect the costs as well as the benefits of edge-row trees at harvest. A method of relating harvesting costs to design parameters was developed and is described in the section 3.12.

The hydrological effects of timberbelts depend on site factors, including topography, soil texture and hydrogeology are highly variable. No attempt was made to measure them in this project. Consequently, this part of BLUEBELTS was deleted from the model.

The main sections of the model are shown in Appendices 11 to 18 inclusive.

Certain assumptions and extrapolations were made for economic modelling purposes, in order to assist farmers to apply the results. This included fencing cost and the growth of edge-row trees when belts are close enough to interfere with growth of trees in adjacent belts.

Fencing cost was excluded, as this is considered unnecessary. Although fences had been erected by the farmers at most of the sites for this project, it has been shown elsewhere (B.Mattinson pers.comm.) that with careful management sheep can graze in and around blue gum plantations within 12 months of planting without undue damage to the trees (cattle are generally excluded for a longer period). In general, it is assumed that the farming enterprises can be managed to avoid fencing costs without any other cost penalty. The model was also run with a fencing cost component added, so as to show the potential implications of fencing for design and profitability.

It was assumed that trees in adjacent belts would not compete with one another unless within 2 tree heights of one another, based on the observed pattern of pasture growth. It was further assumed that the yield advantage of edge-row trees would reduce in proportion to the ratio of alley width to 2 tree heights. This was done to allow the model to estimate the profitability of designs with belts closer than those measured in the field. For example, the volume superiority of edge-row trees would be halved if alley width were equal to one tree height.

3.11 Grazing and pulpwood returns

Gross margins achieved by graziers (i.e. gross income minus variable costs, expressed on a per hectare basis) vary widely in response to markets, site quality and management. A gross margin of \$70 per hectare per year is used in this study as a notional median value (Appendix 11), but for a given paddock the gross margin may well be as low as \$30 or as high as \$200 (Kingdon and Sawyer 1994) (BankWest, 1998). Sensitivity analysis is essential to apply the results of this research to the full spectrum of farms where blue gums could be grown.

Similarly, pulpwood returns at the end of a 10 year rotation vary in response to markets, site quality and management. Sensitivity analysis is required to encompass a range of volumes and stumpages, the latter partly dependent on location, which dictates haulage distance to chipmill and thence to port.

The base assumption of a harvest volume of 0.2 cubic metres per inside row tree (Appendix 14) translates to 200 cubic metres per hectare of plantation. Stumpage decreases by about \$1 per tonne for every 10 km extra haulage distance. This is relevant because blue gums are grown as far as 150 km from chipmills. The base assumption is 60 km (Appendix 18).

Blue gum plantations are typically expected to produce two crops, first clearfall at 8 to 12 years, with a slightly shorter coppice rotation yielding a similar volume at lower cost. Direct comparison of the plantation option with various alley farming designs in this project is limited to the first rotation (Appendix 16) because field measurements have only been possible on first rotation sites.

Landholders have generally been paid annuities or rentals in excess of \$150 per hectare per year by plantation companies, but the profitability of do-it-yourself blue gums grown for a single rotation (i.e. yielding 200 t/ha after 10 years) is calculated here to be \$56/ha/yr. This is for purposes of comparison with alley farming. The reason for this substantial difference lies partly in the single rotation but is also believed to be due to the effectiveness of taxation arrangements made by prospectus companies on behalf of investors. The annuity equivalent for a two-rotation project on the same land is calculated by the same method to be \$105/ha/yr.

3.12 Integration of pasture values

Total annual pasture yield does not fully reflect the value of pasture for grazing animals. Pasture is generally in short supply during the autumn and early winter period in Mediterranean southwestern Australia. In contrast, the spring yield flush exceeds immediate animal requirements and is partly conserved as hay or silage for feeding out during the autumn/winter feed gap. In conserving this feed a farmer incurs costs of mowing, raking, harvesting, transport, storage and feeding out. Typically, the cost of this conserved feed is approximately 10 cents per kilogram of dry matter, compared to a cost of 5 cents per kg of dry matter from spring pasture.

A formula was developed in the model to differentially weight autumn and spring pasture values. The weighting was based on the assumption that autumn pasture yield is a) 10 per cent of the annual total (whilst spring production 90 per cent of the total) and b) double the value per kilogram of spring pasture. This proved desirable because the pasture loss distance was found to be greater in autumn than in spring (see section 4.1.7).

3.13 Harvesting costs

Most blue gums grown in plantations for pulplog production are harvested by specialised equipment. A typical harvesting operation involves full use of a harvester, a forwarder and part-time use of a utility for travel by a supervisor. The combined capital cost of this equipment is about \$1 million. The cost of owning this equipment is high, as is the cost of log hauling trucks designed to minimise haulage cost. Blue gums grown in inside rows at conventional spacing (4 m by 2 m) generally have negligible limb diameter and few limbs as such due to self-pruning. Each tree can be felled, debarked and sectioned into millable logs within less than a minute by conventional harvesting machinery.

In contrast, unless pruned, edge-row trees must be handfelled, in which case the bark remains on the logs. Logs with bark on now attract a price penalty of \$5 per tonne at the chipmill (P.Durrell, pers. comm.). Selling logs with bark on also has the effect of removing some valuable nutrients from the paddock (C.Shedley pers.comm.).

As harvesting costs constitute about one third of the mill door value of blue gum pulplogs, and may be strongly influenced by design of an alley farming system, it was decided to incorporate in the model, as far as possible, the influence of design on harvest cost.

The harvesting operation was broken into its main constituents, namely

- felling by the harvester,
- travelling by the harvester,
- self-loading by the forwarder,
- travelling and unloading by the forwarder,
- roaming to permit transport access to loading points, and
- moving equipment between properties.

The time taken for each of these steps was calculated as a function of tree distribution, trunk volume and whether the edge trees were pruned, based on advice from the foremost industry harvesting manager in WA (P.Durrell pers. comm.).

Details of the component costs, and their relationships to tree size and dispersal, are detailed in Appendix 18.

Edge trees have larger roots than internal trees and can prevent efficient cutting at ground level by certain harvesting heads. This potential loss of the log at its widest butt point represents a reduction in marketable yield. This feature of edge trees was not included in the model because it was not reliably quantified and because new harvesting technology will be developed to overcome the loss.

3.14 Shelter value of the trees

One of the many reasons farmers adopt alley farming is that the belts of trees can reduce windspeed in the adjacent crop/pastured area. Research in other agricultural regions has shown that this beneficial wind protection can increase pasture/crop yield, reduce maintenance intake requirements of livestock and reduce lambing deaths (Bird *et al.* 1992). The most spectacular benefits of shelter are observed when ‘off-shears’ sheep would otherwise be subjected to cold wet windy weather. In some circumstances effective windbreaks can also reduce the severity of wind erosion (Bird *et al.* 1992).

The design of the current project did not permit the measurement of shelter effects. In order to incorporate as fully as possible all the likely effects of trees on pasture into the economic analysis, it was decided to include a cautious estimate of shelter value.

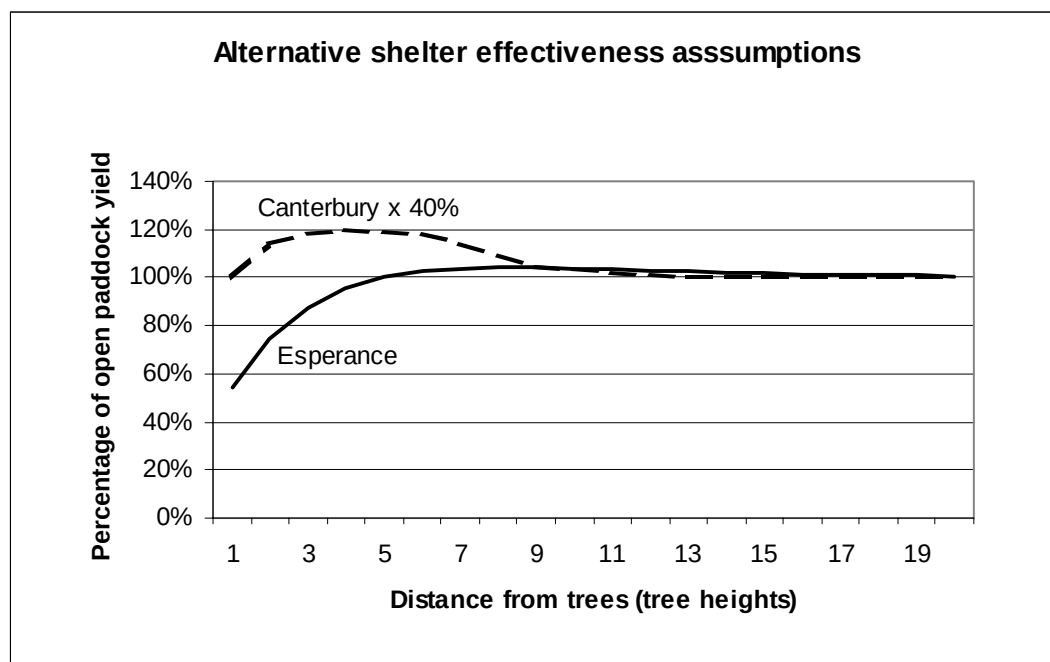
BLUEBELTS and FARMTREE are agroforestry economic models, which use the relationship of yield to distance downwind found by Radcliffe on the Canterbury Plains of New Zealand (Radcliffe 1983), modified to reflect climatic severity (Loane 1992).

More recent research on the Esperance sandplain (R. Sudmeyer, pers. comm.) suggests that the yield improvements due to shelter are considerably smaller than on the Canterbury Plains, and that long established pine windbreaks depress pasture and crop yields to a distance of as much as 4 tree heights. The results of these respective studies are represented in Figure 3.

The current project involves blue gums of no more than 10 years of age in a higher rainfall environment than Esperance. It was decided to use the arithmetic mean of the responses predicted by the New Zealand and Esperance workers, as the predictor of yield effects beyond one tree height. In contrast in this blue gum alley

farming project, the effects of the tree/pasture interface competition were found to remain within one tree height of the base of edge trees.

Figure 3. Pattern of shelter values based on New Zealand and Esperance research.



4. Results

4.1 Pasture production

The main aim of the pasture production component of the project was to quantify the yield loss in the tree/pasture interface competition zone. This section presents data on both the autumn and the total season pasture yield loss distance in relation to tree orientation, tree age and site rainfall.

4.1.1 Total season pasture loss width regression analysis

The results of the regression analysis of the pasture loss distance (m) for the total season are detailed below (see Tables 3 and 4). Clearly, the regression is highly significant (p -value < 0.001) and the percentage variance accounted for is 70.2%.

Response variate: AdjPasture loss

Fitted terms: Constant + Year + South + Orientation + Tree Age category + Rain + South by Tree Age Category + Orientation by Tree Age Category + South by Rain + Orientation by Rain + Tree Age Category by Rain + Year by Tree Age Category + Site Location

(FACTORIAL limit for expansion of formula = 2)

Table 3. Summary of total season pasture loss distance (m) regression analysis.

	d.f.	s.s.	m.s.	v.r.	F.pr
regression	57	320.4	5.6	4.2	<0.001
residual	21	27.9	1.3		
total	78	348.4	4.5		

Percentage variance accounted for 70.2

Standard error of observations is estimated to be 1.15

Table 4. Accumulated analysis of variance of total season pasture loss distance (m) regression.

	d.f.	s.s.	m.s.	v.r.	F.pr
Year (Y)	2	4.4	2.2	1.7	0.213
South (S)	1	4.0	4.0	3.0	0.097
Orientation (O)	2	34.9	17.4	13.1	<0.001
Tree Age category (T)	6	114.9	19.1	14.4	<0.001
Rain (R)	1	5.5	5.5	4.1	0.056
S by T	6	5.7	1.0	0.7	0.640
O by T	11	21.5	2.0	1.5	0.215
S by R	1	5.3	5.3	4.0	0.058
O by R	2	23.6	11.8	8.9	0.002
T by R	5	6.1	1.2	0.9	0.493
Y by T	7	61.0	8.7	6.6	<0.001
Site Location (L)	13	33.5	2.6	1.9	0.086
residual	21	27.9	1.3		
total	78	348.3	4.5		

There are significant effects due to Orientation (not South vs Rest) ($p < 0.001$) and Tree Age category ($p < 0.001$). There is also a significant Orientation by Rain interaction ($p = 0.002$) and a significant Year by Tree Age Category interaction ($p < 0.001$). The latter is caused in part by a large pasture loss value from one of the two paddocks adjacent to 2 year old treebelts in 1996. This value also affects the overall mean for Tree Age Category 2 years.

The regression analyses were also significant in the individual 1996 ($p = 0.010$), 1997 ($p = 0.036$) and 1998 ($p = 0.004$) total seasonal pasture data sets (see Appendix 19, 20 and 21 respectively).

4.1.2 Autumn pasture loss width regression analysis

A similar analysis of the combined 1996 to 1998 (ie. 'all years') autumn data was also undertaken. The results are detailed in Tables 5 and 6 below.

Table 5. Summary of autumn pasture loss distance (m) regression analysis.

	d.f.	s.s.	m.s.	v.r.	F.pr
regression	57	672.1	11.8	2.9	0.007
residual	19	78.5	4.1		
total	76	750.5	9.9		

Percentage variance accounted for 58.2

Standard error of observations is estimated to be 2.03

Table 6. Accumulated analysis of variance of autumn pasture loss distance (m) regression.

	d.f.	s.s.	m.s.	v.r.	F.pr
Year (Y)	2	9.7	4.9	1.2	0.330
South (S)	1	8.5	8.5	2.1	0.168
Orientation (O)	2	36.5	18.2	4.4	0.027
Tree Age category (T)	6	261.8	43.6	10.6	<0.001
Rain (R)	1	5.9	5.9	1.4	0.248
S by T	6	9.6	1.6	0.4	0.877
O by T	12	94.3	7.9	1.9	0.101
S by R	1	0.9	0.9	0.2	0.639
O by R	2	14.1	7.0	1.2	0.207
T by R	5	25.6	5.1	1.2	0.329
Y by T	7	54.7	7.8	1.9	0.127
Site Location (L)	12	150.4	12.5	3.0	0.015
residual	19	78.4	4.1		
total	76	750.5	9.9		

There are significant effects due to Orientation ($p = 0.027$) and Tree Age Category ($p < 0.001$). There was no Year by Tree Age Category interaction.

The regression analyses was also significant in the individual 1996 ($p < 0.001$) and 1997 ($p = 0.048$) but not with the 1998 ($p = 0.062$) autumn pasture data sets (see Appendix 22, 23 and 24 respectively).

4.1.3 Effect of tree orientation on pasture width loss

The Orientation variable was significant in 1996, 1997 and in the 'all years' total seasonal data, but not significant in 1998 with more pasture loss on the north side (in particular) and south side relative to the east or west sides. In the 'all years' and also in the 1996 data set there was no significant difference between the north and south sides nor between the east and west sides. But there was significantly more pasture loss on the north relative to the east or west sides. Also there was significantly more pasture loss on the south relative to either the east or west sides. However, in the 1997 data set there was significantly more pasture loss on the north side relative to the south, east or west sides. In this data set there was no significant differences between the south, east or west pasture loss distances. In general there was more pasture loss on the north side than on the south side which is in contrast to an original hypothesis predicting less growth on the southern side of a tree belt due to less favourable light and temperature conditions. However, as alley farming tree belts have pasture on both sides of the tree belt the mean value of pasture loss on the north/south combination must be directly compared with the mean east/west combination. In this comparison the mean north/south pasture loss distance was appreciably more than the mean east/west combination. The larger mean north/south pasture loss distance is detailed in Table 7.

Table 7. Effect of orientation on total season pasture loss distance (m).

Orientation	1996	1997	1998	'All years'
North	7.6	7.2	6.6	7.1
South	8.2	5.6	7.0	6.7
East	4.9	4.9	6.5	5.4
West	4.8	4.9	6.1	5.4
N/S mean	7.7	6.4	6.8	6.9
E/W mean	4.9	4.9	6.3	5.4

The autumn Orientation variable was significant in the 'all years' and also in the 1996 data set but not significant in the 1997 or in the 1998 data set. The 'all years' autumn pasture data set again clearly shows less pasture growth on the north side of the tree belts relative to yields on the south, east or west. The increased autumn pasture loss on the north/south side relative to the east/west orientation is detailed in Table 8.

Table 8. Effect of orientation on autumn pasture loss distance (m).

Orientation	'All years'
North	9.0
South	7.1
East	7.1
West	7.4
N/S mean	8.0
E/W mean	7.2

4.1.4 Effect of tree age on pasture width loss

The tree age category variable in the total seasonal pasture data set was significant in all analyses (i.e. individual years and 'all years') and clearly supports the hypothesis that the pasture/tree competition increases with tree age. This increased pasture loss distance is detailed in Table 9.

Table 9. Effect of tree age on total seasonal pasture yield loss (m).

Tree age (years)	1996	1997	1998	'All years'
1	3.6			3.6
2	6.0	3.3		4.2
3	4.8	3.2	2.7	3.5
4	6.9	5.5	3.5	6.2
5	6.4	5.7	5.8	5.8
6	7.6	5.9	6.5	6.6
<6	5.0	6.7	7.2	6.6

In the above 'all years' total seasonal pasture data set the linear regression relationship between the tree age (i.e. 1 to 6 years) and the width of pasture loss is:

$$\text{Width of total seasonal pasture loss (m)} = 0.64 (\text{tree age in years}) + 2.73. \quad r^2 = 0.76$$

This linear relationship can be used to predict the future expected pasture loss of an existing tree belt at a given tree age (see Table 10).

Table 10. Width of total seasonal pasture loss (m) increases with tree age.

Tree age (years)	Width of total seasonal pasture loss (m)
1	3.4
2	4.0
3	4.7
4	5.3
5	5.9
6	6.6
7	7.2
8	7.9
9	8.5
10	9.2
mean	6.3

The autumn pasture yield data set also shows the tree age variable to be significant in all analyses (see Table 11).

Table 11. Effect of tree age on autumn pasture yield loss (m).

Tree age (years)	1996	1997	1998	'All years'
1	3.8			3.9
2	5.1	2.4		3.4
3	9.6	3.9	5.0	6.1
4	5.6	6.2	4.2	6.0
5	8.3	8.5	6.8	7.9
6	9.8	6.7	8.5	7.9
<6	8.5	9.5	9.5	9.3

In the autumn 'all years' data set the linear regression relationship between the tree age (i.e. 1 to 6 years) and the width of pasture loss is:

$$\text{Width of autumn pasture loss (m)} = 0.95 (\text{tree age in years}) + 2.53. \quad r^2 = 0.87$$

Again this linear relationship can be used to predict the future expected autumn pasture loss of an existing tree belt at a given tree age (see Table 12).

Table 12. Width of autumn pasture loss (m) increases with tree age.

Tree age (years)	Width of autumn pasture loss (m)
1	3.5
2	4.4
3	5.4
4	6.3
5	7.3
6	8.2
7	9.2
8	10.1
9	11.1
10	12.0
mean	7.8

The hypothesis that the pasture/tree competition increases with tree age is correct both with the autumn and the total seasonal pasture yields.

4.1.5 Effect of the interaction between orientation and rainfall on pasture width loss

Another important feature of the total seasonal analyses was the significant interaction of the Orientation and the Rainfall variables (see Table 13). This data set supports the hypothesis that pasture losses will increase with increased competition (here from a combination of both reduced rainfall and the N/S orientation).

Table 13. Effect of orientation and rainfall on pasture loss distance (m).

Orientation	High rain (>750mm)	Low rain (<750mm)
North	6.8	7.3
South	5.7	7.0
East	5.2	5.6
West	5.2	5.7
N/S mean	6.3	7.2
E/W mean	5.2	5.7

4.1.6 Effect of year and effect of rainfall on pasture width loss

Neither the Year nor the Rainfall variables were significant in either the autumn or the total seasonal data despite the seemingly large differences in the farm rainfall and the subsequent seasonal conditions experienced during the project (see Table 14).

Table 14. Effect of Year and Rainfall on pasture loss distance (m).

Year	Autumn	Total season	Rainfall	Autumn	Total season
1996	7.6	6.4	High (>750mm)	7.6	5.7
1997	7.5	5.8	Low (<750mm)	7.7	6.3
1998	7.9	6.2			

4.1.7 Comparison of autumn and total season pasture width loss

Comparative analyses of pasture loss distances of the autumn against the total seasonal data sets were not directly undertaken. However, indirect comparisons indicate that the autumn pasture loss values exceed those for the total season. This can be illustrated in both the significant Tree age category and in the Orientation variables. In the Tree age category linear regression equations (detailed above), the gradients for autumn and total seasonal are 0.95 and 0.64 respectively whilst their Y axis intercepts are essentially the same. The orientation comparison is detailed below in Table 15.

Table 15. Comparison of the autumn and total seasonal pasture loss distances (m).

Orientation	Autumn	Total seasonal
North	9.0	7.1
South	7.1	6.7
East	7.1	5.4
West	7.4	5.4
N/S mean	8.0	6.9
E/W mean	7.2	5.4

These comparisons again support the hypothesis that pasture losses will increase with increased competition. The increased autumn pasture loss will exacerbate the autumn/winter feed gap and has the impact of reducing farm profitability.

4.2 Tree production

The primary aim of the wood production component of the project was to quantify the 'edge effect' (the impact on wood production of reduced competition between trees at the edge of a planting of blue gums). This section presents data on the magnitude of the 'edge-effect' and its development with tree age.

4.2.1 Size of 'edge effect'

The project found that the volume of wood produced in the edge row was approximately twice that of the second row. Table 16 details wood volume by row for all six sites with trees of 'harvestable age' (sites 27 to 32 inclusive). At sites 27 to 30 inclusive only 3 rows were measured, whilst at sites 31 and 32 tree production data was collected from six rows (see sections 3.1 and 3.9 above). Table 17 details the extra volume of wood in row 1 compared with row 2 and the extra volume of wood in row 2 compared with row 3, both expressed as a percentage. The mean volume of extra wood produced in row 1 compared with row 2 was 94 per cent, a significant difference at $p < 0.001$ level (see Tables 18 and 20). The mean volume of extra wood produced in row 2 compared with row 3 was 18 per cent. This is not a significant difference at the $p = 0.05$ level.

Table 16. Wood volume per hectare by row for 9.7-year-old *E. globulus*.

Site number	Wood volume (m ³ /ha)					
	Row 1	Row 2	Row 3	Row 4	Row 5	Row 6
27	463	399	402			
28	724	396	279*			
29	735	275	223			
30	436	226	181			
31	646	326	253	248	248	270
32	413	202	222	212	138	248
mean	570	304	260			

*only 2 replications instead of 3

Table 17. Extra wood production of row 1 compared with row 2, and of row 2 compared with row 3 for 9.7-year-old *E. globulus*.

Site number	Extra wood in row 1	Extra wood in row 2
27	16	-1
28	83	42
29	167	24
30	93	25
31	98	29
32	104	-9
Mean	94	18

An analysis of variance (see Table 18) of the wood volume data (rows 1, 2 and 3 only) details the highly significant difference in wood volume between rows ($p < 0.001$).

Table 18. ANOVA for mean volume per hectare by row for 9.7-year-old *E. globulus*.

Source	d.f.	s.s.	m.s.	F value	F.pr.
Site	5	266107	53221	7.43	<0.001
Row	2	989897	494948	69.06	<0.001
Site by row	10	242994	24299	3.39	0.003
Error	35	250855	7167		

A T-test (Table 19) details the significant differences between sites ($p < 0.05$).

Table 19. Results of T-test on sites for mean wood volume per hectare for 9.7-year-old *E. globulus*.

Site number	Number of	Mean wood volume	T grouping*
27	9	421	B
28	8	490	B
29	9	411	B
30	9	281	A
31	9	408	B
32	9	279	A

* Note – common letters indicate non-significant differences ($p < 0.05$).

Ignoring sites, all the means for each row type (i.e. rows 1, 2 and 3) were analysed to determine the least significant difference between rows. It confirms that row 1 is significantly different from row 2 but that row 2 and 3 are not significantly different (see Table 20).

Table 20. Results of T-test on row for mean volume per hectare for 9.7-year-old *E. globulus*.

Row number	Number of	Mean wood volume	T grouping*
1	18	570	B
2	18	304	A
3	17	260	A

* Note – common letters indicate non-significant differences ($p < 0.05$).

The extra wood production of the edge row is illustrated in Figures 4 and 5 for two typical sites (Sites 31 and 32).

4.2.2 Width of 'edge effect'

Data on wood volume per hectare by row from Sites 31 and 32 were collected from the six outside rows. This additional data confirms that extra wood production was restricted to just the edge row and that the volume of wood produced was approximately the same for each row from row 2 to row 6 (see Figures 4 and 5). Any differences in wood production between rows 2 to 6 is at least partly caused by variations in tree stocking (trees/ha) between rows. One example is row 5 of site 32 where a lower wood volume correlates with a lower stocking (731 trees/ha), where as the mean stocking across rows 2 to 6 was 974 trees/ha.

Figure 4. Wood volume of row 1 to 6 for 9.7-year-old *E.globulus* at Site 31.

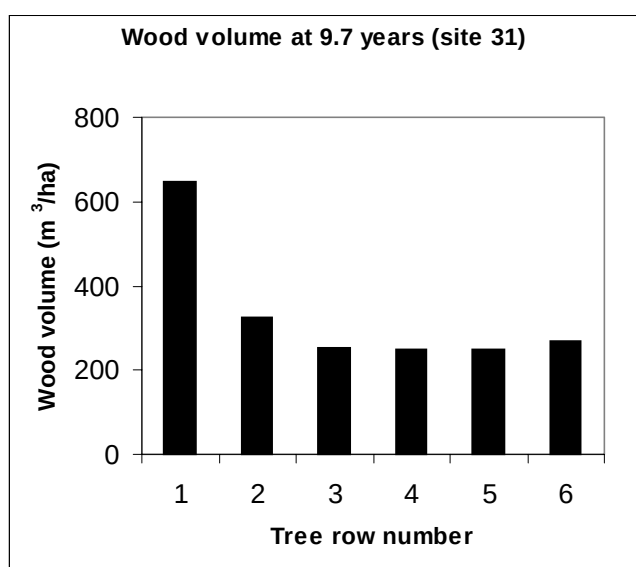
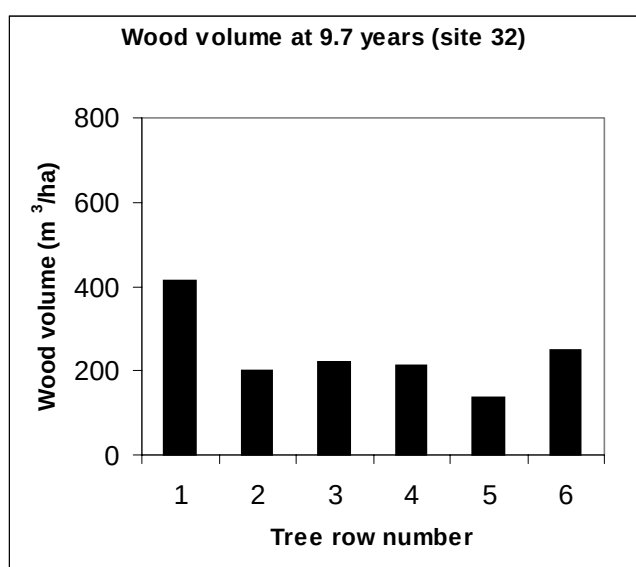


Figure 5. Wood volume of row 1 to 6 for 9.7-year-old *E.globulus* at Site 32.



4.2.3 Development of 'edge effect' with age

Data on wood volume per hectare by row was collected for trees 1.7 years and older. This enabled the age at which the 'edge effect' became apparent to be determined (see Table 21).

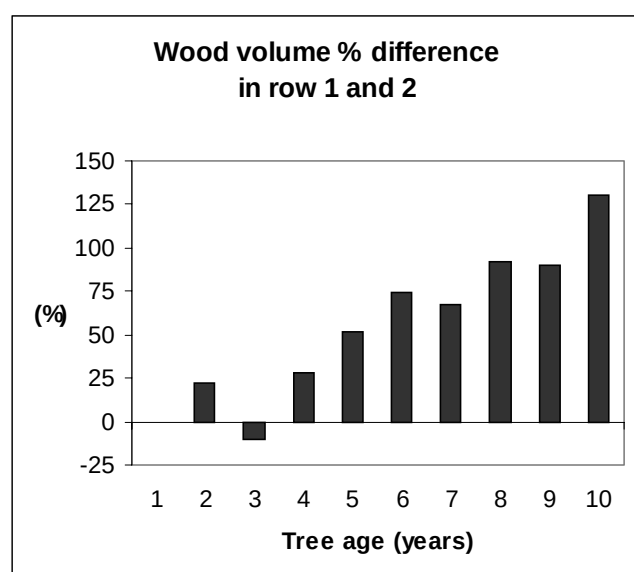
Table 21. Percentage differences in wood production between row 1 and 2 by year from age 1.7 to 9.7 years for *E. globulus*.

Site no	Tree age (years)								
	1.7	2.7	3.7	4.7	5.7	6.7	7.7	8.7	9.7
1			54	69	84				
2			31	57	74				
4					9	24	41		
5	9	3	27						
6	97	10	10						
7				96	103	107			
8				122	126	141			
9		-15	-1	16					
10		-7	24	51					
11	18	-3							
12	-38	-26							
13		-29	-16	-2					
14		-9	-1	19					
15					114	125	138		
16			54	85	103				
17			46	60	84				
18			80	99	126				
19			47	61	76				
22			7	19	47				
23				72	60	67			
24				44	44	50			
25				-5	7	20			
26				25	47	65			
27						2	10	16	
28						72	79	83	
29							169	173	167
30							117	89	93
mean	22	-10	28	52	74	67	92	90	130

Note Site number 3 was terminated in 1996 and site numbers 20 and 21 were not used because trees were too young (small) to confidently calculate wood volume.

Table 21 details that on most sites the 'edge effect' was apparent by 4.7 years. At this age the mean volume of wood in row 1 was 52% greater than the mean volume of wood in row 2. During the following 4 years (to age 8.7 years) it averaged 75%. The development of the 'edge effect' is illustrated graphically in Figure 6.

Figure 6. Change in percentage difference in wood volume of row 1 compared with row 2 over the period 1.7 to 9.7 years for *E.globulus*.



4.2.4 Impact of site quality on 'edge effect'

The size of the edge effect varies from 16 to 167 per cent for the six oldest sites (see Table 17). It is hypothesised that the higher the site quality the lower the edge effect. On sites of high quality there is a non-limiting level of nutrient and moisture and consequently edge trees do not respond as much as they do on low quality sites where growth factors are more limited.

To test this hypothesis the size of the edge effect at 6.7 years was compared with various site parameters such as rainfall (Appendix 2), soil phosphorus level, soil salinity level, soil organic carbon and depth to hardpan (Appendix 4). Data at 6.7 years were used because by this age the edge effect was well established and there was a greater number of sites available to examine. However, no consistent pattern was found with any of these 5 parameters (see Table 22).

Table 22. Relationship of the size of the 'edge effect' and various site parameters for *E.globulus* at 6.7 years of age.

Site number	Extra wood in row 1 compared with row 2 (%)	Phosphorus (Olsen test) (ppm)	Rainfall (mm/yr)	Salinity (E.C.) (ms/m)	Organic carbon (%)	Depth to hardpan/impeding layer (cm)
4	24	11.7	730	6.50	2.60	40
7	107	2.8	760	2.49	1.79	270+
8	141	0.7	1015	4.01	2.36	25
9	16	17.3	780	9.69	3.05	180+
10	51	26.2	780	11.49	2.78	30
15	125	12.0	625	10.00	2.75	180+
23	67	2.8	1000	4.00	2.49	W.T. at 80
24	50	22.7	1000	10.50	1.72	W.T. at 80
25	20	11.4	660	4.10	3.79	200+
26	65	11.1	660	5.03	2.14	200+

Note. W.T. = watertable

4.2.5 Impact of orientation on 'edge effect'

It was not possible to identify the impact of orientation on wood production in this project. From an experimental point of view different orientations on a uniform site were required. Such sites could not be found for this project.

4.2.6 Impact of tree height on 'edge effect'

Data on mean tree height of row 1, 2 and 3 for the six 'harvestable age' sites is detailed in Table 23. Although the mean height of the outside edge row is less than that of the inside rows this difference was not significant ($p>0.05$), (see Table 24).

Table 23. Mean height by row for 9.7-year-old *E. globulus* at the 6 project sites.

Site number	Row 1 (m)	Row 2 (m)	Row 3 (m)
27	19.9	22.7	23.3
28	20.7	22.0	19.9
29	19.1	20.0	20.0
30	16.0	18.0	17.3
31	19.7	21.5	22.5
32	20.2	20.9	20.4
Mean	19.2	20.8	20.6

Table 24. ANOVA for mean tree height by row for six 9.7-year-old *E. globulus* sites.

Source	d.f.	s.s.	m.s.	F value	F.pr.
Site	5	2096.6	419.3	145.7	<0.001
Row	2	7.7	3.8	1.3	0.283
Site by row	10	16.9	1.7	0.6	0.809
Error	23	66.2	2.9		

4.3 Effects of design on profit

Belt width, alley width and orientation are the three components of design on which this project can inform farmers. The benefit of north-south orientation of timber belts for pasture production has been made clear (section 4.1.3.), but it has not been possible to identify any effect on wood production. The primary focus of economic analysis has been on the effects of belt width and alley width on the profitability of north-south oriented alleys.

It was also important to determine whether site quality for blue gums would modify these effects by virtue of raising or lowering the value of wood production, and whether pruning could alter the relative profitability of different designs.

It should be noted that for modelling purposes the results of field measurements have been extrapolated to apply to narrow belts. For example, no field observations were made on 2-row belts. On most sites the belts were more than 10 rows wide. It is possible, although unlikely, that edge effects between trees and pasture are different when the belts are very narrow.

Alley farming, being a combination of two different land uses, will only be more profitable than either of these land uses when the positive interaction between trees and grazing system is large enough to outweigh the superiority of the more profitable one over the other. For example, alley farming will not be selected when plantation returns are ten times those of grazing, or vice versa. The ranges of plantation and grazing returns within which alley farming is the preferred system will be identified in some detail in Section 4.3.6.

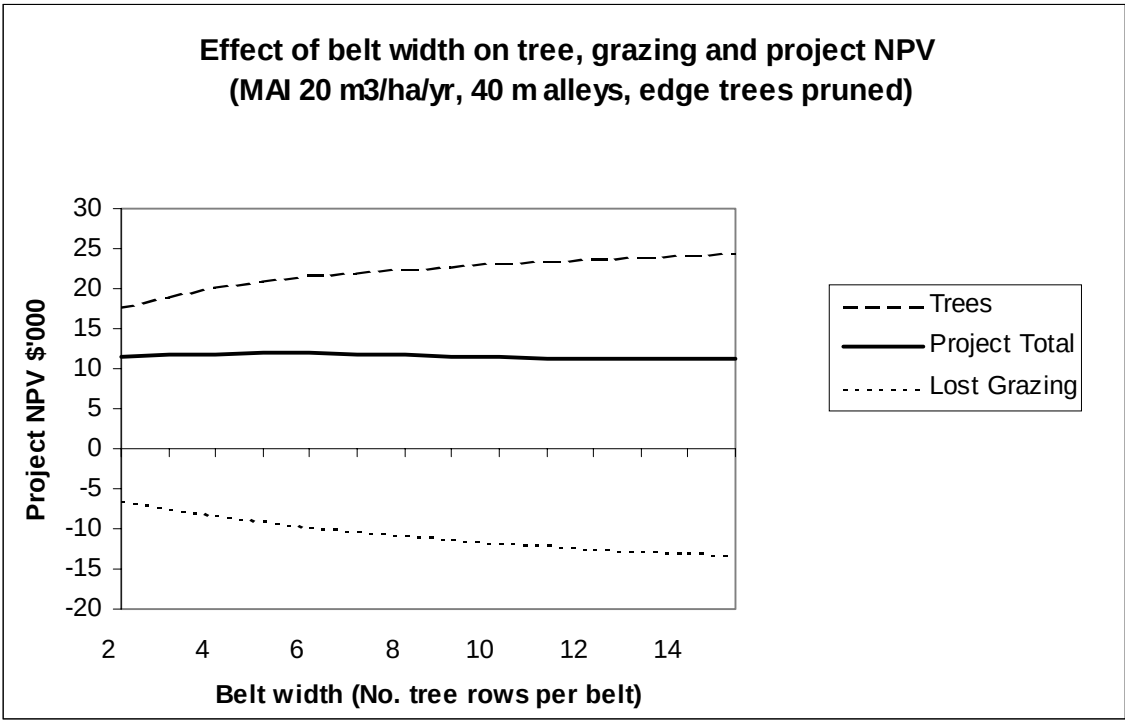
The same logic dictates that the respective gross returns for blue gums and grazing have a major bearing on the relative profitability of alley farming designs in which one land use or the other predominates. Any conclusions about optimal belt width and alley width must therefore be related to specific yield and price assumptions. As mentioned in Section 3.11, gross margins for grazing and plantation blue gums range from less than half to more than double the median values assumed for most of the analyses below.

4.3.1 Effects of belt width on profit

Figure 7 shows that the profitability of alley farming appears to be unaffected by belt width for a project with 40 m alleys on a site that is mid-range for blue gums (MAI 20m³/ha/yr for inside row trees).

The NPV of this project is consistently about \$12,000.

Figure 7. Net Present Value of a 40 ha blue gum alley farming project with alleys 40 m wide, on a median site for a range of belt widths.



However, narrow tree belts are more profitable when evaluated in terms of Internal Rate of Return (IRR), provided that alley width does not exceed about 150 m, as can be seen in Figure 8. This is because the maximum agroforestry effect is achieved for the money invested.

When belts are more than about 100 m apart, they must be at least 5 rows wide to produce enough logs to contain harvesting costs. Increasing the area planted to widely spaced narrow tree belts will not contain harvest costs, because of the cost associated with the extra distance logs must be carried to the landing from thinly spread plantings.

Figure 8. Internal Rate of Return for a 40 ha blue gum alley farming project on a median site for a range of belt widths.

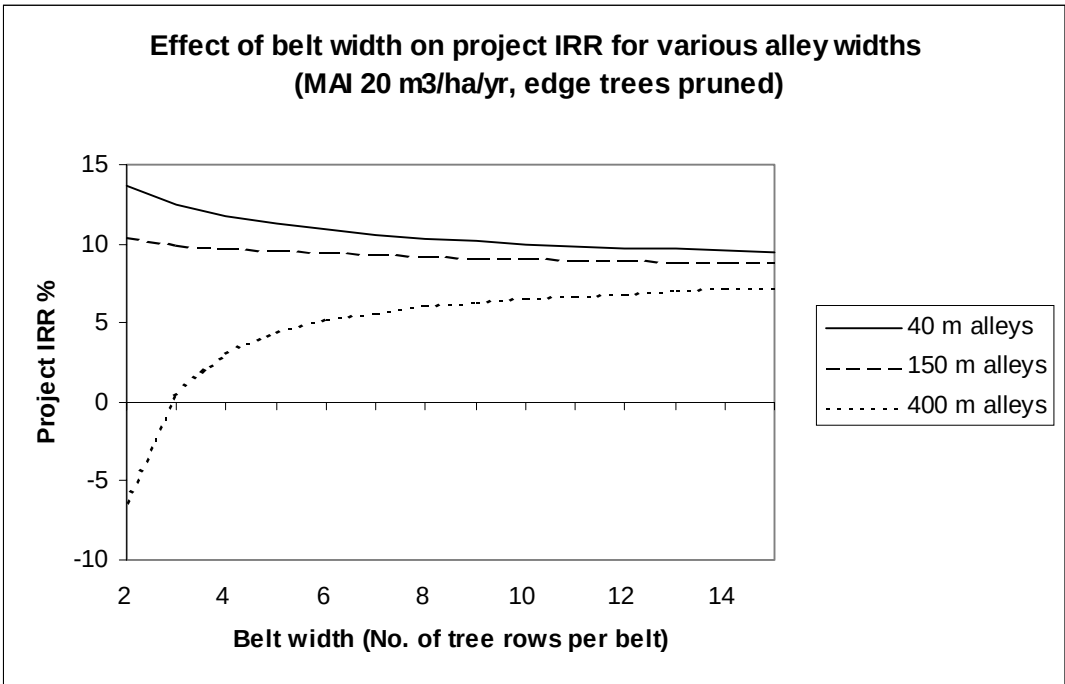
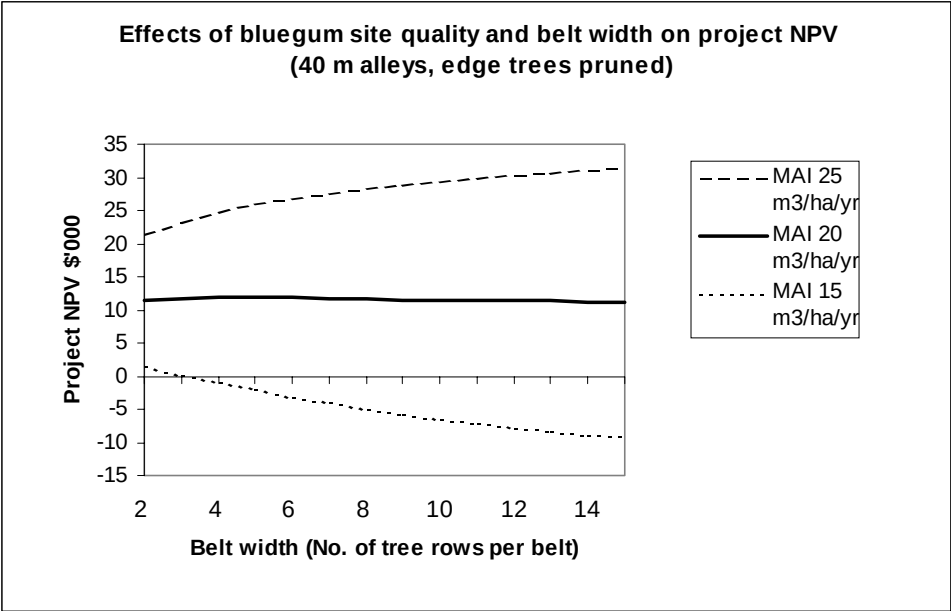


Figure 9 shows that to maintain profitability on lower yielding sites it is very important to plant narrow belts. It is much less profitable when blue gum site quality is low. Narrower belts have a higher proportion of edge trees, which produce higher log volumes per tree. On sites good for blue gums, wider belts have a higher NPV. Increasing the distance of the project site from the mill, or reducing the mill door price, both have an effect similar to lower site quality, because they reduce the revenue from log sales.

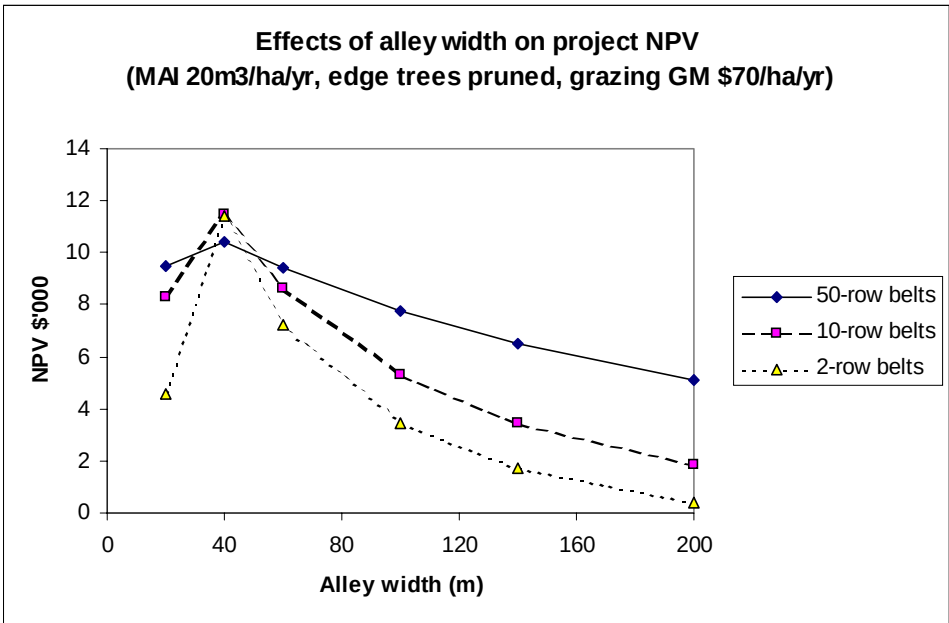
Figure 9. Net Present Value of a 40 ha blue gum alley farming project with 40 metre alleys on sites of high, medium and low quality for blue gums, for a range of belt widths.



4.3.2. Effects of alley width on profit

Figure 10 shows that on a site that can produce 20 m³ of blue gum pulplogs per hectare per year from a plantation, when grazing gross margin is \$70/ha/yr, it is most profitable to have alleys about 40 metres wide. Very wide alleys are unprofitable because only a small volume of wood is produced on the project area. The sharp fall in profitability when alley width is less than 40 metres is due to the assumption made that trees within two tree heights of each other compete for resources, thus mutually suppressing growth.

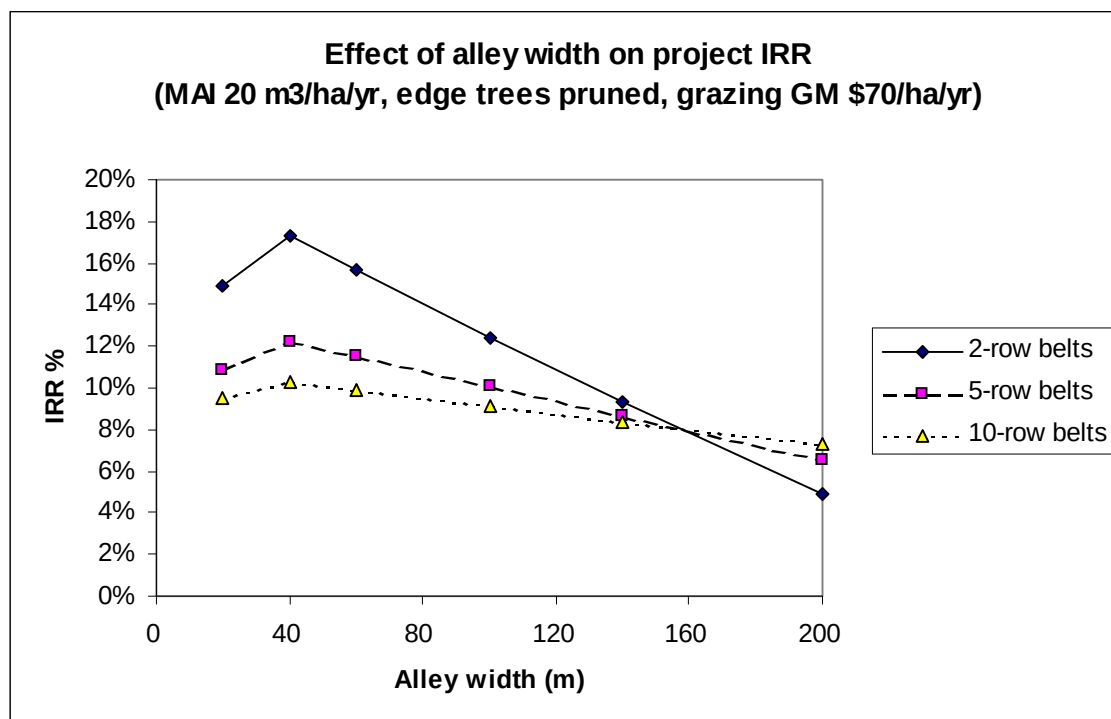
Figure 10. Net Present Value of a 40 ha blue gum alley farming project, on a mid-range site for a range of alley widths and belt widths.



Blue gums in plantations yielding 20 m³ of blue gum pulplogs per hectare per year are assumed to reach a top height of about 20 m at age 10 years (S.J.Quain, pers. comm.). As tree height is a key indicator of site quality, it is likely that edge trees would suffer from competition on high quality sites unless alley width was proportionally greater than 40 metres.

The same picture emerges in Figure 11, when the project is evaluated in terms of Internal Rate of Return.

Figure 11. Internal Rate of Return for a 40 ha blue gum alley farming project on a mid-range blue gum site for a range of alley widths, for 2-row, 5-row and 10-row belts.



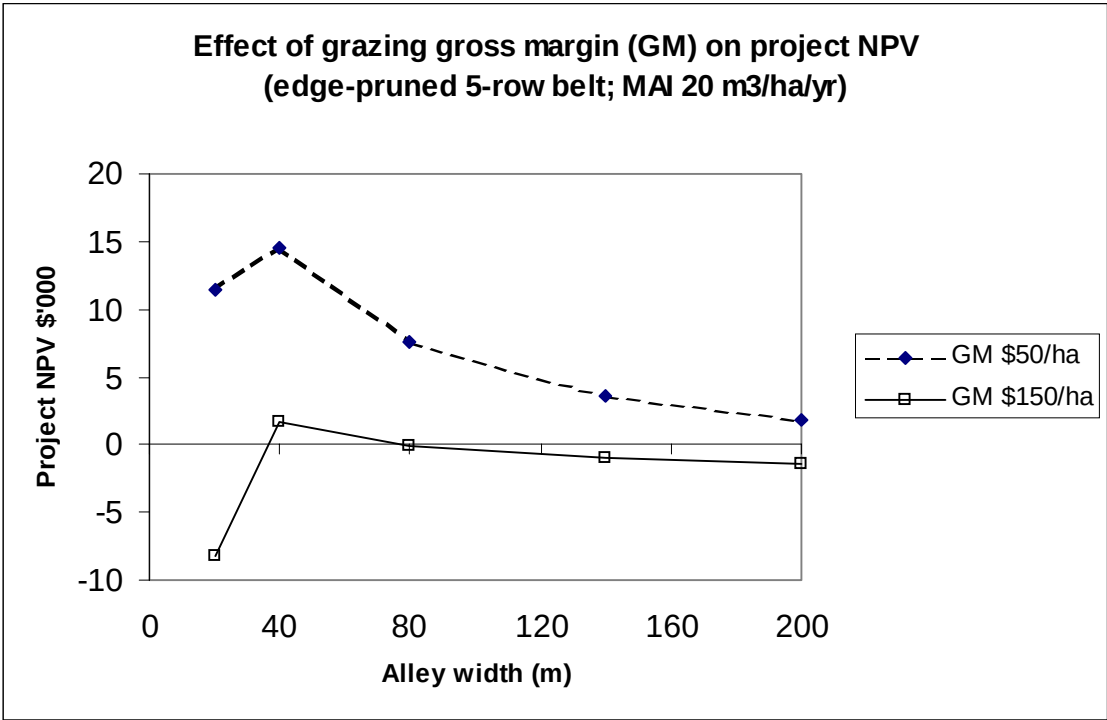
The value of limiting alley width to two tree heights is most obvious for 2-row belts, whereas IRR for 10-row belts is influenced much less by alley width.

The optimum alley width depends very much on the relative profitability of grazing and blue gums as enterprises in their own right. Narrow alleys are better when tree returns are higher than grazing returns. Wider alleys are better when grazing returns are higher than tree returns.

4.3.3 Effects of interactions between alley width and enterprise returns on profit

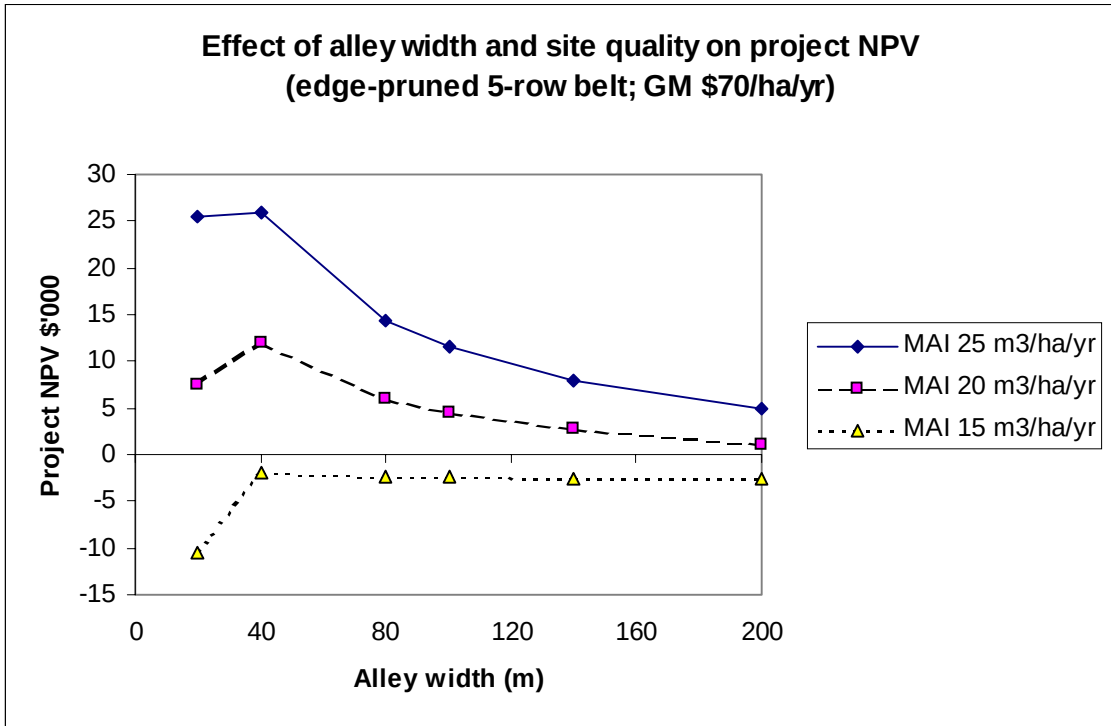
Figure 12 confirms that the profitability of blue gum belts is very sensitive to the level of grazing returns, especially when the belts are less than 80 metres apart. Gross margin (GM), defined as the margin of gross income over variable costs, is a commonly used measure of agricultural returns. Under the assumptions shown, if GM is \$150/ha/yr, blue gum alleys are only profitable for alley widths between 40 m and 80 m. When GM is \$50/ha/yr, blue gum alleys are profitable for all alley widths, but alleys 40 m wide are the most profitable spacing of belts.

Figure 12. Net Present Value of a 40 ha blue gum alley farming project using edge-pruned 5-row belts for alley widths between 20 m and 200 m, on sites with high and low productivity for grazing.



Blue gum site quality also influences the relative profitability of different alley widths. Alley widths of less than 80 m are more profitable than wider alley widths for 5-row belts when MAI is 25 m³/ha/yr, as shown in Figure 13. In contrast, 5-row belts are not profitable for any alley width when MAI is 15 m³/ha/yr, especially if tree growth is further suppressed by closer spacing of belts due to very narrow alleys.

Figure 13. Net Present Value of a 40 ha blue gum alley farming project using edge-pruned 5-row belts for alley widths between 20 m and 200 m, on sites with high, medium and low productivity for blue gums.

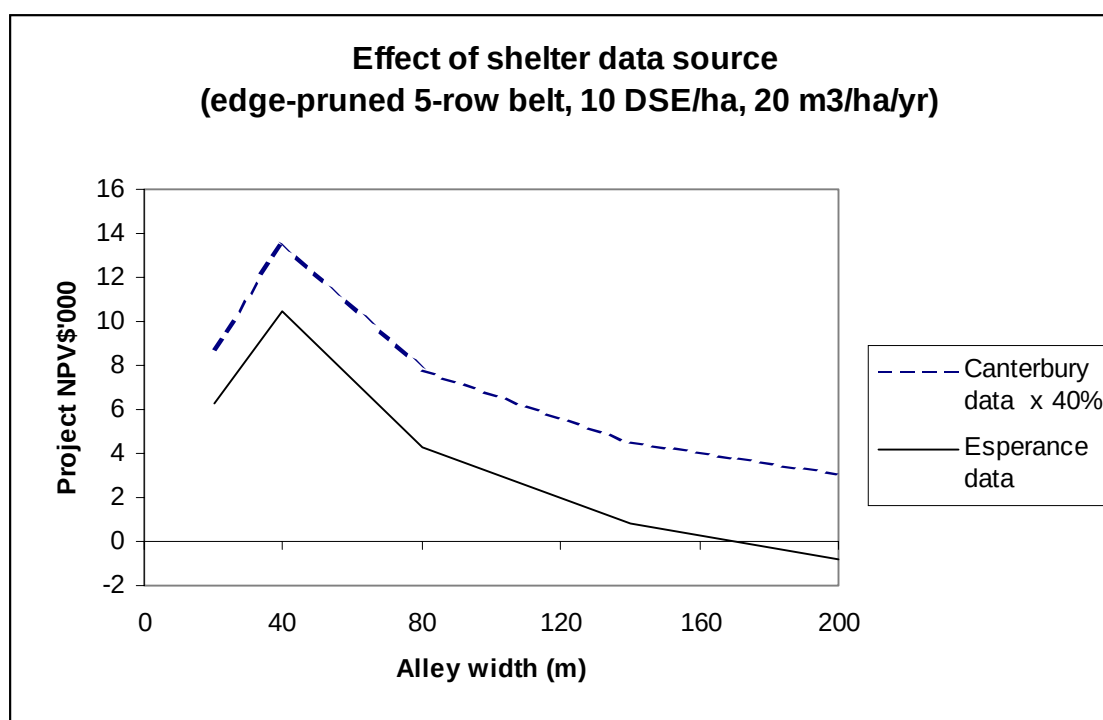


4.3.4 Significance of shelter value on profit

It appears unlikely that the value of belts of blue gums as shelter is a decisive factor in the design of alley farming systems in the grazing belt of South Western WA, at the level of returns generally received on broadacre farms. This was shown by using two different estimates of the effect of shelter on grazing, as outlined in section 3.13. Figure 14 shows that the replacement of a modified Canterbury response (which assumes yield increases by up to 20 per cent at 5 tree heights) with the Esperance response (which has a maximum yield benefit of 4 per cent at 9 tree heights) does not change the optimal alley width. This is because the value of grazing is low relative to that of the tree crop when MAI at harvest is 20 m³/ha/yr and distance to the chipmill 60 km.

Canterbury data were modified to reflect the more moderate climatic conditions usually experienced in southern Western Australia. That is, with less extreme cold, rainfall and wind speed, it was assumed that yield responses to shelter would be 40% of those measured on the Canterbury plains.

Figure 14. Net Present Value of a 40 ha blue gum alley farming project under alternative assumptions of shelter benefits on an average blue gum site 60 km from chipmill.

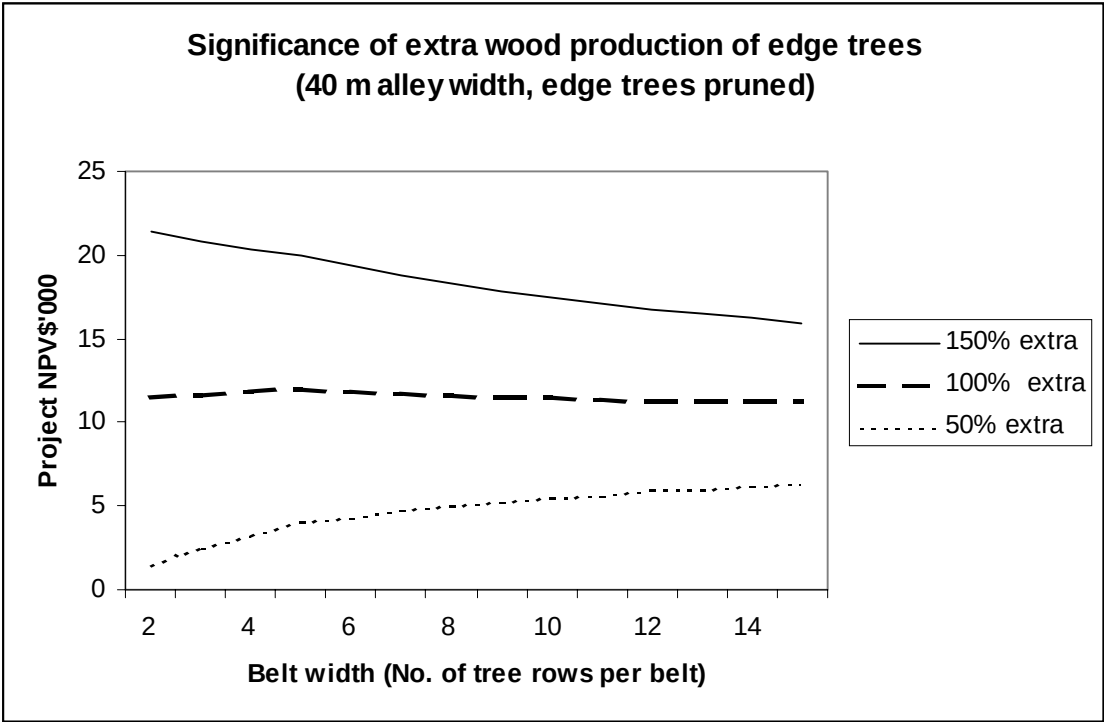


4.3.5 Significance of edge tree advantage on profit

The relative wood volume advantage edge trees have over inside trees is an important determinant of the profitability of blue gum alley farming. Figure 15 shows that the profitability of narrow belts is especially dependant on the magnitude of the edge tree advantage, although the project remains better than grazing even if the edge tree advantage is as low as 50 per cent.

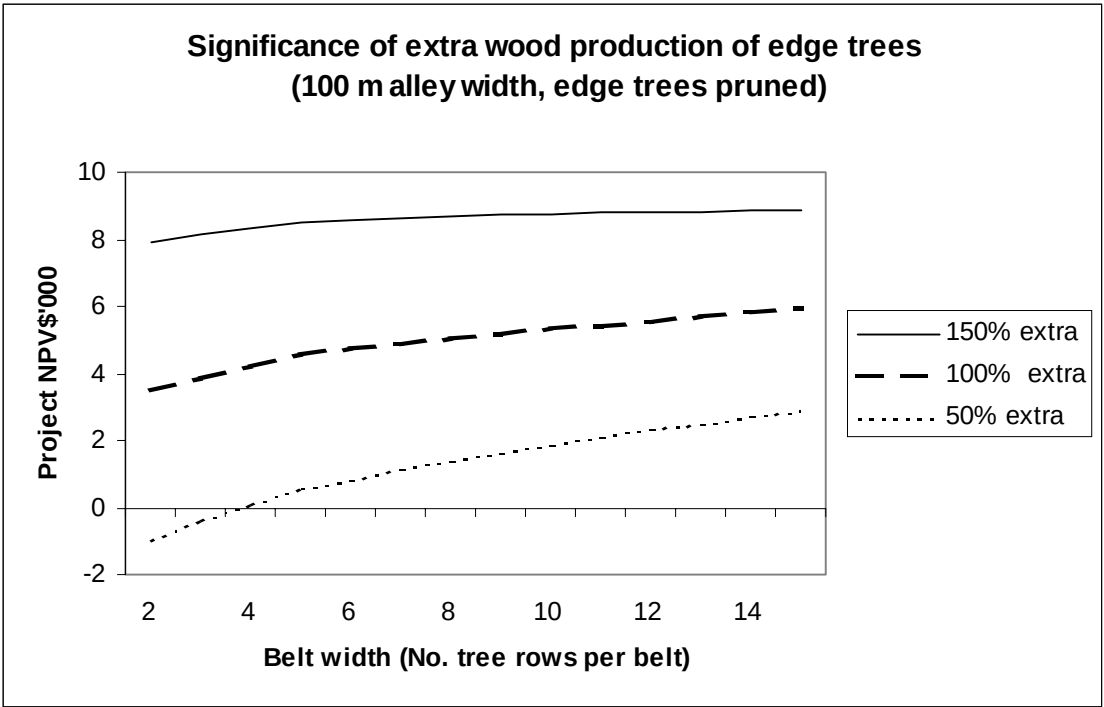
The importance of the edge tree advantage is magnified with increasing distance to the chipmill, because it could compensate for reduced stumpage due to extra haulage costs.

Figure 15. Net Present Value of a 40 ha blue gum alley farming project with 40 m alleys under alternative assumptions about extra wood production of edge trees.



Assuming median site quality for blue gum volume (MAI of 20 m³/ha/yr in plantation) wider belts become necessary to ensure profitability when alley width is 100 m. This is shown in Figure 16.

Figure 16. Net Present Value of a 40 ha blue gum alley farming project with 100 m alleys under alternative assumptions about extra wood production of edge trees, on a mid-range blue gum site.



4.3.6 The 'window' of opportunity for alley farming

As explained early in Section 4.3, beyond the question of alley farming design is the question of whether alley farming is superior to alternative systems. This project does not examine alternatives such as widely spaced individual trees grown for sawlogs, but it can identify the range of situations in which it will be superior to grazing or plantation.

Tables 25 and 26 show how plantations, pure grazing and alley farming each have a role to play, depending on the site suitability for grazing and blue gums respectively. Spreadsheets were used to calculate NPV for a 40 ha paddock for each of four land use systems:

Grazing	no trees
Plantation	100% blue gums (single rotation)
Alley Farming	2-row blue gum belts (single rotation) with 40 m alleys (i.e. trees on 17% of paddock)

Note that other alley designs are not included as an option because they would not be as profitable as 2-row belts with 40 m alleys under the assumptions used in this study. Note also that hydrologic considerations are excluded.

Table 25 shows that the niche for alley farming is not limited by site quality for a single land use (i.e. grazing or plantation), but it is determined by the relative returns of the two components of alley farming.

Table 25. Farming system with highest Net Present Value (50 km to chipmill).

	Site quality for blue gums (plantation MAI m ³ /ha/yr)		
Grazing gross margin (\$/ha/yr)	15	20	25
0	Alley Farming	Plantation	Plantation
30	Alley Farming	Plantation	Plantation
60	Alley Farming	Plantation	Plantation
90	Alley Farming	Alley Farming	Plantation
120	Grazing	Alley Farming	Plantation
150	Grazing	Alley Farming	Plantation
180	Grazing	Alley Farming	Plantation
210	Grazing	Grazing	Alley Farming
240	Grazing	Grazing	Alley Farming

MAI Mean annual increment at age 10.

Comparing Table 25 and Table 26 shows that the more distant the pulplog market, the lower the range of grazing returns at which alley farming finds its niche.

Table 26. Farming system with highest Net Present Value (100 km to chipmill).

	Site quality for blue gums (plantation MAI m ³ /ha/yr)		
Grazing gross margin (\$/ha/yr)	15	20	25
0	Alley Farming	Plantation	Plantation
30	Alley Farming	Alley Farming	Plantation
60	Grazing	Alley Farming	Plantation
90	Grazing	Alley Farming	Plantation
120	Grazing	Alley Farming	Alley Farming
150	Grazing	Grazing	Alley Farming
180	Grazing	Grazing	Alley Farming
210	Grazing	Grazing	Alley Farming
240	Grazing	Grazing	Grazing

4.3.7 Reliability of conclusions

The sequences of equations in spreadsheets used for economic modelling in this project do not in themselves propagate any errors which may or may not have occurred in the physical measurements of pastures and trees.

The extent to which uncertainty about individual variables affects profit, for any hypothetical blue gum alley farming project, is captured in sensitivity analyses. Site characteristics appear to affect the degree of edge tree volume superiority quite markedly, and affect the width of pasture loss to a lesser degree. To the extent that these relationships are as yet undescribed, and both tree and grazing returns uncertain, farmers cannot be certain of the most profitable alley farming design for a given paddock.

5. Discussion

5.1 Effects of blue gum alley farming design on pasture production

In this project tree belt orientation and tree age are the two significant variables that affected the interface competition between trees and adjacent pasture. In contrast, the rainfall variable had no significant effect on the width of pasture loss.

Tree belt orientation affected pasture growth with the largest width of pasture loss on the north side of 7.1 m. The width of pasture loss on the south, east and west sides were 6.7, 5.4 and 5.4 m respectively.

Although it was hypothesised that the south side would have the greatest width of pasture loss it was not recorded in this project. However, higher soil moisture (due to lower light, less heat and therefore less evaporation) can be expected on the south side, which could negate the effect of sub-optimal light and temperature and result in more normal pasture growth. In this project the relative values of the three major plant growth yield constraints (i.e. temperature, light and moisture) were not measured. From a practical perspective, because alley farming tree belts have pasture on both sides of the tree belt the mean 6.9 m of pasture loss on the north/south combination must be directly compared with the mean 5.4 m in the east/west combination. Here the mean north/south pasture loss distance is approximately 20% more than in the mean east/west.

This result has direct economic implications for farmers planning a bluegum alley farming layout. Clearly, alley farming treebelts planted in a north/south direction (i.e. with pastures on the east and west sides of the treebelt) will minimise the tree/pasture interface competition, the subsequent pasture loss and ultimately grazing (or fodder conservation) losses. This implication is consistent with 'best management practice' in the horticultural industry.

Increasing tree age affects the width of pasture loss. As the tree age increases the tree/pasture interface competition increases which results in an increasing width of pasture loss. A linear regression can be fitted to this relationship.

$$\text{Width of total seasonal pasture loss (m)} = 0.64 (\text{tree age in years}) + 2.73. \quad r^2 = 0.76$$

It must be noted that this project only measured the tree/pasture interface competition in the first tree harvest cycle (i.e. up to 10 years after the initial tree planting). As with many other commercial tree crop species *Eucalyptus globulus* can coppice for subsequent harvests at approximately 10 year intervals. It is expected that *E. globulus* can profitably yield 3 crops (in 30 years) before the stand needs to be replaced. It is anticipated that the tree/pasture interface competition effect on pasture yield loss during the entire second and third tree harvest cycles will approximate (if not exceed) the first harvest cycle predicted 10 year value (i.e. 9.2 m).

Site rainfall (or the two rainfall categories of < and > 750 mm) did not significantly affect the tree/pasture interface competition. It has been concluded that, at the driest site, there was sufficient rain not to significantly limit tree growth and consequently not increase the tree/pasture interface competition.

The autumn pasture yield losses were greater than those recorded for the total season. This is an example where the tree roots to the detriment of the shallow rooted pasture sward have accessed limited soil moisture. This wider autumn pasture loss distance will exacerbate the autumn/winter feed gap and will result in reducing farm profitability.

5.2 The effect of the ‘edge’ on wood production

The extra wood produced in the edge row was almost double that of the second row by age 9.7 years (harvestable age for most sites). This extra production is substantial and therefore an important factor to take into account when deciding how many rows per belt to plant. The greatest wood production can be obtained from 2-row belts due to all the trees being edge trees. With each additional row, overall wood production will be less. Table 27 illustrates the relationship between belt width and overall wood production. For the purpose of this illustration it has been assumed that wood production in the outside row is double that of the inside rows (see Figures 4 and 5).

Table 27. Impact of belt width (number of rows per belt) on overall wood production, assuming production of inner rows is 200 m³/ha and edge row is 400 m³/ha.

Rows/belt	Wood production by row (m ³ /ha)	Wood production (m ³ /ha)
2	400 + 400	400
4	400 + 200 + 200 + 400	300
6	400 + 200 + 200 + 200 + 200 + 400	260
8	400 + 200 + 200 + 200 + 200 + 200 + 200 + 400	250
10	400 + 200 + 200 + 200 + 200 + 200 + 200 + 200 + 200 + 400	240

The factors that led to accelerate tree growth of edge trees are identical to those harnessed in ‘wide-spaced silviculture’. The work of Knowles (1991) and Anderson *et al.* (1988) with pine showed how the growth rate of individual trees could be greatly increased by reducing competition between trees. Increasing the distance between trees lessens the competition between trees.

Increased distance between trees gives each tree greater access to moisture, nutrients and sunlight – the essential elements for growth. The extra wood production of edge trees occurs for the same reasons. Edge trees are able to develop bigger root systems and crowns than trees within plantations, and thereby gain greater access to the essential elements for growth. Land adjacent to trees is commonly used for pasture production only (usually shallow rooted annual pastures) and trees are able to make use of this space and grow faster.

The results indicate that the ‘edge effect’ does not extend beyond the first row. Wood production of row 2 is no greater than that in rows 3 to 6 (see Figures 4 and 5). This suggests that trees in row 2 are not able to access significantly more moisture, nutrients or sunlight than trees in row 3.

The extra wood production is likely to be especially valuable in areas where blue gum plantations are considered a marginal proposition, e.g. areas of low rainfall. Blue gums arranged in belts in a low rainfall zone (<700 mm/year) could lift overall production from marginal to satisfactory (Eckersley, 1994).

If belt layouts enable trees to have greater access to soil moisture, it follows that the risk of trees dying from drought is lessened. Furthermore it has been suggested that if trees are to overcome the entrenched problem of rising watertables, they need to be dispersed across the landscape (Bartle *et al.* 1996). Trees in belts with alleys in between for agricultural production is an arrangement with potential to meet both economic and environmental goals.

There are costs associated with growing trees in belts. The main one is pruning. Edge trees need to be low-pruned to enable harvesting equipment to operate satisfactorily. Bunnings TreeFarms have found that unpruned edge trees cannot be harvested by machine because the harvesting ‘head’ cannot strip off the large branches (P.Durell, pers. comm.). The edge trees of plantations are usually felled and trimmed with a chainsaw. However, edge trees that had been pruned were able to be harvested using conventional equipment (D.Jenkins, pers. comm.). There is no evidence that the quality of pulpwood from edge trees is less (P.Durell, pers. comm.).

Low pruning has benefits in addition to making harvesting easier. Low pruning improves visibility through belts of trees, which can make it easier to check and muster stock. Low pruning also improves pasture growth by reducing shading adjacent to trees (D.Jenkins, pers. comm.) and enables closer access to rows when applying fertiliser by tractor into the tree belts.

Table 28. Summary of advantages and disadvantages of growing trees in belts.

Advantages	Disadvantages
• Doubled wood production from edge row. • Improved overall wood production and returns, especially for narrow belts. • Potential to overcome challenging land use problems such as rising water table through dispersing trees across the landscape. • Potential to lift pulpwood production from marginal to satisfactory at the lower end of the rainfall range. • Reduced likelihood that trees will die from drought in marginal areas. • Belts are able to complement agriculture better than blocks (e.g. by providing shelter).	• More complicated to layout and establish. • Extra management cost of low pruning. • Loss of pasture production adjacent to trees. • High fencing costs, if fencing is considered necessary for the particular farming system.

5.3 The effect of design on system profit.

Belt width is an important design variable. Narrow belts are attractive because of the greater wood production of edge trees, despite the extra cost of pruning the heavier branches on the outside. The advantage dissipates rapidly as belt width is increased because only the outside rows have any advantage.

Two-row belts have a particular advantage in areas with lower rainfall, where both tree growth rate and stumpage are likely to be lower. Two-row belts also have the advantage that the risk of drought deaths in blue gums is likely to be reduced. In these circumstances a plantation is unprofitable, whereas two row belts are clearly profitable provided MAI exceeds 15 m³/ha/yr and the belts are close enough to allow total pulplog production of about 2,000 m³.

Conversely, on sites that are close to a chip mill and produce large wood volumes but only modest returns from grazing, a plantation is the most profitable design.

Unless another more profitable land use such as horticulture is an option, blue gum plantations are the most profitable land use on sites where stumpage exceeds \$25/m³ and MAI greater than 25 m³/ha/yr. The equivalent annual return at this yield and price has been estimated at \$266/ha (Agriculture Western Australia and Department of Conservation and Land Management 1999 b). Grazing gross margin rarely exceeds this level in the beef industry (Kingdon and Sawyer 1994) and on half the farms surveyed, gross margin was less than \$172/ha/year (the returns for blue gum alleys with a MAI of 20m³/ha/year). The gross margin/ha is generally lower in the sheep and cropping industry. A survey of Kojonup farms, where the dominant land use is sheep grazing with some cropping, provides evidence of this. Farms in the top quartile (profit based) of surveyed farms in Kojonup Shire produced an operating return of \$145.70/ha in 1997 (BankWest, 1998). Gross margin is marginally higher than operating return because cash overheads have been deducted as well as variable costs.

Choice of alley width is mainly affected by the relative profitability of grazing and blue gums in their own right. Higher stumpage and yield of blue gums enhance the value of narrow alleys relative to wide alleys. Hydrologists have suggested that trees will not affect desired water use beyond 10-30 m (George *et al.* 1999). In discharge areas it is suggested that bays (alleys) wider than 50 m may have little effect on watertables within the bays (Thorburn and George, 1999). Incorporation of the benefits of extra water use into the economic model would favour narrower alley widths.

There is no single best design for all situations, because of the differences between sites in terms of tree growth, grazing returns and distance to chip mill. Fortunately, most of these can be estimated, but the size of the wood volume advantage of edge trees cannot yet be predicted accurately. The choice of design for planting blue gums in an alley farming layout must rest with the landowner, taking into account these and other farm planning considerations, including landscape (visual) and labour issues.

A computerised model such as BLUEBELTS or the spreadsheet used in this project is necessary to integrate a number of site-specific variables. This would allow selection of an optimal design, other than for the continuing uncertainties of price and yield.

Project size is itself another design consideration. When two-row belts and wide alleys are selected, larger projects may be needed to contain the costs of bringing harvesting machinery to the site.

The size of the edge effect on wood production has a major impact on profit, as shown in Figure 15. However, as shown in section 4.2.4, this project cannot explain why the edge effect varies. Too few sites with harvest-aged trees were available to identify the sources of this variability. Site factors such as soil depth, rainfall and soil fertility status may be related. Further investment in research on this subject would appear to be worthwhile in order to give farmers some predictive tool relating edge effect to readily measurable site variables.

5.4 Future research directions

There is potential to add value to this project by finding the reasons for variation in edge effects on the trees. The economic modelling would be enhanced by fully integrating the hydrological and shelter effects with the relationships found for the competition zone, and the site characteristics which have predictive value for tree edge effect.

6. Outcomes

This project confirms predictions by agroforestry advisers and practitioners that the so-called 'agroforestry effect' can occur in a silvo-pastoral system where blue gums are grown in an alley farming layout alongside subterranean clover based pastures grazed by sheep and cattle. That is, the physical productivity of trees and pasture grown in combination exceeds that of either grown separately. However, growing them in combination will only be the most profitable system within a certain range of relative prices of the agricultural and forestry commodities produced.

The findings of this project are important in the light of recent developments, which include

- mounting evidence that blue gum growth rates are strongly related to rainfall, soil depth and soil fertility (Harper et al 1999)
- plantation blue gums at age 6-10 years on suitable sites are likely to have a Mean Annual Increment of only 12 to 15 m³/ha/yr in the 600-700 mm rainfall zone, whereas MAI in excess of 30 m³/ha/yr at age 10 years is often achieved on good sites where rainfall exceeds 800 mm (R.Harper pers. comm.).
- hardwood woodchip prices follow the downward long term trend that is typical of primary industry commodity markets (Penmm and Connell 1997).

Grower concern at the latter trend is leading to stronger interest in managing blue gum stands for production of solid wood products. It has been estimated that by August 1999, some 500 hectares of eucalyptus plantations in Western Australia were already under silvicultural regimes aimed at sawlog production (Western Timber Cooperative pers. comm.).

This begs the question of whether edge trees have the same value per cubic metre as inside row trees for sawing purposes.

7. Appendices

7.1 Appendix 1: Site details.

Site number	Location	Tree age (planting year)	Number of rows in tree belt	Tree line to fence (m)	N, S, E or W facing pasture
1	Many Peaks	1992	6	2.1	N
2	Yellanup	1992	10	5.1	S
3	Woodburn	1990	7	2.0	W
4	Woodburn	1990	7	2.0	E
5	Woodburn	1994	6	1.2	N
6	Woodburn	1994	6	1.6	S
7	Napier	1991	8	2.4	S
8	Redmond	1991	10	2.5	N
9	Narrikup	1993	6	2.5	E
10	Narrikup	1993	6	2.5	W
11	Marbellup	1995	14	2.0	S
12	Marbellup	1995	14	2.0	N
13	Kendenup	1993	10	2.1	E
14	Kendenup	1993	10	2.1	W
15	Perillup	1990	15	1.8	N
16	Manurup	1992	10	2.7	S
17	Manurup	1992	12	1.6	W
18	Manurup	1992	12	4.3	N
19	Manurup	1992	13	4.5	E
20	Busselton	1995	10	2.0	W
21	Busselton	1995	10	2.0	E
22	Scott River	1992	7	2.5	E
23	Scott River	1991	9	2.5	N
24	Scott River	1991	7	3.0	W
25	Mayanup	1991	13	none	E
26	Mayanup	1991	13	none	W
27	Witchcliffe	1989	16	3.7	E
28	Witchcliffe	1989	10	3.5	N
29	Ruabon	1988	23	2.0	E
30	Ruabon	1988	23	2.0	W
31	Ruabon	1988	30	2.0	E
32	Witchcliffe	1988	block	none	E

7.2 Appendix 2: Site total annual rainfall (mm).

Site number	Actual mean 1996/1998	Rainman data	Actual relative to Rainman (%)
1	539	760	71
2	664	750	88
4, 5, 6	654	730	90
7	659	760	87
9, 10	661	780	85
8, 11, 12	775	1015	76
13, 14, 15	463	625	74
16, 17, 18, 19	548	660	83
20, 21	875	780	112
22, 23, 24	1040	1000	104
25, 26	684	660	104
27, 28	1079	1150	94
29, 30	878	840	105
mean	732	808	91

7.3 Appendix 3: Site soil profile description.

Site 1

0 cm	5 cm	2.5y 6/1, grey sand.
5	40	10yr 6/6, brownish yellow coarse sandy clay loam, >50% gravel, slightly cemented.
40	95	10yr 6/8, brownish yellow, 5% red mottles (faint), light medium clay.
95	130	10yr 7/6, yellow, 5% red & orange mottles (distinct), heavy clay.
130	150	5yr 7/2, pinkish grey, 15% red mottles (prominent), heavy clay, 2% ironstone gravel.
		ec 30msm @ 150cm.

Site 2

0 cm	10 cm	10yr 5/1, grey fine sand.
10	30	10yr 6/1, grey fine sand.
30	50	10yr 8/2, white fine sand.
50	55	10yr 7/2, light grey fine sand.
55	100	2.5y 5/2, greyish brown, ortstein pan, moderately cemented, continuous.

Site 4

0 cm	5 cm	10yr 5/1, grey fine sand.
5	30	2.5y 6/3, light yellow brown fine sand, 50% ironstone gravel.
30	40	2.5y 6/3, light yellow brown clayey sand, 50% ironstone gravel.
40>		ironstone pan moderately cemented, broken.

Sites 5 and 6

0cm	5cm	10yr 5/1, grey fine sand, 2% ironstone gravel.
5	15	2.5 y 6/2, light brownish grey fine sand, 20% ironstone gravel.
15	30	2.5y 7/2, light grey loamy sand, 50% ironstone gravel.
30	40	2.5y 7/3, pale yellow fine sandy clay loam, 10% ironstone gravel.
40	80	10yr 7/8, yellow, 5% white mottles (faint), light clay.
80	170	2.5yr 5/6, red, 30% white mottles (distinct), fine sandy clay loam.
170	200	2.5y 7/3, pale yellow, 30% red and grey mottles, light-medium clay, evidence of slight waterlogging.
		ec 0msm @ 200cm.

Site 7

0 cm	30 cm	10yr 6/1, light grey fine sand.
30	200	10yr 8/1, white fine sand.
200	240	10yr 6/1, light grey fine sand.
240	270	10yr 5/3, brown loamy sand.
270>		10yr 5/2, greyish brown, ortstein pan, moderately cemented, continuous.

Site 8

0 cm	5 cm	10yr 6/1, grey loamy sand, 2% ironstone gravel.
5	15	10yr 6/2, light brownish grey fine sand, 50% ironstone gravel.
15	25	10yr 6/2, light brownish grey fine sand.
25>		ironstone pan moderately cemented, continuous.

Site 9

0 cm	5 cm	10yr 5/2, greyish brown loamy fine sand.
5	15	2.5y 7/3, pale yellow loamy fine sand.
15	40	siltstone pan, weakly cemented.
40	80	7.5yr 6/8, reddish yellow light clay.
80	95	10yr 7/6, yellow, 40% red and grey mottles (distinct), light clay.
95	150	n7, light grey, 15% red and yellow mottles (distinct), clay loam silty, slight waterlogging.
150	180	5y 6/4, pale olive, 30% light green (gley) mottles, clayey sand, waterlogged.
180	200	5y 6/4, pale olive, 30% light green (gley) mottles, silty loam ec 20msm @ 95-150cm.

Site 10

0 cm	5 cm	10yr 5/1, grey fine sand.
5	20	10yr 7/1, light grey fine sand.
20	30	10yr 5/4, yellowish brown fine sand.
30>		weak pan.

Sites 11 and 12

0 cm	30 cm	10yr 6/1, grey sandy loam.
30	40	10yr 6/2, light brownish grey sandy loam.
40	75	10yr 6/2, light brownish grey, 5% orange mottles (distinct), fine sandy clay loam, 20% ironstone gravel.
75	90cm	ironstone pan broken.
90	110	2.5y 7/2, light grey, 5% brown yellow mottles (distinct), light clay.
110	150	5y 7/1, light grey light medium clay.
150	180	5y 7/1, light grey, 15% yellow red mottles (prominent), light clay, 20% ironstone gravel.
180>		ironstone pan moderately cemented. ec 10msm @ 180cm.

Sites 13 and 14

0 cm	10 cm	10yr 4/2, dark greyish brown loamy sand, 50% ironstone gravel, 10% granite coarse fragments on surface.
10	40	2.5y 7/3, pale yellow clayey coarse sand, >50% ironstone gravel.
40	90	2.5y 7/8, yellow, 20% orange mottles (distinct), light clay, 10% ironstone gravel.
90	110	2.5y 7/2, light grey, 20% orange mottles (distinct), medium clay, 10% quartz coarse fragments.
110	130	2.5y 7/2, light grey, 5% orange mottles (faint), heavy clay, 10% quartz coarse fragments.
130	170	2.5y 8/2, pale yellow, 5% red mottles (distinct), heavy clay, 20% quartz coarse fragments.
170	200	2.5y 7/2, light grey, 40% red and white mottles (distinct), medium-heavy clay, 30% quartz coarse fragments.

Site 15

0 cm	10 cm	2.5y 5/2, greyish brown loamy sand.
10	60	10yr 5/3, brown loamy coarse sand, >50% ironstone gravel.
60	140	10yr 7/1, light grey, 5% orange mottles (prominent), light-medium clay.
140	180	10yr 8/1, white, 15% orange mottles (prominent), clay loam.

Site 16

0 cm	5 cm	10yr 4/2, dark greyish brown sandy loam.
5	15	10yr 5/4, yellowish brown clayey loam.
15	40	10yr 5/6, yellowish brown light-medium clay.
40>		2.5y 7/2, light grey, 40% dark red and 5% yellow mottles, heavy clay, 10% quartz coarse fragments.

Site 17

0 cm	10 cm	10yr 2/1, black sandy loam.
10	30	2.5y 6/3, light yellowish brown clayey coarse sand.
30	85	2.5y 6/3, light yellowish brown coarse sandy clay loam, 50% ironstone gravel.
85	150	2.5y 7/2, light grey, 30% olive yellow mottles (distinct), light clay (coarse sandy), 20% ironstone gravel.
150	190	2.5y 7/2, light grey, 30% white and 5% olive yellow mottles, light-medium clay (coarse sandy), partly waterlogged.
190	200	n7, light grey, 15% olive yellow mottles (faint), light-medium clay (coarse sandy).
		ec 30msm @ 200cm.

Site 18

0 cm	10 cm	10yr 4/2, dark greyish brown sandy loam, 10% ironstone gravel.
10	25	10yr 5/4, yellow-brown coarse sandy clay loam, 20% ironstone gravel.
25	85	10yr 6/8, brown-yellow light clay (very coarse sandy), 50% ironstone gravel.
85	100	2.5y 7/2, light grey, 20% brown yellow mottles (distinct), light-medium clay, 10% ironstone gravel.
100	150	2.5y 7/2, light grey, 20% brown yellow mottles (distinct), light-medium clay, 20% ironstone gravel.
150	160	10yr 8/2, brown yellow, 20% gley mottles (distinct), medium clay, 50% ironstone gravel, water logged.
160>		n8, white, 40% dark red mottles (prominent), heavy clay.

Site 19

0 cm	10 cm	10yr 3/2, very dark grey brown clayey sand, 20% ironstone gravel.
10	35	10yr 5/2, grey brown clay loam coarse sandy, 50% ironstone gravel.
35	50	10yr 6/3, pale brown, 10% brown yellow mottles (faint), light-medium clay, 50% ironstone gravel.
50	60	10yr 6/8, brown yellow light clay, 20% ironstone gravel.
60>		ironstone pan, continuous, cementation unknown.

Site 20

0 cm	10 cm	10yr 5/1, grey loamy sand.
10	30	10yr 8/1, white sand.
30	95	10yr 4/1, dark grey, 10% white mottles (faint), loamy sand.
95	110	10yr 5/2, grey brown loamy sand.
110	140	organic pan, continuous, weakly cemented, 10% ironstone gravel.
140	180	10yr 6/2, light grey brown, 30% yellow mottles (faint), clayey sand.
180	190	10yr 7/2, light grey, 5% yellow mottles (faint), clayey sand.
190>		ortstein pan, continuity and cementation unknown. water table at 90cm. ec 10msm @ 80cm.

Site 21

0 cm	10 cm	10yr 5/1, grey sand.
10	85	10yr 7/2, light grey sand.
85>		organic pan, continuous, cementation unknown. ec 20msm @ 180cm.

Site 22

0 cm	5 cm	10yr 4/1, dark grey loamy sand.
5	50	10yr 6/1, grey coarse sand.
50	150	10yr 5/2, grey brown coarse sand, waterlogged.
150	160	10yr 4/1, dark grey loamy coarse sand.
160	200	10yr 4/2, dark grey brown clayey sand. ec 10msm @ 200cm.

Site 23

0 cm	10 cm	10yr 5/1, grey loamy coarse sand.
10	100	10yr 6/2, light brownish grey loamy coarse sand.
100	150	10yr 5/2, greyish brown coarse sand.
150>		organic pan, continuous, moderately cemented. water table at 80cm.

Site 24

0 cm	10 cm	10yr 7/1, light grey coarse sand.
10	30	10yr 6/2, light brownish grey coarse sand.
30	80	10yr 7/2, light grey, 5% gley mottles (faint), coarse sand.
80	170	10yr 7/2, light grey coarse sand.
170>		n7, light grey, 5% gley mottles (faint), clayey coarse sand, waterlogged. water table at 70cm.

Sites 25 and 26

0 cm	10 cm	10yr 4/2, dark greyish brown, loamy coarse sand.
10	30	10yr 4/1, dark grey loamy coarse sand.
30	80	10yr 5/3, brown clayey coarse sand, 20% ironstone gravel.
80	100	10yr 6/3, pale brown clayey coarse sand, 50% ironstone gravel.
100	120	ironstone pan, continuity unknown, weakly cemented.
120	150	2.5y 7/2, light grey, 30% orange mottles (distinct), light clay.
150	200	n7, light grey, 30% red mottles (prominent), medium clay. ec 0msm @ 200cm.

Site 27

0 cm	5 cm	2.5y 4/2, dark greyish brown sandy loam, 10% ironstone gravel.
5	45	2.5y 7/6, yellow clay loam sandy, 50% ironstone gravel.
45	100	ironstone pan, continuous, moderately cemented.

Site 28

0 cm	15 cm	7.5yr 4/3, brown sandy loam.
15	30	7.5yr 5/8, strong brown sandy clay loam.
30	60	7.5yr 5/8, strong brown clay loam sandy.
60	120	7.5yr 6/8, reddish yellow clay loam sandy, 20% ironstone gravel.
120>		ironstone pan, continuous, moderately cemented.

Sites 29 and 30

0 cm	10 cm	2.5y 5/1, grey fine sand.
10	20	2.5y 7/2, light grey fine sand.
20	30	2.5y 6/3, light yellow grey loamy sand.
30	80	2.5y 7/4, pale yellow, 10% olive yellow mottles (faint) fine sandy clay loam.
80	110	2.5y 7/1, light grey, 25% olive yellow mottles (distinct), light clay.
110	170	2.5y 7/1, light grey, 25% olive yellow mottles (distinct), fine sandy clay loam, 10% ironstone gravel.
170	190	2.5y 7/1, light grey light-medium clay, 20% ironstone gravel.
190>		ironstone pan, continuous, moderately cemented water table. ec 10msm @ 200cm.

7.4 Appendix 4: Site soil nutrient analysis.

Site number	Total nitrogen (%)	Phosphorus HCl ppm	Phosphorus Olsen (ppm)	Potassium HCl (ppm)	Potassium available (ppm)	pH (CaCl ₂)	Total soluble salts (g/kgs)	EC (ms/m)	Organic carbon (%)
1	0.25	66.4	3.4	97.0	84.0	4.08	0.16	7.83	3.43
2	0.19	72.1	17.0	51.9	43.2	5.61	0.20	9.66	2.66
4	0.25	69.8	11.7	78.2	86.0	3.89	0.13	6.56	2.60
5	0.36	131.8	26.5	115.0	54.2	3.90	0.11	5.42	3.52
6	0.32	95.7	17.6	134.5	71.4	4.04	0.16	7.82	3.32
7	0.11	22.5	2.8	15.2	17.5	3.56	0.04	2.49	1.79
8	0.16	29.2	0.7	29.4	25.6	4.39	0.07	4.01	2.36
9	0.27	83.3	17.3	78.2	70.0	4.93	0.20	9.69	3.05
10	0.23	81.1	26.2	57.9	41.6	4.54	0.24	11.49	2.78
11	0.44	151.0	10.8	66.2	40.8	4.36	0.25	12.04	5.79
12	0.40	154.4	11.4	78.2	42.8	4.28	0.19	9.31	5.63
13	0.41	419.2	50.8	174.2	122.2	5.49	0.12	6.22	4.21
14	0.47	556.8	33.3	194.5	75.4	5.07	0.20	10.06	4.70
15	0.26	147.6	12.0	105.2	65.9	4.11	0.20	10.00	2.75
16	0.43	513.9	27.4	139.7	62.3	5.30	0.14	6.98	4.80
17	0.28	120.6	10.8	76.7	56.4	4.78	1.25	51.80	3.39
18	0.34	259.2	12.6	178.0	121.0	5.41	0.15	7.58	4.25
19	0.26	164.5	6.6	115.7	49.9	5.28	0.10	4.88	3.37
20	0.22	49.5	9.9	10.7	19.5	4.25	0.13	6.55	2.12
21	0.28	28.1	1.0	15.9	19.1	3.93	0.08	4.39	4.48
22	0.06	15.7	1.9	5.4	8.8	5.34	0.10	5.00	1.39
23	0.08	7.8	2.8	12.9	20.6	3.29	0.07	4.00	2.49
24	0.11	54.0	22.7	20.4	25.8	3.79	0.22	10.52	1.72
25	0.28	219.8	11.4	67.0	42.6	4.70	0.07	4.12	3.79
26	0.19	156.6	11.1	64.0	46.5	4.67	0.10	5.03	2.14
27	0.42	559.0	18.5	130.0	86.0	4.61	0.16	7.93	4.16
28	0.50	644.7	14.9	110.5	43.4	4.62	0.17	8.23	6.12
29	0.19	55.2	6.0	53.4	42.2	3.80	0.20	9.93	2.29
30	0.20	55.2	4.9	70.0	58.4	3.78	0.15	7.57	2.28

7.5 Appendix 5: 1996 cumulative seasonal pasture yields - kg/ha.

Distance from treeline (m)	26 Jun	21 Jul	19 Aug	17 Sep	22 Oct	19 Nov	21 Dec
0	0	0	0	0	0	0	0
1	0	0	0	0	0	0	0
2	0	0	0	0	180	180	180
Site number 1	5	0	110	210	340	840	870
10	130	380	600	1570	2790	3080	5080
20	140	390	640	1450	2590	2950	4950
50	120	240	450	1460	2660	3060	5060
Open pdk yield plateau	130	340	560	1490	2680	3030	5030
Pasture loss distance (m)	7.5	6.2	6.0	6.6	6.1	6.2	6.6

Distance from treeline (m)	25 Jun	21 Jul	19 Aug	18 Sep	22 Oct	19 Nov	21 Dec
0	0	0	0	0	0	0	0
1	0	0	0	0	0	0	0
2	0	0	0	0	0	0	0
Site number 2	5	260	260	360	460	570	680
10	680	1050	1570	2320	3010	3070	4170
20	380	760	1450	2510	3680	3960	6440
50	270	540	1200	2480	3970	4490	6770
Open pdk yield plateau	440	780	1410	2500	3830	4230	6610
Pasture loss distance (m)	5.2	6.2	6.5	7.3	8.5	8.9	9.8

Distance from treeline (m)	25 Jun	21 Jul	19 Aug	17 Sep	22 Oct	19 Nov
0	0	0	0	0	0	0
1	0	0	0	0	0	0
2	0	0	0	0	0	0
Site number 4	5	0	0	70	100	150
10	80	230	1310	2510	3690	4170
20	160	320	1710	3090	4000	4430
50	150	340	1720	2800	3860	4220
Open pdk yield plateau	160	330	1720	2950	3930	4330
Pasture loss distance (m)	11.1	9.8	9.1	8.5	7.8	7.6

Distance from treeline (m)	25 Jun	21 Jul	19 Aug	17 Sep	22 Oct	19 Nov
0	0	0	0	0	0	0
1	0	0	0	0	0	0
2	130	430	650	1340	3040	3230
Site number 5	5	60	400	890	1720	4530
10	80	390	1150	2440	5540	6450
20	90	440	1050	2320	5570	7620
50	130	710	1880	3050	5710	7390
Open pdk yield plateau	110	580	1470	2690	5640	7510
Pasture loss distance (m)	5.0	5.6	5.8	4.6	3.3	5.0

Distance from treeline (m)	25 Jun	21 Jul	19 Aug	17 Sep	22 Oct	19 Nov
0	0	0	0	0	0	0
1	0	0	0	0	0	0
2	60	350	450	760	920	1650
Site number 6	5	110	440	700	1940	3380
10	80	500	810	2180	4030	5250
20	110	550	920	2420	4600	7100
50	150	660	1260	2490	4720	7730
Open pdk yield plateau	130	610	1090	2460	4660	7420
Pasture loss distance (m)	6.1	4.7	6.0	4.6	5.2	7.1

Distance from treeline (m)	25 Jun	21Jul	19 Aug	17 Sep	22 Oct	19 Nov
0	0	0	0	0	0	0
1	0	0	0	0	0	0
2	0	0	0	0	0	270
Site number 7	5	10	30	100	180	1470
	10	50	90	260	1190	2800
	20	230	350	960	2150	3770
	50	240	390	930	2040	3680
Open pdk yield plateau	240	370	950	2100	3730	4210
Pasture loss distance (m)	13.2	12.9	12.5	10.4	7.8	7.5

Distance from treeline (m)	23 Jun	20 Jul	19 Aug	18 Sep	21 Oct	20 Nov
0	0	0	0	0	0	0
1	0	0	0	0	0	0
2	0	0	0	0	80	80
Site number 8	5	0	0	90	260	590
	10	60	120	320	710	1500
	20	620	1270	2450	4080	5430
	50	500	1470	2860	4290	5650
Open pdk yield plateau	560	1370	2660	4190	5540	6720
Pasture loss distance (m)	14.2	14.3	14.0	13.5	12.5	12.2

Distance from treeline (m)	27 Jun	22 Jul	19 Aug	18 Sep	22 Oct
0	0	0	0	0	0
1	0	0	0	0	0
2	0	0	0	0	0
Site number 9	5	50	90	1260	1770
	10	110	280	1820	2630
	20	460	710	2600	3130
	50	330	510	2230	2850
Open pdk yield plateau	400	610	2420	2990	5100
Pasture loss distance (m)	12.4	11.0	7.3	6.0	4.5

Distance from treeline (m)	27 Jun	22 Jul	19 Aug	18 Sep	22 Oct
0	0	0	0	0	0
1	0	0	0	0	0
2	0	0	0	0	0
Site number 10	5	50	70	880	1120
	10	140	210	1220	1980
	20	190	290	1570	2060
	50	130	260	1680	2380
Open pdk yield plateau	160	280	1630	2220	4060
Pasture loss distance (m)	7.2	8.3	7.2	6.3	5.2

Distance from treeline (m)	23 Jun	20 Jul	19 Aug	18 Sep	21 Oct	20 Nov
0	0	0	0	0	0	0
1	0	0	0	0	0	0
2	300	350	350	350	350	350
Site number 11	5	260	520	1050	2190	2720
	10	350	510	1150	2190	3400
	20	310	640	1460	2580	3780
	50	560	830	1760	3320	4820
Open pdk yield plateau	440	740	1610	2950	4300	8300
Pasture loss distance (m)	5.2	6.0	6.6	6.2	6.4	4.5

Distance from treeline (m)	23 Jun	20 Jul	19 Aug	18 Sep	21 Oct	20 Nov
0	0	0	0	0	0	0
1	0	0	0	0	0	0
2	50	100	100	100	100	100
Site number 12	5	120	310	880	1830	3490
	10	120	300	1140	2050	4180
	20	160	490	1590	2860	5290
	50	160	450	1460	2570	5510
Open pdk yield plateau	160	470	1530	2720	5400	7900
Pasture loss distance (m)	5.8	7.1	7.0	6.6	6.6	4.6

Site 13 Trial not sampled

Site 14 Trial not sampled

Distance from treeline (m)	20 Aug	16 Sep	21 Oct	18 Nov
0	0	0	0	0
1	0	0	0	0
2	0	0	0	0
Site number 15	5	0	430	1860
	10	770	1810	3820
	20	1090	2300	4090
	50	1200	2170	3880
Open pdk yield plateau	1150	2240	3990	5380
Pasture loss distance (m)	10.0	8.2	5.9	7.4

Distance from treeline (m)	22 Jul	20 Aug	16 Sep	21 Oct	18 Nov
0	0	0	0	0	0
1	0	0	0	0	0
2	0	0	0	0	0
Site number 16	5	50	90	190	360
	10	530	880	1290	1750
	20	830	1610	2540	3580
	50	720	1560	2700	3790
Open pdk yield plateau	780	1590	2620	3690	5160
Pasture loss distance (m)	9.6	10.6	11.0	11.0	9.8

Distance from treeline (m)	22 Jul	20 Aug	18 Sep	21 Oct	18 Nov
0	0	0	0	0	0
1	0	0	0	0	0
2	200	350	520	760	1180
Site number 17	5	270	560	850	1140
	10	520	1120	1680	2150
	20	500	1300	1960	2740
	50	660	1610	2440	3150
Open pdk yield plateau	580	1460	2200	2950	5180
Pasture loss distance (m)	5.7	7.2	7.3	7.5	6.7

Distance from treeline (m)		22 Jul	20 Aug	16 Sep	21 Oct	18 Nov
Site number 18	0	0	0	0	0	0
	1	0	0	0	0	0
	2	0	0	0	0	0
	5	150	200	410	950	1300
	10	820	1180	1800	2310	2830
	20	820	1370	2280	3390	4270
	50	720	1380	2730	3830	4520
	Open pdk yield plateau	790	1380	2510	3610	4400
Pasture loss distance (m)		6.7	8.0	9.0	9.1	9.0

Distance from treeline (m)		22 Jul	20 Aug	16 Sep	21 Oct	18 Nov
Site number 19	0	0	0	0	0	0
	1	0	0	0	0	0
	2	0	0	0	0	0
	5	340	450	980	2080	2570
	10	550	770	1600	2910	3670
	20	470	690	1960	3400	5140
	50	570	860	2040	3640	5410
	Open pdk yield plateau	530	780	2000	3520	5280
Pasture loss distance (m)		4.9	5.2	7.0	6.4	7.8

Distance from treeline (m)		20 Jun	16 Jul	08 Aug	16 Oct	02 Nov	21 Dec
Site number 20	0	0	0	0	0	0	0
	1	900	900	900	900	900	900
	2	850	1350	1490	3000	4000	5500
	5	890	1320	1460	3850	4850	6350
	10	1090	1430	1580	4280	5280	6780
	20	860	1320	1470	4040	5040	6540
	50	1020	1670	1960	4710	5710	7210
	Open pdk yield plateau	990	1500	1720	4380	5380	6880
Pasture loss distance (m)		1.3	1.9	2.4	2.6	2.4	2.2

Distance from treeline (m)		20 Jun	16 Jul	08 Aug	16 Oct	02 Nov	21 Dec
Site number 21	0	0	0	0	0	0	0
	1	900	900	900	900	900	900
	2	850	1850	2020	3540	4540	6040
	5	890	1460	1710	4620	5620	7120
	10	1090	1660	1920	5000	6000	7500
	20	860	1610	1820	4510	5510	7010
	50	1020	1450	1710	4390	5390	6890
	Open pdk yield plateau	990	1610	1840	4630	5630	7130
Pasture loss distance (m)		1.3	0.9	1.0	1.8	1.7	1.7

Distance from treeline (m)		18 Jun	15 Jul	09 Sep	07 Oct	07 Nov	21 Dec
Site number 22	0	0	0	0	0	0	0
	1	0	0	0	0	0	0
	2	0	0	0	0	3460	4960
	5	200	340	810	1230	4660	6160
	10	560	630	1420	1890	5420	6920
	20	610	880	2000	2920	5620	7120
		50	460	690	1610	2450	5560
Open pdk yield plateau		540	790	1810	2690	5590	7090
Pasture loss distance (m)		6.0	7.2	7.3	7.9	3.2	2.8

Distance from treeline (m)		18 Jun	15 Jul	14 Aug	09 Sep	07 Oct	07 Nov	21 Dec
Site number 23	0	0	0	0	0	0	0	0
	1	0	0	0	0	0	0	0
	2	0	0	0	0	0	0	0
	5	50	580	580	600	610	1350	3350
	10	780	1700	1720	1940	2210	3200	5200
	20	1240	2060	2130	2590	3100	4310	6310
		50	1560	2210	2400	2970	3290	4610
Open pdk yield plateau		1400	2140	2270	2780	3200	4460	6460
Pasture loss distance (m)		10.7	7.9	8.3	8.9	9.0	8.4	6.9

Distance from treeline (m)		18 Jun	15 Jul	14 Aug	09 Sep	07 Oct	07 Nov	21 Dec
Site number 24	0	0	0	0	0	0	0	0
	1	0	0	0	0	0	0	0
	2	0	0	0	0	0	0	0
	5	440	860	960	1010	1290	3950	4950
	10	830	1300	1420	1590	2330	5570	6570
	20	1390	1900	1970	2240	3130	6050	7050
		50	1220	1620	1730	2070	3410	6180
Open pdk yield plateau		1310	1760	1850	2160	3270	6120	7120
Pasture loss distance (m)		8.9	7.5	7.2	7.6	8.1	5.6	5.3

Distance from treeline (m)		20 Jul	19 Aug	16 Sep	21 Oct	18 Nov
Site number 25	0	0	0	0	0	0
	1	120	370	690	2370	3960
	2	200	610	1010	2780	4660
	5	360	750	1120	2530	4580
	10	370	790	1160	2740	4500
	20	370	670	960	2600	4850
		50	350	600	910	2810
Open pdk yield plateau		360	700	1030	2720	4850
Pasture loss distance (m)		2.1	1.2	0.8	0.9	1.5

Distance from treeline (m)	20 Jul	19 Aug	16 Sep	21 Oct	18 Nov
0	0	0	0	0	50
1	150	150	240	730	1090
2	150	180	440	930	1610
Site number 26	5	340	490	1310	2430
	10	370	580	1630	2900
	20	210	430	1600	2920
	50	300	610	1790	3130
Open pdk yield plateau	310	540	1700	3030	5140
Pasture loss distance (m)	2.0	2.9	4.0	3.7	4.7

Distance from treeline (m)	18 Jun	15 Jul	14 Aug	09 Sep	07 Oct	07 Nov	21 Dec
0	0	0	50	250	250	250	250
1	0	0	50	250	250	250	250
2	0	0	50	250	250	250	250
Site number 27	5	80	380	590	660	1050	3480
	10	190	630	970	1400	1960	4680
	20	110	540	870	1010	1800	4280
	50	80	370	610	810	1880	4780
Open pdk yield plateau	130	510	820	1070	1880	4580	7080
Pasture loss distance (m)	5.0	4.5	4.4	4.2	4.8	4.3	4.0

Distance from treeline (m)	18 Jun	15 Jul	09 Sep	07 Oct	07 Nov	21 Dec
0	0	0	0	0	0	0
1	0	0	0	0	0	0
2	0	0	0	0	0	0
Site number 28	5	150	390	460	780	2450
	10	400	870	1250	2070	4560
	20	400	810	1360	2410	5120
	50	50	400	1270	2410	5280
Open pdk yield plateau	280	690	1320	2410	5200	6700
Pasture loss distance (m)	5.4	5.3	6.5	7.3	6.5	5.9

Distance from treeline (m)	04 Jul	05 Aug	04 Sep	16 Oct	21 Dec
0	0	0	0	0	0
1	0	0	0	0	0
2	70	170	380	1190	1190
Site number 29	5	50	280	660	1740
	10	260	440	690	4590
	20	700	1010	1180	5200
	50	520	850	1130	4930
Open pdk yield plateau	610	930	1160	5070	7070
Pasture loss distance (m)	11.2	9.9	7.6	6.4	5.5

Distance from treeline (m)	04 Jul	05 Aug	04 Sep	16 Oct	21 Dec
0	0	0	0	0	0
1	0	0	0	0	0
2	60	120	210	1800	1800
Site number 30	5	80	120	430	2650
	10	240	340	510	2960
	20	410	580	720	2770
	50	990	1320	1660	3860
Open pdk yield plateau	700	950	1190	3320	5570
Pasture loss distance (m)	11.8	11.6	10.0	4.0	3.3

7.6 Appendix 6: 1997 cumulative seasonal pasture yields - kg/ha.

Distance from treeline (m)	15 Apr	21 May	18 Jun	24 Jul	20 Aug	15 Oct
0	0	0	0	0	0	0
1	0	0	0	0	0	0
2	0	0	0	0	0	0
Site number 1	5	200	320	330	400	560
	10	460	670	840	1430	2120
	20	470	690	1000	1630	2200
	50	450	710	960	1530	2230
Open pdk yield plateau		460	700	980	1580	2220
Pasture loss distance (m)	5.8	6.0	7.2	7.2	6.8	7.0

Distance from treeline (m)	15 Apr	21 May	18 Jun	24 Jul	20 Aug	15 Oct
0	0	0	0	0	0	0
1	0	0	0	0	0	0
2	0	0	0	0	0	0
Site number 2	5	20	190	230	330	700
	10	140	470	620	1000	1900
	20	160	510	790	1400	2550
	50	130	490	870	1500	2680
Open pdk yield plateau		150	500	830	1450	2620
Pasture loss distance (m)	7.2	6.4	8.3	8.9	8.5	6.8

Distance from treeline (m)	15 Apr	21 May	18 Jun	24 Jul	20 Aug	15 Oct
0	0	0	0	0	0	0
1	0	0	0	0	0	0
2	0	0	0	0	0	0
Site number 4	5	80	330	450	720	1190
	10	730	1120	1770	2650	3760
	20	810	1160	1870	2890	3910
	50	730	1110	1830	2740	3820
Open pdk yield plateau		770	1140	1850	2820	3870
Pasture loss distance (m)	7.5	6.4	6.9	6.9	6.5	5.8

Distance from treeline (m)	15 Apr	21 May	18 Jun	24 Jul	20 Aug	15 Oct
0	0	0	0	0	0	0
1	0	0	0	0	0	0
2	260	470	670	1170	1790	5950
Site number 5	5	650	910	1330	2350	3160
	10	910	1070	1530	2630	3750
	20	880	1120	1830	2810	3830
	50	800	1020	1770	2720	3800
Open pdk yield plateau		860	1070	1800	2770	3820
Pasture loss distance (m)	3.9	3.2	4.9	3.6	3.4	2.7

Distance from treeline (m)	15 Apr	21 May	18 Jun	24 Jul	20 Aug	15 Oct
0	0	0	0	0	0	0
1	0	0	0	0	0	0
2	1070	1160	1400	1670	2200	3720
Site number 6	5	1050	1160	1580	2050	2950
	10	940	1110	1580	2230	3250
	20	1130	1240	1630	2400	3400
	50	1200	1390	1840	2450	3500
Open pdk yield plateau	1170	1320	1740	2430	3450	6760
Pasture loss distance (m)	3.5	3.4	2.9	3.3	3.2	3.4

Distance from treeline (m)	16 Apr	21 May	18 Jun	24 Jul	20 Aug	15 Oct
0	0	0	0	0	0	0
1	0	0	0	0	0	0
2	0	0	0	0	0	0
Site number 7	5	60	320	460	590	800
	10	190	670	1080	1620	2630
	20	430	930	1490	2320	3740
	50	420	890	1330	2280	3690
Open pdk yield plateau	430	910	1410	2300	3720	7110
Pasture loss distance (m)	11.1	8.1	8.0	8.7	8.8	7.2

Distance from treeline (m)	17 Apr	21 May	17 Jun	22 Jul	19 Aug	14 Oct
0	0	0	0	0	0	0
1	0	0	0	0	0	0
2	0	0	0	0	0	0
Site number 8	5	0	0	0	190	970
	10	70	360	790	1280	2050
	20	220	660	1210	2100	3130
	50	240	660	1200	2120	3260
Open pdk yield plateau	230	660	1210	2110	3200	6960
Pasture loss distance (m)	12.7	10.9	10.1	10.5	9.9	9.4

Distance from treeline (m)	23 Jul	20 Aug	15 Oct
0	0	0	0
1	0	0	0
2	0	0	0
Site number 9	5	500	1390
	10	840	1800
	20	990	1940
	50	920	1880
Open pdk yield plateau	960	1910	7740
Pasture loss distance (m)	6.3	5.0	3.9

Distance from treeline (m)	23 Jul	20 Aug	15 Oct
0	0	0	0
1	0	0	0
2	0	0	0
Site number 10	120	390	3530
10	220	930	4740
20	230	820	4750
50	150	830	4770
Open pdk yield plateau	200	860	4760
Pasture loss distance (m)	5.1	5.7	4.6

Distance from treeline (m)	17 Apr	22 May	17 Jun	22 Jul	19 Aug	14 Oct	21 Nov
0	0	0	0	0	0	0	0
1	120	120	120	120	120	120	120
2	80	280	800	1170	1910	4030	5510
Site number 11	80	410	1030	1330	1990	5350	8020
10	80	370	960	1190	1980	5420	7580
20	120	440	1010	1290	2050	5090	8060
50	150	460	1110	1340	2020	5460	8160
Open pdk yield plateau	140	450	1030	1320	2040	5320	8110
Pasture loss distance (m)	6.1	3.7	1.8	2.3	1.9	1.9	2.7

Distance from treeline (m)	17 Apr	22 May	17 Jun	22 Jul	19 Aug	14 Oct	21 Nov
Site number 12	0	0	0	0	0	0	0
1	110	110	110	110	110	110	110
2	110	330	440	600	760	2380	3770
5	240	430	870	1030	1650	4550	6230
10	190	370	940	1200	1950	5310	8960
20	270	460	1060	1370	2010	5190	10840
50	210	390	970	1310	1970	5470	11020
Open pdk yield plateau	230	410	1020	1340	1990	5320	10930
Pasture loss distance (m)	2.0	1.6	3.7	4.2	3.5	3.2	5.9

Distance from treeline (m)	23 May	19 Jun	23 Jul	21 Aug	16 Oct
0	0	0	0	0	0
1	0	0	0	0	0
2	0	0	0	200	200
Site number 13	220	620	1340	1560	4520
10	300	840	1820	2420	7240
20	300	850	1940	2790	9020
50	270	820	1890	2710	8700
Open pdk yield plateau	290	840	1920	2750	8860
Pasture loss distance (m)	4.5	4.5	5.1	6.0	6.8

Distance from treeline (m)	23 May	19 Jun	23 Jul	21 Aug	16 Oct
0	0	0	0	0	0
1	0	0	0	0	0
2	0	0	0	150	150
Site number 14	5	180	460	1130	2260
	10	190	480	1300	2350
	20	320	860	2040	3290
	50	360	920	2160	3600
Open pdk yield plateau		340	890	2100	3450
Pasture loss distance (m)	8.7	8.9	8.2	7.2	6.7

Distance from treeline (m)	23 May	19 Jun	23 Jul	21 Aug	16 Oct
0	0	0	0	0	0
1	0	0	0	0	0
2	0	0	0	0	0
Site number 15	5	0	220	450	600
	10	200	680	1580	2920
	20	270	1130	2270	3680
	50	330	1190	2340	3730
Open pdk yield plateau		300	1160	2310	3710
Pasture loss distance (m)	10.0	9.8	9.1	8.4	7.2

Distance from treeline (m)	16 Apr	17 Jun	22 Jul	19 Aug	14 Oct	21 Nov
0	0	0	0	0	0	0
1	0	0	0	0	0	0
2	0	0	0	0	0	0
Site number 16	5	50	140	270	370	4000
	10	110	750	1410	3040	7490
	20	180	740	1590	3490	8880
	50	210	810	1830	3670	9050
Open pdk yield plateau		200	780	1710	3580	8970
Pasture loss distance (m)	9.7	7.0	8.2	8.2	6.9	6.1

Distance from treeline (m)	16 Apr	17 Jun	22 Jul	19 Aug	14 Oct	21 Nov
0	0	0	0	0	0	0
1	0	0	0	0	0	0
2	30	70	260	810	4190	4190
Site number 17	5	50	220	520	1340	4280
	10	370	790	1530	2690	7050
	20	640	1250	2140	3560	7940
	50	640	1210	2160	3440	7890
Open pdk yield plateau		640	1230	2150	3500	7920
Pasture loss distance (m)	10.3	9.4	8.5	7.2	5.1	4.8

Distance from treeline (m)	16 Apr	17 Jun	22 Jul	19 Aug	14 Oct	21 Nov
0	0	0	0	0	0	0
1	0	0	0	0	0	0
2	0	0	0	0	0	0
Site number 18	5	30	100	200	560	4840
	10	230	460	890	2300	8000
	20	500	1170	2010	3420	9500
	50	500	1060	2060	3380	9160
Open pdk yield plateau	500	1120	2040	3400	9330	10280
Pasture loss distance (m)	11.3	11.5	11.3	9.3	6.5	6.3

Distance from treeline (m)	16 Apr	17 Jun	22 Jul	19 Aug	14 Oct	21 Nov
0	0	0	0	0	0	0
1	0	0	0	0	0	0
2	0	0	0	0	0	0
Site number 19	5	30	60	120	280	2500
	10	50	240	1090	2850	8890
	20	370	960	2080	4100	9300
	50	370	1150	2300	4190	10210
Open pdk yield plateau	370	1060	2190	4150	9760	11000
Pasture loss distance (m)	13.7	13.1	11.0	9.6	7.1	6.8

Distance from treeline (m)	09 Jun	09 Jul	18 Aug	22 Oct	14 Dec
0	0	0	0	0	0
1	0	0	0	200	200
2	140	970	1520	2520	3620
Site number 20	5	300	1320	2620	6130
	10	270	1320	2690	6460
	20	310	1290	2570	6370
	50	290	1230	2490	6290
Open pdk yield plateau	300	1290	2590	6370	7470
Pasture loss distance (m)	3.3	2.0	2.3	2.8	2.6

Distance from treeline (m)	09 Jun	09 Jul	18 Aug	22 Oct	14 Dec
0	0	0	0	0	0
1	0	0	0	500	500
2	270	970	1520	2720	4220
Site number 21	5	380	1220	2160	6260
	10	420	1290	2390	6640
	20	420	1230	2180	6680
	50	500	1200	2150	6800
Open pdk yield plateau	460	1240	2240	6740	8240
Pasture loss distance (m)	3.7	2.0	2.3	3.0	2.7

Distance from treeline (m)	16 Jun	21 Jul	18 Aug	13 Oct
0	0	0	0	0
1	0	0	0	0
2	0	0	0	0
Site number 22	5	620	1010	2460
	10	890	1530	2960
	20	970	1510	2820
	50	1070	1580	2830
Open pdk yield plateau	1020	1550	2870	5900
Pasture loss distance (m)	6.0	5.0	4.1	4.0

Distance from treeline (m)	21 May	16 Jun	21 Jul	18 Aug	13 Oct
0	0	0	0	0	0
1	0	0	0	0	0
2	0	0	0	0	0
Site number 23	5	170	280	450	920
	10	310	590	740	1130
	20	380	1020	1140	1890
	50	430	1170	1390	2040
Open pdk yield plateau	410	1100	1270	1970	5010
Pasture loss distance (m)	7.6	9.9	9.2	8.8	8.3

Distance from treeline (m)	16 Jun	21 Jul	18 Aug	13 Oct
0	0	0	0	0
1	0	0	0	0
2	0	0	0	0
Site number 24	5	170	370	1020
	10	580	1130	1820
	20	500	1030	1780
	50	510	1030	1820
Open pdk yield plateau	530	1060	1810	4500
Pasture loss distance (m)	6.2	6.1	5.2	4.8

Distance from treeline (m)	04 Jun	25 Jul	21 Aug	16 Oct
0	70	220	260	1090
1	110	320	480	2490
2	150	440	1130	3450
Site number 25	5	330	900	1940
	10	400	1050	2440
	20	380	1090	2570
	50	410	1090	2440
Open pdk yield plateau	400	1090	2510	6730
Pasture loss distance (m)	3.1	3.3	3.5	3.8

Distance from treeline (m)	04 Jun	25 Jul	21 Aug	16 Oct
0	70	120	170	1230
1	110	370	800	1700
Site number 26	2	140	400	1060
	5	250	510	1120
	10	290	680	1500
	20	330	760	1700
	50	360	850	1800
Open pdk yield plateau	350	810	1750	5870
Pasture loss distance (m)	4.6	4.6	4.3	4.8

Site 27 Trial not sampled

Distance from treeline (m)	16 Jun	21 Jul	13 Oct
0	0	0	0
1	0	0	0
2	0	0	0
Site number 28	5	120	730
	10	100	460
	20	300	1340
	50	370	1540
Open pdk yield plateau	340	1440	6350
Pasture loss distance (m)	11.3	10.6	9.3

Distance from treeline (m)	30 May	24 Jun	01 Aug	04 Sep	10 Oct	14 Dec
0	0	0	0	0	200	200
1	0	0	0	0	500	500
2	0	0	0	350	1070	1870
Site number 29	5	0	600	850	1060	3010
	10	580	1540	2350	2640	5810
	20	680	1490	2400	2640	6140
	50	610	1540	2450	2760	6300
Open pdk yield plateau	650	1520	2430	2700	6220	7270
Pasture loss distance (m)	8.3	5.9	6.3	5.8	5.6	5.2

Distance from treeline (m)	30 May	24 Jun	01 Aug	04 Sep	10 Oct	14 Dec
0	0	0	0	0	100	100
1	0	0	0	0	300	300
2	0	0	90	90	900	1700
Site number 30	5	0	0	160	1520	3080
	10	40	460	820	2080	5250
	20	380	1060	1550	2920	6410
	50	460	1220	1710	2920	6640
Open pdk yield plateau	420	1140	1630	2920	6530	7530
Pasture loss distance (m)	14.3	12.0	10.7	7.5	6.7	6.1

7.7 Appendix 7: 1998 cumulative seasonal pasture yields - kg/ha.

Site 1 Trial not sampled

Distance from treeline (m)	29 Apr	27 May	01 Jul	29 Jul	25 Aug	05 Nov
0	0	0	0	0	0	0
1	0	0	0	0	0	0
2	0	0	0	0	0	0
Site number 2	5	100	150	150	250	330
	10	680	930	1460	1940	3140
	20	880	1520	2260	3020	4500
	50	840	1490	2340	3090	4600
Open pdk yield plateau		860	1510	2300	3060	4550
Pasture loss distance (m)		8.6	10.0	10.0	9.9	9.5

Distance from treeline (m)	29 Apr	27 May	01 Jul	30 Jul	26 Aug	05 Nov
0	0	0	0	0	0	0
1	0	0	0	0	0	0
2	0	0	0	0	0	0
Site number 4	5	290	290	390	590	770
	10	980	1550	3200	4120	5530
	20	1300	2070	3730	4660	5960
	50	1300	2100	3800	4710	6060
Open pdk yield plateau		1300	2090	3770	4690	6010
Pasture loss distance (m)		8.5	8.9	8.2	7.9	7.6

Distance from treeline (m)	29 Apr	27 May	02 Jul	30 Jul	26 Aug	05 Nov
0	0	0	0	0	0	0
1	0	0	0	0	0	0
2	90	240	540	1310	3030	7530
Site number 5	5	860	2420	3840	4940	7110
	10	980	2480	4000	5100	7050
	20	1200	2450	3880	4990	7040
	50	1200	2470	3920	4990	6950
Open pdk yield plateau		1200	2470	3930	5030	7040
Pasture loss distance (m)		5.9	3.4	3.3	3.0	2.6

Distance from treeline (m)	29 Apr	27 May	02 Jul	30 Jul	26 Aug	05 Nov
0	0	0	0	0	0	0
1	0	0	0	0	0	0
2	1380	1680	1780	2380	3610	6750
Site number 6	5	2650	4140	5040	5740	7150
	10	2650	4340	5750	6700	8530
	20	2650	4370	5840	6930	8640
	50	2260	4030	5540	6710	8490
Open pdk yield plateau		2550	4250	5710	6820	8570
Pasture loss distance (m)		2.4	2.8	3.3	3.6	3.3

Distance from treeline (m)	29 Apr	27 May	01 Jul	30 Jul	26 Aug	19 Oct
0	0	0	0	0	0	0
1	0	0	0	0	0	0
2	0	0	0	0	0	0
Site number 7	240	340	540	710	1090	3700
10	600	1450	2490	3010	4400	8230
20	710	1620	2900	3780	5800	10650
50	680	1550	2760	3820	6000	10800
Open pdk yield plateau	700	1590	2830	3800	5900	10730
Pasture loss distance (m)	7.1	7.3	7.6	8.3	8.7	7.9

Site 8 Trial not sampled

Distance from treeline (m)	29 Apr	27 May	02 Jul	29 Jul	25 Aug	05 Nov
0	0	0	0	0	0	0
1	0	0	0	0	0	0
2	0	0	0	0	0	0
Site number 9	140	240	440	440	830	4450
10	650	1440	2460	3260	4740	9060
20	720	1830	3050	3870	5230	9610
50	650	1760	2950	3770	5290	9650
Open pdk yield plateau	690	1800	3000	3820	5260	9630
Pasture loss distance (m)	7.1	8.4	8.3	8.1	7.6	6.1

Distance from treeline (m)	29 Apr	27 May	02 Jul	29 Jul	25 Aug	05 Nov
0	0	0	0	0	0	0
1	0	0	0	0	0	0
2	0	0	0	0	0	0
Site number 10	160	210	510	830	1550	4690
10	400	1220	2420	3360	4710	10310
20	400	1130	2300	3300	4610	10530
50	400	1240	2320	3240	4540	11040
Open pdk yield plateau	400	1200	2350	3300	4620	10790
Pasture loss distance (m)	5.9	6.8	6.6	6.5	6.2	6.1

Distance from treeline (m)	29 Apr	26 May	30 Jun	28 Jul	25 Aug	04 Nov	03 Dec
0	0	0	0	0	0	0	0
1	110	110	110	110	110	110	110
2	300	1040	1040	1920	2960	5980	7290
Site number 11	400	1010	1710	2650	3760	6760	8150
10	790	1540	2680	3500	4610	7830	9390
20	990	1880	3020	3840	4810	7770	9380
50	990	1830	2900	3810	4830	7810	9560
Open pdk yield plateau	990	1860	2960	3830	4820	7800	9470
Pasture loss distance (m)	6.7	5.4	5.2	4.3	3.5	2.5	2.6

Distance from treeline (m)		29 Apr	26 May	30 Jun	28 Jul	25 Aug	04 Nov	03 Dec
Site number 12	0	10	10	10	10	10	20	30
	1	110	110	110	110	110	110	110
	2	200	800	1000	1000	1980	5580	6840
	5	690	1090	1450	2400	3970	7530	9260
	10	1470	1870	2430	3170	4690	7790	9390
	20	1470	1870	2700	3450	4880	8020	9810
	50	1380	1780	2810	3570	5220	8540	10170
Open pdk yield plateau		1440	1840	2760	3510	5050	8280	9990
Pasture loss distance (m)		5.2	4.2	5.5	4.9	4.1	2.9	2.9

Distance from treeline (m)		28 Apr	26 May	02 Jul	28 Jul	26 Aug	03 Nov
Site number 13	0	0	0	0	0	0	0
	1	0	0	0	0	0	0
	2	0	0	0	0	0	0
	5	350	560	1130	2220	3500	7320
	10	890	1530	2780	3780	5020	10860
	20	1150	1970	3250	4140	5790	11490
	50	1310	2060	3300	4160	5800	12800
Open pdk yield plateau		1230	2020	3280	4150	5800	12150
Pasture loss distance (m)		8.4	8.2	7.3	6.0	6.1	5.9

Distance from treeline (m)		28 Apr	26 May	02 Jul	28 Jul	26 Aug	03 Nov
Site number 14	0	0	0	0	0	0	0
	1	0	0	0	0	0	0
	2	0	0	0	0	0	0
	5	1090	1430	1850	2060	3410	7350
	10	1310	2160	3260	4040	5370	11850
	20	1420	2370	3520	4330	6080	12140
	50	1420	2270	3450	4390	6140	12080
Open pdk yield plateau		1420	2320	3490	4360	6110	12110
Pasture loss distance (m)		5.0	5.6	5.9	6.2	6.2	5.2

Distance from treeline (m)		28 Apr	26 May	02 Jul	28 Jul	26 Aug	03 Nov
Site number 15	0	0	0	0	0	0	0
	1	0	0	0	0	0	0
	2	0	0	0	0	0	0
	5	120	120	120	120	300	4600
	10	460	700	1580	2450	4110	10310
	20	780	1520	2570	3470	5110	11570
	50	700	1470	2640	3550	5010	11870
Open pdk yield plateau		740	1500	2610	3510	5060	11720
Pasture loss distance (m)		9.7	11.2	10.3	9.6	8.7	6.8

Distance from treeline (m)	28 Apr	26 May	30 Jun	28 Jul	27 Aug	03 Nov
0	0	0	0	0	0	0
1	0	0	0	0	0	0
2	0	0	0	0	0	0
Site number 16	440	900	1230	1430	1430	4850
10	990	1690	2650	3050	4810	9490
20	1200	1890	2900	3500	5140	10480
50	1200	1770	2790	3550	5010	10570
Open pdk yield plateau	1200	1830	2850	3530	5080	10530
Pasture loss distance (m)	7.3	6.1	6.3	6.9	6.8	6.4

Distance from treeline (m)	30 Apr	28 May	30 Jun	29 Jul	27 Aug	03 Nov
0	0	0	0	0	0	0
1	0	0	0	0	0	0
2	320	320	720	1020	1680	1680
Site number 17	300	400	900	1370	2670	6910
10	480	780	1840	2500	4090	8590
20	880	1160	2470	3300	5080	11640
50	880	1300	2570	3370	5000	11560
Open pdk yield plateau	880	1230	2520	3340	5040	11600
Pasture loss distance (m)	8.8	8.4	7.5	7.1	6.1	6.8

Distance from treeline (m)	30 Apr	28 May	30 Jun	29 Jul	27 Aug	03 Nov
0	0	0	0	0	0	0
1	0	0	0	0	0	0
2	0	0	0	0	0	0
Site number 18	520	520	920	1420	1980	6040
10	960	1050	1870	2480	3210	7010
20	1920	2230	3360	4220	4860	9180
50	1920	2200	3370	4250	5110	9730
Open pdk yield plateau	1920	2220	3370	4240	4990	9460
Pasture loss distance (m)	10.2	10.5	9.7	9.3	8.6	6.9

Distance from treeline (m)	30 Apr	28 May	30 Jun	29 Jul	27 Aug	03 Nov
0	0	0	0	0	0	0
1	0	0	0	0	0	0
2	0	0	0	0	0	0
Site number 19	130	130	330	430	1020	5140
10	680	970	1690	2320	3560	9400
20	860	1600	2680	3490	4710	9590
50	860	1550	2710	3530	4790	9830
Open pdk yield plateau	860	1580	2700	3510	4750	9710
Pasture loss distance (m)	8.5	10.1	9.8	9.6	8.5	5.6

Distance from treeline (m)	27 Apr	25 May	29 Jun	27 Jul	24 Aug	28 Oct
0	0	0	0	0	0	600
1	0	500	500	500	500	2190
2	0	500	500	500	500	3880
Site number 20	5	250	750	1450	2020	2580
	10	250	750	1450	2140	3540
	20	350	850	1400	2150	3640
	50	350	850	1400	2090	3630
Open pdk yield plateau	350	850	1430	2130	3640	9350
Pasture loss distance (m)	6.8	3.1	2.4	3.0	4.4	2.9

Site 21 Trial not sampled

Distance from treeline (m)	27 Apr	25 May	29 Jun	27 Jul	24 Aug	27 Oct
0	0	0	0	0	0	0
1	0	0	0	0	0	750
2	0	0	0	0	0	890
Site number 22	5	240	750	1120	1640	3070
	10	560	1330	2050	2600	4020
	20	660	1690	2340	2880	4470
	50	660	1810	2410	2910	4390
Open pdk yield plateau	660	1750	2380	2900	4430	7510
Pasture loss distance (m)	7.2	7.6	6.6	6.0	5.4	5.2

Distance from treeline (m)	27 Apr	25 May	29 Jun	27 Jul	24 Aug	27 Oct
0	0	0	0	0	0	300
1	0	0	0	0	0	650
2	0	0	0	0	0	880
Site number 23	5	110	110	110	310	510
	10	300	520	1120	1730	3100
	20	500	1240	2070	2890	4480
	50	590	1670	2300	3040	4620
Open pdk yield plateau	550	1460	2190	2970	4550	8130
Pasture loss distance (m)	10.1	12.0	11.0	10.2	9.4	7.6

Distance from treeline (m)	27 Apr	25 May	29 Jun	27 Jul	24 Aug	27 Oct
0	0	0	0	0	0	200
1	0	0	0	0	0	620
2	0	0	0	0	0	880
Site number 24	5	110	110	110	490	2100
	10	200	350	1160	2140	3850
	20	200	710	1470	2220	4100
	50	300	890	1620	2380	4260
Open pdk yield plateau	250	800	1550	2300	4180	6960
Pasture loss distance (m)	7.2	11.2	9.1	7.2	6.1	5.4

Distance from treeline (m)	01 May	29 May	03 Jul	31 Jul	28 Aug	25 Oct
0	0	0	0	0	100	630
1	0	0	0	0	120	880
2	0	0	200	200	610	1630
Site number 25	5	300	330	880	1170	1870
	10	520	980	1990	2390	3140
	20	740	1540	2630	3160	3960
	50	740	1430	2570	3200	4060
Open pdk yield plateau	740	1490	2600	3180	4010	10320
Pasture loss distance (m)	8.1	9.2	7.8	7.8	6.9	6.6

Distance from treeline (m)	01 May	29 May	03 Jul	31 Jul	28 Aug	25 Oct
0	0	0	0	0	0	510
1	0	0	0	0	0	850
2	0	0	0	90	280	1940
Site number 26	5	300	300	500	1050	1600
	10	520	770	1550	2180	2840
	20	740	1300	2260	2930	3690
	50	740	1390	2280	2970	3730
Open pdk yield plateau	740	1350	2270	2950	3710	9010
Pasture loss distance (m)	8.1	9.8	9.0	8.0	7.4	6.6

Site 27 Trial not sampled

Distance from treeline (m)	27 Apr	25 May	29 Jun	27 Jul	24 Aug	28 Oct
0	0	0	0	0	0	0
1	0	0	0	0	0	350
2	0	0	0	0	0	600
Site number 28	5	0	0	400	800	1260
	10	0	190	830	2000	2880
	20	420	1500	2500	3700	4780
	50	420	1560	2600	3820	4950
Open pdk yield plateau	420	1530	2550	3760	4870	9220
Pasture loss distance (m)	15.0	14.1	11.9	10.2	9.5	8.3

Distance from treeline (m)	19 Aug	06 Oct	30 Nov
0	0	0	0
1	0	0	0
2	0	570	1220
Site number 29	5	180	2560
	10	450	4010
	20	1090	5980
	50	1140	6470
Open pdk yield plateau	1120	6230	9010
Pasture loss distance (m)	11.3	8.3	7.9

Distance from treeline (m)		19 Aug	06 Oct	30 Nov
Site number 30	0	0	0	0
	1	0	0	0
	2	0	1120	1700
	5	340	3010	4160
	10	370	3980	6140
	20	1000	5480	8590
	50	990	6140	9040
Open pdk yield plateau		1000	5810	8820
Pasture loss distance (m)		10.8	7.4	7.5

7.8 Appendix 8: 'Open paddock' total seasonal pasture yield plateau.

Site number	Open paddock total seasonal pasture yield plateau (T/ha)			Number of pasture yield measurements		
	1996	1997	1998	1996	1997	1998
1	5.0	6.2	n/s	7	6	n/s
2	6.6	5.4	8.8	7	6	6
3	n/s	n/s	n/s	n/s	n/s	n/s
4	4.3	7.6	9.6	6	6	6
5	7.5	8.3	13.2	6	6	6
6	7.4	6.8	15.3	6	6	6
7	4.2	7.1	10.7	6	6	6
8	6.7	7.0	n/s	6	6	n/s
9	5.1	7.7	9.6	5	3	6
10	4.1	4.8	10.8	5	3	6
11	8.3	8.1	9.5	6	7	7
12	7.9	10.9	10.0	6	7	7
13	n/s	8.9	12.1	n/s	5	6
14	n/s	8.6	12.1	n/s	5	6
15	5.4	7.3	11.7	4	5	6
16	5.2	10.5	10.5	5	6	6
17	5.2	9.2	11.6	5	6	6
18	4.4	10.3	9.5	5	6	6
19	5.3	11.0	9.7	5	6	6
20	6.9	7.5	9.4	6	5	6
21	7.1	8.2	n/s	6	5	n/s
22	7.1	5.9	7.5	6	4	6
23	6.5	5.0	8.1	7	5	6
24	7.1	4.5	7.0	7	4	6
25	4.8	6.7	10.3	5	4	6
26	5.1	5.9	9.0	5	4	6
27	7.1	n/s	n/s	7	n/s	n/s
28	6.7	6.3	9.2	6	3	6
29	7.1	7.3	9.0	5	6	3
30	5.6	7.5	8.8	5	6	3
mean	6.0	7.5	10.1	6	5	6
number of sites	27	28	25	27	28	25

n/s: not sampled

7.9 Appendix 9: Pasture loss width.

Site number	Width of autumn pasture loss out from the treeline (m)			Width of total seasonal pasture loss out from the treeline (m)		
	1996	1997	1998	1996	1997	1998
1	6.2	6.0	n/s	6.6	7.0	n/s
2	6.2	6.4	8.6	9.8	6.8	9.4
3	n/s	n/s	n/s	n/s	n/s	n/s
4	9.8	7.5	8.5	7.6	5.8	7.5
5	5.6	3.9	5.9	5.0	2.7	2.6
6	4.7	3.5	2.4	7.1	3.4	4.5
7	12.9	8.1	7.1	7.5	7.2	7.9
8	14.2	10.9	n/s	12.2	9.4	n/s
9	11.0	6.3	7.1	4.5	3.9	6.1
10	8.3	5.1	6.8	5.2	4.6	6.1
11	6.0	1.8	6.7	4.5	2.7	2.6
12	7.1	3.7	5.2	4.6	5.9	2.9
13	n/s	4.5	8.4	n/s	6.8	5.9
14	n/s	8.9	5.0	n/s	6.7	5.2
15	n/s	9.8	9.7	7.4	7.2	6.8
16	9.6	7.0	7.3	9.8	6.1	6.4
17	5.7	10.3	8.8	6.7	4.8	6.8
18	6.7	11.3	10.2	9.0	6.3	6.9
19	4.9	13.1	8.5	7.8	6.8	5.6
20	1.3	2.0	3.1	2.2	2.6	2.9
21	1.3	2.0	n/s	1.7	2.7	n/s
22	6.0	6.0	7.2	2.8	4.0	5.2
23	10.7	9.9	10.1	6.9	8.3	7.6
24	8.9	6.2	11.2	5.3	4.8	5.4
25	2.1	3.3	8.1	1.5	3.8	6.6
26	2.0	4.6	8.1	4.7	4.8	6.6
27	4.5	n/s	n/s	4.0	n/s	n/s
28	5.3	10.6	14.1	5.9	9.3	8.3
29	11.2	8.3	n/s	5.5	5.2	7.9
30	11.8	12.0	n/s	3.3	6.1	7.5
mean	7.1	6.9	7.7	5.9	5.5	6.0
number of sites	26	28	23	27	28	25

n/s: not sampled

7.10 Appendix 10: Tree data.

Site 1: 1996 (tree age 3.7 yrs)

Sub plot	Row	DBHOB (cm)	Height (cm)	Mean tree volume (m ³ /tree)	Row volume/ha (m ³ /ha/row)	Number of trees	Row SPH (trees/ha/row)
1	1	15.6	1079	0.077	109.3	8.0	1420
2	1	14.5	1006	0.073	92.2	8.0	1263
3	1	15.9	1104	0.076	99.5	8.0	1304
row 1 mean		15.3	1063	0.075	100.4	8.0	1329
1	2	14.4	1038	0.059	63.3	6.0	1065
2	2	14.0	1104	0.061	67.3	7.0	1105
3	2	12.6	1083	0.048	62.4	8.0	1304
row 2 mean		13.7	1075	0.056	64.3	7.0	1158
1	3	13.9	1071	0.057	80.9	8.0	1420
2	3	13.2	1130	0.057	72.2	8.0	1263
3	3	15.3	1205	0.085	111.5	8.0	1304
row 3 mean		14.1	1135	0.067	88.2	8.0	1329
1996 mean		14.4	1091	0.066	84.3	7.7	1272

1997 (tree age 4.7 yrs)

1	1	16.2	1064	0.095	120.1	8.0	1263
2	1	17.5	1168	0.097	126.4	8.0	1304
3	1	16.9	1116	0.096	123.3	8.0	1284
row 1 mean		14.9	1085	0.067	71.0	6.0	1065
1	2	14.8	1147	0.071	78.2	7.0	1105
2	2	13.5	1135	0.058	75.4	8.0	1304
3	2	14.4	1122	0.065	74.9	7.0	1158
row 2 mean		14.4	1113	0.063	90.0	8.0	1420
1	3	13.9	1150	0.066	83.1	8.0	1263
2	3	17.9	1360	0.116	132.6	7.0	1141
3	3	15.4	1208	0.082	101.9	7.7	1275
row 3 mean		15.4	1153	0.079	97.1	7.5	1233
1997 mean		15.6	1163	0.083	101.7	7.6	1233

1998 (tree age 5.7 yrs)

1	1	18.1	1213	0.124	176.0	8.0	1420
2	1	17.3	1140	0.117	147.6	8.0	1263
3	1	19.1	1245	0.124	161.1	8.0	1304
row 1 mean		18.2	1193	0.120	154.4	8.0	1284
1	2	15.1	1188	0.076	80.9	6.0	1065
2	2	15.4	1273	0.083	91.8	7.0	1105
3	2	13.9	1244	0.068	89.3	8.0	1304
row 2 mean		14.8	1235	0.076	87.3	7.0	1158
1	3	14.6	1225	0.073	103.4	8.0	1420
2	3	14.2	1226	0.074	93.0	8.0	1263
3	3	18.4	1511	0.137	156.5	7.0	1141
row 3 mean		15.7	1321	0.095	117.6	7.7	1275
1998 mean		16.2	1252	0.097	122.2	7.6	1254

Site 1 Summary

1996	14.4	1091	0.066	84.3	7.7	1272
1997	15.6	1163	0.083	101.7	7.6	1233
1998	16.2	1252	0.097	122.2	7.6	1254

Site 2: 1996 (tree age 3.7 yrs)

Sub plot	Row	DBHOB (cm)	Height (cm)	Mean tree volume (m ³ /tree)	Row volume/ha (m ³ /ha/row)	Number of trees	Row SPH (trees/ha/row)
1	1	13.9	1125	0.060	69.3	8.0	1154
2	1	12.3	1028	0.044	47.5	8.0	1076
3	1	12.8	1058	0.048	57.2	8.0	1188
row 1 mean		13.0	1070	0.051	58.0	8.0	1139
1	2	9.6	1030	0.032	37.2	8.0	1154
2	2	11.6	1055	0.043	46.2	8.0	1076
3	2	11.8	1108	0.041	48.5	8.0	1188
row 2 mean		11.0	1064	0.039	44.0	8.0	1139
1	3	10.5	1096	0.036	41.3	8.0	1154
2	3	10.5	1079	0.038	40.7	8.0	1076
3	3	9.7	929	0.031	32.6	7.0	1040
row 3 mean		10.2	1035	0.035	38.2	7.7	1090
1996 mean		11.4	1056	0.041	46.7	7.9	1123

1997 (tree age 4.7 yrs)

1	1	18.2	1398	0.126	145.0	8.0	1154
2	1	16.1	1284	0.094	101.6	8.0	1076
3	1	16.3	1294	0.094	112.3	8.0	1188
row 1 mean		16.9	1325	0.105	119.6	8.0	1139
1	2	11.7	1208	0.062	71.1	8.0	1154
2	2	13.7	1298	0.074	79.9	8.0	1076
3	2	13.6	1338	0.065	76.9	8.0	1188
row 2 mean		13.0	1281	0.067	76.0	8.0	1139
1	3	12.9	1364	0.067	77.8	8.0	1154
2	3	12.3	1231	0.060	64.1	8.0	1076
3	3	12.2	1172	0.055	49.0	6.0	891
row 3 mean		12.5	1256	0.061	63.6	7.3	1040
1997 mean		14.1	1287	0.077	86.4	7.8	1106

1998 (tree age 5.7 yrs)

1	1	21.5	1655	0.207	239.3	8.0	1154
2	1	18.9	1446	0.148	158.8	8.0	1076
3	1	19.6	1399	0.148	176.0	8.0	1188
row 1 mean		20.0	1500	0.168	191.4	8.0	1139
1	2	14.7	1471	0.109	110.1	7.0	1010
2	2	15.6	1421	0.107	114.7	8.0	1076
3	2	15.2	1429	0.087	102.8	8.0	1188
row 2 mean		15.2	1440	0.101	109.2	7.7	1091
1	3	14.9	1568	0.105	120.9	8.0	1154
2	3	13.7	1324	0.081	87.0	8.0	1076
3	3	15.4	1368	0.086	63.9	5.0	743
row 3 mean		14.6	1420	0.091	90.6	7.0	991
1998 mean		16.6	1453	0.120	130.4	7.6	1074

Site 2 Summary

1996	11.4	1056	0.041	46.7	7.9	1123
1997	14.1	1287	0.077	86.4	7.8	1106
1998	16.6	1453	0.120	130.4	7.6	1074

Site 3: 1996 (tree age 5.7 yrs)

Sub plot	Row	DBHOB (cm)	Height (cm)	Mean tree volume (m ³ /tree)	Row volume/ha (m ³ /ha/row)	Number of trees	Row SPH (trees/ha/row)
1	1	12.1	954	0.042	42.2	7.0	1010
2	1	13.9	1020	0.056	54.6	8.0	984
3	1	16.9	1207	0.092	74.9	6.0	814
row 1 mean		14.3	1060	0.063	57.2	7.0	936
1	2	11.7	898	0.036	42.0	8.0	1154
2	2	11.8	989	0.039	47.4	10.0	1230
3	2	14.6	1176	0.066	71.3	8.0	1086
row 2 mean		12.7	1021	0.047	53.6	8.7	1156
1	3	10.5	970	0.029	37.4	9.0	1298
2	3	12.1	960	0.048	53.1	9.0	1107
3	3	11.5	1051	0.038	45.9	9.0	1222
row 3 mean		11.3	994	0.038	45.5	9.0	1209
1996 mean		12.8	1025	0.049	52.1	8.2	1100

1997 (tree age 6.7 yrs)

1	1	14.2	1027	0.062	62.6	7.0	1010
2	1	16.0	1103	0.081	69.5	7.0	861
3	1	19.4	1258	0.127	103.1	6.0	814
row 1 mean		16.5	1129	0.090	78.4	6.7	895
1	2	12.5	951	0.044	50.7	8.0	1154
2	2	12.5	1029	0.046	56.4	10.0	1230
3	2	15.7	1200	0.078	84.7	8.0	1086
row 2 mean		13.6	1060	0.056	63.9	8.7	1156
1	3	11.2	1018	0.035	45.3	9.0	1298
2	3	12.8	997	0.057	62.6	9.0	1107
3	3	11.9	1056	0.041	49.9	9.0	1222
row 3 mean		12.0	1023	0.044	52.6	9.0	1209
1997 mean		14.0	1071	0.063	65.0	8.1	1087

1998 (tree age 7.7 yrs)

1	1	16.4	1134	0.092	92.9	7.0	1010
2	1	18.5	1187	0.115	98.9	7.0	861
3	1	22.2	1388	0.183	149.4	6.0	814
row 1 mean		19.0	1237	0.130	113.8	6.7	895
1	2	13.3	1049	0.055	64.0	8.0	1154
2	2	13.3	1104	0.056	68.5	10.0	1230
3	2	16.9	1363	0.103	111.8	8.0	1086
row 2 mean		14.5	1172	0.071	81.5	8.7	1156
1	3	12.0	1118	0.044	56.5	9.0	1298
2	3	13.8	1072	0.071	78.9	9.0	1107
3	3	12.5	1167	0.050	60.5	9.0	1222
row 3 mean		12.7	1119	0.055	65.3	9.0	1209
1998 mean		15.4	1176	0.085	86.8	8.1	1087

Site 3 Summary

1996	12.8	1025	0.049	52.1	8.2	1100
1997	14.0	1071	0.063	65.0	8.1	1087
1998	15.4	1176	0.085	86.8	8.1	1087

Site 5: 1996 (tree age 1.7 yrs)

Sub plot	Row	DBHOB (cm)	Height (cm)	Mean tree volume (m ³ /tree)	Row volume/ha (m ³ /ha/row)	Number of trees	Row SPH (trees/ha/row)
1	1	2.0	175	0.000	0.1	8.0	1017
2	1	2.9	248	0.001	0.4	8.0	1026
3	1	2.4	216	0.000	0.2	5.0	725
row 1 mean		2.4	213	0.000	0.2	7.0	922
1	2	2.2	215	0.000	0.2	7.0	890
2	2	2.6	238	0.000	0.2	6.0	769
3	2	2.4	244	0.000	0.3	6.0	870
row 2 mean		2.4	232	0.000	0.2	6.3	843
1	3	2.7	227	0.000	0.2	5.0	636
2	3	3.0	237	0.001	0.4	8.0	1026
3	3	3.0	275	0.001	0.6	7.0	1014
row 3 mean		2.9	246	0.001	0.4	6.7	892
1996 mean		2.6	231	0.000	0.3	6.7	886

1997 (tree age 2.7 yrs)

1	1	5.1	409	0.003	2.9	8.0	1017
2	1	5.6	455	0.004	4.4	8.0	1026
3	1	5.4	463	0.004	3.1	6.0	870
row 1 mean		5.4	442	0.004	3.4	7.3	971
1	2	5.0	424	0.003	2.8	7.0	890
2	2	5.2	448	0.004	2.7	6.0	769
3	2	6.1	494	0.005	5.0	7.0	1014
row 2 mean		5.4	455	0.004	3.5	6.7	891
1	3	6.6	507	0.006	3.8	5.0	636
2	3	5.5	429	0.004	3.4	8.0	1026
3	3	5.9	500	0.005	3.5	5.0	725
row 3 mean		6.0	479	0.005	3.6	6.0	795
1997 mean		5.6	459	0.004	3.5	6.7	886

1998 (tree age 3.7 yrs)

1	1	9.0	674	0.017	17.1	8.0	1017
2	1	9.7	725	0.019	19.9	8.0	1026
3	1	10.5	717	0.021	18.3	6.0	870
row 1 mean		9.7	705	0.019	18.4	7.3	971
1	2	8.7	696	0.016	14.0	7.0	890
2	2	8.6	708	0.015	11.3	6.0	769
3	2	9.5	783	0.019	19.0	7.0	1014
row 2 mean		8.9	729	0.016	14.8	6.7	891
1	3	11.2	826	0.028	18.1	5.0	636
2	3	8.8	686	0.015	13.9	8.0	1026
3	3	9.5	798	0.020	14.4	5.0	725
row 3 mean		9.8	770	0.021	15.5	6.0	795
1998 mean		9.5	735	0.019	16.2	6.7	886

Site 5 Summary

1996	2.6	231	0.000	0.3	6.7	886
1997	5.6	459	0.004	3.5	6.7	886
1998	9.5	735	0.019	16.2	6.7	886

Site 6: 1996 (tree age 1.7 yrs)

Sub plot	Row	DBHOB (cm)	Height (cm)	Mean tree volume (m ³ /tree)	Row volume/ha (m ³ /ha/row)	Number of trees	Row SPH (trees/ha/row)
1	1	3.7	308	0.001	1.1	8.0	1101
2	1	2.5	215	0.000	0.3	7.0	925
3	1	3.0	228	0.001	0.3	8.0	1101
row 1 mean		3.1	250	0.001	0.6	7.7	1042
1	2	2.7	278	0.001	0.7	7.0	963
2	2	2.1	223	0.000	0.1	6.0	793
3	2	2.5	214	0.000	0.1	8.0	1101
row 2 mean		2.4	238	0.000	0.3	7.0	952
1	3	2.3	242	0.000	0.2	6.0	826
2	3	2.6	253	0.001	0.4	7.0	925
3	3	2.4	224	0.000	0.2	6.0	826
row 3 mean		2.4	240	0.000	0.3	6.3	859
1996 mean		2.7	243	0.001	0.4	7.0	951

1997 (tree age 2.7 yrs)

1	1	5.0	407	0.003	2.4	6.0	826
2	1	5.5	432	0.004	3.5	7.0	925
3	1	7.3	483	0.008	6.7	6.0	826
row 1 mean		5.9	440	0.005	4.2	6.3	859
1	2	5.2	435	0.003	3.4	7.0	963
2	2	5.0	425	0.003	2.4	6.0	793
3	2	6.2	483	0.006	6.3	8.0	1101
row 2 mean		5.5	448	0.004	4.0	7.0	952
1	3	5.8	461	0.005	5.1	8.0	1101
2	3	5.5	479	0.004	3.7	7.0	925
3	3	5.5	477	0.004	4.5	8.0	1101
row 3 mean		5.6	472	0.004	4.4	7.7	1042
1997 mean		5.7	453	0.004	4.2	7.0	951

1998 (tree age 3.7 yrs)

1	1	8.8	703	0.016	12.9	6.0	826
2	1	9.5	726	0.018	16.6	7.0	925
3	1	11.9	807	0.034	28.4	6.0	826
row 1 mean		10.0	745	0.023	19.3	6.3	859
1	2	9.1	733	0.017	15.9	7.0	963
2	2	8.9	763	0.016	13.1	6.0	793
3	2	10.0	801	0.023	24.9	8.0	1101
row 2 mean		9.3	766	0.019	18.0	7.0	952
1	3	9.5	799	0.021	22.7	8.0	1101
2	3	9.0	776	0.017	15.4	7.0	925
3	3	9.6	790	0.021	22.9	8.0	1101
row 3 mean		9.4	788	0.019	20.3	7.7	1042
1998 mean		9.6	766	0.020	19.2	7.0	951

Site 6 Summary

1996	2.7	243	0.001	0.4	7.0	951
1997	5.7	453	0.004	4.2	7.0	951
1998	9.6	766	0.020	19.2	7.0	951

Site 7: 1996 (tree age 4.7 yrs)

Sub plot	Row	DBHOB (cm)	Height (cm)	Mean tree volume (m ³ /tree)	Row volume/ha (m ³ /ha/row)	Number of trees	Row SPH (trees/ha/row)
1	1	13.0	891	0.055	66.0	7.0	1193
2	1	13.5	1030	0.055	73.5	8.0	1326
3	1	14.5	1041	0.068	83.2	9.0	1233
row 1 mean		13.7	988	0.059	74.2	8.0	1251
1	2	11.7	990	0.043	44.0	6.0	1023
2	2	8.7	884	0.023	26.4	7.0	1160
3	2	10.5	1116	0.034	42.1	9.0	1233
row 2 mean		10.3	997	0.033	37.5	7.3	1139
1	3	9.0	963	0.026	30.9	7.0	1193
2	3	9.8	1011	0.028	32.9	7.0	1160
3	3	10.7	1129	0.037	45.9	9.0	1233
row 3 mean		9.9	1034	0.030	36.6	7.7	1195
1996 mean		11.3	1006	0.041	49.4	7.7	1195

1997 (tree age 5.7 yrs)

1	1	17.0	1142	0.110	112.1	6.0	1023
2	1	16.9	1220	0.104	137.4	8.0	1326
3	1	17.4	1300	0.119	146.7	9.0	1233
row 1 mean		17.1	1221	0.111	132.1	7.7	1194
1	2	14.1	1222	0.076	77.4	6.0	1023
2	2	10.6	1051	0.043	49.3	7.0	1160
3	2	12.4	1242	0.054	66.2	9.0	1233
row 2 mean		12.4	1172	0.057	64.3	7.3	1139
1	3	10.7	1126	0.043	51.4	7.0	1193
2	3	11.8	1210	0.050	57.5	7.0	1160
3	3	12.5	1253	0.056	68.7	9.0	1233
row 3 mean		11.6	1196	0.049	59.2	7.7	1195
1997 mean		13.7	1196	0.073	85.2	7.6	1176

1998 (tree age 6.7 yrs)

1	1	19.3	1220	0.153	156.2	6.0	1023
2	1	19.7	1361	0.156	207.2	8.0	1326
3	1	19.3	1426	0.162	199.8	9.0	1233
row 1 mean		19.4	1336	0.157	187.7	7.7	1194
1	2	15.8	1332	0.104	106.6	6.0	1023
2	2	11.8	1204	0.063	72.7	7.0	1160
3	2	13.5	1383	0.072	89.1	9.0	1233
row 2 mean		13.7	1306	0.080	89.5	7.3	1139
1	3	11.9	1294	0.063	75.2	7.0	1193
2	3	13.2	1343	0.070	81.3	7.0	1160
3	3	13.6	1419	0.076	93.9	9.0	1233
row 3 mean		12.9	1352	0.070	83.5	7.7	1195
1998 mean		15.3	1331	0.102	120.2	7.6	1176

Site 7 Summary

1996	11.3	1006	0.041	49.4	7.7	1195
1997	13.7	1196	0.073	85.2	7.6	1176
1998	15.3	1331	0.102	120.2	7.6	1176

Site 8: 1996 (tree age 4.7 yrs)							
Sub plot	Row	DBHOB (cm)	Height (cm)	Mean tree volume (m ³ /tree)	Row volume/ha (m ³ /ha/row)	Number of trees	Row SPH (trees/ha/row)
1	1	17.2	1268	0.120	142.9	8.0	1188
2	1	13.5	1075	0.066	66.7	8.0	1004
3	1	17.0	1330	0.104	125.2	8.0	1200
row 1 mean		15.9	1224	0.097	111.6	8.0	1131
1	2	9.5	1081	0.036	42.6	8.0	1188
2	2	11.7	1109	0.048	54.3	9.0	1130
3	2	11.3	1213	0.048	50.3	7.0	1050
row 2 mean		10.8	1134	0.044	49.1	8.0	1123
1	3	14.3	1324	0.076	90.6	8.0	1188
2	3	9.5	944	0.034	34.5	8.0	1004
3	3	13.7	1300	0.072	64.8	6.0	900
row 3 mean		12.5	1189	0.061	63.3	7.3	1031
1996 mean		13.1	1183	0.067	74.6	7.8	1095
1997 (tree age 5.7 yrs)							
1	1	20.3	1369	0.181	214.7	8.0	1188
2	1	16.9	1201	0.118	118.7	8.0	1004
3	1	20.2	1469	0.164	196.8	8.0	1200
row 1 mean		19.1	1346	0.154	176.7	8.0	1131
1	2	11.0	1198	0.054	64.4	8.0	1188
2	2	14.0	1280	0.079	89.7	9.0	1130
3	2	13.1	1374	0.073	76.8	7.0	1050
row 2 mean		12.7	1284	0.069	77.0	8.0	1123
1	3	16.3	1483	0.111	131.6	8.0	1188
2	3	10.8	1090	0.051	51.4	8.0	1004
3	3	15.8	1468	0.109	98.4	6.0	900
row 3 mean		14.3	1347	0.090	93.8	7.3	1031
1997 mean		15.4	1326	0.105	115.8	7.8	1095
1998 (tree age 6.7 yrs)							
1	1	23.8	1594	0.293	348.0	8.0	1188
2	1	19.9	1408	0.196	196.6	8.0	1004
3	1	23.0	1629	0.242	290.1	8.0	1200
row 1 mean		22.2	1543	0.243	278.2	8.0	1131
1	2	12.0	1353	0.076	89.7	8.0	1188
2	2	16.2	1504	0.123	139.5	9.0	1130
3	2	14.8	1539	0.106	110.9	7.0	1050
row 2 mean		14.3	1465	0.102	113.4	8.0	1123
1	3	17.8	1673	0.150	177.9	8.0	1188
2	3	12.1	1238	0.076	76.2	8.0	1004
3	3	17.5	1658	0.152	136.6	6.0	900
row 3 mean		15.8	1523	0.126	130.2	7.3	1031
1998 mean		17.4	1510	0.157	174.0	7.8	1095
Site 8 Summary							
	1996	13.1	1183	0.067	74.6	7.8	1095
	1997	15.4	1326	0.105	115.8	7.8	1095
	1998	17.4	1510	0.157	174.0	7.8	1095

Site 9: 1996 (tree age 2.7 yrs)

Sub plot	Row	DBHOB (cm)	Height (cm)	Mean tree volume (m ³ /tree)	Row volume/ha (m ³ /ha/row)	Number of trees	Row SPH (trees/ha/row)
1	1	8.7	793	0.017	19.3	8.0	1159
2	1	8.9	771	0.019	21.5	8.0	1127
3	1	9.9	851	0.024	22.0	7.0	933
row 1 mean		9.1	805	0.020	20.9	7.7	1073
1	2	8.4	793	0.017	17.0	7.0	1014
2	2	9.4	874	0.024	26.9	8.0	1127
3	2	10.4	949	0.027	32.4	9.0	1200
row 2 mean		9.4	872	0.023	25.4	8.0	1114
1	3	8.4	855	0.018	20.3	8.0	1159
2	3	9.4	938	0.022	28.5	9.0	1268
3	3	10.0	948	0.025	30.2	9.0	1200
row 3 mean		9.3	914	0.022	26.4	8.7	1209
1996 mean		9.3	863	0.021	24.2	8.1	1132

1997 (tree age 3.7 yrs)

1	1	10.6	920	0.030	35.0	8.0	1159
2	1	10.4	888	0.032	35.8	8.0	1127
3	1	11.4	947	0.034	31.9	7.0	933
row 1 mean		10.8	918	0.032	34.2	7.7	1073
1	2	9.5	864	0.023	23.1	7.0	1014
2	2	10.7	968	0.034	38.6	8.0	1127
3	2	11.4	1041	0.036	43.7	9.0	1200
row 2 mean		10.5	958	0.031	35.1	8.0	1114
1	3	9.9	951	0.027	31.6	8.0	1159
2	3	10.9	1061	0.034	43.4	9.0	1268
3	3	10.9	1032	0.033	39.3	9.0	1200
row 3 mean		10.6	1015	0.031	38.1	8.7	1209
1997 mean		10.6	964	0.032	35.8	8.1	1132

1998 (tree age 4.7 yrs)

1	1	13.0	1058	0.054	62.7	8.0	1159
2	1	12.5	994	0.052	58.5	8.0	1127
3	1	13.2	1074	0.053	49.5	7.0	933
row 1 mean		12.9	1042	0.053	56.9	7.7	1073
1	2	10.8	957	0.034	34.7	7.0	1014
2	2	13.0	1184	0.052	51.5	7.0	986
3	2	12.8	1151	0.052	61.9	9.0	1200
row 2 mean		12.2	1098	0.046	49.4	7.7	1067
1	3	11.3	1071	0.041	47.4	8.0	1159
2	3	12.6	1193	0.051	64.2	9.0	1268
3	3	12.2	1157	0.046	55.2	9.0	1200
row 3 mean		12.0	1140	0.046	55.6	8.7	1209
1998 mean		12.4	1093	0.048	54.0	8.0	1116

Site 9 Summary

1996	9.3	863	0.021	24.2	8.1	1132
1997	10.6	964	0.032	35.8	8.1	1132
1998	12.4	1093	0.048	54.0	8.0	1116

Site 10: 1996 (tree age 2.7 yrs)							
Sub plot	Row	DBHOB (cm)	Height (cm)	Mean tree volume (m ³ /tree)	Row volume/ha (m ³ /ha/row)	Number of trees	Row SPH (trees/ha/row)
1	1	8.5	759	0.019	25.3	7.0	1313
2	1	10.2	814	0.026	32.1	8.0	1237
3	1	11.4	906	0.034	42.4	8.0	1244
row 1 mean		10.0	826	0.026	33.3	7.7	1264
1	2	10.1	844	0.026	38.9	8.0	1500
2	2	10.5	978	0.028	35.2	8.0	1237
3	2	9.3	864	0.024	33.1	9.0	1399
row 2 mean		10.0	895	0.026	35.7	8.3	1379
1	3	10.2	917	0.027	30.3	6.0	1125
2	3	10.3	994	0.028	34.6	8.0	1237
3	3	9.9	990	0.027	33.0	8.0	1244
row 3 mean		10.1	967	0.027	32.6	7.3	1202
1996 mean		10.0	896	0.027	33.9	7.8	1282
1997 (tree age 3.7 yrs)							
1	1	11.1	880	0.038	50.0	7.0	1313
2	1	12.9	949	0.049	60.1	8.0	1237
3	1	14.4	1036	0.063	78.2	8.0	1244
row 1 mean		12.8	955	0.050	62.7	7.7	1264
1	2	11.5	941	0.038	57.1	8.0	1500
2	2	11.7	1054	0.038	47.2	8.0	1237
3	2	10.6	971	0.034	47.9	9.0	1399
row 2 mean		11.3	989	0.037	50.7	8.3	1379
1	3	11.6	997	0.039	44.1	6.0	1125
2	3	11.9	1105	0.042	52.0	8.0	1237
3	3	11.5	1065	0.039	48.5	8.0	1244
row 3 mean		11.7	1056	0.040	48.2	7.3	1202
1997 mean		11.9	1000	0.042	53.9	7.8	1282
1998 (tree age 4.7 yrs)							
1	1	14.6	1070	0.072	80.8	6.0	1125
2	1	15.1	1068	0.075	93.0	8.0	1237
3	1	16.5	1151	0.092	114.9	8.0	1244
row 1 mean		15.4	1096	0.080	96.3	7.3	1202
1	2	12.5	990	0.047	70.2	8.0	1500
2	2	12.7	1126	0.048	59.8	8.0	1237
3	2	11.3	1064	0.043	60.5	9.0	1399
row 2 mean		12.2	1060	0.046	63.5	8.3	1379
1	3	12.7	1045	0.050	55.8	6.0	1125
2	3	13.0	1160	0.053	65.5	8.0	1237
3	3	12.1	1079	0.045	56.4	8.0	1244
row 3 mean		12.6	1095	0.049	59.2	7.3	1202
1998 mean		13.4	1084	0.058	73.0	7.7	1261
Site 10 Summary							
1996		10.0	896	0.027	33.9	7.8	1282
1997		11.9	1000	0.042	53.9	7.8	1282
1998		13.4	1084	0.058	73.0	7.7	1261

Site 11: 1996 (tree age 0.7 yrs)

Sub plot	Row	DBHOB (cm)	Height (cm)	Mean tree volume (m ³ /tree)	Row volume/ha (m ³ /ha/row)	Number of trees	Row SPH (trees/ha/row)
1	1	n/a	131	n/a	n/a	8.0	1257
2	1		135			8.0	1188
3	1		135			8.0	1026
row 1 mean			134			8.0	1157
1	2	n/a	109	n/a	n/a	8.0	1257
2	2		154			8.0	1188
3	2		104			7.0	897
row 2 mean			122			7.7	1114
1	3	n/a	172	n/a	n/a	7.0	1099
2	3		130			8.0	1188
3	3		145			9.0	1154
row 3 mean			149			8.0	1147
1996 mean			135			7.9	1139

1997 (tree age 1.7 yrs)

1	1	4.5	436	0.003	3.5	8.0	1257
2	1	4.4	368	0.003	2.6	8.0	1188
3	1	3.7	335	0.002	1.6	8.0	1026
row 1 mean		4.2	380	0.002	2.6	8.0	1157
1	2	4.6	329	0.003	2.5	8.0	1257
2	2	5.0	419	0.003	3.3	8.0	1188
3	2	3.1	327	0.001	0.7	6.0	769
row 2 mean		4.2	358	0.002	2.2	7.3	1071
1	3	6.1	516	0.006	7.6	8.0	1257
2	3	4.8	443	0.004	4.4	8.0	1188
3	3	5.3	464	0.005	5.3	9.0	1154
row 3 mean		5.4	474	0.005	5.8	8.3	1200
1997 mean		4.6	404	0.003	3.5	7.9	1143

1998 (tree age 2.7 yrs)

1	1	7.6	596	0.010	11.2	7.0	1099
2	1	5.8	443	0.006	6.8	8.0	1188
3	1	7.1	560	0.008	5.3	5.0	641
row 1 mean		6.8	533	0.008	7.8	6.7	976
1	2	7.0	476	0.009	8.6	8.0	1257
2	2	7.5	628	0.010	11.5	8.0	1188
3	2	5.6	463	0.004	3.1	6.0	769
row 2 mean		6.7	522	0.008	7.8	7.3	1071
1	3	8.6	721	0.017	20.8	8.0	1257
2	3	7.8	655	0.013	15.5	8.0	1188
3	3	7.8	630	0.013	15.1	9.0	1154
row 3 mean		8.1	669	0.014	17.1	8.3	1200
1998 mean		7.2	575	0.010	10.9	7.4	1082

Site 11 Summary

1996		135				7.9	1139
1997	4.6	404	0.003	3.5		7.9	1143
1998	7.2	575	0.010	10.9		7.4	1082

Site 12: 1996 (tree age 0.7 yrs)

Sub plot	Row	DBHOB (cm)	Height (cm)	Mean tree volume (m ³ /tree)	Row volume/ha (m ³ /ha/row)	Number of trees	Row SPH (trees/ha/row)
1	1	n/a	170	n/a	n/a	9.0	1189
2	1		142			8.0	1143
3	1		151			8.0	882
row 1 mean			154			8.3	1072
1	2	n/a	155	n/a	n/a	9.0	1189
2	2		183			6.0	857
3	2		162			9.0	993
row 2 mean			167			8.0	1013
1	3	n/a	153	n/a	n/a	6.0	793
2	3		139			7.0	1000
3	3		137			7.0	772
row 3 mean			143			6.7	855
1996 mean			155			7.7	980

1997 (tree age 1.7 yrs)

1	1	6.2	532	0.006	6.8	9.0	1189
2	1	5.1	445	0.004	4.1	8.0	1143
3	1	5.7	469	0.005	4.0	8.0	882
row 1 mean		5.7	482	0.005	5.0	8.3	1072
1	2	6.8	527	0.007	8.1	9.0	1189
2	2	7.2	583	0.008	7.0	6.0	857
3	2	7.1	561	0.008	8.3	9.0	993
row 2 mean		7.0	557	0.008	7.8	8.0	1013
1	3	6.2	507	0.006	4.6	6.0	793
2	3	6.8	500	0.007	6.1	7.0	1000
3	3	6.5	501	0.006	4.7	7.0	772
row 3 mean		6.5	503	0.006	5.1	6.7	855
1997 mean		6.4	514	0.006	6.0	7.7	980

1998 (tree age 2.7 yrs)

1	1	9.8	807	0.023	27.0	9.0	1189
2	1	7.9	628	0.013	14.4	8.0	1143
3	1	9.2	644	0.016	12.1	7.0	772
row 1 mean		9.0	693	0.017	17.8	8.0	1035
1	2	9.8	773	0.021	24.7	9.0	1189
2	2	10.5	850	0.026	22.1	6.0	857
3	2	9.8	787	0.024	23.5	9.0	993
row 2 mean		10.0	803	0.023	23.4	8.0	1013
1	3	8.5	725	0.017	13.5	6.0	793
2	3	8.5	703	0.017	17.5	7.0	1000
3	3	8.6	660	0.014	11.1	7.0	772
row 3 mean		8.5	696	0.016	14.0	6.7	855
1998 mean		9.2	731	0.019	18.4	7.6	968

Site 12 Summary

1996		155				7.7	980
1997	6.4	514	0.006	6.0		7.7	980
1998	9.2	731	0.019	18.4		7.6	968

Site 13: 1996 (tree age 3.7 yrs)

Sub plot	Row	DBHOB (cm)	Height (cm)	Mean tree volume (m ³ /tree)	Row volume/ha (m ³ /ha/row)	Number of trees	Row SPH (trees/ha/row)
1	1	8.1	601	0.012	13.6	9.0	1149
2	1	9.0	658	0.015	16.3	8.0	1111
3	1	7.0	601	0.009	8.0	8.0	909
row 1 mean		8.0	620	0.012	12.6	8.3	1056
1	2	10.0	709	0.019	19.2	8.0	1021
2	2	8.3	701	0.014	17.0	9.0	1250
3	2	9.2	760	0.017	15.5	8.0	909
row 2 mean		9.2	723	0.016	17.2	8.3	1060
1	3	9.2	699	0.017	14.8	7.0	894
2	3	9.5	758	0.019	15.4	6.0	833
3	3	8.4	715	0.014	16.3	10.0	1136
row 3 mean		9.0	724	0.016	15.5	7.7	954
1996 mean		8.7	689	0.015	15.1	8.1	1024

1997 (tree age 4.7 yrs)

1	1	11.2	807	0.030	34.0	9.0	1149
2	1	11.9	850	0.034	37.3	8.0	1111
3	1	10.0	741	0.022	19.8	8.0	909
row 1 mean		11.1	799	0.028	30.4	8.3	1056
1	2	12.8	881	0.038	39.1	8.0	1021
2	2	10.8	921	0.029	36.6	9.0	1250
3	2	11.6	916	0.033	29.8	8.0	909
row 2 mean		11.7	906	0.033	35.2	8.3	1060
1	3	11.5	889	0.033	29.7	7.0	894
2	3	11.5	955	0.034	28.6	6.0	833
3	3	10.7	874	0.028	31.9	10.0	1136
row 3 mean		11.2	906	0.032	30.0	7.7	954
1997 mean		11.3	870	0.031	31.9	8.1	1024

1998 (tree age 5.7 yrs)

1	1	14.4	1001	0.060	69.0	9.0	1149
2	1	14.3	986	0.057	63.0	8.0	1111
3	1	12.4	804	0.037	33.5	8.0	909
row 1 mean		13.7	930	0.051	55.2	8.3	1056
1	2	15.4	1051	0.066	67.5	8.0	1021
2	2	12.6	996	0.044	54.5	9.0	1250
3	2	13.5	961	0.047	42.7	8.0	909
row 2 mean		13.8	1003	0.052	54.9	8.3	1060
1	3	13.3	970	0.047	42.0	7.0	894
2	3	13.2	1013	0.049	40.9	6.0	833
3	3	11.9	904	0.037	41.6	10.0	1136
row 3 mean		12.8	962	0.044	41.5	7.7	954
1998 mean		13.4	965	0.049	50.5	8.1	1024

Site 13 Summary

1996	8.7	689	0.015	15.1	8.1	1024
1997	11.3	870	0.031	31.9	8.1	1024
1998	13.4	965	0.049	50.5	8.1	1024

Site 14: 1996 (tree age 3.7 yrs)

Sub plot	Row	DBHOB (cm)	Height (cm)	Mean tree volume (m ³ /tree)	Row volume/ha (m ³ /ha/row)	Number of trees	Row SPH (trees/ha/row)
1	1	8.5	615	0.012	14.6	8.0	1212
2	1	9.2	629	0.015	16.6	9.0	1120
3	1	9.0	676	0.015	15.2	7.0	1010
row 1 mean		8.9	640	0.014	15.5	8.0	1114
1	2	8.7	703	0.015	17.8	8.0	1212
2	2	8.7	675	0.016	16.0	8.0	996
3	2	9.2	744	0.017	17.2	7.0	1010
row 2 mean		8.9	707	0.016	17.0	7.7	1073
1	3	9.7	749	0.019	23.4	8.0	1212
2	3	9.5	762	0.018	23.0	10.0	1245
3	3	8.6	694	0.016	16.3	7.0	1010
row 3 mean		9.3	735	0.018	20.9	8.3	1156
1996 mean		9.0	694	0.016	17.8	8.0	1114

1997 (tree age 4.7 yrs)

1	1	11.4	764	0.027	32.9	8.0	1212
2	1	12.2	783	0.032	36.3	9.0	1120
3	1	12.5	863	0.036	36.8	7.0	1010
row 1 mean		12.0	803	0.032	35.4	8.0	1114
1	2	11.0	870	0.029	34.8	8.0	1212
2	2	11.1	904	0.036	35.5	8.0	996
3	2	12.2	946	0.037	37.2	7.0	1010
row 2 mean		11.4	906	0.034	35.8	7.7	1073
1	3	12.3	934	0.039	46.8	8.0	1212
2	3	12.1	938	0.037	45.9	10.0	1245
3	3	11.6	899	0.037	37.3	7.0	1010
row 3 mean		12.0	923	0.037	43.4	8.3	1156
1997 mean		11.8	878	0.034	38.2	8.0	1114

1998 (tree age 5.7 yrs)

1	1	14.0	950	0.052	62.9	8.0	1212
2	1	14.6	987	0.058	65.1	9.0	1120
3	1	15.2	1023	0.064	64.8	7.0	1010
row 1 mean		14.6	987	0.058	64.2	8.0	1114
1	2	12.3	981	0.041	49.1	8.0	1212
2	2	12.8	1040	0.056	55.4	8.0	996
3	2	14.2	1043	0.056	56.5	7.0	1010
row 2 mean		13.1	1021	0.051	53.6	7.7	1073
1	3	13.9	1058	0.056	68.4	8.0	1212
2	3	13.7	1139	0.058	72.0	10.0	1245
3	3	13.0	986	0.051	52.0	7.0	1010
row 3 mean		13.5	1061	0.055	64.1	8.3	1156
1998 mean		13.7	1023	0.055	60.7	8.0	1114

Site 14 Summary

1996	9.0	694	0.016	17.8	8.0	1114
1997	11.8	878	0.034	38.2	8.0	1114
1998	13.7	1023	0.055	60.7	8.0	1114

Site 15: 1996 (tree age 5.7 yrs)

Sub plot	Row	DBHOB (cm)	Height (cm)	Mean tree volume (m ³ /tree)	Row volume/ha (m ³ /ha/row)	Number of trees	Row SPH (trees/ha/row)
1	1	13.0	1113	0.050	58.7	8.0	1176
2	1	13.2	1040	0.055	61.4	8.0	1111
3	1	13.3	1001	0.054	61.6	10.0	1141
row 1 mean		13.2	1051	0.053	60.6	8.7	1143
1	2	10.9	1068	0.034	30.3	6.0	882
2	2	10.0	1023	0.028	31.0	8.0	1111
3	2	10.4	963	0.029	23.3	7.0	798
row 2 mean		10.4	1018	0.030	28.2	7.0	931
1	3	9.7	1003	0.027	31.8	8.0	1176
2	3	10.1	1033	0.029	36.4	9.0	1250
3	3	12.5	1077	0.045	35.5	7.0	798
row 3 mean		10.7	1038	0.034	34.6	8.0	1075
1996 mean		11.5	1036	0.039	41.1	7.9	1049

1997 (tree age 6.7 yrs)

1	1	14.5	1189	0.067	79.3	8.0	1176
2	1	14.4	1130	0.071	78.8	8.0	1111
3	1	15.1	1091	0.075	85.6	10.0	1141
row 1 mean		14.7	1137	0.071	81.2	8.7	1143
1	2	11.6	1185	0.043	37.9	6.0	882
2	2	10.8	1105	0.035	38.4	8.0	1111
3	2	11.3	1053	0.039	31.2	7.0	798
row 2 mean		11.2	1114	0.039	35.8	7.0	931
1	3	10.5	1074	0.034	40.4	8.0	1176
2	3	10.7	1129	0.036	44.5	9.0	1250
3	3	13.7	1213	0.060	47.5	7.0	798
row 3 mean		11.6	1138	0.043	44.1	8.0	1075
1997 mean		12.5	1130	0.051	53.7	7.9	1049

1998 (tree age 7.7 yrs)

1	1	16.0	1208	0.083	97.5	8.0	1176
2	1	15.8	1145	0.086	95.5	8.0	1111
3	1	16.5	1093	0.090	103.2	10.0	1141
row 1 mean		16.1	1149	0.086	98.7	8.7	1143
1	2	12.4	1180	0.049	43.5	6.0	882
2	2	11.5	1118	0.040	44.4	8.0	1111
3	2	12.0	1047	0.044	35.3	7.0	798
row 2 mean		12.0	1115	0.044	41.1	7.0	931
1	3	11.1	1080	0.039	46.2	8.0	1176
2	3	11.3	1139	0.040	50.1	9.0	1250
3	3	14.6	1226	0.069	55.4	7.0	798
row 3 mean		12.4	1148	0.050	50.6	8.0	1075
1998 mean		13.5	1137	0.060	63.5	7.9	1049

Site 15 Summary

1996	11.5	1036	0.039	41.1	7.9	1049
1997	12.5	1130	0.051	53.7	7.9	1049
1998	13.5	1137	0.060	63.5	7.9	1049

Site 16: 1996 (tree age 3.7 yrs)

Sub plot	Row	DBHOB (cm)	Height (cm)	Mean tree volume (m ³ /tree)	Row volume/ha (m ³ /ha/row)	Number of trees	Row SPH (trees/ha/row)
1	1	10.8	773	0.025	25.9	8.0	1030
2	1	10.9	823	0.027	29.9	8.0	1101
3	1	11.3	823	0.029	31.9	10.0	1115
row 1 mean		11.0	806	0.027	29.2	8.7	1082
1	2	7.1	684	0.012	12.9	8.0	1030
2	2	9.1	807	0.020	18.9	7.0	963
3	2	10.3	864	0.025	25.0	9.0	1004
row 2 mean		8.8	785	0.019	18.9	8.0	999
1	3	8.8	855	0.019	26.9	11.0	1416
2	3	11.3	952	0.033	40.5	9.0	1239
3	3	11.6	899	0.033	26.1	7.0	781
row 3 mean		10.6	902	0.028	31.2	9.0	1145
1996 mean		10.1	831	0.025	26.5	8.6	1075

1997 (tree age 4.7 yrs)

1	1	13.7	886	0.046	47.5	8.0	1030
2	1	13.8	955	0.051	55.7	8.0	1101
3	1	14.4	963	0.054	60.6	10.0	1115
row 1 mean		13.9	935	0.050	54.6	8.7	1082
1	2	9.5	844	0.024	21.2	7.0	901
2	2	10.7	909	0.030	28.5	7.0	963
3	2	12.3	986	0.040	39.8	9.0	1004
row 2 mean		10.8	913	0.031	29.9	7.7	956
1	3	10.2	947	0.028	39.8	11.0	1416
2	3	13.0	1062	0.049	60.2	9.0	1239
3	3	13.3	1034	0.050	39.3	7.0	781
row 3 mean		12.1	1015	0.042	46.4	9.0	1145
1997 mean		12.3	954	0.041	43.6	8.4	1061

1998 (tree age 5.7 yrs)

1	1	15.4	1016	0.067	69.1	8.0	1030
2	1	15.7	1059	0.074	81.4	8.0	1101
3	1	16.2	1087	0.078	87.1	10.0	1115
row 1 mean		15.7	1054	0.073	79.2	8.7	1082
1	2	10.3	949	0.032	28.8	7.0	901
2	2	11.5	1013	0.039	37.2	7.0	963
3	2	13.2	1109	0.052	52.1	9.0	1004
row 2 mean		11.7	1023	0.041	39.4	7.7	956
1	3	11.1	1015	0.036	51.4	11.0	1416
2	3	13.9	1169	0.062	76.3	9.0	1239
3	3	14.3	1104	0.063	49.3	7.0	781
row 3 mean		13.1	1096	0.054	59.0	9.0	1145
1998 mean		13.5	1058	0.056	59.2	8.4	1061

Site 16 Summary

1996	10.1	831	0.025	26.5	8.6	1075
1997	12.3	954	0.041	43.6	8.4	1061
1998	13.5	1058	0.056	59.2	8.4	1061

Site 17: 1996 (tree age 3.7 yrs)

Sub plot	Row	DBHOB (cm)	Height (cm)	Mean tree volume (m ³ /tree)	Row volume/ha (m ³ /ha/row)	Number of trees	Row SPH (trees/ha/row)
1	1	11.9	933	0.039	49.3	8.0	1257
2	1	10.9	878	0.031	40.1	8.0	1304
3	1	12.4	1001	0.043	54.6	8.0	1263
row 1 mean		11.8	937	0.038	48.0	8.0	1275
1	2	11.5	1051	0.040	50.0	8.0	1257
2	2	9.9	917	0.025	28.8	7.0	1141
3	2	9.6	918	0.024	22.6	6.0	947
row 2 mean		10.3	962	0.030	33.8	7.0	1115
1	3	10.0	983	0.032	39.6	8.0	1257
2	3	8.7	906	0.020	26.7	8.0	1304
3	3	8.3	889	0.017	21.2	8.0	1263
row 3 mean		9.0	926	0.023	29.2	8.0	1275
1996 mean		10.4	942	0.030	37.0	7.7	1221

1997 (tree age 4.7 yrs)

1	1	15.4	1114	0.078	98.1	8.0	1257
2	1	14.3	1035	0.062	81.1	8.0	1304
3	1	16.2	1164	0.084	105.6	8.0	1263
row 1 mean		15.3	1104	0.075	94.9	8.0	1275
1	2	14.1	1198	0.067	84.5	8.0	1257
2	2	12.4	1140	0.049	55.6	7.0	1141
3	2	12.1	1073	0.044	41.9	6.0	947
row 2 mean		12.8	1137	0.053	60.7	7.0	1115
1	3	12.1	1160	0.055	68.7	8.0	1257
2	3	10.7	1049	0.035	46.0	8.0	1304
3	3	10.4	1068	0.032	40.4	8.0	1263
row 3 mean		11.1	1092	0.041	51.7	8.0	1275
1997 mean		13.1	1111	0.056	69.1	7.7	1221

1998 (tree age 5.7 yrs)

1	1	18.0	1149	0.111	139.8	8.0	1257
2	1	17.3	1100	0.098	127.5	8.0	1304
3	1	19.6	1228	0.132	166.1	8.0	1263
row 1 mean		18.3	1159	0.114	144.5	8.0	1275
1	2	15.7	1254	0.088	110.4	8.0	1257
2	2	13.9	1174	0.064	73.0	7.0	1141
3	2	13.6	1155	0.060	57.1	6.0	947
row 2 mean		14.4	1194	0.071	80.2	7.0	1115
1	3	13.2	1215	0.069	86.4	8.0	1257
2	3	11.7	1071	0.044	57.0	8.0	1304
3	3	11.4	1083	0.039	49.8	8.0	1263
row 3 mean		12.1	1123	0.051	64.4	8.0	1275
1998 mean		14.9	1159	0.078	96.3	7.7	1221

Site 17 Summary

1996	10.4	942	0.030	37.0	7.7	1221
1997	13.1	1111	0.056	69.1	7.7	1221
1998	14.9	1159	0.078	96.3	7.7	1221

Site 18: 1996 (tree age 3.7 yrs)

Sub plot	Row	DBHOB (cm)	Height (cm)	Mean tree volume (m ³ /tree)	Row volume/ha (m ³ /ha/row)	Number of trees	Row SPH (trees/ha/row)
1	1	13.2	985	0.047	44.3	8.0	934
2	1	14.2	1029	0.056	55.1	8.0	984
3	1	13.7	1025	0.053	60.0	11.0	1126
row 1 mean		13.7	1013	0.052	53.1	9.0	1015
1	2	11.4	1006	0.036	29.2	7.0	817
2	2	12.7	967	0.045	33.2	6.0	738
3	2	9.9	880	0.026	24.0	9.0	922
row 2 mean		11.4	951	0.036	28.8	7.3	825
1	3	11.6	1024	0.037	34.5	8.0	934
2	3	9.6	922	0.027	19.7	6.0	738
3	3	9.5	903	0.025	20.8	8.0	819
row 3 mean		10.2	949	0.030	25.0	7.3	830
1996 mean		11.8	971	0.039	35.6	7.9	890

1997 (tree age 4.7 yrs)

1	1	16.4	1083	0.081	75.3	8.0	934
2	1	17.6	1104	0.093	91.5	8.0	984
3	1	17.0	1107	0.089	100.0	11.0	1126
row 1 mean		17.0	1098	0.087	88.9	9.0	1015
1	2	13.4	1051	0.052	42.5	7.0	817
2	2	15.4	1055	0.073	53.5	6.0	738
3	2	11.6	919	0.038	35.2	9.0	922
row 2 mean		13.5	1008	0.054	43.7	7.3	825
1	3	13.3	1050	0.051	47.2	8.0	934
2	3	11.2	963	0.039	29.0	6.0	738
3	3	11.0	950	0.037	30.2	8.0	819
row 3 mean		11.8	988	0.042	35.5	7.3	830
1997 mean		14.1	1031	0.061	56.0	7.9	890

1998 (tree age 5.7 yrs)

1	1	18.8	1159	0.113	105.8	8.0	934
2	1	19.4	1170	0.122	119.6	8.0	984
3	1	19.0	1204	0.120	135.6	11.0	1126
row 1 mean		19.1	1177	0.118	120.3	9.0	1015
1	2	14.4	1096	0.062	51.0	7.0	817
2	2	16.2	1083	0.085	62.7	6.0	738
3	2	12.3	948	0.046	42.5	9.0	922
row 2 mean		14.3	1042	0.064	52.0	7.3	825
1	3	14.2	1074	0.059	55.2	8.0	934
2	3	11.8	987	0.046	33.6	6.0	738
3	3	11.9	985	0.044	35.9	8.0	819
row 3 mean		12.6	1015	0.050	41.6	7.3	830
1998 mean		15.3	1078	0.077	71.3	7.9	890

Site 18 Summary

1996	11.8	971	0.039	35.6	7.9	890
1997	14.1	1031	0.061	56.0	7.9	890
1998	15.3	1078	0.077	71.3	7.9	890

Site 19: 1996 (tree age 3.7 yrs)

Sub plot	Row	DBHOB (cm)	Height (cm)	Mean tree volume (m ³ /tree)	Row volume/ha (m ³ /ha/row)	Number of trees	Row SPH (trees/ha/row)
1	1	12.7	816	0.036	41.5	8.0	1148
2	1	10.9	770	0.030	34.8	8.0	1165
3	1	11.2	779	0.028	30.7	8.0	1086
row 1 mean		11.6	788	0.031	35.6	8.0	1133
1	2	9.7	854	0.022	25.1	8.0	1148
2	2	10.2	813	0.024	24.8	7.0	1019
3	2	9.6	828	0.021	22.3	8.0	1086
row 2 mean		9.8	831	0.022	24.1	7.7	1085
1	3	8.7	769	0.018	20.9	8.0	1148
2	3	9.1	804	0.019	21.6	8.0	1165
3	3	8.9	821	0.018	19.9	8.0	1086
row 3 mean		8.9	798	0.018	20.8	8.0	1133
1996 mean		10.1	806	0.024	26.8	7.9	1117

1997 (tree age 4.7 yrs)

1	1	15.7	843	0.057	65.6	8.0	1148
2	1	13.6	799	0.051	58.9	8.0	1165
3	1	14.3	846	0.050	54.3	8.0	1086
row 1 mean		14.5	829	0.053	59.6	8.0	1133
1	2	11.2	908	0.032	36.9	8.0	1148
2	2	12.4	843	0.037	37.9	7.0	1019
3	2	11.6	908	0.033	36.2	8.0	1086
row 2 mean		11.7	886	0.034	37.0	7.7	1085
1	3	10.1	845	0.027	31.2	8.0	1148
2	3	10.7	881	0.028	32.9	8.0	1165
3	3	10.5	879	0.028	30.8	8.0	1086
row 3 mean		10.4	868	0.028	31.6	8.0	1133
1997 mean		12.2	861	0.038	42.7	7.9	1117

1998 (tree age 5.7 yrs)

1	1	17.0	910	0.072	82.6	8.0	1148
2	1	15.1	880	0.070	81.7	8.0	1165
3	1	15.7	928	0.066	71.3	8.0	1086
row 1 mean		15.9	906	0.069	78.5	8.0	1133
1	2	12.0	936	0.039	44.7	8.0	1148
2	2	13.2	876	0.044	44.8	7.0	1019
3	2	12.5	940	0.040	43.6	8.0	1086
row 2 mean		12.5	917	0.041	44.3	7.7	1085
1	3	10.6	860	0.031	35.7	8.0	1148
2	3	11.4	895	0.033	37.9	8.0	1165
3	3	11.3	874	0.032	35.3	8.0	1086
row 3 mean		11.1	876	0.032	36.3	8.0	1133
1998 mean		13.2	900	0.047	53.1	7.9	1117

Site 19 Summary

1996	10.1	806	0.024	26.8	7.9	1117
1997	12.2	861	0.038	42.7	7.9	1117
1998	13.2	900	0.047	53.1	7.9	1117

Site 20: 1996 (tree age 0.7 yrs)							
Sub plot	Row	DBHOB (cm)	Height (cm)	Mean tree volume (m ³ /tree)	Row volume/ha (m ³ /ha/row)	Number of trees	Row SPH (trees/ha/row)
1	1	n/a	91	n/a	n/a	8.0	1137
2	1		103			9.0	1330
3	1		104			7.0	901
row 1 mean			99			8.0	1123
1	2	n/a	87	n/a	n/a	8.0	1137
2	2		109			5.0	739
3	2		78			9.0	1159
row 2 mean			91			7.3	1012
1	3	n/a	87	n/a	n/a	8.0	1137
2	3		94			7.0	1034
3	3		74			8.0	1030
row 3 mean			85			7.7	1067
1996 mean			92			7.7	1067
1997 (tree age 1.7 yrs)							
1	1	3.1	303	0.001	1.0	8.0	1137
2	1	4.1	356	0.002	2.3	9.0	1330
3	1	4.2	403	0.002	1.9	7.0	901
row 1 mean		3.8	354	0.002	1.7	8.0	1123
1	2	3.2	276	0.001	0.7	7.0	995
2	2	4.2	328	0.002	1.2	5.0	739
3	2	2.1	228	0.000	0.2	8.0	1030
row 2 mean		3.2	277	0.001	0.7	6.7	921
1	3	2.3	228	0.000	0.3	8.0	1137
2	3	2.9	288	0.001	0.7	6.0	887
3	3	3.0	295	0.001	0.8	8.0	1030
row 3 mean		2.7	270	0.001	0.6	7.3	1018
1997 mean		3.2	300	0.001	1.0	7.3	1021
1998 (tree age 2.7 yrs)							
1	1	7.5	601	0.010	11.4	8.0	1137
2	1	7.3	623	0.010	13.4	9.0	1330
3	1	9.2	747	0.018	16.3	7.0	901
row 1 mean		8.0	657	0.013	13.7	8.0	1123
1	2	6.5	554	0.006	6.4	7.0	995
2	2	7.8	636	0.013	9.5	5.0	739
3	2	5.4	571	0.005	5.2	8.0	1030
row 2 mean		6.5	587	0.008	7.0	6.7	921
1	3	6.6	586	0.008	8.7	8.0	1137
2	3	7.6	647	0.010	9.1	6.0	887
3	3	7.8	645	0.011	11.0	8.0	1030
row 3 mean		7.3	626	0.010	9.6	7.3	1018
1998 mean		7.3	623	0.010	10.1	7.3	1021
Site 20 Summary							
1996			92			7.7	1067
1997		3.2	300	0.001	1.0	7.3	1021
1998		7.3	623	0.010	10.1	7.3	1021

Site 21: 1996 (tree age 0.7 yrs)							
Sub plot	Row	DBHOB (cm)	Height (cm)	Mean tree volume (m ³ /tree)	Row volume/ha (m ³ /ha/row)	Number of trees	Row SPH (trees/ha/row)
1	1	n/a	116	n/a	n/a	9.0	1134
2	1		106			8.0	1224
3	1		117			7.0	1250
row 1 mean			113			8.0	1203
1	2	n/a	110	n/a	n/a	11.0	1387
2	2		104			6.0	918
3	2		114			8.0	1429
row 2 mean			109			8.3	1244
1	3	n/a	95	n/a	n/a	8.0	1008
2	3		107			7.0	1071
3	3		97			7.0	1250
row 3 mean			100			7.3	1110
1996 mean			107			7.9	1186
1997 (tree age 1.7 yrs)							
1	1	5.0	423	0.003	3.2	8.0	1008
2	1	3.6	336	0.002	1.8	8.0	1224
3	1	4.6	415	0.003	3.3	7.0	1250
row 1 mean		4.4	391	0.003	2.8	7.7	1161
1	2	4.3	409	0.003	3.7	11.0	1387
2	2	3.8	351	0.002	1.6	6.0	918
3	2	4.2	393	0.002	3.1	8.0	1429
row 2 mean		4.1	384	0.002	2.8	8.3	1244
1	3	3.8	339	0.002	1.8	8.0	1008
2	3	4.6	409	0.003	2.9	7.0	1071
3	3	4.5	411	0.003	3.2	7.0	1250
row 3 mean		4.3	386	0.002	2.6	7.3	1110
1997 mean		4.3	387	0.002	2.7	7.8	1172
1998 (tree age 2.7 yrs)							
1	1	8.3	664	0.015	17.2	9.0	1134
2	1	7.6	558	0.010	7.5	6.0	933
3	1	8.0	704	0.013	15.9	7.0	1250
row 1 mean		8.0	642	0.013	13.5	7.3	1106
1	2	8.0	740	0.014	19.5	11.0	1387
2	2	6.6	601	0.008	9.3	8.0	1244
3	2	7.7	710	0.012	17.7	8.0	1429
row 2 mean		7.5	684	0.011	15.5	9.0	1353
1	3	7.4	699	0.013	12.8	8.0	1008
2	3	7.8	668	0.013	17.5	9.0	1399
3	3	8.6	737	0.015	18.6	7.0	1250
row 3 mean		7.9	701	0.013	16.3	8.0	1219
1998 mean		7.8	676	0.012	15.1	8.1	1226
Site 21 Summary							
1996			107			7.9	1186
1997		4.3	387	0.002	2.7	7.8	1172
1998		7.8	676	0.012	15.1	8.1	1226

Site 22: 1996 (tree age 3.7 yrs)

Sub plot	Row	DBHOB (cm)	Height (cm)	Mean tree volume (m ³ /tree)	Row volume/ha (m ³ /ha/row)	Number of trees	Row SPH (trees/ha/row)
1	1	9.7	699	0.020	30.5	8.0	1491
2	1	9.1	578	0.016	19.1	9.0	1350
3	1	7.5	486	0.010	13.5	7.0	1355
row 1 mean		8.8	588	0.015	21.1	8.0	1399
1	2	7.8	599	0.014	18.5	8.0	1491
2	2	7.6	583	0.014	14.8	8.0	1200
3	2	8.7	653	0.015	22.6	8.0	1548
row 2 mean		8.0	611	0.014	18.6	8.0	1413
1	3	6.1	601	0.008	12.0	8.0	1491
2	3	6.9	567	0.011	14.2	10.0	1500
3	3	6.4	619	0.009	15.8	9.0	1742
row 3 mean		6.5	596	0.009	14.0	9.0	1578
1996 mean		7.8	598	0.013	17.9	8.3	1463

1997 (tree age 4.7 yrs)

1	1	13.5	849	0.047	70.7	8.0	1491
2	1	12.9	735	0.040	41.5	8.0	1200
3	1	10.6	649	0.027	36.6	7.0	1355
row 1 mean		12.3	744	0.038	49.6	7.7	1349
1	2	10.9	821	0.034	38.0	7.0	1304
2	2	10.4	828	0.034	35.2	8.0	1200
3	2	11.0	803	0.028	43.7	8.0	1548
row 2 mean		10.7	817	0.032	39.0	7.7	1351
1	3	8.6	847	0.020	26.2	7.0	1304
2	3	9.6	791	0.024	28.5	9.0	1350
3	3	8.1	772	0.017	29.7	9.0	1742
row 3 mean		8.8	803	0.020	28.1	8.3	1465
1997 mean		10.6	788	0.030	38.9	7.9	1388

1998 (tree age 5.7 yrs)

1	1	16.4	1010	0.086	127.6	8.0	1491
2	1	14.2	894	0.065	78.2	8.0	1200
3	1	15.0	860	0.057	66.7	6.0	1161
row 1 mean		15.2	921	0.069	90.8	7.3	1284
1	2	11.1	946	0.045	58.5	7.0	1304
2	2	11.1	969	0.046	55.0	8.0	1200
3	2	12.8	945	0.044	68.5	8.0	1548
row 2 mean		11.7	953	0.045	60.7	7.7	1351
1	3	10.9	1046	0.035	33.0	5.0	932
2	3	11.6	931	0.039	47.0	9.0	1350
3	3	9.4	889	0.027	46.2	9.0	1742
row 3 mean		10.6	955	0.034	42.0	7.7	1341
1998 mean		12.5	943	0.049	64.5	7.6	1325

Site 22 Summary

1996	7.8	598	0.013	17.9	8.3	1463
1997	10.6	788	0.030	38.9	7.9	1388
1998	12.5	943	0.049	64.5	7.6	1325

Site 23: 1996 (tree age 4.7 yrs)

Sub plot	Row	DBHOB (cm)	Height (cm)	Mean tree volume (m ³ /tree)	Row volume/ha (m ³ /ha/row)	Number of trees	Row SPH (trees/ha/row)
1	1	18.8	1099	0.145	173.6	7.0	1200
2	1	20.5	1394	0.159	212.0	8.0	1333
3	1	17.9	1264	0.144	218.7	9.0	1517
row 1 mean		19.1	1252	0.149	201.4	8.0	1350
1	2	15.1	1307	0.093	111.0	7.0	1200
2	2	17.3	1397	0.111	129.0	7.0	1167
3	2	15.6	1417	0.095	111.5	7.0	1180
row 2 mean		16.0	1374	0.099	117.2	7.0	1182
1	3	15.2	1385	0.088	120.1	8.0	1371
2	3	14.7	1329	0.091	122.0	8.0	1333
3	3	14.3	1179	0.087	103.1	7.0	1180
row 3 mean		14.7	1297	0.089	115.1	7.7	1295
1996 mean		16.6	1308	0.112	144.6	7.6	1276

1997 (tree age 5.7 yrs)

1	1	21.1	1206	0.199	239.0	7.0	1200
2	1	22.8	1470	0.210	279.9	8.0	1333
3	1	21.6	1441	0.204	274.6	8.0	1348
row 1 mean		21.8	1372	0.204	264.5	7.7	1294
1	2	17.2	1428	0.131	179.2	8.0	1371
2	2	19.1	1571	0.152	176.8	7.0	1167
3	2	16.7	1487	0.117	138.1	7.0	1180
row 2 mean		17.7	1495	0.133	164.7	7.3	1239
1	3	16.5	1489	0.112	154.0	8.0	1371
2	3	18.0	1574	0.135	156.9	7.0	1167
3	3	17.6	1463	0.131	132.0	6.0	1011
row 3 mean		17.4	1509	0.126	147.7	7.0	1183
1997 mean		19.0	1459	0.154	192.3	7.3	1239

1998 (tree age 6.7 yrs)

1	1	25.6	1473	0.301	309.7	6.0	1029
2	1	24.6	1589	0.268	357.4	8.0	1333
3	1	23.5	1518	0.259	349.6	8.0	1348
row 1 mean		24.6	1527	0.276	338.9	7.3	1237
1	2	18.3	1513	0.162	221.7	8.0	1371
2	2	20.4	1709	0.188	219.3	7.0	1167
3	2	17.7	1609	0.147	173.1	7.0	1180
row 2 mean		18.8	1610	0.165	204.7	7.3	1239
1	3	17.5	1529	0.130	178.6	8.0	1371
2	3	19.1	1637	0.157	183.0	7.0	1167
3	3	18.9	1548	0.158	159.4	6.0	1011
row 3 mean		18.5	1571	0.148	173.6	7.0	1183
1998 mean		20.6	1569	0.197	239.1	7.2	1220

Site 23 Summary

1996	16.6	1308	0.112	144.6	7.6	1276
1997	19.0	1459	0.154	192.3	7.3	1239
1998	20.6	1569	0.197	239.1	7.2	1220

Site 24: 1996 (tree age 4.7 yrs)

Sub plot	Row	DBHOB (cm)	Height (cm)	Mean tree volume (m ³ /tree)	Row volume/ha (m ³ /ha/row)	Number of trees	Row SPH (trees/ha/row)
1	1	18.5	1167	0.112	135.1	10.0	1210
2	1	18.7	1229	0.115	114.9	7.0	995
3	1	17.5	1188	0.104	130.3	9.0	1256
row 1 mean		18.2	1194	0.110	126.8	8.7	1154
1	2	16.1	1229	0.110	93.4	7.0	847
2	2	14.3	1279	0.075	74.3	7.0	995
3	2	15.9	1199	0.098	95.8	7.0	977
row 2 mean		15.4	1235	0.094	87.8	7.0	940
1	3	17.1	1274	0.103	100.1	8.0	968
2	3	15.2	1243	0.089	101.6	8.0	1137
3	3	10.4	1153	0.045	25.2	4.0	558
row 3 mean		14.2	1223	0.079	75.6	6.7	888
1996 mean		16.0	1218	0.095	96.7	7.4	994

1997 (tree age 5.7 yrs)

1	1	21.1	1302	0.162	196.4	10.0	1210
2	1	20.5	1349	0.151	150.2	7.0	995
3	1	20.1	1317	0.154	192.8	9.0	1256
row 1 mean		20.6	1322	0.156	179.8	8.7	1154
1	2	18.2	1373	0.154	130.7	7.0	847
2	2	16.1	1397	0.104	103.6	7.0	995
3	2	17.9	1353	0.141	137.4	7.0	977
row 2 mean		17.4	1374	0.133	123.9	7.0	940
1	3	18.8	1423	0.143	138.7	8.0	968
2	3	17.1	1373	0.124	141.2	8.0	1137
3	3	12.4	1255	0.067	37.3	4.0	558
row 3 mean		16.1	1350	0.111	105.7	6.7	888
1997 mean		18.0	1349	0.133	136.5	7.4	994

1998 (tree age 6.7 yrs)

1	1	23.2	1450	0.222	268.1	10.0	1210
2	1	23.7	1479	0.221	220.3	7.0	995
3	1	22.4	1421	0.206	258.9	9.0	1256
row 1 mean		23.1	1450	0.216	249.1	8.7	1154
1	2	19.8	1496	0.200	169.3	7.0	847
2	2	17.3	1586	0.138	137.6	7.0	995
3	2	19.6	1527	0.192	187.3	7.0	977
row 2 mean		18.9	1536	0.177	164.8	7.0	940
1	3	20.2	1591	0.188	181.8	8.0	968
2	3	18.4	1543	0.162	184.6	8.0	1137
3	3	13.9	1445	0.094	52.5	4.0	558
row 3 mean		17.5	1526	0.148	139.6	6.7	888
1998 mean		19.8	1504	0.180	184.5	7.4	994

Site 24 Summary

1996	16.0	1218	0.095	96.7	7.4	994
1997	18.0	1349	0.133	136.5	7.4	994
1998	19.8	1504	0.180	184.5	7.4	994

Site 25: 1996 (tree age 4.7 yrs)

Sub plot	Row	DBHOB (cm)	Height (cm)	Mean tree volume (m ³ /tree)	Row volume/ha (m ³ /ha/row)	Number of trees	Row SPH (trees/ha/row)
1	1	13.1	981	0.048	47.6	8.0	984
2	1	9.9	860	0.026	30.1	8.0	1171
3	1	12.0	952	0.042	52.6	10.0	1255
row 1 mean		11.6	931	0.039	43.5	8.7	1137
1	2	11.2	995	0.038	37.1	8.0	984
2	2	11.3	1018	0.036	46.9	9.0	1317
3	2	11.8	1043	0.044	55.7	10.0	1255
row 2 mean		11.4	1019	0.039	46.6	9.0	1185
1	3	10.9	1038	0.035	38.7	9.0	1107
2	3	10.0	989	0.029	33.7	8.0	1171
3	3	10.7	1054	0.037	32.4	7.0	879
row 3 mean		10.5	1027	0.034	34.9	8.0	1052
1996 mean		11.2	992	0.037	41.7	8.6	1125

1997 (tree age 5.7 yrs)

1	1	16.1	1216	0.089	87.3	8.0	984
2	1	12.2	1029	0.047	55.2	8.0	1171
3	1	15.7	1191	0.090	112.9	10.0	1255
row 1 mean		14.6	1145	0.075	85.2	8.7	1137
1	2	13.1	1243	0.064	62.7	8.0	984
2	2	13.2	1238	0.059	78.1	9.0	1317
3	2	14.0	1294	0.080	100.1	10.0	1255
row 2 mean		13.4	1258	0.068	80.3	9.0	1185
1	3	12.8	1249	0.059	65.4	9.0	1107
2	3	12.9	1287	0.056	57.8	7.0	1024
3	3	12.8	1274	0.063	55.4	7.0	879
row 3 mean		12.8	1270	0.060	59.5	7.7	1003
1997 mean		13.6	1225	0.067	75.0	8.4	1108

1998 (tree age 6.7 yrs)

1	1	19.1	1368	0.141	138.4	8.0	984
2	1	14.0	1156	0.075	87.7	8.0	1171
3	1	18.7	1405	0.153	192.0	10.0	1255
row 1 mean		17.3	1310	0.123	139.3	8.7	1137
1	2	14.7	1416	0.092	90.9	8.0	984
2	2	14.6	1384	0.082	108.4	9.0	1317
3	2	15.8	1483	0.119	149.4	10.0	1255
row 2 mean		15.0	1428	0.098	116.2	9.0	1185
1	3	14.3	1497	0.089	98.7	9.0	1107
2	3	14.4	1459	0.079	81.2	7.0	1024
3	3	14.4	1476	0.096	84.1	7.0	879
row 3 mean		14.4	1477	0.088	88.0	7.7	1003
1998 mean		15.6	1405	0.103	114.5	8.4	1108

Site 25 Summary

1996	11.2	992	0.037	41.7	8.6	1125
1997	13.6	1225	0.067	75.0	8.4	1108
1998	15.6	1405	0.103	114.5	8.4	1108

Site 26: 1996 (tree age 4.7 yrs)

Sub plot	Row	DBHOB (cm)	Height (cm)	Mean tree volume (m ³ /tree)	Row volume/ha (m ³ /ha/row)	Number of trees	Row SPH (trees/ha/row)
1	1	11.8	992	0.041	41.2	9.0	1011
2	1	13.0	1012	0.050	67.6	9.0	1343
3	1	10.6	918	0.033	39.6	9.0	1189
row 1 mean		11.8	974	0.041	49.4	9.0	1181
1	2	9.6	996	0.027	23.8	8.0	899
2	2	10.0	949	0.031	41.0	9.0	1343
3	2	12.1	1122	0.045	54.0	9.0	1189
row 2 mean		10.6	1022	0.034	39.6	8.7	1144
1	3	11.6	1063	0.040	31.5	7.0	787
2	3	10.8	915	0.034	30.2	6.0	896
3	3	13.0	1189	0.053	49.0	7.0	925
row 3 mean		11.8	1055	0.042	36.9	6.7	869
1996 mean		11.4	1017	0.039	42.0	8.1	1065

1997 (tree age 5.7 yrs)

1	1	15.3	1232	0.086	87.2	9.0	1011
2	1	16.2	1213	0.094	125.6	9.0	1343
3	1	13.2	1114	0.065	77.1	9.0	1189
row 1 mean		14.9	1187	0.082	96.7	9.0	1181
1	2	11.6	1215	0.047	41.9	8.0	899
2	2	11.8	1141	0.054	72.5	9.0	1343
3	2	13.7	1304	0.071	84.4	9.0	1189
row 2 mean		12.4	1220	0.057	66.3	8.7	1144
1	3	14.3	1277	0.072	56.9	7.0	787
2	3	12.5	1115	0.057	50.9	6.0	896
3	3	15.1	1394	0.084	77.8	7.0	925
row 3 mean		14.0	1262	0.071	61.9	6.7	869
1997 mean		13.8	1223	0.070	74.9	8.1	1065

1998 (tree age 6.7 yrs)

1	1	18.2	1408	0.139	140.3	9.0	1011
2	1	19.1	1394	0.150	201.3	9.0	1343
3	1	15.6	1227	0.101	120.1	9.0	1189
row 1 mean		17.6	1343	0.130	153.9	9.0	1181
1	2	12.9	1338	0.064	57.3	8.0	899
2	2	13.4	1268	0.079	105.8	9.0	1343
3	2	15.4	1458	0.101	119.9	9.0	1189
row 2 mean		13.9	1354	0.081	94.3	8.7	1144
1	3	16.1	1417	0.102	80.5	7.0	787
2	3	15.8	1468	0.099	73.7	5.0	746
3	3	16.4	1544	0.109	101.3	7.0	925
row 3 mean		16.1	1476	0.104	85.2	6.3	819
1998 mean		15.9	1391	0.105	111.1	8.0	1048

Site 26 Summary

1996	11.4	1017	0.039	42.0	8.1	1065
1997	13.8	1223	0.070	74.9	8.1	1065
1998	15.9	1391	0.105	111.1	8.0	1048

Site 27: 1996 (tree age 6.7 yrs)

Sub plot	Row	DBHOB (cm)	Height (cm)	Mean tree volume (m ³ /tree)	Row volume/ha (m ³ /ha/row)	Number of trees	Row SPH (trees/ha/row)
1	1	22.5	1660	0.268	254.5	8.0	949
2	1	21.0	1665	0.236	202.4	6.0	857
3	1	18.2	1534	0.196	209.5	9.0	1071
row 1 mean		20.6	1620	0.233	222.2	7.7	959
1	2	18.2	1701	0.168	159.8	8.0	949
2	2	20.0	1929	0.207	236.1	8.0	1143
3	2	21.9	1950	0.250	267.6	9.0	1071
row 2 mean		20.0	1860	0.208	221.2	8.3	1054
1	3	18.4	1706	0.170	161.4	8.0	949
2	3	20.8	2070	0.237	270.4	8.0	1143
3	3	19.7	1915	0.250	238.1	8.0	952
row 3 mean		19.6	1897	0.219	223.3	8.0	1015
1996 mean		20.1	1792	0.220	222.2	8.0	1009

1997 (tree age 7.7 yrs)

1	1	25.4	1828	0.386	366.3	8.0	949
2	1	23.6	1835	0.330	282.9	6.0	857
3	1	20.1	1637	0.260	278.8	9.0	1071
row 1 mean		23.1	1766	0.325	309.3	7.7	959
1	2	20.1	1844	0.225	213.0	8.0	949
2	2	21.5	2146	0.268	306.5	8.0	1143
3	2	23.3	2182	0.318	340.2	9.0	1071
row 2 mean		21.6	2057	0.270	286.5	8.3	1054
1	3	19.9	1924	0.224	212.2	8.0	949
2	3	22.5	2216	0.297	339.1	8.0	1143
3	3	21.2	2100	0.321	305.9	8.0	952
row 3 mean		21.2	2080	0.281	285.7	8.0	1015
1997 mean		22.0	1968	0.292	293.9	8.0	1009

1998 (tree age 8.7 yrs)

1	1	28.6	1998	0.536	508.3	8.0	949
2	1	26.1	2033	0.441	377.6	6.0	857
3	1	24.4	1939	0.393	374.6	8.0	952
row 1 mean		26.4	1990	0.457	420.2	7.3	919
1	2	22.0	2113	0.308	292.6	8.0	949
2	2	22.8	2329	0.325	371.9	8.0	1143
3	2	24.7	2381	0.392	420.0	9.0	1071
row 2 mean		23.1	2274	0.342	361.5	8.3	1054
1	3	21.3	2065	0.284	269.1	8.0	949
2	3	24.0	2493	0.383	437.3	8.0	1143
3	3	24.7	2449	0.463	386.2	7.0	833
row 3 mean		23.3	2335	0.377	364.2	7.7	975
1998 mean		24.3	2200	0.392	382.0	7.8	983

Site 27 Summary

1996	20.1	1792	0.220	222.2	8.0	1009
1997	22.0	1968	0.292	293.9	8.0	1009
1998	24.3	2200	0.392	382.0	7.8	983

Site 28: 1996 (tree age 6.7 yrs)							
Sub plot	Row	DBHOB (cm)	Height (cm)	Mean tree volume (m ³ /tree)	Row volume/ha (m ³ /ha/row)	Number of trees	Row SPH (trees/ha/row)
1	1	20.8	1670	0.267	336.7	8.0	1263
2	1	24.3	1951	0.309	419.5	8.0	1356
3	1	24.3	1795	0.343	395.5	8.0	1154
row 1 mean		23.1	1805	0.306	383.9	8.0	1258
1	2	20.4	2030	0.227	250.8	7.0	1105
2	2	16.1	1735	0.162	165.0	6.0	1017
3	2	21.7	1987	0.253	255.5	7.0	1010
row 2 mean		19.4	1917	0.214	223.8	6.7	1044
1	3	14.3	1553	0.120	151.1	8.0	1263
2	3	16.4	1656	0.150	178.3	7.0	1186
3	3	10.5	1166	0.053	53.1	7.0	1010
row 3 mean		13.8	1458	0.107	127.5	7.3	1153
1996 mean		18.7	1727	0.209	245.0	7.3	1152
1997 (tree age 7.7 yrs)							
1	1	23.1	1726	0.343	432.7	8.0	1263
2	1	26.6	2038	0.391	530.2	8.0	1356
3	1	26.8	1914	0.461	532.2	8.0	1154
row 1 mean		25.5	1893	0.398	498.4	8.0	1258
1	2	21.9	2123	0.279	308.0	7.0	1105
2	2	17.6	1802	0.203	206.1	6.0	1017
3	2	23.7	2091	0.324	327.3	7.0	1010
row 2 mean		21.1	2005	0.268	280.5	6.7	1044
1	3	15.4	1636	0.151	190.9	8.0	1263
2	3	20.0	2002	0.213	216.3	6.0	1017
3	3	11.0	1176	0.061	61.9	7.0	1010
row 3 mean		15.5	1605	0.142	156.4	7.0	1097
1997 mean		20.7	1834	0.269	311.7	7.2	1133
1998 (tree age 8.7 yrs)							
1	1	25.6	1931	0.463	584.5	8.0	1263
2	1	28.7	2209	0.495	670.8	8.0	1356
3	1	29.5	2070	0.618	712.6	8.0	1154
row 1 mean		27.9	2070	0.525	656.0	8.0	1258
1	2	23.4	2387	0.360	397.7	7.0	1105
2	2	19.1	2003	0.269	273.9	6.0	1017
3	2	25.5	2210	0.401	405.2	7.0	1010
row 2 mean		22.7	2200	0.343	358.9	6.7	1044
1	3	15.9	1746	0.181	228.9	8.0	1263
2	3	21.4	2228	0.272	276.8	6.0	1017
3	3	12.5	1376	0.086	62.1	5.0	721
row 3 mean		16.6	1784	0.180	189.3	6.3	1000
1998 mean		22.4	2018	0.349	401.4	7.0	1101
Site 28 Summary							
1996		18.7	1727	0.209	245.0	7.3	1152
1997		20.7	1834	0.269	311.7	7.2	1133
1998		22.4	2018	0.349	401.4	7.0	1101

Site 29: 1996 (tree age 7.7 yrs)

Sub plot	Row	DBHOB (cm)	Height (cm)	Mean tree volume (m ³ /tree)	Row volume/ha (m ³ /ha/row)	Number of trees	Row SPH (trees/ha/row)
1	1	28.2	1666	0.355	423.6	8.0	1194
2	1	28.4	1708	0.383	525.8	8.0	1371
3	1	31.6	1558	0.433	530.2	8.0	1224
row 1 mean		29.4	1644	0.390	493.2	8.0	1263
1	2	17.9	1592	0.159	142.0	6.0	896
2	2	16.5	1545	0.133	136.7	6.0	1029
3	2	21.3	1894	0.233	285.4	8.0	1224
row 2 mean		18.6	1677	0.175	188.0	6.7	1050
1	3	19.5	1677	0.170	152.0	6.0	896
2	3	16.0	1627	0.123	147.4	7.0	1200
3	3	19.8	1865	0.193	177.5	6.0	918
row 3 mean		18.5	1723	0.162	159.0	6.3	1005
1996 mean		22.1	1681	0.242	280.1	7.0	1106

1997 (tree age 8.7 yrs)

1	1	30.1	1869	0.453	540.8	8.0	1194
2	1	30.3	1824	0.467	640.9	8.0	1371
3	1	33.3	1616	0.503	615.6	8.0	1224
row 1 mean		31.2	1770	0.474	599.1	8.0	1263
1	2	19.2	1745	0.198	177.1	6.0	896
2	2	16.9	1687	0.150	154.7	6.0	1029
3	2	22.3	2070	0.278	340.3	8.0	1224
row 2 mean		19.5	1834	0.209	224.0	6.7	1050
1	3	20.4	1792	0.201	179.8	6.0	896
2	3	16.7	1710	0.140	168.2	7.0	1200
3	3	20.7	1972	0.224	206.0	6.0	918
row 3 mean		19.3	1824	0.188	184.7	6.3	1005
1997 mean		23.3	1809	0.290	335.9	7.0	1106

1998 (tree age 9.7 yrs)

1	1	32.5	1963	0.553	660.5	8.0	1194
2	1	32.3	1940	0.577	790.7	8.0	1371
3	1	34.8	1839	0.616	754.4	8.0	1224
row 1 mean		33.2	1914	0.582	735.2	8.0	1263
1	2	20.4	1848	0.235	210.5	6.0	896
2	2	17.8	1820	0.190	195.3	6.0	1029
3	2	23.4	2326	0.343	420.4	8.0	1224
row 2 mean		20.5	1998	0.256	275.4	6.7	1050
1	3	21.5	1940	0.241	216.0	6.0	896
2	3	17.3	1909	0.168	202.0	7.0	1200
3	3	22.0	2138	0.272	249.7	6.0	918
row 3 mean		20.3	1996	0.227	222.6	6.3	1005
1998 mean		24.7	1969	0.355	411.0	7.0	1106

Site 29 Summary

1996	22.1	1681	0.242	280.1	7.0	1106
1997	23.3	1809	0.290	335.9	7.0	1106
1998	24.7	1969	0.355	411.0	7.0	1106

Site 30: 1996 (tree age 7.7 yrs)

Sub plot	Row	DBHOB (cm)	Height (cm)	Mean tree volume (m ³ /tree)	Row volume/ha (m ³ /ha/row)	Number of trees	Row SPH (trees/ha/row)
1	1	22.3	1357	0.261	286.0	7.0	1094
2	1	25.7	1674	0.387	434.2	7.0	1123
3	1	21.6	1568	0.219	263.4	8.0	1200
row 1 mean		23.2	1533	0.289	327.8	7.3	1139
1	2	15.8	1578	0.112	157.5	9.0	1406
2	2	16.7	1573	0.125	160.1	8.0	1283
3	2	16.0	1635	0.115	138.1	8.0	1200
row 2 mean		16.1	1595	0.117	151.9	8.3	1297
1	3	13.4	1460	0.082	102.0	8.0	1250
2	3	14.7	1551	0.101	129.6	8.0	1283
3	3	16.5	1539	0.123	147.3	8.0	1200
row 3 mean		14.8	1517	0.102	126.3	8.0	1244
1996 mean		18.1	1548	0.169	202.0	7.9	1227

1997 (tree age 8.7 yrs)

1	1	23.6	1367	0.307	335.8	7.0	1094
2	1	28.4	1689	0.492	553.1	7.0	1123
3	1	21.6	1600	0.222	199.8	6.0	900
row 1 mean		24.5	1552	0.340	362.9	6.7	1039
1	2	16.7	1664	0.132	186.0	9.0	1406
2	2	17.8	1683	0.155	199.0	8.0	1283
3	2	17.4	1705	0.145	173.4	8.0	1200
row 2 mean		17.3	1684	0.144	186.2	8.3	1297
1	3	14.1	1588	0.096	119.7	8.0	1250
2	3	15.6	1671	0.124	159.7	8.0	1283
3	3	17.3	1610	0.145	173.7	8.0	1200
row 3 mean		15.7	1623	0.122	151.1	8.0	1244
1997 mean		19.2	1620	0.202	233.4	7.7	1193

1998 (tree age 9.7 yrs)

1	1	25.1	1389	0.361	395.2	7.0	1094
2	1	29.8	1756	0.571	640.9	7.0	1123
3	1	24.9	1662	0.303	272.6	6.0	900
row 1 mean		26.6	1602	0.412	436.2	6.7	1039
1	2	17.7	1804	0.161	226.4	9.0	1406
2	2	18.9	1761	0.186	239.1	8.0	1283
3	2	18.6	1843	0.179	214.2	8.0	1200
row 2 mean		18.4	1803	0.175	226.6	8.3	1297
1	3	15.1	1718	0.122	152.3	8.0	1250
2	3	16.4	1743	0.144	185.1	8.0	1283
3	3	18.1	1726	0.173	207.4	8.0	1200
row 3 mean		16.5	1729	0.146	181.6	8.0	1244
1998 mean		20.5	1711	0.244	281.5	7.7	1193

Site 30 Summary

1996	18.1	1548	0.169	202.0	7.9	1227
1997	19.2	1620	0.202	233.4	7.7	1193
1998	20.5	1711	0.244	281.5	7.7	1193

7.11 Appendix 11: Economic modelling format – farm and paddock assumptions and design inputs.

Modelling inputs	Amount	Unit	Symbol/formula
1. Grazing returns			
stocking rate	10	dse/ha	s (entered)
grazing gross margin	7	\$/dse	g (entered)
grazing gross margin (net of per head, fertiliser & livestock capital costs)	70	\$/ha	$G=s*g$
2. Paddock dimensions			
total area	40	ha	A (entered)
average width (East - West)	1000	m	W (entered)
average length (North - South)	400	m	$L = A*10000/W$
3. Shelterbelt dimensions			
gap between belts (min pasture width)	100	m	D_1 (entered)
alley width (max pasture width)	104	m	$D_2 = D_1+T$
number of belts	9.26		$B=W/(D_2+w_1)$
rows of trees per belt	2		R (entered)
tree spacing - between rows	4.0	m	T (entered)
tree spacing - within rows	2.0	m	r (entered)
total length of tree rows	8	km	$L*B*R/1000$
width planted (within plantinglines) ⁽¹⁾	4	m	$w_1=T*(R-1)$
width planted (max treated)	8	m	$w_2=T*R$
number of trees planted	3704		$N=L*1,000/r$
total area of shelterbelts	1.48	ha	$U_1=L*B*w_1/10000$
total planted area (tree costs)	2.96	ha	$U_2=L*B*w_2/10000$
net grazing area remaining	38.49	ha	$A-U_1$
proportion of paddock in shelterbelts	7.41	%	$Z=U_2/A$
perimeter of belts	7481		$p=B*(2*(w+L))$
pruning done at age 3yrs (YES/NO)	YES		
tree survival rate at pruning	90	%	Sp (entered)

⁽¹⁾ Note that in this project, for the purpose of grazing calculations, the edge of the tree belt is defined as the planting line for the outside row of trees because pasture measurements used this as the reference point.

7.12 Appendix 12: Economic modelling format – effects of competition and shelter on pasture productivity.

Year	Average tree height (m)	Project tree height (m)	Area of lost production (m ²)	Effect of shelter beyond one tree height (% of normal)	Overall grazing value of alleys # (% of normal)
0	0.0	0.0	0	0	100
1	2.8	2.8	25,798	1	95
2	5.5	5.5	30,738	3	95
3	8.3	8.3	36,432	4	94
4	11.0	11.0	41,372	4	93
5	13.5	13.5	46,449	3	91
6	15.5	15.5	52,007	2	88
7	17.1	17.1	57,084	0	85
8	18.4	18.4	62,642	0	84
9	19.4	19.4	67,719	0	82
10	20.0	20.0	73,276	-4	78

aggregate effects of competition and shelter

7.13 Appendix 13: Economic modelling format – calculating change in effective grazing area in competition zone

Year	‘Loss distance’		Effective width of alley for grazing			‘Loss distance’	
	Total pasture loss (m)	Autumn loss (m)	Spring feed (m)	Autumn feed (m)	Weighted average feed (m)	Weighted average (m)	Weighted average tree heights
0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1	3.4	3.5	97.2	97.0	97.2	3.42	1.2
2	4.0	4.4	96.0	95.2	95.9	4.07	0.7
3	4.7	5.4	94.6	93.2	94.3	4.83	0.6
4	5.3	6.3	93.4	91.4	93.0	5.48	0.5
5	5.9	7.3	92.2	89.4	91.7	6.15	0.5
6	6.6	8.2	90.8	87.6	90.2	6.89	0.4
7	7.2	9.2	89.6	85.6	88.9	7.56	0.4
8	7.9	10.1	88.2	83.8	87.4	8.30	0.5
9	8.5	11.1	87.0	81.8	86.1	8.97	0.5
10	9.2	12.0	85.6	80.0	84.6	9.71	0.5

Basis of seasonal pasture value weighting

Parameter	Unit	Autumn feed	Spring feed
Value of seasonal pasture	c/kg	\$0.05	\$0.10
Seasonal production	kg/ha	9000	1000
Value of seasonal pasture (assuming 100% utilisation)	\$/ha	\$450	\$100

7.14 Appendix 14: Economic modelling format – tree performance assumptions.

Modelling inputs	Amount	Unit	Symbol/formula
Tree yield/return			
tree survival rate at first harvest	80	%	S (entered)
yield of centre row trees 10 years old	0.2	m ³ /tree	y (entered)
total length of edge rows	7,407	m	=L*B*2
total number of edge trees at first harvest	2963		E=L*B*2/r*S
total number of inside trees at first harvest	0		=N*Sp-E
maximum yield advantage of outside rows	100	%	a ₁ (entered)
outside row advantage if gap is < 50m	0	%	a ₂ (entered)
actual yield advantage of outside rows	100 %	> centre rows	a=a ₁ (a ₂ if gap<2hts)
average yield of all trees cut at 10 years	0.400	m ³ /tree	Y=y*(R+2*a)/R
yield of belts cut year 10	400	m ³ /ha	N*S*Y/U ₂

7.15 Appendix 15: Economic modelling format – tree cost assumptions

Year	Operation	\$/unit	Unit	\$/ha
P	Mounding			50
P	Ripping			150
P	Earthworks			150
P	Planting			100
P	Plants	0.3	each	375
P	Replanting factor	0	%	0
P	Fertiliser			100
P	Pest control			40
P	Re-usable fencing	\$0	/km	0
P	Labour			200
P	Weed control			100
1	Weed control			125
2	Fertiliser			100
3	Pruning			450
4	Fertiliser			100
5				0
6	Fertiliser			100

7.16 Appendix 16: Economic modelling format – summary of costs and returns and profitability measures.

Year	Direct costs and benefits (\$)	Grazing lost under trees (\$)	Decrease in production on grazing alley area (%)	Decrease in value of production on grazing alley area (\$)	Total change in value of animal production (\$)
0	-3,748	0	0	0	0
1	-370	104	5	140	244
2	-296	104	5	139	243
3	0	104	6	153	257
4	-296	104	7	181	285
5	0	104	9	241	344
6	-296	104	12	314	418
7	0	104	15	405	508
8	0	104	17	443	547
9	0	104	18	478	581
10	23,661	104	22	597	701

Profit measure	Project value #
Benefit:Cost Ratio (BCR)	1.42
Net Present Value (NPV)	\$3,465
Internal Rate of Return (IRR)	11.9 %
Annuity value on paddock overall	\$12.33/ha/yr
Annuity value on paddock overall	\$493/yr

values shown apply only under assumptions shown above

7.17 Appendix 17: Economic modelling format – bluegum pulplog harvesting equipment costs.

Annual ownership cost	Unit	Harvester	Forwarder	Utility
initial cost (A)		\$400,000	\$575,000	\$25,000
disposal value (B)		\$40,000	\$60,000	\$2,500
years owned (C)	yrs	8	8	8
annual depreciation $[(A-B)/C]$	\$/yr	\$45,000	\$64,375	\$2,813
annual interest # $(R[A+B]/2)$	\$/yr	\$22,000	\$31,750	\$1,375
insurance and shelter $(.02[A+B]/2)$	\$/yr	\$4,400	\$6,350	\$275
total annual cost	\$/yr	\$71,400	\$102,475	\$4,463
hours operating per year	\$/yr	2,000	2,000	1,000
ownership cost per hour		\$36	\$51	\$4
Running costs		Harvester	Forwarder	Utility
power	kW	60	60	60
fuel consumption	l/hr	15	12	10
fuel price	c/l	45	45	70
fuel cost	\$/hr	\$6.75	\$5.40	\$7.00
oil and filters (10 % of fuel)	\$/hr	\$0.68	\$0.54	\$0.70
repairs, maintenance	\$/hr	\$60.00	\$40.00	\$3.00
tyres and batteries	\$/hr	\$20.00	\$15.00	\$1.00
total running cost	\$/hr	\$87.43	\$60.94	\$11.70
operator cost	\$/hr	\$25	\$25	\$25
low loader cost	\$/hr			\$100
Total costs		Harvester	Forwarder	Group
felling/loading	\$/hr	\$148	\$137	\$306
travelling	\$/hr	\$128	\$137	\$206
moving between properties	\$/hr			\$189

R = real interest rate = nominal rate minus inflation rate of asset (10%)

7.18 Appendix 18: Economic modelling format – stumpage calculation

Stumpage (net return to grower) = mill door price - harvest cost – transport cost

All values not marked as (entered) have been calculated from other variables

stumpage at year 10 (bark-off)	\$19.97	\$/m ³
stumpage at year 10 (bark-on)	\$14.97	\$/m ³
log density	1.00	t/m ³
mill door price (bark-off)	\$43	\$/t (entered)
mill door price (bark-on)	\$38	\$/t (entered)
transport to chipmill		
transport distance to mill	60	Km (entered)
transport cost	\$0.10	\$/t/km (entered)
transport cost	\$6	\$/t
harvest/extraction/loading costs		
harvest/extraction cost - total for this project	\$17.03	\$/t
-includes felling, loading, travelling, snigging,		
loading/unloading cost	\$2	\$/t (entered)
harvest/extraction cost - industry standard	\$14	\$/t
minimum plantation yield for standard rate	150	m ³ /ha
pruning edge trees to avoid large branches at harvest		
pruning done at age 3 years (YES/NO)	YES	(adjusted in BLUEBELT)
pruning cost (outside of outside row)	\$0.40	\$/tree (entered)
	\$1.00	\$/t
harvesting - felling/debarking ; travelling to next trees		
harvester cost when felling	\$148	\$/hour
harvester cost when travelling between trees	\$128	\$/hour
machine felling time - inside row trees	0.5	minutes/tree (entered)
machine felling time - pruned edge row trees	0.6	minutes/tree (entered)
harvester felling time - total for project	30	hours
harvester travelling time - standard 5 row cut	0.1	minutes/tree (entered)
harvester travelling time - this project	0.25	minutes/tree
harvester travelling time - project total	12.35	hours
hand felling costs (applies when outside rows are		
hand feller hourly rate	\$35	\$/hour (entered)
hand feller work rate	400	lineal m/hour (entered)
marketable length of inside tree (=vol x 100)	20	lineal m/tree
marketable volume of edge tree	0.4	m ³ /edge tree
	0.02	m ³ /lineal m
	8	m ³ /hour
	\$0	\$/project
total hand-felling cost - unpruned edge trees		
forwarder - transfer logs to truck (i.e. snig)		
forwarder total cost when loading	\$137	\$/hour
forwarder total cost when travelling	\$137	\$/hour
forwarder loading time - 5 row cut, standard tree	0.15	minutes/tree (entered)
industry average snig distance	300	m (entered)
average snig distance this paddock (qtr diagonal)	269	m
number of landings per project	1	
snig time - industry standard (16x18t loads/9 hrs)	1.875	minutes/tonne
	0.67	minutes/tree
forwarder travel/unload time this project	0.52	minutes/tree
volume/tree - standard	0.2	m ³ /tree (entered)
volume/tree - this project	0.4	m ³ /tree
forwarder total loading time for project	15	hours
forwarder total snig/unload time	26	hours
moving equipment between properties		
equipment transfer time per property	12	Hours (entered)
equipment transfer cost per hour	\$189	\$/hour
equipment transfer cost - project total	\$2,270	\$/project
equipment transfer cost per cubic metre	\$3.83	\$/m ³
roading	\$2,000	\$/landing (entered)

7.19 Appendix 19: 1996 total seasonal pasture regression analysis

Response variate: AdjLoss

Fitted terms: Constant + South + Orientation + Tree Age category + Rain + Location

Summary of analysis

	d.f	s.s.	m.s.	v.r.	F.pr
regression	18	150.6	8.4	6.1	0.010
residual	7	9.6	1.4		
total	25	160.1	6.4		

Percentage variance accounted for 78.6

Standard error of observations is estimated to be 1.17

Accumulated analysis of variance

	d.f	s.s.	m.s.	v.r.	F.pr
South	1	18.1	18.1	13.2	0.008
Orientation	2	31.9	16.0	11.7	0.006
Tree Age category	6	49.1	8.2	6.0	0.017
Rain	1	2.5	2.5	1.8	0.218
Location	8	49.0	6.1	4.5	0.032
residual	7	9.6	1.4		
total	25	160.1	6.4		

7.20 Appendix 20: 1997 total seasonal pasture regression analysis

Response variate: AdjLoss

Fitted terms: Constant + South + Orientation + Tree Age category + Rain + Location

Summary of analysis

	d.f	s.s.	m.s.	v.r.	F.pr
regression	19	91.9	4.8	3.6	0.036
residual	8	10.9	1.4		
total	27	102.8	3.8		

Percentage variance accounted for 64.3

Standard error of observations is estimated to be 1.17

Accumulated analysis of variance

	d.f	s.s.	m.s.	v.r.	F.pr
South	1	1.1	1.1	0.8	0.404
Orientation	2	23.1	11.6	8.5	0.010
Tree Age category	5	52.2	10.4	7.7	0.006
Rain	1	0.8	0.8	0.6	0.466
Location	10	14.7	1.5	1.1	0.466
residual	8	10.9	1.4		
total	27	102.8	3.8		

7.21 Appendix 21: 1998 total seasonal pasture regression analysis

Response variate: AdjLoss

Fitted terms: Constant + South + Orientation + Tree Age category + Rain + Location

Summary of analysis

	d.f	s.s.	m.s.	v.r.	F.pr
regression	17	77.1	4.5	8.3	0.004
residual	7	3.8	0.5		
total	24	81.0	3.4		

Percentage variance accounted for 83.7

Standard error of observations is estimated to be 0.740

Accumulated analysis of variance

	d.f	s.s.	m.s.	v.r.	F.pr
South	1	0.1	0.1	0.1	0.735
Orientation	2	1.6	0.8	1.4	0.300
Tree Age category	4	64.7	16.1	29.5	<0.001
Rain	1	0.0	0.0	0.0	0.879
Location	9	10.8	1.2	2.2	0.158
residual	7	3.8	0.5		
total	24	81.0	3.4		

7.22 Appendix 22: 1996 autumn pasture regression analysis

Response variate: AdjLoss

Fitted terms: Constant + South + Orientation + Tree Age category + Rain + Location

Summary of analysis

	d.f	s.s.	m.s.	v.r.	F.pr
regression	17	305.3	18.0	14.2	<0.001
residual	8	10.1	1.3		
total	25	315.4	12.6		

Percentage variance accounted for 90.0

Standard error of observations is estimated to be 1.12

Accumulated analysis of variance

	d.f	s.s.	m.s.	v.r.	F.pr
South	1	3.9	3.9	3.1	0.116
Orientation	2	12.4	6.2	4.9	0.041
Tree Age category	6	133.2	22.2	17.6	<0.001
Rain	1	0.1	0.1	0.1	0.763
Location	7	155.6	22.2	17.6	<0.001
residual	8	10.1	1.3		
total	25	315.4	12.6		

7.23 Appendix 23: 1997 autumn pasture regression analysis

Response variate: AdjLoss

Fitted terms: Constant + South + Orientation + Tree Age category + Rain + Location

Summary of analysis

	d.f	s.s.	m.s.	v.r.	F.pr
regression	19	251.3	13.2	3.2	0.048
residual	8	33.0	4.1		
total	27	284.3	10.5		

Percentage variance accounted for 60.8

Standard error of observations is estimated to be 2.03

Accumulated analysis of variance

	d.f	s.s.	m.s.	v.r.	F.pr
South	1	14.0	14.0	3.4	0.102
Orientation	2	14.9	7.4	1.8	0.226
Tree Age category	5	154.7	30.9	7.5	0.007
Rain	1	4.2	4.2	1.0	0.345
Location	10	63.5	6.3	1.5	0.277
residual	8	33.0	4.1		
total	27	284.3	10.5		

7.24 Appendix 24: 1998 autumn pasture regression analysis

Response variate: AdjLoss

Fitted terms: Constant + South + Orientation + Tree Age category + Rain + Location

Summary of analysis

	d.f	s.s.	m.s.	v.r.	F.pr
regression	16	127.7	8.0	3.6	0.062
residual	6	13.5	2.2		
total	22	141.1	6.4		

Percentage variance accounted for 65.0

Standard error of observations is estimated to be 1.50

Accumulated analysis of variance

	d.f	s.s.	m.s.	v.r.	F.pr
South	1	10.8	10.8	4.8	0.071
Orientation	2	12.4	6.2	2.8	0.142
Tree Age category	4	78.8	19.7	8.8	0.011
Rain	1	1.4	1.4	0.6	0.466
Location	8	24.3	3.0	1.4	0.365
residual	6	13.5	2.2		
total	22	141.1	6.4		

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