AN ECONOMIC EVALUATION OF COPPICE FUELWOOD PRODUCTION FOR CANTERBURY

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Research Report No. 199

April 1989

Agribusiness & Economics Research Unit
Lincoln College
Canterbury
NEW ZEALAND

ISSN 0069-3790

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PREFACE

The economics of new crops is an important topic for research and one that the AERU has taken an interest in from time to time. Given the recent changes in the economics of crop and pastoral production there is lively interest in any alternative, and at such times there is value in any research that throws light on the potential viability of new crops.

This report examines the prospects for fully-mechanised biomass production from short-rotation eucalyptus trees grown as a field crop. The report considers the prospects for coppice fuelwood production in Canterbury and is therefore of value to those considering alternatives here. In addition the report has application to those areas where tree growth is expected to exceed that obtained in the relatively drier Canterbury climate.

Finally, the detailed analysis of gross margins gives an indication of what factors affect the viability of long-term crops and therefore has implications relevant to both forestry and crop farming.

Professor A.C. Zwart
Director, A.E.R.U.

ACKNOWLEDGEMENTS

The authors are grateful for assistance given by Mr Tim Parker and Mr Tim Bell of Coppice Fuelwoods New Zealand Limited, Hastings. In addition, we thank our colleagues John Lay and Bruce Robson for their review of an earlier draft of this report.

Mr Ralph Sims, Agricultural/Horticultural Machinery, Massey University, provided a careful review of this report, especially the technical side. Mr Dudley Franklin, Forest Research Centre, Christchurch, Mr Mark Belton and Mr Ross Jamieson, Ministry of Forestry, Christchurch, provided critical comments, especially on forestry matters.

AUTHORS' NOTE

Both authors have personal interest in growing trees including practical experience with eucalypts. We have grown a number of species in woodlot, forestry and agroforestry settings in Canterbury. In addition, both authors have a broad education in primary production and related disciplines. We believe that there is considerable scope and potential for a variety of tree crops in both Canterbury and New Zealand. Coppice fuelwood is one developing use of trees in New Zealand.

As part of our interest in this concept we are minority shareholders in Coppice Fuelwoods NZ Ltd. However, we write this report taking every effort to be realistic and objective, and to scrutinise all aspects of the coppice fuelwood process. Parallel to our personal interest in the coppice fuelwood enterprise is our concern to learn about its viability as a crop. In comparison with the available literature, our assessment is thorough and we believe that it will be of value to anyone wanting detailed information. Nevertheless this declaration of self-interest is essential and we invite constructive criticism or further questions. Contact addresses are as follows:

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SUMMARY

This report describes the process of growing trees on a short rotation and intensive cultivation (SRIC) basis for the production of briquettes as a domestic fuel. The objective is to assess coppice fuelwood as a potential crop for Canterbury and to compare it with alternative farm crops.

Orthodox firewood regimes are reviewed to show that they can be viable, and important factors in SRIC biomass production are discussed to show that spacing, length of rotation and annual increment are key factors. Overseas studies show that SRIC biomass production can be economically viable, and the limited amount of New Zealand literature indicates that eucalypt yields of 50 tonnes per hectare after three years are possible for Canterbury.

The economic analysis for a 30 year budget, with a 60 tonne per hectare yield, shows that the ten year gross margin for coppice fuelwood is lower than all other field crops, and the 20 year gross margin is similar to the adjusted average of all field crops. The assumptions in this budget are discussed in detail and found to be reasonable, although uncertainty rests with yield and price, and with harvesting, shredding and processing costs. Sensitivity analysis shows that yield, price, establishment costs and annual maintenance each have a major impact on viability.

We conclude the SRIC biomass production from eucalypts is only viable as a new crop for Canterbury provided good management is used and good yields can be obtained. Further research is needed to provide a sound data base from which better estimates of viability can be made.

CHAPTER 1

INTRODUCTION - PROSPECTS FOR SRIC BIOMASS PRODUCTION

From earliest settlement Canterbury has produced a wide range of crops, including both dominant crops and specialised crops, such as sugar beet or blueberries. One specialised crop that is quite new to New Zealand is the production of wood biomass from fast-growing trees managed on an intensive basis and harvested frequently. Trees grown with a short rotation and with intensive cultivation are referred to as a SRIC biomass crop, in this instance for coppice fuelwood.

Coppice fuelwood production is founded on the fact that certain trees can coppice, i.e., they can grow from a stump after being cut to remove the original tree or sapling. Usually these trees coppice more than once so that a number of harvests are possible once the initial trees are established. In Canterbury and New Zealand coppicing hardwoods are presently being recognised as useful for firewood production. To this end a number of species are being planted and managed in an orthodox way with a view to harvesting firewood in about five or ten years time after planting or regrowing. Typically, eucalypts are planted because of their fast growth rate potential and because of their good wood burning qualities. Also, eucalypts can produce more energy per hectare than pines, for example (Frederick, et al., 1985a). (Eucalypts are considered in this report but other trees, such as *Acacia, Salix, Populus* or *Robinia* may also be used for SRIC biomass production.) This orthodox type of fuelwood production typically involves chainsaw and manual processing of wood so that the end product is delivered in loose form and of variable moisture content.

Short-rotation, intensive cultivation (SRIC) biomass production is based on coppicing qualities and fast growth rate potentials as in orthodox fuelwood regimes. In addition, it seeks to mechanise the entire process, use a much shorter rotation period, and produce a homogeneous product of guaranteed moisture content. In the process we are considering here, the biomass is used to produce a briquette for domestic fuel. In essence, SRIC biomass production of briquettes involves mechanical planting, harvesting and processing of trees to produce a briquette of uniform size and moisture content.

The main steps of the SRIC and briquette process are as follows (some aspects of this process have yet to be refined under New Zealand or Canterbury conditions):

1. Preparation, planting and maintenance. Typically, great care is taken to prepare the ground prior to planting. The ground can be cultivated and/or deep ripped. Seedlings are machine planted with a regulated dose of water, where necessary, and with fertiliser. Animal pests and weeds must be controlled mechanically or chemically. Spraying for insect pests may be necessary.

2. Mechanical cutting and air drying. During early summer the standing trees are cut with a mobile harvester taking care not to damage roots or stumps, and cutting stems with minimal damage. Saplings are left to air dry for a few months. The site is later cleared leaving the stumps free to regrow during autumn in preparation for reharvesting two to four years later.

3. Shredding and compression into briquettes. After field drying, the leaves, twigs and stems are mechanically picked up, shredded and taken by truck to the compressing plant. This plant compresses the dried chips, leaves and all, into briquettes with excellent burning characteristics and with dimensions of 210 mm by 130 mm by 60 mm thick. The briquettes stack neatly onto pallets ready for conventional mechanised distribution and delivery.

In all these steps the trees are managed as an intensive crop rather than any conventional forestry operation. Considerable attention is given to the optimisation of growth rates and the efficient use of machinery.

Advantages of SRIC biomass production for briquette manufacture appear to be as follows:

1. All of the above-ground biomass, including leaves, is utilised. This is an advantage over orthodox firewood regimes where branches and leaves are left behind. This residue creates fire risks. In addition, leaves have a slightly higher energy content per unit of weight than the stem of the tree.

2. Biomass production is maximised and tailored to the harvest regime. Harvesting can be timed to coincide with peak mean annual increment of biomass and to give maximal regrowth rates.

3. The finished product is uniform and of acceptably low moisture content because the compression process apparently requires that moisture content does not exceed 25 percent (dry basis) or 20 per cent (wet basis). The briquettes are of good quality and are purported to have excellent burning characteristics. Briquettes on pallets make for easy delivery and

convenient end use. The product is clean, dense, and without loose material.

4. Mechanisation appears to provide an efficient way of obtaining the end product and eliminates several labour-intensive operations.

Disadvantages of SRIC biomass production appear as follows:

1. There is high dependence on mechanisation which inevitably gives some risk of breakdown leading to interruption in all phases of production. However, delays would be of less consequence than for annual or horticultural crops. In addition, it is likely that greater energy inputs, particularly fossil fuels, are required compared to orthodox regimes of firewood production.

2. Intensive cultivation entails monoculture and attendant risks from pests and diseases. Eucalypts in New Zealand can suffer from acute leaf defoliation by tortoise beetle *(Paropsis charybdis)*, although this damage is species specific. It is possible that silver leaf fungi (*Stereum purpureum*) may enter wounds but this may be prevented during or after harvesting by applications of fungicide. A sawfly and a gall wasp are other insect pests that have arrived recently in New Zealand and are beginning to spread and may adversely affect eucalypts. Recently introduced parasites for tortoise beetle and sawfly may mitigate their effects.

3. There is uncertainty of production yields and coppice life. Precise data on yields from eucalypts at close spacings in Canterbury are not yet available. It is not known how many harvests can be sustained at viable levels from the original planting. We have heard of South African experience which suggests that 18 harvests of eucalypt are possible. The European tradition is much longer, but also less intensive.

4. Intensive cultivation necessitates the use of fertiliser. Eucalypts tend to absorb nitrogen from the soil at greater rates than do pines or leguminous trees (Madgewick et al., 1981). Mixed plantings of eucalypts and acacias might reduce needs for nitrogen fertiliser and pest control. Acacias by themselves would appear to be less demanding of nitrogen fertiliser, but both species are likely to respond to phosphate fertilisers. An additional requirement for intensive cultivation is water, and irrigation would be required in dry years.

5. There is uncertainty associated with market prospects for briquettes in Christchurch. Even if consumers

readily accept briquettes in place of traditional firewood, there is still going to be competition from traditional suppliers, both private and commercial, who obtain trees at little or no cost. However, traditional methods are very labour-intensive, the product is expensive and the supply appears to be dwindling. In the case of the Christchurch market, there is the possibility of restrictions on open fires, and the increased use of wood burners may decrease demand because of their high combustion efficiency. Conversely, consumers may use efficient wood burners more than open fires.

The focus of this report is limited to an assessment of the economics of SRIC biomass production for briquette manufacture, and growing eucalypts in Canterbury. If this application of the SRIC concept is not viable, it remains possible that other applications could be viable. For example, SRIC biomass production has the potential to be incorporated into sewage or effluent treatment processes (with fuelwood as by-product). SRIC biomass production systems can use waste-water to boost growth and also absorb nutrients that would otherwise be fed into natural waterways or treated at great cost. Because of growing sensitivity to effluent discharges, alternative treatment systems using trees are being evaluated in New Zealand. It remains possible that the SRIC biomass concept can be used to purify water in a less costly way than traditional methods. Freezing works and dairy companies, with seasonal production of wastewater, may find trees to be a competitive way to treat effluents with the incidental benefit of partly fulfilling their own energy requirements.

SRIC biomass can be used to fuel industrial furnances and this avoids the shredding and compression processes. Such "hog fuel" can readily replace coal after minor alterations to the fuel loading mechanism, or be blended with it. Another prospect is to use eucalypt leaves as the basis for extracting essential oils. These oils have uses in the medical, industrial and perfume industries and may be a valuable by-product of the SRIC biomass production process. There is potential to obtain large quantities of fresh leaves efficiently before the mechanical shredding process. Further, hardwood chips can be exported for overseas manufacture of high-quality paper, but this would require separation of wood from bark and leaves. Projections of demand for such papers, and mounting concerns over the dwindling supply of suitable indigenous forests, suggest a good future for paper manufacture. Finally, there are some benefits from shelter in the growing of trees as an adjunct to crop/pasture farming.

The concept of SRIC biomass production in New Zealand has been developed by Mr Tim Parker, Managing Director, and Mr Tim Bell, Operations Manager of Coppice Fuelwoods New Zealand Limited, located in Hastings. The company seeks to establish a manufacturing and marketing operation for wood briquettes to be used in home heating. This New Zealand-owned company is developing briquette technology in conjunction with encouraging farmers on suitable land to plant appropriate trees for coppicing. Farmers are to be given the option to invest in and develop a grower-orientated company.

The company is exploring technological developments, including a mobile shredder, and it is involved in research using coppicing hardwoods for sewage and waste-water treatment. The company emphasises an integrated system of commercially-oriented techniques, from the selection of seed stock and ranging through all of the essential operations including the importation of machinery and the marketing of the end product. Production and distribution around Hastings is underway for the 1989 fuelwood season.

Figures for estimated return on investment for growers are provided by the company, and these (together with other information) are used as the basis for evaluating the economics of SRIC biomass production for Canterbury. The economic analysis uses gross margins to compare fuelwood production with other crops, and it gives attention to many aspects of production and returns in order to critically assess the reliability and validity of the budget assumptions. Sensitivity analyses show up the important factors in the economics of coppice fuelwood production. Before this economic assessment, we review some of the literature on the important factors in SRIC biomass production, and we review the economics of fuelwood production under traditional regimes.

CHAPTER 2

ECONOMICS OF ORTHODOX FUELWOOD REGIMES

2.1 Introduction

Growing hardwoods for fuelwood, especially eucalyptus species, is of increasing importance in New Zealand. The objective here is to briefly review some of the economic analyses of fuelwood production to provide background for a more detailed evaluation of SRIC biomass production. If traditional fuelwood regimes are viable but SRIC biomass production is more efficient, then the latter should be a viable proposition provided it meets the needs of growers and does not introduce adverse social consequences. Also, some details of orthodox fuelwood regimes serve as a useful contrast to the newer short rotation, intensive cultivation (SRIC) approach.

2.2 An Overview of Some New Zealand Research

Hosking (1982) provided a detailed analysis of five fuelwood regimes using pines, eucalypts and acacia species to produce a 14 cm diameter stem. The hypothetical sites were relatively flat and close to the market. Five management systems were examined, each with about 6,000 stems per hectare, except for option five. The five systems were:-

1. Non-coppicing eucalypts. Replant every four years.
2. Coppicing eucalypts. Two harvests every four years followed by replanting.
3. Acacia. Grown from seed for ten years.
4. Radiata pine. Woodlot grown for nine years.
5. Radiata pine thinnings. Initial stocking at 1,700 stems per hectare. First thinning at age five to six years (900 stems per hectare), second thinning at age nine to ten years (400 stems per hectare).

For each management option Hosking derived a minimum, average and maximum return possibility from differing levels of costs and returns. Using three methods (discounted cash flow analysis, internal rate of return and break-even pricing) the results show that the acacia option and the radiata pine thinnings option gave the best financial propositions. These two options show favourable returns and would be viable at the current prices for firewood. However, on balance, Hosking concluded that the two coppice options (eucalypts and acacias) rank ahead of pine thinnings because they produce a more valuable product. Radiata pine thinnings have the lowest cost of production over a twelve year period followed by acacia, then radiata pine as a woodlot. Also, transport costs affect viability. Hosking advocates high stocking rates of about 6,700 stems per hectare to produce 14 cm. diameter trees with long straight stems within four years. Finally, an analysis of energy content and combustion efficiency shows that wood is cost effective as a fuel in all but the least efficient of woodburning appliances (i.e., open fireplaces).

Hosking's dissertation provides good detail for a range of management options and documents with realistic precision the expected profitabilities to show that coppicing systems are viable in good locations.

There are other evaluations of fuelwood production in Canterbury but these are very brief and the results are mixed. Ministry of Forestry staff (pers. comm.) in 1984 evaluated the prospects for a 50 hectare woodlot with a ten to 15 year life. Their main management system involved coppicing eucalypts or acacias, chemical weed control, and planting five hectares per year at 2,500 stems per hectare. Costs of production were estimated at $2,250 per hectare in 1984 and there was an estimated return of $4,000 per hectare after ten years. These estimates were taken to indicate that the economics of firewood production appeared favourable, even before taking advantage of the 50 percent forestry encouragement grant available from the government at that time.

Another assessment of a similar proposal suggests that firewood production is unprofitable (Douglas, 1988, pers. comm.). For an 18 year life and 3 harvests, the costs of production per hectare were estimated to be about $5,600 and the returns were estimated to be $3,600. In this analysis a conservative net return per cubic metre was used. Neither of the above two studies include estimates of the costs of extraction.

Another Ministry of Forestry evaluation was completed recently in Otago (Edmonds et al., 1987). That report reviews many aspects of firewood production, including species, management, District Schemes and forestry taxation. In their economic evaluation the authors costed all inputs, including land, for a planting density of 2,000 stems per hectare and harvest at eight years. A discounted cashflow analysis shows that the first rotation has a net present value of $130 per hectare at an eight percent discount rate, and an internal rate of return of 8.3 percent. After the second harvest the net present value is $1,160 and the internal rate of return is 10.3 percent. As earlier, distance to market was found to affect viability. The authors concluded that the long term prospects for fuelwood cropping looked promising.

More recently, a Lincoln College student examined firewood production in conjunction with a farm operation (Speight, 1988). Eucalypts were to be grown for six years, planted on an annual basis for continuous supply. Sales were either on a stumpage basis, i.e., as standing timber, or on a billetted basis. Five different types of labour organisation were considered in the economic analyses, ranging from full contract labour through to the farmer supplying all labour, processing and hauling. Results showed that the best net present value figure is obtained when the wood is sold on a stumpage basis and the farmer's spare labour is taken as a costless input. The internal rate of return for this option was 18.8 percent, and the highest profitability was obtained because the option did not require post-harvest labour. It is noteworthy that with full contract labour at $10 per hour for planting and management, the net present value is negative (with the discount rate at ten percent) and the internal rate of return is 8.8 percent. Speight concluded that firewood production using offpeak surplus labour would provide returns greater than currently achievable from pastoral production and that it could be a low cost means of increasing returns and spreading risk.

2.3 Conclusion

The main point of the above review is that under favourable conditions orthodox firewood regimes can be viable. These analyses take current costs and returns and apply them over a number of years using more or less sophisticated budget analyses and using a variety of management strategies.

It is apparent that the success of firewood production depends on a considerable number of factors. Our experience, and from details of the above literature not reported in this chapter, indicates that the main variables affecting the economics of orthodox firewood production are as follows (in no particular order):

1. Site quality
2. Species choice
3. Rotation length
4. Number of harvests
5. Planting density
6. Type of planting stock - bare-rooted, root-trainer, or direct seeding
7. Sales based on stumpage or delivery
8. One large planting or a sequence of smaller plantings
9. Transportation costs.

The major uncertainties with orthodox firewood production are as follows:

1. Yield
2. Projected demand
3. Severity of pest, disease and soil fertility problems
4. Maintenance costs, i.e., costs after establishment
5. The life of the trees.

CHAPTER 3

IMPORTANT FACTORS IN SRIC BIOMASS PRODUCTION

3.1 Introduction

Before presenting data on the anticipated economics of SRIC biomass production for briquettes in Canterbury, we highlight some of the literature on the SRIC concept. This literature provides details of management and productivity which are important to understanding and applying the SRIC concept in New Zealand. Most of the literature presented derives from North and South America, Australia, and New Zealand, and includes discussion of stand dynamics, economics of production, yields and management factors.

3.2 Stand Dynamics in Intensive Culture of North American Hardwoods

The concept of SRIC biomass production was first developed in the United States by McAlpine et al. (1966) in the form of "silage sycamore" (Smith and De Bell, 1973). The idea was to grow increased amounts of wood fibre using intensive culture. The concepts of total tree and complete stand utilisation have been advanced by Young (1964) and combined with short rotation culture. The SRIC concept has been trialed for a range of North American species in order to identify the most suitable species, to estimate the possible yields, and to determine the distribution of above ground weight for different sizes of tree (Smith and De Bell, 1973). Hardwoods such as red alder and black cottonwood are superior to conifers in growth rate at young ages. Generally, there was only limited data available in the 1970s because there had been little research on close spacing with these species.

The available data showed that for black cottonwood, spaced at approximately 0.3 m by 0.3 m (111,111 stems per hectare), produced high mortality with only 78 percent survival to the first harvest at age two years (Smith and De Bell, 1973). Preliminary data showed that the potential yields were very high. These technical issues were a backdrop to management issues such as the costs of establishment and the costs of processing the chips for industrial use. Smith and De Bell concluded that for some growers SRIC biomass production could be economically viable.

Heilman et al. (1972) provided yield data for black cottonwood and found that yields at the first harvest (two years) were affected significantly by both spacing and fertiliser. Highest production occurred at 0.3 m by 0.3 m spacing (111,111 stems per hectare) and lowest production occurred at 1.22 m by 1.22 m spacing (7,142 stems per hectare). However, spacing had little effect by the time of second harvest. Fresh weight yield ranged from 17.6 tonnes per hectare per year for 1.22 m by 1.22 m spacing to 25.2 tonnes per hectare per year for 0.61 m by 0.61 m spacing. Death of root stocks was a major problem, with greatest mortality at the close spacings. The authors concluded that wider spacings and longer rotations of three to five years may give greater annual production.

Ek and Dawson (1976) advanced the study of growth dynamics for poplar under intensive culture (with irrigation and fertiliser) and developed a growth simulation model. Data from the results of a four-year trial were used to extrapolate to 25 years. The projected yields covered a range of six spacings (from 0.228 m or 192,366 stems per hectare to 2.44 m or 1,736 stems per hectare) and provided estimates of yield in terms of mean annual increment (MAI) and maximum current annual increment (CAI). Results showed that there was early culmination of CAI so that maximum CAI was reached by age four to six years at all spacings. Maximum CAI was greatest for the 2.44 m spacing and generally was related to spacing, with the closer spacings having slightly lower yields. Maximum MAI ocurred in the eight to fifteen year range for all spacings, with similar dry weight yields of about 23 tonnes per hectare. There was considerable flexibility in rotation length between eight to sixteen years with little sacrifice in dry weight yields. Apparently, poplar keeps on growing rapidly beyond the point of maximum MAI.

The findings for poplar have been consolidated by Hansen et al. (1983) who noted that spacing has minimal effect on sustained biomass yield as long as harvest is timed to occur when MAI culminates. They observed that research results showed that the same biomass yield can be obtained for a wide range of densities, however, as spacing increases so does crop growing time. Further, as crop growing time increases, so does the size of tree. Other relevant relationships include: the percentage of stem biomass increases with decreasing spacing and with increasing age; the percentage of bark decreases with wider spacing and with age; wider spacings and longer growing times will drain less nutrients, and finally, harvesting costs of dense plantations, expressed in dollars per dry ton harvested, will be higher than that of open stands.

The literature on North American hardwoods, while it may not be directly relevant to eucalypts in New Zealand, indicates some of the relevant stand dynamics that should be examined in the New Zealand context. There are complex relationships between many important factors as they relate to management and productivity, even before economic factors are considered. Definite answers to questions about eucalypt performance and dynamics can be found only with detailed New Zealand research, but in the absence of this research the above literature provides indicators of the likely pattern of relationships. Particularly important are spacing, length of rotation, current annual increment and mean annual increment. It is very likely that spacing relates to yield through rotation length, with close spacings being harvested more often to coincide with maximum current annual increment.

3.3 Economic Assessments from Overseas

Bowersox and Ward (1976) determined the cost of producing and harvesting stemwood, bark and branches of three hybrid *Populus* species. Oven dry yields were calculated using a regression analysis based on actual yield data. For two of the three clones, production was at a maximum for a three year first harvest and a four year second harvest, giving yields of 10.5 tonnes per hectare per year to 12.5 tonnes per hectare per year. To extend the analysis, the authors calculated the costs for both production and harvest, and applied a compound interest rate of six percent over the relevant number of years. For the two most productive clones, the lowest costs were for the above three and four year harvests, and these occurred at 0.7 m by 0.7 m (20,408 stems per hectare). In general, while the findings indicated that the costs per ton of chips is not low, the authors concluded that where land is not being fully utilised and equipment is available, the system is a justifiable land use alternative. This research suggests that wider spacing, i.e., up to 0.7 m by 0.7 m at least and possible wider still, give better yields and profitability. Also, profitability was directly related to yield, suggesting that yield is an important determinant of profitability.

Inman et al. (1977) examined costs for silvicultural biomass farms and provided a valuable set of conclusions. They found that biomass production was competitive with the costs of fuel oil, and that with higher productivity there were lower total costs of production. Costs were less sensitive to changes in productivity at highly productive sites than at less productive sites. Typically, capital costs comprised from nine to 11 percent of total costs, and the major production costs occurred in the management of the crop, such as with irrigation and fertilisation. SRIC biomass production was unlikely to be viable on prime agricultural land. Biomass transport was roughly ten percent of total costs and was the third most expensive cost item for the particular cases considered. Finally, energy captured in the form of plant biomass was ten to 15 times the "man-made" energy consumed during the farm operation.

A number of related and specific issues were the focus of Rose and De Bell (1978). Cost and yield information were used as inputs to a cash flow programme to calculate measures of economic performance such as present net worth, internal rate of return, and breakeven requirements. Their paper examines three alternative 20 year management regimes for the production of hardwood chips. Alternative I was coppiced every two years with regeneration planting at year 11 and spaced at 0.609 m by 1.2 m (13,683 stems per hectare). Alternative II was coppiced every four years and spaced at 1.2 m by 1.2 m (7,142 stems per hectare). Alternative III was coppiced every ten years and spaced at 3.6 m by 3.6 m (772 stems per hectare). Only the second two alternatives were viable. In particular, Alternative II offered a rate of return of 14 percent for average costs, price and yield.

Rose and De Bell were cautious about the prospects for two-year SRIC production. Sensitivity analyses indicated that for Alternative I, unless average yields were consistently obtained, substantial changes in current culture and harvest technology would be needed to make this alternative economical. This finding is in contrast to Bowersox and Ward, but their production cost estimates, based on corn harvest costs, were less than half those of Rose and De Bell, reflecting the latter's conviction that costs will be higher than that of corn production. For Alternative III there was great potential if high yields could be obtained.

Rose and De Bell noted that their estimate of harvest cost is high and that only a minor reduction in harvest cost would make a difference to some of the alternatives. Further, they note that profitability is enhanced at the wider spacing and lengthening the cutting cycle. Harvest of wider spacings costs less and can use conventional equipment. The authors conclude that SRIC biomass production may be suitable to small-scale industrial land managers. It is clear from this analysis that SRIC biomass production based on close spacings and two to four year rotations will be viable if harvest costs are low.

In a brief note on the economics of fuelwood production, Sacks and Low (1983) found that for oven dried wood, production rates need to be greater than 33.6 tonnes per hectare per year. The breakeven price at this yield was US$47 per tonne for the first harvest and US$22 per tonne for the second harvest. These prices were competitive with local chip prices in 1983. At that time harvest costs were 15 percent of total costs over four years.

In general, the results summarised above and others in the literature emphasize the economic importance of management factors such as spacing, yield, rotation length, and harvest efficiency. There is evidence that high yields of biomass can be obtained from high density plantings i.e., about 20,000 stems per hectare. The literature suggests that there is a trade-off between high planting density with high potential yields, and the costs required to obtain these yields. One major cost is the cost of harvesting.

The absence of data on the efficiency and costs associated with new SRIC harvesting machinery will make current economic evaluations difficult to undertake. While the detailed results of the above studies are not entirely consistent, there are good indications that SRIC biomass production overseas is viable, provided management is soundly based and effectively applied.

3.4 Eucalypt Yields

There are a variety of measures of biomass yield in both metric and imperial units. In this survey of SRIC eucalypts, all yields are expressed in tonnes per hectare oven dry weight (air dried weight is about 20 percent moisture). Much of the published yield data measures the amount of wood produced rather than total above-ground biomass. As it is this latter item that is of interest here, we report only those studies using this term. Generally, as Table 1 indicates, there are different management factors such as species, spacing and rotation length which impinge on yield, and fertiliser is the main additional factor.

Yields in Table 1 are not uniform and the relevant approach is to focus on the New Zealand studies of eucalypt yields although some comparisons with overseas trials are available. For example Cromer et al. (1981) compare their yield data from *E. nitens* and *E. fastigata* with overseas findings (not included in Table 1) and find that *E. nitens* production is third highest when compared to 53 hardwood stands, and that compared to four year old stands of *E. saligna* in Brazil both *E. nitens* and *E. fastigata* had larger weights of leaves, branches and stems. (Also found by Cromer et al. is the quite different nature of the two species, with *E. fastigata* having distinctly more branches, which might be quicker for machine-harvesting.) The yields for *E. nitens* in New Zealand are higher than fertilised *E. globulus* in Australia reported by Cromer et al., but the latter had a lower stocking rate. New Zealand yields were obtained without fertiliser for these two species.

In further comparisons, Frederick et al. (1985b) conclude that New Zealand yield data for *E. regnans* was comparable to that of *E. grandis* and *E. globulus* on good sites in Uganda and the Transvaal, with a mean annual increment of 25 tonnes per hectare per annum. Further, mean annual increment of dry matter achieved in New Zealand was nearly double that for *E. grandis* in Australia and exceeded values for *P. radiata* grown in New Zealand.

Table 1
A Sample of Yields for Eucalypts from a Range of Stocking Rates and Locations

Species	Spacing (m)	Stems Per Hectare[1]	Age (years)	Yield (T/ha)[2]	MAI (T/ha/yr)	Management Factors Noted	Location	Source
E. camaldulensis	3.0 x 2.0	-°	5	6		(wood 'productivity')	Brazil	Lima, 1986
E. camaldulensis	0.9 x 0.9	12,345°	2	76	38	Yields 10% high - no border	California	Sacks and Low, 1983
E. grandis	0.76 x 0.76	17,200°	1	20	-	(In third year of growth) Irrigation	"	"
E. saligna	3.0 x 2.0	1,667°	7	74	10	Fertiliser	Brazil	Ayling and Martins, 1981
E. camaldulensis	3.0 x 2.0	1,667°	7	64	9	"	"	"
E. grandis	1.0 x 1.5	1,666°	2.7	80	30	--	South America	Cited in Ayling & Martins, 1981
	3.0 x 2.0	1,666°	2.7	40	15			
E. alba	2.0 x 2.0	2,500°	2.8	35	13	(Assuming density of 600 kg/m^3)	Brazil	"
	3.0 x 1.5	2,222°	3	28	9			
E. saligna	3.0 x 1.5	2,222*	6	95	16		Brazil	"
E. globulus-bicostata	0.3 x 0.3	55,974*	3	43	14	Fertiliser	Australia	Hillis & Brown, 1984
	0.6 x 0.6	17,761*	3	33	11	"	"	"
	2.4 x 0.3	12,240*	4	41	10	"	"	"
	2.4 x 0.6	6,454*	4	35	9	"	"	"
E. Viminalis	0.3 x 0.3	29,063*	3	25	8	Fertiliser	Australia	Hillis & Brown, 1984
	0.6 x 0.6	8,073°	3	11	4	"	"	"
E. saligna		62,500°	1	14	14	--	--	Douglas, cited in Hosking, 1982
		"	2	60	30			"
		"	3	108	36			"
		"	4	120	30			"
E. globulus	2.1 x 2.1	2,196°	2	5	2	Fertiliser @ planting	Australia	Cromer et al., 1975
			4	16	4			
	"	"	2	8	4	Fertiliser @ 0, 8 and 15 months	"	"
			4	30	7			
E. globulus		20,000°	2	34	17	Fertiliser	Australia	Cited in Cromer et al., 1975
E. nitens		6,470*	4	80	20	No fertiliser	New Zealand	Madgwick et al., 1981
E. fastigata		6,870*	4	62	16	No fertiliser	"	"
E. regnans		2,050*	4	68	17	Fertiliser @ 0 and 1 yr	New Zealand	Frederick et al., 1985b
		1,850*	7	198	28	No fertiliser	"	"
		1,075*	10	319	32	Fertiliser @ 0 and 2 yr	"	"
		1,300*	13	294	23	Fertiliser @ 0 and 5 yr	"	"
		1,250°	17	460	27	No fertiliser		
E. regnans		2,150°	8	172	22	Fertiliser @ 0 and 1 yr	New Zealand	Frederick et al., 1985a

Notes:

1. The * indicates actual stocking rate at harvest, and ° indicates stocking rate at establishment. For the high stocking rates (over 15,000 sph) there is a considerable difference between the two.
2. Oven dry tonnes for the total above-ground biomass.

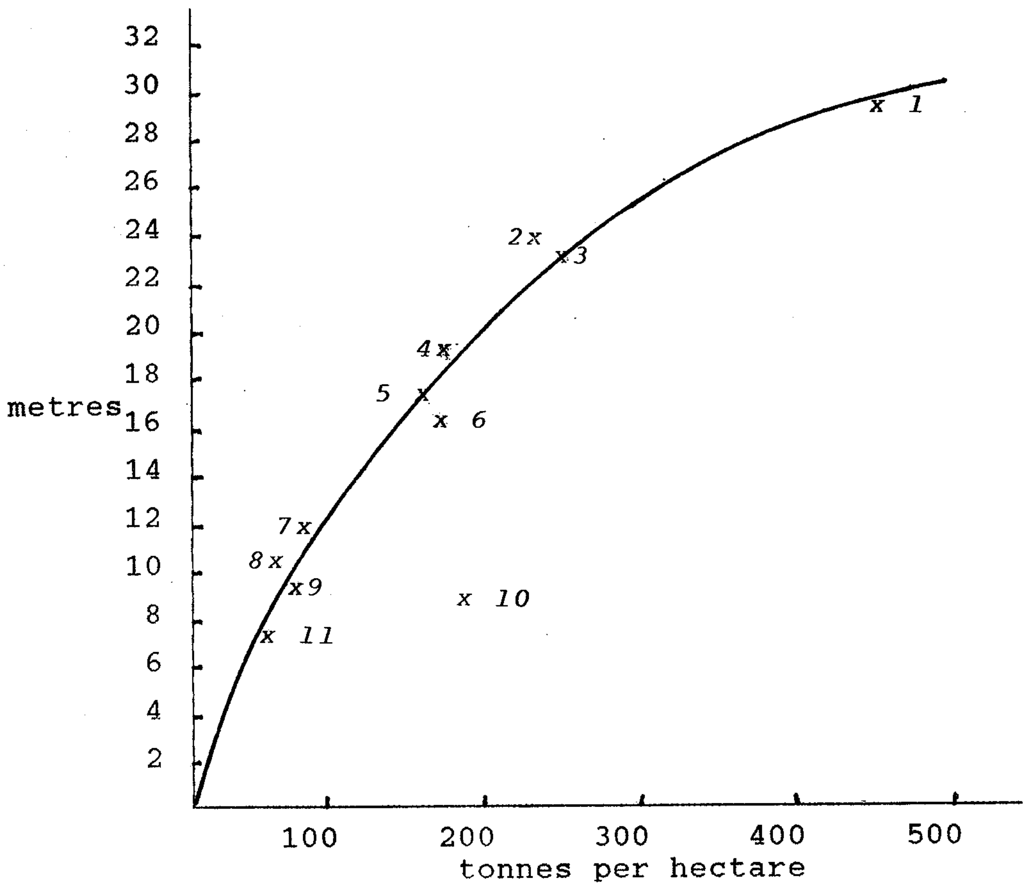
By taking just the New Zealand data from Table 1, a reasonable estimate of biomass yield for a four year crop is from 60 to 80 tonnes per hectare, with a MAI of 15 to 20 tonnes per hectare per year. These yields occur for stocking rates ranging from 2,050 to 6,870 stems per hectare. Coppice Fuelwood New Zealand Limited report yields of 68 tonnes per hectare at 20 percent moisture content in three years from *E. saligna* at 6,800 stems per hectare, and 54 tonnes per hectare in two years from *E. botriodes* at 3,500 stems per hectare.

The estimated typical yield of 60 to 80 tonnes per hectare after the first four years is for North Island conditions, and in Rotorua in particular where the average rainfall is 1680 mm per annum. Conditions in Canterbury are drier, so it is likely that yields will not be as high. The following presentation estimates eucalypt yields in Canterbury to be 50 tonnes per hectare after three years and under optimum conditions.

A DSIR and Tree Crops Trust trial at Boundary Road near Lincoln College (Speight, 1988) provides diameter and height data for six species of eucalypts planted at approximately 3 m by 3 m or 1667 stems per hectare. The three fastest growing species are *E. regnans*, *E. nitens* and *E. ovata*. The site has good soil and the ground was ripped and sprayed at planting.

In order to estimate comparable biomass yield from the available height data, we have prepared a height by weight graph relating the two dimensions. Figure 1 shows the eleven points used to fit a curve to the available yield data that included tree heights. Spacings ranged from 1,075 stems per hectare to 7,250 stems per hectare, with one outlier at 62,500 stems per hectare. Most of the points are close to the line of best fit, suggesting that there is a regular relationship between height and total biomass for a variety of sites, spacings and species. It is likely that most trial sites are selected for good quality, so we do not know if this relationship holds for trees on poor sites.

Figure 1: Average Height (metres) by Yield (tonnes per hectare) for a Number of Eucalypt Trials



Notes:

	Source	Species	Stocking
1.	Frederick et al. (1985b)	regnans	1,250
2.	" "	"	1,300
3.	" "	"	1,075
4.	" "	"	1,850
5.	Frederick et al. (1985a)	regnans	2,150
6.	" "	dealbata	2,875
7.	" "	radiata	1,775
8.	Frederick et al. (1985b)	regnans	2,050
9.	Madgwick et al. (1981)	nitens	6,470
10.	Hosking (1982)	saligna	62,500
11.	Madgwick (1981)	fastigata	7,250

The growth data for the Boundary Road trial are shown in Table 2, along with the estimated yields.

Table 2
Estimated Biomass Yield for Two Eucalyptus Species on a Good Site in Canterbury

	Height (m)	Height/year (m)	Estimated Yield (t/ha)	MAI (t/ha)
E. nitens				
- 5 years	7.7	1.5	62	12
" " - 6 years	9.7	1.6	82	20
E. ovata				
- 3 years	7.1	2.4	56	19
" " - 4 years	8.1	2.0	64	16

E. ovata is the tallest species, and after four years produced an estimated 64 dry tonnes per hectare in Canterbury. *E. nitens*, widely accepted at present as one of the best species for Canterbury, has a slower growth rate and an estimated 62 tonnes per hectare after five years, but it has an estimated MAI of 20 tonnes per hectare after six years which is close to North Island rates. A favourable estimate of yield from *E. nitens* at four years is 50 tonnes per hectare. By taking the best yield of biomass available on a good site in Canterbury, we estimate that a typical yield on these sites is 50 tonnes per hectare for three years. The productivities for *E. ovata* are similar to the North Island data, although at the low end of the 60-80 tonnes per hectare range. However, with the stocking rate at approximately 1667 stems per hectare in Canterbury but 6470 stems per hectare in the North Island, the Canterbury yields would be lower because of lower density. We do not know what increase can be expected from plantings at greater density and our estimate of 50 tonnes per hectare may be conservative.

The Boundary Road site has good soil and the yield figure may be an above-average one for Canterbury. The trees in this trial were given good management, gaining an average height per year of 1.9 metres. Other data for eucalypts and acacia on dry and demanding sites in Canterbury show slower growth rates (John Sheppard, DSIR Lincoln, pers. comm.). For a windbreak trial using many species, and in some cases different provenances within species, mean heights for eucalypts ranged from 4.25 metres to 9.50 metres after eight years (*Acacia dealbata* and *A. decurrens* grew to a mean height of 7.5 metres). For this trial, on Templeton silt loam, about ten to 20 of each species or provenances was grown, and spaces were at 2.0 m. by 2.5 m. *E. dalyrympleana* and *E. viminalis* had best mean heights of about eight to nine metres. The site was sprayed for weed control but not ripped. It is likely that ripping would increase growth rate to more closely match the performance on the Boundary Road trial. Further, the planting stock was grown in plastic bags not root-trainers, so root development was possibly sub-optimal. Clearly, dry sites and suboptimal management reduce eucalypt growth, in this case by over a factor of one half.

Other data from these windbreak and provenance trials show that on Selwyn stony sandy soil the best eucalypt mean height was just over three metres in seven years for a site that was ripped and for which no weed control was necessary. On this dry site, *A. dealbata* and *A. mearnsii* performed better than the best eucalypts, reaching 4.5 to 5.6 metres in mean height. A site at Cass Bay, on Banks Peninsula, with eroded Takahe soils, had mean heights of 7.3 metres for *E. fastigata* in six years, and 7.7 metres for *E. radiata*. For a four year trial on the same site *E. barberi, E. bicostata, E. nitens, E. regnans* and *E. ovata* grew to over five metres, with one provenance of E. regnans to six metres mean height. Acacia trials at Cass Bay on harder and drier slopes showed that *A. mearnsii* grew best to a mean height of 6.4 metres in five years. At best, these trees on hard sites are averaging little above one metre per year. This is considerably slower than the Boundary Road trial at 1.9 metres per year. These preliminary indications suggest that in Canterbury, high yields can only be obtained on good soils which have adequate moisture and available nutrients.

The above trials also produced data which showed that there is wide variation in performance within species, indicating that cultivar selection has potential to increase yields. Further, *Acacia* species can grow well on drier sites and since they coppice and fix nitrogen these may be useful for SRIC biomass production in some situations.

The above data suggest that 50 tonnes per hectare after three years is a reasonable estimate of yield for good sites and good management. The lower yields on poor sites may not be a serious problem because traditional crop yields will also be lower on these sites. The relevant data from the grower's point of view are the financial returns from coppice fuelwood versus alternative crops for relatively constant soil quality. Thus, a person with low quality soils could still consider coppice fuelwood crops because lowered yields will be matched by the yields from any alternative. In some cases it may be that trees grow relatively better than other crops. A further possibility is that slower-growing trees may have more desirable qualities for chip export, for example, and thereby gain a premium price in that market.

3.5 Other Management Factors

The literature reviewed in this study identifies many factors that affect yield or are relevant to SRIC biomass production in other ways. However, as with many crop trials, few have identified fully the relative significance of these factors under experimental conditions. Nevertheless, the available evidence on these factors is discussed below.

Fertiliser. The impact of fertiliser on eucalypt growth is widely known, and many reports cite the Australian data of Cromer et al. (1975) on this phenomenon. Their study is relevant because it relates fertiliser effects to biomass yield. *E. globulus* seedlings at 2.1 metre spacings received four levels of fertiliser (a commercial blend of ammonium phosphate and ammonium sulphate at 18 percent N and eight percent P). The four treatments were: (A) no fertiliser, (B) 85 grams per tree at planting, (C) 170 grams per tree at planting and at eight months, and (D) as for the latter plus at 15 months (broadcast). Their results showed substantial increases in biomass with increasing quantities of applied fertiliser. At age two, the increase was most marked between A and B and not significant between C and D. Total biomass at age two ranged from one tonne per hectare without fertiliser to 8.6 tonnes per hectare with the heaviest application. At age four there were significant differences between all treatments, with biomass ranging from 6.3 tonnes per hectare to 30.3 tonnes per hectare, a nearly five-fold increase. Cromer et al. noted that at four years the mean annual increment and current annual increment curves were still rising sharply and high production figures can be expected for up to ten years. They also found that the leaves contained the greatest amounts of nutrients, suggesting that they should be left on site to mitigate nutrient loss.

The data in Table 1 show that New Zealand yields are higher than those in Australia, even when the latter received fertiliser. It is likely that fertiliser response in New Zealand is not as significant as in Australia because the soils here are more suitable to eucalypt growth.

Biomass Proportions. One of the features of SRIC biomass production is that the whole tree is harvested so that all of the above-ground biomass can be used for fuel. This factor also has obvious implications for fertiliser requirements. It is relevant to learn exactly what proportion of above-ground biomass is in leaves and branches, and what proportion is in woody stems, so that the advantage of total biomass harvest compared to traditional fuelwood regimes is known. These proportions are also relevant for production of chips for pulp where bark is not used typically. Cromer et al. (1975) and Madgwick et al. (1981) provide precise data for Australian and New Zealand eucalypts, and their data are summarised in Table 3. The proportions are on a dry weight basis and the planting densities are provided in stems per hectare.

Table 3
Biomass Proportions In Four Eucalyptus Trials

	Percentages					
	Leaves	Branches	Σ	Bark	Wood	Σ
E. globulus						
2196 sph, 4 years	17	18	(35)	11	54	(65)
2196 sph, 2 years	46	17	(63)	9	28	(37)
E. nitens						
6470 sph, 4 years	12	14	(26)	10	65	(75)
E. fastigata						
6870 sph, 4 years	17	21	(38)	7	54	(61)

The data in Table 3 show that leaves and branches typically account for 26 to 38 percent of total weight in four year rotations. Typically, *E. nitens* is less branchy than *E. globulus* or *E. fastigata*, so that the former has 75 percent of its weight in bark and wood. The Table also shows that for a two year rotation compared to a four year rotation, there is a higher proportion of leaves, about the same proportion of branches, and lower proportions of bark and wood.

Coppice Yields. Recorded experience indicates that coppice yields vary over time. The FAO in 1979 gave figures showing that the second harvest produced more than the first harvest by 120 percent. The third and fourth harvests were from 80 to 100 percent of the first crop. Carter (1972) noted other reports indicating that the decline in yield is not so great, and suggested an influential factor may be the extent of the thinning of regrowth shoots. He argued that unthinned regrowth may compensate deaths and sustain yield. Ayling and Martins (1981) report Brazilian data showing that the second harvest yields seven percent less than the first harvest, and the third harvest was 19 percent less.

We lack precise information on the management factors associated with these changes in yield, and we do not know to what extent yield relates to management. Nor has the effect of soil compaction upon SRIC biomass production been fully investigated. In New Zealand, we can expect a possible increase in yield for the second harvest because roots are well-established, then a decline. Also, fertiliser application after harvest may sustain the yields at high and constant levels. We do not know what yields can be expected after 20 or 30 years, although there are occasional unsubstantiated reports of coppicing occurring beyond this length of time

Cultivation. The literature indicates that complete site preparation is important for rapid eucalypt growth. Luckoff (1955), cited in Carter (1972), compared top height at 20 months for *E. saligna* under four cultivation treatments. Complete cultivation gave over two times the height growth compared to line cultivation at 1.5 metres wide. It is standard practice for commercial, large-scale eucalypt plantations in Brazil to provide complete site preparation (Ayling and Martins, 1981). For New Zealand conditions it is likely that deep ripping followed by cultivation would be effective, while deep ripping and chemical weed suppression may be sufficient. However, the efficiency and impact of herbicides have yet to be adequately documented in SRIC situations.

Species Selection. Research indicates that there is wide variability in biomass production both between species and within species. The US research using poplars reports high yields (up to 25 dry tonnes per hectare per year) and it is probable that high yields from poplars could be obtained in Canterbury, especially if irrigation is used. Also worth consideration are the *Acacia* species. Frederick et al. (1985a) found that *A. dealbata* produced more above-ground biomass than *E. regnans* and *P. radiata* on North Island sites. Research on eucalypts and acacias in Canterbury using different provenances shows wide variability (John Sheppard, DSIR Lincoln, pers. comm.). This point is also made by Skolman (1983) regarding eucalypts selected for growing in California.

Frost hardiness (particularly for seedlings and young growth) is another crucial factor in Canterbury and limits the available choice of species. *E. nitens* has proven hardiness and *E. ovata* appears to be suitable.

Irrigation. Some studies of irrigation show that eucalypts respond well to water, but we have not found reports directly comparing irrigation to non-irrigation, or using different rates of water application. Australian research is advanced in this area with a number of trials examining irrigation with effluent (e.g., Allender, 1988;

Stewart and Salmon, 1986; Stewart et al. 1986). Similar trials are underway in New Zealand. Because of their susceptibility to root rots, ash eucalypts (e.g., *E. regnans, E. fastigata*) are unlikely to be successful under irrigation, but *E. nitens, E. globulus* and *E. ovata* and other gums respond well to water in a dry climate (Franklin 1989, pers. comm.)

3.6 Conclusion

The overseas literature on stand dynamics is far from complete but shows that spacing, length of rotation and annual increment are important factors in SRIC biomass production. With attention to these factors the overseas literature shows that it is possible to produce biomass in an economically viable way. The general points emerging from the overseas literature are valuable in the application of SRIC biomass production with Eucalypts in New Zealand. However, there is much scope for New Zealand research to document precise growth responses under carefully identified combinations of New Zealand conditions.

Eucalypt yields in the North Island range from 60 to 80 tonnes per hectare over four years and match the best yields of eucalypts grown overseas, in some cases doing better in New Zealand without fertiliser. For good sites in Canterbury, it is likely that, at best, yields will be about 60 tonnes per hectare for four years, and 50 tonnes per hectare for three years. Yields will be much lower where the sites are not favourable because of soil, rainfall, frost or fertility factors. There are sites with good quality soils close to all major urban areas. Urgently needed are trials with a variety of species planted with a wide range of stocking rates, including 5,000 stems per hectare.

There is scope for effective management of eucalypts incorporating fertiliser and irrigation to boost yields. We know that leaves and branches account for about one third the weight of biomass, but we do not know how long eucalypts can be coppiced intensively on short rotation and still sustain high yields.

CHAPTER 4

ECONOMICS OF SRIC BIOMASS PRODUCTION IN CANTERBURY

4.1 Introduction

The chapter begins with a gross margin analysis based on a budget for growing coppiced eucalypts. The assumptions of this budget are discussed in order to gauge their relevance, and a sensitivity analysis shows the significance of changing particular values in the budget. The intention is to explicitly identify vital assumptions thus providing for critical (re)assessment in ways uncommon in the literature to date.

4.2 Gross Margin Analysis

The costs and returns from a coppice woodlot operation were provided by Coppice Fuelwoods New Zealand Ltd and forms the basis of the gross margin analysis in this report. The budget is based on a close relationship between the grower and Coppice Fuelwoods New Zealand Ltd. The company advises on management and can supply services and planting stock. They offer a higher price per tonne of biomass for shareholders than for non-shareholders.

The budget considers a two hectare area, one hectare planted in the first year and the other hectare in the second year, each planted at 5,000 stems per hectare. These trees are grown for three years and then harvested every two years after first harvest (i.e., one hectare per year). The budget yield is 60 air dry tonnes per hectare which is higher than our estimate for Canterbury. The establishment costs are estimated at $4,400 per hectare, including ground preparation, planting and tree stock. The budget includes a $500 per hectare annual maintenance cost, including fertiliser, and a coppice maintenance cost from year four of $200 for the two hectares. Finally, there is a transport cost each year from year three of $480 (50 km at $0.16 per km per tonne) and an initial cost of shares in the company at $1,000 per hectare planted in this particular example. These data form the basis of the annual sequence of costs and returns shown in Table 4. The returns are derived from the estimated yield of 60 tonnes per hectare and a price to the grower of $90 per tonne (air dry weight). Yields are assumed to be constant over the entire growing period, although this may be unlikely in practice.

Some general points can be noted first. Omitted from these figures are dividends that derive from company shareholding. Some returns from this source may be expected, particularly if a grower cooperative is established. Land costs are not included because the objective of this economic analysis is to compare the farmer's returns from a fuelwood crop with his/her returns from other land uses. All labour costs are included in the budget, and the price paid per tonne of biomass is net of harvesting costs, since the company own and operate the harvesting and shredding equipment. Finally, the annual maintenance figure of $1,000 for two hectares is relatively high and would cover a number of contingencies.

Table 4 shows the first income and annual profit is made in year three while the cumulated profit becomes positive by year six. To interpret these figures appropriately it is necessary to calculate the net present value (NPV) over a particular time period. NPVs were calculated by summing the discounted net cash flows. NPVs were then amortised to obtain an amount relevant to a future time but expressed in current dollars. Finally, these amortised figures are halved to achieve an annualised gross margin per hectare. These calculations were made using an interest rate of ten percent and for time horizons of 10, 20 and 30 years.

For the costs and returns estimated by Coppice Fuelwoods New Zealand Ltd, Table 4 shows that the gross margins are: $239 for ten years, $664 for 20 years, and $828 for 30 years. Obviously, the longer time horizons give a better return because there are more profit years to weigh against the first three years of loss. There is a large increase of $425 hectare between the ten year and 20 year options, and a smaller increase of $164 per hectare in the third decade. While the 20 year figures appear better than the ten year figures, this apparent financial gain has to be weighed against increased uncertainty that initial assumptions will remain valid for 20 years.

Of immediate interest to Canterbury farmers is a comparison of these gross margins, for a yield of 60 tonnes per hectare, with their alternative crops. The Lincoln College Farm Management Department estimates gross margins, labour costs excluded, for a number of annual crops. These are listed in Table 5. Any interpretation must bear in mind that these crop gross margins would be lower if labour costs were included. (Labour costs are relevant to the coppice woodlot budget because establishment requires contract labour whereas farmers often establish their own annual crops without incurring labour costs.) In addition, the comparison is between a long-term crop and a short-term crop. Further, the crop gross margins over time have to be brought to constant dollar terms.

Table 4
Budget for 30 Year Coppice

AREA PLANTED: 1 Ha Year 0 & 1 Ha Year 1
Yield: 60 T/Ha
Price: $90.00 Per T
Interest Rate: 10
TRANSPORT
Distance 50
Cents/Km $0.16

Year	0	1	2	3	4	5	6	7	8	9	10	20	30
Establishment	4400	4400											
Annual Maintenance		500	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000
Coppice Maintenance					200	200	200	200	200	200	200	200	200
Transport				480	480	480	480	480	480	480	480	480	480
Shares	1000	1000											
Total Costs	5400	5900	1000	1480	1680	1680	1680	1680	1680	1680	1680	1680	1680
Income				5400	5400	5400	5400	5400	5400	5400	5400	5400	5400
Profit/Loss	-5400	-5900	-1000	3920	3720	3720	3720	3720	3720	3720	3720	3720	3720
Cumm Prof/Loss	-5400	-11300	-12300	-8380	-4660	-940	2780	6500	10220	13940	17660	54860	92060

	30 Yrs	20 Yrs	10 Yrs
NPV	$15,611	$12,522	$4,511
Equivalent Annuity	$ 1,656	$ 1,328	$ 478
Annualised GM/Ha	$ 828	$ 664	$ 239

Table 5
Gross Margins for Canterbury Crops of the Last Eight Seasons

	$/hectare 1988/89	$/hectare 1987/88	Average 1980 to 1988 In Real Dollars
Malting Barley	434	251	773
Winter Wheat	567	252	787
Field Peas	389	307	420
Vining Peas	516	541	941
Ryegrass	227	358	505
White Clover	374	178	580
Average	418	314	668
Coppice fuelwood (estimated) -	30 years, 828		
	20 years, 664		
	10 years, 239		

Notes:1. For ryegrass and white clover, the gross margin excludes annual income from grazing.
2. The average gross margins 1980 to 1988 are in real dollars using the Consumer Price Index for the adjustment.

Coppice fuelwood grown for 20 and 30 years would exceed the 1988/89 gross margins for all Canterbury crops. The ten year figure is lower than all crops, except ryegrass, for that year. However, there is considerable annual variation in estimated gross margins from cropping. In the 1987/88 season most of the crop gross margins were somewhat higher than the ten year coppice figure, but the 20 year gross margin for coppice fuelwood appears very attractive. The buoyant prices for 1988/89 crops reflect the occurrence of drought in the United States, and the low 1987/88 prices reflect uncertainties in the domestic market. In general, the estimated ten year gross margin for coppice fuelwood is lower than most crops in a year of low returns, and the 20 year gross margin is higher than all crops even in a year of high returns.

Table 5 also shows gross margins in real dollars averaged over eight years. The ten year gross margin is lower than all of them while the 20 year gross margin is similar and almost identical to the average for all crops ($664 compared to $668). Using these adjusted figures brings the comparison between coppice gross margins and crop gross margins to a more relevant level because the comparisons involves crop viabilities over time. However, the present comparison involves relating historical crop gross margins to future coppice gross margins, and the past is not always a good indicator of the future. World Bank (1988) data suggest that energy commodity prices will increase by the year 2000 while crop prices will be lower than in recent years. As New Zealand crop and energy prices are influenced by world prices, the World Bank data suggest that, in future, the relative position of energy commodities will improve when compared to food crops. Thus, our comparison above is weighted against coppice fuelwood crops.

Gross margins were not provided in other economic analyses of fuelwood production. Edmonds et al. (1989) estimate a net present value of $130 per hectare after eight years and $1,160 after 10 years.

4.3 Validity of Assumptions

Comment is required on the figures and assumptions used in the Coppice Fuelwood New Zealand Ltd. budget. The next section extends this appraisal by demonstrating how sensitive our gross margin calculations are to changes in the budget. The assumptions discussed now include production, price and demand, establishment costs and maintenance costs.

Production. Yields of 60 tonnes per hectare every four years are readily achievable in the North Island, but this is possibly over-optimistic for Canterbury sites because they are drier. Section 3.4 showed that 60 to 80 tonnes per hectare of biomass was achieved in four years near Rotorua without any fertiliser. For three years the yield would be an estimated 50 tonnes per hectare. Our estimate of 64 tonnes per hectare (see Table 2) after four years for a well-managed good site in Canterbury suggests that yields of 50 tonnes per hectare in three years are likely on good sites with good management. There is more uncertainty regarding yields of the coppice crops after the first harvest. Very good management would be required to achieve the 60 tonnes per hectare yield in the budget every two years. Improved yields for two-year rotations could be obtained by planting at high densities (at least three times the density of 1,667 stems per hectare from which the existing yield data were derived) and by properly applying fertiliser. In our opinion, since 50 tonnes after three years is possible from establishment, 50 tonnes from coppice regrowth is possible in two years because the trees are established and because they will be fertilised.

Price and Demand. The return to the grower of $90 per tonne is an area of great uncertainty for two reasons. First we do not know the precise costs of harvesting, shredding and briquette manufacture. Coppice Fuelwoods New Zealand Ltd. estimates their costs at $15 per tonne for harvesting and $15 per tonne for shredding. If we assume that compressing costs $30 per tonne (it is a slower and more demanding process than harvesting or shredding) then the costs of producing briquettes is $150 per tonne. There are additional costs associated with storage, distribution and marketing.

Usually firewood in Christchurch is sold for over $100 per cord loose stacked (and delivered) which is equivalent to approximately half a cord of solid wood (Sims 1989, pers. comm.). Thus, at current prices, one cord of solid dry hardwood is worth at least $200. Now we need to calculate from this value, the price for one tonne of briquettes. One cord at 128 cubic feet or 3.6 cubic metres of loose stacked wood is equivalent to 1.8 to 2.3 cubic metres of solid wood. Finally, two cubic metres of dry wood weighs one tonne. Thus, one cord of solid wood at say two cubic metres is equivalent to one tonne of briquettes which is worth $200. At an estimated cost of production of $150 the margin is $50, excluding costs of storage, distribution and marketing. Coppice Fuelwood New Zealand Limited currently sell 1 tonne of briquettes for $400, and at this price the margin is $250, excluding costs of storage, distribution and marketing.

It must be stressed that there is uncertainty regarding the cost of harvesting, shredding and compressing. Further information on these costs would facilitate more accurate assessment of the Company's returns from the sale of briquettes in the short term and hence the realism of their present and projected price to shareholding growers of $90 per dry tonne.

The second reason for uncertainty over the budgeted price of $90 per tonne relates more to long-term stability of supply and demand rather than short-term realism of processing costs. The 15 year picture is not a serious concern for annual cropping except where expensive, specialised machinery or knowledge is required. However, since a coppice woodlot is projected to begin making cumulated profit only in its sixth year, and an average-to-low gross margin by year ten, the longer time horizon cannot be ignored even for modest plantings of two hectares.

It is possible, but by no means certain, that prices paid to the farmer will remain near $90 per tonne (inflation and cost adjusted) for 30 years. The relationship of supply to demand for coppiced eucalypt wood cannot be predicted with certainty over such periods. Some factors, including the increased stringency of air pollution restrictions, the mounting shortage of clean-burning hardwood, the rising costs of electricity and the age-old human satisfaction from fire heating, suggest a bright future for Canterbury coppice fuelwood. Beside fuelwood, the strong prospects of additional demand for coppice woodlots (export chips for fine paper manufacture, fuel substitution in industrial/ institutional boilers, and land-based disposal of sewage and dairy/freezing works effluent) also imply stable or even rising profitability. Last, as will be seen, gross margins are very sensitive to rising transportation costs. This should discourage plantings at great distance from the processing plant and may in turn serve to avoid oversupply.

Nevertheless, a recurring pattern in agriculture is that early successes with innovative crops are soon emulated, resulting in overproduction and price declines after an initial flush of high profits for the 'early birds'. Even with generous assumptions about urban demand for fuelwood briquettes, that market could be easily oversupplied either by established growers expanding their woodlots or by new entrants. Our peliminary estimations of total demand for briquettes in Christchurch show that about 300 hectares could meet total requirements. If other attractive possible markets or uses did not materialise, prices to the farmer could fall unless an effective growers' cooperative existed. The prospects for such cooperatives are good given the expertise required and the several items of specialised and expensive equipment whose cost is best spread. And if prices did plummet, growers would be faced with higher than normal ground preparation costs of converting mature eucalypt coppice back into annual cropping.

What mix of these scenarios materialises in 15 years cannot be known with precision but a global perspective warrants some optimism: the supply-demand situation for quality papers looks bright, the pressures for cleaning up our waterways are escalating as are the costs of fertiliser, and the cost of domestic, industrial and institutional heating. Thus, at the aggregate level the long-term prospects for Canterbury coppice woodlots seems good. Yet within this bright overall future, a number of management factors could seriously affect the fortunes of individual growers, especially establishment and maintenance costs.

Establishment Costs. The budgeted stocking rate is 5000 stems per hectare. For a 1988 cost of 70 cents per root-trainer seedling (discounted for bulk supply), the total cost for stock is $3,500. The remainder from $4,400 is $900 which is available for ground preparation, planting and fertiliser. One Canterbury tree planting operator estimates that machine planting costs are approximately three cents per tree or $150 for 5000 seedlings (one hectare). This estimate may not accurately reflect the full cost involved with transport and storage of large numbers of seedlings. Costs of ground preparation, including deep ploughing and rotary hoeing are about $200 per hectare (Financial Budget Manual, 1988). Alternatively, deep ripping costs about $160 per hectare (Edmonds et al., 1987) at 2000 stems per hectare. So for 5000 stems per hectare $200 is a good estimate, since additional trees can be planted in the same row and obviate the need for additional rips. Fertiliser at planting at 60 to 80 grams per tree, which may be too high, costs $425 to $500 per hectare for manual application and when adjusted to 5,000 stems per hectare (Speight, 1988; Edmonds et al., 1987). These costs add up to $850 and are very close to the $900 available after purchase of seedlings.

There are other studies of costs of establishment with which comparison can be made. Edmonds et al. (1987) estimated establishment costs for ripping, pre-plant spraying, bare-rooted trees, planting and fertiliser to be $1,630 per hectare. This cost is for 2000 stems per hectare, so for 5000 stems per hectare the estimated cost is $4,075, a figure quite close to the budgeted cost. Similarly, Speight's (1988) estimate for establishing one hectare, including ripping, spraying, bare-rooted trees and fertiliser comes to $4,048 when adjusted to 5000 stems per hectare.

With SRIC management, cost savings could be made with the mechanical planting process which also allows for simultaneous mechanical application of fertiliser. The alternative estimates used above are for manual fertilisation following manual planting. In addition, these other two studies used bare-rooted seedlings which are cheaper than root trainer stock ($0.35 compared to $0.70), making the estimated establishment cost lower than in the budget analysis used here. However, the mechanised planting in the SRIC budget is cheaper. It is also possible to consider using bare-rooted stock with mechanised planting in SRIC biomass production, and thus lower establishment costs. However, Coppice Fuelwood's exerience to date suggest higher survival rates with root-trained stock, so this could counterbalance the lower cost of bare-rooted stock.

The Coppice Fuelwood New Zealand Ltd budget assumes a high survival rate from root trained stock at planting. They have achieved survivals in excess of 95 percent, but recent experience in the 1988/89 growing season with plantings on difficult sites in a drought year show survival rates as low as 60 to 70 percent. Freak frosts can also kill or slow growth in poorly selected species or provenances. Rabbits, hares or 'Possums are additional threats to seedling trees. The costs of manually replacing dead stock or continuing to sustain commensurate losses cannot be ignored. For example, a loss rate of 30 percent represents 1,500 stems per hectare for which replacement stock alone costs $1,050. Adding the labour cost will increase the total additional cost to say $2,000. The maintenance budget of $500 per hectare is not sufficient to cover a poor strike rate. Thus, establishment costs could rise in excess of 50 percent of the budget cost if contract labour had to be employed and replacement stock paid for by the grower.

Maintenance Costs. With good survival the total annual maintenance budget of $600 per hectare after four years is an adequate allowance for weed, insect and pest control, and for fertiliser. It is unlikely that spraying for insects would be required every year, and it is likely that some species of eucalypt will be less susceptible to insect damage. Where aerial spraying is needed the costs come to $112 per hectare, derived as follows. Assuming that considerable volume of spray is needed to cover the trees, the rate would be roughly equivalent to brushweed spraying at 200 to 220 litres per hectare. At this rate the application cost is $80-$100 per hectare (Financial Budget Manual, 1988). A chemical suitable for leaf-eating insects is Maldison, which costs $12 per kilogram and applied at one kilogram per hectare.

Maintenance expenditures are required to foster maximum growth after taking a coppice crop. Fungicide, if needed, would be applied during or after cutting and is a minor component of coppice cost. Thinning of shoots, which is recommended in traditional regimes, is not required for SRIC biomass production because multiple shoots are expected to maximise biomass production and would be easier to cut and shred. The main requirement is fertiliser application to foster continued high levels of production. It would be possible to broadcast fertiliser by truck to one hectare each alternate year after harvesting, rather than place a specific amount of fertiliser next to each tree. Broadcast application would be suitable because tree roots will be widespread. An additional requirement may be weed control (although this may not be needed for a fast growing, established and fertilised coppice). The annual costs for this worst case need of both fertiliser and weed control are $425 per hectare, derived as follows.

The equivalent of 80 grams of urea (for example) per tree for 5000 stems per hectare costs $175 for fertiliser alone (Speight, 1988) and truck application is $50 per hectare (Financial Budget Manual, 1988), totalling $225. Ground application of an appropriate herbicide at ten litres per hectare would cost $175 for the chemical and $18 per hectare for contract spraying (Financial Budget Manual, 1988). The total cost of a herbicide application is about $200 per hectare, bringing the estimated total cost for fertiliser and weed control to $425 per hectare each year on an alternating basis.

The fertiliser maintenance costs would be very important to insure high yields and could not be omitted. Some adjustments to the amount and type of fertiliser would be necessary in the light of experience, soil type and cropping history. For example, additional fertiliser could be applied because the root systems would be large. Fertiliser application alone at 80 grams per tree costs an estimated $225 per hectare and doubling the rate of urea to 160 grams per tree equivalent increases the cost to $400. Trebling the rate to 240 grams per tree equivalent increases the cost to $575. The necessity for weed control in an established coppice is unknown and may be required only after the first harvest, if at all. It seems likely that for well-established eucalypts, regrowth would outgrow any weeds. Thus a well-fertilised coppice that did not require insect or weed control would cost an estimated $575 per hectare in maintenance costs, which is similar to the budgeted amount of $600 per hectare. Occasional spraying for insects would not seriously deplete the amount of money available for fertiliser especially where the two operations are combined.

The coppice maintenance figures do not include any costs for replacing trees, because it is assumed that they will continue to grow for 30 years. There is no New Zealand data to support this assumption, and tree failure would incur expensive replacement costs because planting could not be mechanised.

The road transport cost figure in the budget is lower than costs quoted in the Lincoln College Financial Budget Manual which quotes $0.50 per kilometre per tonne for bulk grain or bulk lime (which is the closest approximation to wood chips). At this rate the cost is $0.34 per kilometre per tonne more than the Coppice Fuelwood New Zealand Ltd. figure of $0.16 per kilometre per tonne. The potential significance of higher transport cost is discussed below.

4.4 Sensitivity Analysis

The general viability of coppice fuelwood production has been indicated, subject to the assumptions of the analysis. The analysis also allows for variation in any of the parameters and the following discussion identifies which variables are important, and how the gross margins change as any one assumption is adjusted. Sensitivity analyses show that yield, price, establishment costs, and annual maintenance each have a major impact on viability, as indicated by comparing the amount of change in the particular variable with the amount of change in the gross margin. Table 6 summarises these findings and they are discussed in detail below. Main variables have a relatively larger impact on gross margin.

Main Variables. Yield has an important bearing on gross margin. If the yield increases from 60 tonnes per hectare to 70 tonnes per hectare (17 percent increase) the ten year gross margin is $414 (73 percent increase) and the 20 year gross margin is $932. If the yield decreases to 50 tonnes per hectare (perhaps realistic for Canterbury even on very good sites) the gross margins are $65 and $396 respectively. At this yield, the ten year gross margin is low and it is only after 20 years that the crop approaches comparative viability. The 20 year gross margin of $396 is lower than the $668 average for all crops over the last eight years (see Table 5). Hence, management factors influencing yield are important, and further research is needed to evaluate whether boosting yield with applications of fertiliser and water would be economically viable. This would occur naturally if part of an effluent disposal scheme.

Table 6
Comparison Between Percentage Changes in Budget Variables and Ten Year Gross Margins

	% Change in Variable	% Change in 10 Year Gross Margin
Main Variables:		
Yield	+17	+73
Price	+11	+53
Establishment Costs	-20	+33
Annual Maintenance	-50	+57
Minor Variables:		
Interest Rate	-50	+30
Coppice Maintenance	-50	+ 8
Transport Costs	-38	+16

Price received per tonne of biomass is also very important. If the price paid increases from $90 per tonne to $100 per tonne (11 percent increase) the ten year gross margin is $367 (53 percent increase) and the 20 year gross margin is $868. If the price decreases to $80 per tonne the gross margins are $112 and $468 respectively. Prices of $70 per tonne and $60 per tonne would decrease the ten year gross margins to $16 and -$143, and reduce the 20 year gross margins to $272 and $76.

Establishment costs in years one and two also have a significant effect on gross margin. If the establishment costs are reduced from $4,400 per hectare to $3,500 per hectare (20 percent decrease) the ten year gross margin is $322 (35 percent increase) and the 20 year gross margin is $747. If establishment costs are increased to $5,500 the gross margins are $138 and $563 respectively. For the situation we considered earlier of a 30 percent mortality rate, here applied to both establishment years, the establishment cost increases to $6,000 per hectare. At this rate the ten year gross margin is $92 and the 20 year gross margin is $519.

Annual maintenance has the following effect. A decrease from $500 per hectare to $250 per hectare (50 percent decrease) produces a ten year gross margin of $376 (57 percent increase) and a 20 year gross margin of $858 (29 percent increase). If annual maintenance increases to $750 per hectare (50 percent increase) the gross margins are $102 (57 percent decrease) and $470 respectively.

Minor Variables. The other variables have a lesser effect on gross margins. A decrease in interest rate from ten percent to five percent (50 percent decrease) increases the ten year gross margin to $311 (30 percent increase). Coppice maintenance, if reduced from $200 per year to $100 per year (50 percent decrease) increases the ten year gross margin to $257 (eight percent increase) though it is very likely reduced fertilisation would reduce yields and thus lower gross margins. For transport costs, a decrease from $0.16 per kilometre to $0.10 per kilometre (a 38 percent decrease) increases the ten year gross margin to $278 (16 percent increase). However, transport costs at $0.40 per kilometre (250 percent increase) reduces the ten year gross margin to $86 (64 percent decline), and transport costs at this level would drastically reduce viability. Alternatively, at $0.40 per kilometre for 60 tonnes the maximum distance for trucking within the budgeted transport cost of $480 is 20 kilometres from the factory.

Two remaining variables deserve discussion. First, the cost of the purchase of shares is an integral part of the existing budget. As an alternative, Coppice Fuelwoods New Zealand Ltd. will purchase biomass from non-shareholders and is offering $60 per tonne. At this price the ten year gross margin is negative at - $51 and for 20 years is a paltry $168. Finally, transport distance is an important variable. If the distance decreases from 50 kilometres to 25 kilometres (50 percent decrease) the ten year gross margin is $290 (21 percent increase); conversely an increase in distance to 75 kilometres (50 percent increase) reduces the ten year gross margin to $188 (21 percent decrease). While the ten year gross margin for 100 kilometres is $137, for 125 kilometres it is $86. Obviously, proximity to the briquette factory is important, and larger distances will have to be balanced by the other factors being set at very favourable levels. However, the costs of distance may help mitigate the chances of oversupply.

The costs and returns in the budget analysis allow for adequate annual maintenance and coppice maintenance figures. It may be possible to grow eucalypts with low maintenance inputs without significantly jeopardising the yield. For example, spraying for insect control at low infestation levels may not be necessary, and fertiliser applications could be minimised or dovetailed with other operations to reduce costs. Applying less fertiliser will lower soil fertility and yields, especially in later years. In the case of no maintenance of either kind, and assuming yields stay at 60 tonnes per hectare, the ten year gross margin is

$549 and the 20 year gross margin is $1,111. If yields decrease to 50 tonnes per hectare the gross margins are $375 and $843 respectively; for 40 tonnes per hectare they are $200 and $575.

We also consider some combinations of changes, in particular the effects of changing establishment cost and yield. It is relevant to consider the impacts of, say, increasing expenditure at establishment where such expenditure might increase yields. It is quite likely that increasing planting density increases yield especially for short rotations, as was found in Section 3.2 for poplars. Planting density is directly related to cost via the cost of seedlings. For example, a stocking rate of 7000 stems per hectare rather than 5000 stems per hectare increases the cost of seedlings at $0.70 each from $3,500 to $4,900. Allowing for the cost of planting, this stocking rate would have establishment costs of about $6,000 and Table 7 shows the gross margins for a range of yields at this establishment cost.

Table 7
Gross Margins for a Range of Yields
from 7000 Stems per Hectare

	10 years	20 years	30 years
Tonnes per hectare			
70	266	785	985
80	441	1,053	1,289
90	615	1,321	1,593
100	789	1,589	1,897
110	964	1,857	2,201
120	1,138	2,125	2,505

The data in Table 7 show that even with a modest increase in yield from 60 to 70 tonnes per hectare (17 percent) the ten year gross margin increases from $239 to $266 (11 percent). Yields at 80 tonnes per hectare (33 percent increase) produce a ten year gross margin of $441 (84 percent increase). If high stocking rates lead to increased biomass production then the additional expense at establishment may be worthwhile, especially if high density results in higher yields from coppice regrowth in two years. At the other extreme, establishment costs of $2,000 for lower density planting lead to a ten year gross margin of $286 for a 50 tonne per hectare yield.

A final issue is rotation length. The existing budget assumes a three year period for establishment to first harvest and then harvest at every two years. We consider the effect of extending the rotation length to four years and assume that yields will be higher. For this scenario coppice maintenance remains at $100 per hectare for each harvest year only, that is, at year four and five, eight and nine etc. Annual maintenance is sustained at $500 per hectare. Table 8 shows the gross margins for a number of yields.

Table 8
Gross Margins for a Range of Yields for a Four Year Rotation

	10 years	20 years	30 years
Tonnes per hectare			
100	82	420	554
110	171	555	707
120	259	690	861

Projections in Table 8 show that to approximate the ten year gross margin of $239 for the original production regime, a four year rotation requires a yield of about 120 tonnes per hectare, or double the 60 tonnes per hectare yield in two years of rotation. Since fertiliser will be generously applied this yield could be realistic. Additional analysis with no maintenance expenditure but coppice maintenance of $200 in the harvest years shows that a 90 tonne per hectare yield every four years gives a ten year gross margin of $268. While there may be some financial advantages in longer rotations these regimes may not be compatible with machine harvesting because of increasing stem diameter. For this reason it is preferable to use two year rotations and high densities typical of SRIC biomass production.

4.5 Conclusion

SRIC biomass production would be viable under the assumptions made for a 30 year budget based on provisional figures provided by Coppice Fuelwoods New Zealand Ltd. For a ten year rotation the gross margin is lower than other crops, and for a 20 year rotation the gross margin is similar to the adjusted average for all crops. However, profitability is highly sensitive to a number of variables. In particular, if yields in Canterbury do not match the 60 tonnes per hectare budgeted but reach only 50 tonnes per hectare, which is our expectation based on current data, the gross margins are significantly lower. The 20 year gross margin at this yield is lower than the adjusted average for all other crops over the last eight years. If trees do not coppice for 30 years the gross margins will be significantly lowered yet again. For Canterbury conditions, some aspects of management will need modification to assure reasonable gross margins in ten years. However, it is possible that yields in Canterbury might be higher than indicated by the available data because they are based on traditional stocking rates of about 1,000 stems per hectare.

The other assumptions of the budget generally are good. The budgeted costs of establishment appear to be very close to alternative estimates (assuming high survival). The total annual maintenance cost budgeted is $600 per hectare, and our estimates for a well-fertilised coppice that did not require insect or weed control fall within this level. Insect control, if needed, would not seriously deplete the per hectare maintenance budget. Less certain at present are the costs associated with harvesting, shredding and briquette manufacture, but our tentative estimates show scope for a satisfactory margin, assuming briquettes sell for $200 per cord. Finally, the budget estimates for transport costs appear to be low, and large changes from the level in the budget can have major impacts on viability.

Sensitivity analyses show that yield, price, establishment costs, and annual maintenance are the items in the budget that have most impact on viability. Combinations of change in establishment costs and yields affect gross margins, but it is difficult to evaluate the precise impact because we do not know what impact changes in establishment costs and fertiliser maintenance will have on yield.

CHAPTER 5

CONCLUSION

There is scope in Canterbury for growing eucalypts on a short rotation, intensive culture (SRIC) basis for briquette manufacture. Our economic assessment does not indicate that SRIC biomass production is of certain viability, but it does show that with proper management and good yields coppice fuelwood may compete with other crops. Research on many aspects of SRIC biomass production is required before confident predictions on viability can be made.

Potential growers have to compare coppice fuelwood with other crops and this comparison can never be perfect. For example, there may well be significant management or economic considerations which make coppice fuelwood attractive when compared to other crops even at low gross margins. A fuelwood crop may well be established on smaller parcels of land unsuited to other crops, provide needed shelter, or use labour at times of the year when it is otherwise not used to capacity. Further, the comparison of gross margins may be misleading because it is comparing an annual crop to a perennial crop. In its favour, coppice fuelwood should bring relatively steady returns in the future, provided prices stay constant, because establishment is required only once and may result in production for 20 to 30 years. In essence, it is problematic to compare an annual gross margin with a 30 year averaged gross margin.

At the heart of the problem of comparison is the issue of price stability. Before any growers undertake coppice fuelwood production they have to consider availability of suitably located harvesting and processing equipment and future demands for the products. In addition, there are many management factors involved, as discussed in Chapter 4. Long-term predictions have uncertainty, and the penalty for poor predictions may be costly crop or re-pasture establishment. Despite these problems, it is unlikely that any grower will have to be fully committed to coppice fuelwood and this new crop could be incorporated successfully into an existing mixed farm enterprise.

Underlying the major areas of uncertainty in coppice fuelwood production is a shortage of New Zealand research on the growth of SRIC hardwoods in general and eucalypts in particular. Research is needed in six main areas, as follows:

1. There is the general question of production from trees. One aspect is the comparative growth among different coppicing species. While the focus of this report has been on eucalypts it is

quite possible that trees of other species are suitable. *Populus, Salix, Acacia* and *Robinia* species have been used overseas and some combination of species may prove superior. Another aspect is length of time for which trees will coppice. Urgently needed is careful scrutiny of long-established, overseas coppices in order to gauge the viability of SRIC coppice in New Zealand. Then there is the question of selection within species. For example, only some eucalypts will be most suited to the Canterbury Plains, and within a species, some cultivars have dramatically superior growth rates.

2. There is the question of management techniques as they relate to yield. Likely factors are fertiliser, density and irrigation. Urgently needed are Nelder trials which will demonstrate the relationship between density and biomass yield under Canterbury conditions.

3. There is the question of technical improvements in SRIC biomass production. Some considerable advances have been made by Coppice Fuelwoods N.Z. Ltd. in importing and developing planting, harvesting, shredding and briquette-making machinery. But there is scope for developing improved machinery which can operate both effectively and reliably for the large scale at which SRIC biomass production is capable of operating.

4. There is the question of sewage treatment and irrigation. We need good data on the effect of irrigation on yield, and the effect of sewage application on growth rate, soil residues and ground water quality. This area of research is very important because it is likely that eucalypts under a sewage treatment regime will grow at fast rates even under 'dry' summer conditions.

5. The burning characteristics of hardwood briquettes need investigation, particularly to establish their air quality implications relative to softwoods and low-sulphur coal. Also related to this issue is the energy efficiency of the overall SRIC process.

In short many questions about the application of SRIC technology in New Zealand remain unanswered.

SRIC biomass production is an exciting technological development with potential to be applied in a number of ways for a variety of outputs. Our study indicates that one immediate application, that of briquette manufacture for domestic fuel, could have economic viability when undertaken in a careful way with proper attention to good management and where high yields of biomass can be obtained. Developments in this and related areas appear to have bright prospects for the future.

In addition to meeting the economic and other individual needs of the grower, manufacturer/distributor and end-user, coppice fuelwood is likely to have a number of desirable social and environmental implications. Within the Christchurch clean air zone, consistently dry and clean burning hardwood briquettes used in approved appliances appear to offer the best hope of retaining firewood heating while still meeting stringent air quality standards. Even though the SRIC production system eliminates labour, this loss may be a net gain since it is the hazardous use of chainsaws that would be reduced most. The overall energy efficiency of coppice fuelwood is not immediately clear, but where it substitutes for coal (or other fossil fuels) this represents an economically competitive shift from non-renewable to renewable energy sources.

It is in the areas of effluent and sewage disposal, water treatment, nutrient capture and recycling (from furnace ash) that the gains may be sufficiently large to justify SRIC woodlots without considering the fuelwood which becomes almost incidental, but valuable, "waste" by-product. If SRIC biomass also comes to command a market in the manufacturer of fine quality papers then this could alleviate pressure for the large scale chipping of native hardwood forests throughout the world, together with the attendant social disharmony. Moreover, if drought persists in Canterbury as some observers predicted, then trees imply numerous additional advantages including the increased crop productivity and reduced soil losses offered by wind protection. These additional considerations auger well for SRIC biomass production in Canterbury.

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