



Harvesting Trees on Farms

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

Bob McCormack, Bill Kerruish,
John Reid, Eva Antilla, Mark Stewart

Forest Technology Program - CSIRO & University
of Melbourne

May 2000

RIRDC Publication No 00/46
RIRDC Project No CSF-51A

© 2000 Rural Industries Research and Development Corporation.
All rights reserved.

ISBN 0 642 58076 6
ISSN 1440-6845

Harvesting Trees on Farms
Publication No. 00/46
Project No. CSF-51A

The views expressed and the conclusions reached in this publication are those of the author and not necessarily those of persons consulted. RIRDC shall not be responsible in any way whatsoever to any person who relies in whole or in part on the contents of this report.

This publication is copyright. However, RIRDC encourages wide dissemination of its research, providing the Corporation is clearly acknowledged. For any other enquiries concerning reproduction, contact the Communications Manager on phone 02 6272 3186.

Researcher Contact Details

Dr Bob McCormack
CSIRO Forestry and Forest Products
PO Box E4008
Kingston ACT 2604

Phone: 02 62818234
Fax: 02 62818239
Email: bob.mccormack@ffp.csiro.au
Web Site: <http://www.ffp.csiro.au>

RIRDC Contact Details

Rural Industries Research and Development Corporation
Level 1, AMA House
42 Macquarie Street
BARTON ACT 2600
PO Box 4776
KINGSTON ACT 2604

Phone: 02 6272 4539
Fax: 02 6272 5877
Email: rirdc@rirdc.gov.au
Website: <http://www.rirdc.gov.au>

Published in May 2000
Printed on environmentally friendly paper by Canprint

Foreword

In 1996 the RIRDC/LWRRDC/FWPRDC Joint Venture Agroforestry Program published a resource kit titled *Commercial Farm Forestry in Australia, Development of a Strategy Framework*.

Within this publication a number of impediments to the widespread adoption of commercial farm forestry were identified.

In order to address some of these impediments the Joint Venture Agroforestry Program (RIRDC/LWRRDC/FWPRDC) commissioned four projects designed to address key impediments. The four projects were designed to:

- strengthen links between farm forest growers and the forest industry;
- identify policy reforms for farm forestry;
- identify opportunities for harvesting trees on farms; and
- identify opportunities for processing wood products on farms.

This report examines the harvesting of trees on farms with an emphasis on operations conducted by the farmer. It reviews the international literature, reports a number of case studies and a survey of farmers' harvesting intentions in Victoria, and looks at the likely impact of cost factors particularly important to smaller scale farm forest harvesting operations. The project uncovered a number of difficulties but demonstrated that there is a range of options available to strengthen links between small-scale growers and industry.

This project was funded by three R&D Corporations — RIRDC, LWRRDC and FWPRDC. These Corporations are funded principally by the Federal Government.

RIRDC's involvement in this project and in the Joint Venture Agroforestry Program is part of the Corporation's Agroforestry and Farm Trees R&D Program which aims to foster integration of sustainable and productive agroforestry within Australian farming systems. It is an addition to RIRDC's diverse range of over 450 research publications.

Most of our publications are available for viewing, downloading or purchasing online through our website:

- downloads at www.rirc.gov.au/reports/Index.htm
- purchases at www.rirc.gov.au/pub/cat/contents.html

Peter Core
Managing Director
Rural Industries Research and Development Corporation

Acknowledgements

The contributions of the six forest farmers in Victoria who shared their experiences with us is warmly acknowledged.

Glossary

<i>Feller Buncher</i>	Mechanical tree feller, capable of stacking severed trees in bunches.
<i>Flail Chipper</i>	Processing unit for removing branches and bark, using a rotating chain flail, and converting stems to chips.
<i>Forwarder</i>	A forest tractor + trailer + loading crane combination used to pick up logs from the stump areas and transport them to a roadside collection point
<i>Grapple Skidder</i>	Forest Tractor (Skidder) fitted with a grapple to pick up and hold logs during skidding
<i>Increment</i>	Increase in stand volume over a defined period (usually annual)
<i>Landing</i>	A roadside collection point where logs are stored for subsequent loading onto trucks. Sometimes also the site of log processing.
<i>MAI (Mean Annual Increment)</i>	The average yield of the forest since planting (MAI= Current Merchantable Volume divided by years since planting)
<i>Silviculture</i>	Planting, tending or harvesting of forest trees.
<i>Skidder</i>	Forest tractor (usually rubber tyred) used to drag logs from the stump area to a roadside collection point
<i>Skyline</i>	Timber harvesting systems using a carriage running on a cable suspended between a central tower and a distant anchor to lift and convey logs to a central landing. Used predominantly in steep terrain where ground based machines cannot operate.
<i>Small Scale Forestry</i>	Forest ownership and management by individuals, at a farm or individual property level.
<i>Stand Cleaning</i>	Silvicultural treatment to remove small trees and weed species competing with main crop (often by use of motorised saw)
<i>Thinning</i>	Silvicultural treatment that selectively harvests and removes a proportion of the stems in a stand, leaving the remaining stems to continuing growing.

Contents

FOREWORD	III
ACKNOWLEDGEMENTS	IV
GLOSSARY	IV
EXECUTIVE SUMMARY	VII
1. INTRODUCTION	1
2. HARVESTING TREES ON FARMS – THE REGIONAL CONTEXT	2
TYPES OF PLANTATION	2
REGIONAL INFLUENCES	3
3. APPLICABLE HARVESTING TECHNOLOGIES	4
4. INTERNATIONAL EXPERIENCE WITH SMALL-SCALE FORESTRY - A LITERATURE REVIEW	7
5. SMALL-SCALE FOREST HARVESTING CASE STUDIES	10
CASE STUDY 1. SOUTH EAST VICTORIA - <i>PINUS RADIATA</i> PLANTATION	10
CASE STUDY 2. SOUTH EAST VICTORIA - <i>PINUS RADIATA</i> PLANTATION	11
CASE STUDY 3. SOUTH EAST VICTORIA - <i>PINUS RADIATA</i> PLANTATION	12
CASE STUDY 4. NORTH EAST VICTORIA - <i>PINUS RADIATA</i> PLANTATION	13
CASE STUDY 5. SOUTH WEST VICTORIA - <i>PINUS RADIATA</i> PLANTATION	15
CASE STUDY 6. SOUTH EAST VICTORIA - MIXED SPECIES NATIVE FOREST	16
DISCUSSION OF CASE STUDIES	17
6. POSTAL SURVEY OF FARM FORESTRY	19
7. COSTS CONSIDERATIONS FOR HARVESTING OF TREES ON FARMS	22
COST CONSIDERATIONS FOR HARVESTING TREES ON FARMS	22
SOURCES OF 'ONE-OFF' COST	22
8. IMPLEMENTING THE SMALL-SCALE HARVESTING COST ESTIMATOR	26
9. EVALUATING SMALL-SCALE FORESTRY OPERATIONAL COSTS	30
SCENARIO 1 - MECHANISED FIRST THINNING	30
SCENARIO 2 - CHAINSAW FELLING AND PROCESSING, FORWARDER EXTRACTION	33
DISCUSSION OF COST EVALUATIONS	34
10. DISCUSSION AND CONCLUSION	35
11. IMPLICATIONS OF THE RESEARCH	38
12. APPENDICES	40
APPENDIX A: ANNOTATED BIBLIOGRAPHY	40
Australia	40
New Zealand	41
Finland and Sweden	42
North America	50
Wood Supply Systems	50
Appropriate Harvesting Technologies for Small-Scale Forests	51
APPENDIX B: SURVEY TEMPLATE	53
13. BIBLIOGRAPHY	56

List of Tables

Table 1	Self employment of private woodlot owners in silvicultural work	9
Table 2	Product yields and distance to market for Case Study 4.....	14
Table 3.	Summary of case studies	17
Table 4.	Job and setup assumptions for Scenario 1- mechanised first thinning	30
Table 5.	Machinery cost details for Example 1- mechanised first thinning	31
Table 6.	Results of cost estimation for Example 1 - mechanised first thinning.....	31
Table 7.	Input data for Scenario 2 - chainsaw felling and forwarder extraction	33
Table 8.	Results for Scenario 2 - chainsaw felling and forwarder extraction	33

List of Figures

Figure 1	Relationship of farm forestry to other plantations	3
Figure 2.	Rate of response from various regions of Victoria to mail survey.	19
Figure 3.	Breakdown of involvement in harvesting and processing trees on farms.	20
Figure 4.	Volume output of all harvest operations over the projected six-month harvest season.	20
Figure 5.	The different groups likely to conduct the harvest over the projected six-month harvest season.....	21
Figure 6.	Classification of farm forestry sites	24
Figure 7.	Section 1 -job details and cost inputs.....	27
Figure 8.	Section 2 - machinery cost inputs.....	28
Figure 9	Section 3 - Example of the output of the cost estimator.....	29
Figure 10.	Setup and relocation costs in relation to distance and volume for Scenario 1	32

Executive Summary

There are considerable areas of forest on private land, and there are number of important reasons to develop and maintain a vital small scale forest sector involved in the active management and harvesting of these forests. Currently, while small-scale private (non-industrial) private forests make an important contribution to our national wood supply, owners appear to have little involvement in production – there is little small-scale forestry with most operations being performed by contractors from the industrial forestry sector. A more active farm-forestry sector offers the prospect to owners of diversification of income, opportunities for seasonal work balancing, and greater returns to the farm gate. This report examines the role of small-scale forestry with an emphasis on the harvesting activities and seeks to identify impediments to more widespread adoption.

A review of the literature demonstrates the clear capacity of small-scale forestry in other countries to supply internationally competitive industries, for example in Scandinavia and in the Southern USA. There, large total volumes of wood are drawn from small, privately owned forests, by highly developed (but very different) harvesting, transport and marketing systems that reflect the different industrial and social cultures. The Scandinavian experience has much to offer farmers who wish to increase their income by direct participation in the management of their forest.

The literature reports that harvesting operations in Scandinavia are becoming more capital and skill-intensive with a trend towards harvesting being done by farmer cooperatives or specialised contractors. Some farmers are investing in the more specialised equipment and skills required to harvest and deliver wood to roadside from their own and their neighbours properties, the latter on a contract basis. Key features of such operations must include:

- The ability to quickly relocate to new sites
- A capacity to maximise the value of the logs recovered from the forest
- A capacity to harvest and deliver wood to an efficient road transport system.

The literature also points to an opportunity to increase silvicultural inputs. These increase the value of the logs and can reduce the costs of harvesting trees and represents perhaps the best opportunity to use on-farm labour and equipment.

New Zealand reports point to the deficiencies of small-scale logging operations i.e. inadequate skills, inappropriate equipment and high fixed costs. A fairly negative future was projected for small-scale logging compared with industrial operations.

To evaluate the contemporary Australian situation, six case studies of small-scale harvesting operations were studied in Victoria to gain a preliminary measure of their productivity and costs. The cases included two contractor and four owner operations. The studies revealed an infant industry, with harvesting costs, operational impacts and occupational health and safety falling short of the standards now being achieved in industrial-scale operations.

While the original intent of this project was to permit a comparison with industrial-scale operations, it soon became apparent, that this would be of limited value. While our industrial operations are highly developed and can claim to represent ‘world's best practice’, the small-scale operations were ‘pioneering’ with improvised equipment, limited skills and short-term marketing arrangements. It is also of note that some of the contract operations did not perform better than owner operations, possibly because of the owners' inability to effectively select and supervise the contractors. The case studies identified a need for basic forest management / business knowledge on the part of the forest owner whether operations are contracted out or not.

To extend the project's information base beyond the literature and case studies, a survey of Victorian small-scale forestry was undertaken to establish harvesting intent during 1996-97. The address data-base of a Victorian Agroforestry Newsletter was used to contact wood-lot owners. Of the 940 respondents, only about 60 intended to be actively involved in harvesting operations. However, most (about 50) were planning to harvest only small volumes in the upcoming six-month period, leaving ten intending to harvest and sell roundwood. This low level of harvesting activity in small-scale operations in Victoria meant that a series of production studies was originally planned to quantify the effect of scale on the farm harvesting could not be undertaken.

In an alternative approach, the project concentrated on a theoretical analysis of important cost sources. Those identified included (a) set-up and administrative costs (negotiation of works and perhaps sales contracts, completion of permit and other regulatory requirements etc), (b) development of appropriate access infrastructure for machinery and trucks, and (c) costs of equipment relocation. A spreadsheet-based model was developed to assess the impact of these costs. Several scenarios were tested to indicate cost sensitivity to different operations. For these examples, cost penalties for intermediate (50 km) relocation distances were estimated at about 2%-5% of operational costs.

Our main conclusions and suggestions are:

- ◆ Overseas, small-scale forestry does provide a basis for internationally- competitive forest industries, particularly where there is a substantial total volume of wood and there are well-developed wood supply systems.
- ◆ To date, forestry in Australia has focussed on industrial-scale operations. In contrast, small-scale forestry is very much at a formative phase. The next step is the development of economically efficient wood supply systems for small scale forests. This requires consideration of all phases, silviculture, harvesting, transport and marketing.
- ◆ It is suggested that efforts should focus in the two or three regions that have the potential to yield significant volumes of wood.
- ◆ Even where the development of efficient wood supply systems limit the farmers ability to be involved in harvesting, on-farm labour might still profitably be committed to silvicultural operations, eg. growing fewer, larger trees whose harvesting costs are less influenced by scale.

1. Introduction

Farm forestry is receiving increased attention in Australia. A considerable proportion of native forest and a small but increasing proportion of plantation forest are found on farms, and considerable environmental and economic benefits should flow from their effective management. The practice of farm-forestry takes a number of forms depending on the level of involvement by the farmer in the forestry work. Small-scale forestry, where farmers and small forest owners are actively involved, offers one strategy to increase the level of management of these forests. This report addresses some of the issues relating to small-scale forestry. Victoria was selected as the study area and analysis of activity in that state indicated that the primary focus should be on harvesting of farm plantations. This report also touches other aspects of farm-forestry.

Our first sections provide a description of the regional context, and a broad description of the technical possibilities and choices facing farmer wishing to harvest trees. The next section reviews the international literature, and evaluates the farmer's role in forestry in other countries. This is followed by descriptions from case studies undertaken in Victoria to establish the on-the-ground situation in the harvesting of smaller-scale farm forests. The next section details a mail-out survey, undertaken to establish management intentions. Next, an analysis of farm forest operational costs was undertaken. Finally conclusions are drawn and recommendations made for future development.

2. Harvesting Trees on Farms – The Regional Context

Timber harvesting of farms occurs for a number of reasons and at a number of scales. Some harvesting supports activity on the farm, is undertaken on a small scale, eg. for fence posts, poles or firewood, and is often conducted in native forests. Plantations, however, are more often established for commercial purposes, and harvesting is more likely to be for commercial sales of logs. This report focuses on the latter purpose, the harvesting of logs for commercial sale. These sales bring the growers into contact with the regional log market, whose characteristics do much to shape the opportunity for successful outcomes. This section explores aspects of the regional log market of importance to farm foresters. It begins with an analysis of the relative position of small-scale farm plantations in the broader forestry context.

Types of Plantation

There are several categories of privately owned plantations in Victoria. The largest areas have been established by industry, usually as a component of a vertically integrated system including the log processing plants. These large-scale industrial forests are managed in similar fashion to the recently privatised plantations forests established by government, and we have positioned both of them together as large-scale industrial forests. The second long-standing group are the small private plantations established by farmers and landholders over the years. These are almost all small in size, and we characterise these as the small-scale plantations, and these are a primary focus of this study. A third, recently expanding group, are those plantations established on a share farming, or investment basis. In these, a significant proportion of the investment funding has come from parties other than the landowner and/or the land-owner does not live on the land or has his plantation managed by a third party. We term these *investor* plantations. In these cases, while individual landholding may be individually small in scale, the off-farm partner may have interests in many separate plantations.

Figure 1 represents the relative position of these plantation forestry groups. This figure also addresses the level of involvement. In this context, involvement is considered as the use of on-farm or enterprise resources (equipment and labour) to plan and implement forestry operations. Some farmers choose to be actively involved in most or all phases of the forestry work, while others more passively respond to industry offers or initiatives, with industry personnel substantially responsible for planning and implementing the forestry operations. The two extreme types, characterised as the *Farm Forester* and the *Investor* are positioned at the opposite ends of the *involvement* axis. In practice, a number of arrangements and levels of involvement occur along the spectrum. We characterise industrial forestry as having an intermediate level of involvement, because while much of the forest management decision making and planning are performed using internal staff and resources, the actual operations are almost always performed by contractors (ie. outside resources).

We conclude that there at least two important aspects related to plantation types, scale and level of owner involvement.

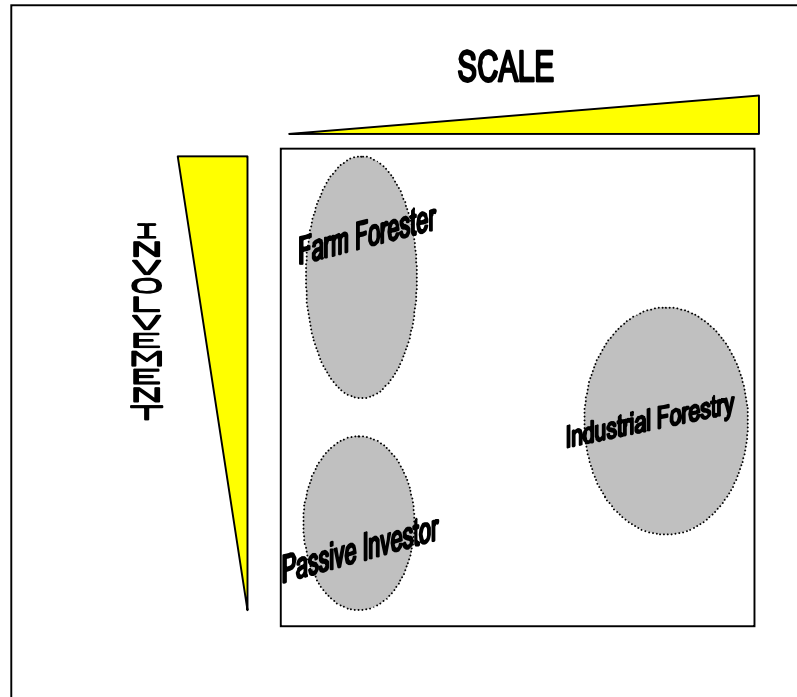


Figure 1 Relationship of farm forestry to other plantations

Regional Influences

Next we consider the implications of regional context. The first issue concerns the scale of processing industry. There are economies of scale in most timber processing operations, and in some cases (eg. pulp milling operations) these are very important. This has led development toward relatively few larger processing plants. Obviously the locations and log demands from these plants are key factors in regional log markets. The second issue, which follows from the needs of larger scale industry is existence and character of the regional *wood supply system*. Forest industry log input demands are more or less continuous throughout the year, and these need to be supported by a wood supply system that effectively supplies mill needs. The wood supply system is the complex of personnel, equipment and infrastructure that supports purchase, logging planning and the scheduling of harvesting and transport to achieve continuous log delivery. In most parts of Australia wood supply systems are currently tuned to supply from large industrial plantations and with timber harvesting and transport performed by dedicated specialist harvesting contractors. These plantations are usually serviced by good all weather roading systems, and if private plantations do not provide similar reliability, they can be at a competitive disadvantage.

The numbers and sizes of other forest plantations in the region are also of importance. Small scale farm-forestry is likely to be advantaged where there are a large number of small-scale plantations in a region, particularly when collectively these make up an appreciable component of mill log supplies, and have secured the important adaptation of the regional wood supply systems. Currently, the level of supply from small-scale plantations is small, and existing wood supply systems have not had to adapt to their needs. The desire by small-scale forest managers to conduct their own harvesting operations has been the exception rather than the rule. A large number of small-scale owners in a region also encourage the development of a competitive supply system for ancillary services such as nurseries and contractors.

3. Applicable Harvesting Technologies

This section reviews currently available timber harvesting technologies, and contrasts systems that we believe might be applicable to small-scale activities, with those that are used as part of a larger scale industrial approach.

Two alternative *styles* of farm plantation harvesting systems are described here. The *industrial style* assumes that harvesting operations would be implemented by contractors, and generally represents current practice in industrial operations. The *farm-forestry style* assumes that some part, or all of the operations would be undertaken with on-farm resources. Three harvesting methods are described, (1) shortwood, (2) tree-length and (3) in-forest chipping. All three are used to some degree in plantation harvesting in Australia and could find application in farm-forestry. Farm-forestry and industrial variants are described for each.

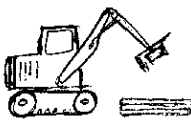
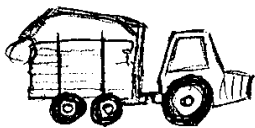
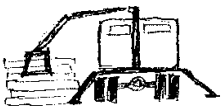
Shortwood or cut-to-length methods

This is currently the most widely used method of harvesting Australian plantations. Much of the equipment is imported from Scandinavia, where shortwood is also the dominant method. Trees are processed at the stump into as many as 4 -5 different log products according to tree quality and mill demand. Logs are extracted from the forest by forwarder. The forwarder is a purpose built self loading all-terrain forestry tractor – trailer combination. In farm application, farm tractors towing specialist trailers can perform similar functions.

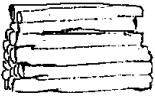
The industrial systems now use specialised mechanical equipment for most felling and processing. These harvesting machines are typically very capital intensive, and require high levels of utilisation to be economic. The farm-forestry based alternative would be based on the use of a chainsaw for felling and processing. Logs are stacked at roadside after forwarding, for later collection by log truck. In industrial applications, specialist loaders are used to load trucks, but in farm application, self loading trucks could be used. The system's advantages include:

- can extract small to intermediate sized wood efficiently
- extracting wood over considerable distances economically
- can separate and segregate different products, although separation can reduce efficiency.
- can operate at low damage levels in residual stands during thinning operations
- can operate with low visual impacts

An industrial example:

			
Harvester	Forwarder	Loader	Shortlog Truck

A farm-forestry example:

			
Chainsaw	Farm Tractor + Trailer	Log Stockpile	Self Loading Truck

Tree length or long-wood methods

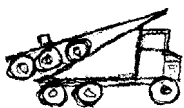
This method is the used commonly in clearfelling in many part of the world. Stems are extracted (generally by snigging or skidding) in the longest possible length to a landing where they are converted to log products. In some cases stems can even be transported to the mill in long length. The methods have some attraction for farm-forestry as lower cost skidding units can be used, although these can have limited capacity.

This method's advantages include:

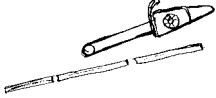
- able to harvest large logs
- suited to extraction over short to moderate distances
- good ability to recover many different log products at the landing
- can harvest over a wider range of terrain.

Tree length logging is generally not appropriate for thinning unless great care is taken to minimise damage to the remaining trees.

An industrial example:

			
Chainsaw	Grapple Skidder	Excavator Loader	Long length Truck

A farm forestry example:

			
Chainsaw	Modified Farm Tractor with winch or Skidder	Chainsaw crosscut to Shortlog at landing	Self Loading Truck

In-forest chipping methods

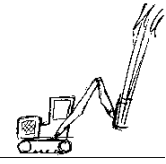
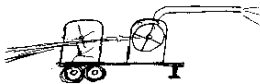
This method involves conversion of the logs to chips before transport, either at the stump, or more commonly at the landing. Chips can be suitable inputs for further manufacturing (eg. boards or pulp) or can be used for energy production.

Modern innovations have seen large chippers coupled to chain flail processors which remove limbs, bark and foliage before chipping. These combined units can meet clean chip specifications for most processes today. Chips can be produced at a low cost, and because trees and even limbs of a wide range of shapes and sizes can be economically chipped, the systems typically have high rates of wood recovery per unit area. However, while the systems are highly productive (50 to 70 tonnes per hour), they are also relatively immobile and not well suited to harvesting small tracts of forest. These systems are still at a disadvantage in some circumstances. Field chipping still cannot meet the stringent grit content and low bark content demanded for some paper making processes. Arrangements for the return of bark and limbs from the roadside flail are generally not very satisfactory and the removal of high levels of bark, limbs and foliage from the site can deplete soil nutrients and organic matter in some forest systems.

Where there is a market for energy wood, chip quality standards can be lower. Less precisely dimensioned chips can be produced, with a greater tolerance for grit, and even including bark and perhaps foliage permitting whole tree chipping methods to be used. This allows a much wider range of chipper to be used, including small, farm tractor mounted models, and also permits operations closer to the stump.

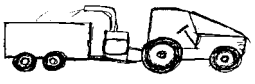
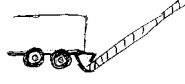
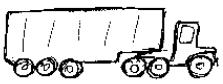
An industrial example:

Industrial Scale Chipping

			
<i>Feller Buncher</i>	<i>Grapple Skidder</i>	<i>Mobile Flail / Chipper</i>	<i>Chip Truck</i>

A farm forestry example:

Farm-Scale Chipping (Energy wood)

			
Chainsaw	Farm Chipper	Chip Loader	Chip Truck

Summary

Farm-forest harvesting can be undertaken either by contractors, or by using on-farm resources. Appropriate harvesting methods for the two alternative styles have been outlined. The system chosen by the farmer will need to fit in with the broader systems operating in the region and meet the needs of the customers.

4. International Experience with Small-Scale Forestry - A Literature Review

There is little literature detailing the harvesting of trees from small-scale Australian farm plantations, largely because our level of activity is low. Scandinavia (Sweden, Finland, Norway) and the US South and a number of other regions have far larger and more active areas of farm-based forestry activity. Scandinavia is notable because it has a high level of active involvement by farmers (small non-industrial private forest owners) in the forestry work and logging, and dominates the literature. Northern European countries have had a long association between farming and forestry. Their experience is relevant to our plantation operations because, although species, terrain and system of industrial organization are different, the operational practices and equipment are substantially the same as we derived our approach from their systems. In the US South however, tree sizes and types (eg. Pinus species) and the system of contractor organization are similar to ours, although the equipment and methods used are different and this provides another viewpoint. Much of the key literature is only published in Swedish and Finnish languages, and the project team was fortunate to have the multilingual skills to access these. English summaries were prepared (by Eeva Antilla) and these are presented in the more complete annotated bibliography (Appendix A).

Harvesting Operations

In the Scandinavian countries, a significant proportion of the industry's wood intake is sourced from farm forests. Wood is purchased directly by agents of the mills, or more commonly through farm-forestry cooperatives. In 1983/84, about ½ of the Swedish cut was obtained from non-industrial private forests Sennblad (1984), and about 1/3 of the work was performed by the farmer or his family. Similarly, in the 1989/90 logging season, 1/3 of the wood harvested from farms in Finland was sold at roadside (with the farmer responsible for the logging). A study by Uotila and Peltola (1990) in Finland highlighted the wide range of contractual agreements used between grower and buyer, permitting a range of types of involvement in the harvesting operations by the forest owner. The study compared farm income from (i) selling trees standing, (ii) sale at roadside using contractors to do the logging, and (iii) by the farmer doing the logging to roadside. Net income was increased by 9% if the farmers did their own felling delimbing and log- making, and by 37%, when farmers also did the forwarding (delivering wood stacked at roadside). In comparing the additional returns to Australian conditions, it should be noted that at the time, stumpages in Finland were at least twice as high as those in Australia.

There is, however, a shift in the types of equipment in use. In the earlier phases of mechanisation (1960's – 1970's) either small winches mounted to farm tractors, or tractors plus trailers which were either loaded by hand or by mechanical winches were used. A study by Koistinen (1991) showed that these were being replaced by four-wheel-drive farm tractors pulling trailers fitted with hydraulic cranes. Using data from earlier surveys also shows a small trend toward increasing use of contractors, especially in delimbing of thinnings and in forwarding in Finland. The ownership and use of specialised equipment was greater for farms with larger forest areas (> 50 ha). The survey indicated that younger farmer were less inclined to carry out all phases of the forest harvesting work and more inclined to use contractors.

This development may also be consistent with the needs of small-scale plantation owners in Australia. The prime requirement is for a capacity to deliver wood to roadside so that large trucks have reliable access to the wood. The distance from stump to roadside may be considerable. Purchase of specialist equipment may be difficult for small-scale owners to justify for their own property, but can be justified by one owner who gains work in other small-scale forests servicing the needs of a group.

At a small-scale forestry conference in New Zealand, Olsen (1985), suggested that while smaller landowners might attempt all or part of the logging with their own equipment, less than 5% were considered competent in harvesting. He concluded that most would be better served by employing a contractor. He believed that the small tract size had a major effect, limiting the scale of operations due to the short life of each operation, and creating discontinuity of forward work, high relocation costs and marketing problems. Concerns over access and roading, given that small holdings having virtually no internal access roads, were also raised. At the same conference, Fraser (1985) argued that in logging of plantations in New Zealand, economies of scale are achieved through the application of appropriate technology of production rather than through specialisation and division of labour. In small-scale logging, he argues that the key factors are the level of production and fixed costs.

In the US South, most of the wood used by industry is also obtained from private forest lands, much of in from small areas. However, most of the actual logging work is done by contractors. In a comparative analysis of the wood supply systems of the southern United States and Sweden, Laestadius (1990) identified significant differences in *style* of technologies adopted. Both countries rely heavily on small tracts of privately-owned forest to meet the wood supply needs of their industries. His observations were that the way fluctuations in wood supply and demand were accommodated was central to understanding their differences. In Sweden fluctuations were accommodated by maintaining large stockpiles of wood, allowing harvesting operations, with their considerable investments in specialised equipment and skills, to produce at a high level. It also allows farmers to log at their own rate, delivering to roadside stockpile. In the US South this adjustment was made by varying the output of a less sophisticated harvesting technology while minimising wood stockpiles. This requires stop/start operations that respond on a relatively short time frame. Coordination of farmer produced wood is correspondingly more difficult. An ability to stockpile may be one of the key requirements of a high level of farmer involvement in logging.

Silvicultural Operations

Koistinen's (1991) study of some 2790 woodlots in Finland, found that most silvicultural work was done by on-farm labour, including family members, compared with only about 40% of the harvesting. Silvicultural work includes site preparation, planting, weeding etc.).

Natural regeneration was the most common means of regenerating woodlots and this led to tending / weeding and pruning being the major silvicultural tasks undertaken. Silvicultural tasks such as re-establishment, fertilizing, weed control, tending/spacing, pruning, annual maintenance and protection from fire and wildlife on small forest tracts can be efficiently implemented using on-farm labour and equipment. People are 'on the job', and many of the tasks can be done in small parts as time becomes available and carry low overheads, and these factors help offset the disadvantages of small tract size. These operations add value to a farm forest by accelerating growth and by increasing the quality and value of the log products. It appears that these other silvicultural jobs may be more attractive to farmers than harvesting, where there are limits on availability or willingness of on-farm resources.

Vihlhelmson (1990) sought the views of selected farmers in Sweden as to how they might increase their farm income. The main opportunity identified was for *some* farmers to increase their amount of forestry work – silvicultural and harvesting - on both their own and on their neighbours' forests. These conclusions were reached against a background of an increasing proportion of private forests being

controlled by absentee owners and an ageing farmer population, many of whom may not wish to do the silvicultural and harvesting work. This study highlights the opportunity for farmers who wish to extend their income from trees and are prepared to invest in acquiring the skills and equipment to provide services to other forest owners. There is some evidence that such operators are better suited to small tracts of forest and are more acceptable to small-scale forest owners than are the larger industrial contractors.

Table 1 Self employment of private woodlot owners in silvicultural work

Treatment	Percentage of all woodlots treated.	Percentage of treated area worked by farm labour	Percentage of treated woodlots worked by farm labour
Clearing	31	61	71
Site preparation	4	18	32
Planting	17	51	64
Sowing	2	78	72
Weeding	16	86	91
Tending stands	44	73	82
Pruning	5	82	89
Fertilization	5	36	57

Source Koistinen (1991) *Table 2. Self employment of private woodlot owners in silvicultural work on woodlots at least 5 hectares*

Summary

In both Scandinavia and southern USA, relatively small tracts of privately- owned forest supply a high proportion of the log intake for their internationally- competitive forest industries. Both are characterised by large total areas of existing forest and highly organised (but very different) harvesting, distribution and marketing systems. These conditions don't yet exist in Australia with the possible exception of Tasmania.

Scandinavian farmers have traditionally been directly involved in silvicultural and harvesting operations and have drawn a significant component of their income from the forest. Growing larger and more valuable trees that are less expensive to harvest is seen as an alternative opportunity for the input of on-farm labour and equipment. There is a trend towards a declining involvement of farmers in harvesting as these operations become more capital- and skill-intensive and farmers get older. This represents an opportunity for some farmers to augment their income by offering their services on a contract basis to other landowners.

A characteristic of the Scandinavian wood supply system is the development of a harvesting technology that delivers the wood to roadside landings that are accessible to a highly efficient road transport system. Modern 60-80 kW, four-wheel-drive tractors and self-loading trailers are central to this capacity.

Another important feature is the wide range of agreements that exist between wood buyers and farmers that allows the farmer to participate in parts of the harvesting process. Provision is often made for the farmer to do some of the work in collaboration with a cooperative or contractor.

Laestadius (1990) reminds us of the need to think in terms of a total wood supply system and of how cultural considerations mould the development of these systems.

5. Small-Scale Forest Harvesting Case Studies

A small number of forest –farmers were selected for case studies as a first stage to assess the key issues related to harvesting trees on farms. This phase was intended to be followed by a broader, sample based approach.

Arrangements were completed for studies to be made of six farm-forest harvesting operations. Each site was visited, and where possible short studies made of operations. Much of the information was obtained by interview and we also sought to establish indicative cost and productivity information.

Case Study 1. South East Victoria - *Pinus radiata* plantation

Site Information

The plantation is located within 40 km of a pulp mill. The plantation was established on fertile red, grey and sandy loams with an average slope of 25°. Rainfall averages 1000 mm per annum. Harvesting conditions are most favourable in the summer months, but still occurs in the wetter months on selected sites. During winter the farmer is in a good position to monitor the weather and site conditions and can begin harvesting almost immediately should there be three or more days without rainfall.

The Resource

The farmer planted his first site approximately 40 years ago. Currently he is involved in first, second, third, fourth thinning and clear fell harvest operations. His work habits and harvesting systems differ significantly from normal commercial harvest operations. The plantation estate totals 20 ha of varying ages of pine (1 - 40 years) at various stocking rates.

Marketing

The farmer has had a range of contracts to supply pulp and sawlogs to the pulp mill and affiliated saw mill for many years. The numerous contracts made management and administration difficult for the farmer, causing him great anxiety. To simplify matters the farmer negotiated a single contract with a single price structure. The contract allowed him to supply a range of logs (first thinning through to 40-year-old sawlog-quality logs) for a single flat rate.

The owner was supplying only pulpwood at the time of the study, even though some of the logs were of sawlog grade. In fact the diameter of some of the potential sawlogs exceeded the maximum diameter allowable by the pulp mill so these logs were split to pass them as pulp wood. When questioned as to why he downgraded the logs to pulp he indicated that the time and effort required to meet the stringent sawlog specifications was not worth the extra \$10 per m³ he would receive for them.

Harvesting System

The farmer was nearing retirement age and worked alone for most of the time. All trees were felled using a chainsaw, logs were skidded out using a Ferguson 399 4WD farm tractor (100 hp) and loaded onto a custom-built forwarder made up of a Fiat 6066 4WD farm tractor and trailer (6 tonne load capacity). The trailer was modified with a crane and grapple attachment for loading. The farmer also owned an International 1900 truck (190 HP and 12 tonne load capacity) used for haulage to the mill.

Yield and Income

For all thinning and clear fell harvest operations combined, the farmer estimated a yield of 500 m³ per hectare. However for the purpose of this analysis he was unable to determine the yield for the first thinning operation alone. The farmer did not record costs associated with each harvest operation. His 'gut feeling' was that first thinnings were a break-even operation and that costs halved for each subsequent thinning operation due to the increasing yield per tree harvested.

General Observations

The farmer has been harvesting trees on his property for 20 years and has developed work habits and systems that suit his lifestyle and personal capacity.

His ingenuity in developing a custom-built forwarder is to be admired, but the occupational health and safety implications of his working alone might be questioned.

Operational efficiency and environmental acceptability of his harvest operation could not be thoroughly assessed within the time frame allowed for this report.

Case Study 2. South East Victoria - *Pinus radiata* plantation

Site Information

The plantation is located within 35 km of a pulp mill. The plantation was established on a grey clay loam with an average slope of 12°. Rainfall averages 1100 mm per annum. Harvesting is most favourable in the summer months, but is attempted all year round. As with the first case study the farmer was in a good position to recommence harvesting almost immediately if the conditions become favourable two or three days after rain.

The Resource

The farmer planted his first site approximately 18 years ago. At the time of the study he was involved in a clear fell harvest operation of 8 ha. from a total of 45 ha. of pine plantation and 20 ha. of blue gum plantations. The current site had undergone two previous thinning operations but, following an inspection, the pulpmill's purchasing officer advised him that the remaining trees would only ever meet pulp specifications, and as a result the farmer was clear felling the site in readiness to replant with blue gums.

Harvesting System

The farmer and his son carried out all the felling, extraction and haulage to market. The son did the physical work whilst the farmer drove the vehicles.

The trees were felled using a chainsaw. On the steeper sites logs were skidded out using a Timberjack 230D (100 hp). Logs were then transferred to a second-hand Volvo 971 forwarder. Wherever possible logs were loaded directly on to the forwarder. The forwarder then travelled up to 500 m over dairy pasture paddocks to transfer the logs onto an International 2150B single-axle rig with jinker trailer (150 hp). The truck has a 15 m³ capacity. The two-person team harvested about 7.5 m³ per day and had a contract to deliver 75 m³ per fortnight.

Yield and Income

The clear fell operation yielded about 470 m³ per ha for a total of about 3760 m³. Income for logs delivered to the mill was about \$36 / m³.

General Observations

The farmer and his son appeared to run an efficient operation. The machinery used, whilst being second hand, was of an industrial standard. He acknowledged that he was over-capitalised, but believed that the greater productivity of the machines was worth the risk. He also noted that if the forwarder, for example, required a new transmission he would be unable to afford the repair.

Case Study 3. South East Victoria - *Pinus radiata* plantation

Site Information

The plantation was established over three consecutive years commencing in 1976 by the father of the present owners. The soil is a clay loam. The site was planted to pine in areas identified by the farmer as marginal agricultural land. As a result the plantation was placed on slopes averaging 20°. Rainfall averages 1143 mm per annum and the site is generally accessible only in the drier months of the year.

Due to the steepness of the slopes the owners, who are professional logging and haulage contractors, indicated that in the normal course of business they would not attempt to harvest such a site with their mechanised harvesting equipment.

The Resource

During the study, approximately 24 ha out of a total plantation holding of 55 ha were treated with a first thinning. Stocking rate before harvest was 1500 and after the thinning was 600 stems / ha with most of the thinnings being sold for pulp.

Marketing

The owners sought and negotiated a contract with a local pulpmill to supply pulplogs and a small number of sawlogs to a nearby sawmill.

Harvesting System

The harvesting equipment employed for this site was industrial type and fully mechanised. The equipment used for this operation represents the standard industrial alternative to farmers carrying out their own harvesting, especially on sites with slopes less than 20° and with access to good roads. Felling and processing was done by a professional crew, whilst the extraction and haulage was done by the owners themselves. Trees were felled using a Timberjack 990 with a 762 grapple processing head and extracted using a Timberjack 1210 forwarder with a 14 tonne load capacity. The logs were transported to market 44 km away using a Volvo F16 truck(500 hp) with tri-axe trailer.

Income and Cost Chain Analysis

Total yield from thinning of 24 ha of plantation was about 3850 m³. Income was about \$43 per m³ delivered to mill. Total costs for the harvest operation were unknown, but the owners noted from past experience that first-thinning harvests such as this are at best a break even situation, especially given the steepness of the site and difficulties of access for the heavy equipment.

As a general estimation, the owners believe the felling and extraction stages were unusually expensive due to difficulties of access and the steepness of many of the slopes. However they believe that in this situation they would still be able to cover most if not all of the additional costs from stumpage income.

General Observations

At the time of the interview the harvest had just been completed so that a study of the occupational health and safety issues was not possible and the operational efficiency and environmental acceptability of the harvest could not be assessed.

The owners believed that longer-term financial benefits would be achieved by thinning their plantation. They were fortunate to have the equipment, personnel and finance to carry out the silvicultural work and look forward to greater returns in the future.

Case Study 4. North East Victoria - *Pinus radiata* plantation

Site Information

The plantation is located in the North East Victoria and has an average slope of 12°. Rainfall averages 750 mm per annum. The harvesting season was restricted to the period between November through to May. Access to the farm was restricted to a single poorly formed earth track. Truck access for loading logs for haulage was also restricted to one location near the front gate to the property.

The Resource

Approximately 40 ha of pine were planted by the owners over three consecutive years commencing in 1976. The mean annual increment (MAI) has been estimated by the farmer at 20 m³/ha/yr. Half the plantation was undergoing a second thinning, reducing the stocking rate from 900 stems down to 450 stems per ha.

Marketing

Distance to markets ranged from 35 km for posts and poles to as far as 120 km for sawlogs. The post and pole products were debarked and air dried on site then bundled and packaged to suit individual orders.

The owners held no long-term supply contracts, and orders and markets were constantly changing. The uncertainty of the markets was an obvious source of concern and made harvest scheduling extremely difficult.

Harvesting System

The farmer was not actively involved in the physical components of the harvest, concentrating on marketing and overall supervision and planning. The actual harvesting work was carried out by full-time employees of a company set up by the contractor and part financed by the farmer. Their intention was to provide a harvesting service for other small plantations within the immediate area, once they managed to reduce costs of the operation.

This case study was significantly different from the others because the plantation owner did not have a single buyer for his produce. The sawlogs were marketed to three different buyers with approximately a third going to each buyer.

The farmer was experimenting with the posts and poles market for vineyards. The contractor purchased a mobile debarking machine that runs off the back of an old farm tractor. The small-diameter logs were debarked, sorted into diameter classes and air dried, bundled and sent for preservation.

Yield and Income

Estimates of yield for the second thinning are presented in Table 2.

Costs of felling and extraction were estimated initially to be as high as \$60/m³ but were around \$38/m³ at the time of study. They were hoping to further reduce the costs to about \$25/m³. Haulage costs were only available as a combined total for haulage to all destinations and was estimated at \$14.36/m³.

Table 2 Product yields and distance to market for Case Study 4

Product	Yield (m ³ /ha)	Distance to market and % of total product		
Sawlog	70	35km (33%)	65km (33%)	120km (33%)
Pulp	16	85km (100%)		
Preservation	5	Road side (100%)		

Sale prices for the various products differed depending on the destination, for example sawlogs delivered to market 65 km away gained a price of \$50/m³ whilst sawlogs delivered at a distance almost twice that (120 km) obtained a sales price about \$60/ m³.

The markets for preservation products were reported as some what better. In preliminary trials the venture was making a good profit. However the markets for such products were also regarded as insecure and unpredictable.

Case Study 5. South West Victoria - *Pinus radiata* plantation

Site Information

The plantation is located in South West Victoria on the coast. The soil is a clay loam prone to waterlogging. The slope within the plantation averages 18°. Rainfall averages 1780 mm per annum. Harvesting can occur only during the drier months of the year. On average harvesting can occur on only 130 days per year.

The Resource

The farmer has 13 ha of plantation. The harvest area was 4 ha and the operation was a clearfelling. The MAI was estimated by the owner at 35 m³/ha/yr. Stocking before harvest was 600 stems/ha.

Marketing

The farmer normally employed contractors to harvest his plantations. He had not planned to harvest any of his plantations in the study year because the stumpage had fallen from \$35/m³ the previous year to under \$30. The harvest eventuated because a native forest contractor approached him about the possibility of harvesting some of his plantation offering to pay a stumpage of \$30/m³. No formal legal contract was entered into.

Harvesting Details

The contractor had a crew of three. All felling is done manually using a chainsaw and skidded out using a Caterpillar D7 dozer (180 hp) and then loaded onto a Mack Valueliner 350 which has a maximum capacity of 26 m³.

Income

The only information available was the stumpage rate of \$30/m³. Costs of the harvest operation for the contractor were unknown.

General Observations

The site being harvested was being severely degraded due to use of inappropriate machinery for this site and type of plantation. The owners were concerned about the conduct of the operation, but had little influence short of halting the harvest.

Past experience by the farmer of using contractors has not been entirely satisfactory. This is the fifth contractor in as many years to harvest trees on the farmer's property. A brief inspection of the farm revealed plantations that had been stripped of the best trees and then abandoned, piles of lower quality logs and harvest waste not properly cleaned up and a site that require extensive site preparation to return it to a state of productivity.

Case Study 6. South East Victoria - Mixed species native forest

Site Information

The small area of native forest is located within 46 km of a pulpmill. The soil is a light grey loam with an average slope of 10°. Average rainfall is 1270 mm per annum. Harvesting activity is generally restricted to the months of November to June.

The Resource

The farmer has about 40 ha of mixed species native forest on his property and of that total approximately 8 ha was harvested using a clearfell silvicultural regime. The stand was 57-year-old regrowth from the 1939 Victorian bushfire and had not been previously managed for timber production.

Marketing

The farmer sought and received a contract to supply his pulplogs to the nearby pulpmill. The harvest produced an extremely small volume of sawlogs which were retained by the farmer for his own processing and consumption. The farmer intended to use the sawn timber in the construction of a new house.

Harvesting Details

The farmer felled approximately 10% of the site whilst a neighbour was employed to fell the remaining 90%. The logs were extracted, loaded and transported to the Maryvale mill by the farmer using entirely his own equipment.

All trees were felled and cross-cut using a standard farm chainsaw. The logs were then extracted to a landing dump using a Caterpillar D4E (75 hp). A Caterpillar 930 (75 hp) loader was then used to load the logs.

Yield and Income

Total yield from the job was about 2000 m³. Income was about \$36 m³ at the mill door. The farmer was in a position to do most of the harvesting operation, particularly the extraction and haulage components and as a result his contract with the Maryvale mill included provisions for payment to the farmer for the harvesting, extraction and haulage to the mill.

General Observations

At the time of the interview the harvest had just been completed so occupational health and safety issues, operational efficiency and environmental acceptability of the harvest could not be assessed. Even though the farmer did not know the costs associated with his work, he was impressed that his bank balance had increased sufficiently to allow investment in on-farm capital improvements such as fencing and pasture improvement.

Discussion of Case Studies

The summary of results from the case studies (Table 3) illustrates a number of important aspects of farm forest harvesting. None of the owners kept comprehensive details of harvesting costs and they could only provide a guess of actual costs. It was not generally possible to differentiate between the three stages of harvesting (cutting, extraction and haulage). Also, as farmers often aggregated the running cost of machinery and equipment across all farm activities, certain costs had to be artificially separated from other on-farm activities employed in traditional agriculture.

The case studies covered harvest tract sizes of 4-24 ha. They all supplied wood to conventional industry and appeared to receive prices (at the mill door) comparable to those received for wood from normal industrial operations. In a number of the cases, however the returns to the farm grower, however, after costs, appeared to be considerably less for the farm wood than those received by industrial growers

The cases illustrate a number of the possible reasons. In one case, the cutting and extraction costs (Case 4) were particularly high (\$38.00). The apparent reason in this case was that the operators were still developing their equipment and methods. Overall, the estimate of cutting and extraction costs ranged from \$15 to \$19 per m³ in early thinnings and down to \$13.45 for clearfell. Anecdotal evidence from comparable industrial operations at the time indicated costs of \$14 to \$16 per m³ for thinning and \$8 to \$10 for late thinning and clearfell. Direct comparison is difficult, however, as the industrial-scale costs represent 'best practice', while appropriate methods and techniques for the small-scale operations are still under development.

Table 3. Summary of case studies

	Activity	Costs (\$/m ³)			Yield (m ³ /ha)	Income (\$/m ³)
		Cutting	Extracting	Haulage		
Case Study 1	Thin 1 (pine)	15.00	12.00	8.00 (40 km)	500 (Average over T1-T4 & CF)	15.00 (stump) 50.00 (delivered)
Case Study 2	Clearfell (pine)	13.45	Included in cutting	7.70 (35 km)	470	15.00 (stump) 36.15 (delivered)
Case Study 3	Thin 1 (pine)	19.77	Included in cutting	8.36 (44 km)	160	15.00 (stump) 43.00 (delivered) (contract price)
Case Study 4	Thin 2 (pine)	38.00 (including debarking)	Included in cutting	14.35 average cost over 35 - 120 km)	91	Pulp 30.00 delivered Saw 50.00 delivered Presrv 90.00 (dried) own marketing
Case Study 5	Clearfell (pine)	-	-	N/A	200	30.00 (stump)
Case Study 6	Clearfell (native)	18.23	Included in cutting	10.12	250	7.23 (stump) 35.58 (delivered)

Thin 1, T1 = first thinning Thin 2 = second thinning CF = Clearfall

Haulage cost estimates ranged from \$8.00 to \$8.36 for first thinnings, down to \$7.70 for clearfell in Case Study 2. Again the costs for Case 4 (\$14.35) were high compared with all other operations, but this is explained by a considerably greater haul distance (120 km) for the preservation material. Overall, haulage prices depend most strongly on distance and truck size and in the case studies they appeared to be comparable with those of industrial-scale operations.

Estimates of net income are subject to a number of sources of variation. Operational costs and mill door sales price vary with the type of product (eg. lower-value early thinnings, late thinnings, or higher-value clear fell logs). Net returns can only be estimated after operational costs are deducted, and true operational costs are difficult to establish in the short run. Increased operational costs result in lower net returns. This was particularly the case for first thinnings where it was recognised by farm forest owners that they might, at best, break-even. This can also occur in industrial forestry operations.

With the exception of Case Study 3, where specialist mechanised equipment was used by the contractor-forest owner, damage to the site and to the quality of the residual stands appeared high and would be unlikely to be acceptable in industrial forestry.

Machinery selection was not always appropriate (Case Study 5) and the relative complexity and /or unfamiliarity related to log grading led at least one of the farmers to produce low-value assortments (pulpwood only). Limited capital to invest in and to maintain equipment was common to most case studies. The lack of readily available technical advice on harvesting and marketing practices was a constraint for those undertaking the operation themselves, and even where the work was contracted out.

Conclusion

Indications obtained from the six case studies in Victoria suggest that harvesting costs of the small-scale operations are higher than for industrial-scale operations. Whether this was because of scale or the 'quality' of the operations is not clear. The operations studied were characterised by:

- 'Makeshift' equipment - farmers were still experimenting with methods and equipment in some cases
- Limited knowledge of harvesting practices and product specifications
- Little encouragement or support in developing their operations
- Poor or non-existent medium / long-term marketing arrangements.

The operations reflected a lack of business experience and technical knowledge related to the particular forestry operations. However, the review of farm forestry in other countries points to a significant role by small-scale operations, although the exact form this takes does vary from country to country. Further, the operations studied were at an early stage of development and obvious improvements could be made. It was apparent that even where the work was contracted out, out-comes were sometimes poor, explained by either lack of appropriate technical knowledge or ineffective contracts.

6. Postal Survey of Farm Forestry

In the next phase of this project, farm-forest owners in Victoria were surveyed to assess their intentions with respect to both harvesting and processing of wood. The survey focussed on intentions for the summer of 1996/97 and sought to find out:

- who was going to harvest the trees,
- the expected volume of the harvest,
- the anticipated products.

It was intended that a representative sample of respondents would then be contacted for follow-up interviews and operations assessments.

Survey Design and Data Collection

The Agroforestry-News address data base was selected as most likely to provide access to the largest group of farm forest owners in Victoria. Nine questions were asked, and of these, four focused on identifying harvesting operation, four identifying processing operations and one question sought consent for further contact in relation to involvement in the research program. A copy of the survey is presented in Appendix 2. The harvesting component of the survey was restricted to harvesting intention in the then current season, and made no attempt to determine either prior or intended future level of harvesting. The survey was posted in September 1996 to over 2168 subscribers of the Agroforestry-News within Victoria.

Results

The response rate to the survey was 43.4% (940 replies from the 2168 surveys posted). The South-West network achieved the lowest response rate of only 14% whilst the best was achieved by the Shepparton network (Figure 2).

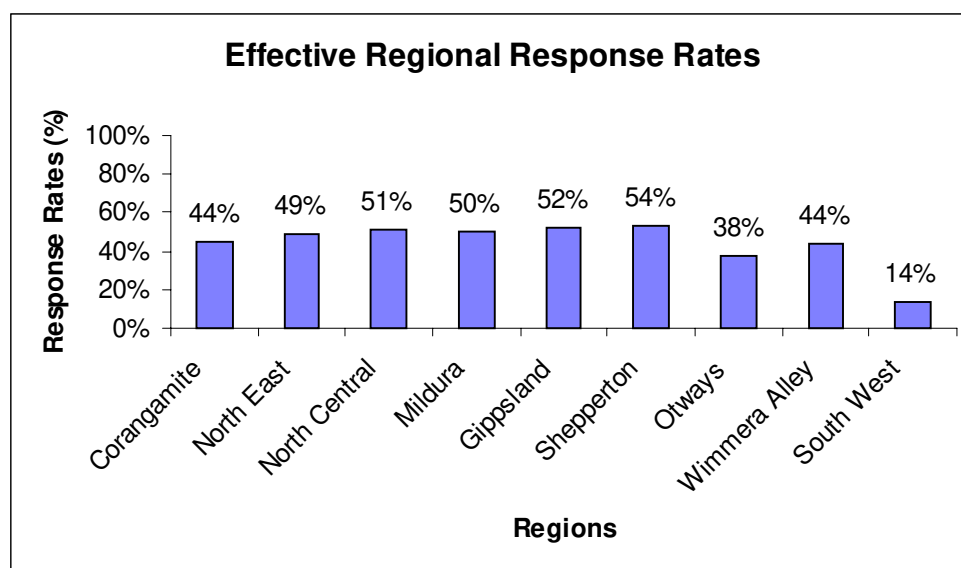


Figure 2. Rate of response from various regions of Victoria to mail survey.

Unfortunately, most respondents were not planning to undertake either harvesting or processing within the time frame of the research (Figure 3). Some 2% of respondents were planning harvesting but requested that they not be contacted for any further information. Overall 5% (47) of respondents were involved in harvesting and authorised further contact.

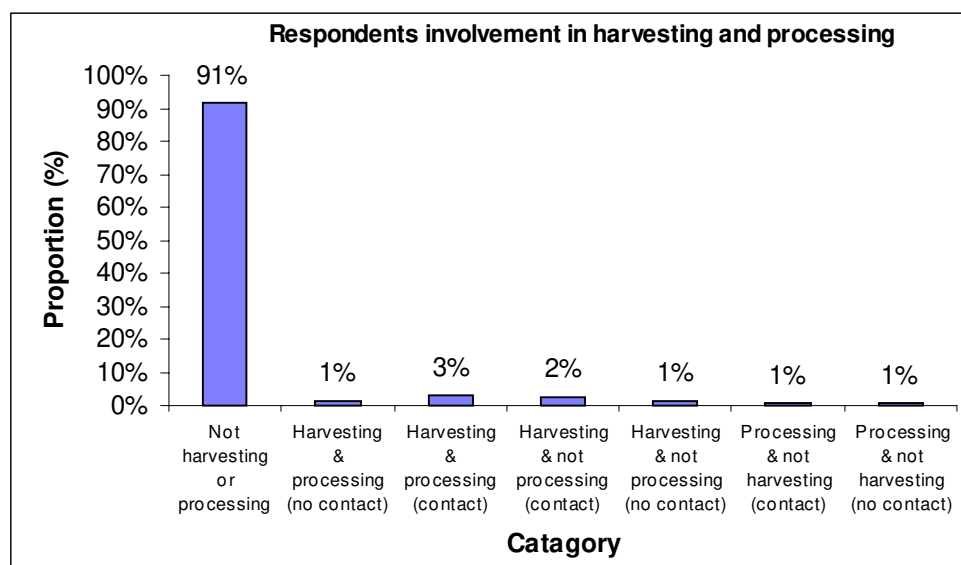


Figure 3. Breakdown of involvement in harvesting and processing trees on farms.

Most (83%) of the respondents who were planning to harvest and who gave permission for contact were harvesting relatively small volumes (less than 500 m³ over a six-month period). Almost half of the 47 respondents were harvesting less than 25 m³ over a six-month period; many of the respondents were harvesting only a single tree.

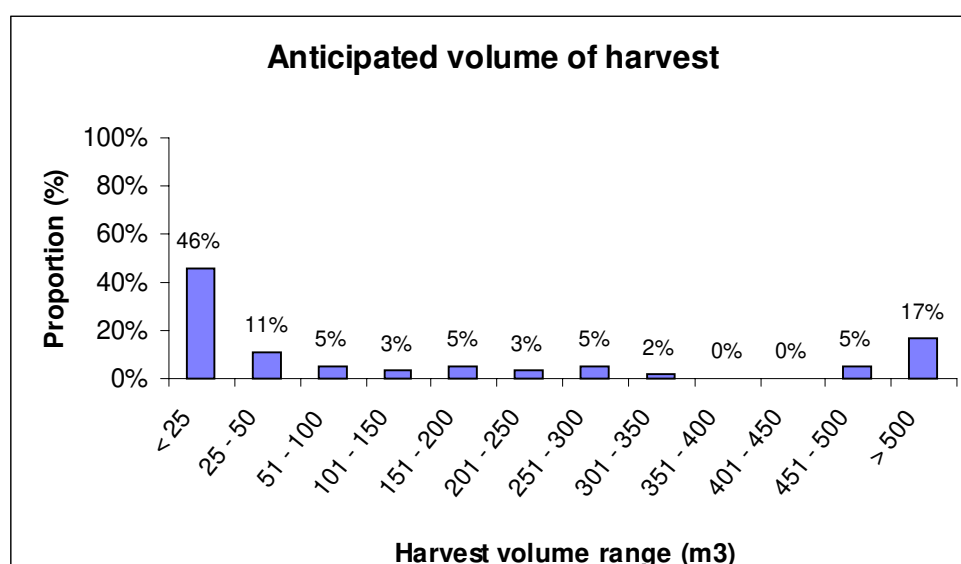


Figure 4. Volume output of all harvest operations over the projected six-month harvest season.

More than half (55%) of the operations were expected to be conducted by family members (Figure 5). Contractors were expected to be employed in about 30% of cases.

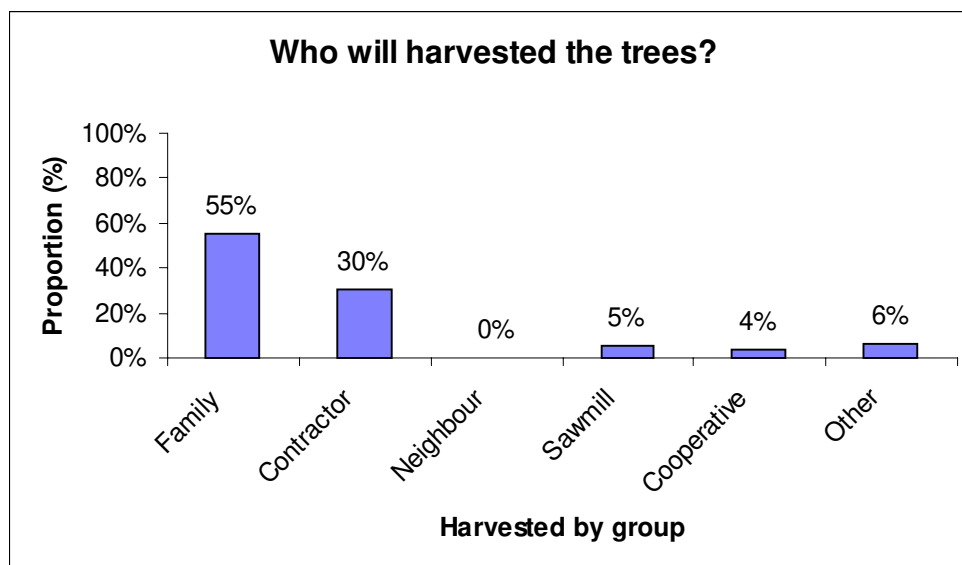


Figure 5. The different groups likely to conduct the harvest over the projected six-month harvest season.

Of the eight respondents (17%) that were both planning to harvest significant volumes and were prepared to assist through further contact, two had already been studied in the earlier case study phase, and one was not actually ready to harvest. The remaining five cases were evaluated in detail, but did not yield any new opportunity for field study.

Discussion of Postal Survey

It can be concluded from the high response rate that there is considerable interest in agro-forestry. Unfortunately, with the then current state and age of wood-lot development and possibly limited market opportunities in Victoria, there was a very low level of harvesting activity. This proved to be a major limitation in this research.

7. Costs Considerations for Harvesting of Trees on Farms

This section presents an analysis of the sources of additional cost for harvesting of trees on farms, as compared to large-scale industrial plantation forestry. A major result from the survey (previous section) was the conclusion that there was not a pool of active farm-forestry operations harvesting trees in Victoria. This precluded studies of actual farm operations as a source of data for cost analysis. The issue is one of considerable importance to the viability of small-scale farm forestry. Higher farm related costs would severely reduce farm forest profitability. Conversely, there are opportunities in the use of on-farm equipment and labour might be a competitive advantage. In the absence of actual study data we have undertaken a theoretical analysis of the likely costs. This has been done in three sections. In the first, we identify major sources of likely additional cost. In the next section we describe the development of a spreadsheet cost model implemented to assist in comparative analysis. In the last part, we describe results from a comparative analysis of expected costs for different harvesting relocation distances and differing harvested volumes.

Cost considerations for harvesting trees on farms

Two broad types of arrangement are used for harvesting trees on farms, (1) use of on-farm resources of labour and equipment (the *on-farm* model), or (2) the use of *off-farm* resources – the *contractor* model. We were unable to obtain useful estimates of the costs for operations for the on-farm model because candidate operations were not available for study (as described above in the case studies). This part of the industry is in a preliminary stage of development, at least in Victoria. We were restricted, therefore, to a more theoretical evaluation of the alternative model, the use of off-farm contractors. We adopted an approach of identifying the likely sources of additional costs associated with small-scale forestry operations as compared to industrial large-scale practice.

Sources of 'One-off' Cost

Sources of one-off cost that might be of particular significance to a small-scale / farm forest harvesting operation include

1. Negotiation Costs (with government, contractors, and wood buyers).
2. Site reconnaissance and planning,
3. Equipment relocation to the job site, and
4. Roading or other costs required to ensure transport access.

These costs may be incurred by the farmer, the contractor or the purchasers, or all three.

1 Negotiation Costs

Harvesting operations can require negotiations by the forest owner with harvesting contractors, log purchasers, and possibly government and Code of Practice regulators. The time and effort required for these discussions is not necessarily in direct proportion to the volumes being harvested. In some cases it takes as long to negotiate a small job as a large one.

Negotiation costs between farmers and contractors are more likely to be more efficient and less time consuming where the farmer has prior experience in contracting-out operations on his farm forest. Where farmers are unfamiliar with the nature and requirements of harvesting operations, negotiations can take longer, and there may be increased risk of dispute during and after operations, for example regarding issues such as tolerable levels of damage to site / stand / farm road / fences.

Farm-forest managers need an adequate understanding of customer requirements in regard to log specification and delivery procedures to effectively negotiate sales contracts and supervise operations. Developing this understanding can be a time-consuming task and can lead to higher *first-time* costs.

In this analysis, negotiation is considered as a lumped time and travel cost. Contractors are also likely to include an additional margin for risk in their pricing where they perceive the potential for increased dispute or disruption stemming from unfamiliarity with harvesting on the part of the owner.

2 Site Reconnaissance and Planning

These depend largely on expected harvesting difficulty. From the viewpoint of harvesting, farm forestry blocks can be classified firstly according to terrain (flat or steep) and secondly, according to truck access (good access or having special transport problems

Figure 6). Quadrants other than **Flat / Good Access** are most likely to incur higher cost levels.

For **Flat** sites, reconnaissance related to harvesting may require only a boundary check, with an emphasis on locating restrictive fencing distances and ensuring accessibility for equipment. **Steep** sites are generally those over about 20° for plantation forestry, where conventional operations of ground-based equipment is difficult, dangerous, or no longer possible. Usually, some form of specialist cable extraction machinery is required for steep land. Operation of these systems is usually expensive and requires detailed specialist planning and operator skills.

The adequacy of roading in farm-forest stands for harvesting and log transport can be problematic. Assessment of both the local public road infrastructure as well as on-farm access is required. In regions where large trucks are routinely used for other agricultural purposes (e.g. transport of animals, or products such as milk), **Good Access** conditions to the farm gate can often be established easily. In other areas, the public road network servicing farms sometimes includes older low-load-capacity bridges which cannot carry fully-laden log trucks, and alternative routing might be required. The weight and dimensions of some harvesting machines can require specialised transporters which cannot negotiate tight corners.

	<i>GOOD ACCESS</i>	<i>POOR ACCESS</i>
<i>FLAT</i>	• Conventional equipment may be used • Low planning requirement for both harvesting and truck transport	• Conventional equipment may be used • Low planning requirement for harvesting , but extra work to plan access
<i>STEEP</i>	• Specialised equipment must be used (or, at lower margin, conventional equipment used with great care and increased risk of environmental harm) • Planning costs high. This is a rare case, as steep terrain is usually associated with poor access.	• Specialised equipment must be used (or, at lower margin, conventional equipment used with great care and increased risk of environmental harm) • Planning costs for both harvesting and road access planning are high

Figure 6. Classification of farm forestry sites

In much of conventional agriculture, large trucks do not enter the farm past selected loading points. Farm tractors and other specialised equipment is used for on-farm transport and this is usually equipped with larger, lower pressure tyres suited to transport operations on unprepared surfaces. Farm equipment can usually negotiate considerably tighter corners and steeper grade changes than conventional road trucks. As a result, on-farm truck access conditions for the larger articulated truck-trailer combinations conventionally used to haul logs is often **Poor Access**. Seasonal reliability of on-farm access can also be a difficulty with reliance on natural soil surfaced tracks which rapidly become impassable in wet weather. Dry weather access 'across paddock' can sometimes be used, potentially changing the access class to "seasonally" **Good**. Reconnaissance and planning to locate and overcome on-farm access difficulties can be a time-consuming task. The combination of **Steep** terrain with **Poor Access** can require detailed planning of special on-farm roads, with attendant costs. In this analysis, job reconnaissance and planning times are considered as a time and wage cost, and are included in the costing model as part of the total sum in the coupe setup costs.

3 Equipment Relocation

There are two components of relocation cost which should be considered in a comparison with industrial forestry practice. The first is actual transportation cost for equipment removal to the new site. The second is associated with the lost productive time of the harvesting system, assuming transfer occurs during normal working hours. The cost may be approximated by the time taken for the move and hourly standing charge estimated from an accounting model. When sites are relatively close, rubber tyred machines such as forwarders can sometimes be driven, where road conditions permit. Driving speeds are usually slow for harvesting machinery, limiting transfer distances to a usual maximum of 10-20 km (where the machinery can be driven on the road at all).

4 Road Construction Costs

Additional construction or modification and upgrading of existing road structures can be required for successful harvesting of farm forest blocks. Secure, all-weather road access is very useful for the management of forests and supports the continuity of wood supply schedules for forest industries. Most larger-scale industrial plantation forests have this and this is a significant advantage. Where on-farm access can economically be upgraded to similar standards, the expenditure can be regarded as a significant longer-term asset. Forests without secure access may be at a disadvantage.

One alternative to expenditure on road construction is to use primary transport equipment (e.g. forwarders), or a secondary intermediate transport phase, to transfer timber from the forest block to a roadside location accessible to conventional truck transport. Forwarders are typically equipped with larger tyres and exert lower ground pressure than road trucks, and can operate on soils with somewhat lower load-bearing capacity (e.g. wetter conditions). However, the degree of relief obtained from this measure can be limited because the continued operations required to maintain delivery schedules in wet weather often lead quickly to deep rutting, and closure of haulage.

8. Implementing the Small-Scale Harvesting Cost Estimator

The cost model estimates the total system cost for the full period required to harvest the specified forest block. The model is implemented as an Excel spreadsheet (Version 97). It has four main sections:

1. job and production specification table, including once-off job set-up and transfer costs (Figure 7),
2. individual machine costing table (Figure 8),
3. system productivity and work requirements output table (Figure 9), and
4. graphical representations of variation of job relocation cost impacts with varying distance and track volumes (Figure 10).

Key assumptions used in constructing the model fall in three areas:

1. One-off costs - (job set-up and relocation),
2. System productivity balancing,
3. Individual machine costing

One-off Costs

Provision is made for:

- Set-up (negotiation and relocation),
- Relocation,
- Roadbuilding costs (discussed in the introductory section).

Set-up costs (negotiation, site inspection and planning) are assumed to be site visitation costs (travel) and time related (discussion). There must be estimated by the user and totalled to a single lump sum.

Road-related costs can be entered as either specific cost estimates for road, drainage and access related features (either based on unit cost by construction class or multiplied by number or length), or input as a single user-estimated total road and access cost. Where restricted access is accepted and a decision made to use forwarding or skidding equipment for on-farm transport, these costs are included in the model by reducing machine productivity. This results in the additional cost burden being reflected in costs of the individual harvesting phase rather than in the relocation cost section (see Figure 7).

However, the impact of the cross-farm transport can be estimated by running the model twice. In the first run, assume normal productivity, and in the second assume reduced forwarding (skidding) productivity and then compare results.

Relocation costs assume use of a transporter with one machine per trip. Provision is made for a minimum call-out fee which is applied until it is exceeded by the total based on hourly rate, trip length and speed. System relocation costs include a paid round trip for the transporter to the new job site, and machine standing costs and operator wages for the period of the trip plus loading and unloading time.

Small Scale Contracting Harvesting Cost Estimator					
***** shaded cells are the variables *****					
GENERAL INFORMATION		LOG HAULAGE INFORMATION		ROADS TO BE BUILT	
Standard SMH per Day	=1 hrs	Haul Rate	0.15 \$/tonne-km	Type	KM/#
Days per Week	=5	Haul Distance	40.00 km	Permanent	0.0
Plantation ha	=15.00	Average Speed	55.00 kmh	Temporary	0.0
Vol to be harvested per ha	120.0 m3	Load Size (m³)	28	Push-out	0.0
Distance home	=55.00 km	Unload Time	20 minutes	Entrances	0
		Load Time	30 minutes	OR	
		kg/m³	1000	TOTAL ROAD COST	
MACHINE TRANSPORT INFORMATION		JOB SUPPORT INFORMATION		NEGOTIATION AND SETUP	
Move Distance (1 way)	=60.00 km	Vehicle	1	Coupe setup cost	= \$1,000.00
Call out charge (minimum)	= \$160	Saws	1		
Float Hourly rate	= \$80.00 /hr	Overhead	1000		
Average float speed	= 50.00 kmh	Foreman	1000		
Machine loading/unloading	= 0.25 hrs				
MACHINE INFORMATION				Protected Cells=====	
Ident	Productivity (m3/hr)	Availability	Number		
Phase 1	43.8 m3/hr	85%	1	\$60.00 \$	58.45
Phase 2	43.8 m3/hr	85%	1	\$1,000.00 \$	133.50
Phase 3	50.0 m3/hr	85%	1	480 \$	1,731.95

Figure 7. Section 1 -job details and cost inputs

System Productivity Balancing Methodology

The user estimates hourly productivity, machine availability and number of machines required in each phase. System production rate is set by the slowest phase, and the required machine hours for machines in other phases adjusted to maintain that level. A truck productivity module is included to provide information on the impact of haul distance on truck requirements.

Individual Machine Costing Methodology

A simple approach to individual machine costing based on estimating hourly values for capital, labour and consumable usage charges is adopted. When using the spreadsheet model, items requiring user inputs are shaded (Figure 8). Capital charges are calculated on the basis of straight-line depreciation and simple interest on average invested capital. The user supplies current prices for machine purchase, productive life and salvage value. Calculations are based on real (inflation corrected) interest rate and assume current prices. Contractor margins for return on investment and risk premium are added to the interest rate. Machine utilisation is calculated from the expected days per year and daily utilisation levels derived from machine system balance requirements (discussed in the next section). Machine working life in years is estimated from annual utilisation estimates and the expected service life of the machine (working hours) and this is used in the depreciation calculations.

Operating expenses provided for in the model include repair, tyres, fuel and oil. Repairs, and insurance, registration and administration costs are each assumed to be a (user estimated) proportion of initial purchase price. Tyre replacement price and life, and fuel and oil consumption and price are supplied by the user.

Machine cost calculator					
		Phase 1	Phase 2	Phase 3	
Item	Unit	Data Entry	Data Entry	Data Entry	
Delivered Equipment Cost	\$	\$285,000.00	\$150,000.00	\$150,000.00	
Salvage value	\$	\$185,000.00	\$80,000.00	\$80,000.00	
Working Life	Hours	10000	10000	10000	
Interest rate (Nominal)	%	5.50%	5.50%	5.50%	
Rate of inflation	%	1.00%	1.00%	1.00%	
% of delivered cost for license, insurance, admin	%	5.00%	5.00%	5.00%	
Days worked per year		240 days	240 days	240 days	
Scheduled machine hours per day	hours	11 hrs	11 hrs	11 hrs	
Expected PMH / Year	hours	2244.00	2244.00	1965.74	
Working Life	Years	4.5	4.5	5.1	
Depreciable value (less tyres)	\$	\$88,000.00	\$58,000.00	\$58,000.00	
Real cost of capital	%	4.46%	4.46%	4.46%	
Annual depreciation (straight line method)	\$/year	\$19,747.20	\$13,015.20	\$11,401.32	
Annual interest expense	\$/year	\$10,470.30	\$5,123.76	\$5,123.76	
Annual cost of taxes, license, insurance and storage	\$/year	\$14,250.00	\$7,500.00	\$7,500.00	
Annual ownership cost	\$/year	\$44,467.50	\$25,638.96	\$24,025.08	
Ownership cost	\$/PMH	\$19.82/PMH	\$11.43/PMH	\$12.22/PMH	
Item	Unit	Data Entry	Data Entry	Data Entry	
% of purchase price for repairs & maintenance	%	80.00%	80.00%	80.00%	
Tyre/Track Cost (set)	\$	\$12,000	\$12,000	\$12,000	
Tyre/Track life (hrs)	Hrs	4000	4000	4000	
Fuel consumption rate	l/hr	15.00 l/hr	15.00 l/hr	15.00 l/hr	
Oil consumption rate	l/hr	4.00 l/hr	4.00 l/hr	4.00 l/hr	
Fuel cost (delivered)	\$/l	\$0.75/l	\$0.75/l	\$0.75/l	
Oil cost (delivered)	\$/l	\$3.00/l	\$3.00/l	\$3.00/l	
Repairs & Maintenance	\$/hr	\$22.80 /hr	\$12.00 /hr	\$12.00 /hr	
Tyres / Tracks	\$/hr	\$3.00 /hr	\$3.00 /hr	\$3.00 /hr	
Fuel	\$/hr	\$11.25 /hr	\$11.25 /hr	\$11.25 /hr	
Oil	\$/hr	\$12.00 /hr	\$12.00 /hr	\$12.00 /hr	
Operating cost	\$/PMH	\$49.05/PMH	\$38.25/PMH	\$38.25/PMH	
Item	Unit	Data Entry	Data Entry	Data Entry	
Base wage operator	\$/hour	\$40.00 /hr	\$35.00 /hr	\$35.00 /hr	
Non machine hrs/day	hrs/day	5.00 hrs/day	4.00 hrs/day	4.00 hrs/day	
% of base wage for workcare	%	3.00%	3.00%	3.00%	
% of base wage for super	%	12.00%	12.00%	12.00%	
% of base wage for overheads	%	5.00%	5.00%	5.00%	
Operator Hours / Day		14.35 hrs/day	13.35 hrs/day	12.19 hrs/day	
Direct labour cost	\$/PMH	\$61.39/hr	\$49.97/hr	\$52.09/hr	
Indirect labour costs	\$/PMH	\$8.00/hr	\$7.00/hr	\$7.00/hr	
labour cost	\$/PMH	\$69.39/PMH	\$56.97/PMH	\$59.09/PMH	
Individual Machine costs (sub total)		\$138.26/SMH	\$106.65/SMH	\$109.56/SMH	
Total Machine Standing + Operating Costs		\$354.47/SMH			
Total Machine Standing Costs		\$228.92/SMH			

Figure 8. Section 2 - machinery cost inputs

Operator payments per operating machine hour are developed from a base hourly cost. The requirement for paid hours per day is calculated from the expected machine utilisation plus a user input of extra paid hours per day. The overheads model for workers compensation, superannuation and holidays is based on percentage of base pay and is added to the hourly base rate. Total daily direct and indirect payments are divided by productive machine hours (PMH) to give equivalent payment per operating hour.

Output is provided in tabular and graphical forms. An example of the tabular data format showing costs for the individual phases (e.g. felling an processing, forwarding, trucking) including relocation, is shown in Figure 9. Graphical representation of the costs of system relocation are also provided (e.g. Figure 10). These highlight the relativity of the relocation cost to overall harvesting costs as a function of relocation distance and job total harvested volume.

Use of the model

The model's main purpose is to evaluate the sensitivity of logging costs to variation in the factors relating to job set-up and transfer costs (as outlined above). The system may have some utility as a general farm-forestry harvesting cost estimator, although knowledge of a considerable number of input parameters is required.

RESULTS						Haulage
	Phase 1	Phase 2	Phase 3			
Required Hours per Day	9.4	9.4	8.2	Truck Productivity	12.2 m ³ /hr	
Achieved Utilisation	0.85	0.85	0.74	Round Trip	137 mins	
System Rate			Total Machines to Move	Plantation volume (m ³)=	1800.0 m ³	
Daily Production (m ³)	409.5 m ³ /DAY		3	Days to cut plantation =	4 days	
Weekly production (m ³) =	2047.7 m ³ /WEEK			Approx truck loads =	64 loads	
-----Total Cost per PMH (All Machines) -----						Cost Estimate
Activity	m ³ /PMH	Ownership	Operating	labour	Total	\$/m ³
Phase 1	43.80	21.39	49.05	35.35	105.79	2.42
Phase2	43.80	12.23	38.25	35.35	85.83	1.96
Phase3	50.00	13.14	38.25	36.10	87.49	1.75
Hauling	12.24	***	***	***	***	6.00
Support (Vehicle, Chainsaws, Foreman, and Overhead)				Total Support and Supervision COST	\$ 840	0.47
Roading				Estimated Total Roding COST	\$ -	0.00
Moving time to new stand	1.25	(1 hr 18 min)		Estimated Total Moving COST	\$ 1,732	0.96
Total Cost						\$ 24,396 \$ 13.55

Figure 9 Section 3 - Example of the output of the cost estimator.

9. Evaluating Small-Scale Forestry Operational Costs

In this section we evaluate the general magnitude and importance of the of some expected cost impediments to small-scale forestry operations by using the cost estimator. Two scenarios were evaluated: a mechanised first thinning and a chainsaw based later thinning/clearfelling.

Scenario 1 - Mechanised first thinning

This system uses two machines, an excavator-based harvester, and rubber-tyred forwarder. Two trips are required to relocate the system. Costs would be higher if road access to within close proximity of the stand were not available for the machine transporter, and an additional time were required for 'walking' the excavator from the unload point to the job site. Similarly, any requirement to forward logs longer distances from the stand across farm tracks or paddocks to a truck loading point would reduce forwarding productivity. Input values for the job setup and costing phases are listed in Table 4. Data for the two machines are listed in Table 5.

Table 4. Job and setup assumptions for Scenario 1- mechanised first thinning

Standard SMH/Day	11	Haul rate	0.12
Days / week	5	Haul distance	40
Plantation area	15 ha	Average haul speed	55
Volume / ha	90 m	Load size	28
Distance home	55 km	Unload time	20
		Load time	30
Move distance	50	Kg/m3	1000
Call out charge	\$160		
Float hourly rate	\$80	Vehicles	2 @ \$0.80
Average float speed	50	Saws	1 @ \$750
Machine load / unload		Overhead	\$1000
		Foreman wages/week	\$1500
Phase 1	18 m/hr @85%		
Phase 2	20 m/hr @85%	Road cost	\$1000
Phase 3		Negotiation and setup	\$500

Table 5. Machinery cost details for Example 1- mechanised first thinning

Delivered equipment cost	425000	35000
Salvage value	150000	150000
Working life	10000	10000
Interest rate	11%	11%
Rate of inflation	1%	1%
License / insurance	5.0	5.0
Days per year	210	210
Repairs and maintenance	80%	60%
Track / tyre cost	12000	12000
Track / tyre life	4000	3000
Fuel consumption	15.00	15.00
Oil consumption	2.50	2.50
Fuel cost	0.75	0.75
Oil cost	3.00	3.00
Base wage	\$25.00	\$25.00
Non-machine hours	2.00	2.00
Work care	3.0%	3.0%
Superannuation	12.0%	12.0%
Other labour costs	5.0%	5.0%

Results from the application of the cost estimator to these data are presented in Table 6.

These are based on a 10 ha plantation yielding 90 m³ ha. The logging is projected to take five days, at a total cost of about \$20000. Setup costs were set at \$500, which might be considered low, if the operation were a 'first time' one and significant legal advice and negotiation were required. Relocation costs were estimated by the transport and time-lost model to be about \$500. Expenditure of \$1000 for road and upgrades and access provision was also factored in, and production levels were not considered to be reduced (e.g. for reasons such as longer cross-farm forwarding. Total setup, relocation and road costs in this example were estimated at \$2000, or about \$2 m³.

Table 6. Results of cost estimation for Example 1 - mechanised first thinning

RESULTS							Haulage
	Phase 1	Phase 2	Phase 3				
Required Hours per Day	9.4	8.4	0.0		Truck Productivity	11.4 m ³ /hr	
Achieved Utilisation	0.85	0.77	0.00		Round Trip	147 mins	
System Rate				Total Machines to Move	Plantation volume (m ³)=	900.0 m ³	
Daily Production (m ³)	168.3 m ³ /DAY			2	Days to cut plantation =	5 days	
Weekly production (m ³) =	841.5 m ³ /WEEK				Approx truck loads =	32 loads	
-----Total Cost per PMH (All Machines) -----							Cost Estimate
Activity	m ³ /PMH	Ownership	Operating	labour	Total		\$/m ³
Phase 1	18.00	51.62	55.75	35.35	142.72		7.93
Phase2	20.00	42.71	39.25	35.94	117.90		5.90
Phase3	0.00	0.00	0.00	0.00	0.00		0.00
Hauling	11.41	***	***	***	***		4.80
Support (Vehicle, Chainsaws, Foreman, and Overhead)					Total Support and Supervision COST \$	1,626	1.81
Roading					Estimated Total Roading COST \$	1,000	1.11
Moving time to new stand	7.25	(1 hr 18 min)			Total Setup and Moving COST \$	1,067	1.19
Total Cost							\$ 22.73

The general relationship of relocation cost with distance is presented Figure 10. The 1000 m³ curve most closely representing the modelled situation, is marked with crosses and is the fourth line from the top, also note that the index values tested for the impact of distance are not uniformly spaced across the bottom axis, resulting in the apparently curved relationship.

Current pulpwood royalties (where markets exist) are in the range \$5-\$15 per m³, so it is apparent that relocation and access costs can be a significant factor.

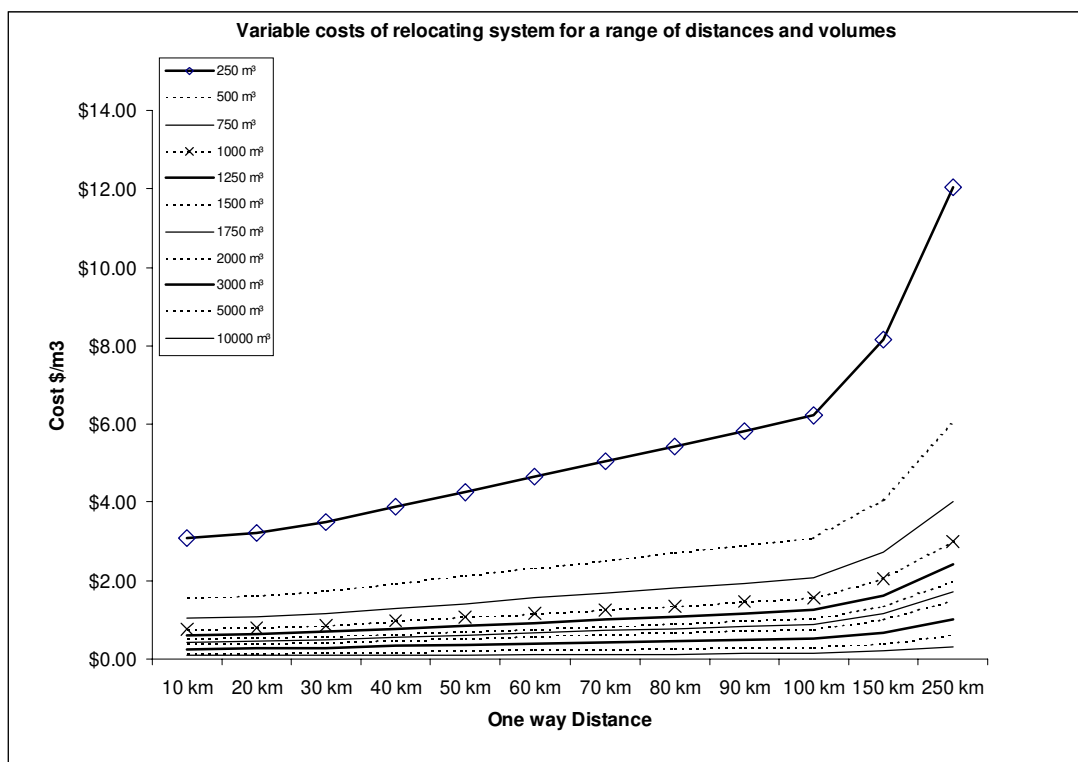


Figure 10. Setup and relocation costs in relation to distance and volume for Scenario 1

Scenario 2 - Chainsaw Felling and Processing, Forwarder Extraction.

This example is based on chainsaw methods, with only one piece of specialised harvesting equipment employed (forwarder). Similar job parameters are used as in the previous example, with payment rate of \$5.00 per m³ assumed for the chainsaw work.

Table 7. Input data for Scenario 2 - chainsaw felling and forwarder extraction

Standard SMH/Day	11	Haul rate	0.12
Days / week	5	Haul distance	40
Plantation area	15 ha	Average haul speed	55
Volume / ha	90 m	Load size	28
Distance home	55 km	Unload time	20
		Load time	30
Move distance	50	kg/m ³	1000
Call out charge	\$160		
Float hourly rate	\$80	Vehicles	2 @ \$0.80
Average float speed	50	Saws	1 @ \$750
Machine load / unload		Overhead	\$1000
		Foreman wages/week	\$1500
Phase 1	18 m/hr @85%		
Phase 2	20 m/hr @85%	Road cost	\$1000
Phase 3		Negotiation and setup	\$500

Table 8. Results for Scenario 2 - chainsaw felling and forwarder extraction

RESULTS						Haulage
	Phase 1	Phase 2	Phase 3			
Required Hours per Day	0.0	9.4	0.0	Truck Productivity	12.2 m ³ /hr	
Achieved Utilisation	0.00	0.85	0.00	Round Trip	137 mins	
System Rate						Plantation volume (m ³) = 1800.0 m ³
Daily Production (m ³)	280.5 m ³ /DAY			Total Machines to Move		Days to cut plantation = 6 days
Weekly production (m ³) =	1402.5 m ³ /WEEK					Approx truck loads = 64 loads
Total Cost per PMH (All Machines)						Cost Estimate
Activity	m ³ /PMH	Ownership	Operating	labour	Total	\$/m ³
Phase 1	0.00	0.00	0.00	0.00	0.00	5.00
Phase2	30.00	40.32	38.25	35.35	113.92	3.80
Phase3	0.00	0.00	0.00	0.00	0.00	0.00
Hauling	12.24	***	***	***	***	4.80
Support (Vehicle, Chainsaws, Foreman, and Overhead)						
				Total Support and Supervision COST	\$ 1,390	0.77
Roading				Estimated Total Roading COST	\$ 1,000	0.56
Moving time to new stand 1.25 (1 hr 18 min)				Estimated Total Moving COST	\$ 775	0.43
Total Cost						\$ 27,636 \$ 15.35

These results indicate a moderate reduction in the job relocation penalty for the model scenario when measured on a unit output basis (reduction of about \$0.20 / m³) as compared to Scenario 1. The reduction is due to the lower machine transport costs over the relatively short relocation distance.

Discussion of cost evaluations

Costs associated with negotiation, equipment relocation and establishing a road infrastructure to permit truck access are likely to be particularly significant in farm forestry harvesting operations. This is because these up-front costs have to be amortised over low total volumes. A spreadsheet-based costing model was developed to evaluate their influence. The impact of variation in relocation requirements was modelled by comparing two scenarios.

On the basis of the modelled levels of cost and scale operations (10 ha), imposts of between \$1000 and \$2000 per operation or \$1.00 and \$2.00 per m³ were estimated. It is stressed that information was not available to assess the actual levels of costs such as negotiation and securing adequate road access being experienced by farm forest owners. These can be expected to vary substantially with owner skills and farm forest location. However, indications from the costs model are that they might equal or exceed equipment relocation costs and be an important source of cost to owners of small-scale forests.

This work is intended to be indicative only. Further work is required to identify and establish realistic costs differences for small-scale forestry and will depend in part on the emergence of a more broadly based small-scale forestry sector.

10. Discussion and Conclusion

Regional Context

Small-scale farm forest owners were identified as a special category by virtue of their interest in participating in the management of their forests. Several aspects of the regional forest economy were identified as having considerable influence on the success of these forestry ventures, including the scale of the processing industries that provide potential markets, and the relative size and importance of small-scale private growers in supplying these markets. Wood supply systems are often complex and can be slow to evolve.

Suitable Harvesting Systems

Common systems of plantation harvesting were identified and described, with both an industrial forestry and a small-scale forestry variant in each case. There can be significant advantages for suitably trained and equipped small scale forestry specialists to enhance on-farm income by providing local contracting services. However, a considerable degree of specialist knowledge is required, and presently there are few avenues to obtain this. Modifications of both harvesting and silvicultural approaches (eg. growing fewer larger trees) will likely be required to maximise the efficiency of small scale operations.

Literature

There is almost no literature directly addressing the operational aspects of Australian farm forestry, especially in relation to harvesting, and this is identified as a significant gap. Review of international sources shows a number of alternative situations which might be relevant. In Scandinavia, farm forestry has been widely practiced for a long time. Farm workers develop and practice forestry skills as a normal (often winter) part of the annual farming cycle. Much of the forest resource is in private hands and a variety of harvesting technologies and selling practices have co-evolved with industrial requirements to ensure efficient wood flow. There are a number of operational forestry tasks besides harvesting, and the literature indicates that while farmers still play a role in harvesting, the role of harvesting contractors is increasing and farm labour increasingly directed toward silvicultural treatment.

Reports from North America, and New Zealand indicate a situation part way and mid-way between those of Scandinavia and Australia, with less traditional reliance on farm wood sources, and a consequent lesser resource of trained farm labour. As increased supply of and demand for wood from small private owners was recognised, skill and equipment needs were met by targeted training and small-scale forestry R&D programs. Australia has little or no tradition of farm forestry, and consequently a limited reservoir of skill among the farm labour population, and a similarly limited equipment and R&D base.

Comparative studies of wood-supply systems indicate that these take significant periods to develop, and evaluation is needed of all the aspects of the system, not just the harvesting equipment and its application.

Case Studies

A series of studies of harvesting operations and interviews with farm-forest owners was conducted in Victoria. There was an emphasis on plantation operations, and operations conducted with on-farm labour. Case studies were necessarily of short duration, and results must be considered indicative only. However, it would appear that most of the projects were offering little financial return to the farmer and the operations fell short of current industrial standards for environmental care and occupational health and safety. Operations were characterised by:

- Makeshift operations - farmers were still experimenting with methods
- Farmers had minimal knowledge of harvesting practices and product specifications
- Farmers received little encouragement or support in developing their operations
- Poor or non-existent medium- / long-term marketing arrangements.

These results might be expected, given the infant stage of plantation farm forestry in Australia, and our lack of forestry tradition.

The alternative approach, generally favoured by the wood-using industry, is to use professional industrial forestry contractors. However, this can have its difficulties, highlighted in the case studies, farm forest owners lack knowledge of appropriate harvesting or marketing practice. One probable development, observed overseas, is the emergence of specialist contractors with equipment and expertise suited to operating on small blocks. At the smallest scale this can include the development of contracting by local farmers investing in specialist harvesting and transport equipment to needs of neighbours as well as themselves.

Survey

The third phase sought to identify a broader representative sample of farm forest harvesting operations, by conducting a large mail survey in Victoria. Results indicated a very low level of current farm forest harvesting in Victoria. This may be a consequence of the relatively young age of many farm forests, and a greater level of activity might be expected in the future.

Cost Model

The last phases of the project examined cost impediments by assessing likely sources of cost most closely related to harvesting small blocks, and developed a model to cost this type of operation. The assessment was based primarily on a contractor model because data and observations were not available to model the complementary farmer implemented activity.

A number of sources of one-off cost were identified which, while they can apply in general to all forestry operations, are of particular significance to small-scale farm forestry because of the limited volumes of product over which to amortise cost. Job negotiation, planning and in some cases approvals, (broadly, 'setup' costs), road access and machine system relocation were identified as important one-off costs types. The magnitude of these depends substantially on skill, knowledge and experience, as well as geography and forest factors.

These were evaluated in the context of an economic model of small-block harvesting operations. Actual cost data was not available, so several scenarios were constructed using data from the collaborators in the production studies (described above) and advice on likely costs from industry personnel and the researcher's experience. Under the assumptions used in the scenarios (\$1000 roading cost and

approximately \$750 - \$1000 setup and relocation costs), costs were generally < 10% of estimated harvest and transport costs for blocks yielding > 1000 m³ and relocation distance < 90 km. While the predictions for these scenarios provide some insight into cost levels, they must be taken as indicative only. Each forest situation, particularly on farms, will have its unique advantages and disadvantages. For example, any significant requirement for access gravelling or engineered stream or watercourse crossing could multiply the road cost many times. Similarly, needs for professional planning advice for steep country harvesting or environmental approval could also greatly increase planning and setup costs.

These scenarios are based on the use of professional contractors with industrial equipment, and thus industrial levels of machine productivity are assumed. Observations from the case studies, however, showed older, simpler equipment and methods being used by on-farm labour at much lower levels of productivity. The cost implications of this cannot readily be modelled.

Overall, farm-forest harvesters can be expected to face considerable challenges. Skill and experience are needed. Where forests are favourably located with good access, additional cost imposts related to small-scale can be minor. However, there are several areas where inappropriate choice of location or operational method could result in considerable economic loss. Provision of better information is urgent. Immediately, it would guide forest investment in relation to location and operational impediments. In the future it would also assist farm foresters in strategies and choices relating to silviculture and the best ways to capitalise on on-farm labour.

11. Implications of the Research

Strengthening the Links Between Farm Forestry and the Forest Industry

The current perception of most Australian industry leaders is that small-scale forestry cannot match the reliability of supply and low costs of industrial-scale production. The case studies and postal survey of Victorian farm forestry described in this report do little to dispel that perception.

Yet some of the world's more competitive forest industries are reliant on small-scale forestry. The literature indicates that these countries have developed complete wood supply systems - the combination of forest owners, managers, harvesting, transport and marketing, that allow small-scale forestry to meet industrial supply / price needs. However, the developments were evolutionary, and appear to require significant total wood flows. Importantly, they included elements well beyond the specifics of harvesting equipment or methods.

We are impressed by the need to focus on the development and demonstration in Australia of an appropriate wood supply system as a means of convincing both farmers and the forest industry that small-scale forestry can contribute to industrial production. Tasmania appears to be the region of Australia best able to meet the requirement of having substantial total volumes of wood on farms, and it may be there that we will see the first large scale emergence of such a small farm forest based wood supply system. Western Australia may also present opportunities as the joint venture blue gum plantations approach harvestable age.

Identifying Opportunities for Harvesting Trees on Farms.

Two broad opportunities are available to the owners prepared to be more directly involved in forest operations, harvesting and silviculture. Farmers can become involved in harvesting. This does require special skills, and it might well be that some farmers invest in more specialised harvesting (and possibly processing) skills and equipment to become local contractors. This will allow them to harvest (and process) their own and their neighbours forest and achieve economic levels of machine utilisation justifying investment in appropriate equipment. This pattern has emerged in Scandinavia and there is evidence to suggest that such contractors are more acceptable to farmers than industrial contractors.

Another important avenue is the investment of on-farm labour and equipment in silvicultural activities in the forest. This can shorten the rotation, increase the forest's value and substantially reduce its harvesting costs. Owners might find it more rewarding to establish a few ha each year rather than periodic large plantings that will be difficult to manage on a schedule. By a combination of on-farm silvicultural inputs and the harvesting of larger trees which require less sophisticated equipment, the effect of scale can be minimised.

Farmers who lease their land to large forest owners or wood buyers may need to meet different criteria, depending on the terms of the agreement. Most leases and many joint ventures do not provide for the farmer's involvement and there is little opportunity to reduce or modify the influence of scale on costs. In this environment the best results will be obtained by planting relatively large tracts of forest; most industrial companies seek a minimum of 20 ha. Our observations suggest that total volume from a region may also be important.

Identifying Opportunities for Processing Wood Products on Farms.

This topic has been addressed by a separate project (Stewart and Hanson 1998). Our observations suggest that opportunities exist for farmers to harvest and process wood to meet on-farm needs on a very small-scale. The postal survey indicated that more than half the very small-scale operations were also processing the wood on farm. Some may expand that capacity to serve adjacent forest owners.

Identifying Policy Reforms on Farm Forestry

Research and development: We suggest that R&D should place greater emphasis on (i) the development wood supply systems for regions with substantial volumes of wood now available, and (ii) the development of operational technologies for silviculture, harvesting and processing appropriate to small-scale forestry.

Education and training: Graduate Certificate and Master Tree Growers courses are run from the University of Melbourne in close collaboration with regional farm-forestry groups and are proving to be most effective introduction to farm forestry. It is suggested that courses that place an increased emphasis on harvesting technologies appropriate to small-scale forestry should be developed.

Planning requirements: The costs of negotiating and setting up sales can be significant. The formal requirements (state and local government) vary from state to state and even between local government areas. In many cases these relate to planning legislation. Finding out about and satisfying local and state requirements can be a major impediment to implementing farm -forestry harvesting operations.

12. Appendices

Appendix A: Annotated Bibliography

Australia

Wilson, S.M., Whitham, J.A.H., Bahati, U.N., Horvath, D. and Tran, Y.D. 1995. Survey of trees on Australian Farms: 1993-94, ABARE Research Report 95.7, Canberra.

A report by ABARE (1995) presents the results of a large national survey of trees on farms. Whilst the report is most valuable in understanding why farmers are planting trees, it also provides some useful information regarding harvesting intentions.

Of the 35% of farms nationally that planted trees within the last three years before the survey, only 2% indicated they had planted the trees to produce sawlogs or pulpwood. However the national trend emerging is that whilst the majority of farmers originally plant trees for non-commercial reasons, when it comes to an analysis of farms actually harvesting, they tend to make up the majority.

The significance of this observation is that farmers 'drift' towards the idea of harvesting rather than adopting planting strategies that will assist in minimising harvesting costs in the future, especially roading and access which represent a substantial sunk cost in small-scale forest operations.

Reid, R. Stewart, A. 1995. Agroforestry; productive trees for shelter and land protection in the Otways. The National Farm Forestry Program, Otway Agroforestry Network.

The book is a manual for landowners interested in using agroforestry as a land management tool to provide: shelter for stock and crops, land degradation control, fire protection, diversification of income, or simply beautification. Agroforestry is not presented as an alternative land use to agriculture but rather as possible solution to the common land management problems facing farmers and other land owners across the region. A physical description of the area is prepared beginning with a description of the farming systems and by identifying major land systems in the region. The concerns raised by landowners and the role that trees and shrubs may be able to play in meeting these needs are discussed. In a similar manner, the nature and management of the native and plantation forests in the region are analysed followed by a practical look at suitable tree species, management options and local marketing opportunities for timber and other products.

Race D. (ed.) 1993. Agroforestry, trees for productive farming. Australia. Dept. of Conservation and Natural Resources; Dept. of Agriculture, Victoria

The aim of this book was to provide the latest information on agroforestry in south-eastern Australia. It is practical, so that farmers may better plan and manage their agroforests. Contributors represent a wealth of skills and experience in agroforestry; they include farmers, industry professionals and scientists.

Wallace, M. A. 1994. Comparative economic study of wood growing in Australia and selected countries. Gottstein Memorial Trust Fund, The National Educational Trust of the Australian Forest Products Industry. Victoria, Australia.

Greater investment in plantations is proposed by various bodies as a future wood resource policy for Australia. Australia's viability as wood producer could be improved by increasing plantation productivity, reducing early rotation costs and achieving higher prices for wood commensurate with market forces. Options for this include e.g. research to improve productivity and reduce costs, forming market co-operatives, trading of plantations, and easing export restrictions. The publication contains economic comparisons including the Pacific Northwest of the USA, British Columbia, Canada, Chile and New Zealand.

New Zealand

Liley, W.B (ed.). Limited-Scale Logging. Proceedings of a seminar held in Rotorua, June 1985. New Zealand Logging Industry Research Association Inc.

Papers presented include results of a survey of current operators of limited-scale logging; an analysis of the resource base for limited-scale forests; factors of limitation including discussions on labour, equipment, planning and management, scale of operation, weather and soil type, and cost experience. Off-site factors are also discussed including markets, marketing, organisation and documentation; an owner's viewpoint of logging the farm forest; a wood buyer's viewpoint of the economic problems facing limited scale logging; economies of scale in logging limited-scale forests; the effects of tract size on harvesting costs; and issues relating to value recovery; costs for 18 limited-scale logging operations ranging in size from 0.2 ha to 3.5 ha in clearfelling, and 4 ha to 21.8 ha in thinning are summarised:

Operation	Range of costs
Clearfelling	\$6.50 to \$18.45/m ³
Loading	\$1 to \$2.67/m ³
Transporting equipment	\$0.33 to \$1.04/m ³
Cleanup	\$0.70 to \$3.66/m ³
Roading	\$0.15 to \$4.61/m ³
Supervision and management	\$0.51 to \$5.16/m ³

* 1985 costs (New Zealand)

Discussion:

Smaller landowners may attempt all or part of the logging with their own equipment, but from the experiences of Olsen (1985), less than 5% of owners are competent in harvesting. Olsen concludes that for the majority of private owners the most satisfactory option is to employ a professional contractor. He notes that for the small contractor or farm logger, the small tract size has a major effect on limiting scale of operations due to the short life of each operation, discontinuity of forward work, shifting costs and marketing problems. Concern over access and roading, given that the majority of small holdings having virtually no internal access roads was also raised. Key points were:

1. Public roads have to be constructed to carry economic payloads. Difficulties can be encountered in regard to bridge strength, radius of turns, and pavement strength particularly in wet weather.
2. Private roads on farms generally are lacking or insufficient, requiring expensive formation, culverting and metalling. Many roads are restricted to dry weather access across paddocks.

An argument put forward by Fraser (1985) was that in logging, economies of scale may be achieved through the application of appropriate technology of production rather than through specialisation and division of labour. Improved utilisation of particular equipment may provide some economies of scale, but it is less important than the scale of output and the spreading of fixed costs. In small-scale logging the key variables are the level of production and fixed costs. He presented a hypothetical harvest operation and for simplicity, the cost structure for the two systems was assumed to be identical except for the difference in capital costs.

	Case A	Case B
Annual production (tonnes)	18,000	23,000
Fixed costs (\$)	190,550	215,750
Variable costs (\$)	54,000	69,000
Total costs (\$)	244,550	284,750
Total costs/tonne (\$)	13.59	12.38

Case A is capable of producing 18,000 tonnes per annum at \$13.59 per tonne, whilst Case B can deliver 23,000 tonnes at \$12.38 per tonne. The higher total costs in system B are more than offset by the large increase in annual production and resulting reduction in fixed costs per unit.

The New Zealand experience suggests that economies of scale are possible in small woodlots but in reality may be very difficult to achieve, given market constraints and other factors beyond direct control of the owner.

Smaller, P.G. and Meister, A.D. 1983. The practices, problems and economics of farm woodlots. Discussion Paper in Natural-Resource Economics, Department of Agricultural Economics and Farm Management, Massey University, New Zealand. No. 6, 78 p.; 5 ref., many tab., 1 app.

The study considers farmer knowledge, experience, attitudes and intentions regarding farm forestry in New Zealand, and compares the possible financial return from woodlot growing with that from alternative activities. The data are based on a questionnaire survey of a sample of woodlot owners in the planning districts of Taranaki, Manawatu and Rangitikei. Six case studies were selected from the sample and were subject to discounted cash flow analysis. Woodlot plantings with a dual purpose (shelter, weed control and diversification) are more likely to be made than single-purpose planting, and anticipated planting rates show a gradual decline over 10 years. Government assistance for woodlot operators appears to be a bonus to those already committed to some plantings rather than an incentive to those who are not. From a purely financial point of view the return of woodlots on a pre-tax basis, in most cases, did not compare favourably with the returns from alternative enterprises.

Finland and Sweden

Opportunities to Increase Farm Income.

Uotila, E. and Peltola, A. 1990. A method for calculating residual incomes from delivery and standing sales of timber. Hankinta- ja pystykaupan tulojen katelaskentamenetelmä. Finnish Forest Research Institute. Folia Forestalia 756.

The purpose of this study was to develop a calculation method for analysing the profitability of timber sales alternatives from the point of view of a private woodlot owner in Finland. The woodlot owner's

participation in the felling and / or haulage work was regarded as a part of a timber selling alternative. The method enables the user to calculate residual incomes from delivery and standing sales and to compare the profitability of logging either done by themselves or by employing an external labour force in the case of a stand marked for cutting. First the income from timber sales is divided into incomes from timber sold and delivery activity. Next, the delivery activity income is divided into income from logging work and a delivery surplus estimated, if the gross income from delivery activity is greater than the costs of the logging work carried out by an external party. The residual incomes can be calculated on different levels of contribution calculations. The taxation of the delivery sales can also be taken into account in calculations.

Table 1. Items of income from timber sales (FIM, before taxes)

	Standing sales	Delivery sales, logging labour force external	Delivery sales, logging labour force own
Timber sales gross income	20 800	32 800	32 800
Timber sales preparation costs	-100	-100	-100
Standing sales net income (net income from timber sold)	20 700	-20 700	-20 700
Delivery activity gross income		12 000	12 000
logging by external labour force		-10 200	
Delivery surplus		1 800	-1 800
Logging work gross income			10 200
Variable costs accrued from wear and tear of equipment in self-employed logging			-1 200
Contribution profit of logging work			9 000
Fixed costs of own logging equipment			-3 100
Net income from logging work			5 900

More than one third of the timber sales done by the non-industrial private forest owners in Finland during the logging season 89/90 were delivery sales (to roadside), where the forest owner does the logging work. The income from the different forms of timber sales can be divided as follows:

The income and costs: The gross income is calculated both in delivery- and standing prices. The costs are:

- Costs from preparing the timber sales
- Capital and running costs from using their own harvesting equipment
- Travelling costs when logging work done self
- Administrative- and planning costs using external labour
- The salary costs for the external labour

Table 2. Timber sales net incomes (FIM before taxes)

	Standing sales	Delivery sales, logging labour force external	Delivery sales, logging labour force own
Delivery surplus		1 800	1 800
Net income from logging work			5 900
Net income from delivery activity		1 800	7 700
Standing sales net income	20 700	20 700	20 700
Net income from timber sales	20 700	22 500	28 400

Vilhelmson, P. 1990. Ways of increasing income from forestry within the combined farm - an inventory and empirical study. Rapport Sveriges-Lantbruksuniversitet,-Institutionen-for-Ekonomi., No. 33, 85 p.; 43 ref., Uppsala, Sweden.

The study aimed to make an inventory of possibilities that might exist in forestry for the mixed farm in Sweden, and assess their viability. Interviews were conducted with 15 farmers who have moved some resources from agriculture into forestry, the rationale being that returns from forestry are not changing, while those agriculture have declined. The inventory was based on the following headings: increased use of the farmer's own labour; increasing the forested area; selling labour and services to other foresters; and more professional management. Some of the potential areas for development identified in the inventory were: (1) more work in the farmer's own and other forests on planting and clear felling, the creation of windbreaks and snowbreaks, and logging on difficult land (using modern small-scale technology such as mini-skidders, off-road vehicles, tractor-mounted processors, etc.); (2) increased co-operation between combined farmers and other private forest owners; (3) more clear felling, better management, and expansion; and (4) management training. The interviews largely supported the inventory, although some activities, such as clear felling and windbreaks, etc., were not profitable. Few new opportunities were identified. There is also not much more scope for transferring arable land into forestry, and farmers were reluctant, for conservation reasons, to transfer open land around their farm to forest use.

Utilising Farm Labour.

Koistinen, A. 1989. The status of forestry on Finnish farms. Finnish Work Efficiency Institute, Tyoteknisen Julkaisuja 310.

The study had two main purposes. Firstly, the significance that forestry has for farmer forest owners was estimated. This was done by examining the economic and employment effect of owning forest on the farmer and his/her household. Secondly, it determined the prerequisites of emphasising and specialising in forestry and the individual willingness of farmers to change over to tree farming.

In the 1980's, income from forestry on agriculturally active farms with forest areas less than 50 ha has, on the average, been less than 10%. The corresponding figure for farms with 50-99 ha of forest was 10-20% and in the case of farms with at least 100 ha of forest it was 20-40%.

Self employment in forest work played an important role in farm forestry. During the ten years prior to the study, some 80% of the farmers who had sold timber had sold at least some of it on the delivery basis (on the roadside). Of the volume sold, delivery sales accounted for less than half. The decisions to sell the timber on stump instead of the delivery basis had been influenced mainly by lack of time and the inadequacy of the farmers' forest haulage equipment.

Grapple loaders had become so widespread that they were in use on approx. 25% of the farms with at least 50 ha of forest. The most common handtool that the farmers were planning to acquire was a clearing saw. Self-employment in silvicultural work had consumed more time than any other forestry work. The relative proportion of work carried out by farmers and members of their families was at its maximum for tending of young stands and for pruning.

The respondents were willing to develop the practice of forestry on their farms in a number of ways. The most popular means of doing it was to increase the relative proportion of silvicultural work carried out using the farm's own labour force and to intensify the degree of utilisation of the farm's forest area. Other common choices were increased self employment in timber harvesting, thereby increasing the relative share of delivery sales. However, the farms generally lacked an adequate labour force. In other words, in most cases intensified forestry would require reductions in the input of labour in agriculture. Farmers who intend to specialise in forestry are, according to this study, those who have already practised intensive forestry.

Koistinen, A. 1991. On the development of forestry work carried out by the private woodlot owners in Finland. Finnish Work Efficiency Association, Finland.

The data for the study were collected in autumn 1990 by means of (1) a questionnaire sent to private woodlot owners throughout Finland, (2) a questionnaire sent to instructors of woodlot owners, and (3) interviews with forestry experts. In 1989 the forest owners (or their family members) did 3.8 million work days of forest work in their own woodlots. This about 40% of the total amount of forest work done in Finland during the year. The figures on the amount of the silvicultural work done by the forest owner or his family are from the years 1984-85. In 1984 some 400 000 man-days were spent tending young stands and 200 000 man-days were spent planting and sowing regeneration sites in Finland. On 2% of the woodlots some of the regeneration was done by sowing. On about 72% of the woodlots this was done by the owner. Planting was done on 17% of the woodlots, two thirds of which was by the owner. Woodlot owners and forestry experts thought that artificial regeneration would decrease slightly in 1990-95. The time woodlot owners spent weeding and thinning young stands is expected to increase. Competing vegetation was controlled (stand cleaning) on 16 % of the woodlots, most of this was done by the owner.

In the logging season 1989-90, woodlot owners felled 24% and extracted 20% of the total volume of wood brought to the market from private woodlands; the proportion of timber harvested by woodlot owners was less than in 1982-83. Woodlot owners spent nearly 2 million man-days harvesting timber. Wood was sold on delivery sales (on the roadside) on 120 000 woodlots in the logging season 1989-90. Self-employment in cutting work was used on 110 000 and in haulage on 80 000 woodlots. The proportion of delivery sales of the volume of all timber sales was about one third. The mean size of all delivery sales was 138 m³ and the mean size of the delivery sales done by farmers was bigger, 187 m³. The wood sold on delivery sales is mainly from thinnings. The proportion of delivery sales is expected to decrease in 1990-95; contractors are expected to do more extraction.

Table 1. Self employment on private woodlot owners in silvicultural work in woodlots at least 5 ha in size (2790 woodlots)

Treatment	Percentage of all woodlots treated.	Percentage of treated area worked by farm labour	Percentage of treated woodlots worked by farm labour
Clearing	31	61	71
Site preparation	4	18	32
Planting	17	51	64
Sowing	2	78	72
Controlling competing vegetation	16	86	91
Tending stands	44	73	82
Pruning	5	82	89

Fertilisation	5	36	57
---------------	---	----	----

Table 2. The proportions of self employment and contracted labour in roadside sales during the logging seasons 1978-79, 1982-83 and 1989-90 (a=thinnings, b=other cuttings) (n=149)

Form of cutting	78/79	82/83	89/90a	89/90b
Percentage of all woodlots				
Entirely with farms own workforce	91	89	84	84
Partly using contracted labour	7	8	5	8
Entirely using contract labour	2	3	11	8
Total	100	100	100	100

Table 3. The proportions of extraction work done by self and by contracted labour in delivery sales of timber during the logging seasons 1978/79, 1982/83 and 1989/90 (a=thinnings, b=other cuttings) (n=149)

Forest haulage	78/79	82/83	89/90a	89/90b
Percentage of all woodlots				
Entirely with farm's own labour force	77	84	61	60
Partly using contracted labour	9	9	8	4
Entirely using contracted labour	14	7	31	36
Total	100	100	100	100

Table 4. Participation of woodlot owners in timber harvesting in private woodlots during the logging season 1989-90.

Delivery sales of timber	All woodlots %	Work done by self		Working days
		Timber volume of delivery sales %	Volume of all timber harvested in private woodlots %	
Felling	92	78	24	1 535 000
Forest haulage	69	65	20	390 000

Most of the delivery sales were cut by chainsaw. Less than one-tenth of the volume was logged by a processor or a harvester.

Table 5. Felling methods used in delivery sales of timber during the logging season 1989-90.

Felling method	Percentage of logging volume
Chainsaw only	91
chainsaw + processor	3
harvester	6
total	100

Table 6. Forest haulage and methods used in delivery sales of timber during the logging seasons 1978-79, 1982-83 and 1989-90 (n=182)

Forest haulage method	78/79	82/83	89/90
Percentage of logging volume			
Farm tractor			
* + winch/skidding block	29	33	16
* + trailer + manual loading	21	28	8
* + “ + winch and mechanical loader	16	11	4
* + “ + hydraulic loader	7	10	41
* + skidding grapple	-	1	8
Forest tractor	12	13	17
Horse	14	4	1
Other	1	1	5
Total	100	100	100

Haulage was done mainly with a farm tractor and auxiliary equipment. The most common method was a hydraulic loader and a trailer or a sledge. 41% of the delivery volume was hauled using these combinations.

Younger (<40-yr-old) owners of woodlots expected to do more work on a contract basis. Three scenarios of development trends were constructed on the basis of the views expressed by woodlot owners and forestry experts, viz. (1) traditional forestry, (2) extensive forestry (in which rural areas are depopulated) and (3) intensive forestry (in which labour inputs liberated from agriculture are used in developing forestry). It is concluded that the structural change in forest ownership will probably have a greater influence on the woodlot owners' involvement in harvesting than in silviculture. [With English figures and tables.]

Gullberg., T. 1991. Analysis of logging systems for pre-commercial thinnings within the non-industrial private forest sector. Report, Swedish University of Agricultural Sciences, Dept. of Operational Efficiency.

The study compares different logging systems in pre-commercial and commercial thinning. Both conventional softwood systems and systems where wood fuel assortments were extracted have been included in the study.

The report covers:

- a. Comparison of the productivity and costs for the systems in type stands for pre-commercial and commercial thinnings,
 - b. Comparison of different assortment choices in respect of resulting volumes and wood values in the type stands,
 - c. Effective levels of payment for work during self-employment for the different systems in different type stands at different annual levels of activity (hours/year, volume/year),
 - d. Discussion of other aspects and effects of importance in the choice of different logging systems.
-

Sennblad, G. 1984. Survey of logging and silviculture in non-industrial private forestry in Sweden 1984. Swedish University of Agricultural Sciences, Report. Report No175/88.

Results from a survey of non-industrial private forestry in Sweden are presented. The sample comprised 3000 private forest holdings of more than 5ha of forest land. The objective of the survey was to give an actual description of private forestry with regard to silviculture and logging conditions. The forest area of private forest sector in Sweden was around 10 million ha in 1984. The pure forest holdings portion was 55% of the total private forest area, the rest was combined farm forests. The volume harvested during the logging season 1983-84 was 35 million m³. About 36% of the volume cut was thinnings. The forest owner and his family performed 34% of the total cutting work. The level of self-employment in off-road transport work was considerably lower, 26%. The farm tractor with different kinds of auxiliary equipment dominated among off-road transport equipment. About 61% of the volume was transported with the farm tractor. Among the auxiliary equipment the wire crane and trailer had the largest portion, 22%, while the grapple loader and trailer had 19% of the volume. The level of self-employment in silviculture work was very high in private forestry. About 60%-70% of the common tasks such as cleaning, planting and pre-commercial thinning was done by the owners or their family members. About 246 000 power saws were owned by private forest owners.

Ryynanen, S. 1985. Logging conditions and methods in farm forests of Finland in the logging season 1982-83. Finnish Work Efficiency Association, Tyotehoseuran Julkaisuja. Finnish.

The results are given of an interview survey of 1127 farmers throughout Finland, of which 547 had carried out logging in 1982-83.

On active farms, a sale at delivery price (the wood is sold on the roadside) is clearly more common than a sale on the stump (the buyer does the logging). In the logging season 1982-83, 75% of the selling farms of the population made a sale at delivered price, 18% a sale on the stump and 8% used both. Volume felled as delivery contracts had increased from 39% to 61%. The proportion of small lots, less than 100m³ was 56% in the sales at delivered price but only 13% in the sales on the stump.

Comparisons with a previous survey for 1978-79 showed that the proportion of conifer wood had decreased from 87% to 80%. There was clearly less saw timber but correspondingly more coniferous pulpwood. The emphasis was, thus, in the intermediate cuttings.

In the delivery cuttings the farms managed with their own labour and machines. A sixth of delivery farms needed outside help in the hauling and tenth in the cutting. Use of outside labour for sales on the stump had decreased from 85% to 68% for felling and from 90% to 55% for haulage. The farmers also participated, more than earlier, in the harvesting of timber from the stands sold on the stump, in both the cutting and hauling of the timber.

Log transport by farm tractor was the most common for delivery cuttings and transport by forwarder in the case of sales on the stump. The forest haulage distance was in all logging of farm forests 0.66 km, a little shorter in delivery cuttings and a little longer in sales on stump. When compared with the logging season 1978-79, the transport distance was a little longer.

Ryynanen, S. 1986. Tractors and forest equipment for them on Finnish Farms. Finnish Work Efficiency Association, Tyotehoseuran julkaisuja.

A survey of 1127 farmers, of which 71% used tractors in the forest. Data are presented on numbers of tractors, their make and size, and ancillary equipment used in the forest (sledges, trailers, skidding and loading devices, circular saws, choppers, splitters, chippers, etc.).

In the spring 1983, the farms had 224 100 tractors. About 98 500 farms had one tractor, 46 000 two tractors and 8 900 three or more tractors. The make of two-thirds of the tractors was Massey Ferguson, Ford or Valmet. The age of the tractors, counted on the basis of the annual model was, on an average 12-13 years. Half of the tractors were bought second hand. The engine power of the tractors was on average 45 kW. The newer tractors were more powerful than older ones. In the spring 1983, the farms had about 16 000 four-wheel-driven tractors.

Table 1. Farm tractor use in the forest.

	Tractor used in forest		Of the farm's tractors in forest		
	Total number of farms	Percentage using tractor for haulage	Newest	second	other
			Percentage of farms in forest		
South Finland	41 500	78	75	20	5
West Finland	41 400	82	88	10	2
East Finland	16 900	62	95	5	0
North Finland	11 500	47	92	6	2
Whole country	111 300	71	85	13	2

Of the farms owing a tractor, 71% employed the tractor in the forest, either in haulage of wood for their own use or for haulage of wood sold on a delivery sale. Usually, the newest tractor of the farm was used in the forest.

In the forest haulage the tractor is usually equipped with a sledge, because timber is often transported in the wintertime. Transport with a sledge was used on 58 000 farms or on more than half of the farms practising forest haulage. The corresponding figures for trailers were 30 900 and 28%. Half of the trailers used for forest haulage were ordinary farm trailers, the other half proper forest trailers, about three-quarters of which were home-made. A little more than half of the farms had tractor driven skidding and loading devices. The most common were skidding bunks and skidding winches, which can be coupled to the three-point linkage. Loading of timber manually was still quite common.

A circular saw was the most common machine used in making fire-wood (about 78 000 or 46% of farms). The sales of tractors' forest equipment has increased lately, in particular sales of hydraulic loaders has grown. Proper forest trailers have also become general in a short time.

Table 2. Number and ownership of skidding and loading devices used with farm tractors for the years 1977 and 1983.

Forest device of the farm tractor	1977		1983		Change	
	Number	% of farms	Number	% of farms	number	%
Skidding bunk	30 000	18	45 400	29	15 400	+ 51
Winch	21 900	13	34 800	22	12 900	+ 59
Boom loader	3 500	2	15 100	10	11 600	+ 331
Hydraulic loader	2 000	1	7 400	5	5 400	+ 270

Table 3. Estimation of the numbers and ownership of farm tractor's forest devices on the active farms in the end of the year 1985.

Device	Number	Percentage of active farms
Winch	36 800	23
Skidding grapple	3 600	2
Boom loader	15 300	10
Hydraulic loader	16 500	10
Forest trailer	33 700	21
Sledge	70 200	44

North America

Economics of Farm Forests

Sedjo, Roger A. 1983. The comparative economics of plantation forestry. Washington D.C., USA. Resources for the Future.

The book considers the growing importance of tree plantations for growing wood for industrial use. The study tries to define the long-run world supply and demand situation for the forest products; describe the future pattern of US forest resource trade, the different regions contribution to future supplies, the role of plantations in future and the role of the United States in the world forest economy in the future. Specifically, the purpose of this study is to investigate the potential of plantation forests.

Vardaman, J.M. 1978. Tree Farm Business Management. James M. Vardaman & Co., Inc. Forest Management Specialists. USA.

This book lists some of the many advantages and rewards that can be realised from tree farming. It describes the tree farming, lists the available forestry services, describes the selling of timber, management costs, the income, finance, taxation. The book also contains a couple of cases of successful tree farmers.

Wood Supply Systems

Laestadius, L.H. 1990. A comparative analysis of wood supply systems from a cross-cultural perspective. Swedish University of Agricultural Sciences, Garpenberg. Results, 180/1990.

Laestadius (1990) describes and compares the wood supply systems of the Southern United States and Sweden, identifying cultural influences that result in the very different 'styles' of technologies adopted by these two countries. Both rely heavily on small tracts of privately owned forest to meet the wood supply needs of their industries. The way fluctuations in harvesting rate are accommodated is central to the differences. In Sweden fluctuations are accommodated by maintaining large stockpiles of wood, allowing harvesting operations, with their considerable investments in specialised equipment and skills, to produce at a high level. In the Southern States this adjustment is made by varying the output of their less sophisticated harvesting technology, while minimising wood stockpiles.

Common characteristics of these two regions that provide the basis for their highly competitive forest industries are: large aggregate volumes of wood and highly developed harvesting, transport and marketing system that reflects the social and industrial culture of the different countries.

Appropriate Harvesting Technologies for Small-Scale Forests

Brandl, H. (ed.) 1992. Proceedings, Meeting of IUFRO-group P 3.04-00 'Small-scale Forestry': Economic results of private forestry in international comparison, and suitable forest technology for operations in forest smallholdings. Eighteen papers from the meeting held on 2-3 September 1992, during the IUFRO Centennial Meeting in Berlin/Ebenswalde. The papers include studies in Germany, France, UK, Austria, Slovenia, Sweden etc.

Folkema, M.P. 1986. Logging winches for farm tractors. Technical Note, Forest Engineering Research Institute of Canada.

Notes are given on the general use of logging winches on farm tractors and comparisons are made between 13 winches currently available from 5 manufacturers in E. Canada. Each winch is designed for a certain size tractor (15-74 kW) and can provide a max. line pull of 2500-6000 kg depending on the model.

Folkema, M.P. 1987. Logging trailers for farm tractors. Technical Note, Forest Engineering Research Institute of Canada. TN-97.

A discussion of trailers equipped with grapple loaders, with particular reference to Canadian-made trailers and trends in trailer design in Sweden and Finland. Results are also presented of a production study carried out at 3 sites in Quebec with 3 different types of trailer, each fitted with a GAJEC loader. Specifications of 10 trailers are tabulated.

McCallum, B., 1993. Equipping the farm tractor for forest operations, Forest Engineering Research Institute of Canada, FERIC Handbook No. 11.

The handbook is 75 pages long and is illustrated throughout with line drawings. It handles the important tractor features for forest use, protection of the tractor and operator, safety hazards in woodlot operations, site layout and planning, matching the tractor and implements to forestry operations and forestry implements for the farm tractor.

Hamilton, P.S. 1993. The Logmaster: a Canadian designed farm tractor skidding/forwarding grapple. Field Note, Forest Engineering Research Institute of Canada. FN No: Skidding/Forwarding -23.

In November 1992 the author visited a P.E.I. -based logging contractor and a metal fabrication shop who were jointly responsible for the conception, production and testing of a prototype farm tractor -mounted skidding/forwarding grapple. The field note describes the grapple and its operation.

Hamilton, P.S. 1994. Remote controls for farm tractor winches. Field Note, Forest Engineering Research Institute of Canada. FN No 24.

The performance of 2 types of remote control (infrared and radio-remote) on a silvicultural contractor's farm tractor logging winch was evaluated over a period of 2 years. The operation and installation of each system are described and the advantages offered by both systems assessed.

Kosicki, K.T. 1989. Evaluation of logging trailers for farm tractors. Paper, American Society of Agricultural Engineers, Univ. of Alberta, Canada.

A theoretical evaluation of 4 basic tractor/logging trailer configurations was carried out. For each analysed configuration maximum weight of payload, maximum velocity, minimum coefficient of traction and gradeability were established. It was found that performance of tractor/trailer forwarding units depends on the number and location of powered axles. The simplest configuration, a 2WD-tractor and non-powered trailer, is recommended only for favourable terrain and ground conditions. A 4WD-tractor with a non-powered trailer only slightly improved the performance of the forwarding unit. Powered trailers should be employed when the terrain is rough.

Gingras, J.-F. and Ryans, M. 1992. Future woodlands equipment needs in eastern Canada: 1992-2001. Forest Engineering Research Institute of Canada. Technical Note TN-193.

This report presents a ten-year (1992-2001) forecast of woodlands equipment population trends based on FERIC internal statistics and survey of forestry professionals across central and eastern Canada. Information is given on harvesting systems, harvesting approach, regeneration methods, harvesting equipment, silvicultural prime mover market, equipment ownership, financing and advanced technologies.

Riley, J.G.; Smith, N.; and Schaufler, D.F. 1984. A Development and test of a yarder and cable logging system for small woodlots. Agric. Engineering Dep., Univ. of Maine, Orono, ME, USA. Paper, American Society of Agricultural Engineers. No. 84-1600.

A small-scale logging system was designed. The system comprises a 12 hp hydraulically operated, two-drum yarder and an 18 ft lightweight tubular steel tower. It may be rigged as a simple yarding winch, as a high-lead system with haulback, or as a standing skyline with a locking carriage. Preliminary results are reported.

Eeronheimo, O. 1982. Tapio tree-harvesting head mounted on a farm tractor. Tapio kuormainharvesteri maataloustraktorissa. For. Res. Inst., Finland. Folia Forestalia, No. 506, 12 p. Finnish.

The Tapio harvesting head is a multi-purpose logging device of Finnish manufacture which can be mounted, in place of a conventional grapple, on the hydraulic loader of any agricultural tractor or forwarder with a minimum engine power of 44 kW. In trials with a Ford 5000/Fiskars F 5000/Tapio unit in mixed Scots pine/Norway spruce/birch stands in S. Finland, the average production rate in clear felling was 6.8 m³/h at a stand density of 690 stems/ha and an average stem volume of 0.17 m³. The production rate in thinning was 4.9 m³/h, when the number of stems removed was 250/ha and the average volume 0.20 m³/stem. Because of its low operating cost compared with heavy multi-purpose machines, the Tapio harvesting head is competitive especially when the trees and logging areas are small.

Appendix B: Survey Template.

A survey to determine landholder involvement in harvesting and on-site processing of forest and in particular plantation timber.

Introduction: The survey comprises 3 sections:

Section **A** should be attempted by all respondents.

Complete Section **B** if you anticipate harvesting will occur on your property in the next six months.

Complete Section **C** if you anticipate processing will occur on your property in the next six months.

Definitions: Timber **Harvesting** entails any or all of the following:

Planning, falling, sectioning, snigging, debarking, loading, and transport of timber for sale, trade or on farm usage (other than firewood).

Timber **Processing** entails any or all of the following:

Debarking, milling, chipping, air drying, kiln drying, and treatment with preservatives of timber for sale, trade or on farm usage.

Section A. All respondents please complete this section.

Question 1 Do you anticipate **harvesting** trees on your property in the next six months? ☐ Yes
☐ No

Question 2 Do you anticipate **processing** trees on your property in the next six months? ☐ Yes
☐ No

If you answered **NO** to both the first two questions then you have completed the survey. Thankyou for your time.

If you answered **YES** to either of the first two questions then please continue.

Question 3 Do you wish to be considered for involvement in other phases of this study in the coming six months? This will include a researcher visiting your forest to study and analyse the harvesting or processing operation. ☐ Yes (please provide a contact)
☐ No

Contact Name:
Contact Number:

Best time of day to call:

AM/PM

Section B. To be completed by respondents who anticipate harvesting will occur on their property in the next six months.

Question 4 Please tick the **most** likely person or organisation that will harvest the majority of the trees on your property. (You may tick multiple boxes)

- ☐ Self or family
- ☐ Contractor
- ☐ Neighbour
- ☐ Sawmill
- ☐ Cooperative
- ☐ Other (Please specify)

.....
.....
.....
.....

Question 5 Please tick the anticipated **total volume** of timber to be harvested within the next 6 months.

- ☐ Less than 25 m³
- ☐ 25 - 50 m³
- ☐ 51 - 100 m³
- ☐ 101 - 150 m³
- ☐ 151 - 200 m³
- ☐ 201 - 250 m³
- ☐ 251 - 300 m³
- ☐ 301 - 350 m³
- ☐ 351 - 400 m³
- ☐ 401 - 450 m³
- ☐ 451 - 500 m³
- ☐ More than 500 m³

Question 6 Please tick the products that you anticipate will be produced from the harvest operations over the next six months. (You may tick multiple boxes)

- ☐ Pulpwood
- ☐ Preservation grade logs
- ☐ Sawlogs
- ☐ Veneer/peeler logs
- ☐ Other (Please specify)

.....
.....

.....

Section C. To be completed by respondents who anticipate processing will occur on their property in the next six months.

Question 7 Please tick the **most** likely person or organisation that will process the majority of logs on your property.

- ☐ Self or family
- ☐ Contractor
- ☐ Neighbour
- ☐ Sawmill
- ☐ Cooperative
- ☐ Other (Please specify)

.....
.....
.....
.....

Question 8 Please tick the anticipated **total volume** of logs to be processed within the next 6 months.

- ☐ Less than 25 m³
- ☐ 25 - 50 m³
- ☐ 50 - 100 m³
- ☐ 101 - 150 m³
- ☐ 151 - 200 m³
- ☐ 201 - 250 m³
- ☐ 251 - 300 m³
- ☐ 301 - 350 m³
- ☐ 351 - 400 m³
- ☐ 401 - 450 m³
- ☐ 451 - 500 m³
- ☐ More than 500 m³

Question 9 Please tick the products that you anticipate will be produced from the processing operation over the next six months. (You may tick multiple boxes)

13. Bibliography

Brandl, H. (ed.) (1992). Proceedings, Meeting of IUFRO-group P 3.04-00 'Small-scale Forestry': Economic results of private forestry in international comparison, and suitable forest technology for operations in forest smallholdings. Eighteen papers from the meeting held on 2-3 September 1992, during the IUFRO Centennial Meeting in Berlin/Ebenswalde.

Eeronheimo, O. (1982). Tapio tree-harvesting head mounted on a farm tractor. Tapio kuormainharvesteri maataloustraktorissa. Folia Forestalia, Institutum Forestale Fenniae, No. 506, 12 p. Finnish.

Folkema, M.P. (1987). Logging trailers for farm tractors. Technical Note, Forest Engineering Research Institute of Canada, TN-97.

Folkema, M.P. (1986). Logging winches for farm tractors. Technical Note, Forest Engineering Research Institute of Canada, TN-90.

Fraser, P (1985). In: Limited Scale Logging. Proceedings of a seminar held in Rotorua, June 1985. Liley, W.B. (ed.) New Zealand Logging Industry Research Association Inc (LIRA).

Gingras, J.-F. and Ryans, M. (1992). Future woodlands equipment needs in eastern Canada: 1992-2001. Technical Note, Forest Engineering Research Institute of Canada, TN-193.

Hamilton, P.S. (1993). Remote controls for farm tractor winches. Field Note, Forest Engineering Research Institute of Canada, FN No. 24.

Hamilton, P.S. (1993). The Logmaster: a Canadian designed farm tractor skidding/forwarding grapple. Field Note, Forest Engineering Research Institute of Canada. 1993. FN No. 23.

Koistinen, A. (1991). On the development of forestry work carried out by the private woodlot owners in Finland. Finnish Work Efficiency Association, Finland.

Koistinen, A. (1989). The status of forestry on Finnish farms. Finnish Work Efficiency Institute, Tyotehoseuran Julkaisuja 310.

Kosicki, K.T. (1989). Evaluation of logging trailers for farm tractors. Paper, American Society of Agricultural Engineers.

Laestadius, L.H. (1990). A comparative analysis of wood supply systems from a cross-cultural perspective. Swedish University of Agricultural Sciences, Garpenberg. Results, 180/1990.

Liley, W.B.(ed.) (1985). Limited Scale Logging. Proceedings of a seminar held in Rotorua, June 1985. New Zealand Logging Industry Research Association Inc (LIRA).

McCallum, B. (1993). Equipping the farm tractor for forest operations. Forest Engineering Research Institute of Canada, Handbook 11, 73 p.

Ohlsen, P. H. (1985) In: Limited Scale Logging. Proceedings of a seminar held in Rotorua, June 1985. Liley, W.B. (ed.) New Zealand Logging Industry Research Association Inc (LIRA).

Race, D. (ed.) (1993). Agroforestry, trees for productive farming. Australia. Dept. of Conservation and Natural Resources; Dept. of Agriculture, Victoria.

Reid, R. and Stewart, A. (1995). Agroforestry; productive trees for shelter and land protection in the Otways. The National Farm Forestry Program, Otway Agroforestry Network.

- Riley, J.G.; Smith, N. and Schaufler, D.F. (1984). Development and test of a yarder and cable logging system for small woodlots. American Society of Agricultural Engineers, Paper No. 84-1600.
- Ryynanen, S. (1985). Logging Conditions and methods in farm forests of Finland in the logging season 1982-83. Finnish Work Efficiency Association, Tyotehoseuran Julkaisuja. Finnish.
- Ryynanen, S. (1986). Tractors and forest equipment for them on Finnish farms. Finnish Work Efficiency Association, Tyotehoseuran Julkaisuja.
- Sedjo, Roger A. (1983). The comparative economics of plantation forestry. Washington D.C., USA. Resources for the Future.
- Sennblad, G. (1984). Survey of logging and silviculture in non-industrial private forestry in Sweden 1984. Swedish University of Agricultural Sciences. Report No 175/88.
- Smaller, P.G. and Meister, A.D. (1983). The practices, problems and economics of farm woodlots. Discussion Paper in Natural-Resource Economics, Department of Agricultural Economics and Farm Management, Massey University, New Zealand. 1983., No. 6, 78p.
- Stewart, M. and Hanson, I (1998). On- site Processing for Farm Forestry. RIRDC, Pub no 98/ 079, Canberra
- Gullberg, T. (1991). Analysis of logging systems for pre-commercial thinnings within the non-industrial private forest sector. Report, Swedish University of Agricultural Sciences, Dept. of Operational Efficiency.
- Uotila, E. and Peltola, A. (1990). A method for calculating residual incomes from delivery and standing sales of timber. Finnish Forest Research Institute, Helsinki. Folia Forestalia 756.
- Vardaman, J.M. (1978). Tree Farm Business Management, James M. Vardaman & Co., Inc. Forest Management Specialists. USA.
- Vilhelmson, P. (1990). Ways of increasing income from forestry within the combined farm - an inventory and empirical study. Rapport No. 33, Sveriges Lantbruksuniversitet, Institutionen for Ekonomi. Uppsala, Sweden. 85p.
- Wallace, M. A. (1994). Comparative economic study of wood growing in Australia and selected countries. Gottstein Memorial Trust Fund, The National Educational Trust of the Australian Forest Products Industry. Victoria, Australia.
- Wilson, S.M., Whitham, J.A.H., Bahati, U.N., Horvath, D. and Tran, Y.D. (1995). Survey of trees on Australian Farms: 1993-94. ABARE Research Report 95.7, Canberra.