THE IMPORTANCE OF SIZE AND SCALE IN FORESTRY AND THE FOREST INDUSTRIES*

W. R. J. SUTTON†

SYNOPSIS

Increase in forest size results in marginally lower direct costs, considerably lower overhead and administration costs (farm forests are an exception), no potentially greater risk of pathological attack and probably fire, but possibly greater social problems. As economic studies have shown that forest profitability depends more on tree management than on the actual growing costs, the forests with the greatest managerial flexibility should be the most profitable. In practice this is most likely to be the small, independent forest.

With sawmilling there appear to be few economies of scale, the higher direct operating costs of small sawmills being offset by lower capital, depreciation and transport costs. In the use of residues and in marketing, larger sawmills have an advantage.

The pulp and paper industry has clear economies of scale; companies tend to expand existing mills rather than build new ones.

Although now a reality in New Zealand, integration in the wood processing industry has not resulted in some of the expected advantages — especially the ability to pay high stumpages. Indeed the total *profits of the major companies when expressed as a price per unit volume are not much higher than current stumpages being paid in the log export trade.*

THE IMPORTANCE OF SIZE IN FORESTRY

Forest size and the scale of operations can influence many aspects of forestry. It can have a significant influence on both direct and indirect costs, and can be an important consideration in the availability and quality of labour, in the susceptibility and control of forest diseases, in the prevention and suppression of forest fires and in managerial flexibility. All of these aspects can be important in determining forest profitability.

Direct Costs

In principle, large forests and/or large-scale operations should have the lowest direct costs. The possibilities for in-

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*Paper presented to 12th N.Z. Science Congress, Palmerston North, February, 1972.

†Scientist, Forest Research Institute, Rotorua.

creasing efficiency through rationalization, mechanization, method development, labour specialization, etc., are greater with large-scale than with small-scale forestry. There should also be advantages of competition and better management. This should result in lower direct costs for the large-scale forests. In practice there is little evidence that the potential advantages of large-scale forestry have been realized.

A limited and unpublished study (J. O. Drewitt, pers. comm.) of direct costs for silvicultural operations in New Zealand failed to demonstrate any obvious trend towards lower costs with either the larger forests or the large-scale operations. Other factors, such as site, working conditions, labour and management quality were just as important, if not more so.

Land clearing costs in New Zealand are very variable but there are some indications that direct costs are lower when the scale of operations is large enough to allow machinery to work near its capacity (Chavasse, 1969).

Cost studies on New Zealand logging and harvesting (Terlesk, 1972) have also failed to show any obvious advantage of scale; work method, and to a lesser extent piece size, topography, etc., are more important than scale. Indeed, some small-scale contractors have been able to achieve average man-day and machine productions (at correspondingly lower costs) up to 50% better than have the State or large private companies in comparable work. Fenton (1970a) has shown, at least for the State operations, that radiata pine clearfelling average man-hour production remained virtually constant in the 8-year period, 1961-8.

One observation common to all the above studies was that, while large-scale operations may not have the lowest costs, they are almost certainly not likely to have the highest. Increasing the scale of operation appears to be more important in preventing high costs than in ensuring low ones.

Overseas studies are rare. Jarrold and Griffin (1966) in a study of establishment costs on private forests in Great Britain showed that there was ". . . little decrease in costs with increase in [forest] size". They found, as in New Zealand, that other factors such as site etc. were equally important in determining costs.

In a Swedish study Streyffert (1957) claimed that the possibilities for increasing efficiency are greater for the large than the small forestry enterprises, but the small enterprise may also raise its efficiency through some form of co-operation. However, no actual values are given.

New Zealand experience suggests that large-scale forests or large-scale operations do not of their own accord ensure lowest costs. Indeed, it appears that there has generally been inertia among the large operators either to improve efficiency or to reduce costs.

In early 1969, Kaingaroa's work study officer published (Terlesk, 1969) details of the ladder and jack-saw method of pruning which had been introduced by contractors two years earlier. This improved method reduced the costs of the 2.4 to 4.3 m pruning lift by 30 to 40% over current methods. By 1970 only the smallest Forest Service conservancy (Westland) and one of the smaller private companies had formally adopted the new method as standard practice — although Southland Conservancy was using it in conjunction with conventional pole saws (James *et al.*, 1970). By 1972 the method was not universal even at Kaingaroa Forest and was not used on neighbouring forests such as Rotoehu or Whakarewarewa. Rogers (1970) discussing problems of implementing the new method claimed that its introduction was more difficult in wage gangs than with contractors.

A study of Soviet logging enterprises (Romanov, 1966) showed that increasing labour productivity offered much more scope for reducing costs than increasing the size of the enterprise.

Better management, methods studies and competition would therefore appear to offer a surer means of reducing direct costs than increasing the scale of operations. This could be achieved in part by placing much less emphasis on the physical aspects (men employed, areas planted, volumes extracted, etc.) when assessing staff for promotion and much more on the actual costs and efficiency of operations. As suggested by the experience cited above in logging and pruning, lowest costs are likely to be achieved by using contractors where possible, and by encouraging and rewarding men and their managers for the development and improvement of better methods.

Indirect Costs

These include all costs which cannot be directly allocated to a specific area or operation; namely, the costs of general administration, fire prevention, social services (*e.g.*, housing, work camps), repairs and maintenance (*e.g.*, roads, bridges, buildings), capital costs of buildings and depreciation, and external overheads. Since many of these services must be provided irrespective of how much they are used, it should be expected that there are economies of scale. Larger forests should also allow greater specialization and this should also reduce unit costs.

In a study of my own (Sutton, 1969) of the major non-capital costs (general administration, camps and hostels, fire protection, repairs and maintenance) of New Zealand State exotic forests I found that although there was some variation resulting from the level of activity on the forest there was an obvious trend towards lower unit costs on the larger forests. If the costs for Kaingaroa Forest (New Zealand's largest at 120 000 ha approximately) expressed as an annual cost in dollars per hectare per annum are taken as a base, then as a general rule the unit costs for forests in the 4-8000 ha range are just over double, and those in the 400-800 ha range quintuple, those for Kaingaroa. Similar trends almost certainly exist for the other indirect costs — mainly capital costs (*e.g.*, buildings, roads, vehicles) and their depreciation — but no detailed analysis is available.

In the above study the average (rounded) unit costs (in dollars/ha/year) for Kainagaroa (based on costs for 1962-4) for those overhead costs studied were:

	$	$
Administration general	1.48	
Camps and hostels	0.50	
Total		1.98
Fire protection (incl. suppression)		0.50
Repairs and maintenance		1.00
Grand total		3.48/ha

On a 4-8000 ha State forest these costs were about \$7.40/ha and on a 4-800 ha State forest about \$17.00/ha/year. If these costs are capitalized at 5% compound interest this is equivalent to \$69/ha for Kaingaroa, \$150/ha on a 4-8000 ha forest and \$345/ha for a 4-800 ha forest. Had the other indirect costs (*e.g.*, capital cost of buildings and their depreciation) been included, the magnitude of the difference would have been even greater.

The magnitude of the economies of scale for indirect costs is therefore such that it is doubtful if small State forests (at least those under 4000 ha) can be justified economically.

Indirect costs on private forests are not known but it would be reasonable to assume that for the large company forests these costs would be similar to those of the State — especially the on-forest overhead costs as discussed above.

For the independent and relatively small operator, however, these advantages of size and scale do not necessarily apply. Indeed, both the small forest owner and the independent contractor at the lower end of the operational scale appear to have definite advantages. Frost (1971) showed that, even with a 20% loading on direct costs, the small private forest grower in New Zealand would incur only two-thirds of the total growing costs which would be expected by the State or a large private company. Weber's (1953) study of U.S.A. forest products firms showed that, although the large operator may be more efficient, his costs will be higher than the small operator as there are many overhead costs which the latter can avoid.

Small company forests should be able to avoid some of the overhead costs found in the State and large companies. With possibilities for more personal involvement there should be less need for a large administrative overhead.

Other overseas studies tend to confirm the New Zealand observations. Cost studies in South Australia (Woods, 1965) on plantation maintenance costs showed a variation from \$9.15/ha per annum to over \$24.70; most of the difference derived from forest size.

Sinden's (1966) study of forest size in Wales demonstrated the importance to costs of maintaining regularity of operations. He suggested that this could be achieved by amalgamating small forests into larger management units with an estimated 2% saving in overall expenditure.

I found one overseas reference which implied that there was an upper limit to forest size. A Russian comparison (Sudackov and Vitalev, 1967) of the management efficiency of 38 "forests" ranging from 60 000 ha to 100 million ha (an area four times the size of New Zealand!) showed that the optimum size should be 80-100 000 ha in the central and southern Siberia and 400-500 000 ha in the north. On these standards and considering growth rates in New Zealand, Kaingaroa and N.Z. Forest Products Ltd (both now around 120 000 ha) are too large.

Labour and Social Aspects

In principle, increase in forest size should benefit the labour and social aspects of forestry. Larger scale operations have greater scope for better management and for labour specialization (which should improve efficiency and make the job more attractive). The larger the concern, the better should be the facilities which can be provided and supported in forest villages and townships.

Since in the past the greater part of New Zealand forest labour has consisted ". . . of left-overs from the general labour pool" (Entrican, 1957), and as a consequence labour turn-overs have been high (115-195% — Fenton, 1969) there has been little scope for specialization. Only with the introduction of incentive work and more recently contract work have better workmen been employed. However desirable they may be, contractors are difficult to hold when the silvicultural operations on which they depend are generally one of the first expenditure items to be cut in periods of financial restraint.

Industrial unrest and strikes are rare in New Zealand State forests; the only official strike, at least since 1945, has occurred in our largest forest, Kaingaroa. The Kaingaroa unrest was interesting as it highlights a psychological aspect of labour which affects large organizations rather than small ones. The Forest Service wished to introduce a more efficient system of clearfelling, but this was not acceptable to the fellers.

Despite attempts at improvement many of the problems of the forestry village have not been solved. The problems have been documented elsewhere (Chapple, 1972) and fully discussed by Fenton (1969). They can be summarized:

". . . the . . . rural disadvantages of poor educational, religious, cultural, medical and commercial services."

". . . the difficulty . . . where a supervisor lives next door to an employee".

". . . the wives and children . . . have to bear the greater part of the social disadvantages".

". . . limited number of job vacancies [for] teenage children" etc.

". . . The inhabitants overwhelmingly depend[ent] on one industry".

Fenton, (1969).

In practice it is doubtful if large villages have any advantages. Indeed, it is almost certainly better to do away with forest villages completely. Overhead costs are high and it is now almost always cheaper to transport men from a neighbouring town (Grainger, 1969). Such changes are likely to favour the small forest.

The problems of the forestry village are only one symptom of a much more important social problem in forestry. Since forestry tends to be largely a monolithic rural industry in which the ultimate employers are generally one government department or a few large companies, there exist the dangers common to all large organizations ". . . viz. over-centralisation and the suppression of initiative in the junior members of the service" (Hiley, 1930), or, as has been so ably summed up in the quotation from Robert Townsend's book *Up the Organisation* (1970).

"AND GOD CREATED THE ORGANISATION AND GAVE IT DOMINION OVER MAN"

In forestry the problem is compounded because of insufficient pressure to make operations efficient and profitable, and because of the time scale involved malpractices do not immediately affect the financial returns. These organizational problems are the most probable explanation for the non-realization of many of the potential advantages of large-scale forestry.

Pathological Considerations

As ". . . forest management has become more intensive, trees have been grown on large areas in even-aged stands" (Smith, 1970). This practice of large-scale monoculture has in the past been generally condemned by overseas forest pathologists.

> Smith continued ". . . If this type of growth pattern is not natural to the tree species, the situation becomes analogous to that extant in agriculture [where] . . . much effort must be applied to avoid the occurrence of epidemics".

> Boyce (1961): "Pure stands are more susceptible to diseases . . . an ideal situation for a pathogen to build up to epidemic proportions. The most hazardous pure stands are even-aged . . .".

> Graham and Knight (1965): ". . . foresters tend to favour large-scale pure stand silviculture over practices that grow trees diversified [in] age and size classes. In the past this has led to encouraging pests . . . that under primitive forest conditions were unknown".

> Peace (1957): "Condemnation of monoculture is so general that it is scarcely necessary to quote references . . ."

> In particular reference to New Zealand, de Gryse (1955) claimed that: ". . . to ignore the notorious susceptibility of *P. radiata* to attack by insects and fungi, the extreme vulnerability of the extensive monoculture in which it occurs,

> or the astounding aggressiveness of radiata under New Zealand conditions, is tantamount to challenging all the laws of nature . . ."

The underlying assumptions of the pathologists' claims are that natural forests are generally a mixture not only of age classes but also of species, that these forests are less susceptible to disease and insect attack than artificially established forests, the implications for management being that large-scale forests with a single species should be avoided; that mixtures are preferable to pure stands; and that, within a forest, areas of a single age class should be kept as small as possible.

How well supported are these basic claims and to what extent should forest management heed the recommendations?

Contrary to general belief, the natural forest habitats of most of the commercially important temperate zone softwoods (including the pines) are even-aged monocultures (Jones, 1945). Even the natural stands of radiata pine on the Californian coast are generally uniform with the pine dominant; although in the region from which the New Zealand stands are considered to have largely originated (Ano Neuvo) the radiata pine sometimes occurs in mixture with Douglas fir (Forde, 1966; I. J. Thulin, pers. comm.). The virgin stands of Douglas fir are also generally pure and even-aged (Isaac, 1959).

Losses to pathogens in indigenous forests are considerable. Davidson and Buchanan (1964) estimated the total annual losses from forest tree diseases in the United States and Canada at 139 and 27 million m^3 respectively. This is equivalent to a half and quarter, respectively, of the total annual cuts for these countries. All these losses were in indigenous forests. Nearer home the recently discovered New Zealand totara and West Australian jarrah deaths provide further demonstration that the natural forest environment is no guarantee of protection.

New Zealand experience with the introduced pathogens has served only to strengthen, rather than weaken the case for large-scale monoculture. The introduced *Sirex noctilio* wood wasps did more to demonstrate the importance of timely silviculture than support a trend to species other than radiata pine — stem losses being generally confined to the lower dominance classes (Spurr, 1962; Jackson, 1955).

The introduction of *Dothistroma pini* needle cast has shown that diversification with species of the same genus is no guarantee of protection — ponderosa and Corsican pines being more seriously affected than radiata.

The discovery of the Douglas fir needle fungus (*Phaeocryptopus gaeumannii*) in some stands (Anon., 1969) has shown that our main alternative genus may be potentially just as prone to attack as the major one.

From an economic point of view, diversification can probably only be justified if the alternative species has similar growth rates and if it can be grown in plantations on the sites available. The only practical alternative to radiata in

New Zealand are some of the *Eucalyptus* species (but wood properties are not similar).

Even a moderately intensive spraying programme to control *Dothistroma pini* on radiata has a relatively minor effect on the species' profitability. It is the equivalent of about 4% of the total compounded growing costs (assuming 7% compound interest — Fenton and Tustin, 1969). This certainly would not justify diversification to another less productive species. On the other hand, Corsican and ponderosa pine crops are so marginal from an economic point of view that the cost of spraying only adds to their undesirability.

Physical separation of forests has not effectively prevented the spread of any of the three major introduced pathogens, although it may have slowed down their rate of spread. There would seem little point, therefore, in restricting forest size simply on the grounds that it may slow down the rate of initial infection and attack. Experience with the introduction of *Dothistroma pini* in Kenya supports this view. Gilmour (1968) reported that, although radiata plantings were generally in small blocks of 4 to 20 ha and scattered amongst the other exotic species and indigenous forest, this did not prevent the spread of the disease. It was, however, a factor in preventing the introduction of an effective spraying control programme which has been so successful in New Zealand.

Monoculture of radiata in New Zealand has now been generally accepted. Knight (1971) after visiting New Zealand stated:

> Everyone recognises that growing plants over large areas in single species stands is more risky than hiding them as single stems in a vast mixture of species. However, I do not go along with those who might suggest making major changes in the management of radiata pine in New Zealand. Commonsense tells us that monocultures are more risky than mixed forests but commonsense also tells us that depite the 'dangers' we have no valid reason to change the management system. We need radiata pine monocultures and we must be willing to pay for the precautions necessary to maintain them.

With pathological considerations the advantages appear to favour the large-scale forest. Control measures on small forests are likely to be more expensive but costs could be reduced by planting blocks as large as possible in areas where there is, or will be, considerable forestry development.

Fire Prevention and Control

All indications are that fire protection costs are assisted by an increase in forest size. In New Zealand State forests, fire protection costs showed similar trends to that of general administration and other indirect costs — *i.e.,* they can be expected to be five times higher per unit area on a 400-800 ha forest than at Kaingaroa Forest, etc. (Kaingaroa costs were 50c/ha per year in 1964 — Sutton, 1969). Similar trends were observed by Woods (1965) in South Australia.

Woods also found that fire protection required a minimum strength (not specified) of adequately trained personnel — a factor also important in New Zealand (see statement by

Canterbury Conservancy on page 38 of James *et al.*, 1970). This aspect of control is assisted by the increase in forest size.

It could be argued that the larger the forest the greater the area at risk. It is claimed that, once started, a crown fire is almost impossible to put out. Where large forests are established on flat country fire losses of well in excess of 20 000 ha are possible; on broken terrain fire losses would be minimal as evidenced by experience with several serious fires at Golden Downs (W. Girling-Butcher, pers. comm.). The largest two exotic fires in New Zealand occurred in forests on flat sites: the 1964 Taupo fires and the 1956 Balmoral fire, destroying 12 000 and 2 540 ha, respectively (Anon., 1946 and 1956). With improved experience and knowledge of fire control methods, it is less likely that such losses will be repeated. Also, past forest losses were in untended forests which have an accumulation of ground fuel and branch-covered stems, both of which assisted the fire and allowed crowning. The tended forest of the future, especially if grown on the economically superior short-rotation regime (Fenton and Sutton, 1968), or its variants, in which the stand is reduced to the final crop stocking of pruned stems as soon as possible, should be safer after high pruning, and safer still if the regime is combined with grazing as is now suggested (Knowles, 1972).

For the small forest owner, especially a farm forester growing trees in combination with grazing, the risk of fire is so small that it can probably be ignored after first selection pruning.

GENERAL DISCUSSION

The main advantages of scale in forestry are lower overhead and administration costs and some advantages in fire and pathological control. The implications for the State and for the larger private companies are that production should be concentrated in large forests and that ideally these should be expanded before new forests are begun. New forests should only be started if the forest is likely to be large — at least in excess of 4000 ha and preferably several times this size.

The social and organizational problems of large-scale forestry could be reduced by better management and by a much greater emphasis on efficiency and economics at all levels.

There appears to be little place for the small State forest. On the other hand, there does appear to be an important role for the small, independent forest which can be either a small company forest or an individually-owned forest such as a farm forest. It could also include the local body forest.

While the area in small forests is not large (*e.g.*, of New Zealand's total plantation resource of about 570 000 ha (Anon., 1971a) about 30,000 ha (5%) are in ownership holdings of 20 ha or less), and although the proportion of these holdings is now small, their contribution to the forestry economy is still important — an estimated 236 000 m^3 of sawn timber per year or a little less than 20% of the total exotic cut, and an estimated 225-280 000 m^3 of log exports, or about 15% of the total volume exported* (1970 figures — I. A. Frost, pers. comm.).

Some overseas studies have indicated that yields from independently-owned forests are lower than from State or large company forests (Hasel, 1954; Abetz, 1958). It is doubtful if this is so in New Zealand for practically all forests (both State and private) being utilized are largely untended, and the small private forests are often on better quality sites.

Despite their size the small independent forests, whether company or privately owned, have several advantages over the large forestry organization (State or company):

(1) As the forest is unlikely to be committed, produce can be sold on a free market and if the market declines there is the option of not selling without incurring financial loss and at only minimal risks.

(2) Because of the smallness of their organization the management of such forests can be highly flexible.

The small private forest has two further advantages:

(3) That of low overhead and administration costs.

(4) Since the owner has no national or company interests or status to worry him and since he is spending his own, rather than someone else's money, he has every direct incentive to reduce all costs and to sell on the best market.

Of these, flexibility of management is probably the most important advantage. In traditional forestry the importance of costs has been heavily emphasized. However, current economic studies (namely, the current FRI economic models, Fenton *et al.*, 1968a, b, c) have shown that individual costs have a relatively minor effect on overall profitability. Far more important than costs is the timing of operations and the regimes on which the trees are grown. For example, the total direct growing costs of trees grown on the short-rotation sawlog regime (equivalent to \$200/ha discounted at 7%) could be more than doubled and the regime would still be considerably more profitable than trees grown on a conventional extraction thinning regime for which the overall profitability is about \$270/ha lower (at 7%) (Fenton, *et al.*, 1968a, b).

As one directly concerned with the advocation of the new forest regimes (Fenton and Sutton, 1968), I can say that, while there has been slow acceptance of the new regimes by most of the large State† and large private company forests, we have had a fair amount of success with the smaller private companies and individual private growers. Indeed, some of the latter two groups must be credited with the introduction of the new regimes before their advocation by research workers

*Some of these volumes would have come from small owners with holdings greater than 20 ha.

†In some State forests, notably those in Nelson and Westland Conservancies, new regimes similar to those proposed have been adopted.

— some organizations and individuals having given invaluable assistance in the development of the new regimes.

Because of their possible flexibility both in management and marketing, the potentially most profitable forests are likely to be those of independent owners. The small independent company has some of the same advantages but also has the disadvantage that they could be forced into take-overs by the large companies. The local body forest has the potential advantages of the small independent company, without the risk of a take-over. Whether the potential is realized will depend largely on the quality of the forest manager and freedom he is given. For the State and the large private companies, the advantages of scale do not appear to be sufficient to offset the disadvantages of a generally inflexible management and they are unlikely to attain maximum profits from their forestry operations.

IMPORTANCE OF SIZE AND SCALE IN MAJOR FOREST INDUSTRIES

Sawmilling Industry

The classical study of the sawmilling industry is Thunell's Swedish study (MacGregor, 1956) in which the economics of 8 types of sawmills cutting from 4 000 to 47 000 m³ were compared. Thunell found that, although labour costs per unit volume of production approximately halved and the conversion efficiency improved with the increase in sawmill size, these gains were almost entirely offset by much greater capital and depreciation costs in the larger plants. When the transport costs (larger sawmills tend to obtain their supplies from a wider area) were included, the total production costs were practically the same for all sawmills; the implications are that there are few economies of scale in sawmills. In conversion, in the utilization of waste, and in the provision of amenities for workers, etc., the larger sawmills were superior.

Few other studies are known. Duerr (1960) suggested that there were few economies of scale in sawmilling. Limited New Zealand studies also support this view. Some of the old indigenous mills, for example, despite their lower conversion have so little capital overhead that the cost of sawing is virtually limited to the direct cost of sawlogs. They, therefore have some of the lowest unit costs (C. H. Brown, pers. comm.).

Zaremba (1963) in a study of U.S.A. sawmills found evidence of a trend away from both small and large sawmills to medium-sized mills and this he regarded as optimum. He defined this mill size at 190 000 to 280 000 m³ for the west, and 35 000 to 47 000 m³ for the east. (In New Zealand there are 462 sawmills and of these only 9 produced over 24 000 m³ per year — their average production being 75 000 m³ — Yska, 1970).

While the actual cost of sawing does not appear to be dependent on mill size, there are other considerations. Use of mill residues is now an important aspect of mill economics. Although there can be some tolerance of bark in low grade pulps and there are now some flotation processes for removing bark from chips, it still appears preferable to debark logs prior to sawing (J. M. Uprichard, pers. comm.). Since modern sawlog debarkers cost in excess of \$50 000 it is only possible for the larger sawmills to install such equipment.

On the marketing side small sawmills have a distinct disadvantage. The range of products from the exotic forests has become so great that grading, sorting and storing constitute a major cost in sawmilling. For radiata pine there are at least one and often three or more grades of at least 16 common sizes of sawn timber. These can be supplied in most combinations of finish, dryness or preservative treatment; combinations which give a total of at least 400 common basic treatments *without* the complication of specified piece lengths. For other species such as Douglas fir the problem is simpler since the timber is generally sold ungraded and untreated. To provide a full service, stocks must be large. Waipa sawmill, for example, had sawn timber stock valued at \$1.3 million dollars in 1970 — equivalent to nearly 14% of its total sales, or four times the mill operating profit (Anon., 1971a). It is not difficult to see that it is only the large exotic sawmills that can provide such service. Similar problems exist for the small independent sawmills in the U.SA. (Senate Report, 1959).

One possible solution to the marketing problem would be the creation of co-operative or independent timber merchants who would be supplied from several sawmills and thereby free individual sawmills from the need to produce the full range of sawn end products.

This system has worked well in some areas of the U.S.A. ". . . but had led to some abuses in others" (Senate Report, 1959). Merchants in this system provide a service and do more than act as commission agents as they tend to in New Zealand at present.

The general conclusion is that, although there are a few apparent economies of scale in sawmilling, there are advantages to size in the utilization of residues and in marketing.

Pulp and Paper Industry

In the pulp and paper industry there are many references to the importance of scale (Duerr, 1960; Sandwell, 1960; etc.). Pulp and paper companies tend to expand existing mills rather than build new ones. Studies of the economics of scale in pulp mills provide confirmation of this. Recent studies on the investment requirements for pulpmills are summarized in Table 1.

The figures show that there are economies of scale especially with sulphate pulps — for these 400 to 500 tonnes per day (say 450 tonnes) appears to be an objective minimum size. Assuming a conversion factor of 4.5 m^3 per short ton (Yska, 1970) this is an equivalent to about 2 000 m^3 per day or about 700 000 m^3 per year. Under New Zealand conditions with a mean annual increment of around 21 m^3/ha/year, the forest area would need to be at least 32 000 ha assuming all production goes to the pulpmill.

TABLE 1: INVESTMENT REQUIREMENTS PER DAILY TONNE FOR MILL

(J. M. Uprichard, pers. comm.)

Rated Capacity Daily (tonnes)	*Groundwood ($US'000)*	*Unbleached Sulphate ($US'000)*	*Bleached Sulphate ($US'000)*
800	22	58	80
600	23	65	86
400	25	78	103
200	36	122	148
100	53	194	250+

Similar economies of scale are considered to apply in paper mills. An exception would be specialists' papers where technique and quality are probably more important than plant size.

Pulp and paper authorities, however, are not always in complete agreement on the importance of size. Burd (1970) claimed that ". . . technological changes in the next 20 years might make smaller mills viable"; Gibson (1970) questioned whether too much emphasis was being placed on size — he instanced St Anne's pulp mill (in the U.K.) which showed that it was not necessary to be big to obtain a reasonable return.

The Problems of Pulp Mill Supply and its Importance to Forest Management

To enable pulp mills to realize the full economies of scale, forests on which they depend for supply must not only be large but they should also be under the complete control of the mill so that a continuous supply of raw material can be assured. For this reason pulp companies prefer either to own their own forests (as with N.Z. Forest Products Ltd which has a forest of 96 000 ha and is planning on 160 000 ha — Anon., 1971b), or to have long-term supply contracts (as with Tasman Pulp and Paper Co. Ltd to which the N.Z. Forest Service is committed to supply 1 700 000 m³ annually for 60 years (Anon., 1971c) — 650 000 m³ of which was originally negotiated at a price of 88 cents/m³ (Hansard, 1954)). In practice this means that forest considerations must be subservient to those of the pulp mill. In the private sector, at least, the return on capital to the pulp mill is considered far more important than the return on forest capital. This has a depressing effect on forest management and has almost certainly been a contributing factor in failing to realize the potential economies of scale in the forests as discussed above. Inefficient and less profitable practices such as the maintenance of high stocking, production thinning, and long rotations tend to exist in our industrial supply forests because they are considered necessary to ensure efficiency in the pulp mills.

Recent economic studies both in New Zealand (Fenton, 1970b) and overseas (Segur, 1970, and others) have shown that, despite the high capital requirements of the processing mills, the capital value of the supplying forests is at least as great as the plant which it supplied; for example, for the southern U.S.A., Segur (1970) calculated the forest investment to be almost 150% more than that in the plant. It should therefore be just as important to ensure a maximum return on the forest investment as on the plant investment. Maximum profitability can only be assured if the forests as well as the processing industry are efficient. The forest should never undertake non-profitable operations because of possible minor effects on pulp mill profitability.

Because of the economies of scale in the pulp and paper industry and because of the relative smallness of our forest resource and our population, it is probably inevitable that New Zealand's two major companies have achieved monopoly positions and have chosen not to compete in the various pulp and paper end-products (Doig, 1969). This is one of the possible disadvantages of scale.

Other Wood-using Industries

There are probable economies of scale in the panel product industries (plywood, particle board, etc.) but they would not be of the same order as in pulp mills since the production units required are not very large (Worrell, 1959).

For some specialist industries such as furniture and joinery where considerable human skill is required, there are probable diseconomies of scale since increase in the factory size can result in poor supervision (Duerr, 1960).

Integration of Forest Industries

Entrican (1950) claimed that "integration of manufacture [was] the key to optimum forest development". Integration he defined as:

> . . . a system of economically combining the various types of conversion-sawmilling, plywood manufacture, structural fibreboard production, pulp and paper manufacture etc. Each section of the integrated set-up takes the particular kinds of raw forest material most suited to its production and thereby secures these at a minimum price . . . Yet by the sharing of common facilities . . . both capital and operating costs per unit of product are so reduced that the forest owner can realise a higher total value for his raw material.

The two largest wood-using companies in New Zealand (N.Z. Forest Products Ltd and Tasman Pulp and Paper Co. Ltd) each has a sawmill integrated with its pulp and paper mills. It is not known what N.Z. Forest Products pay internally for stumpage or what actual stumpage is now paid by Tasman for wood from the State, but the latter is known to be less than the average of 116 cents/m^3 paid for standing sales in Rotorua Conservancy since the other major supply was to Waipa sawmill at 176 cents/m^3 (Anon., 1971a). An analysis of company profits expressed as price per m³ is probably the best indicator of profitability.

For Tasman for the year ended 30 October 1970 the total profit before taxation was \$9.7 million and after taxation \$5.3 million (Anon., 1970). During the year the mill processed 1 262 000 m^3 so the profit was \$7.70/m^3 and \$4.20/m^3 before and after tax, respectively.

N.Z. Forest Products in the year ending 31 March 1971 had a net operating profit before tax of \$15.9 million and after tax \$8.5 million (Anon., 1971b) The volume processed is not given but their annual report stated that "over 2 000 000 tons of logs are used annually by the company". At Kaingaroa's conversion factor of 0.98 m^3 per tonne (J. D. Mackintosh, pers. comm.) this is equivalent to about 2 million m^3. The profit is therefore about \$8.00/m^3 and \$4.30/m^3 before and after tax, respectively.

These company profit levels are generally considered very satisfactory but it should be noted that, especially for N.Z. Forest Products Ltd, there is a considerable degree of processing involved. However, the gross profit per cubic metre after all processing is only marginally better than the residual stumpage being currently paid for logs sold on the log export trade (\$6.00/m^3 or more — Anon., 1971d; Fenton *et al.*, 1968c; there are unofficial reports of stumpages well over \$7.00/m^3 — Barr, 1973).

It is extremely doubtful, therefore, whether integrated industries when in open competition can ever match the stumpages of the export log trade. The small independent forest with its major advantage in managerial flexibility is likely to be the most profitable, provided always that there will be an open market and that there are sufficient numbers of small owners to ensure continual supply.

ACKNOWLEDGEMENTS

Although opinions and interpretations of basic information are the responsibility of the writer, many Forest Service officers have given considerable assistance in providing information and references. In particular, C. Bassett, R. T. Fenton, I. A. Frost, J. D. Mackintosh, C. J. Terlesk, K. Walker, J. M. Uprichard, J. M. Valentine. The writer is also indebted to A. P. Thomson and W. Girling-Butcher for their comments on the original draft. The technical editing assistance of I. W. Davey is also appreciated.

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