OBITUARY.—David Tannock

The death occurred recently in Surrey, England, of David Tannock, O.B.E., formerly Superintendent of Reserves for the Dunedin City Corporation. He was a foundation member of our Institute, and in 1937 was elected an honorary member.

Born in Ayrshire in 1873, he took up horticulture as his career, and after training at the Royal Botanic Gardens, Kew, he served with the Agricultural Department at Dominica, in the West Indies. In 1903 he came to New Zealand as Superintendent of Reserves for the Dunedin City Corporation, a position he held until his retirement early in 1940. He was responsible for encouraging Dunedin to commence an afforestation programme, and under his guidance some 8,000 acres of the catchment areas for the City water and hydroelectric supplies were eventually planted.

THE SILVICULTURE OF RED BEECH IN NELSON AND WESTLAND

By M. J. CONWAY

1. Introduction

One century of settlement in New Zealand has seen the native forest depleted of the greater part of its valuable softwoods. Totara, matai and kahikatea remain in small quantities, while kauri in sufficient area is denied forest management. Rimu, the principal remaining podocarp, is being milled at a rate which calls for conservation to prevent its early extinction. Unfortunately, too, the podocarps, being dioecious and small seeded, present problems of considerable difficulty in their silvicultural reproduction. Moreover, the most accessible stands occupy land which in due course may be required for farming.

Apart from the conservation of rimu and the preservation of the forest protecting the headwaters of our many rivers, particularly those serving hydro-electric schemes, the emphasis in the management of our indigenous forest estate is now on the production of hardwoods on a sustained yield basis. In this respect the Nothofagus species play a dominant role, by virtue of their wide distribution and their ready response to silvicultural measures. The silviculture of silver beech (N. menziesii) in Southland has already been described (1).
Red beech (*Nothofagus fusca*) may be found throughout the country from the centre of the North Island to Southland. From a silvicultural point of view the potentially most productive forests are confined to the north-west of the South Island, more particularly in the region of Ahaura and Reefton. This paper makes proposals for the silviculture of red beech there, based on a review of past experiments and "pilot operations," and in the light of more recent knowledge.

2. The Natural Forest

(a) Composition—Pure red beech stands of any great extent are rare in this district. Even in the Maruia, Matakitaki and Tutaki Valleys, where some of the finest mature red beech is to be found, there is an admixture of its near relative hard beech (*N. truncata*) and silver beech. In the more western valleys of the Grey and Inangahua River systems podocarps are prominent, and it is with these mixed crops that we are mostly concerned. In these beech-podocarp forests rimu is numerically and economically the most important species, although kahikatea, miro and matai are to be found in the few remaining forested valley flats. Owing to the wide range of the beech species, forest types may vary from one of silver beech and kahikatea to one of hard beech and rimu. Red beech itself has an altitudinal range from sea-level to 3,500 feet. It is most important economically between 500 feet (the level of most of the broad western valleys) and 1,500 feet in the southern or Westland district, and up to 2,500 feet in the northern or Nelson area. On flood plains and on the low recent terraces of inland valleys it is often displaced on the wetter sites by silver beech, which elsewhere in the presence of red beech tends to form a persistent understorey. Higher up the valley slopes red beech is found in association with hard beech, which tends to replace it on dry spurs and ridges. On level terraces with poor drain-age mountain beech (*N. cliffortioides*) may be its companion. A vigorous and freely seeding species, red beech is dominant in all its complex associations, but especially on good sites of moist well-drained soil not given over to podocarps. It hybridises readily with hard or mountain beech, but not with silver beech.

No volume tables exist for red beech, mainly owing to the variable incidence of hidden defects which makes cruising of the older trees very difficult. Volumes of beech saw-timber range from 100 to 1,000 cubic feet per acre in mature beech-podocarp forest, and reach 3,000 cubic feet per acre in pure beech stands, although 1,000 to 1,500 cubic feet per acre is the normal return. The stocking of trees above six inches in diameter is extremely variable. It may be as low as 30 trees per acre, or as high as 75 per acre. Overmaturity is an unfortunate feature of many of the beech trees. Merchantable size is usually not reached before 100 years of age (except as mining timber), and millable trees generally average some 200 years. One
veteran of 450 years is recorded, and it is likely that this is near the limit of the life of the species.

What evidence we have suggests certain seral phases in composition, based primarily on climatic changes. There appears to be an overall gradual ousting of podocarps by the beech species, while within the beeches themselves there is incursion into the red beech and silver beech stands by mountain beech.

(b) **Tree Size, Rate of Growth and Volume**—A summary of data compiled by R. B. Moorhouse (2) is contained in Table 1. It may be seen that in very good natural stands dominant trees may attain in 75 years breast height diameters of 18 inches, and total heights of over 100 feet. Near Ahaura, on the old Canterbury Track, trees aged 62 years measured 20 inches in diameter, with a merchantable height of 60 feet.

Diameter increment in unthinned even-aged crops up to an age of 75 years is of the order of 0.15 inches annually. Only dominants exceed 0.20 inches, with a maximum of 0.30 inches. The mature tree averages about 30 inches in diameter, although veterans in the Maruia and Upper Inangahua Valleys exceed 5 feet in diameter. One tree near Reefton measured 104 inches at breast height where there was some flange effect, and 92 inches in diameter at 10 feet where flange swelling was negligible. The bole of this tree was 60 feet high, but decay had set in.

In heavily stocked stands on favourable sites, red beech dominants grow 18 inches a year up to 75-80 years. It is only on poor sites, generally at altitudes above 1,500 feet, that the rate falls below 12 inches annually. Stems in an 80 year old crop of high quality have reached a height of 100 feet with a diameter of only 12 inches, but the height growth then tends to fall off, and mature trees do not usually exceed 130 feet in height.

A log length of 75 feet represents optimum development, although one specimen in the Maruia Valley is reputed to have yielded a log of 107 feet. In virgin forest however an average of 45 feet is considered satisfactory. For example, in the above valley thirty sample trees, aged 140-370 years, averaged 32 inches d.b.h. and 101 feet in total height, with a log length of 45 feet.

When grown in the open red beech may develop the heavy branching characteristic of the pioneer tree, but in well-stocked even-aged stands the poles are straight and clean, with remarkably little taper. High initial stocking, especially on flat country, facilitates self pruning, and the occlusion of branch stubs less than one inch in diameter results in a clean stem to heights up to 70 feet. On flat land clear stems to within 30 feet of total height are the general rule. On steeps hillsides the down-slope branches are naturally heavier and more persistent. In pole sizes the taper is as low as one inch in every
ten feet of stem to the first branch of the canopy, thereby making ideal mining timber.

Owing partly to the above-mentioned defects, utilisation from red beech is lower than for the podocarp species. Conversion factors of five to six board feet per cubic foot are obtained from selected logs. Some trees when cut down may not be worth taking to the mill, others may give a factor of eight. Trees that are milled to-day range from 40 cubic feet to 300 cubic feet, yielding 200 feet board measure to 1,800-2,000 feet respectively. A sawn volume of 6,000 board feet is nearing the limit of output in beech-podocarp associations, although in isolated pockets or in the nearly pure red beech stands a volume of up to 20,000 feet board measure is possible.

(c) **Injurious Agencies**—Animal damage is confined to regeneration. It is fortunate that in the southern part of Nelson and in Westland the deer population is not high compared with that in the silver beech forests of Southland. There is local evidence, however, that considerable change in the composition of the lower tiers of the forest has resulted from the browsing of these relatively few deer. In the north, nearer Nelson itself, successful reproduction of the beech species will require a reduction in the number of deer or other preventive measures (3).

Domestic and feral cattle and sheep destroy much regeneration, particularly on the forest margins, thus preventing any increase in the forest area; in many cases they are at least as important as deer.

The only serious insect pest is a buprestid beetle, (*Nasioioides enysii*), which attacks red beech in the main, although it has not yet been established that it is the primary cause of death (3). Decay due to fungi (*Polyporus* and *Fomes* species) has earned for beech a bad name in the past. It is now apparent that such a defect is virtually absent in fast-grown trees up to 120 years old, and that its incidence is high only in suppressed trees, or in trees beyond that age. Rot in the roots and heartwood is generally impossible to detect but other types of fungal attack can usually be associated with spikes, bark collapse, swellings and scars.

Of the climatic factors, wind and snow are the most important. Some scorching of seedlings not firmly established in the exposed mineral soil may be expected. The effect of heavy frost on tree growth has not been assessed, but is believed to be of minor consequence compared with the damage to exotic species. Snow at high altitudes, 2,000-3,500 feet, causes the crowns of mature trees to break, but there are many instances of their rejuvenation. Nevertheless, an avenue for the development of rot is provided. Except in gullies where deep snow may drift, the young crops appear to withstand normal snowfall. Beech, being shallow-rooted, is subject to windthrow. The largest recorded blowdown was in August 1867 in the forests of the Wairau and neighbouring valleys, in the vicinity of Lakes Rotoroa and Ro-
toiti. A serious windfall has also occurred in the Lake Hochstetter locality east of Ahaura. An unseasonable north-easterly gale also affected the higher beech forests south of Golden Downs in 1948.

Extremes of climate which impose unaccustomed stresses on the normal function of the tree result in considerable mortality. Attack by *Nascioides, Armillaria* and "soot fungus" are most noticeable after abnormal seasons.

(d) **Pole Stands**—Pole stands of extensive area are located east of Ahaura and near Lake Rotoiti. These originated after the gales referred to, with the result that the major pole crop is all of about the same age. A high proportion of the young forest is however of mountain and silver beech. Perhaps the finest and best known small pole stand occurs at Staircase Creek, south of Reefton, where an outwash of debris, resulting presumably from a local flood of some violence, provided an excellent seed bed over an area of 50 acres. Two periods of regeneration are represented, the main part of the crop being 50-80 years old. Details of these trees will be given when discussing the treatment of pole stands.

There are no areas of regeneration brought about as a result of deliberate silviculture, apart from small groups in Tawhai Forest immediately south of Reefton, where underscrubbing and ringbarking coupled with seed-trenching exposed the forest floor prior to seedfall. Valuable stands have established themselves, however, after the clear-felling activities of miners, both in pursuit of alluvial gold in valley bottoms and creeks, and around the larger settlements centred on the quartz mines, where the forest was felled for fuel and for building and mining timber. Their distribution is naturally irregular, particularly in the case of alluvial mining, being confined to pockets and strips, and often in steep gullies. Up to 300 acres occur near major centres, such as at Globe Hill near Reefton, and in parts of Granville Forest in the south. Since goldmining commenced on a large scale in this Ahaura-Reefton district in the 1870's and widespread cutting of the forest ceased about the turn of the century, these crops are also 50-80 years old.

(e) **Age-class Distribution**—A high proportion of the beech trees in the virgin forest are mature or overmature, and in comparison with areas where this is so the extent of pole stands is very small. Nor is there adequate stocking of sound stems in the lower diameter classes to replace the mature stems when the forest is logged, although saplings and poles are to be found, either in small groups resulting from irregular and infrequent breaks in the canopy, or as suppressed trees beneath a full canopy.

The few thousand acres (provisionally estimated at 5,000) that we do possess of pole stands as a result of windthrow and the thirst for gold are of the same age class: 50-80 years. There is then a long interval to the partially regenerated sawmill areas of the last 25 years.
Some 10,000 acres exist in the Reefton-Ahaura region of milled beech-podocarp forest which may be brought into regeneration blocks by the removal of the beech and podocarp remnants.

Although the most accessible stands have been logged, the un-milled forest is still extensive, far exceeding the acreage of pole stands and partially milled forest. Much of the land however is not under the jurisdiction of the Forest Service. An accurate assessment of the total manageable area awaits the completion of the National Forest Survey.

3. The Managed Forest

The silviculture of red and hard beech may conveniently be discussed under three headings:—

(a) The silvicultural system.
(b) The regeneration technique.
(c) The treatment of the growing stock.

(a) The Silvicultural System—The silviculture of red beech is strictly speaking in its infancy. Although many studies have been carried out over the last 25 years, they have been confined mainly to saplings and poles of fortuitous origin. In the late 1930's some instructive work was done near Reefton with underscrubbing and seed trenching, but it was not carried to its logical conclusion, as we see it to-day. There is doubtless a wealth of information in the minds of men no longer in a position to apply it, information which has regrettably not been recorded to assist the foresters of the present day.

In a short paper of this nature the merits of the silvicultural systems as practised in Europe cannot be debated in respect of our Nothofagus forests. Regeneration released by ringbarking and removal of culls at Tawhai Forest in 1936-1940 suggests strongly that red beech would prosper under the Group Selection System as defined by Troup (4). Such groups would need to be uniform in composition, and at least two chains in diameter to allow felling and extraction of mature trees without damage to the adjacent groups of younger stock. An area of this size can be seeded without difficulty. It is also apparent from an inspection of roadways, tramways and forest margins that the Shelter-Wood Strip System is readily applicable. Beech is a shallow-rooted tree liable to be uprooted when suddenly exposed to winds of gale force, and the total loss of seed trees under the Uniform System could be disastrous considering the long interval between seed years. In steep country we may yet see the introduction of a modified strip system accommodated to skyline methods of logging. This system may also be adopted in steep and broken country where the crop is to be managed on a mining timber rotation. But the systems mentioned above require a higher standard of logging practice and conduct than we now enjoy. We are doubly fortunate therefore that the red beech species in particular, being aggressive
and light demanding, fits into the Uniform System, and that this same system is the one most readily adapted to the present methods of sawmillers. The risk from catastrophic windthrow must remain a calculated one. Only two major windfalls have been recorded, the last some 75-80 years ago.

As pointed out earlier, the greater part of our manageable beech forests contain or contained varying proportions of desirable softwoods. In this region there have been three phases of exploitation—the pursuit of white pine in the 1920's and early 1930's, followed by the milling of rimu in greater quantity during the late 1930's and early war years, and since then the combined production of podocarps and beech. In the past the extraction of podocarps only has resulted in many large areas of beech forest being left below economic value (approximately 5,000 board feet per acre), while at the same time the opening of the canopy has been insufficient to allow the beech species to regenerate to any great extent, certainly not as much as would be achieved under regularised group fellings. These are the problem forests which may ultimately be re-established only under State logging. We are faced to-day with the conversion of the remaining beech-podocarp associations to an even-aged beech forest. It must be appreciated that we have no alternative. It is beech or nothing, the podocarps of these mixed forest types being incapable of rapid or large-scale regeneration. In many of the forests, rimu is still the “draw card”, and the milling of beech but incidental. However, the swing in production is continually in favour of the beech, so much so that in the year 1951-52 more beech than rimu was cut in the Inangahua Ranger District centred on Reefton. With the growing recognition by producer and consumer alike of the qualities of the beech species, a fourth and final phase is envisaged by the end of another century—the growing of beech on a sustained yield basis (primarily under the Uniform System) with the reservation of rimu as a high grade special purpose building and furniture timber, many of its wide present-day uses having fallen to the lot of the ubiquitous Pinus radiata and other exotic softwoods.

(b) The Regeneration Technique—The method of regeneration consists essentially of a timed preparation of the forest floor and the reservation of adequate seed-bearers. In this initial stage of conversion to the uniform crop it is also necessary to dispose of unmerchantable trees.

Nature has made no secret of her method of perpetuating the species. In quarries, on earthquake-shattered bluffs, on disused roads, on the tailings of Chinese goldminers, at abandoned mill sites and among the debris of windthrow and flood we find substantial second growth. In other words, wherever the seed has made contact with the mineral soil, regeneration is assured. This knowledge was applied at Tawhai Forest in 1936 when seed trenches were prepared
by grubbing off the litter and duff in lanes three to four feet wide, the lanes being some ten feet apart. Regeneration, after a good seed year, was excellent (5). A cheaper method was then adopted, preparation being by clearing small patches at six foot spacing. A total of 145 acres was treated in this manner, and although the seedlings flourished for a few years, they have shown little recent growth due to suppression. Where gaps have occurred or were made in the canopy, however, groups of excellent quality have resulted.

In 1951 an area of 25 acres was treated at Staircase Creek in Hukawai Forest, in conjunction with milling operations. In this case, any heavy growth of kamahi, Quintinia and broadleaf was cut down or ringbarked, and Blechnum fern was removed with Ansell grubbers or by hand pulling. Some windrowing of slash was carried out to leave the soil exposed, and the extraction of logs by tractor further disturbed the ground. Seed trees were reserved before milling commenced. Seed which fell in March 1952 germinated in late September and early October, and an adequate stocking of seedlings is apparent on the cleared ground. It should be noted that in this instance the preparation of the seed bed preceded logging. This may have resulted in the duplication or negation of effort, in that tractor working would be imposed on ground already hand cleared, and heavy slash would be accumulated on chosen ground. Better results may well be obtained by extending the ground cleared during logging, at a later and convenient date, that is, prior to seed years. On the above area the removal of unmerchantable beech and other species has yet to be carried out to conform with the conditions of the Uniform System.

Sufficient opening of the canopy and suitable treatment of the forest floor do not in themselves guarantee regeneration. An adequate seed supply at the right time is essential, but unfortunately mast years occur at long and irregular intervals of seven to thirteen years, and as yet we have no proof that beech seed in contact with the ground is viable for more than one year. In the Reefton district, mast years have been recorded in 1936, 1945 and 1952, with a partial mast year in 1942. If logging, with or without extra soil preparation, is carried out one year after seedfall, there is thus an interval of several years in which the regeneration area may be invaded by weed species, and during which a litter may be built up to hinder if not to prevent germination and survival of a later seedfall. The practical answer is to concentrate seed bed preparation into the spring of flowering and the summer months prior to the shedding of the seed. With several mills operating in widespread areas devoted to intensive silviculture, this concentration of effort will involve manpower and expenditure not at present available. The pulling of fern, underscrubbing and ringbarking can seldom be done at better than one-quarter of an acre per man-day. To keep pace with the present annual rate of milling over selected areas (approximately 500 acres) ten men are required.
At times of concentrated effort, say every ten years, a total of 100 men could therefore be gainfully employed on this process alone. In the intervening years there would be ample work for them in the tending of pole stands and the re-establishment of old sawmill areas. The present labour position is such that only a fraction of the desirable area can be treated. It would appear that in the absence of man-power, resort must be made to machines for scarification of the soil, although their use will be limited to easy country. Small tractors (D.4 type) fitted with crawler tracks and a blade can in any case be used to release men for axework. In view of the dense regeneration observed after fire in coincidence with seed fall there are those among us who are bold enough to prescribe the light burning of slash under control in expectation of a good seed year.

There are strong indications that the prolific flowering of beech is dependent upon a hot dry spring and early summer, when flower primordia are laid down. A. L. Poole (6) has discussed this and has provided a table illustrating the effect of temperature. The relationship between rainfall and beech flowering is given in Table II of this article. (It may be seen that considerable credence may be given to the saying of the Maori: “When the beech flowers, it will be a wet summer”.) Such hot dry summers may then give us a few extra months in which to plan the intensification of preparatory measures.

Under the Uniform System, twelve to fifteen beech seed trees per acre are required. Seed is carried at least a distance of two chains from a mature tree. In the managed pole stands the forester can develop by thinnings the crown and vigour of trees selected as seed bearers and the number of trees may be reduced, but in the virgin forest of podocarps and beech his choice is decidedly limited, partly by the representation by species and partly by the factor of economical working. Most millers in the past sought only the podocarps and selected the best beech to attain an economic volume per unit area whenever the podocarps fell short of this. Although beech trees were branded, such branding still gave the miller the option of felling, an option which was readily exercised to the ultimate detriment of the forest. Not only was it “creamened” by the removal of the most valuable species and individual trees, leaving the residue unattractive for future working, but the canopy was not sufficiently opened to allow the establishment of a new crop over the whole area, although some groups were naturally formed. This state of affairs has been righted in areas selected for intensive management, where if necessary the miller is now compelled to remove branded beech species. This measure, in the space of a few years, has resulted in a higher degree of utilisation than formerly. There is the opposite, if rare, case of the miller who possesses an expanding beech market and who needs to be restrained from removing all the merchantable trees, for if he were given a free hand the future crop could only stem from inferior parents. On the one hand we have to encourage and even enforce greater ex-
traction, on the other to prevent over-cutting. Flexibility of control based on local knowledge of the individual forest and the individual sawmiller is essential. The forester of the present day must strike a fine balance between his silvicultural requirements and the loud demands of the miller. If the best trees are excluded from sale, the latter is loath to spend time and money on the less profitable faulty and smaller trees, and may look elsewhere for his supplies. Some compromise is necessary, and in this transition stage of silviculture, greater stress is being laid on fuller utilisation and on the more complete opening of the canopy than on the desirable number and quality of seed trees. At present it is the practice to reserve three to five healthy vigorous trees of good form per acre, the balance of the seed being obtained from trees of less perfect form or with some defect more attributable to environment than heredity. It is contended that the quality of the ensuing stand can be improved by subsequent silvicultural selection of the better stems, and that the matter can be rectified at the end of the first rotation. The alternative is State logging, in whole or in part. Either the whole crop can be extracted by Forest Service employees and silvicultural criteria observed to the last letter, or salvage gangs can be employed to dispose of culls and remove for sale to the miller the doubtful and smaller trees. The former cannot be advocated as yet, but the latter is to be recommended, having borne fruit in silver beech management in Southland.

Ringbarking of unmerchantable stock has been carried out over the years, but has several disadvantages. Death is not rapid, the dead stems and branches increase the hazard of a crown fire and cause damage to regeneration when they ultimately fall, and the operation is slow and costly. The death of the tree may be hastened by frilling and the use of poisons such as sodium arsenite, and basal bark spraying with a toxic chemical may yet play a part in reducing the cost. The most satisfactory and hygienic method, however, is the felling of the culls by the salvage team in the wake of the miller. Powersaws are well suited to this work, and together with the crawler tractor can bring about an appreciable increase in the area treated, and at lower cost, after a modest capital outlay.

One hundred per cent regeneration is not expected, and adequate stocking may call for artificial measures. Red or hard beech regeneration, after fire especially, may exceed 20,000 per acre, and in some instances is well-nigh impenetrable. Such high stocking is not an embarrassment inasmuch as there is adequate mortality in the sapling and pole stages. By the time the crop is 30 years old a reduction to approximately 5,000 stems per acre has taken place, and the competition over this period has resulted in the stems being of very good form and highly profitable as mining timber in the next ten years or so. An initial stocking of 4,000 stems per acre is recommended as the minimum. Blanking by means of transplanting wildings from adjacent areas of dense regeneration has every indication of success.
The spacing should not be greater than two feet by three feet. It is preferable to plant closely in small groups wider apart (up to six feet) in selected pockets of soil. Spot sowings have been tried experimentally at Tawhai Forest, but although successful can be ruled out on a large scale on the grounds of expense, both in seed collection and the actual sowing. As a reserve for seedlings bush nurseries can be established on suitable sites, either naturally or artificially, as evidenced by the experiments at Tawhai in 1936.

The regeneration period is being tentatively fixed at 20 years, thereby allowing for two major seed years. It has not yet been possible to determine sites totally unsuited to the regeneration of red beech or of any of the other beeches, and interplanting with proven exotics is envisaged only as a last resort in areas of persistent failure, and where it is necessary to ensure a reasonable volume per unit area over the forest as a whole.

(c) The Treatment of the Growing Stock—In the earliest stages, protection is the keynote. We tend to regard the forest we enter as natural and primitive, failing to appreciate the effect of introduced animals, yet in any area from which such animals have been excluded, either naturally by topographic barriers or artificially by fencing, we find a different ground vegetation and a marked increase in beech regeneration. Protection from fire is also essential. Mature forest which has been burnt may reassert itself gradually from margins and remnants, or spontaneously if burning coincides with a seed year, but second growth is completely destroyed without hope of reproduction.

It must here be admitted that due to the maldistribution of age classes we have had little experience in the treatment of even-aged stands in the thicket and sapling stages. In the partially milled and therefore partially regenerated forest of the last two or three decades the obvious course is to release the young growth from suppression by the remaining trees. Such work has been commenced north of Ruatoria, where it is found that the pattern after treatment is a mosaic of groups comprising large trees of the original mature crop together with groups of its normal pole complement, and the released thickets. It is not possible to obtain uniformity without the sacrifice of some sound stems, and whenever groups of healthy older trees occur they are spared. Similarly any clumps of the original poles are freed. Groups are thus formed, any growing stock not "in phase" with the character of a particular group being removed by felling or ring-barking. The method therefore corresponds to the Group Selection System. These areas will afford a valuable comparison with forests managed under the Uniform System.

In the forest managed from infancy there will be no such partial canopy to suppress the young stock, and silvicultural treatment can then be confined in the first three or four decades to the removal of
wolves and malforms, and in securing adequate stocking. A detailed study of our limited evidence on sapling and small pole stages reveals that early weeding and thinning is unnecessary, except where competition from *Weinmannia* and *Quintinia* is too fierce. The removal of such species when they are acting as nurses or assisting in natural pruning of the young crop cannot be upheld.

From data given in Table I it may be seen that both height and diameter increment of dominants fall off at age 45-50 years. Any thinning prior to that critical age will result in increased diameter at the expense of the form of the tree. The object of thinning at this time is the release of the best dominants and co-dominants, and this can only be achieved by a crown thinning. Any low thinning brings about a reduction in the number of stems which would in any case die eventually from suppression, and removes the understorey which is frequently of the more shade tolerant silver beech. The removal of subdominants and suppressed trees together with some co-dominants allows the incursion of weed species and advance growth of beech. The only advantage from a low thinning of a light nature, and such has been the tendency, is an increase in the diameter of the smallest stems remaining. Table III illustrates that low thinning (the removal of small diameter trees only) results in no increased growth of dominants. It may be seen that the diameter increments in thinned and unthinned plots are almost identical. (In older stands crown thinning has almost doubled diameter increment.) In this control plot there now remain more stems of a size suited in due course to mining timber, and more stems above a diameter of six inches from which selection can be made in later thinnings. The form of the trees in the unthinned stand is slightly better than in the thinned, due to greater self pruning.

For a district where there is a demand for mining timber, and such is the case in the Ahaura-Reefton locality, the view is held that "thinning to waste" is therefore not justified. It should be carried out, however, where there is no coal mining industry, such as nearer Nelson, and where the emphasis will be on fast diameter growth and the production of milling timber at as early an age as possible, rather than on the length and number of poles suitable in the first instance for pitwood. Whether or not there is a market for mining timber, the thinning to be recommended is a crown thinning of the dominants at approximately 45 years of age. Sub-dominant and suppressed trees should be left to clean the merchantable stems and to maintain suitable ground conditions. With labour at a premium the object must be to produce large diameter logs as soon as possible (commensurate with the requirements of the mining industry), without striving for a park-like appearance. Overmuch time should not be spent in making a tidy forest, although it is desirable to consider the provision of access. It is essential not to scar the remaining trees in thinning operations, nor to leave thinnings lying against the butts of standing trees, a sure source of fungal attack.
It has been found that at age 50 years, when the average stocking is 1,900 per acre in unthinned stands, the number of stems over six inches in diameter is 350 per acre. At age 55 years the total stocking is 1,500 per acre and the number of such stems reaches its peak of 375 per acre. From then on we have visual and statistical evidence of the keenness of competition, with suppression of stems which could be used in the mines. By age 75 years this class of tree numbers only 280 per acre, a fall of 26 per cent. This is due mainly to mortality, and partially to lack of recruitment from the lower diameter classes. At Staircase Creek in Hukawai Forest the numerical loss of all stems in sample plots between the years 1937-49 (age 70-82 years) was as high as 30 per cent, nearly all this being in the six inch to nine inch diameter class. Since the taper of red beech is very little, stems eight inches in diameter, for example, and of a height of 80 feet at age 60 years, give merchantable mining timber lengths of 40 to 50 feet. Such numerical loss can amount to 1,000 cubic feet per acre (in the round) of mining timber. Even if thinning is not carried out at roughly age 45 years, it must be done at this second critical age of approximately 55 years. We are again faced with the need for concentration of effort unless, and in the present case until, the age classes are well balanced. The young crop requires relatively little tending, but in the mid-pole stage the wages of sinful neglect is death to the tree. At this time a crown thinning should be made to promote the growth of dominants. From then on light and frequent thinnings to allow uninterrupted crown development should be carried out. With the present shortage of labour this is wishful thinking, although it is being done on a small scale in selected stands by mining timber contractors. An interval of four or five years between thinnings appears most satisfactory, but thinnings at intervals of ten years are more likely to be the practice.

Height growth tends to slow down when a height of 100 feet is reached. In the best even-aged stands (thinned once only) this is at age 80-85 years, when the average diameter is 12 inches, and the maximum 20 inches. It is at this stage that a heavy thinning should be made to increase the diameter of sound, relatively slow-grown stems, and final stocking, 80-100 per acre, may be achieved by this thinning. First quality sites only will be able to support this high stocking until the end of the rotation at 120 years. At this age a minimum log of 18 inches diameter and length of 45 feet should be obtained. There is ample evidence today that on the best sites some of the logs will scale at 24 to 30 inches by 70 feet, a convenient size for handling in bush and mill. On inferior sites or where trees of larger diameter are required, the crop may be reduced to 60 stems at age 100 years. A reduction in stocking coupled with a lengthening of the rotation to 140 years will ensure a proportion of large sized hardwoods with a high heartwood content.
The proposed thinning regime for red beech on first quality sites, and where there is a mining timber market may be summarised as follows:

Age 20: Stocking of 4000 stems per acre, including silver beech component.
Age 20-40: Removal of wolves and malforms.
Age 45-50: Crown thinning to 800-1000 stems per acre.
Age 55: Crown thinning to 500-600 stems per acre.
Age 60-80: Crown thinnings at five yearly or ten yearly intervals to 120-150 stems per acre.
Age 85: Final thinning to 80-100 stems per acre, with first yield of sawlogs and final yield of mining timber.
Age 100: Thinning to 60 stems per acre in selected areas for trees of greater diameter.
Age 120: Final felling at end of rotation.

Red beech is a light-demanding species, unlike *Fagus sylvatica*, and accordingly the gradual transition from development thinnings to regeneration fellings as practised in Europe is unnecessary. Moreover, there is no need for the sequence of seeding, secondary and final fellings, each of one-third to one quarter of the crop by volume, since the young crop requires little or no overhead protection. A heavy or total felling may thus be made, according to circumstance. When the end of the rotation corresponds with a mast year, the whole of the crop may be removed in one operation. But since seed years are at long and irregular intervals and the seed is apparently not viable for more than one year, it is advisable to wait for the setting of the seed in a mast year, or seedfall itself, before making this irrevocable step. Where there is reason to doubt that full regeneration will be obtained, due for example to insufficient preparation of the ground, some seed trees may of course be left as a precautionary measure. Every effort should be made to make the end of the rotation coincide with a mast year. On the basis of an average flowering cycle of ten years and a rotation of 120 years, the adjustment necessary is never more than five per cent of the rotation. Advantage should be taken of these mast years and flexibility of management is essential at this time. On the other hand, where it is not practicable to shorten or extend the rotation, then an adequate number of seed trees, say 10-15 per acre, must be reserved at this major felling, and reliance placed on sufficient seed being shed from them in one or two mast years to restock the area within the regeneration period of 20 years. In this case a minor final felling is required, with the delicate removal of seed trees from above the seedlings.

The yield from a fully managed stand is expected to be 8000 cubic feet per acre, including 1500-2000 cubic feet of mining timber from periodic thinnings. Such volumes will only be possible from fully stocked stands of red beech. Much of the forest coming within the current beech management schemes contains varying proportions
of silver and mountain beech, not all of which can be eliminated before final stocking is reached. Where these latter species are more numerous and obviously more suited to a particular site, a silvicultural technique different from the above will need to be devised, possibly with a longer rotation and certainly with lesser yields.

4. Conclusion

It is held that the production of native hardwoods will play an increasing and important role in the timber industry of New Zealand. The beech forests, by their wide distribution over a variety of sites, provide both protection and production forest. In the Nelson-Westland region the emphasis will be on the management of red and hard beech for sawlogs and mining timber. These species are most amenable to silviculture, which however is dependent for success upon the provision of machinery and the supply of a labour force sufficient to carry out the timely measures necessary to ensure regeneration and to maintain its uninterrupted growth.

5. Summary.

A brief account is given of the occurrence and condition of the local beech forests, together with details of the ecology and rate of growth of red beech (*Nothofagus fusca*) in Nelson and Westland. The suggested methods of silviculture are described, involving the conversion of beech-podocarp forest to even-aged beech forest under the Uniform System, and the tending of pole stands by frequent crown thinnings for the production of mining timber and medium-size sawlogs. A rotation of 120 years is shown to be desirable and practicable, with an anticipated total yield of 8000 cubic feet per acre on the best sites.

References


4. Troup, R.S. Silvicultural systems.


TABLE I.  

Summary of data from twenty three sample plots of even-aged naturally regenerated, unthinned stands of *N. fusca* and *N. truncata* in the Reefton District.

Compiled from "The growth of even-aged young Nothofagus forest in the more accessible and better quality sites of Reefton District" by R. B. Moorhouse, *N.Z. Jour. of Forestry*, Vol. IV, No. 4, 1939.

<table>
<thead>
<tr>
<th>Age—Years</th>
<th>10</th>
<th>20</th>
<th>30</th>
<th>35</th>
<th>40</th>
<th>45</th>
<th>50</th>
<th>55</th>
<th>60</th>
<th>65</th>
<th>70</th>
<th>75</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stocking per acre</td>
<td>—</td>
<td>—</td>
<td>4870</td>
<td>3410</td>
<td>2900</td>
<td>2350</td>
<td>1880</td>
<td>1500</td>
<td>1080</td>
<td>730</td>
<td>400</td>
<td>280</td>
</tr>
<tr>
<td>Maximum diameter class Inches</td>
<td>—</td>
<td>—</td>
<td>8</td>
<td>10</td>
<td>13</td>
<td>14</td>
<td>15</td>
<td>15</td>
<td>16</td>
<td>17</td>
<td>18</td>
<td>18</td>
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<tr>
<td>Average D.B.H. o.b. Inches</td>
<td>—</td>
<td>—</td>
<td>4.95</td>
<td>5.20</td>
<td>5.33</td>
<td>5.97</td>
<td>6.50</td>
<td>7.10</td>
<td>7.80</td>
<td>8.55</td>
<td>9.40</td>
<td>(10.3)</td>
</tr>
<tr>
<td>Height : Site Quality I. Feet</td>
<td>10.5</td>
<td>28.5</td>
<td>48.0</td>
<td>57.5</td>
<td>66.0</td>
<td>73.5</td>
<td>79.5</td>
<td>84.0</td>
<td>88.5</td>
<td>92.0</td>
<td>95.0</td>
<td>98.0</td>
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<tr>
<td>Height : Site Quality II Feet</td>
<td>7.5</td>
<td>19.5</td>
<td>32.5</td>
<td>40.0</td>
<td>47.0</td>
<td>54.0</td>
<td>60.0</td>
<td>66.5</td>
<td>71.5</td>
<td>76.0</td>
<td>80.0</td>
<td>82.5</td>
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<tr>
<td>Height : Average Site Quality Feet</td>
<td>9.0</td>
<td>23.0</td>
<td>39.5</td>
<td>47.5</td>
<td>55.0</td>
<td>63.0</td>
<td>70.0</td>
<td>75.5</td>
<td>80.0</td>
<td>84.0</td>
<td>87.0</td>
<td>90.0</td>
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<tr>
<td>Volume per acre to 4.5 inches top Cubic feet i.b.</td>
<td>—</td>
<td>—</td>
<td>575</td>
<td>750</td>
<td>1080</td>
<td>1550</td>
<td>2100</td>
<td>2850</td>
<td>3750</td>
<td>4700</td>
<td>5700</td>
<td>6700</td>
</tr>
</tbody>
</table>

Note: (1.) Site Quality I: Height 80 feet at age 50 years. Site Quality II: Height 60 feet at age 50 years.
(2.) The volume given above is "the possible production assuming trees are of perfect form." A stump height of 18 inches was used. The top diameter of 4.5 inches was the minimum for quartz mining timber. For present day coal mining the minimum is 6.0 inches, and the merchantable volumes given above should be reduced accordingly.
TABLE II.

Table showing the relationship between rainfall and known years of beech flowering.
(At Reefton)

<table>
<thead>
<tr>
<th></th>
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<th></th>
<th></th>
<th></th>
<th></th>
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</thead>
<tbody>
<tr>
<td>October</td>
<td>7.30</td>
<td>17.0</td>
<td>8.0</td>
<td>19</td>
<td>6.2</td>
<td>19</td>
<td>9.6</td>
<td>15</td>
<td>7.9</td>
</tr>
<tr>
<td>November</td>
<td>6.88</td>
<td>14.8</td>
<td>1.5</td>
<td>6</td>
<td>6.1</td>
<td>14</td>
<td>3.2</td>
<td>13</td>
<td>8.5</td>
</tr>
<tr>
<td>December</td>
<td>5.80</td>
<td>14.2</td>
<td>2.3</td>
<td>5</td>
<td>1.7</td>
<td>6</td>
<td>4.1</td>
<td>12</td>
<td>8.0</td>
</tr>
<tr>
<td>January</td>
<td>6.10</td>
<td>13.0</td>
<td>8.2</td>
<td>19</td>
<td>3.3</td>
<td>7</td>
<td>7.6</td>
<td>14</td>
<td>5.8</td>
</tr>
<tr>
<td>February</td>
<td>4.75</td>
<td>10.5</td>
<td>8.8</td>
<td>9</td>
<td>4.2</td>
<td>10</td>
<td>9.0</td>
<td>11</td>
<td>4.5</td>
</tr>
<tr>
<td>March</td>
<td>5.05</td>
<td>11.3</td>
<td>4.7</td>
<td>8</td>
<td>6.0</td>
<td>11</td>
<td>3.7</td>
<td>13</td>
<td>9.4</td>
</tr>
<tr>
<td>Total:</td>
<td>35.88</td>
<td>80.8</td>
<td>33.5</td>
<td>67</td>
<td>27.5</td>
<td>67</td>
<td>37.2</td>
<td>78</td>
<td>44.1</td>
</tr>
<tr>
<td>Variation from 1904-50 average</td>
<td>-2.4 -14</td>
<td>-8.4 -14</td>
<td>+1.3 -3</td>
<td>+8.2 +26</td>
<td>-9.1 -24</td>
<td>+17.6 +22</td>
<td>-10.0 -15</td>
<td>+17.7 +23</td>
<td></td>
</tr>
</tbody>
</table>
**TABLE III.**

Data relating to Sample Plot N.56, Tawhai Forest.

Sub-plots “A” and “B” thinned at age 46 years.

Sub-plot “C” unthinned.

Illustrates negative effect of low thinning.

<table>
<thead>
<tr>
<th></th>
<th>Sub-plot “A”</th>
<th>Sub-plot “B”</th>
<th>Sub-plot “C”</th>
</tr>
</thead>
<tbody>
<tr>
<td>Volume to 4.5 inches i.b., in 1937. Age 44 years.</td>
<td>1385</td>
<td>1514</td>
<td>1480</td>
</tr>
<tr>
<td>Stocking per acre. 1937.</td>
<td>2964</td>
<td>2508</td>
<td>2676</td>
</tr>
<tr>
<td>Stocking before thinning in 1939</td>
<td>2168</td>
<td>1836</td>
<td>—</td>
</tr>
<tr>
<td>Stocking after thinning in 1939</td>
<td>808</td>
<td>868</td>
<td>—</td>
</tr>
<tr>
<td>Stocking in 1949. Age 56 years.</td>
<td>756</td>
<td>840</td>
<td>1340</td>
</tr>
<tr>
<td>Stocking in 1952. Age 59 years.</td>
<td>748</td>
<td>824</td>
<td>1256</td>
</tr>
<tr>
<td>Stems per acre above 5.5 inches d.b.h. in 1952</td>
<td>472</td>
<td>516</td>
<td>596</td>
</tr>
<tr>
<td>Percentage of 1937 stocking:</td>
<td>16.0</td>
<td>20.5</td>
<td>22.0</td>
</tr>
<tr>
<td>Stems per acre above 6.5 inches d.b.h. in 1952</td>
<td>348</td>
<td>396</td>
<td>460</td>
</tr>
<tr>
<td>Percentage of 1937 stocking:</td>
<td>11.7</td>
<td>15.7</td>
<td>17.1</td>
</tr>
<tr>
<td>Mean annual diameter increment since 1939, dominants only. (Inches)</td>
<td>0.155</td>
<td>0.140</td>
<td>0.153</td>
</tr>
<tr>
<td>Mean annual diameter increment since 1939, 120 best stems per acre. (Inches)</td>
<td>0.210</td>
<td>0.177</td>
<td>0.214</td>
</tr>
</tbody>
</table>

Note: Sub-plot “A” was thinned in 1952 to 330 stems per acre, and Sub-plot “B” to 480 stems per acre. Sub-plot “C” remains as control.
Plate 1.—Red Beech Regeneration following 1936 mast year, subsequently released by ringbarking of silver beech on right. The heavy stocking has occurred in prepared seed beds. Tawhai Forest.

Photo: N.Z. Forest Service
Plate 2.—Red Beech Pole Stand, aged 85 years. Average diameter 12 ins. Maximum diameter 16.5 inches. Height 100-110 feet Thinned to 164 stems per acre. Hukawai Forest

Photo: N.Z. Forest Service
Plate 3.—The Method of Regeneration. Red beech seed-tree in background, with ring barked kamahi understorey. The scarified floor in the foreground carries a light but adequate crop of inch-high seedlings following upon the 1952 seedfall. Hukawai Forest.

Photo: N.Z. Forest Service
Plate 4.—Red Beech Regeneration in an area milled in 1945. Young crop being released by ringbarking silver beech overwood. Typical of the condition of much of the beech forest milled in the last twenty years. Eastern Inangahua Forest.

Photo: N.Z. Forest Service