MANAGEMENT OF SHELTERBELTS FOR WOOD PRODUCTS

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ABSTRACT

A literature review shows a serious lack of information on the use of shelterbelts for wood production, but there is widespread historical evidence that, in several countries, they have been either mismanaged, or unmanaged, and have thus tended to fall into disrepute. What evidence there is indicates that timber can be produced from shelterbelts without detriment to their shelter value and that yields in both volume and value can exceed those from forest stands, provided that proper management is applied and that the produce is efficiently marketed. In view of the potential importance of this source of timber in New Zealand (estimates of likely areas for the whole country lie between 300 000 and 740 000 ha) there is clearly a need for further research: first, to determine volume yields and timber values; secondly, to confirm silvicultural practices; and thirdly, to elucidate the whole question of shelter on hilly pastoral land, where firm information is almost totally lacking.

INTRODUCTION

A literature search shows that there are very limited data, world-wide, abstracted on the subject of wood yields from shelterbelts, largely because their value as shelter obscures all other values, and they are considered to be the concern of farmers, not foresters. Surprisingly, there is far more information on this subject from New Zealand sources than from the rest of the world. This contrasts markedly with the enormous amount of overseas data on the effects of shelter on crops of all kinds, including grass. It draws attention to the need for research: for example, what volumes and qualities of wood could shelterbelts yield? What forms of tending (pruning, thinning) and structure (number of rows, spacing, species) give optimum results for timber yield values, and what effects do such silvicultural practices have on shelter values?

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These are important questions in New Zealand, because shelter can make a substantial contribution to agricultural and horticultural yields, and because much of New Zealand is subject to frequent strong winds; thus the potential wood yield from shelterbelts could be very substantial. Molloy *et al.* (1980: 143) estimate that the national area in shelterbelts could be as high as 740 000 ha. A survey by the Forest Research Institute in 1980 indicated that shelterbelts should occupy about 3% of arable land. For horticultural crops it could be higher. Hill land shelter needs are more difficult to assess; the literature is almost devoid of information on this subject. Some hilly country may need some 20% in shelter plantings but for less windy, and warmer, areas, it could be between 8 and 10%. A realistic guess would be in the vicinity of 300 000 ha for the whole country. Efficient management to produce optimum yields of wood from such a large area could make a substantial contribution to farming income and national productivity in addition to shelter value, estimated by some authors (*e.g.*, Smail, 1979) to give a 20% increase in farm yields.

THE HISTORICAL PERSPECTIVE

Molloy *et al.* (1980) note that tree planting on New Zealand farms has been marked by cycles of activity and neglect. Hosking (1978) reported that in the North Island there is a "generation gap" in farm shelter; belts are mostly old, unmanaged, decayed and damaged by wind, with little or no timber value. Stringer (1978) reported a similar situation in Canterbury, deploring especially the practice of topping trees in an attempt to obviate windthrow. Both authors are, however, certain that many farmers realise their need for shelter. Yeates (1959) presents a graphic description of the typical New Zealand shelterbelt — malformed, weed-infested, unkempt and valueless for timber. Stronge (1969) gives some reasons for the decline in shelterbelt planting; use of land for such a purpose is thought to be uneconomic, there is transfer of fertility and build-up of disease in the vicinity of belts, while stumpages offered by sawmillers are universally low. In his view, farmers are mostly unaware of the benefits of shelter and make no attempt to understand forestry. They may indeed be hostile to trees.

The position is much the same in Britain (Caborn, 1965), where shelterbelts have been allowed to decay or have been removed and not replaced. Yet the future timber supply position dairy farm where shelterbelts are being planted deliberately with the objective of obtaining a "cashable crop"; and of a hill property where 14% of the land is being planted in trees with the confident expectation that the farm yield will be greatly enhanced and the timber will have a salable value at maturity. They conclude that up to 20% of hilly land in Britain could be planted in trees without any reduction in farm output.

In Australia Brown and Hall (1968) report that shelterbelts can provide timber for farm use or for sale; while Wilson (1977) concluded that the most important single benefit may not be income from the trees *per se* but income stabilisation — the ability to harvest and sell trees when income from stock or arable land is depressed. Apart from this, the shelter may increase farm yields by 25% (similar to Smail's (1979) figure for New Zealand).

In Columbia, Ladrach (1978) has produced yield tables for eucalypts planted along field boundaries and suggests that producing timber in this way should not affect farm production.

In the Sudan, Bayoumi (1977) notes that shelterbelts should have multi-purpose objectives, including shelter and timber production, improved farm yield and decreased use of irrigation water. To achieve this the farmers must enjoy the direct benefits of the wood yield.

In New Zealand there is some doubt about the value of producing wood from shelterbelts, possibly owing to traditionally low stumpages and oversupply of wood. Meyer (1968) deplores the lack of "cold hard facts" even though he admits that part of the value of shelterbelts is the cash return from wood when they reach maturity. Stronge (1969) records, however, that in Taranaki over 95% of the millable timber has come from shelterbelts and small woodlots, and deplored the lack of replacement planting. Most of the wood harvested there was radiata pine, but a number of farmers consider that species other than pine (including those with durable timbers) could be grown on farms. For example, Panther (1971) advocated growing *Eucalyptus viminalis* for providing split or sawn battens, while Steele (1925) records the production of "splendid" poles (*Eucalyptus viminalis* and *E. globulus*), posts (*E. obliqua*) and bridge stringers (*E. eugenioides* (*E. globoidea* Blakely)) from old shelterbelts in Marlborough. Molloy *et al.* (1980) advocate the production of timber from small areas such as shelterbelts in districts where the risks of storm damage and fire are high (*e.g.*, Canterbury), rather than in forests.

in Britain is regarded as alarming (CAS, 1980). The best estimate is that 26% self-sufficiency in timber could be achieved by the year 2025 provided there is full integration of farming and forestry. The potential area is similar to that estimated for New Zealand shelterbelts, and such an area could be planted with minimum reduction in agricultural production. But practically nothing is being done to promote the management of shelterbelts for wood production.

In the Great Plains of the U.S.A. Tinus (1976) records that windbreaks have not been managed and the current major problem is renovation *in situ.* The optimum structure of belts has not been researched and they are now largely inappropriate in their present form (wide, gable-shaped) for new forms of agriculture. In other words, the whole system has been allowed to run down since the enthusiastic planting of the 1930s, and many farmers now believe they are not necessary. There are several thousand kilometres of these multi-row belts, but virtually no attention has been given to them as a source of usable wood.

THE POSSIBILITIES OF PRODUCING WOOD FROM SHELTERBELTS

Rackham (1977), discussing hedgerow trees in Britain, which were valued for shade and shelter, noted that during the period 1550 to 1759 they were a major source of timber for house- and ship-building and, where pollarded, for firewood. In some places they were growing as close as one tree per perch (*c.* 5 m) of hedgerow, which was denser than in the New Forest. Even as late as 1950, after a long slow decline, it was estimated that there were still 67 million merchantable hedgerow trees in England and Wales, giving a mean stocking of 5 trees/ha. Income from these trees, in the past, was substantial. Caborn (1965) endorses this and found that many timber businesses flourished on this source of supply. He is convinced that "with care and forethought" timber production and wind protection can be combined successfully.

Helliwell (1967) estimated that 400 000 ha could be planted in shelter woodlands of various sorts in lowland Britain, with considerable environmental and economic benefits. Some landowners there are convinced that tree planting, maintenance and harvesting are essential elements in estate management (Hayes *et al.*, 1978) and see no incompatibility with planting for both shelter and timber production. These authors give details of one

YIELD DATA

Yield data, whether volume or value, are very scarce, but there is some agreement that yield per unit of area is higher in shelterbelts than in forest stands (Caborn, 1965; Bagley, 1976). (Bagley, however, sees the tree harvest on farms as a source of energy for farm and home use.) Brown and Hall (1968) merely note that if trees are grown for shelter that does not preclude a financial return from the timber. Caborn (1965) is equally vague, but considers that shelterbelts can be managed to earn "fair profits" from the sale of the timber.

There are a few more concrete examples from New Zealand. Barr (1974) notes that, even with the old-style four-row untended shelterbelts of pines and cypresses, when they are ready for utilisation, there can be a useful yield. The interior rows, at about 30 years, provide good sawlogs 18 to 21 m long, with dbhob around 60 cm. The outside trees, rough and branchy, can still yield some useful timber, mainly for sawn posts (for city sections) and fence battens. Hosking (1980) gives some information on a 42-year-old untended belt of radiata pine, *Cupressus macrocarpa, C. lusitanica* and *Eucalyptus macarthuri.* The trees were heavily branched, mainly leaning, with curved stems. Much of the wood was given away as firewood, but a proportion was taken to a local sawmill and sawn and treated as battens at a cost of $1370. The current price of the battens was $2653. The cost of felling and clearing the site was $970; thus the profit on the operation was $313.

Smail (1979) reports on an "unkempt and unloved" shelterbelt yielding 572 m^3/ha after a useful life of 40 years as shelter. More recent figures, from Smail's property, are even more encouraging (D. Stringer, pers. comm.). They are taken from a two-species belt on Lismore stony silt soil in a rainfall of 860 mm/yr. The belt was 45 years old when the radiata pine was felled; mean height was then 28.6 m and mean dbhob 54.9 cm. The pine was pruned at 29 years of age. After felling, there remained a belt of *Cupressus macrocarpa* 14 m tall. The length of belt felled was 172.6 m, yielding 139 logs from 82 trees. The equivalent merchantable volume yield was 567 m^3/ha, with a stumpage value of $10 212/ha. Local yield tables are not available for a stand of this age, but the North Canterbury Yield Table shows 476 m^3/ha for a stand of 36 years old (sawlogs only).

Even in remote localities, wood from shelterbelts can have a considerable value. Chisholm and Irvine (1976) noted that the main utilisation value of shelterbelts at Molesworth Station would be for firewood. They estimated that the internal rate of return would be 8% for growing Scots pine in shelterbelts on a 30-year rotation.

Factual data on volume yields are given by Steele (1925) for shelterbelts in Marlborough. Although eucalypts were largely suppressed by radiata pine, they yielded good poles; m.a.i. of *E. globulus* at 45 years old, with a stocking of 791 stems/ha, was 16.4 m^3/ha/yr. Yields of three areas of radiata pine are given, with other stand details, in Table 1.

TABLE 1: YIELDS OF RADIATA PINE IN SHELTERBELTS IN MARLBOROUGH
(From Steele, 1925)

Parameter	*Area No.* *1*	*2*	*3*
Age (yr)	24	41	43
Mean tree:			
dbhob (cm)	33.5	50.5	44.5
Height (m)	27.4	34.7	36.6
Vol. (m^3)	0.78	2.15	2.01
Stand:			
Stems/ha	890	657	640
Vol./ha (m^3)	860	1413	1292
MAI (m^3/ha/yr)	36.2	34.5	30.0

These stands were completely untended, and the quality of the sawn timber was not good because of dead knots. Steele suggested that much better results would have been obtained had the trees been planted at 3.6 × 3.6 m or 4.2 × 4.2 m and then pruned; thinning was not suggested.

Recent measurements on P. Smail's property at Hororata in Canterbury provided the data given in Table 2. The "plots" are:

1. 4 rows radiata pine, 1 row cedar, planted in 1962 (data for radiata pine only).
2. 4-row belt of radiata pine planted in 1958.
3. 4 6-row belts of radiata planted in 1957.

Mr Smail's belts have been tended, but the evidence suggests that, even with untended belts, the potential yield is appreciable while (at least when intelligently marketed) untended belts have a positive market value exceeding the cost of clearing.

Thevenard (1963) gives information on a tended belt of radiata pine planted in 1948, felled in November 1961, 60 yards

TABLE 2: YIELDS OF RADIATA PINE IN SHELTERBELTS IN CANTERBURY (PRELIMINARY FIGURES)

Parameter	*Area No.* 1	2	3
Age (yr)	19	23	24
Mean tree:			
dbhob (cm)	28.4	34.1	37.6
Height (m)	14.7	18.1	19.4
Vol. (m^3)	0.338	0.578	0.725
Stand:			
Stems/ha	1194	737	770
MAI (m^3/ha/yr)	21.21	18.52	23.29
BA/ha (m^2)	77.5	69.3	88.8
% malforms	6.4	26.6	31.0
% sawlogs (by volume)	65.3	78.9	57.1
Total volume/ha (m^3)	403	426	559
Canterbury yield table (m^3/ha):			
Total stem volume	283	—	427
Utilisable volume	232	—	353
% utilisable	82.0	—	82.7

long with 5 yards between fences. Pruning consisted of removing one whorl of branches each year up to 15 ft. At felling, the largest tree was 23.2 m tall with dbhob of 46 cm. This small belt yielded 19/16 ft sawlogs and 8/10 ft stays. The timber was excellent. Thevenard concludes that radiata pine grown for shelter should be looked upon as a crop and grown on a 15- to 20-year rotation; trees must be pruned to give good timber.

MARKETING

Most farmers regard their old belts as worthless, try to retain them until they more or less disintegrate (Hosking, 1978), and make little or no effort to market the produce. Smail (1979) reports on a farmer who was doubtful whether the price he could obtain for his trees would be sufficient to cover the cost of cleaning up but, by "organized marketing, he received a good clean-up job plus $4000". Stronge (1969) makes the point that, if small parcels of farm-grown timber are to attract worthwhile prices, there needs to be a proper marketing set-up. Chavasse (1970a) notes that the question of scale is important for marketing any species. While a single log of walnut or sycamore can command a high price, any wood-using industry must be assured of continuity of supply. He recommends restricting the number of different species grown in a region. Caborn (1965) also discusses this question.

Smail (1972) notes that uniform and orderly marketing can be ensured by employing skilled appraisers and then selling the timber by tender; he considers this method is liked by both growers and sawmillers. A Condition of Sale document is necessary. But Smail (1979) also notes that the farm forester must always aim at quality, because this will ensure a sale, and quality should be taken into account when appraising the timber. He requires "world stumpage rates" for any timber he grows, and sees no justification for farmers undervaluing their timber.

The need for adequate marketing is also noted in overseas literature. Contributors to Hayes *et al.* (1978) consider that the business of establishing, managing and selling shelterbelts should be undertaken by reliable consultant/contractors.

Helliwell (1967) considers that it is necessary to employ properly qualified staff in order to create steady local markets for timber, while Caborn (1965) considers that the local timber market can have a major effect on the profitability of producing wood from shelterbelts.

In the U.S.A., Bagley (1976) draws attention to the difficulty of selling shelterbelt timber in the Great Plains region. He considers that, if farmers would accept tree growing as part of the farm cropping system, and would therefore build up a regional "inventory of trees", this would attract wood-using industries. This in turn would ensure that the shelterbelts would be properly managed for their primary shelter function and replaced on a regular basis.

There has been some interest in forming co-operatives in New Zealand to market farm timber. The situation, however, is very different from that in Sweden and Finland where "farms" are largely forest, and the farmed portion may be no more than 20% of the property. Helliwell (1967) considers that, in the U.K. (where most farmers would have only small and intermittent yields of timber), woodland co-operative societies are highly desirable to ensure proper marketing. This could work in New Zealand also.

MANAGEMENT OF SHELTERBELTS FOR TIMBER PRODUCTION

(a) *The Need for Management*

There is general agreement that shelterbelts must be managed if they are to provide good shelter. Management for timber production is by no means incompatible with this, and indeed may enhance shelter value or reduce problems associated with shelterbelts (*e.g.*, Caborn, 1965). Tinus (1976) notes the decay of the shelterbelt system in the Great Plains where belts have been managed neither for shelter nor timber production while Bagley (1976) indicates that, were these belts effectively managed for wood production, then this would be a solution to their management for continued shelter values.

Bayoumi (1977) insists that, in the Sudan, the maximum benefit from shelterbelts cannot be obtained unless they are properly maintained and managed. He draws attention (Bayoumi, 1976) to the disadvantages of shelterbelts — reduction of the cropping land to the extent of 1% to 8% of area, the shading of part of the crop, competition for soil moisture and overheating in the vicinity of the belts in summer, all of which can lead to reduced crop yields. He is, however, certain that the advantages of shelter far outweigh these drawbacks and, with proper management, the deleterious effects can be kept to a minimum. Bayoumi was concerned with a planned shelterbelt system over a large area and it is interesting to observe that this concept was applied in New Zealand in the 1870s (Steele, 1925). It is only recently that catchment authorities have again adopted the idea of regional shelterbelt systems in New Zealand.

In regard to the management of individual shelterbelts, Hosking (1978) notes that radiata pine shelter must be managed and regarded as a crop to be replaced every 20 to 30 years. Smail (1971) points out that the problems of barley-grass and horehound are related to ill-formed and neglected shelterbelts. The problems are clearly understood by the South Canterbury Catchment Board (Stringer, 1978). Jackson (1963) considered that farmers were far better placed than foresters to produce really high-quality timber by proper detailed management.

The evidence, therefore, is that shelterbelts effectively managed for timber production would be an inducement to plant more of them for shelter.

(b) *The Structure of Shelterbelts*

Evidence from overseas is that the old style of wide belt, with a "house-roof" profile, is being superseded increasingly by narrow belts. Hayes *et al.* (1978) note that in the U.K. farmers prefer a single-species belt as the most practical approach because it is easiest to manage. For Australia, Brown and Hall (1968) recommend either single or double rows of both tall and medium shelter (*Pinus radiata* or *P. canariensis, P. halepensis, Cupressus* *arizonica* or *C. torulosa,* respectively); but they also suggest belts 30 to 90 m wide for combined shelter and timber production (largely from thinnings).

In New Zealand, Barr (1960, 1968) suggests that tall, narrow, single-row shelterbelts, if properly managed, can produce excellent timber. He was concerned largely with hardwoods, especially eucalypts, and he insists (1960) that these must never be grown in double- or multiple-row belts. Chavasse (1970a) endorses this, noting that in multiple-row belts the outside rows lean, producing curved logs and reaction wood (also noted by Hosking, 1980). Rawson (1961) considers single-row belts are also best for radiata and Corsican pines. However, single rows of trees are not entirely satisfactory. Barr (1968) notes that, if "uncontrolled", the trees become coarse, with heavy branches, and become open at the base. He therefore recommends that shade-tolerant trees should be planted as a "bottom storey" which will continue giving shelter after the principal trees are harvested. Jackson (1963), Bunn (1961) and Sturrock (1972) also recommend this sort of structure. However, difficulties can be foreseen. When the tall shelter is harvested, it may be difficult to preserve the low shelter during the felling and logging operations. Bunn (1961) suggested an alternative — two- or three-row belts of coppicing eucalypts. The two rows can be harvested alternately in order to retain continuous shelter. For the three-row belt, the centre row can be grown to produce large sawlogs, while the outside rows could be managed on a coppice rotation, again alternately.

Smail (1971), considering softwood species, notes that the aim should be to provide the maximum amount of shelter on the minimum amount of land, and recommends a two-row "double storey" belt, one row providing high, and the other low, shelter. Smail (1979) enlarged on this, recommending that one species should be fast-growing and the other slower-growing. Milligan (1972) is also in favour of this structure, with radiata pine on the leeward side and Douglas fir, deodar cedar or western red cedar on the windward side. Such a structure allows thinning of the pine without diminishing the shelter value of the belt. Caborn (1965) also favours this system as it allows felling one half of the belt at a time, while maintaining the shelter.

(c) *Tending of Shelterbelts*

Several authors (*e.g.*, Steele, 1925) draw attention to the poor quality of timber sawn from untended shelterbelt trees owing to bark-encased knots, and also to the poor quality of the shelter afforded by untended belts (*e.g.*, Yeates, 1959). There is general agreement that shelterbelts, if they are to be fully effective as shelter, and/or if they are to be a useful source of timber, must be properly tended and managed. The two objectives are entirely compatible. Caborn (1965) endorses this.

Jackson (1963) deplores the practice of topping shelterbelts as this not only reduces their shelter value but also makes the trees totally useless for sawlog production; as a result, the cost of disposal of such belts, when they are finally removed, is exorbitant. Rawson (1961), however, recommends that, when the better trees at reasonable spacings have been selected for pruning to produce clear timber, the remainder could be topped — a form of thinning which is appropriate to a single-row single-species belt.

To produce quality logs, nearly all authors recommend pruning. In Australia, Brown and Hall (1968) consider that the outside rows should not be pruned in order to maintain shelter value or, alternatively, the density should be maintained by planting suitable shrubs or small trees on the windward side. As an alternative to this, Smail (1979) recommends trimming branches back on one side of the belt — a common practice in the South Island. While this leads to the formation of a "hedge" along the lower part of the belt, it also keeps branches small and live; the resultant timber cuts out as dressing grade or No. 1 framing for conifers.

Pruning is recommended by Rawson (1961) for pines, Barr (1960) for poplars and (1968) radiata pine, Chavasse (1970a) for hardwoods including eucalypts and poplars, Sturrock (1972), Smith (1977) for general use, especially radiata pine, Hosking (1978) for cypresses, and Smail (1979) for conifers generally. Smail recommends that every second fast-growing tree (*i.e.*, in contrast to the second row of a slower-growing species) should be pruned to control air flow through the belt and also to produce quality saw- or peeler-logs.

Smith (1977) recommends that pruning should start when trees are 4 or 5 m high, taking first the side of the shelterbelt where branches are heaviest (usually the sunny side), leaving any branches that are "pointing more or less in the same direction as the row". The other side can be pruned later (again leaving branches running along the row). This is sometimes called "fan pruning". Further pruning lifts can be done in the same way in subsequent years, up to a maximum of about 5 m. Above this (Smith, 1977) branches tend to be smaller and more widely spaced.

Sturrock (1972), while noting that pruning is needed if good quality timber is to be produced, states that pruning is not difficult and can readily be assimilated into the work programme of the average farm. He suggests removing one whorl of branches each year up to a height of 6 m. He considers that pruning reduces the wind damage hazard, making topping unnecessary.

Some authors also recommend cautious thinning, with frequent light operations (*e.g.*, Brown and Hall, 1968) starting early in the rotation in order to avoid reducing shelter values (also Caborn, 1965). Milligan (1972) sees no problem in thinning radiata pine belts for post production provided there is a second row of another species.

Thinning is more important for hardwoods than for softwoods. Chavasse (1970a) notes that fast diameter growth produces mild high-quality timber, especially with eucalypts. Barr (1960) endorses this, recommending that, where eucalypts are planted 6 ft apart, every second tree should be thinned out later. Such thinned belts can produce timber of excellent quality.

(d) *Rotations and Regeneration of Shelterbelts*

Caborn (1965) states that there must always be a general policy for regenerating shelterbelts in order to continue to provide shelter and produce timber indefinitely. Brown and Hall (1968) recommend the simplest method is to clearfell and replant, perhaps taking short sections each year. They tentatively suggest planting a new row of trees near the older belt some time before felling; a similar suggestion is found in Steele (1925). However, this can often be a difficult, and sometimes ineffective, operation and complicates harvesting.

Jackson (1963) endorses the need for planning and advocates that shelterbelt planning should be co-ordinated with planning of all the other farm operations, especially fence replacement.

Stringer (1978) points out that, especially on shallow soils or where there is danger of windthrow, the timing of rotations is of major importance. The question of rotation length is related both to the site and to the need for maintaining shelter. However, marketing is another aspect which might need to be considered. For example, Stronge (1959) considers short-rotation belts of radiata pine for the production of fencing materials (see also Thevenard, 1963, in this connection). Barr (1974) while noting that, although harvesting leaves "an ugly blank", also finds that trees replanted on a felled site "get away extra well" and (Barr, 1968) replacement can be done immediately after harvesting. He recommends (1968) rotations of 20 to 25 years for radiata pine and poplars, and 30 to 40 years for eucalypts.

An alternative method of regenerating shelterbelts is by suckering or coppicing. Rackham (1977) considers that elm (*Ulmus procera*) is the ideal hedgerow tree as it renews itself by suckering (but this species is being obliterated in Britain by the Dutch elm disease). Bayoumi (1977) proposed two-row belts of coppicing eucalypts with an understorey of drought-resistant bamboo, where the market would be largely building poles and fuelwood. Management could be either by cutting whole rows of trees (one at a time) or by cutting alternate trees in rows (which is preferred, even if it is more difficult to manage). The felling would be followed, during the next year, by thinning the coppice shoots. The bamboo would also be harvested.

Brown and Hall (1968) also recommend coppicing species; so does Bunn (1961). If the belts are harvested one row at a time, then the coppice shoots provide dense low shelter. Most coppicing eucalypts can be harvested five or six times before they lose vigour.

Buchanan (1962) recommends that, where large trees would be a nuisance, shelter could be provided by coppice of eucalypts, poplars, chestnut, oak and ash, all of which could produce useful material. Since then there has been increasing interest in growing "biomass" on farms for production of (*e.g.*) methane (see also Bagley, 1976). The concept of "silage" wood crops is also gaining popularity overseas, where the crops are grown as coppice on very short rotations (2 to 3 years) for a number of purposes including (in Canada) production of amino acids.

(e) *Management of Belts in New Zealand*

In October 1979 a questionnaire was widely distributed throughout New Zealand with the objective of locating belts which were being managed to produce timber, and also to solicit opinions on this theme. Although replies were more scanty than had been hoped, there is evidently widespread interest in the proper management of shelterbelts, including tending for timber production, and that several farmers, widely scattered throughout New Zealand, are managing shelterbelts for this purpose. In addition, some catchment authorities (notably the South Canterbury Catchment Board and the Wairarapa Catchment Board), although primarily concerned with soil erosion, are actively encouraging the proper management of belts, taking into consideration their potential for timber production.

SELECTION OF SHELTERBELT SPECIES

The selection of species (apart from their compatibility with site conditions) can depend on a number of factors, including the objectives of the landowner. Bayoumi (1977), for example, required trees that can be easily established, fast-growing, windfirm, evergreen, drought-resistant and capable of coppicing. *Eucalyptus microtheca* met these criteria in the Sudan, while low shelter was provided by drought-resistant bamboo.

Brown and Hall (1968) favour conifers — *Pinus radiata* and *P. canariensis* for tall shelter; *P. halepensis, Cupressus arizonica* and *C. torulosa* for medium shelter on well-drained soils. Eucalypts are also suitable for some sites.

Much of the New Zealand literature deals with radiata pine shelterbelts, often because of its fast growth (*e.g.*, Smith, 1977). Rawson (1961) recommends also Corsican pine. Barr (1960) suggests Douglas fir, *Cryptomeria japonica, Cupressus torulosa* and *Libocedrus decurrens*. Milligan (1972) includes Douglas fir, deodar cedar and western red cedar. Hosking (1978) recommends *Cupressus macrocarpa* and *C. lusitanica* for hill country, as small plantations where trees can be pruned and thinned. He also favours *Cryptomeria japonica* (with reservations about its timber).

Other authors favour hardwoods (*e.g.*, Buchanan, 1962). Chavasse (1970b) gives a list of timber trees that can be used for shelter: *Eucalyptus delegatensis, E. obliqua, E. regnans, E. botryoides, E. saligna,* poplars, European ash, plane. Van Kraayenoord (1961) and Barr (1960) recommend poplars; however, many poplar clones are now subject to rust attack. Barr (1960), Bunn (1961) and Hosking (1978) favour eucalypts, preferably those producing good timber.

A list of the species favoured by respondents to the F.R.I. questionnaire is given in Table 3; however, too much weight should not be placed on this list owing to the uneven coverage and few replies.

Indeed, the list is rather surprising; because of the many frightful examples of abandoned radiata pine and macrocarpa shelterbelts throughout New Zealand, it is said that they are now heartily disliked, yet radiata pine was recommended by almost all respondents to the questionnaire and macrocarpa was also popular. So is Lawson cypress, in spite of widespread

TABLE 3: APPARENT POPULARITY OF SPECIES FOR SHELTERBELTS

Species/Genera	*Recommended for (No. of Regions) in:* *North Island*	*South Island*	*Total*
Pinus radiata	9	8	17
Cypresses	8	6	14
Eucalypts	8	5	13
Thuja plicata	6	5	11
Poplars (other than Lombardy)	7	3	10
Douglas fir	3	5	8
Cedars (deodar and atlas)	3	5	8
Lawson cypress	4	4	8
Cryptomeria japonica	6	2	8
Lombardy poplar	2	5	7
Redwoods (coast and sierra)	4	3	7

dieback. It is of note that, with the possible exception of Lombardy poplar (which, however, produces sawlogs in Chile), all the species on this list are potential timber producers.

RESEARCH NEEDS

The foregoing analysis makes it clear that research into production of timber from shelterbelts is very limited indeed, even on flat land, and virtually non-existent on hilly (pastoral) land, throughout the world. For example, Bagley (1976) in the Great Plains study (U.S.A.) drew attention to the need for more research into "multi-purpose belts" including utilisation of the wood as a basis for rejuvenating the whole system in this vast region. In this country Hosking (1978) recommended the establishment of a "study group", one of whose objectives would be to find out how to produce high-quality timber from shelterbelts so that they would provide income for the farmer. Molloy (1980), under the heading "Research and promotional needs", notes that, for hill country, there is a need to determine the optimum siting of shelter, the best form, species and placement.

Much of the evidence collected in this paper is qualitative rather than quantitative, but there is sufficient knowledge now to show that shelterbelts can be managed for timber production in such a way that their shelter value may even be enhanced, and certainly not seriously diminished. It is also clear that shelterbelts have fallen into disrepute because farmers have grossly undervalued them as a source of wood, have clung to moribund and decaying belts until they have more or less completely disintegrated because of this belief (while still tacitly acknowledging the need for shelter), or grossly maltreated them by topping, thereby ensuring that they do indeed have no timber value. It would appear that these practices are due (at least to a substantial extent) to ignorance of shelterbelt management. But there is sufficient evidence to show that those farmers who have managed their belts have reaped a reward not only from the shelter value but also from the sale of timber. There is also some evidence that the yield of wood from shelterbelts is high, both in volume and value, if they are carefully tended and managed, and that the amount of effort required for this is not great.

Research and demonstration are needed to quantify these findings beyond doubt. However, much of the silvicultural research already done at the Forest Research Institute is relevant for New Zealand: this includes the production of high-quality nursery stock, proper seedling handling procedures, suitable methods of site preparation and after care, and tending schedules to produce high-quality timber. For many species there is adequate information on wood characteristics, on mensuration and yields, on health and hygiene, and on proper siting. But most of this species-specific information has been obtained from stands, not shelterbelts, so the special aspect of growing these species in shelterbelts needs to be studied — *e.g.,* degree of malformation, proportion of reaction wood, variations in form (taper) and growth, etc.

It is suggested that, initially, research should be concentrated on the most useful species, in order not to dissipate effort. A tentative selection (from Table 3) would be radiata pine, selected cypresses, selected eucalypts, selected poplars, Douglas fir, atlas and deodar cedar, *Cryptomeria japonica,* and both coast and sierra redwoods. Apart from poplars, all these species are already being studied at F.R.I., and thus shelterbelts research could be tied in with (and be germane to) research already under way. Extension into other species would initially involve provenance selection, which may not be feasible at present.

The specific work required is:

(1) Assessments of yields in volume and value. These data can be obtained from older shelterbelts, ready for harvesting, by means of sawmill studies (although the lack of pruning would limit the full value of such studies).

(2) Studies to determine the best shelterbelt structure (number of rows, species, etc.) and derivation of suitable tending schedules (with related study of the effect(s) of tending on shelter values). These studies would have to begin with young belts ready for first pruning.

(3) Study of shelter on hilly pastoral land, to decide the best form of shelter, its siting and management. This can be tied in with tatter flag studies already under way.

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