1. Selective Description of the Country:
   a. Nature and Extent of the Forest Resource:

   It is well known that Scotland as a whole is generally divided into two geographic regions, the Lowlands to the south and the Highlands to the north. The Lowlands form the more fertile region, better suited to agriculture and more heavily industrialised and opportunities for forestry, although considerable, are not so great as in the Highlands where large planting programmes have been and are being carried out. Dickson and Innes (1959) have dealt with the history, climate, geology and soils of the Scottish Highlands in general terms and have discussed the history of land use, from the seventeenth century, in the seven crofting countries. The three main uses of the land have been for hill farming, crofting and forestry and the two authors have briefly reviewed the deterioration of all of them as viable, economic industries, a process which was accompanied by the depopulation of the Highlands. The density of population of the Highlands region in 1959 was one person per 30 acres and the average number of people, aged over 65 years, had increased during the previous 70 years by 36 percent. The Forestry Commission's policy was and is to acquire land in the region for the establishment of
forests. Progress was, however, slow and during the decade from 1955 to 1965, only about 25,000 to 35,000 acres which were suitable for forestry were acquired. Dickson and Innes attributed this slow rate to the conditions governing the crofting system, particularly its landlord tenant arrangements and to the soils held under crofting arrangements. Also, there was a reluctance on the part of estate owners to give up to forestry any of the small amount of land which could be planted to forests, which remained outside the common grazing lands of the crofters. The accepted policy of the Forestry Commission itself, to acquire land in as large blocks as possible, added a further deterrent to rapid land acquisition since some small areas available for purchase were rejected.

The majority of forests in the Highlands lay in certain broad groups. The Upland Heath forests occupy soils which have a shallow layer (rather than a thin layer or no layer) of raw humus with, underneath, a leached layer lying on top of the drift. The soil type varies in quality according to the depths of the raw humus and leached layers. The dominant vegetation types on these soils are heather (*Calluna vulgaris*) and heath (*Erica cinerea* and *E. tetralix*). In rich conditions, grasses and herbs are plentiful, whilst in areas of poor fertility heather, lichen and *Scirpus* predominate. The rainfall on
the Upland Heaths is from 25 to 30 inches per annum, extremes of temperature are rare and gales are few. Dickson and Innes have described the silviculture and management of the soils, as they were understood at the time.

The forests of the Scottish north coast vary greatly in their soil characteristics which range from deep peat to sand but they have the common characteristic of being subject to exposure and generally poor soils. All of the forest land in this area was once used for sheep grazing and some of it was previously wooded, with timber in the more sheltered valleys and scrub elsewhere. All the forested areas of the North Coast are either flat or gently sloping. The Caithness and East Sutherland areas are exceedingly windswept and there were very few trees there, since the impoverished soils and the exposure frequently make tree planting hazardous, if not impossible. As an example, the land elevation at the Naver forest is from sea level to 900 feet but the plantable land, because of the severe exposure, lies below the 500 foot contour in all but the most sheltered flushes. Most of the aspects in the area are northerly. On the peat bogs of this land, *Scirpus* predominates and heather and heath (*C. vulgaris* and *E. tetralix*) occur along with occasional purple moor grass (*Molinia coerulea*) and cotton grasses (*Eriophorum*).
augustifolium and E. vaginatum). On the heath lands are found Calluna and, frequently, Scirpus and lichen (Cladonia sp.). On the sandy soils of Dunnett, the vegetation is mostly Marram grass with sedges and hypnaceous mosses and a surprising abundance of Primula scotica. The north coast rainfall varies from 35 to 40 inches per annum, the damaging winds blow from the north-west and the number of calm days is quite small. Because of the conditions, Dickson and Innes (1959) felt that large areas of the north seemed to be ruled out for planting, although research plots were expected to yield more information in marginal areas of soil and experience. The prerequisites for successful afforestation appeared to be the occurrence of a good ploughing chance and a gentle slope, to accomplish surface drainage. The only species which are able to withstand the exposure, apart from sheltered pockets in the terrain, are Sitka spruce and lodgepole or shore pine. To avoid planting check and secure good initial growth it was necessary, in most cases, to manure the plants with a phosphate fertiliser at the time of planting.

The West Coast forests of Scotland were formerly sheep farm or deer forests* and are mostly located on steep to very steep slopes. In the Coastal strip, the plantable

* The term "deer forest" usually refers to open, virtually treeless land occupied by herds of Scottish red deer.
elevations vary from sea level up to 1,000 feet and at
Glenshiel from 600 feet at the valley floor to 1,300 feet at
the upper planting limit. The geology is complex. On
the lower ground, morainic drift covers the solid bedrock
and, higher up, these soils give way to peat, leaching is
common and there is some hard pan formation. An important
factor to planting and forestry is the thin depth of peat
which overlies the morainic knolls at the higher elevations,
a depth that increases between the knolls. The rich, heavy
soils on the lower valley slopes usually carry handwood
scrub or, alternatively, finer grasses with Anthoxanthum and
a finer mountain grasses, which give way to Festuca,
Molinia and Nardus on the middle and upper slopes. There
is a marked absence of Deschampsia flexuosa and bracken
frequently occurs on the creep slopes. Calluna and Scirpus
are the main species on the moraines with Calluna dominant
on the lower ground and Scirpus with sparse Calluna some-
what higher. The heather found in these west coast moraines
is less vigorous in growth and more open in stocking than
that of the east coast heaths. Associated with the Calluna
and Scirpus there are, in the wetter areas, varying amounts
of Molinia coerulae and cross-leaved heath (Erica tetralix)
and, on flushed peats, the Molinia becomes dominant. On
the flushed, mineralized peats, the rushes Juneus articu-
latus and J. communis are generally found with bog myrtle
(Myrica gale). On the dryer knolls, Erica cinerea is a component along with Scirpus and Calluna.

The climate of the west coast forests is essentially mild and wet with an annual rainfall, evenly distributed but with frequent spring droughts, varying from 60 to 100 inches, according to locality. The low elevations are usually sheltered and the highest ground is exposed to high winds, causing heavy windblow. The requirements considered to be necessary (in 1959) for successful growth on the climactic peats include good drainage and manuring the plants with phosphate coupled with planting in shallow, inverted turf or with ploughing. The West Coast forests contain a variety of exotic species, the early plantings having consisted of Sitka and Norway spruces, Douglas fir and European, Japanese and Hybrid larches. The species generally favoured at the present time are Sitka spruce and shore pine.

The Great Glen forests were almost all planted on steep to very steep slopes and are found at all elevations up to about 1,100 feet. The exposure is not particularly severe. In the eastern half of the Great Glen, the soils are generally rich but, from Glengarry westwards peat - mostly Molinia peat - predominates. The average rainfall is from 35 - 40 inches in the east to about 100 inches in
the west. In the western areas of the Great Glen, plantings have mostly been of Norway and Sitka spruces and Douglas fir is common throughout the Glen. Scots pine has been planted in some areas but with variable results.

The forests of the basalt soils need not be dealt with in detail since they are located in the Scottish Islands, are highly exposed and experience heavy rainfall of 60 - 90 inches per annum, according to locality. Apart from the exposure, geographical considerations place the Islands in a difficult position from a utilisation viewpoint and, as a result, very little forest has been planted on them.

A comprehensive regional account of the Highlands and Islands of Scotland has been written by O'Dell and Walton (1962). Whilst it is not reviewed herein, it contains much of value for a background understanding of the region. Statistics for the Scottish forests are contained elsewhere in this review as are comments on the forests of the Lowlands, including the Borders.

b. Nature and Extent of the Forest Industry:

As has been mentioned previously, the first pulp mill has only recently been constructed in Scotland and the sawmill industry is, with exceptions, in need of mod-
ernisation. The position of the forests is such that increases in industrial capacity are necessary to utilise the growing volume of forest produce.

Sandwell and Company Limited (1959) have reported on the feasibility and economy of establishing small scale pulp mills in the United Kingdom. It was found that only an integrated groundwood mill might be economic at a capacity level of only 30 tons of pulp per day. On the basis of a wood supply costing 170 shillings per bone dry long ton of wood, the following minimum capacities would be required for three kinds of process, to be economically feasible.

<table>
<thead>
<tr>
<th>Process</th>
<th>Minimum Capacity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bleached sulphate pulp (flash dried)</td>
<td>80 long tons of pulp per day</td>
</tr>
<tr>
<td>Groundwood pulp (flash dried)</td>
<td>200 long tons of pulp per day</td>
</tr>
<tr>
<td>Groundwood pulp, (integrated)</td>
<td>35 long tons of pulp per day</td>
</tr>
</tbody>
</table>

At a level of 30 tons per day and to be economically feasible, plants of the types studied could afford to pay the following prices for wood.

<table>
<thead>
<tr>
<th>Process</th>
<th>Price</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bleached sulphate pulp (flash dried)</td>
<td>20 shillings per bone dry long ton</td>
</tr>
<tr>
<td>Groundwood pulp (flash dried)</td>
<td>Nil</td>
</tr>
</tbody>
</table>
Groundwood pulp (Integrated) 150 shillings - per bone dry long ton

Sandwell and Company concluded that integrated groundwood pulping, particularly when located close to the sources of wood supply, offered the best possibilities for new, small-scale pulping units in the United Kingdom. A bleached sulphate mill would be the most economic independent plant but it should have at least 50 to 100 tons per day capacity, depending upon the price of available wood.

Sandwell and Company Limited noted that, in 1958, there were 212 paper and board mills and 81 pulp mills*. The annual per capita consumption of paper was stated to be 180 lbs. and the United Kingdom production and consumption was tabulated as:

* Of these mills, only four were converting wood into pulp, the remainder being involved in re-pulping or the use of other materials.
United Kingdom Pulp and Paper Statistics (1956)
(Thousands of long tons.)

<table>
<thead>
<tr>
<th>Product</th>
<th>Production</th>
<th>Consumption</th>
<th>Import - Export</th>
<th>+</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mechanical pulp</td>
<td>80</td>
<td>790</td>
<td>-710</td>
<td></td>
</tr>
<tr>
<td>Unbleached Kraft pulp</td>
<td>-</td>
<td>297</td>
<td>-297</td>
<td></td>
</tr>
<tr>
<td>Other wood pulp for paper</td>
<td>15</td>
<td>927</td>
<td>-912</td>
<td></td>
</tr>
<tr>
<td>Straw etc. pulp</td>
<td>41</td>
<td>155</td>
<td>-114</td>
<td></td>
</tr>
<tr>
<td>Waste Paper</td>
<td>1,174</td>
<td>1,079</td>
<td>+ 95</td>
<td></td>
</tr>
<tr>
<td>Dissolving pulp</td>
<td>-</td>
<td>226</td>
<td>-226</td>
<td></td>
</tr>
<tr>
<td><strong>Total Pulp</strong></td>
<td><strong>1,310</strong></td>
<td><strong>3,474</strong></td>
<td><strong>-2,164</strong></td>
<td></td>
</tr>
<tr>
<td>Newsprint</td>
<td>653</td>
<td>960</td>
<td>-307</td>
<td></td>
</tr>
<tr>
<td>Kraft Paper &amp; Board</td>
<td>264</td>
<td>490</td>
<td>-226</td>
<td></td>
</tr>
<tr>
<td>Other Paper &amp; Board</td>
<td>2,365</td>
<td>2,602</td>
<td>-237</td>
<td></td>
</tr>
<tr>
<td><strong>Total Paper &amp; Board</strong></td>
<td><strong>3,282</strong></td>
<td><strong>4,052</strong></td>
<td><strong>-770</strong></td>
<td></td>
</tr>
</tbody>
</table>

These figures emphasise the concern of the British Government, as reflected in their forest policies, to make Britain more self-reliant in wood products. The cost of these imports, along with those of lumber, represent a very large import cost at a time when Britain's balance of payments are acute.

The Sandwell report noted that the woodlands of Great Britain were producing some 100 M.M. Hoppus feet (1.27
M.M.c.f.) per annum of timber. The paper industry consumed approximately 20 M.M.H.F. (0.25 M.M.c.f.) per annum, of which three quarters was imported and the remainder home-grown. It was estimated that the following maximum surpluses might become available at various centres where the pulp plants might logically be built.

Estimated Wood Surpluses Within 100 Miles Road Distance (1,000 B.D.L.T.)

<table>
<thead>
<tr>
<th>Location</th>
<th>Price Basis*</th>
<th>1960</th>
<th>1965</th>
<th>1975</th>
<th>1985</th>
</tr>
</thead>
<tbody>
<tr>
<td>Inverness I</td>
<td>25</td>
<td>44</td>
<td>50</td>
<td>81</td>
<td></td>
</tr>
<tr>
<td>Inverness II</td>
<td>6</td>
<td>25</td>
<td>31</td>
<td>63</td>
<td></td>
</tr>
<tr>
<td>Fort William I</td>
<td>31</td>
<td>44</td>
<td>56</td>
<td>81</td>
<td></td>
</tr>
<tr>
<td>Fort William II</td>
<td>12</td>
<td>25</td>
<td>44</td>
<td>66</td>
<td></td>
</tr>
<tr>
<td>Lochgilphead I</td>
<td>14</td>
<td>25</td>
<td>44</td>
<td>63</td>
<td></td>
</tr>
<tr>
<td>Lochgilphead II</td>
<td>8</td>
<td>16</td>
<td>37</td>
<td>56</td>
<td></td>
</tr>
<tr>
<td>Dumbarton I</td>
<td>-</td>
<td>37</td>
<td>63</td>
<td>88</td>
<td></td>
</tr>
<tr>
<td>Dumbarton II</td>
<td>-</td>
<td>19</td>
<td>44</td>
<td>69</td>
<td></td>
</tr>
<tr>
<td>Newcastle</td>
<td>-</td>
<td>8</td>
<td>25</td>
<td>34</td>
<td></td>
</tr>
</tbody>
</table>

Based on these figures, the requirements of a 50 tons per day groundwood mill for 17,000 B.D.L.T. per annum and of a 50 ton per day bleached sulphate pulp mill for

*Basis I - Pulpwood prices would be equal to, and Basis II lower than, the prices of other products of similar specification. 80 H.F. = 1 B.D.L.T. (Bone dry long ton.)
39,000 B.D.L.T. per annum, it appeared to Sandwell and Company Ltd. that, at least by 1965, enough timber would be available for a new small-scale pulp mill.

The relative economics of bleached sulphate, groundwood pulp and integrated groundwood pulp at a capacity of 50 tons per day were considered along with the effect of plant locations (comparing Fort William, Lochgilphead, Dumbarton and Inverness and assuming pulp consumption centres at Glasgow and Edinburgh).

Sandwell and Co. Ltd. (1959a) also conducted a survey of the economics of Board mill operation in the United Kingdom. The feasibility of establishing hardboard, wood chipboard and insulating board mills, based upon the utilisation of home-grown timber (forest thinnings) was investigated. The particular situations which were studied were:

<table>
<thead>
<tr>
<th>Plant Description</th>
<th>Nominal Capacity L.T. per Day</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hardboard</td>
<td>60,000 sq.ft. per day (¼&quot; basis) 35</td>
</tr>
<tr>
<td>Hardboard</td>
<td>120,000 sq.ft. per day (¾&quot; basis) 70</td>
</tr>
<tr>
<td>Wood chipboard</td>
<td>30,000 sq.ft. per day (¾&quot; basis) 35</td>
</tr>
<tr>
<td>Wood chipboard</td>
<td>60,000 sq.ft. per day (¾&quot; basis) 70</td>
</tr>
<tr>
<td>Insulating board</td>
<td>100,000 sq.ft. per day (½&quot; basis) 30</td>
</tr>
<tr>
<td>Insulating board</td>
<td>200,000 sq.ft. per day (½&quot; basis) 60</td>
</tr>
</tbody>
</table>
The economics of these plants were considered for west Wales, mid-Scotland, North Scotland, West Scotland and Southern England. The studies indicated that, although there was a relatively large market for hardboard, the manufacture of this product would not be economically attractive unless plant economy could be improved by means such as integration with other wood-consuming industries. There were indications, also, that the manufacture of both wood chipboard and insulating board would be economically attractive only in the larger sized mills and then only if forest thinnings could be delivered to the mills for between 11 and 12 pounds sterling per bone dry long ton, or between 13 and 14 pounds sterling per bone dry long ton for insulating board. Southern England appeared to be the most favourable area for plant location.

For purposes of comparison, the study employed assumed arbitrary costs for wood, delivered at mill in West Wales, of 8.5 and 17 pounds sterling per B.D.L.T. Wood costs for other areas were adjusted upward and downward from these figures to compensate for differences in transportation charges. The lower figure was equivalent to North American costs for coniferous pulpwood thinnings but considerably less than the then existing market for similar wood products, such as unpeeled pitwood, which sold for approximately 15 pounds sterling per B.D.L.T. The
higher figure was selected simply as the upper limit of the range within which it was felt that wood costs would fall.

On this basis the calculated percent gross returns on investment for areas in Scotland which could possibly be supplied from North Scotland Conservancy, were given. In another approach, it was assumed that, to be economically attractive, a new board industry should earn a gross return before interest, depreciation and income tax of approximately 20 percent. The wood prices which the various plants would have to pay to earn this return were given and led to the conclusions given above.

The author did not locate literature dealing with economics of the Scottish sawmilling industry but did visit a number of sawmills. Recognising the danger of generalities, it was nevertheless clear, particularly by contrast with British Columbia sawmills, that plant capacities and productivity were low. The small capacities present obvious problems in automation to raise productivity and would not merit the relatively large capital expenditures necessary to reach high productivity. The first stage of re-development of the industry appeared to lie in consolidation of plants i.e. fewer, larger plants and discussions toward this end were in progress.
c. Red Deer and Forestry:

As has been mentioned, wild life and agriculture are important land uses in Scotland. In the Scottish Lowlands, much of the land surface is suitable for arable farming and sheep farming and the opportunities for large-scale forestry are limited. In the Scottish Highlands, arable farming land is of limited extent and the land is mainly used for wild life, sheep grazing and forestry. The question of sheep grazing is dealt with later in this review. The major wild life uses in the Highlands are the propagation of Scottish red grouse and red deer. The eastern grouse moors are used for sporting purposes and show economic results which, generally, preclude their use for forestry. The Scottish red deer, formerly a forest animal, have long been identified with the Scottish mountains and the planting of forests has tended to restrict their range to the mountain tops and in some cases, has restricted their normal overwintering areas.

A symposium on red deer and forestry was held at Inverness in 1967. Black (1968) summed up and drew conclusions. He observed that the next 20 - 40 years would see a continuing expansion of afforestation in Scotland. Also, much of the Highlands was particularly suitable for production of venison and an increasing interest in this activity would result from economic pressure. In addition
to research aimed at assessing and collecting the fundamental biological data which would lead toward sound and informed management programmes, he held that increased attention should be paid to operational research, in order to provide the information necessary for immediate decisions. In the commercial aspects of deer management, there was increasing competition for the European venison market from New Zealand and other Continental countries, coupled with a lack of publicity to promote the consumption of venison in Britain. The stalking of deer as a sport could be more publicised but at the risk of introducing it to people without the necessary skill.

Black described multiple land use as involving the simultaneous use of land for a number of different products and purposes and stated that it was not a patchwork development of land. The problems caused to deer management by the fencing of forest plantations had received much prominence and he welcomed the decision of the Forestry Commission to give up long fence lines and to make provision for downfalls* and shelter. The cost of deer fencing, however, was a grave financial burden which could not be administered by the Red Deer Commission because of the lack of appropriate powers. The costs of deer fencing did not seem

* Downfalls are access routes through afforestation areas from the mountain tops to lower areas.
to be fairly distributed and it appeared that the Government should subsidise deer fences, in line with other subsidies paid to hill-land producers. Where it was decided to carry larger deer populations than the wintering ground could support and it was desirable to avoid marauding, artificial feeding of deer would be necessary. Feeding, however, was expensive and would be almost impossible on a large scale. Black strongly supported the idea of a continuing dialogue between red deer and forestry interests so as to gradually bring the two sides together.

d. The Human Resource - Forestry Training:

Four universities in Great Britain offer professional forestry training, the two in Scotland being the University of Edinburgh and the University of Aberdeen. The latter University offers a Bachelor of Science degree in forestry, in addition to the usual higher degrees. The Department of Forestry at Edinburgh has recently become the Department of Forestry and Natural Resources and offers Ecological Science with four Honours Schools, one being Forestry.

Taylor (1968) has described the development of forestry employment, education and training in Scotland, below University level. In the past, some landowners and
head foresters ran apprenticeship courses and the Highland and Agricultural Society awarded, until 1935, the fore-runners of the Royal Scottish Forestry Society Junior and Senior Certificates. Some training courses were held at the Royal Botanic Gardens in Edinburgh and others at the University of Edinburgh, the Heriot-Watt College (Edinburgh) and through the Agricultural Colleges. University education in forestry became separated from lower educational levels with the establishment of degree courses at Edinburgh University in 1906 and at Aberdeen University in 1914.

The Forestry Act of 1919 gave the newly created Forestry Commission power to promote forestry training. The Commission established Forester Training Schools where a two-year course was given to men who mostly joined the State Service. Short courses were also provided by the Commission for private estate foresters and workers. At the same time, certain other courses were available. In 1963, the Royal Scottish Forestry Society approached the Scottish Technical Education Consultative Council about establishing a sound system of education and training. Taylor has described how subsequent Association and Committee activity followed this approach, resulting in an improved understanding of the need for such a system, although not in all quarters. The Industrial Training Act,
1964, authorised the Minister of Labour to establish industrial training boards to provide the kind of technical training envisaged. It was, in some ways unfortunate that the forest industry training was split between two training boards. The scope of activity prescribed for the Agricultural, Horticultural and Forest Industry Training Board, set up under the Act of 1964, precluded its participation with any establishment engaged in the felling of trees or the preparation of timber, although it could deal with other facets of forestry. The felling of trees or the preparation of timber were activities which were vested in the Furniture and Timber Industry Training Board. Actual facilities for technical education and training for the forest industry were not yet established, although Taylor (a member of the active Royal Scottish Forestry Society education and training committee) stated that they must be established very soon.

2. Major Aspects of Forest Policy:
   a. State Forest Administration:

      The State forest authority is the Forestry Commission, in which are vested the State forests and forest lands. The Commission also has a great influence on private forestry, because of the system of grants and subsidies applied to private forests. The Eighth British Commonwealth Conference (1962) noted that the Commission,
in addition to its liaison with the three National Forestry Committees of England, Scotland and Wales, maintained other advisory committees. One was the Home Grown Timber Advisory Committee comprised of 25 members, of whom 8 represented private woodland owners and 8 represented the timber merchants and others were from Regional Advisory Committees for each Conservancy. The latter consisted of from 7 to 9 members, at least four of whom represented private woodland owners, timber merchants and organisations concerned with the study and promotion of forestry. In addition, the Commission had advisory committees on the utilisation of home-grown timber and on forest research, as well as a mechanical development committee. Some of these Committees are discussed in greater detail later in this Review.

b. Financial Policies:

The Forestry Commission carries the financial responsibility for its own forests and for state assistance to private forests on a sinking fund basis. It may borrow money from the Treasury at prevailing Treasury rates of interest and receives the proceeds of its operations. In addition to the payment of grants to private forestry, the State has special income tax and estate duty provisions to encourage this sector.
(1) Taxation and Estate Duty:

Hart (1962) mentioned some of the unpredictable variables, particularly of labour and currency value which made it understandable why British governments had ensured that owners and occupiers of woodland were treated sympathetically as to the incidence of income tax and surtax, as well as of estate duty.

(a) Income Tax:

Liability arises under the Income Tax Act, 1952 under tax schedules A, B and D. Schedule A refers to the ownership of land, Schedule B deals with presumed income derived from the occupation of land and Schedule D with profits. If an owner keeps his woodland under his own occupancy, he pays tax under Schedules A and B or D. If he lets his woodland, he pays under Schedule A and the occupier normally pays under Schedule B but may elect for Schedule D.

(i) Schedule A - the Landlord's Property Tax:

The basis of taxation is the annual value which is usually from one shilling to three shillings per acre and sometimes includes sporting value when the owner keeps the sport for himself. In estimating the rental value, no notice is taken of the forest crop i.e. it is the rental value, as if the land were bare. The
average rent paid by the Forestry Commission for a lease of plantable land, up to 1962, had been 5 shillings per acre per annum and this figure is generally employed to have unreasonable assessments reduced. Where a woodland is let to another party, the assessment is based on the actual rent e.g. if let at two shillings and sixpence per acre, the gross Schedule A assessment would be the same figure. Having arrived at the gross assessment figure, it is reduced by a repairs allowance equal to one-eighth of the assessment; by five-sixths of any tithe redemption annuity; by any land tax; by any public rate or assessment paid in respect of draining, fencing or embankment and, in Scotland, by the owner's rates. If this process were applied to 100 acres and resulted, for example, in a net Schedule A value of ten pounds sterling, then, with income tax at seven shillings and ninepence in the pound, the tax would be ninepence per acre per annum. Hart noted that if the cost of repairs, maintenance, insurance and management exceeded the one-eighth allowance on the average of the five preceding years, then income tax on the excess
is recoverable through a maintenance claim.

(ii) Schedule B - The Occupier's Tax:

The gross Schedule B assessment is one-third of the gross Schedule A assessment. If the woodlands are managed on a commercial basis with a view to profit and not merely for sport and amenity, an amount of two-ninths of the assessment is claimable as earned income relief, subject to a maximum deduction for any one taxpayer. Using the same example as was used for Schedule A, the gross Schedule B assessment would be four pounds five shillings and the nett Schedule B assessment, three pounds and six shillings. At the same rate of income tax (7s 9d in the pound), the tax payable would be threepence per acre per annum. Any grants which may be received by the occupier are not taxable. Reverting to the example, the total income tax payable under Schedules A and B would amount to one shilling per acre per annum. No additional liability to income tax arises under these schedules, whatever the amount of profit or of grants received.

(iii) Schedule D:
If an occupier can satisfy the Inspector of Taxes that his woodlands are managed on a commercial basis and realise profits he may elect, within two years after the end of the year of assessment, to be assessed under Schedule D instead of under Schedule B on the actual results of the year preceding the year of assessment. This election may apply to all his woodlands on one estate which are managed commercially or be confined to each new plantation, provided that election is made within ten years of planting. If receipts, including grants, are in excess of expenditure, the owner has to pay income tax on the excess. If expenditure is in excess of receipts, the deficit is treated as a loss and set against the owner's other taxable income. Once an election has been made to transfer from Schedule B, the woodlands concerned must remain under Schedule D until the next change of occupier, by sale, lease, gift or inheritance when it would be automatically transferred to Schedule B with a further right of election to the new occupier.

Hart expressed the view that it was usually unwise to place mature or nearly mature
woodlands under Schedule D since income tax would become payable on the nett receipts without any allowance for income tax paid in past, unprofitable years under Schedule B. Neither was such a move wise with woodland managed under the Selection System. It was sometimes advantageous, however, to transfer each new plantation to Schedule D, since the cost of establishment was allowed and the probably excess of expenditure over receipts in the earlier years could be set against the income from other sources. Such an excess, in any year, could also be carried forward. The older woodland of an estate could be treated as a separate unit and remain under Schedule B.

However, there were circumstances under which an election Schedule D, for young plantations, might be unwise. The occupier, for example, might have insufficient taxable income against which to set losses on woodlands. Another circumstance would be where plantations could be established at a cost of little more than the amount of the planting grant.

As has been mentioned above, any area
placed under Schedule D is automatically transferred to Schedule B on the death of an occupier or on the sale, lease or gift of the woodland or its transferral to an estate company. The new occupier may continue under Schedule B, change all to Schedule D or elect for all or part of the past ten years planting to be treated as a separate estate and assessed under Schedule D, whilst the remainder stays under Schedule B. Thereafter, he may elect to have part or all of those woods which he replants assessed under Schedule D. The schedule is based solely on records of receipts and expenditures and does not take account of reductions in capital or stock-in-trade items.

The British Inland Revenue differentiates between areas replanted after felling and those being afforested for the first time and the method of reclaiming tax differs accordingly. Where woodlands are felled and replanted, the cost of clearing up but not felling, the old crop and of preparing the ground for planting is normally disallowed for Schedule D purposes and is treated as a capital expenditure. But if the new plantation is assessed under Schedule D and
is adjacent to existing forest land in the same occupancy or is on land formerly used for husbandry (e.g. rough grazing) the nett expenditure would qualify for tax relief under a capital expenditure claim, as described below.

(iv) **Sporting Value Assessment:**

The assessment to cover sporting value is added to the gross Schedule "A" assessment when land and sporting rights are in the occupation of the owner or are let together or when the owner occupies the land and lets the sporting rights. Where a rent is obtained for sporting, it forms the basis of assessment, otherwise (in 1962) sixpence per acre was a usual assessment.

(v) **Capital Expenditure Claim:**

Under Section 314 of the Income Tax Act, 1952, where an occupier of woodland assessed under Schedule D incurs any capital expenditure on the construction, reconstruction, extension or adaptation of forestry buildings, cottages, fences or other works for the purpose of forestry he was entitled to an allowance for that year of assessment and for each of the subsequent nine years, equal to 10 percent of the expenditure.
Taking into account an investment allowance of 10 percent of the value of new buildings and other items in the first year, tax relief was obtained on an amount equal to 110 percent of the expenditure. Allowances in respect of capital expended in providing plant and machinery used in Schedule D woodlands could be claimed on the same basis as for agricultural plant and machinery or a trade.

(vi) Estate Forest Tree Nurseries:

Profit derived from raising seedlings, transplants and poplars is not taxable if the stock is used for the estate's Schedule B woodlands. For Schedule D woodlands the cost of similar stock, but not covert plants, is allowed as an expense in the computation of tax. However, profit derived from outside sales, in excess of a reasonable quantity of surplus plants, is taxable under Schedule D.

(vii) Christmas Trees:

When Christmas trees fully occupy a substantial area, profits are taxable under Schedule D. However, the taxation position is different when the trees are planted in mixture with other
trees to be grown as timber or when the grower ensures that he always leaves sufficient trees standing after each thinning to comply with current silvicultural enforcement and, ultimately, to provide a final crop of timber or, when only tree tops are used. In these cases, profits are virtually tax-free under Schedule B but fully taxable under Schedule D.

(b.) Surtax:

The basis of assessment for surtax, which is a personal tax at graduated rates on the total net income of an individual in excess of 2,000 pounds per annum but is subject to substantial relief on earned income up to a certain limit, is almost identical with that of income tax.

(c.) Profits Tax:

Where woodlands are owned by a company, whether assessed under Schedule B or D, profits from them may also be chargeable with profits tax.

(d.) Estate Duty:

From the foregoing, it will be appreciated that taxation considerations have a considerable influence on a private land owner's decision to practice forestry or not, as well as influencing the management practices concerned. Estate duty also has an important bearing on these matters.
and concessions are made for private forestry, as described by Hart (1962).

Land growing timber, trees, wood, underwood or coppice, as well as forestry buildings, roads and permanent fences were subject to estate duty at the rates set out in the Finance Act, 1954 but with a 45 percent "agricultural" allowance on the land. The "amenity value" of timber, trees and wood, treated as enhancing the value of the estate at large, was included in the value of the estate and duty was payable on it. Underwood, coppice (when treated as underwood), windfalls and timber used on the estate were exempted from estate duty. In the case of timber, trees and wood, the value is not taken into account in estimating the principal value of the estate or in determining the rate of estate duty chargeable on the whole estate. Secondly, estate duty need not be paid at death but may, if so desired, be paid later. If payment is postponed, then 2 percent interest must be added from the date of receipt of the proceeds of sale, as and when the timber is cut, during the period which may elapse until another death occurs and the estate again becomes subject to estate duty. Hart (1962) emphasised that it was important to agree upon the value of timber, trees and wood at the date of death, since the amount so agreed would normally be the maximum sum liable to duty, even though subsequent
receipts from sales may exceed that amount. If no value is settled all receipts, less outgoings since death, would be subject without limit to estate duty until the next death. However, should all the timber be sold shortly after death for a greater sum than the estimated value, duty would be claimed by the Government on the excess, on the grounds that the estimate was incorrect. Various alternative methods of payment, including lump sum and deferred payment bases are offered. An important provision is that all outstanding estate duty is cancelled upon the death of a successor and a new probate value then has to be agreed. These and other concessions do not automatically make forestry financially attractive but they do assist in that direction.

**Syndicated Forestry:**

The taxation and estate duty position has helped to extend the areas of privately owned land which are devoted to forestry in Scotland and in Britain as a whole. One form of private forestry enterprise which has assumed some importance is syndicated forestry. Several syndicates, mostly of wealthy individuals who have invested large sums of money in woodland property, appear to have done so partly to take fair advantage of the taxation and estate duty concessions. By transferring a portion of their wealth into woodland, they have invested in property on
which the value of the crops, under current legislation, will not be taken into account when the rate of duty on their estate is assessed. Consequently, their estates will fall into a lower taxation bracket and attract a lower rate of duty. The Economic Forestry Group is an association of woodland owners, forest managers and investment consultants among whose aims is the creation of 100,000 acres of productive woodlands in Britain in a wide variety of ownership but under one management. The woodlands, as acquired, are grouped into separate management areas, each of about 10,000 acres. It is the aim that, in time, each management area will have its own integrated forest industries, designed for complete utilisation of the forest products. The group already has its own marketing company. The financial advisory services of the group include the integration of planned forestry investments into family financial schemes so as to produce maximum savings of income tax, surtax and estate duty. Detailed financial plans are prepared showing the expected future annual receipts and expenditures, estimated over a long period of years, with amendments from time to time to allow for changes in the group's policy and conditions of working. The distribution of surplus net income is arranged annually or at frequent intervals. The forestry syndicates may be said to have forwarded Government policy
to foster private forestry and have been responsible for a considerable flow of private capital into forestry.

(2.) Grants for Shelter Belts:

The subject of Government grants to private forestry is discussed later in this review. However, at this point brief mention is made of grants for shelter belts which should form a limited future timber supply in Scotland. Hart (1962) has stated that the Hill Farming and Livestock Rearing Acts, 1946 to 1956, have provided for grants of up to 50 percent of the approved costs of establishing shelter belts on upland stock-rearing farms, as part of a general scheme for improvement of the farms. These grants are administered by the Ministry of Agriculture, Fisheries and Food or by the Scottish Department of Agriculture and Fisheries. Under the Agriculture Act, 1957, grants of up to one-third of the approved cost of establishing shelter belts on any farm may be made under a Farm Improvement Scheme. In certain circumstances, these grants can provide a higher proportion of the total cost than would the Small Woods Grant provided by the Forestry Commission.

(3.) Financial and Economic Considerations in British Forestry:

The whole question of the economic viability of the British forestry enterprise is a topical and widely
discussed area, on which some authors have commented.

(a.) Rate of Discount (Interest):

Mathur (Mathur, R. S. 1967. Ecological and economic considerations in land use planning. M.Sc. Thesis. Edinburgh University.) has considered the rate of discount (interest) which might logically apply to the forestry enterprise. Having given discount rates he discussed economic choices between land use alternative with different time streams and different costs and benefits. It was necessary to make the transitions at different points in time commensurate with each other, by assigning to them equivalent present values (discounting all of them to the present day by compound interest). The discount rate that is used represents the cost of waiting for delayed returns on the investment. The lower the discount rate, the higher would be the present worth of future revenue relative to that of immediate gains. Along with these basic principles Mather noted that the choice of a rate of discount depended on the risk involved in the undertaking. The greater the risk, the higher was the speculative rate of discount needed. Assuming that a forest crop is a very safe investment, many foresters have developed a rate of interest equal to that of a risk-free rate of discount earned in government securities, usually about 4 percent. The Forestry Commission, in 1966, had adopted 5 percent as the
standard discount rate in their internal economic calculations. On the assumption that future timber prices were likely to increase by 1 1/2 percent relative to the prices of other commodities, the effective rate of discount chosen by the Forestry Commission for all future revenues was reduced to 3 1/2 percent at fixed prices. Since the costs (under the policy of afforestation) were incurred mostly in the beginning of the rotation, the rate of discount did not affect them much, except for maintenance and road access costs, which were capitalised at 5 percent.

(b.) British Forest Finance and Economic Policy:

Mutch (1967) has not only dealt more directly with Forestry Commission interest rates but has registered a criticism of the British forest finance policy. Because of the significance of his remarks to overall forest policy they are worth examination in some detail herein. He has dealt in particular, with the accountancy of State forestry at the national level, commenting that the investment liability of the Forestry Commission was building up and that the debt could become entirely unmanageable.

Since 1958, the afforestation policy for State forests had been explicitly planned, insofar as the responsible Ministers had announced the total land areas which they had intended should be acquired and planted in
the subsequent quinquennium. Funds had to be allocated to execute the programmes in the amounts, over the past decade (up to 1966) of from 10 to 15 million pounds sterling annually.

The unusually long time-scale to realise its production made forestry more susceptible than most industries to serious disruption if the flow of funds were to be subject to fluctuations. The advantages of sustentation in the execution of afforestation plans were great enough that foresters had occasionally suggested that Parliament should be invited to consider longer programmes than it had done and to finance the work by occasional large allocations to a Forestry Fund. Those finances would escape annual review and might be placed on a similar cycle to that which was technically appropriate. The forest authority would be able to draw on the fund so created without prior authorisation and would be relieved of anxiety about the medium-term continuity of its finances. However, the arguments that forestry deserved this unusual treatment to redress the results of decades of neglect prior to 1919 and to compensate for the artificially low return obtained from the forced fellings of two world wars did not make economic sense. In effect, the proposed funds would be a means whereby forestry would avoid the restrictions which are placed periodically on investment and it might be regarded
as a purchase price for the national forest estate, not subject to the interest payments levies on the Parliamentary grants-in-aid.

The gross return on the national forest investment, Mutch held, could not reasonably be expected to exceed 3 percent per annum. The Forestry Commission had contended that this gross return was augmented by a continual increase in timber prices, relative to other commodities, of between 1 and 1 1/2 percent per annum. Mutch felt that this argument was weak in that an increase in the real price of timber must make it less desirable to its users and increase the possibility of price substitution by other products. Thus the hypothetical price increase could not be reckoned as an advantage. Also, as a purely financial criterion, the promise of forestry to pay 3 percent gross interest was not impressive because it implied, with a 6 percent borrowing rate, a constant loss of 3 percent per annum on the investment. In addition, forestry was far from being a risk-free investment.

The essential function of an increase in the bank rate (and of the Treasury borrowing rate which is applied to the Commission's drawings) was to persuade investors to abandon the less profitable and least vital schemes but State forestry had avoided the curbs to a considerable
extent, although the cost in accumulated interest had been high. The argument had involved crediting the difference between the actual borrowing rate and the promised timber return to the social attributes of forestry; to the provision of rural employment, recreation opportunities and other indirect benefits. When the borrowing rate for Treasury funds went up, the State forest authority had apparently increased the proportion of social benefit attributed to its investment and had carried on as before with largely unchanged timber-growing techniques. Mutch considered this to be remarkable in view of the objective of the increase in the borrowing rate, the investment restraint in the less productive schemes.

The Report of the Commissioners for the year ending 30th. September 1966 showed, on that date, that the Commission's capital account stood at 281 million pounds sterling of which 114 million pounds had accrued as interest charged at the Treasury borrowing rate each year since 1919. During 1966, 14 million pounds of new money was drawn from Parliament to swell the capital account and 15 million pounds more was charged as interest for the single year. A simple extrapolation of the capital account figures published in successive annual reports suggested that, with conservative estimates of future afforestation and interest rates, the capital account in 1980 would probably stand at
more than 700 million pounds.

The reasons for the adoption of the accounting procedure had never been given publicly. Since the 40th Annual Report of the Commissioners suggested that a gross return of 3 or 3 1/2 percent could be obtained from timber production, it seemed to Mutch to be an irrelevance to publish a capital account assembled at the Treasury borrowing rate (6 1/2 percent or thereabouts in recent years). In the early decades of the Commission's existence, interest rates were very low (2 to 4 percent), mature timber prices were high relative to labour wages and land prices and high productivity/low cost afforestation was the rule. There had been a good chance of making a gross return and a nett profit on the investment since, in basic terms, the trees would be growing faster than the capital account. This was not now the case.

Mutch held that it was unrealistic to persist with the existing system in the hope that the mean borrowing rate would fall as low as 3 percent. An early change of policy was necessary to avoid the creation of an unmanageable capital account. Commenting further on the accounting system, he stated that its worst results lay in the valuation of assets in the Commission's balance sheet. Lands, roads, buildings, machinery, etcetera were valued at cost
and depreciated but represented only about one-sixth of the total assets. The largest asset was the forest growing stock which was taken to be worth the balance of the liabilities and this large assumed asset grew each year as the capital account increased, to match liabilities. In 1966 alone, the assumed increase in value of the growing stock was 21.6 million pounds. It was pure assumption to believe that assets had appreciated as fast as liabilities had grown.

The introduction of a new Forestry Fund, not subject to Treasury interest, which had been suggested as a solution to the accounting difficulty, was unlikely to succeed and would not affect the main issue. Afforestation now promised a negative investment yield to Britain. The promise of the augmentation of that yield by a constant increase of real timber prices over time was illusory.

The national forest policy combined economic aims with the provision of social benefits, such as rural employment, but under the combined stresses of wage increases and attempts to improve the adverse financial position, forestry must inevitably react by reducing its labour employment. Public recreation is the other potentially major social benefit employed but it was small in extent.

As a solution, Mutch suggested that either the
Forestry Commission's drawings from Treasury should be charged at a rate lower than the normal borrowing rate, in order to make allowance for the very large social benefit the forests provide for recreation and other pursuits or the full borrowing rate should be charged only on the purely commercial ventures. These ventures would then slow up during deflationary periods, as in other parts of the economy and the overall system would produce different, sharply differentiated objectives for the forests. An urgent need within the system was an adequate method of measuring social benefits, so as to draw up a meaningful balance sheet.

Prior to 1958, Mutch noted, the Forestry Commission had a simple policy directed to the creation of a strategic timber reserve and the same policy was promoted in private forestry, through the Dedication Scheme and in other ways. When that policy was cancelled, the substitute policy had been inadequately drawn, belatedly published, paid insufficient regard to priorities and lacked clarity, even in such important matters as the Commission's economic role and financial position. Mutch foresaw a real danger that the almost inevitable decision, some years hence, to write off hundreds of millions of pounds of liability generated from the interest accumulation would adversely affect the public attitude toward
forestry and foresters and that, as a result, the whole industry would be discriminated against.

It is the declared intention of the British Government to enter into the European Economic Community and Openshaw (1967) has discussed the effects on forestry. The British import bill for industrial wood products in 1964 amounted to almost 600 million pounds per annum. A comparison of United Kingdom tariffs and the E.E.C. Common Extended Tariff indicated that the former are similar to, if not more than, the latter. But there was no tariff on wood entering the United Kingdom from the European Free Trade Association (E.F.T.A.) and the Commonwealth countries so that much of the wood from Scandinavia and Canada, the largest suppliers, entered the U.K. duty free. Entry with E.E.C. would result in the levy of tariffs ranging from 6 to 18 percent on some timber imports for the first time, amounting to a sum of about 20 million pounds or more. Openshaw assumed that Britain would not be able to switch her imports of industrial wood from the traditional sources to suppliers from the Common Market countries because both the U.K. and E.E.C. were large importers of wood pulp and papers. Secondly, he assumed that Canada and the Scandinavian countries would not join E.E.C. Canada's economy was too much integrated with the U.S.A. to permit of this, although the position of the Scandinavian countries was
less clear. The anticipated tariff increase of about 20 million pounds might require some adjustment downward following publication of the Kennedy Round of tariff cuts. British newsprint manufacturers (but not the newspaper industry) would benefit from E.E.C. entry. In 1967, Scandinavian newsprint cost only 53.4 pounds per ton whereas British and Canadian cost 56.7 pounds per ton. However, Finland, with massive integrated mills was also giving a discount on bulk orders. A 7 1/2 percent tariff on newsprint would bring the Scandinavian price to 57.4 pounds and the Canadian price to 61 pounds. The result of such a tariff and one of 17 percent on paper might be that Canada, and to a lesser extent, Scandinavia, would invest capital in pulp and paper mills in Britain. Pulpwood, wood chips, etc. entered the E.E.C. duty free and might be shipped in to feed mills in Great Britain.

British entry into E.E.C. should also act as a stimulus to British forestry. The marginal upland farmer would find it difficult to survive without subsidies since there would be an estimated surplus of 16 million acres of agricultural land in mainland Europe by 1970. The E.E.C. forestry policy, then in process of being worked out, should favour expansion of the forest area to counter the great reliance of Europe on timber imports and to act as a buffer against the predicted world timber shortage.
The anticipated extra 20 million pounds from tariffs imposed on timber imports entering the U.K., assuming entry into E.E.C. could find its way into the Common Agricultural Fund but Openshaw felt that a good case could be made to use the money for extension of the British forest area, possibly up to 10 million acres. The relatively small pulp mill at Fort William would have to expand as quickly as possible in order to compete on equal terms and the annual planting programme of 52,000 acres for Scotland (36,000 Forestry Commission and 16,000 private) should be increased about 3 times to obtain thriving forest and wood-using industries. The expansion would also ensure that the remoter regions would contribute to the national prosperity.

Mutch (1962) has discussed the economic factors which influence the type of timber grown and the methods of growing it. It could be construed after the abandonment of the policy to form a strategic reserve of timber in Great Britain, that interest-earning capacity was the main reason for investment and that the Faustmann test should be applicable. However, this would imply that afforestation was competing freely with other new investments, which was not the case. Mutch believed that buyer's specifications were likely to determine the type of timber grown and that the technical rotation was thus likely to
take first priority over other rotations. The buyer's specifications would change and management must be flexible, Mutch considered, with a bias in favour of high quality, rather than low.

Johnston (1963) has written on the influence of planning at the management level on forest productivity. Using the criterion of nett discounted revenue per one pound sterling invested and assuming that the larger the profit, the more successful was the undertaking, he has discussed the six principal factors influencing profitability which can be controlled at the planning level. These factors were defined as mean annual increment; cost of establishment (afforestation); cost of road construction; cost of forest maintenance and protection; thinning intensity and rotation lengths.

c. Land Use Policy:

As in North America, there has been a greatly increased interest in recent years in Scotland in the field of land use, particularly in its multiple use aspects and there has been, as a result of this interest and other factors, increasing pressures upon forestry to accommodate itself to a variety of potential uses. The Land Use Study Group of the Department of Education and Science (1966) has reported on land use for forestry, agriculture
and the multiple use of rural land. Great Britain currently produces over half of her total requirements of food and rather less than one-tenth of her requirements of wood products by value. The lack of self-sufficiency in the products of the land emphasised the importance of care in the use of the rural areas. The Study Group concentrated on the selection of criteria to apply to various investment opportunities and an appropriate methodology.

The Group reported that the major land uses in Scotland in 1900, 1935 and 1960 were:

Major Land Uses in Scotland (1) - Millions of Acres.

<table>
<thead>
<tr>
<th>Type of Use</th>
<th>1900</th>
<th>1935</th>
<th>1960</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Agriculture</td>
<td>(14.3)</td>
<td>(15.0)</td>
<td>(16.9)</td>
</tr>
<tr>
<td>(i) Arable</td>
<td>3.5</td>
<td>3.0</td>
<td>3.4</td>
</tr>
<tr>
<td>(ii) Permanent grass</td>
<td>1.4</td>
<td>1.6</td>
<td>1.0</td>
</tr>
<tr>
<td>(iii) Rough grazing (2)</td>
<td>9.4</td>
<td>10.4</td>
<td>12.5</td>
</tr>
<tr>
<td>2. Woodland</td>
<td>0.9</td>
<td>1.1</td>
<td>1.6</td>
</tr>
<tr>
<td>3. Urban development</td>
<td>0.2</td>
<td>0.4</td>
<td>0.5</td>
</tr>
<tr>
<td>4. Other</td>
<td>3.7</td>
<td>2.6</td>
<td>0.1</td>
</tr>
<tr>
<td></td>
<td>19.1</td>
<td>19.1</td>
<td>19.1</td>
</tr>
</tbody>
</table>

(2) The nature of rough grazing was difficult to assess and the figures quoted, not very reliable. The change between 1900 and 1935 may thus not be altogether real, whilst the change between 1935 and 1960 is partly explained by the inclusion of 1 1/2 million acres of deer forests, previously recorded in the category "other".

In 1964, there were 1.2 million acres of forest in Scotland classified as high forest, coppice and coppice with standards and 0.5 million acres of scrub and felled areas, totalling 1.7 million acres. By ownership, this area consisted of 1.0 million acres of private woodland (0.55 million acres of high forest, coppice and coppice with standards and 0.45 million acres of scrub and felled areas) and 0.7 million acres of Forestry Commission woodland (0.65 million acres of high forest, coppice and coppice with standards and 0.05 million acres of scrub and felled areas).

Recent estimates of the respective contributions of forestry and agriculture to national income (gross domestic production at factor cost) showed them to be approximately 900 million pounds for agriculture and 25 million pounds for forestry, comparable to a total national income of 26,000 million pounds, in 1963.
The study group found that no complete surveys of land use capability existed. In Scotland, most of the arable areas have been classified as to their farming potential by the Department of Agriculture in a "field by field" survey and, in several of the more remote areas, surveys had been jointly undertaken with the Forestry Commission. The loss of land in Britain from agriculture to urban development (50,000 acres per annum) and to forestry for planting (60,000 acres per annum) amounted to about 0.25 percent of the land in agriculture. The benefits of forestry were given as the production of wood; the possible provision of shelter and grazing for stock; the stabilisation of water flows; the creation of recreational assets and an input of stimulation or maintenance of the local economy through the employment offered. The Forestry Commission was paying more attention to increasing the beauty of the landscape in the course of planting, by employing the advice of a leading consultant in the landscaping field.

Over the decade 1964-73, the Commission expected to plant a further 450,000 acres concentrated in upland areas where population was declining and where expansion of forestry could bring considerable social and employment benefits. The primary objective, however, was to produce wood for industry with due regard to social, aesthetic and
recreational considerations. The study group also found that, whilst grants and tax allowances provided substantial financial incentives to private owners, to plant and manage wood, the long period from investment to return and a general lack of forest tradition made the activity rather unattractive to most farmers and to many estate owners. New planting on private land had proceeded at a rate of between 15,000 and 20,000 acres per year, in years just prior to 1966. The private forestry interests maintained that, in National Parks and areas of amenity interest, forest planting was sometimes discouraged by the application of the very schemes set up to encourage it. On these areas, the Forestry Commission referred applications under the Dedication Scheme to the planning authorities, who tended to resist the planting or to insist upon conditions making the project less economic. The difficulties stemmed from an unyielding resistance to change on the part of those interested in the preservation of amenity and scenic beauty, according to their individual tastes.

The study group emphasised that the expansion of forestry for the production of wood in Great Britain, in order to diversify industry and to reduce dependence on overseas supplies had an effect, but a relatively small one, on agricultural output. The upland sites favoured by foresters accounted for some 14 million acres of the land
surface of Britain and it was assumed that their contribu-
tion to agricultural output was about 4 percent. Other
uses - water, recreation, amenity and scientific interest -
were in a position which needed better co-ordination be-
tween the many agencies involved.* In many cases, the
co-ordination might best be achieved on a regional basis.
A deterrent to co-ordination was the difficulty of finding
a satisfactory classification of forest land. In connec-
tion with a land-use classification, Langdale-Brown** of
the Department of Forest and Natural Resources,
University of Edinburhgh, has proposed a physical app-
roach to land-use classification to the Government.
The sites would be mapped, based on existing information,
and classified as to the use(s) and production(s) which
they can achieve. Productivity depends on management as
well as site and the economic analyses of the site would be
related to different types of management. e.g. intensive

* Amongth these agencies are the Forestry Commission, the
National Trust, the Nature Conservancy, the National Parks
Commission and, in Scotland, the Highland and Islands Dev-
velopment Board, the Red Deer Commission and the Scottish
Woodland Owners' Association.

** Interview of the author with Dr. Langdale-Brown, Depart-
ment of Forestry and Natural Resources, University of
and extensive management in forestry. "Consequent profits" (i.e. potential profits following the crop raising process should possibly be considered as well.)

The study group stated that a meaningful comparison of the profitability of alternate activities having widely differing production cycles (such as agriculture and forestry) could only be made by calculating the present worth of the respective activities and determining their nett discounted revenues. In a series of demonstration calculations, it had been found that some results were extremely sensitive to even small changes in costs and prices. When this recommended methodology was applied to specific prices it was found that, on the extensively farmed marginal areas, agriculture earned a higher financial return to the Nation and to the private owner than did forestry unless the discount rate (ignoring the effect of possible inflations) was set as low as 3 - 4 percent. On better quality farm land, the profitability of agriculture exceeded that of forestry at a discount rate as low as 3 percent. British agriculture is, however, subsidised and the study group found it to be impossible to assess the effect of the removal of grants and subsidies on the pattern and structure and hence on market prices.* It was

*This difficulty, coupled with the known difficulties of forecasting forestry receipts, particularly those toward the end of the rotation must make the comparison of nett discounted revenue as a means of determining between alternate land uses far from definitive and, at best, a guide.
also evident that any conclusions reached by an economic comparison might be considerably modified by non-economic considerations. In such instances, it was possible to assess the real cost by calculating the income lost from following an alternate activity from that suggested by financial considerations alone. The use to which land will be put would depend upon the objectives to be achieved and these might be different in the case of the private owner and the State, although decisions of the former could be influenced by actions of the latter. One of the national objectives was the creation and maintenance of employment. The decrease in rural employment* had long caused concern but had not created a problem as great as had once been expected. Nevertheless, the employment situation was very difficult to assess. Apart from employment opportunity, the diversification of employment provided by forestry projects might, in itself, help to stem the flow of labour from the countryside and might improve communications, thereby facilitating tourism and other developments.

The study group found that co-ordination of the various land-using interests had been lacking and that change in land-use had been hampered by having most rural land under agriculture, with any competitive activity * and the movement of rural populations to urban areas, including the de-population of the Scottish Highlands.
being required to substantiate its claims. Claims for the integration of activities such as recreation and tourism had frequently been complicated by a lack of mutual understanding between urban and rural populations. A further complication had appeared with the increase of owner-occupiers, a process in which the influence of the large estate owners in co-ordination of land use was being lost. The study group claimed that land-use problems were of a local, rather than a national basis, and this indicated the need for rural development authorities based on regions, with powers and finance to implement a de-centralised national policy and to formulate regional plans which would be subject to central approval. The functions of such an authority should include the purchase of land, as it came on the market, for amalgamation with other units and resale as economic holdings. On economic grounds, much re-organisation of land was necessary in agriculturally marginal areas but, in order to maintain the community, there might be a need for some small farms in these areas, sustained by additional employment (from countryside, rather than industrial projects) outside agriculture.

The study group recommended that more work should be done on important environmental influences and the intrinsic and technical production potential of land in general. There was a need for more precise information on
the likely national, home-grown requirements of food and timber. Further consideration should be given to encouraging private woodland owners to play an increasing part in the rehabilitation of cut-over and derelict woodland and in the expansion of the country's forest estate. A re-examination should be made of the possibilities of additional uses of water-gathering grounds, particularly for forestry or agriculture. More information was needed on amenity and recreational requirements in the countryside, how these requirements should be met and the economic and social implications of meeting them. More scientific study was needed of the effect of technical advances on the ecosystems in the high production lowland areas, in addition to that already being obtained in the semi-natural plant and animal communities in areas of low agricultural potential. Further study of rural depopulation and the effect of concentration of rural populations in the towns and larger villages under the existing circumstances was also needed. More urgent consideration should be given to problems of farm structure, ownership and tenure on a regional basis. Bodies such as Regional Development Authorities should be created and a research unit* should be established to identify and investigate problems in the

* As recommended by the "Slater Committee", set up in 1961 by the Advisory Council on Scientific Policy to examine the implications of establishing a Natural Resources Research Council.
natural resources and multiple land use field.

Mathur (Mathur, R.S. 1967. Ecological and economic considerations in land use planning. M.Sc. Thesis. Edinburgh University) has also discussed land use planning and has dealt with the co-ordinate roles of economic and ecological considerations in arriving at a classification of land capability. He demonstrated the need for an integrated economic and ecological approach employing quantitative and objective methods of analysis. Mathur attempted to evolve a suitable technique, combining the physical capacity of the land with its evaluations in economic terms. The methodology consisted of finding out the economic significance of environmental variations by means of statistical tests and was employed in relation to a specific area near Selkirk, in the southern Uplands of Scotland. Mathur concluded that it was practicable to integrate environmental and economic factors in the classification of land capability by using an analytical method. Of particular interest to this thesis, is Mathur's description of the comprehensive land classification system of Britain as a practical physical classification following the American approach, whereas that of Canada had a more theoretical approach and placed emphasis on the detailed evaluation of numerous environmental factors. It was evident that the comprehensive methods would give more
detailed and acceptable results but, even so the infor-
mation provided by them seemed to be inadequate for land-
use planning work, because of their subjective nature and
qualitative assessments of productive capacity. The need
was, Mathur felt, for a more quantitative and mathematical
approach giving certain concrete values of land capability.

Edwards (1963a) has pointed out that pressure of
population makes the reorganisation of the use of all land
in Britain necessary, including its use for forests. The
classical pattern of forestry, founded on the management of
natural vegetation associations cannot be applied to
British forestry, where the forests have been destroyed
or modified and the soils impoverished by leaching, erosion
and human usage. When the Forestry Commission had been
formed in 1919, there was little evidence available on
which to fix limits of suitability of land for planting.

Research soon showed that alteration of the im-
mediate environment of the tree by drainage, cultivation
and the use of phosphates facilitated the establishment
of the crop and that many exotic species were easier to
establish and grew faster than did native species. Thus
two concepts of marginality became recognised - i.e. the
limit at which trees can be established by simple, tra-
ditional methods. The evidence that the early produc-
tivity of the exotic crops would be maintained was, how-
ever, scanty since the basic limiting factors of climate, soil and species remained to be thoroughly understood. In addition, the forest must be considered economically submarginal if the balance between habitat, a healthy growing crop and marketable products could only be maintained at disproportionate expense. Edwards held that the use of artificial methods in the creation of forests could only be successful if the safeguards of the natural forest (which, in Britain, have been irretrievably lost) were to be replaced by artificial methods of control founded on a precise knowledge of what was happening, what should be happening and the degree of divergence of these two courses. More research, therefore, was necessary into habitat, climate and soil development.

d. Forest Protection Policy:

The greatest damage to forests in Scotland is caused by gales and the subject will be dealt with later in this review.

Forest fires, whilst by no means the problem that they are in British Columbia do occur to a noticeable extent and protection measures including fire lookouts, fire breaks, mechanical equipment and birch beaters, as well as arrangements with the national fire brigade organisation to fight fires. The following fire damage has been reported by the Forestry Commission (1965),
(1966) and (1967).

### Fires in Scottish Forestry Commission Forests

#### 1964 - 1966

<table>
<thead>
<tr>
<th>Year</th>
<th>Number of fires</th>
<th>Area burned (acres)</th>
<th>Value of damage (pounds sterling)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1964</td>
<td>187</td>
<td>26</td>
<td>4,429</td>
</tr>
<tr>
<td>1965</td>
<td>101</td>
<td>117</td>
<td>13,417</td>
</tr>
<tr>
<td>1966</td>
<td>71</td>
<td>140</td>
<td>20,015</td>
</tr>
</tbody>
</table>

The causes of these fires were given as:

#### Causes of Fires in Scottish Forestry Commission Forests

<table>
<thead>
<tr>
<th>Cause</th>
<th>1964</th>
<th>1965</th>
<th>1966</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total</td>
<td>187</td>
<td>101</td>
<td>71</td>
</tr>
<tr>
<td>Railways</td>
<td>100</td>
<td>32</td>
<td>2</td>
</tr>
<tr>
<td>Adjoining land</td>
<td>39</td>
<td>34</td>
<td>6</td>
</tr>
<tr>
<td>Public</td>
<td>23</td>
<td>15</td>
<td>17</td>
</tr>
<tr>
<td>Commission employees</td>
<td>2</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>Incendiarism</td>
<td>3</td>
<td>4</td>
<td>6</td>
</tr>
<tr>
<td>Miscellaneous</td>
<td>6</td>
<td>1</td>
<td>3</td>
</tr>
<tr>
<td>Unknown</td>
<td>14</td>
<td>13</td>
<td>35</td>
</tr>
</tbody>
</table>
The subject of pathological fungi is dealt with later in this review.

e. General Policy:

In the summarised forest history of Scotland given previously, the important changes in forest policy which occurred following the Second World War and coincident with the effects of the development of nuclear weapons into a factor of strategic importance, have been mentioned. The British Commonwealth Conference (1962) has reported the Forestry Commission's statement of summarised policy aims for State forests, to give effect to national forest policy as determined by the Forestry Acts and a policy review of 1958, as follows:

(1) To achieve an orderly expansion of timber production by extending the areas of forest at a steady rate by means of new planting and by managing all Forestry Commission forests in accordance the principles of sustained yield.

(2) To manage the estate as a commercial enterprise and, within the limits set by the other policy objectives, to earn the highest possible return on the capital invested.

(3) To give attention to the aesthetic and protective, as well as the productive role of the forest.

(4) To provide employment in rural areas, especially
where the need is greatest, and to build up and maintain a thriving body of forest workers and their families.

(5) To foster sociological and industrial development ancillary to forestry.

(6) To pay due regard to recreation, sporting interest, fauna and flora. There is also extant, a statement of Forestry Commission objective made in connection with management plans. However it is considered to be more convenient and appropriate to deal with these objectives later, when discussing management plans.

Beresford-Peirse (1963) commented upon the change, indicated in the foregoing policy statement, from the use of forests as a simple defence measure to the pursuit of efficient and cheap forestry so as to compete with world prices and earn a proper return on the money invested. His remarks on the potential profitability of forestry in Britain are in contrast to the views expressed by Mutch (1967) which have been mentioned above. Arguing that, with Britain's small land area in relation to population, the most profitable crops should be grown, Beresford-Peirse felt that, on the average, with the general land quality that the Forest Commission planted, the investment could earn about 5 percent at compound interest. By adding "forest influences" - recreation, the social function of providing employment and the protective
function of forests - the forest programme could be justified, socially and economically, as a sound investment. The main foundation of the enterprise must be, however, the production of an essential raw material for industry. Britain's wood imports were costing 450 million pounds sterling per annum and home-grown wood supplies only amounted to 8 percent of the country's total needs. The British growth rate for spruce was two or three times as great as that which occurred in Scandinavia. There was a wide choice of exotic species that grew well and produced wood of a quality satisfactory for many end uses. With these factors, Britain ought to be able to pick and choose the segments of the enormous home market which home-grown wood would supply by offering an acceptable product and under-selling the imported product. The pitwood, pulp and saw-timber markets all offered good potential in this direction. If the country were to provide about one-third of its wood requirements in the year 2,000 A.D. it would mean that the country would require about 7 million acres of managed and productive woodlands - about 12½ percent of Great Britain's land area and a realistic objective. Whatever the target, a steady programme of forest expansion should occur.

Quite apart from the under-selling of imported, competitive products, Beresford-Peirse held that British
foresters must take the fullest advantage of the various forest sites by practising the highest level of silviculture, keeping in mind the end-products to be grown. Production could be substantially cheapened by modern methods of management, by rationalising of logging processes; by mechanisation, by including good labour relations leading to high output and high earnings and by using work study aids to the full. The planning of production in relation to new or existing markets should be placed on a regional, rather than a national or local basis in the light of what was silviculturally possible. On this basis, forest management must conform to marketing plans. The remarks of Beresford-Peirse have special significance in view of his position of Director-General of the Forestry Commission and, in many ways, they are more revealing of intent than is the Forestry Commission formal statement of policy outlined previously. The remarks were addressed to a meeting. In the discussion which followed their delivery, the opinion was expressed and with relevance to the report of Openshaw (1967) as outlined above, that British entry into the European Economic Community would probably not alter the anticipated heavy imports from the European Free Trade Association countries of pulp and
chip-board under promised lower tariffs*. The discussion also brought out the opinion that the 5 percent compound interest to be derived, in Beresford-Peirse's view, from Forestry Commission operations, ignored inflationary trends which applied to all investments in physical assets and which had been calculated as 3½ percent flat rate, plus 1½ percent for a general rise in standing timber values relative to the general price level.

The forest policy of Great Britain, as Beresford-Peirse mentioned indirectly, has taken cognisance of the future demands for wood. Holtam (1964) has estimated the British industrial requirements for home-grown wood as compared to potential production, for the period 1965-75. It was anticipated that the potential production of private woodlands would exceed the Forestry Commission's potential until 1970, when they would be equal at about 33 M. M. H. F. (42 M. M. cu. ft.) each - a total of

* The author was unable to establish, in a satisfactory way, how binding the alleged promise of lower tariffs was. Obviously, the Free Trade Association countries referred to are the Scandinavian countries and, whilst these have considered the "promises" to be binding, the British Government, judging from current press reports, have a qualified view.
66 M.M.H.F. (84 M.M. cu. ft.). By 1980, the Commission is expected to produce 72 M.M.H.F. (92 M.M. cu. ft.), whereas private woodlands may then have a potential production of about 43 M.M. H.F. (55 M.M. cu. ft.). Between 1965 and 1980, the total potential production of Great Britain was expected to more than double - from 52 M.M. H.F. (66 M.M. cu. ft.) to about 115 M.M. H.F. (147 M.M. cu. ft.) in 15 years. Spruces will account for about one-half of the forecast Forestry Commission potential and for about one-fifth of private woodlands potential.

Small roundwood* production was expected to account for most of the total potential production increase, by rising from 34.5 M.M. H.F. (44 M.M. cu. ft.) in 1965 to 76 M.M. H.F. (97 M.M. cu. ft.) in 1980. Of these amounts, Forestry Commission small, roundwood potential was expected to increase nearly threefold, from 18.6 M.M. H.F. (24 M.M. cu. ft.), of which 44 percent was spruce, in 1965, to 51.1 M.M. H.F. (65 M.M. cu. ft.), of which 55 percent will

*The total potential roundwood production was estimated to 3 inches top diameter over bark. A potential sawlog was estimated to have a minimum top diameter of 8 inches over bark, a minimum length of ten feet and no other requirements. The term "small roundwood" as employed by Holtam was the total potential production less the potential saw-log production.
be spruce, in 1980.

The total potential production of softwood sawlogs was expected to increase from 17.4 M.M. H.F. (22 M.M. cu. ft.) in 1965 to 38.8 M.M. H.F. (49 M.M. cu. ft.) in 1980. Both of these figures represent about one-third of the total potential softwood production in each of the respective years. The proportion of spruce in the potential sawlog production is expected to increase from just below 25 percent in 1956, to more than 33 percent in 1980.

The total industrial requirements (excluding sawmills) for small softwood roundwood were estimated by Holtam, in M.M. H.F. overbark and are converted into cubic feet as follows:

Total Industrial Requirements for Small Softwood Roundwood M.M. cu. ft.

<table>
<thead>
<tr>
<th></th>
<th>Forest Year 1965</th>
<th>Forest Year 1975</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Total</td>
<td>of which Spruce</td>
</tr>
<tr>
<td>Coal Mines</td>
<td>21.4</td>
<td>6.4</td>
</tr>
<tr>
<td>Pulp</td>
<td>13.8</td>
<td>11.6</td>
</tr>
<tr>
<td>Wood Chipboard</td>
<td>4.3</td>
<td>1.0</td>
</tr>
<tr>
<td>Fibreboard</td>
<td>3.1</td>
<td>0.1</td>
</tr>
<tr>
<td>Woodwool</td>
<td>0.5</td>
<td>0.3</td>
</tr>
<tr>
<td>Fencing</td>
<td>6.4</td>
<td>-</td>
</tr>
<tr>
<td><strong>Totals</strong></td>
<td><strong>49.5</strong></td>
<td><strong>19.4</strong></td>
</tr>
</tbody>
</table>
Holtam derived certain implications from these estimates. Existing industries which were based on home-grown wood and industries which would like to change from imported to home-grown wood, together with planned new industries, would share between them such a relatively high potential for expansion and increased use of home-grown wood that it would be most difficult to plan the development of any additional major new industry based solely on home-grown supplies and which was to come into production before about 1982. It also appeared to be likely that increased competition for sawlogs by pulp mills would develop. Imports would continue to contribute such a big proportion of Great Britain's needs for wood and wood products that prices for home-grown wood were likely to continue to follow imported prices. Industries using, or planning to use, home-grown wood could, in most cases, change to imported wood if it were cheaper. If the British mines attracted and utilised home-grown supplies, it appeared that imports of pitwood could be of little significance by 1970. Until 1977-78, private growers would control most of the potential softwood supplies and they should organise a steady flow of logs to the market, if softwood sawmilling were to develop. Holtam also dealt with hardwoods but, since they are of relatively minor economic significance in Scotland, they are not discussed.
f. Marketing Policy:

With the rapidly increasing volumes of wood which are becoming available in Scotland for utilisation, the question of the marketing of timber and timber products has become of vital importance.

The well-known "Watson Committee" from 1954 to 1956, considered and reported upon measures which might be taken within the home timber industry to improve arrangements for marketing produce from privately owned woodlands (Forestry Commission (1956)). It noted that home-grown supplies of over-mature timber would tend to diminish and those of small timber (thinnings) to increase, with two main consequences. The pre-war home-grown timber trade would become smaller in scale and, secondly, its re-growth would be in a new direction calling for initiative, new methods and new plant. It would be an important function of the Forestry Commission to foster new industries. There would, also, clearly have to be better co-ordination between the standing timber owners (both State and private) and timber traders.

The ability of home-grown timber to displace foreign timber would depend, more than anything else, upon
achieving a standard of preparation and service equal to that of the imported article. It was noted that British public bodies such as the Transport Commission, the National Coal Board and the Post Office made extensive use of imported timber and were strong monopoly buyers. There should be some equally strong authority watching the interest of home-grown timber to ensure that it was not ruled out from use by such buyers, by prejudice as distinct from quality. Good quality timber could be grown in Britain, although not all of the standing timber in the woods was of this quality. Also, little was known about the quality, in Britain, of some of the more recently introduced coniferous species planted during the previous 30 years or so. There was room, the Committee felt, for an extension of scientific knowledge and for greater commercial awareness in matters of silviculture and woodland management. Also, it would be important to accompany an expansion of saw-milling capacity with the adoption of up-to-date techniques and high consumer service standards. Lumber grading rules should be employed to facilitate the sale of home timber in markets served by imported timber and to remove the common practice of selling "mill-run".

The British Home Timber Industry is composed, in the main, of three interests and these are the private
growers (landowners), the home timber trade (timber merchants) and the State (Forestry Commission). The former two, although largely separate in activity, are complementary in the business of timber production and conversion. The Forestry Commission grows timber, is responsible for the fulfilment of the Government's forest policy and for promoting the interests of the industry as a whole. The Watson Committee examined these interests in some detail and its comments are pertinent to this thesis.

(1) Private Woodland Management:

Most of the mature and semi-mature timber in Britain is in the hands of private landowners, mostly as part of composite estates where agriculture and other pursuits are also practiced and frequently predominate. The areas in individual ownership range from a few to several thousands of acres with a large proportion being less than 250 acres. The Watson Committee stated that the attitude of owners toward forestry varied from keen professional interest to apathy.

The Committee was primarily concerned with woodlands managed, or capable of being managed on a commercial basis and with the expectation of owners who were assisting the Government's forest policy that their woodlands would be an asset and not a liability to the overall
finances of the estate. On a large estate, it was usual to employ a qualified agent or factor for management but very few private landowners employed professional foresters (University trained), rather they relied on a head forester (technician training level) and a permanent labour force. In other cases, because of cost or choice, an owner may retain or call on the services of a professional firm of land agents for advice and assistance in silvicultural and management problems. There was an increasing number of forestry consulting firms who would consult or perform operations such as fencing, draining, replanting and thinning.

The private woodland owner, in the Committee's view was an individualist with little contact with other woodland owners. As a group, the owners lacked a close degree of co-operation in management problems and sales promotion and co-ordination. A comparatively slow development of co-operative forestry societies had occurred. The Co-operative Forestry Society (Scotland) Ltd. had been founded in 1911 and had a membership (in 1956) of about 700. Covering all of Scotland, its degree of management varied from region to region and the woodlands owned by its members totalled more than 250,000 acres or approximately a quarter of the total area of privately owned woodland in Scotland. Other Associations covered parts of England and
Wales. The Societies provided members with assistance in management and marketing. The Forestry Commission (1948) had recalled their consistent view that there was great scope for the development of co-operative schemes in private forestry and they had actually given some grants, loans and guarantees to foster them. However, it was clear to the Watson Committee that few of the existing societies were in a position to extend the scope of their activities unless they received more whole-hearted support from woodland owners, particularly the larger ones.

There was a number of organisations representing woodland owners. For Scottish landowners, these included the Scottish Landowners' Federation and (by virtue of its other interests) the National Farmers' Union. The Scottish Landowners' Federation took a special interest in forestry even though it was only one of their many activities. The professional land agency bodies shared with it an active concern in private forestry, because many of their members were associated with woodland management and sales of woodland produce. The technical and professional aspects of forestry were (and are) represented in Scotland by the Royal Scottish Forestry Society and the Society of Foresters of Great Britain. Membership of the two societies includes practising woodland owners and any persons with
knowledge of, or interest in, forestry. The United Kingdom Forestry Committee was formed in 1948, with the launching of the government post-war forestry programme to provide a single voice for woodland owners as a whole. It included members elected by the Country Landowners' Association, the Scottish Landowners' Federation and the two Royal Forestry Societies as well as members with experience of land agency, forest economics and the timber trade. It was primarily a co-ordinating committee, meeting as occasion demanded and it had a Scottish sub-committee. However, it had no professional staff and did not engage directly in promoting the affairs of individual woodland owners.

(2) \textbf{The Home Timber Trade:}

The British Home Trade consisted of several hundred merchants who buy home-grown timber and converted it for sale to industrial and other consumers. The Scottish Association was separate from, but maintained close liaison with, the Association for England and Wales. These Associations presented trade views to Government Departments, including the Forestry Commission and supplied trade representation to the various consultative bodies serving the home timber industry. The Home Timber Merchants Association of Scotland was not a trading concern and its
116 ordinary members handled about 90 percent of the total amount of timber converted by the trade in Scotland. There were associate members, largely timber importers who converted home timber from time to time.

The Timber Trade Federation of the United Kingdom dealt with the much larger and more elaborately organised imported timber trade. Its membership chiefly consisted of timber importers, agents and brokers but also included non-importing timber merchants dealing in imported timber. Each group had its own Section or Association linked into the Federation. The Timber Development Association which was largely financed by the Timber Trade Federation to promote the use of timber generally, included some home timber merchants as members. It was concerned with both imported and home-grown timber and co-operated with the Home Timber Association.

(3) The Forestry Commission:

The Watson Committee pointed out that the Forestry Commission, apart from its other functions, had assumed responsibility in the development of new timber consuming industries and had played a leading part in the negotiations leading to the establishment of a number of valuable projects. It was able to do so because of its information on the forest resource and its geographical distribution
and, also, because it could offer substantial guarantees of supplies from its own woodlands, guarantees which the unco-ordinated private sector had been unable to provide.

(4) Consultative Machinery:

The interdependence of the three foregoing principal interests in the home timber trade has resulted in frequent consultation between them. This process was carried on, in the case of the woodland owners by the United Kingdom Forestry Committee or its constituent bodies and, in the case of the home timber trade, by the Home Timber Associations. National Committees (for England, Scotland and Wales) and Regional Advisory Committees, created under statute, worked under the authority of the Forestry Commission and were concerned with a wide variety of matters arising out of the administration of the Government's forest policy. They served, the Watson Committee noted, to safeguard the interest of the public generally. Other bodies had been set up to provide for consultation specifically on the marketing of home-grown timber and these were the National Home-Grown Timber Council, the Home-Grown Timber Advisory Committee and the Advisory Committee on Utilisation of Home-Grown Timber.

(5) The National Home-Grown Timber Council:

This Council was established from recommendations
made in 1933 and incorporated in 1937. It provided a permanent link between growers, buyers, distributors and users of home-grown timber, distributed trade information and statistics, studied economics, undertook research and promoted propaganda. Also, it negotiated, on behalf of the industry, with the Forestry Commission and others on matters affecting industry interest. The bulk of the Council's finances were provided by the Forestry Commission which undertook to provide 7,500 pounds over a period of three years subject to the other interests (mainly growers and merchants) providing a total of not less than 500 pounds annually. In its short pre-war existence it carried out various utilisation experiments and a trial census of woodlands and it made a number of recommendations to the Forestry Commission. With the outbreak of war, its activities lapsed.

(6) The Home-Grown Timber Advisory Committee:

The Forestry Commissioners set up this Committee in 1939 to represent owners, timber merchants, the British Board of Trade and the Commission itself, with a view to agreeing on arrangements, in case of war, for licencing tree felling and controlling timber prices. During the War, it was largely superceded by a number of other Committees set up by other Government Departments but it survived and acted in post-war years as a medium for the discussion
of felling licencing. In 1951, licencing was made a statutory duty of the Commissioners and the Committee was put on a statutory basis for this purpose, although it has, in fact, discussed a number of other marketing topics. The Chairman was from the Forestry Commission and the members came from the Commission, the Board of Trade, the Country Landowners' Association, the Scottish Landowners' Association, the Federated Home Timber Associations, the Home Timber Merchants' Association of Scotland and the Timber Trades Federation.

(7) The Advisory Committee on Utilisation of Home-Grown Timber:

The Committee was set up by the Forestry Commissioners, by a decision taken in 1949, to advise on measures to promote the utilisation and sale of British forest produce. The thought was to make the best use of the country's depleted stocks of timber, to advise private landowners on utilisation problems and to advise on research problems involved in marketing the increasing out-turn of thinnings from the Commission forests. The membership included representatives of the Forestry Commission, the Board of Trade, the Forest Products Research Laboratory, the Rural Industries Bureau, the Timber Development Association, the United Kingdom Forestry Committee, the Federated Home Timber Associations of England and Wales and the Home Timber Merchants' Association of Scotland. A number
of marketing and other investigations were carried out. The Watson Committee gave a simple account of the marketing process, inferring that some owners sold timber without knowing its volume and the range of prices paid in similar, or apparently similar, parcels. The Scandinavian and French pricing procedures had achieved better price stability than in Britain, to the benefit of their private owners. In the case of home-grown mining timber sold to the National Coal Board, however, national marketing procedures and stable price levels had arisen from national fixed price agreements although, in Scotland, there was no guaranteed quantity, as there was in England and Wales.

(8) Conclusions of the Watson Committee:
A major cost factor in the wood marketing process lay in transportation. The high cost of rail transport put an economic radius upon this mode of transportation. The British Transport Commission were hoping to rationalise freight charges based on "loadability" (i.e. the amount that could be loaded on a standard wagon) instead of the value of goods. However, with large scale processing plants, the Committee felt that there might be no alternative to subsidising, on a temporary basis, the carriage of surplus materials to markets outside the normal economic radius. If the transport costs continued to rise, producers in remote areas might have to be assisted on a selective basis. However, the Committee did not propose the use of
subsidies as a normal and integral feature of the marketing of home-grown timber.

The marketing policy of the Forestry Commissioners was to dispose of their timber in the round and in the most remunerative markets. However, the Commission would convert and manufacture for Government use, where no reasonable offer was forthcoming for round timber or where it appeared desirable to carry out pioneer work such as the promotion of some new form of timber utilisation or some new industry.

An important conclusion was that the produce from privately owned woodlands should be integrated with the rapidly growing output from the State woodlands and this total home-grown output integrated into the total pattern of British timber consumption. This recommendation involved a planned and regular flow of production; a fair share of the market to private owners; provision of means to absorb production surpluses; a healthy timber trade, capable of expansion; continued research effort and adequate returns to woodland owners, adequate to support the re-stocking and maintenance of their woodlands and to provide, in due course, a reasonable return on the capital represented by the woodlands. The achievement of these objectives, the Committee believed, required a strong and
effective association of private woodland owners. This was to be a Woodland Owners' Association for all of Britain.* A central consultative body was also required, representative of all the principal interests concerned in the marketing of home-grown timber. The Home-Grown Timber Advisory Committee would function in this role, after re-constitution.

MacGregor (1957) reviewed the Watson Committee's report about a year after its publication and noted some of the objections to it, by woodland owners and foresters. It appeared that there was general agreement as to the excellence of the diagnosis of the ills of the British forest industry, including forestry, but substantial dissatisfaction with some or most of the recommendations. The main criticisms seemed to be that the terms of reference were being too narrowly interpreted when British wood import policy was excluded from consideration; that the Committee were evasive when they used the lack of evidence concerning financial returns as an indication of the need within the industry, as an excuse for making no positive recommendations about price supports; that forestry compared rather badly with agriculture in the extent of fin-

*In practice, the Scottish Woodland Owners' Association was formed separately.
ancial assistance; that more should have been done to in-
spire confidence and stability, especially for the many
small woodland owners; that the proposal to add yet two
more bodies, the Woodland Owners' Association and the
Central Consultative Body, to those already existing for
forestry was unnecessary; that the organisation of what,
in effect, would be a voluntary body without power was
likely to be left to the producers themselves or to those
who were already leaders in the existing organisations and,
perhaps most surprisingly, that detailed marketing machin-
ery was not suggested. Merely to state the pre-requisites
for a sound marketing policy was scarcely a substitute for
appropriate recommendations.

Not all of the criticisms of the Watson Committee's
report were, however, adverse and a number of suggestions
and proposals had been made. Some believed that a Trans-
port Equalisation Scheme was necessary to get the utmost
use from areas capable of growing timber and others had
felt that a reduction in transport costs could be promoted
by greater co-ordination of two-way traffic and by zoning.
Arrangements for the processing and preparation of timber
and forest produce for marketing could be improved. There
was a shortage of felling and hauling contractors who
specialised in preparation for markets. Depots to process
the thinnings of an entire area might be adopted as a means of reducing handling and processing costs. Small, portable pulping or chipping units had been considered as a possibility. The introduction of standard grading rules would, in time, widen the market.

Another proposal was to set up a special committee to advise on finance on the premise that the whole system of financial assistance required overhauling and simplification. Separate organisations had been proposed for Scotland with existing societies involved in them. Thus, there should be a Scottish Woodland Owners' Association, based on the Royal Scottish Forestry Society and the Scottish Landowners' Federation. There should also be a Scottish sub-Committee of the Central Consultative body which should not, however, consist of altering the Home-Grown Timber Advisory Committee in the way proposed by the Watson Committee since this would tend to reduce the Scottish representation as well as that of the timber grower.

MacGregor felt that the main weakness in marketing home-grown timber was associated with the small scale and scattered nature of most private woodlands since this, in the absence of co-operative or organised marketing, led to irregular and insignificant output. Organised marketing
would reduce the cost of the marketing function and improve the prices received. Ways of improving general price levels, apart from any direct Government assistance would arise from improvements in quality, a closer study of consumer requirements, improved efficiency in the conversion processes and industries, development of new industries and increased bargaining strength derived from organized marketing and marketing intelligence.

The imported timber supplies greatly exceeded the home supply and, although the latter should not be unduly sheltered or inefficiency encouraged, there could be some justification in the idea that an industry in the course of rebuilding and expansion should have some form of special temporary arrangement or protection. The Joint Parliamentary Secretary to the Ministry of Agriculture had stated reasons why the Government would be prevented from restricting timber imports because of its acceptance of the General Agreement on Tariffs and Trade (G.A.T.T.). The substantial advantages accruing to Britain from G.A.T.T. could not well be sacrificed to secure immunity from foreign competition for woodland owners.

3. Forest Tenures:
   a. Forestry Commission Lands and Holdings:
      As mentioned previously, the Forestry Commission,
in 1964, owned and held 0.7 million acres of woodland in Scotland, of which 0.65 million acres was classified as high forest, coppice and coppice with standards and 0.05 million acres as scrub and felled areas. The future major increases in area of forest appear to lie in North Scotland Conservancy where considerable areas of impoverished land occur and where the prospects for use of higher economic value than forestry appear to be limited. The possibility of concentrated forest production at an economic level which promises to surpass that of the scattered, smaller forest areas of more densely inhabited regions is apparent. This is not to say, however, that all land purchased by the Commission has been designated for planting by the agricultural authorities or is otherwise suitable for planting. The Forestry Commission (1966a) has given the land use of Commission lands in North Scotland Conservancy in 1966, as:

<table>
<thead>
<tr>
<th>Land Use</th>
<th>Area</th>
</tr>
</thead>
<tbody>
<tr>
<td>Under plantations</td>
<td>203,809 ac.</td>
</tr>
<tr>
<td>To be planted</td>
<td>80,353 ac.</td>
</tr>
<tr>
<td>Agricultural and other land</td>
<td>313,356 ac.</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>597,518 ac.</strong></td>
</tr>
</tbody>
</table>

Nor are all of the forests, planted or to be planted, of large size as is demonstrated by the following Forestry Commission (1966a) figures:
Numbers and Acreages of Forestry Commission Forests in North Scotland Conservancy as at 30th of September, 1966

(Land under plantations and to be planted but excluding certain minor areas on Orkney and the Isle of Lewis)

<table>
<thead>
<tr>
<th>Size of Forest (acres)</th>
<th>Number</th>
<th>Total Acreage</th>
</tr>
</thead>
<tbody>
<tr>
<td>0-999</td>
<td>5</td>
<td>3,395</td>
</tr>
<tr>
<td>1,000-1,999</td>
<td>8</td>
<td>11,946</td>
</tr>
<tr>
<td>2,000-2,999</td>
<td>12</td>
<td>31,685</td>
</tr>
<tr>
<td>3,000-3,999</td>
<td>3</td>
<td>11,067</td>
</tr>
<tr>
<td>4,000-4,999</td>
<td>5</td>
<td>21,871</td>
</tr>
<tr>
<td>5,000-5,999</td>
<td>5</td>
<td>27,049</td>
</tr>
<tr>
<td>6,000-6,999</td>
<td>2</td>
<td>13,816</td>
</tr>
<tr>
<td>7,000-7,999</td>
<td>2</td>
<td>15,145</td>
</tr>
<tr>
<td>8,000-8,999</td>
<td>2</td>
<td>16,739</td>
</tr>
<tr>
<td>9,000-9,999</td>
<td>2</td>
<td>18,925</td>
</tr>
<tr>
<td>10,000-10,999</td>
<td>1</td>
<td>10,290</td>
</tr>
<tr>
<td>11,000-11,999</td>
<td>2</td>
<td>22,531</td>
</tr>
<tr>
<td>12,000-12,999</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>13,000-13,999</td>
<td>2</td>
<td>26,864</td>
</tr>
<tr>
<td>14,000-14,999</td>
<td>1</td>
<td>14,677</td>
</tr>
<tr>
<td>18,000-18,999</td>
<td>1</td>
<td>18,736</td>
</tr>
<tr>
<td>19,000-19,999</td>
<td>1</td>
<td>19,380</td>
</tr>
<tr>
<td></td>
<td>54</td>
<td>284,116</td>
</tr>
</tbody>
</table>

The broken pattern of much of the forest planting is created by the pattern of Forestry Commission land purchase which has been conducted on a basis of voluntary availability rather than by compulsion, as well as the facts that private owners are conducting planting operations in the Conservancy and that land use for forestry is restricted by agriculture and/or unsuitability for planting.
b. Dedicated and Approved Woodlands:

As has been mentioned previously, the Forestry Commission provides incentive for private forestry under its Dedicated and Approved Woodlands Scheme. These Schemes, along with such matters as Small Woods Planting Grants; the purchase, lease or feu of woodlands by the Commission and Tree Preservation Orders are briefly described in the Annexures hereto.

The Forestry Commission (1965a; 1966b; 1967a) has reported on progress with the schemes, as follows:

**Dedication Scheme:**

<table>
<thead>
<tr>
<th></th>
<th>Great Britain</th>
<th></th>
<th>Scotland</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Number</td>
<td>Area (acres)</td>
<td>Number</td>
<td>Area (acres)</td>
</tr>
<tr>
<td>Schemes completed</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>30 Sep./64</td>
<td>2,591</td>
<td>791,384</td>
<td>571</td>
<td>317,384</td>
</tr>
<tr>
<td>30 Sep./65</td>
<td>2,719</td>
<td>826,811</td>
<td>603</td>
<td>335,836</td>
</tr>
<tr>
<td>30 Sep./66</td>
<td>2,831</td>
<td>849,829</td>
<td>635</td>
<td>346,134</td>
</tr>
<tr>
<td>Approved or in preparation</td>
<td>176</td>
<td>60,668</td>
<td>64</td>
<td>41,561</td>
</tr>
<tr>
<td>30 Sep./66</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Approved Woodlands Scheme:

<table>
<thead>
<tr>
<th></th>
<th>Great Britain</th>
<th></th>
<th>Scotland</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Number Area (acres)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Schemes completed</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>30 Sep./64</td>
<td>667</td>
<td>161,417</td>
<td>91</td>
<td>35,991</td>
</tr>
<tr>
<td>Schemes completed</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>30 Sep./65</td>
<td>692</td>
<td>163,508</td>
<td>95</td>
<td>37,078</td>
</tr>
<tr>
<td>Schemes completed</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>30 Sep./66</td>
<td>733</td>
<td>167,493</td>
<td>99</td>
<td>36,425</td>
</tr>
<tr>
<td>Approved or in preparation</td>
<td>5</td>
<td>390</td>
<td>1</td>
<td>38</td>
</tr>
</tbody>
</table>

Martin (1963) has attempted to assess the profitability of a private forestry enterprise in south-east Scotland over the 12-year period from 1949 to 1961. The woods had not previously been under regular managements and, because of wartime fellings, were only 60 percent stocked in 1949. The management aimed at restocking and rehabilitation with minimum cash investment and with Forestry Commission Grants under Schedule D. Under the conditions described by Martin, the profit was equivalent to a yield of 6.4 percent on an average book value of the land plus a growing stock of 70,000 pounds. These figures and others gave a reasonably accurate account of the financial results, although Martin considered that they
underestimated the true value of the woodlands to the estate economy.

4. Forest Management:
   a. Reforestation Programmes and Development in Scotland

   During the decade from 1957 to 1966 the Forestry Commission (1967b) planted 570,000 trees in Great Britain, of which 302,000 were planted in Scotland all at fairly equal annual rates. Of the major species planted, the Forestry Commission (1965b; 1966c; 1967c) during the years 1964, 1965 and 1966 markedly reduced the use of Scots pine in Great Britain, Scotland and North Scotland Conservancy. The use of lodgepole pine and Sitka spruce increased markedly.

   The Forestry Commission (1965c; 1966d; 1967d) has also reported on the areas planted by private owners in Great Britain and Scotland, as follows:
## Estimated Areas Planted by Private Owners in Great Britain and Scotland, During the Forest Years 1964 - 1966

<table>
<thead>
<tr>
<th></th>
<th>1964</th>
<th>1965</th>
<th>1966</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>G.B.</td>
<td>Scotland</td>
<td>G.B.</td>
</tr>
<tr>
<td>Total</td>
<td>33,771</td>
<td>14,485</td>
<td>32,944</td>
</tr>
<tr>
<td>In dedicated woodlands</td>
<td>23,765</td>
<td>10,815</td>
<td>23,440</td>
</tr>
<tr>
<td>In approved woodlands</td>
<td>4,578</td>
<td>1,676</td>
<td>3,166</td>
</tr>
<tr>
<td>With small woods planting grants</td>
<td>3,711</td>
<td>1,244</td>
<td>4,595</td>
</tr>
<tr>
<td>Without grants (estimated)</td>
<td>1,717</td>
<td>750</td>
<td>1,743</td>
</tr>
</tbody>
</table>
The almost complete dependence of Scottish forestry upon planting has been noted. McNeill (1962) has discussed the problems of obtaining natural regeneration in Scotland. The knowledge of the subject was meagre and only the most difficult and complicated problem, that of the recent lack of natural regeneration of Scots pine, a species that regenerated copiously 150 or 200 years ago, had been investigated. Other problems had not been investigated in depth, even though the more recently introduced exotics, *Tsuga heterophylla*, *Chamaecyparis Lawsoniana*, *Picea sitchensis*, *Abies grandis* and *Pinus contorta* were apparently able to regenerate with markedly greater success. McNeill simplified natural regeneration problems into four main groups in a chain of events and these groups were seed production; supply and disposal; seed survival; germination and seedling supply and dispersal. He attached great importance, from his experience, to the role played by ground and surface vegetation, as it affected the germination and later stages of growth. His exploratory investigations with Scots pine in Scotland had suggested that *Vaccinium myrtillus* was a more successful competitor than *Calluna Vulgaris* and that *Deschampsia flexuosa* was more successful than either. He suggested that more research was needed into the subject of natural regeneration, particularly into plant competition and seed losses between seed fall and
germination, based on a record of investigation into known cases of success or failure.

Neustein (1962) has briefly considered the artificial regeneration of second rotation crops and questioned if a more productive species could be used or whether the original species would grow better or worse during the second rotation. In the successful Sitka spruce areas, it was clear that the species, in its second rotation, continued to outgrow all other species with the exception of *Tsuga heterophylla* but that other species of doubtful value as a first crop, showed some promise e.g. *Abies grandis, Abies nobilis, Pseudotsuga taxifolia* and *Chamaecyparis Lawsoniana*. Also, sycamore (*Acer pseudo-platanus* L.) and oak (*Quercus* spp.) had started reasonably. It appeared that, if diversification of species were needed, these would be the species where there might not be too great a loss of increment and which would lead to better stand stability due to deeper rooting or an improved microflora and fauna, resulting in better soil conditions. On the upland heaths, where the first generation was possibly more of a pioneer, the choice of second rotation species was more open. The transplants required for regeneration work must be considerably larger to overcome suppression by weeds, than for afforestation where site preparation dealt
with this problem. On the question of site preparation, the ploughing of wet sites for drainage and turf planting, if necessary for regeneration, would need new designs of equipment, particularly to overcome damage from stumps. Ploughing on drier sites for water conservation was easier when employing wheeled tractors.

The third point discussed by Neustein (1962), dealt with the desirable size of felling area in relation to windthrow, the growth of the second crop and its economic management. The Border forests, comprising the largest (130,000) acres) area of even-aged conifers in Great Britain were of a precarious stability to wind, with shallow peat overlying compacted boulder clay and supporting shallow-rooted spruces. There was controversy as to the size of coupes in this area, particularly on the question of marginal stability following small (5 acre) fellings. Much more experimental evidence would be necessary to solve the questions of felling areas and their shapes.

Neustein noted that the roe deer population of the British forests was increasing and their browsing habits posed a major hazard in replanting. The first possible solution would be to reduce the deer population below the critical level, employing selective control by trappers,
to densities suitable for British conditions. The simplest alternative was the exclusion of deer from the forest by fencing, although standard deer fencing was too expensive for all but the largest areas. The use of brashings and lop and top, by various techniques, to provide barriers to deer movement, was ineffective. Tar-treated nylon and polyethylene netting was being tested for its effective life and other factors, and electric fencing had been successful on an experimental scale.

Forest drainage is an essential part of most afforestation operations in Britain and Henman (1963) has suggested five chief factors in achieving it, viz. the recognition of the features of an ill-drained forest soil and a precise understanding of the objectives of draining it; the examination of the site to determine the factors causing its condition; the devising of a system to correct these factors with the minimum intensity of drainage; the need to allow for a road system and similar capital works and the needs of timber extraction. Noting that the plough is by far the most efficient means of drainage yet devised* since its continuous-action principle easily offsets the capital and overhead costs and gives it a clear advantage over hand work, the "scoop and dump" principle, and the intermediate rotary principles employing bucket-chains, disks, flails, screens or similar processes.
Henman, nevertheless, emphasised its severe limitation in achieving depth of drainage exceeding 20 inches in heavy mineral soils, although in peat profiles greater depths are easily reached. New, deep drainage ploughs were being developed and, on stump covered ground, where the plough was again limited, the hydraulically operated, tractor-mounted digger had a tremendous potential. Henman has stated his view that deeper drains were generally needed and that the present, large amounts of money expended on new forest drains and maintenance should be increased to achieve this. The main benefits to be anticipated probably did not lie in increased growth rates but in the reduction or postponement of windthrow, when premature realisation of the crop reduced profitability.

b. **Upland Heaths and Peats:**

   (1) **The Upland Heaths:**

   The Upland Heaths and Peats are of great importance to British forestry and are likely to become more so as extension of the afforested areas continues. Yeatman (1955) has investigated the rooting of coniferous trees on upland heaths at two forests in Yorkshire and three in Scotland. He employed the definition of an Upland Heath as: "A callunetum or shallow peat in which the roots of the vascular plants penetrate into the sub-peat layer. The peat is commonly two to four and never greater than
twelve inches thick." Great areas of upland heath were available for afforestation in Great Britain, particularly in the north-east, provided that an economic means of establishing successful tree growth on them was available. Yeatman's report was mostly concerned with the establishment of trees by cultivation and the application of fertilisers on the poorer types of heath, in experiments between 1928 and 1943. The principal conifers were investigated.

The climate of the upland heaths is cool, temperate oceanic, with an even distribution of annual rainfall of between twenty-three and forty inches. The density of the Calluna and the type and density of associated species varies with the quality of the heath. The soils are commonly mature, shallow podzols developed on sandy parent material, with the attendant formation in the poorer heaths of a hard, impervious iron pan at depths ranging from six to twenty-four inches. The better heaths, however, overlie a wide range of soil types, some showing little evidence of podzolisation.

The outstanding finding of the study was that roots will only freely exploit soil which is sufficiently porous and well-aerated. In the natural upland heath, the thin surface peat (Ao) prevents aeration of the soil
beneath it, remaining waterlogged for much of the year. The mature podzol soil profiles are markedly layered in horizons differing in texture, compaction and level of fertility. Notably and commonly, the eluvial horizon (A2) is a sterile, compact, leached sand. Any disturbance of the surface horizons alleviates the limiting physical conditions and encourages free root development within the disturbed soil and illuvial horizons beyond. Thus, partial line cultivation induces a high degree of orientation of the primary roots with the direction of ploughing, which in turn endangers the long-term stability of the stand.

Undisturbed hardpan, between 6 and 10 inches in depth and which occurs between the eluvial (A) and illuvial (B) horizons, forms a significant barrier to descending roots. This lends a shallow, storied character to the root system. Undisturbed hardpan, lying between 14 and 24 inches depth and which coincides with the top of a very compact subsoil (parent material), forms a complete barrier to root penetration, as does the subsoil itself. Such a pan and compact subsoil induce a deeper, storied character in the form of the root system with no roots beyond the horizontal flattening at the impenetrable horizon.

The response in vigour of the tree root system to the application of phosphatic fertiliser varied inversely
with the degree of cultivation and, also, inversely with the inherent level of fertility of the site in question. In the case of Japanese larch, the response of the root systems and, consequently, the growth rate to the degree of cultivation was significant. In all cases, healthy well-grown trees had root systems penetrating to some depth by primary, descending roots and by sinkers from the lateral roots, which themselves were not necessarily shallow in the soil. A significant response to fertilisers was obtained only on the poorest sites.

On all sites and soil conditions, Sitka spruce checked severely when growing in connection with Calluna but the response to phosphate application was noticeably greater than for the other species studied. The root system of healthy Sitka spruce extended to some depth by sinkers from lateral roots lying shallow within the soil.

The pines proved to be the best colonisers of poor heathland conditions, with lodgepole pine showing more vigorous root development than either Scots or Corsican pines. The healthy root system was characterised by a pronounced tap root, together with vigorous lateral and sinker roots and a significant response to phosphate was observed only on the poorest site. The greatest response
to the intensity of cultivation of moderately poor sites was reflected in the forms of the root systems. They lost the shallow, storied character in the more complete and deeper cultivations which proved to be the more wind-firm.

As a result of the study, Yeatman proposed that a pre-requisite of any method of cultivation was an adequate burn of the natural callunetum. A complete cultivation of the surface was then necessary on all upland heaths to destroy the continuity of the surface peat and to mix and disturb the mineral soil and peat to some depth. A total cultivation depth of at least 8 inches on the normally poor sites was recommended. Such a depth would also disrupt a large proportion of shallow pan formation. The poorest sites have a relatively shallow (10 - 16 inches beneath the surface) pan/compact subsoil and attendant poor drainage from above the pan might require, in addition, frequent subsoiling to about 18 inches. For preference, the trees should be planted as nearly above the line of subsoiling as possible.

These findings give a reasonably clear account of the requirements for afforesting upland heaths. Generally, the heaths have little or no value for agriculture and they formed a substantial reserve of land considered suitable
for afforestation. They attracted the attention of the Forestry Commission soon after its formation in 1919 and the considerable technical problems encountered in their afforestation, at least certain of the main ones, were solved by research which began in 1921. Operations such as ploughing and manuring have been extended to large-scale planting operations and a good appreciation obtained of the most suitable species of trees to grow on heather-clad uplands. Zehetmayr (1960) has reviewed all the experimental work carried out in the field from 1921 to 1957.

The heaths, generally, have been maintained in their condition by deliberate burning (to deter heather and encourage grass growth) and, to a lesser extent, by grazing without which they would ultimately, in many places revert to forest. Heaths of this type are found in the eastern half of Scotland and in parts of north-east England. Periodically, parts of the upland heaths had been planted but considerable areas of these plantations, composed almost exclusively of the native Scots pine, had been of low production whilst on the poor ground a satisfactory crop had not been obtained. Zehetmayr's conclusions are pertinent to this study.

(a) Mechanical Cultivation:

Cultivation, from the evidence of the older
plantations, had been important from the founding of the Forestry Commission but the main task had been to obtain machines capable of withstanding the very rough usage of wet, compact and stony soils and to determine the most economical method of using them. Whilst it had been shown that every increase in soil disturbance, by increased average depth and repetition, increased growth, the economic method chosen was much less intensive than that adopted in Continental Europe.

The method was that of single cultivation by a heavy plough for each line of plants. Disturbance of the surface peat to promote its aeration and breakdown was the vital factor in this cultivation. Breaking of the pan was of great importance where it lay near the surface, as in the typical iron or peaty podzols. Whilst deep, single-mouldboards ploughs had been used more widely than any other type, they had been largely replaced, since 1950, by a plough with a shallower-going mouldboard mounted on a deep, subsoiling tine. Both types penetrated to a depth of 12 to 15 inches. Ploughing solved the problem of establishment for pines and larches over a wide range of heaths, a result attributable to improvements in aeration, drainage, nitrogen supply, freedom from competition and, in some cases, early shelter. Ploughing had extended the area on
which planting was economically feasible and, on moderately fertile areas, early growth had been radically improved.

(b) **Planting Methods and Species**

Zehetmayr concluded that planting on ploughed ground presented little difficulty and, for the drier areas, furrow-planting had been shown to be best, whilst on wetter areas or areas where the rainfall exceeded 35 inches, planting on the side of the plough ridge was advisable. There remained the problem of slopes which could not be ploughed but these slopes were often more fertile and better drained, making planting by the traditional hand methods, using mattock or spade, adequate. At the time of a first planting, the heather on such areas is often short and can be burnt off. More difficulty arises when the heather is tall and vigorous, as might happen if the area were fenced before planting or if the first planting had failed. No real solution had been found to this problem which existed in several heath forests.

Of the species planted on the Upland Heaths, Scots pine had always been the most important and was likely to remain so. It had responded to preparatory and manurial treatment. The faster-growing Corsican pine suffered from die-back and evidence had been advanced to show that Japanese larch might have a lower production over a
rotation than did Scots pine. A strong factor favouring the pine was natural conservatism which justified the use of a native species of known value as a timber producer, instead of planting exotics of apparently higher production.

Lodgepole pine, according to Zehetmayr, held an increasingly important place as the pioneer species on sites too poor, too high or too exposed for Scots pine. Whilst often regarded as a nurse for Scots pine or Sitka spruce on appropriate ground types, it was being employed as a productive species in its own right. No other species approached its tolerance to extreme heath types, although it was not so resistant to exposure as was Sitka spruce on sites suitable for that species. On the poorer heaths, the production of lodgepole pine was considerably greater than that of Scots pine. The provenance of lodgepole pine was an important factor.

Until the plantations of north-east England showed that Corsican pine could escape or survive die-back, the use of it would remain at a low level. European larch was only of importance as the main species on the more fertile heaths, often on slopes where a hard pan had not developed. Losses due to die-back have caused caution in its use and, in 1960, it was being planted mainly with pine, often in
low proportion as an "enrichment" species and employing carefully selected seed sources.

Experimental work had led to the widespread use of Sitka spruce in mixture with Scots pine and, to a lesser extent, with lodgepole pine or with Japanese larch. To Zehetmayr, it seemed wise to confine its use to the wetter heaths with rainfalls approaching forty inches, where it was particularly useful at the higher altitudes, and also to topographically wet areas on those heaths with lower rainfall. In 1960, large areas of heath carried young pine/spruce mixtures and, until their success was demonstrated, it would be unwise to "overplant" the species on the heath.

Mountain pine (Pinus Mugo) held a special role in forming a wind-firm edge to plantations but is not a timber-producing species nor as good a nurse crop as Japanese larch. Zehetmayr summarised the small scale trials of fifty other species and from them, he noted, several species might be selected to play a part in the heath forests in later rotations. The most successful use of these species had been obtained with nurse crops of other conifers or of broom (Serathamnus scoparius), following intensive ground preparation and manuring. Western hemlock had been the outstanding success in these trials and of
particular value for underplanting and filling gaps. Provided that its subsequent growth and timber quality proved to be satisfactory it could be widely used in later rotations. Grand fir, Lawson cypress, Servian spruce (Picea Omorika (Pancie) Bolle.), Douglas fir and western red cedar had all grown on the more fertile heaths. The place of Norway spruce was more difficult to decide, since it suffered most severely from competition in the presence of heather although, with the establishment of forest conditions, it might be used far more widely.

On the subject of broadleaved trees, it appeared unlikely that they would be used for timber production on typical upland heaths but they were important for the maintenance of soil fertility. Grey alder (Alnus incana), Oregon alder (A. rubra) and two birches, Betula pubescens and B. pendula had survived and grown sufficiently well to appear effective in local soil improvement. It would be a most important problem of the future to determine whether and to what extent such species should be used and how they should be introduced.

The majority of the mixed plantings on heath sites had included Scots pine. A species admixture might serve either to increase early returns by the use of fast-growing species such as Japanese larch or lodgepole pine or to
increase the volume of the final crop by the use of spruce, in which latter case Scots pine was used as a nurse. Adequate ground preparation was essential and the earliest successful mixtures with spruce were obtained only by intensive measures such as re-cultivation, the use of broom as a nurse and the early removal of pine. Later, Japanese larch was shown to be a more successful nurse for spruce. Band mixtures of two or, more recently, three lines of "nurse" and "nursed" species set out alternately appeared to be the most successful arrangement because concentration of the nurses led to earlier suppression of the heather. Differential manuring, by the application of phosphate to the slower growing species helped to even up mixtures. It was anticipated that the band mixtures would thus prove to be easier to maintain and control than were the earlier intimate mixtures although, where the secondary species grew faster than the main one, as with larch in a pine crop, the former could be planted singly or in small groups. Another mixture used on a considerable scale was that of lodgepole pine and Sitka spruce, although examples of successful balancing were rare; usually one species outgrew the other with varying results from site to site.

Upon planting, all species and particularly spruce, normally entered the checked state. The very slow growth
and yellowing of foliage was caused by heather competition. Measures to avoid check have included mulching with cut heather or branches before planting or inter-ploughing and replanting with a nurse species and have shown success, but top dressings of phosphate were singularly ineffective when applied to plantations that had already checked, whilst the effect of nitrogen was lost within a few years of application.

Zehetmayr noted that many heathland forests had been successfully established in Britain. It would have been easy to produce, over large areas, a monoculture of Scots pine and great efforts had been made to vary the crop within the limited range of species available. Future management, he felt, would probably be relatively simple. Large areas of non-heath ground which produced rapid growth and which occurred in most individual forests would aid the movement away from relatively narrow distribution of age classes toward a more normal, age-class structure. Road layout and construction and extraction operations would not present the problems found in the west of Britain. Windblow was likely to be a disturbing factor on the shallower heath soils, although by their growth and low stature, all of the plantations formed had virtually escaped the devastating gale of January, 1953. Damage by
Fomes annosus and insects had been negligible up to 1960 but might become more important, particularly in the driest areas.

The first steps towards improvement of soil structure and fertility had been taken, Zehetmayr asserted, with the initial cultivation. The major silvicultural problem was likely to be the continuation of this improvement and possible lines of approach lay in further cultivation, manuring and the use of soil-improving species, particularly broad-leaved trees.

(2) The Peats:

The Department of Agriculture and Fisheries for Scotland (1962), in its Scottish Peat Committee, has estimated that the total area of peat, two feet or more in depth, in Scotland is 1.7 million acres, of which about 1.0 million acres are capable of being improved and used for agricultural production or forestry.* The Committee

*In terms of fuel and other industrial outlets, the total workable peat deposits in Scotland amount to some 600 million tons of peat solids, equivalent to between 400 and 500 million tons of coal and sufficient to support electrical generating stations of 650 M.W. total capacity for 25 years at 6,000 hours per annum.
discussed the various potential uses for peat, noting that larger-scale exploitation for industrial purposes (mainly electricity and solid fuel) was technically feasible and would lead to the reclamation of some 87,000 acres of land covered by peat and producing little of agricultural value. The Forestry Commission, in the Committee's view had ensured a lasting place for Britain in the planting of raised bogs and blanket bogs and this work had extended to the planting of small areas of peat bog. The Committee concluded that the possibilities of developing areas of peat for agriculture and forestry and the future use of peat for horticultural purposes held out definite and substantial promise. So far as large-scale afforestation was concerned, the position was adequately covered by the Forestry Commission and its research services.

The peats of Northern Ireland are similar to those of Scotland and experience in that country is of interest. Jack (1965) has described the Northern Irish peats. The blanket bog was of a climatic "highmoor" type, even at low altitudes. The surface was rarely flat and level areas greater than 10 acres in extent are unusual. Slopes generally varied from 3 degrees to 15 degrees and, where they exceed 30 degrees, the peat covering was generally very thin. Peat which had been eroded by wind and water,
leaving only "hags' behind was not generally considered plantable. The peat surface topography was often poorly related to the topography of the soil or rock beneath. Local topography was very important. With concave slopes where the rate of water movement was probably slowed there was enrichment and the creation of a "flush", supporting vegetation generally more vigorous and often different in composition from that on adjoining convex slopes. Tree growth was generally fairly satisfactory on "flush" peat types.

The poorest types of deep (over 36 inches) digatrophic peat were generally indicated by vegetation types containing much \textit{Trichophorum caespitosum}, \textit{Sphagnum} spp. and some \textit{Calluna vulgaris}. \textit{Erica tetralix}, \textit{Narthecium ossifragum}, \textit{Eriophorum angustifolium} and the insectivorous \textit{Drosera rotundifolia} were common associates. \textit{Carex panicea} was often present, although inconspicuously. The presence of the vigorous \textit{Eriophorum vaginatum} and \textit{Molinea caerulea} was normally associated with somewhat better conditions of aeration and nutrient status of the peat. The nutrient content of the top 6 inches of wet, unflushed peat, expressed as milligrams per 100 grams, was likely to be 30 for Na, K and P, 100 for Fe and 150 for Ca, with smaller quantities at greater depth. Thus, Jack noted, the total mineral content was small, particularly of P and; to a
lesser extent, of K and Ca. The moisture content was likely to be 900 percent of dry weight and pH under 3.5.

The planting techniques employed on these peats included broadcast application of ground rock phosphate at 4 cwt. per acre, followed by ploughing. Cuthbertson plough types "S", "F" and "P", giving 18 inch deep furrows at 11 feet spacing or combinations of 24 inch deep single mouldboard and 12 inch deep double-mouldboard furrows were used. The ploughing direction was at right angles to road alignments and unploughed strips were left every 75 feet to facilitate future timber extraction. Water was not allowed to collect in the plough furrows and drains were put in to tap all hollows, cut off water flowing on to areas being afforested and collect water from natural springs and flushes. Planting was done with a semi-circular spade or with a notching spade; the large, deep-plough turfs being "stepped" or cut to give a planting turf of about 9 inches in depth at 5½ x 5½ feet, or wider, spacing. Sitka spruce was the species most commonly used and Jack noted that a number of studies of the rooting habits of the spruce and of lodgepole pine had been conducted. The limitations pointed out by Zehetmayr (1954) suggesting that roots generally followed the turf drain and exploited the ploughed turf, had not been noticed in Northern Ireland.
(a) **Ground Preparation of Peats:**

One effect of manuring and ploughing, mentioned by Jack, was the frequent great increase in the vigour of heather (*Calluna vulgaris*) with the tree crop becoming yellow and losing height increment. It was felt that this period might be avoided by some treatment, prior to planting, whereby grasses in the vegetation could be encouraged at the expense of the *Calluna*. In five experiments, there was little change in the vegetation for a year after the application of various manures but, from then on, any of the treatments containing phosphate or ground limestone, produced greater vigour of plants except in mosses. The greatest initial response was to bone meal but, after three seasons, all the phosphate treatments appeared to be quite similar, with the native vegetation standing some 24 inches tall as opposed to 6 inches in the control plots. Very little response was obtained to potash or nitrochalk alone and to burnt lime, although the former made *Trichophorum* look more vigorous in the first year. When manuring was followed by rotovating*, the native sward became re-established except with ground limestone and the control. In the latter cases the sward remained poor and, even after 6 years, the ground was only about 50 percent covered with vegetation.

*In Canadian terminology, roto-tilling.*
In a block protected from grazing (Ballypatrick 7/59) 6 fertiliser treatments, each with and without 3 tons of ground limestone per acre, were tried. Two strips ran across all the treatments, one sown with ryegrass and red clover and the other with ryegrass cleanings, largely *Holcus mollis*, at the time of manuring. Small plots of broom (*Cytisus*) and lupins were also tried. The ryegrass soon disappeared but the ryegrass cleanings were quite persistent in the presence of ground limestone and gave a very dense sward with all P treatments, as well as extending beyond the sown strip. The heaviest sward was probably on the superphosphate limed area; 5 years after manuring there was virtually no *Calluna* in the vegetation and a good tractor bearing surface was present. In the areas which were manured and rotovated, except for those with a vigorous regrowth of sward, tractor-bearing power was lost.

From other experiments, it appeared that, in many instances, peat could best be drained by numerous shallow drains at frequent intervals, although the treatment cannot drain deeply. Since it was impossible to deepen ploughed furrows without cutting tree roots and affecting the stability of the crop, various plough modifications had been tried to give furrows of over 18 inches depth and inverted turfs of about 9 inches depth for planting. The
most successful had been an idea for the automatic stepping of the turf from the single mouldboard. Cuthbertson type "F" plough and another modification giving two inverted planting turfs from the double-mouldboard Cuthbertson type "S" plough.

(b) Manuring at the Time of Planting:

An experiment (Ballypatrick 3/57) tested the manuring of Sitka spruce with various forms of nitrogen and 2 ozs. of basic slag per tree. The overall five years' leader growth 1959-63 showed significant differences related to some extent to the amount of phosphate included in a fertiliser but not to the amount of nitrogen applied. Jack observed that, by 1965, growth of all treatments was falling off and could probably only be maintained by additional manuring.

In another experiment (Ballypatrick 4/57, A57. S.S.) superphosphate, ground rock phosphate, bone meal and basic slag, all weighed to give the equivalent of 40 lbs. water soluble and insoluble P2O5 per acre (equivalent to 2 cwt. of basic slag), basic slag at half this rate and a control, all with and without 50 cwt. of ground limestone per acre and all with and without N as skin meal at 16 lbs. per acre, were compared. The experiment was unreplicated but indications of reactions were obtained. At 1963 (7 years
after establishment), the mean tree height showed little differences between the four higher rates of phosphorus, all of which were better than the half-rate of slag which, in turn, was better than the control. Nitrogen scarcely affected growth and lime gave some response. The best combination was superphosphate with lime or nitrogen. In the complete absence of phosphate, lime gave a response. By 1965, growth rates in this experiment were evidently falling off. At one experiment (P.56. S.S. Ballintempo 1/56) it was found that manuring one year after planting gave poor results compared with manuring at the time of planting, employing the same rate of slag.

In a 3 x 3 factorial design experiment (P61.S.S. Lock Naver 3/61) it was found, by 1963, that a high level of phosphate (112 units P₂O₅ per acre, applied at 18½% superphosphate) gave almost significantly taller growth than the low level (56 units P₂O₅ per acre) which, in turn, was significantly taller than no phosphate. Nitrogen had no beneficial effect. There were no significant interactions between manures but a suggestion that P and K were slightly beneficial in combination. The total growth of the better treatments was very satisfactory and, three growing seasons after planting, many trees in these treatments were more than 50 inches high.
In a recent experiment (P.62.S.S. Beaghs 3/63), the effects of placing phosphate fertiliser on top of the plough turf, below the plough turf and broadcast over the area had not yet given much information. However, better growth resulted from placement on top of the turf ribbon at the end of the first year whilst, by the end of the second year, broadcast fertilising gave the best response. Both of these treatments were much better than placement below the turf or in the planting hole.

(c) Treatments After Planting:

In experiments with after-planting manuring with Semsol at 2 ozs. per tree (Lislap 1/56) satisfactory response was obtained for some five years, after which leader growth began to decrease. The mulching of heather with spoil from deepened drain bottoms gave quite a strong response. Poor Sitka spruce (P55), manured in May 1957, with nitrogenous fertilisers did not respond very well (Ballypatrick 5/57).

Underplantings of western hemlock and grand fir made in 1958 under four P29 Pinus contorta stand thinned to approximately 400 stems per acre (Baronscourt 5/58) were manured with either 7 ozs. special potato manure per tree, 4 ozs. basic slag per tree or a control. By the end of 1963, the manured hemlock was 3½ times taller than the
unmanured hemlock with little difference between the two treatments. The grand fir responded slightly to the special potato manure, but slag made little difference. In a series of experiments employing Semsol and nitro chalk, it was found that Sitka spruce responded to Semsol but there was a rapid falling-off of growth in the fifth growing season after manuring. Lodgepole pine only responded slowly to this manuring. The manuring of Sitka spruce may have helped the average tree more than the dominant tree, possibly resulting in earlier closure of the canopy.

(d) Conclusions:

As a result of the foregoing and other experiments, Jack concluded that it appeared to be possible to grow a crop of trees on deep peat in Northern Ireland. Ploughing to a depth of 24 inches gave young trees a good initial burst of growth but it was not clear what intensity of ploughing or draining treatment was required for maintenance and stability of older stands. It was clear that manuring with phosphate, just before or at the time of planting, was necessary for adequate establishment and early growth. There appeared to be little point in applying more than the prescribed 4 cwt. of ground rock phosphate per acre at the time of planting. Further dressings of phosphate would almost certainly be required, the inter-
val between dressings and the rate of application depending on the nutrient status of the peat.

Applications of K and Ca might be required as stands developed but their value to young crops was unproven. The negligible response to nitrogen in the young stands was of interest but the element might have value at later stages of crop development. The manuring of established stands or mulching with spoil from drain bottoms was probably best undertaken as soon as growth appeared to be slowing down, rather than many years after the trees had "checked". Since the value of manuring had to be set against the cost of the work, it had been disappointing that stands which were growing reasonably well had not responded to fertiliser applications. Blanket (broadcast) application to large areas would be easier to organise than would treatments of scattered pockets of slow growth. It had been shown that Sitka spruce responded much more readily to manuring than did Pinus contorta and that there was often little difference in height growth before treatment. Since Sitka spruce had a total yield some one-third greater than the pine for stands of similar height at 20 years of age, it was obviously the species that must be considered most useful on the peats. It seemed possible that the spruce, with a maximum mean annual increment of 150 Hoppus feet
(191 cu. ft.) per acre could be grown on the blanket bog peats, provided sufficient applications of manure were given.

Other comments relating to the status of afforestation of upland heaths and peats are made later. At this point, however, whilst referring to work in Northern Ireland it is of interest to note some of the opinions expressed at a meeting of the Society of Foresters of Great Britain (1966). The choice of Sitka spruce for afforestation and the virtual exclusion of lodgepole pine from Northern Ireland received criticism. In reply, however, it was emphasised that a small country must plan its marketing ahead and spruce was preferred for boxwood, pulpwood and chipwood. The "check" problem with spruce, caused by heather competition in the early years, had been overcome by selective fertilising and other techniques. Once established on the peat, the production potential of spruce was greater than that of pine. However, if was felt that the experience of lodgepole pine in Northern Ireland would have been more encouraging had the country been able to obtain strains to grow well on western peat. It was felt that reliance upon "regional" strains of lodgepole pine was unsafe because of wide local variations due to site conditions.
It was held, however, that silvicultural techniques would become more closely adopted to particular sites. Peat, beneath a superficially uniform appearance, often had a considerable diversity of substratum and the methods of site preparation and choice of species should vary accordingly. Lodgepole pine was better than Sitka spruce on some sites and birch or alder might prove to be useful auxiliary species on others. It was clear from this meeting report that, whilst Sitka spruce is heavily favoured in practice in Northern Ireland, there are strong proponents for the use of lodgepole pine as well.

Lodgepole Pine:

(1) Reactions to Manuring:

Although lodgepole pine has only been employed to a limited extent on the Northern Irish peats, it is in extensive use in Scotland where it is planted on poorer peats with manuring, using 2 ozs. phosphate per plant. Sitka spruce is usually planted on better quality peat such as that occurring in "flushes" with Molinia present in the vegetation to a significant extent.

Zehetmayr (1960), in summarising work on the Upland Heaths from 1921 to 1957, felt that on the poorest heaths, typified by stunted Calluna and frequent Trichophorum, the value of small doses of phosphate at the
time of planting had been clearly demonstrated. There appeared to be no doubt that production over the rotation would be increased owing to the earlier, faster growth. The practice had been to spread 1½ to 2 ounces of ground mineral phosphate around the planting position of each tree.* On the more fertile heaths such as those occurring in Yorkshire, the results were less marked and phosphate was rarely employed in practice. Many attempts had been made on the heaths to use phosphate top dressings to stimulate checked plants, notably spruce, in the manner which had proved so successful on peat areas. Under conditions where check developed, nitrogen had been shown to be the limiting factor, whereas at the time of planting, when phosphate was effective, nitrogen was made available by the decay of surface peat after cultivation. Application of nitrogen at the planting time had given short-term improvements in growth but not equal to those obtained with phosphate. With species mixtures differential manuring, with the application of phosphate to the slower species only, had been shown to be useful aid to evening-up the early growth.

*With spacings of 4½ x 4½ feet, this amounts to 200 - 270 lbs. per acre, equivalent to 60 - 90 lbs. P₂O₅ per acre.
(2) Provenances:

The growing use of lodgepole pine in Scotland and the variable characteristics of growth demonstrated by the species has made the provenance of seed imported from British Columbia and the United States of great importance, since upon it much of the economic success of the enterprise must rest. The Forestry Commission (1965d; 1966c; 1967c) has reported the planting of almost 45 million plants of the species in Scotland during 1964, 1965 and 1966, of which somewhat more than 16 million were planted in North Scotland Conservancy. During the same three years 6,571 lb. of seed of the species were imported into Britain from Washington, Oregon, British Columbia and Northern Ireland.

Roche (1966) has described variations in growth habit and bark type of lodgepole pine in its native habitat. A common distinction was made between the inland and coastal varieties in British and Irish plantations. The inland variety was generally of good form with a light-branching habit and a narrow crown of sparse appearance, whilst the coastal variety was of poor form with heavy, numerous branches and a dense, bushy crown. The distinction in the native habitat was not actually so clearcut, for in many coastal areas lodgepole pine of good form and
light branching habit might be observed. Because of accessibility and abundance, however, commercial seed was often collected from coastal scrub ecotypes. Much of this seed had entered Great Britain and Ireland with the result that many plantations of coastal source were atypical and exhibited a grossness of form in marked contrast to the inland variety.

The coastal variety characteristically showed deeply fissured, black bark, whereas, the inland variety generally was orange-brown to grey in colour and consisted of thin, loosely-appressed scales. These differences were retained in plantations in Great Britain and Ireland and appeared to be heritable characteristics which could be used in separating the two major varieties. There was considerable variation in the thickness of bark and it appeared, in both varieties, to be largely influenced by environmental factors such as stand density, site quality and age of tree. Roche concluded that bark thickness was not a very reliable variant for precisely delineating intra-specific variation. On the assumption that there is a constant co-relation between needle width and length within the major sub-divisions of the species, the ratio of these two measurements was likely to be useful in delineating sub-specific variation, since it would reduce within-
sample variances by accounting for a percentage of non-genetic variations.

Roche felt that cone collections (in British Columbia), unsupervised by the importer, were likely to contain a high percentage of cones taken from stands of very inferior form. Thus, imported seed which was geographically correct from a provenance point of view was not necessarily genetically appropriate.

The greatest problem associated with the assessment of geographic variation in most characteristics of lodgepole pine, including needle morphology, was that of sampling. The species was an obligatory cross-pollinator and almost continuous in its distribution over an immense area of diverse environments. There was a germinal interchange within a relatively large population. The genotype was thus highly heterozygous and the population heterogenous. For these reasons it was most unlikely that needle measurements from twenty provenances (used by Roche in considering needle morphology) would adequately sample the spectrum of variation in needle morphology within the species and only very tentative conclusions could be drawn on this aspect.

Lines (1966) has discussed the choice of provenance of lodgepole pine for British forests. There was
probably, he noted a greater natural variation due to provenance within the species than in any other common forest tree. The variation lies in appearance; rate of growth, ability to withstand exposed conditions or infertile sites, ability to suppress competing vegetation, stem form and fruiting habits. However, the differences in timber properties of thinnings from a range of different provenances tested by the Forest Products Research Laboratory at Princes Risborough had not been shown to be of great importance.

Lodgepole pine had a range in the natural habitat of 30 degrees in latitude, from California to Alaska, and from sea level to 11,000 feet elevation in the Rocky Mountains. The annual rainfall varied from below 15 inches to more than 150 inches. The area was divided by Lines into Coastal populations, nearly all at an elevation of 500 feet or below and the inland populations which are mostly above 1,000 feet, except for some stands in river valleys which cut through the Coast range. The Coastal area was split into two parts - the north, comprising coastal Alaska and British Columbia, including the major islands, and the south, comprising the coasts of Washington Oregon and California. Seed from a separate sub-species in an outlier in Mendocina County, California had not been
used in British plantations. The inland area was more complex. There was some evidence of a distinct sub-population (sub-species Murrayana) from the Cascade Mountains of Oregon to the Sierra Nevada of California. Seed from this area tended to give homogenous stands, in contrast to the wide diversity shown by other provenances. The bulk of the inland seed used in Britain has come from British Columbia, usually from between 1,000 and 4,000 feet elevation. Lines had distinguished three areas here i.e. (1) The Skeena Valley, (2) North and Central Interior, and (3) the Thompson River and the Interior Wet Belt, which Lines named the Southern Interior.* The rest of the Inland provenances used in Britain were not classified into broad areas. Lines' description of the characteristics of inland and coastal types enlarged upon, but generally coincides with that of Roche (1966) which has been previously reviewed.

The north coastal area was not well represented in British experiments, chiefly because of seed collecting difficulties in the sparsely populated northern part. However, there were large differences in the provenances from within the area. A provenance from Hollis, Prince of

* This term, as used in British Columbia, refers to a larger area, including the Interior Dry Belt.
Wales Island, Alaska (seed lot 52/211) was slow-growing, straight in form and showed good resistance to exposure. Provenances from Haines, at the head of the Lynn Canal in Alaska (seed lot 52/212) and from nearby Skagway, grew more slowly still. A small seed lot (36/42) from the Queen Charlotte Islands showed a slow rate of height growth. Seed lots from the lower reaches of the Fraser River, particularly Lulu Island had proved to be susceptible to exposure damage on severely exposed sites, although manuring with compound fertilisers corrected the fault, at least temporarily. The growth was appreciably slower than the Washington coastal provenance. The Vancouver Island provenances planted before the Second World War in Wales had developed a coastal habit but lacked vigour, whereas those imported from 1956 onwards had grown at rates intermediate between those from Alaska and those from Washington. Provenances from bogs on the west coast of Vancouver Island had not been tested. Two provenances (56/65 Ladysmith and (7116)3 Sooke) had been blasted by winter winds and appeared to have a limited useful range on exposed upland sites. Basal bowing (sweep) occurred in these Vancouver Island provenances but less frequently than in the southern Coastal origins.

In the south coastal area, California was not regarded as a source of commercial quantities of seed for
planting in Britain, because of latitudinal differences. The general appearance and behaviour of provenances from the south coastal area were less divergent than those from the north coastal area and Lines described a typical provenance (Long Beach) and related others to it. The Long Beach provenance, widely distributed in Scottish plantations, was characterised by its bushy crown form and rapid rate of growth. The growth rate was equalled only by some of the Oregon coastal provenances and Long Beach stock had thus become a first choice where its rather poor form was not of prime importance. Lines felt that the defects of stem form could be attributed to a capacity for rapid growth on poor sites. Given sufficient phosphate, the provenance grew quickly from the first and, on soft peat or cultivated mineral soils, the bushy plant became top heavy and the stem was easily swayed by the wind or flattened by heavy snow. The tree was only checked temporarily and new growth adjusted the stem to the vertical, producing basal bowing. This was very often followed by "over correction" and a sinuous stem resulted. The south coastal provenances showed remarkable site tolerance.

The Skeena River area provenances all exhibited rather slow growth in Britain and, although this growth was faster than the Queen Charlotte Islands or Oregon Cascades provenances possessed, they were inferior in
growth rate to other Interior provenances. They had good form and moderate vigour on a wide range of Scottish sites, particularly ones that were difficult for Scots pine. They had not been tested experimentally on severely exposed sites for which the Washington coastal provenances were considered to be more appropriate.

The provenances from the North and Central Interior of British Columbia were mostly from the Prince George area. They were of typical inland appearance with yellow-green foliage, open crown and pale-coloured, thin, smooth bark. The rates of height growth and girth increment were relatively slow and basal bowing was absent. The open crowns had been slow to suppress Calluna in plantations. The provenances were not used on deep, acid peat or particularly exposed sites, although they grew better than Scots pine under exposure and were best suited to low rainfall sites on the east coast or high-elevation sites where snow-damage was a problem. Trees from Williams Lake were quite similar to those from Prince George but those from Fort Fraser, although resisting exposure well, had a height growth slower than any other provenance.

There was some doubt about the exact locations of the southern interior area seed collections but they had come from near Kamloops on the Thompson River and the
Shuswap Lake area. The area was transitional from the Interior Dry Belt at Kamloops to the Interior Wet Belt at Shuswap Lake and has marked precipitation and temperature differences. The lack of precise knowledge of source under these conditions is obviously a serious defect. Of the various collections, two seed lots from the Mount Ida Provincial Forest to the south of Shuswap Lake had grown quite well and could be considered among the most desirable inland provenance from the southern interior seed area. This provenance, on deep Trichophorum (Scirpus) peat on the Lon Mar, was growing in Yield Class 100*. The South Thompson River and Mount Ida provenances were collected between 1,600 and 5,000 feet elevation, those from the highest elevations being less vigorous. The stem form is quite good, apart from a tendency to fork. The Shuswap Lake provenances show considerable variation in growth rate and form, some having smooth bark, good stem form and moderate height growth, whereas others have thick corky bark in small platelets and much poorer form, with forking

* As defined in Forestry Commission Booklet No. 16 - Forest Management Tables. Yield Class 100 for lodgepole pine can be expected to yield a total production, including thinnings, of 6,000 Hoppus feet to a 3-inch top (7,700 cu. ft.) per acre at age 60 years, the age of maximum mean annual increment.
and basal bowing, partly because of their early rapid growth. The variations were believed to be related, possibly, to variations of elevation and climatic factors in the collection sites. These southern interior provenances were considered, despite the good growth of the Mount Ida provenance on the Lon Mor, as best left to the east of Britain and on heathland site types with shallow, peaty, surface layers, rather than on deep peats. The medium-elevation, higher rainfall sources were considered to have the best potential.

The Inland United States area was not comprehensively represented in British experiments. The Idaho provenance, from a fairly low elevation and relatively high rainfall source, had grown fairly rapidly and had a typical inland appearance with sparse, open crown. A provenance from "East Washington" had grown faster but with poorer form and distinctly rough bark. The least vigorous of all provenances were those from the semi-desert area near Klamath and La Pine, having excellent stem form but very slow growth. The Alberta seed source was considered by Lines along with the other Rocky Mountain types (inland U.S.A. area). Its relative performance was difficult to assess, because it was generally planted in areas separate from other provenances, but it was slow-growing with excellent stem form.
Lines concluded that provenance should be selected in relation to the site to be planted and the anticipated end use of the timber, rather than endeavour to select one provenance as being the most suitable for all British conditions. However, the enormous tolerance of the Washington Coast seed origins should possibly lead them to be considered first, with alternative choices being made where particular site conditions and objectives required it.

Jeffers and Black (1963) investigated variability between provenances of lodgepole pine, using three methods of multivariate analysis and applying them to nineteen variables measured on each of nine provenances. The variables included measurements and classifications of needle characters such as length, breadth, thickness and number and type of resin canals; measurement of winter buds and classification of their colour, type, resin and scales; colour and form of shoots; measurements of cones and classification of their colour, type, form, angle, etc.; measurements of seed and seed wings and classification of their colour, type and form; percentage germination of seed; individual and average ring widths for the years 1951-55 and width and percentage of autumn wood; and measurement and classification of uniseriate rays. The analysis confirmed the correctness of the broad division
of Pinus contorta into inland and coastal provenances but suggested an independent classification which accounted for an even greater degree of botanical variation. This classification was a component analysis which made clear that the 19 components employed were not independent of each other and that, if the co-relations were expressed as linear combinations of the original variables, then three components were sufficient to account for almost eighty percent of the variability contained in all 19 of the variables. A third classification, possibly related to timber properties, was also suggested. It was concluded that lodgepole pine could be classified satisfactorily by needle thickness, adaxial thickness of hypodermis; needle length; number of resin canals, width of annual rings in the last five years and percentage of autumn wood.

(3) Industrial Utilisation of Lodgepole Pine

The Ministry of Technology Forest Products Research Laboratory (1968) has studied the timber properties of lodgepole pine grown in Great Britain*. The report has briefly reviewed the factors of provenance, as described

* Additional references are the Home Grown Timber Research Committee Paper No. 85 - Report on the properties of lodgepole pine timber from nine seed provenances (unpublished) and Committee Paper No. 110 - the effect of provenance on the timber properties of lodgepole pine grown in Allerston Forest in the North Riding of Yorkshire (unpublished). Also, Thomas (1966) has reported on the laboratory tests conducted on lodgepole pine at the Forest Products Research Laboratory.
by the authors already mentioned, and noted that, whilst the species was introduced into Britain by Jeffrey in 1853 and the earliest plantations date from 1930, it is only in the past 20 years that it has been planted extensively. Whilst the first plantations were of Coastal provenance and most probably from Washington, most early plantations were of inland provenance, mainly from the southern interior of British Columbia.

It was of interest that, in spite of a British growth rate of about four times that experienced in Montana, the density of the British-grown wood was the same at 29 lbs/cu. ft. (460 kg/m$^3$) at 12 percent moisture content. There was little colour contrast between sapwood and heartwood and the contrast between spring and summer wood was not well marked, the texture being more uniform and even than in Scots pine. The grain was straight or almost so and the overall angle of spirality was much less than in most British-grown conifers. The Laboratory reported that compression wood was common but was only rarely a serious defect. The fibre length increased from 2.1 mm. at an early age to 2.9 mm. at almost 35 years and trees over 50 years old would be expected to have many fibres at least 3 mm. in length, quite similar to those in Scots pine. The British-grown trees of inland provenance were of relatively good form with numerous, small, line knots
and they could yield a fairly high proportion of Grade II or better timber.

On the question of seasoning properties, shrinkage and movement, it was found that sawn timber of the species dried rapidly without trouble and with low distortion. It could be dried without appreciable degrade by a comparatively severe schedule, such as the one recommended for Scots pine. Figures for tangential and radial shrinkages, moisture contents at specified temperature and humidity levels and corresponding tangential and radial movements were given. The strength figures indicated that lodgepole pine was slightly superior to imported whitewood in all mechanical properties except modulus of elasticity, at least equal in strength to maritime pine (Pinus pinaster Aiton) but somewhat inferior to Scots pine and Baltic redwood, except in hardness. However, it seemed probable to the laboratory that wood from older trees (the test material was from trees from 30 to 35 years old) would be mostly as strong as redwood.

The resistance to decay was poor, with the heartwood slightly more resistant. The sapwood was easily treated with preservative, whilst the spring wood might slightly collapse under treatment. The timber could be worked readily with little blunting of tools. It worked
as easily as spruce and the planed surface (unlike that of Sitka spruce) was smooth and often lustrous without woolliness or appreciable areas of raised grain. However, considerable tearing occurred around the small and frequent knots which were live and tight. Arrises were liable to break away in moulding and mortising. The wood nailed, painted and varnished well. In general, its working properties were similar to those of the less resinous British grown Scots pine.

Lodgepole pine had been used, in Britain, in admixture with other softwoods for pulp manufacture but was not one of the major species in commercial use. Laboratory scale trials on British-grown material, using the Kraft process, showed the pulping properties to be generally comparable to those of Scots pine. No differences of practical importance were noted between a number of different provenances.

In general, there seemed to be no reason why the wood should not be used for building uses such as roofing, flooring, interior framing, partitioning, cladding, etc. It should be eminently suitable for slats in cooking towers, when treated with preservative, and for box and crate manufacture. It could be used satisfactorily for pulp manufacture, fencing and mining timber.
The occurrence of basal bowing in the coastal and Shuswap provenances of lodgepole pine has been remarked upon earlier and has been investigated by the author as part of this thesis. It is pertinent at this point, whilst reviewing the timber quality of the species, to observe that Low (1964) has reviewed the literature on the occurrence of reaction wood in conifers. The reaction wood develops, typically, on the underside of inclined or crooked stems and branches of coniferous species. The effects on utilisation are well-known and consist of an exceptionally high longitudinal shrinkage which may lead to serious distortion or splitting during seasoning when both normal and reaction wood are present, especially in boards and small dimension stock. Compression wood also, although less importantly, possesses lower strength per unit weight than normal wood. The working properties are poorer and the value of the wood for pulping is lower than for normal wood.

(4) General:

MacDonald (1954) supported the large scale planting of lodgepole pine in Scotland, particularly on ordinary Calluna heath and low fertility sites, both pure and in mixture. He visualised the employment of both coastal and inland strains and hoped for the selection of a good intermediate form.
Lines (1968) has summarised the silviculture of lodgepole pine in Scotland and noted the suggestion that an intermediate form with some Coastal and some Inland characteristics would best suit British conditions. The provenance from Terrace on the Skeena River showed some of these characteristics and could be compared with those from Hazelton and Smithers. The interest in the Shuswap Lake provenances, for much the same reasons, has already been noted.

d. Sitka Spruce:

Special reference has been made to lodgepole pine because of its current and potential importance to Scottish forestry and, also, to provide background for the field study of lodgepole pine which is related later in this thesis. The other predominant species of relatively new popularity is Sitka spruce, which demonstrates very high growth rates and good resistance to exposure, although requiring somewhat better quality sites than does lodgepole pine. Brief reference is made herein to this species.

(1) Fertiliser Studies:

Leyton and Weatherell (1959) have reported that the growth of semi-checked Sitka spruce on heathland had been stimulated to different degrees by the annual appli-
cation of litter of Scots pine, Corsican pine, lodgepole pine, Japanese larch and Sitka spruce at rates corresponding to normal plantation conditions, following an initial heavier rate. Foliar analysis suggested that the response was at least partially attributable to the influence of the litters on the nitrogen nutrition of the spruce and differences between litters appeared to be largely determined by their total nitrogen contents. In this respect, Japanese larch, with an annual needle fall generally greater than that of the pines and a higher nitrogen content, offered the best promise as a nurse species for spruce.

Davies (1967) has described the silviculture of Norway and Sitka spruces as practised by the Forestry Commission in the West Scotland Conservancy over the previous 50 years and has ascribed certain qualities to Sitka spruce. Firstly, it withstood exposure better than any other species in the Conservancy, if sufficient phosphate had been applied. It was very easy to handle as a transplant and cheap to produce. Given proper treatment, it would grow fast on a wide variety of infertile sites where the only other prospect, in Davies' words, was the "low yielding and doubtfully economic lodgepole pine". The spruce produced good utility saw timber and fine pulp. For the future, Davies held that aerial manuring on a routine basis
adjusted on the basis of foliar analyses, would soon materialise. Net discounted revenue calculations showed that considerable sums could be spent on fertilising and, if the Forestry Commission Yield Class could be raised by 40, an increased profit would result. Of all the species being planted in Scotland, Sitka spruce seemed most likely to repay intensive silviculture.

(2) Provenances:

Sitka spruce is easily the most important species, in terms of current rates of planting, in Scotland. The Forestry Commission (1965d; 1966c; 1967c) has reported the planting of slightly more than 80 million plants of the species in Scotland in 1964, 1965 and 1966, of which almost 16 million was planted in North Scotland Conservancy. As with lodgepole pine, the planting rates appear to be increasing. During 1965 and 1966, the Commission imported 1139 lb. of seed from Washington, Oregon and Alaska none having been imported in 1964.

Burley (1966) has described the development of the terminal bud in one-year seedlings of Sitka spruce as a continuous process. The same sequence of morphological events occurred in 47 provenances examined but with different timings. The buds formed in response to decreasing day-length and an essentially continuous relationship was
demonstrated between time of bud formation and latitude of seed origin. Flushing was controlled largely by temperature and time of flushing reflected the nature of the temperature regime in the native habitat.

The height attained at the end of the growing season was demonstrated to be related to date of bud formation and latitude of seed origin but the relationship was modified by temperature and photoperiod. There was little genetic variation in rate of height growth and variability in time of bud formation was considered to be the major factor causing provenance variation in total height growth. The reactions of two provenances suggested that ecotypic differentiation had occurred in response to specific, local environmental selection pressures. The results supplemented the conclusions of earlier reports, namely, that there was a broad interaction of genotype with environment that should be evaluated before planting the species at any given site.

(3) Industrial Utilisation in Britain:

Broughton (1962) has described the properties of 30 - 37 years old British-grown Sitka spruce timbers. The variability of properties encountered between trees within a site and within individual trees was much greater than variations which could be attributed to differences in
climate or quality class. However, the observed differences in fibre length, strength and seasoning properties of timber taken from different heights in the tree were not of practical importance but, of all the properties investigated, only permeability and resistance to impregnation were fairly uniform. The fibre length varied between 2.6 mm. and 3.3 mm., being adequate for the manufacture of strong paper. Spiral grain, almost invariably anti-clockwise, was found, to some degree, in almost all of the material examined. The average, nominal specific gravity of whole discs was 0.331 (green volume) and for small, clear specimens 0.313 (green volume) or 0.336 at 12 percent moisture content. The maximum crushing strength was 2,130 lbs. per sq. inch (green) and 4,120 lbs. per sq. inch (12% m.c.) and the resistance to impact* was 22 inches (green) and 20 inches (12% m.c.).

The spruce could be dried quickly under the most severe drying schedules without increasing the amount of degrade. Some twist, however, always occurred where the boards were allowed unrestrained movement, owing to the spiral grain. Machine woodworking tests were carried out at moisture contents of 12% and 20% of the oven-dry weight. Hard knots tended to damage the cutter blades and resulted

* Height through which a 3.3 lb. hammer must fall to cause fracture.
in a poor finish to the timber surface. However, this could be overcome by the technique of jointing in which a second bevel was given to the cutter blades. Under wood preservation, creosote retentions of between 6.6 and 11.5 lbs. per cu.ft. of heartwood could be obtained but it was necessary to use slightly lower temperature and pressure combinations during treatment in order to avoid collapse. The sapwood treated readily.

The Forest Products Research Laboratory has found, in planing Sitka spruce lumber, that it was difficult to avoid a woolly finish, although sharp knives and the jointing procedure mentioned by Broughton would reduce the effect. Tearing of the grain was also a common feature, associated with disturbances of the grain due to knots and other defects and, more usually, with spiral grain.

In summary, British-grown Sitka spruce was found to be a preferred species for many pulping processes, particularly for groundwood pulp, because of its light colour and the relatively low power consumption required to chip it. The species also provided material for the lightweight types of fibreboard, such as insulation board, and for moulded fibre board and woodwool, especially that needed for packing food. The species was also suitable for chipboard manufacture, although that industry operated
largely on planer shavings and similar wood waste. The spruce could, also, be used for pit-props (a dwindling market) and would probably last for about twenty years as fence-posts, if barked and treated with preservative. The potential market for the sawn timber is very large but, because of the British-grown wood characteristics and the conversion problems mentioned above, only a small percentage of the output was likely to be Grade I material, suitable for joinery and high-class structural work. Suitable graded material could be used for general building purposes, such as trussed rafters, internal framing, partitioning and the external cladding and for portable buildings. However, for building components, preservation against rot and beetle attack was desirable. Since the heartwood was resistant to pressure treatment, adequate protection could only be achieved by means of a diffusion process. The species was more suitable for boxes, packing cases, cable drums, shuttering and general carpentry*.

* The Forest Products Research Laboratory at the Ministry of Technology possess unpublished material, dealing with the characteristics of British-grown Sitka spruce timber in detail. e.g. Home-Grown Timber Research Committee Paper No. 112 - General investigations on home-grown timbers. Variations within the tree. Report No. 1 Sitka spruce.
Site Productivities, Rotations and Yields:

Sinden (1964 and 1965) has noted the trend in Britain away from the classical approaches to forest management which developed the methods of sustained yield forestry toward more flexible methods on more commercially oriented operations. Within any forest policy, financial decisions on rotations were becoming increasingly important. Sinden, whilst not disputing the importance of rotation length as an important long-term forest planning tool, has concerned himself with the mature stand, posing the recurrent marginal problem of whether to fell now or to allow the crop to grow longer. His approach was based on a consideration of financial criteria and stand production. In slow-growing stands, the decision of when to cut might not be of major commercial importance but, rather, of planning importance, whereas in high productivity stands it could be of critical financial significance.

The technique developed by Sinden employed Faustmann's concept of net discounted revenue combined with certain principles of economic theory. The expectation value was arrived at by comparing potential future receipts with expenditures and ignoring all previous costs and returns i.e. a marginal criterion was employed rather than a rotation length criterion. The technique allowed the marginal decision on rotations to be made rapidly and
to be based on the whole range of cost conditions, productivity classes of selected stands and current product prices. It avoided the severe problems of long-term forecasts of profitability by employing current product prices and costs which were assumed to be steady for, say, the next five years. By the suitable adjustment of the discount procedure, however, the principle could be applied to an infinite series of rotations. A framework was also provided to make an economic analysis of the potential supplies from a given forest area under commercial forest management.

Based on the technique developed and employing costs and prices generally applicable at that time, Sinden briefly considered the justifications for pulpwood rotations in Quality Class II Sitka spruce. In his particular example, he found that, for a zero or very low price for sawtimber (i.e. for a very low ratio - price sawtimber; price pulpwood) the optimum rotation was 30 years and a pulpwood rotation was justified. Similarly, if the price of pulpwood was zero or low, then the optimum rotation was 55-60 years, a sawtimber rotation. It was shown that pulpwood rotations were only justified when the price ratio was very low. Sinden noted that, although actual price determine profits, their influence on rotation length was limited by the ratio productivity: interest
On the subjects of forest inventory and yield control, Johnston and Bradley (1964) have described the changed methods employed for State Working Plans. For the next few decades, most British production would come from thinnings, the yield of which was doubling every ten years. In a free economy it was not possible to plan, in detail, the integration of future wood-using industries with the future production of wood. The construction of expensive, wood-using mills could not be considered by industry, however, until the industries knew the quantities and specifications of the raw material coming onto the market for many years ahead. It was becoming apparent that the greatest single contribution that could be made by timber growers to the establishment of industry and, consequently, to the sale of their own produce, was to provide reasonably precise, long-term forecasts of future production by volume and some form of size-class distribution. More precise, short-term forecasts were needed for market planning and, to some extent, for the actual management of the forests.

The objectives of a forest inventory (of British forests) might, Johnston and Bradley stated, be summarised as follows, in conjunction with the use of management
(1) to record the species and age of each sub-compartment.

(2) to assess the General Yield Class of each sub-compartment which is in the thinning stage, or is likely to come into the thinning stage within the forecasting period.

(3) to assess the Production Class of each species, if necessary on each broad site type in the forest, so that the General Yield Class of each sub-compartment may be converted into a local Yield Class. (A combination of (1), (2) and (3) provides a basis for making long and short-term production forecasts and for controlling thinning yields in the forest.)

(4) to estimate the standing volume of sub-compartments likely to be clear-felled before the next working plan survey. This information is required for short-term market planning.

(5) to provide the basis for a periodic check on the development of the forest and, thus, on the

* Forestry Commission Booklet No. 16. *Forest management tables.* London: H.M.S.O.
accuracy of the Local Yield Class assessments and/or the precision of thinning control.

The method employed was (and is) a stratified random sampling procedure to a pre-determined level of accuracy*. It was intended that plot measurements should be periodic.

The subject of fertilisation (manuring) has a great potential influence on future site productivity, particularly on the less fertile areas of Scotland. Binns and Grayson (1967) have reviewed the position of fertilisation of established crops, noting that British foresters have long been familiar with the necessity of fertilisation in the establishment phase of protection work. Only NPK had been found to be limiting to growth in the British forests, with suggestions from more recent Forestry Commission experiments that Ca might be needed on some deep peats and that Mg might be needed in the future, particularly if the use of NPK became general. The majority of experimental work in Britain had concentrated on crop

* Relative to the standards of the British Columbia Inventory it requires much more field work per acre since it aims at a meaningful sub-compartment accuracy appropriate to the intensive levels of management prevailing in Britain.
establishment or trying to restart growth which had stopped. A number of experiments conducted in mature crops were then reviewed.

Binns and Grayson concluded that, in the north and south temperate zones, only N and P had regularly been found to improve the growth of established crops on mineral soils. On more alkaline soils, and some very impoverished sands, K and Mg might be locally important. Peat soils undoubtedly required additional K but its use (or that of P and K) could not yet be evaluated on these soils, in terms of giving profitable increases in increment in established crops which were already making steady growth. The Research Division and Management Services Division of the Forestry Commission were still engaged in finding out what was necessary on these soils to produce a steadily growing crop. There were, in Britain, examples of responses to N or to P in established crops of Scots pine, Sitka spruce, Norway spruce and Corsican pine (the latter almost all on very sandy soils) and there were examples of no response in Scots pine and Sitka spruce. More work was needed to determine whether N or P would be the key element in fertilising established crops; the forms of N and P which it will be most effective to apply and the most effective season to apply nitrogen. The indications were that, where trees gave an economic res-
-581-

response to nitrogen, it should be applied every 5 or 6 years to maintain the increase in growth. In contrast, P responses were generally longer-lasting. The best rate of application for N appears to lie between 100 and 150 lbs. per acre and, for P, probably 40 lb. and 80 lb. per acre on most soils (40-50 lbs. was often used for top dressing checked crops, while 25-30 lbs. was typically used at the time of establishment.). A problem could arise in the selection of stands for fertiliser treatment, since neither soil analysis or foliar analysis were fully reliable indicators of a potential response.

Binns and Grayson also dealt with the economic implications of fertilisation in the individual stand. Using an actual 80 year old Scots pine stand as an example, they attached money values to the costs and expected returns. The cost of application of N and P, using the cheapest materials, would be about 8 pounds per acre. Assuming that the stand was felled six years after treatment, the extra volume increment of 120 H. ft. (153 cu.ft.) per acre produced over the six years and price at 2s 6d per H. ft. standing, implied a revenue increase of 15 pounds per acre. Discounting this amount at 3½ percent, the value of the response, viewed from the time of fertilisation was 12 pounds per acre. Thus the nett discounted revenue would be 4 pounds per acre. The rate of return on
the capital invested would be 11 percent, which Binns and Grayson considered to be very attractive economically. It is worthy of note, however, that the 3½ percent used as the discount rate for this calculation compares to 7 percent paid by the Forestry Commission on its borrowings, as referred to earlier in this review.

In pole-stage plantations, the increased growth produced by fertilisation might be removed at one time by clear-felling or might include removal by intermediate thinnings. In four actual pole stage stands treated with P, an average growth increase of 215 H.ft. (274 cu.ft.) per acre was achieved over 7 years. If about a half of this increase were to be removed over 2 thinnings and the remainder at the date of final felling 30 years after treatment and thinnings and main crop were valued at 1s 6d and 2s 6d respectively, the discounted revenue would be 10.6 pounds per acre. With a cost of fertiliser and application of some 9 pounds per acre, using a fixed-wing aircraft, the operation was profitable and the nett discounted revenue per pound spent amounted to about 1.8 pounds, i.e. the rate of return on the investment would be 4.5 percent. Binns and Grayson felt that it was possible to imagine that successive fertiliser treatments would be adopted in a crop's life and intermediate yields might be raised in order to remove the bulk of the increased growth
in thinnings. Given sufficient data on costs, yields and prices, it would be possible to draw up relationships of profitability (or loss) for different rates of application for a given treatment. Quite apart from individual stand considerations, national or larger scale considerations to favour fertilisation could include supply of a market with a rate of demand higher than the normal thinning yield and, avoiding, at the same time, losses by premature felling.

In view of the relatively short interval between treatment and the harvest of increased yield, the financing of widespread fertilisation should not constitute a major problem. It would be desirable on economic grounds to cut back on less profitable forms of forest investment and to concentrate more on economic production on existing areas, instead of continually expanding the supply base, with all the extra supervision, maintenance, protection, future harvesting and transport costs that such forest expansion commonly entailed.

In the fields of economic and technical research, Binns and Grayson felt that study was needed, in Britain, into:

(1) growth responses (by species, ages and sites) to different fertiliser treatments and elucidation of
factors controlling such responses.

(2) effects of fertiliser treatment on tree form, timber quality and susceptibility to insect and fungal attacks.

(3) the costs of different fertiliser treatments.

(4) the economic attraction of fertilisation and the implications for species choice, thinning regimes and rotation length and the consequences for marketing.

From an immediate management point of view, there seemed to be enough evidence to indicate that, on some mineral soil sites in the north, occupied by middle-aged and old Scots pine, nitrogen fertilisation at about 100 - 500 lbs N per acre might well be profitable and, on a range of Sitka spruce pole-stage crops in Wales, mainly standing on mineral soils, P fertilisation was likely also to be reasonably profitable. For a crop of given yield class, the lower the stumpage price that was expected or the higher the costs of fertilisation, the less was the justification for treatment. Thus, the same circumstances which favoured more extensive forestry applied to fertilisation also but there would be some sites and conditions of crop where the response to fertilisation would trans-
form the crop's potential and the sort of management applied. Possibly, the major effect that fertilisation could have lay in increasing thinning yields, making a rapid contribution to production and employment in home-based wood industries, effecting import substitution and the diversification and stimulation of regional economics. To the regional economy, forest fertilisation might not be so attractive as other forms of investment, since payments made to fertiliser manufacturers and producers and users of tractors and aircraft do not generate income locally to anything like the same extent as more labour-intensive silvicultural operations.

As described elsewhere, Davies (1967) has pressed for the fertilisation of Sitka spruce in West Scotland Conservancy. In another report (Davies (1967a) ), he has described the helicopter application of 3 cwt. of crude Gafsa phosphate per acre onto a 1,000 acre block of slow-growing coniferous plantations, 10 to 15 years old. The average total cost, including phosphate, contract spreading, labour, radio and transport but excluding any supervisory, administrative or fixed overhead costs, was equivalent to about 4 pounds 12 shillings per acre. Davies foresaw that regular aerial application of fertiliser to standing crops would become routine practice.
Malcolm (1962) has classified the site types normally available for forestry in Britain into three broad classes of soils, namely brown earths and leached brown earths; true and paraclimatic iron podsols and pseudogleys with shallow peat. This list excluded the skeletal soils and deep peats which were a minor part of the range of site types normally encountered.

In relation to rotation length, with suitable selection of species, any reasonable exploitable size should be attainable on freely drained brown earths. On these sites, short (40 year) rotations for the more productive species seemed wasteful of the site potential. However, where the soils were unstable, short rotations of shallow-rooting species might lead to loss of structure and a raised water table, due to lack of root penetration and colloid penetration, particularly if the litter was biologically inactive.

On clay loams and clays, sometimes gleyed, long rotations were excluded for a number of species which were unable to root adequately. Asphyxiation in winter and desiccation in summer eventually led to root infections or windthrow, as with Sitka spruce in British Columbia.

On the podsols, the choice of species was narrow and these soils would probably remain under pine. The
larger area of paraclimatic heath soils supported plantations after initial ameliorative treatment but the subsequent period of unaided growth remained in doubt. Single furrow ploughing for initial establishment might prove to have been insufficient for long rotations and it appeared unlikely to Malcolm that Sitka spruce could be grown for other than short rotations on these soils.

The problem of root restriction occurred again on shallow peat soils and aeration by adequate surface drainage remained the key problem, permitting exploration of the peat by tree roots and its dissipation by biological activity. Wind stability was likely to condition absolutely the rotation length. Where windthrow occurred the peat, disturbed and aerated, disappeared, leaving gleyed, compacted glacial till at the surface and presenting, possibly, a more difficult management condition than the shallow peat.

Thus, all soils, apart from brown earths and true iron podsols, were likely to have a marked effect on rotation length.

The choice of silvicultural system in Britain, with the need to maintain forest conditions and to provide for a measure of stability on the upland areas would probably be patch or group fellings which would allow
activation of accumulated humus while avoiding the worst effects of delayed regeneration. Malcolm held that mixed composition stands could only be justified on the grounds of increased production or soil improvement, as compared to pure stands on the same site. Under British conditions, he felt it to be advisable, probably, to have a proportion of leaf trees mixed with the species with a litter of high C:N ratio on the brown earths, as an aid to rapid circulation of the nutrients. The possibility of useful site amelioration had been established and only awaited the development of suitable techniques. On the more degraded sites, some form of nutrient addition might often be necessary and it appeared that the resulting improved conditions might be maintained by the introduction of species favouring a rapid circulation of the added nutrients.

f. Plant and Forest Utilisation Standard:

It will be readily appreciated that the creation of forests on a large scale in Britain, particularly with the recent policy emphasis on economic operation, has involved and still involves a very considerable financial risk. By and large, the forests have been created with an emphasis upon obtaining successful growth of exotics and it is only natural that the major forestry effort should have been directed toward biological considerations and factors of the environment. The disposal of produce
has been generally considered as the simple sale of roundwood to the existing outlets for sawtimber, chipboard, box-making, mining timbers and props and similar forest products. The impending introduction of a larger industry, along the lines of the Fort William pulp mill and the necessary modernisation of the sawmilling industry to cope with prevailing economic trends has led to an increasingly keen and detailed appreciation of the commercial requirements which, in the final analysis, will govern the financial success or otherwise of the British forestry enterprise.

The construction of the Fort William pulp mill was accompanied by the making of an agreement between the Forestry Commission and the pulp mill company, dealing with a guaranteed volume of log supply, prices and related matters. The author is familiar with the contents of this agreement but has not received permission to review its contents in this thesis. The position is not unusual, in the author’s view, since much of the background knowledge obtained concerning the internal operations of British Columbia industry and certain, related Forest Service information has been obtained on a similar basis. Also, negotiations are proceeding between Scottish private owners and the pulp mill company concerning the possibility of private log sales and these negotiations, again, must
be treated as confidential at the present time. In considering these factors, the author has decided to rely largely on published material which will illustrate some of the considerations involved in these recent developments.

Zehetmayr (1965) has discussed the optimum length for pulpwood, as it relates to place of conversion, loading, length of truck (lorry), stacking space at roadside, method of skidding and the preparation of logs after cross-cutting at the stump.

(1.) Place of Conversion:

On the premise that the carrying out of any operation in the forest was more expensive than doing it at a mill or landing, the de-barking operation was the most obvious operation to carry out at the mill. The public road system of Scotland, although extensive and well-surfaced, restricted maximum loads because of numerous bridges, steep hills, winding routes or underlying peat. Also, the forest road usually had as great a load-bearing capacity as did the public road system. The use of a lower landing (re-load point) for centralised mechanised trimming and cross-cutting (bucking) would introduce extra handling in the form of unloading and re-loading, without any corresponding cost reduction in the second stage of the haul. The maximum loads delivered to the
Fort William pulp mill were from 10 to 18 tons (380-500 H. ft. or 360-640 cu.ft.). If barking were to be eliminated in the woods and cross-cutting reduced to produce long pulpwood, then the question arose as to whether any work should be done at roadside, except for loading onto road transport after skidding.

(2.) Loading:

Manual loading, as practiced in many areas was, Zehetmayr emphasised, unacceptable and the small amounts of pulpwood available at any one place precluded the use of static loading devices. Relatively cheap cranes must be used, not needing to be fully employed to be economic, and they might be truck or tractor mounted. The truck-mounted cranes would only pay at more than one load per day - about 15 to 20 tons - where the truck operated over distances of less than 65 miles and, possibly, working shifts. The tractor-mounted cranes were more expensive but, with large enough supplies, could load more cheaply. The crane reach could be shorter than with truck-mounted units.

An articulated fleet (Pre-load system) with one "tug" or "tractor" unit carrying a crane was theoretically most attractive. However, a fleet of one loader, 2 tugs on shift operation and 6 or 7 trailers could handle over
12,000 tons of pulpwood per annum. The solution to be adopted for Fort William would probably be a compromise, using all three systems in different areas according to the distance from the mill, the output of the various forests in an area and the load restriction in force.

(3.) Length to Fit Trucks:

The longest piece that could be cross-loaded onto trucks for public road haul was 7½ feet, whilst, with longitudinal loading, one or two piles per truck of 8 to 12 feet in length could be accommodated, according to the length of the chassis. Lengths over 12 feet could only form one stack. An analysis of truck-length and pulpwood length showed that 7½ feet lengths, cross-loaded, fitted all truck types. All longer wood, loaded lengthwise did not fit certain sizes and wood 12 feet long only suited short or very long trucks. The taper of British thinnings generally exceeded 1 inch in 7 feet and stacks were awkward unless much of the load was turned and piled top to butt.

(4.) Road Spacing:

Calculations based on annual cut, movement cost for skidding by various methods and road costs indicated a general extraction road spacing of between 300 and 880 yards, as giving the lowest cost combination.
(5.) Stacking at Roadside:

With certain forms of skidding e.g. horse and winch, the movement of logs along a haul road was expensive as compared to movement by tractors or trucks. The provision of stacking spaces (landings) could be very expensive in hilly country and Zehetmayr stated that, under these conditions, the ideal for thinnings was to be able to pile timber all along the road. The stacks did not need to be unduly high even if 75 H. ft. (95 cu.ft.) of 8 to 12 feet lengths were skidded onto each yard of road and the carriageway was left sufficiently clear. Longer lengths had to be laid parallel to the road and the timber capacity per yard was reduced. The wider road spacings occurred with tractor extraction on flatter ground where the provision of extra stacking space was simple. For clearcuts, more space for stacking, not necessarily level, would be needed and progressive removal could be more easily arranged.

(6.) Skidding:

The bulk of pulpwood, at the time of Zehetmayr's investigation, was coming from thinnings. It had been found that wheeled tractors could not work in the vast majority of stands, owing to steep slopes and soft ground. Cost analyses of skidding showed that the choice of economic method lay between the double-drum winch and the horse.
Where wheeled tractors could work, road spacings could widen to half a mile and trailers of up to 3 tons capacity were used. Skidding tractors equipped with loading cranes were under trial with the intention of loading the skidding tractor trailer in racks and re-loading to main-haul trailers on roads. The main extraction methods for thinnings, recommended by Zehetmayr, were the Isachsen No. 3 double drum winch and by horse, with a skidding arch based on the Norwegian Lunnedrag.

(7.) Gathering of Loads for Skidding:

Since horse or winch skidding requires racks (lines of trees removed to provide skid trails), collection of loads in or near them was necessary and the faller did this by hand. The pulpwood length for optimum efficiency was 10 - 11\(\frac{1}{2}\) feet. By spacing racks 20 - 30 yards apart, the average distance which the logs had to be moved was about 3 yards. In early thinnings of Sitka spruce and on steep slopes, directional felling was impossible and the distance was increased to about 5 yards. Sawlogs were left as they fell and moved from stump by the winch. For horse extraction, the distances for hand movement of pulpwood are increased somewhat, since larger loads must be gathered.
Crosscutting (bucking) at the Stump:

Where the pulpwood length exceeded 7 to 10 feet, studies showed that bucking in the woods was more efficient (the amount of moving of poles and pieces necessary at the roadside outweighed the hindrance caused by branches cut off in the stand). One or two men with a chainsaw, carrying out thinning, bucking, limbing and piling for extraction by log winch produced 70 - 120 H. ft. (89 - 153 cu.ft.) per man day with an average tree size of 2 - 4 H. ft. (2.5 - 5 cu.ft.). Whilst output by a two-man team with a double drum winch had reached 550 H. ft. (700 cu.ft.) per day, much more training and experience would be necessary before this became a regular occurrence.

Logging teams of 4 to 8 men would work either horse or double-drum winch to produce from 2,500 to 5,000 tons a year (70,000 to 140,000 H. ft. approximately or 89,000 to 166,000 cu.ft.) and few forests would need more than two such teams.

Conclusion:

The conclusion reached by Zehetmayr, from the forest working aspect, was that the optimum length of pulpwood was from 10 to 12 feet, with a downward tolerance. For the Fort William pulp mill, including added considerations such as mill requirements, transport and reduction of waste, the decision was to employ 10 feet lengths, with
tolerance down to 8 feet.

Woolridge (1962) has discussed the timber requirements of the Scottish sawmilling industry. He argued that, if branches were small and sound in Norway and Sitka spruces, Douglas fir and lodgepole pine, then pruning should be avoided. However, in species such as Douglas fir, Sitka spruce and Corsican pine where branch whorls were pronounced and branches might be coarse, a loss of grade would occur. At best, the price difference would be that between first and third grade timber and, at worst, that between third grade timber and pulpwood. In this case pruning might be advantageous but, apart from the production of sawlogs, should be avoided, if possible. Good tree breeding would assist quality. It was important to achieve straightness of stem to obtain a log length competitive with that from which imported Scandinavian lumber was produced. Ring width and strength were not the problems they were considered to be, although the greater shrinkage of wide-ringed and non-resinous woods needed different shrinkage allowances in conversion. The existing grading rules* specified not less than 8 rings per inch for Grade I and not less than 4 per inch for Grade II. Other grades were not qualified in terms of rings per inch. The

* As defined in the Department of Scientific and Industrial Research Leaflet No. 49
difficulty of marketing timber not in constant supply, in terms of both quantity and quality, was stressed, the exception being good European larch which would always find a market. The size of a log was its least important aspect and the bulk of the timber trade's requirements could come from logs of 8 inches top diameter and larger, with an average top diameter of 10 inches and in lengths of from 8 to 20 feet, averaging 14 feet. The proportion of logs required to make up into 10'' x 3'' battens would be about 15 percent of the total log volume and should be 14 inches top diameter and larger, averaging 15 inches top diameter and from 17 to 22 feet, averaging 19 feet, in length.

Woolridge complained of onerous conditions imposed by the Forestry Commission in the sale of timber. He estimated that a reasonably efficient sawmill needed about 250 M. cu.ft. of logs per annum which would require the cutting of at least 1 MM. cu.ft. of trees per annum by a timber merchant. However, these amounts were insignificant when compared to the volume required by one selling organisation capable of making an efficient entry into the market. For many years, the customer for home-grown forest products would have to be a small user and, in order to change this pattern, big quantities of timber would have to be available to the merchant developing the home
timber market. The large quantity of standing timber which had to be logged to produce the needed amount of timber could result in difficulties in disposing of small round timber until pulp mills began to operate. However, the sudden, large demand of a new pulp mill could be difficult to meet. Woolridge also held that the price of small-size thinnings had been too high in recent years, although the price of standing timber should be as good as that in other parts of the world.

Other authors have concerned themselves with the quality of home-grown wood. Phillips (1962) presented a paper to the Society of Foresters of Great Britain, considering the anatomy of softwoods and its influence on timber quality. In a discussion which followed, it was concluded that moderation should be the aim both for density and ring width. The structure of British-grown timber was considered to be adequate and not inferior to that of imported timber.

g. Road Transportation:

The Forestry Commission (1967c) reported that there were in Scotland, at the end of 1966 forest year, 3,109 miles of forest roads in use. This figure compared with 2,928 miles at the end of 1965 and 2,662 at the end of 1964.
Davidson (1967) has considered the road transportation of Scottish roundwood and his comments and observations are worthy of review in some detail. He noted that when land is under forest in full production, the tonnage of produce to be removed annually might be between 30 and 50 times as much as the land previously produced in the form of livestock and other agricultural produce. There would also be more people employed so that access roads would be required which could sustain a greater volume of traffic. Also, re-appraisal of their standards was needed to carry the heavier types of vehicles used both for forestry and agricultural purposes.

In 1965, the total Scottish timber output was about 760,000 tons and the average haul distance was 75 miles. By 1970, the total quantity was expected to rise to 1 million tons but the average haul might be reduced to 70 miles for logs and sawn mining timber. Generally, the 75 mile average haul of 1965 would cost between 25 and 30 shillings per ton or a total 1965 cost to the Scottish forest industry of 1.05 million pounds. Allowing for a unit cost of between 23.5 and 28 shillings per ton for the 70 mile average haul in 1970, the total cost might then be 1.29 million pounds.

The location of forests to produce timber during
the next 15 to 20 years was fixed and the ability to make new plantations in closer proximity to wood-using centres was limited by, for example, land-use policy, continuing availability of land at any time for the maintenance of the steady expansion of the afforestation programme and the creation of rural employment in districts which might be further from the mills. Planning of this kind, Davidson felt, must also make assumptions, which may be of doubtful validity, on the location of the best markets for all classes of forest produce long after 1980.

The rising output from forests not yet in productive state would affect average hauling distance, depending on the scale of operations at any point of operation. The nearest 2 million H. ft. (2.55 M.M. cu.ft.) of small roundwood to Carlisle from Scotland would, in 1970, be hauled 65 miles but, in 1980, 45 miles. Similarly, the nearest 1 million H. ft. (1.27 M.M. cu.ft.) to Aberdeen in 1970 would be hauled 27 miles but in 1980, 20 miles. The nearest available 6 million H. ft. (7.6 M.M. cu.ft.) of small roundwood, in Commission forests, to Fort William in 1967 was 81 miles but, in 1980, would be 75 miles.

Some relief in roundwood hauling costs might derive from improved handling costs e.g. woods de-barking (to reduce bark and excess water weight). As quantities
of wood coming from groups of forests increased, the conditions justifying the organisation and outlay on forest de-barking equipment would improve.

Considering the standards of Scottish roads, they could be improved to permit maximum haulage in vehicles of large capacity. The difference in cost, in 1965 and 1970, between carrying all wood as 12 ton loads (17 tons gross) and 16½ ton loads (24 tons gross) was between 200,000 and 225,000 pounds sterling annually. Further savings, though at a reducing rate, would accrue from carriage in 20 ton loads (about 30 tons gross). As against these attractive savings, the costs of improving many minor country roads to a 24 ton or 30 ton standard was very high and the annual savings to the forest industry by itself did not provide sufficient financial justification for any immediate and general improvement to all forest access roads.

Scottish Pulp and Paper Mills, the Scottish Development Department and the Forestry Commission in 1962 made a joint survey to assess the priorities over the entire Highland area. The pulp mill at Fort William required 200,000 tons of wood annually from Commission forests scattered over the area. The average distance to the mill was 80 miles and the use of vehicles with capacities of at least 12 tons (the minimum standard agreed for forest
roads) and preferably 16 tons (or about 24 tons gross, the main public road standard at the time), was needed.

The volumes of wood-hauling traffic along the various roads was determined and, in one case (the Tyndrum-Glencoe route), British Rail successfully competed on a heavy volume route. A road capability survey divided the total tonnage for delivery into percentages that could be transported in various sizes of unit loads and the survey was modified where re-routing considerations offered a more economical haul. Finally, three road priority categories were assessed, as follows:

<table>
<thead>
<tr>
<th>Scottish Road Priority Categories for Wood Hauling</th>
</tr>
</thead>
<tbody>
<tr>
<td>Priority</td>
</tr>
<tr>
<td>---------</td>
</tr>
<tr>
<td>I</td>
</tr>
<tr>
<td>II</td>
</tr>
<tr>
<td>III</td>
</tr>
<tr>
<td>TOTALS</td>
</tr>
</tbody>
</table>

The remaining 138,000 tons per annum were capable of being hauled to the mill along routes already suitable for 16 ton net loads. In the final compromise decision, it was agreed that all roads in Categories I and II should be improved to the 24 ton gross standard. This was held
to yield maximum advantages for minimum expenditure. Compared with a scheme for general improvement, it was found to be possible to cut expenditure on roads by 66 percent, but at the same time, to reduce the volume of traffic affected by restriction from 40 percent of the total to only 4 percent.

The standards of road construction and provisions for administrative control within the Forestry Commission are contained in a series of memoranda issued by the Chief Engineer of the Commission.

From the author's observations there is a great deal of interest in forest roads at the present time, particularly in relation to the initial standard of road required and road layout for extraction. In addition, extensive improvements to Scottish public road standards are under way, as described.

h. Forest Utilisation:

The following table has been derived from the Forestry Commission (1965e; 1966e; 1967f) and show the volumes cut in three years:
### AREAS OF PLANTATIONS AND VOLUMES OF FORESTRY COMMISSION TIMBER
### THINNED AND FELLED - 1964 - 1966

<table>
<thead>
<tr>
<th>Year</th>
<th>Forest Area</th>
<th>Area (Acres)</th>
<th>Volume MMHF</th>
<th>Volume MMcf</th>
<th>Area (Acres)</th>
<th>Volume MMHF</th>
<th>Volume MMcf</th>
<th>Total Volume Felled and Thinned MMNF</th>
<th>MMcf</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Scotland</td>
<td>465</td>
<td>1.030</td>
<td>1.3</td>
<td>19,204</td>
<td>7.522</td>
<td>9.6</td>
<td>8.552</td>
<td>10.9</td>
</tr>
<tr>
<td></td>
<td>North (S) Conservancy</td>
<td>126</td>
<td>0.588</td>
<td>0.7</td>
<td>2,564</td>
<td>1.229</td>
<td>0.9</td>
<td>1.817</td>
<td>1.6</td>
</tr>
<tr>
<td>1965</td>
<td>G. B.</td>
<td>4,904</td>
<td>7.929</td>
<td>10.0</td>
<td>47,143</td>
<td>20.444</td>
<td>25.9</td>
<td>28.373</td>
<td>35.9</td>
</tr>
<tr>
<td></td>
<td>Scotland</td>
<td>656</td>
<td>1.434</td>
<td>1.8</td>
<td>19,604</td>
<td>8.456</td>
<td>10.8</td>
<td>9.890</td>
<td>12.6</td>
</tr>
<tr>
<td></td>
<td>North (S) Conservancy</td>
<td>336</td>
<td>0.565</td>
<td>0.7</td>
<td>2,141</td>
<td>1.316</td>
<td>1.7</td>
<td>1.881</td>
<td>2.4</td>
</tr>
<tr>
<td>1966</td>
<td>G. B.</td>
<td>5,418</td>
<td>8.624</td>
<td>11.0</td>
<td>50,868</td>
<td>22.331</td>
<td>28.3</td>
<td>30.955</td>
<td>39.3</td>
</tr>
<tr>
<td></td>
<td>Scotland</td>
<td>770</td>
<td>1.864</td>
<td>2.2</td>
<td>21,794</td>
<td>9.956</td>
<td>12.6</td>
<td>11.820</td>
<td>14.8</td>
</tr>
<tr>
<td></td>
<td>North (S) Conservancy</td>
<td>165</td>
<td>0.526</td>
<td>0.7</td>
<td>3,461</td>
<td>2.223</td>
<td>2.8</td>
<td>2.749</td>
<td>3.5</td>
</tr>
</tbody>
</table>
The bulk of the timber cut was sold standing. Of the timber converted by the Commission, the two major items sold by the Commission, during the forest year 1966, were pulpwood and board mill material and sawlogs.

Private fellings may be derived from the Forestry Commission (1965c; 1966d; 1967d) reports of the volume of timber licenced for felling and thinning, as follows:
VOLUME OF TIMBER LICENCED FOR FELLING AND THINNING ON PRIVATE ESTATES IN GREAT BRITAIN AND SCOTLAND DURING THE FOREST YEARS 1964 - 1966

<table>
<thead>
<tr>
<th></th>
<th>1964</th>
<th></th>
<th>1965</th>
<th></th>
<th>1966</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>G. B.</td>
<td>Scotland</td>
<td>G. B.</td>
<td>Scotland</td>
<td>G. B.</td>
</tr>
<tr>
<td></td>
<td>MMHF</td>
<td>MMcf</td>
<td>MMHF</td>
<td>MMcf</td>
<td>MMHF</td>
</tr>
<tr>
<td>Total Volume</td>
<td>17.811</td>
<td>22.6</td>
<td>5.340</td>
<td>6.8</td>
<td>16.790</td>
</tr>
<tr>
<td>Conifer</td>
<td>7.357</td>
<td>9.3</td>
<td>4.107</td>
<td>5.2</td>
<td>7.537</td>
</tr>
<tr>
<td>Broad-leaved</td>
<td>10.454</td>
<td>18.4</td>
<td>1.233</td>
<td>1.6</td>
<td>9.253</td>
</tr>
</tbody>
</table>
Hart (1962a) has described the system of felling licences by which the Forestry Commission regulates the felling or sale for felling of privately owned growing trees, under the provisions of the "Forestry Act, 1951". There are a number of minor exceptions to felling by licence, the important exception being dedicated woodlands, where an owner may fell in accordance with the agreed Plan of Operations, without a licence. In addition, an owner may fell up to 825 H. ft. (1050 cu.ft.) of timber per quarter of a calendar year for use on his own property. When issuing a licence and, where it is in the national interest that the ground be restocked, the Forestry Commission is empowered to include replanting conditions in the licence and the owner may claim the appropriate planting grants. If the Commission refuse a licence they must state their reasons and an owner aggrieved by a refusal or by the conditions imposed may have the case referred to an impartial committee appointed by the Minister of Agriculture, Fisheries and Food or by the Secretary of State for Scotland. Where the refusal of a licence may mean a loss in value of the trees owing to timber deterioration through age, the owner is entitled to compensation from the Forestry Commission.

Also, under the provisions of the "Forestry Act, 1951", the Commission, at their discretion, may direct an
owner to fell trees within a specified period of two years in order to prevent or check deterioration in the quality of the timber or to improve the growth of other trees. The Commission is required to consider farming interests, amenity and any advice tendered by the Regional Advisory Committee of the Conservancy in which the trees are growing. An aggrieved owner has rights of redress rather similar to those afforded him under a felling licence. The Forestry Commission have the power to enter upon private property and carry out the felling direction themselves, after three months notice and the owner again has a right of application to appeal against such an action. The Commission is not permitted to direct the felling of trees which are under a Plan of Operations for Dedicated or Approved Woodlands.

Baldwin* has discussed Forestry Commission sales of standing timber. The Commission have stated their policy at the request of the Home Grown Timber Advisory Committee. The Commission did not foresee that it would enter into the sawmilling industry. However, on the question of how much timber should be felled and prepared to end-use specification by Commission labour and how much should be

* Mr. Baldwin discussed the disposal of Forestry Commission timber with the author at the Commission's London Headquarters on 31st. May, 1967.
sold standing to timber merchants, as favoured by the Trade Associations, the Commission was not, in effect, prepared to commit itself but held that the proportion would be variable in the light of many factors such as contractual obligations, established practices, the capacity and work quality of the local trade, the availability and maintenance of Commission labour, local markets and prices which timber merchants would pay. The Commission thus insisted on retaining flexibility although it estimated, without guarantee, that by 1970 the volumes of softwoods available for felling by the trade would have increased to about 5 M.M.H.F. (6.4 M.M.c.f.) in England, 10 M.M.H.F. (12.8 M.M.c.f.) in Scotland and 4 M.M.H.F. (5.1 M.M.c.f.) in Wales. In 1965, the figure for Scotland was 6.8 M.M.H.F. (8.55 M.M.c.f.).

Baldwin noted that approximately one-half of the annual production of Forestry Commission timber was sold standing and one-half was cut by Commission labour. All of the standing material was sold competitively and the volume of a sale might range from 20 M to 300 M.H.F. (25.5 - 832 M. cf.). The volume was determined by measuring the quarter-girth of every tenth tree marked to be cut and every hundredth tree was cut down and measured for height and mid-girth to determine volume. The measurements and results are made available to the timber merchant who then
makes an offer, following his inspection which must be completed by a specific date. Until 1964, it was the custom invariably to accept the highest offer but this had been changed to a policy of normally accepting the highest offer but reserving the right to allocate to another bidder, either by reason of consistently poor performance by the highest bidder or allocation to the highest bidder would seriously disrupt the existing industry. On this basis, very few auctions had been held for two years and the Commission considered that auctions or tenders held the disadvantage that a contractor might have to move from forest to forest, rather than be able to locate in a particular forest. There was a strong possibility that the Forest Commission would, in the future, allocate 80 percent of a merchant's requirements to him at a negotiated price but he would have to acquire the balance by competitive bidding. The timber is sold as a lump-sum sale, rather than by the payment of stumpage on the volume recovered by logging. Prices for roundwood would normally vary from 1d and 3d up to 25s per Hoppus foot with the price varying according to size, quality and distance to market. 3s to 4s was considered normal for good quality timber. The average price for standing timber was 1s per Hoppus foot. In Scotland, in 1965, it was 14.2d per H. ft. (18.2d per cu. ft.). Sales of standing timber or
felled timber (the latter may be sold by volume or by weight) were normally arranged in 12 month lots and payment was flexible - for example a purchaser might pay one-sixth of the lump sum for one-sixth of the trees and pay periodically for further rights to cut. In these lump-sum sales, where the estimated volume fell short, the Commission was usually sympathetic and will meet the purchaser.

Commission fellings were usually conducted on a piece-work basis, using Commission equipment, although there was a trend for fallers to own their own saw. Tops were cut to 3 inches. In the case of poles or pulp timber most of the de-barking was by machine. There was also a tendency to train production teams to specialise in timber production.

Sales accounts were and are kept by individual forests and consolidated into Conservancy accounts.

i. Forestry Commission Management Plans:

The Forestry Commission (1968) was currently preparing Conservancy plans consisting of four basic elements, which were:

(1) long term planning and investment appraisals
(2) programmes and forecasts for five years ahead
(3) annual budgets
(4) control (e.g. through Conservancy Annual
The main purposes of the Conservancy plan were to achieve the Commission's forest authority (e.g. timber licencing, dedication scheme) and forestry enterprise (Commission forests) objectives and these were:

(1) As a forest authority by:-
   a. Implementing legislation, mainly concerning private woodlands and plant health.
   b. Undertaking and/or aiding research, education or training.
   c. Assisting industrial and social development connected with forestry.
   d. Paying due regard to amenity, recreation and wild life.

(2) As managers of the National forestry enterprise by:-
   a. Undertaking new planting as directed by the Government.
   b. Giving due consideration to other land use interest.
   c. Safeguarding and enhancing the beauty of the landscape.
   d. Conserving and controlling wild life.
   e. Meeting reasonable requirements for access
and other recreational facilities.

The Conservancy planning system was also designed to ensure that forestry development in a particular Conservancy was consonant with regional developments outside forestry which had been approved by the Government. The system planned and controlled forestry investment; facilitated the orderly devolution of authority and responsibility to Conservators and provided a reasoned basis for five-year forecasts, programmes and annual budgets. The plans were a permanent working document with no fixed period but subject to amendment whenever considered necessary. It was reviewed as a whole once a year by the Conservator and was controlled as a part of the Commission annual budgeting and reporting system. The plans were prepared under a standard set of headings and were subject to approval by the Director General of the Commission.

Once these plans were in operation, it was intended to prepare Forest Plans, with powers of sanction delegated to Conservators. The Forest Working Plan area was the basic unit of the enterprise where data were collected and programmes carried out, so that specific plans were considered to be essential. They must also conform to Conservancy Plans and, because the most important general matters would have been decided in the Conservancy Plan,
the Forest Plans were expected to be relatively simple and concise, with an emphasis on tabular presentation.

j. Effects of Wind:

In any review of Scottish forest management it will be essential to consider the effects of wind. In the first place, the actual amount of windblow has proved to be a critical factor which, in some areas at least, will probably prove to be limiting to the length of rotation and dependent factors. Secondly, wind, coupled with other contributing factors, has had and may well continue to have an important effect upon wood quality, possibly to the extent that it will be a determining factor in choice of provenance or even of species.

The Society of Foresters of Great Britain (1966) has discussed the problems of windfall in relation to Northern Ireland. Jack noted that at Cam Forest, woods reaching the thinning stage had been planted on a wide variety of soil types (mineral soil, shallow peat over banded clay and drift soils, and deep peat) and were often unstable in the wind regime of the area. Windfall problems, coupled with fire damage and uneven growth rates, had raised management problems. Should a clear felling or selective system be adopted? If selection, should it be single tree or group selection? If group selection, how
big should the groups be? If thinning was conducted, how should it be done? How far should management be influenced by markets, economics or silviculture?

Another speaker, Jones, held that technical developments could not be foreseen and it was very doubtful whether long-term management towards supplying specialised industries was a logical approach. Jack pointed out the world trend towards reconstituted wood which, in association with windthrow difficulties, made a strong case for shorter rotations. Penistan held, in connection with stand size and distribution, that the imposition of formed and relatively simple distributions of age classes, on short or long rotations, was unlikely to be a permanent solution. The more arbitrary the distribution, the more likely would be windthrow and other disturbances. The greatest stability and least disturbance of planned production would be likely from a stand distribution based on site and cutting should aim at presenting the maximum number of wind-firm edges. Concerning rotations, although most production might be for pulp, larger average-sized trees were cheaper to handle than the smaller average-sizes and this situation was likely to become more marked as the cost of labour increased. Thus, it was wiser to have smaller, (rather than larger) stand units with random age distribution and the larger tree sizes should be grown.
The aim should be, in short, to have the longest practical economic rotation in stands based on site distribution.

Pyatt (1966) has described soil and windthrow surveys of Newcastleton Forest, Roxburghshire. The soils were classified into well-drained soils (brown earths and iron pan soils), poorly drained impeded soils (surface-water gleys and peaty gleys) and deep peats and they were mapped at a scale of 6 inches to one mile. The susceptibility of individual trees and of crops to windthrow on the different soils was investigated by overturning trees with a standard winching technique and by a survey of actual damage. Deep rooting and relative stability were associated with the well-drained soils and deep peats. The distribution of windthrow suggested that, on topographically exposed sites, risk was greater than on sheltered sites and this relationship provided a reasonable basis for forecasting the time and damage.

Busby (1965) has emphasised that, in addition to soil moisture and topographical influence, windfall is affected in an important way by depth of crown, stand age, stand structure and treatment. In the Scottish Borders region, Williams and Milne Home (1963) stated that the instability of forest crops had caused disquiet. At one forest (Newcastleton), however, fears for the stability of
the whole crop proved groundless. The small amount of windfall that did occur was thought to be largely due to the unsatisfactory drainage systems in the earlier plantations, along with lack of sufficient early thinnings. Nevertheless, windthrow was a threat in the Border forests and made any system of clear felling undesirable. The sporadic patches of windblow and similar gaps made by felling would be regenerated, forming a silvicultural system of management. Thus, the great influence of potential windthrow upon Border Forest management would be counteracted by good drainage, the creation of an irregular stand canopy and the admixture into the shallow-rooting spruce of deep rooting trees as a "firm framework".

Edwards, Atterson and Howell (1963) investigated damage created by wind during the winter of 1959-60, when trees planted from four to eight years earlier were loosened and blown about, although few were blown flat and practically none killed. Many such trees subsequently stabilised themselves, although with a permanently bent butt. This kind of damage had not been noticed before on a large scale. The trouble had been serious among pines planted in ploughed ground on some exposed hard upland heaths in eastern Scotland and north-eastern England. Most of the trees had been fertilised with ground mineral phosphate to obtain good growth on the poor soils. The
problem did not appear to be one of normal exposure. The investigation consisted of root excavation and analysis, co-related with top weight and stem length. Principally, the investigators were trying to determine if morphological differences in the pines accounted for stability variations, what differences between pine and larch were important to the differing stability of the trees and why trees planted on the exposed top of ploughed furrow ridges were more stable than those planted in the furrow. There were no loosened pine trees on ridges. The findings, with reference to pine, were indeterminate in that, although there was some evidence that loosened trees had higher root systems than stable trees, this was not always found to be the case. No qualitative differences occurred in root form or distribution, greater elasticity of stem and absence of needles during the winter. In addition, larch achieved a more intimate mechanical union with the soil, both by its ability to develop new and adventitious roots around the base of the stem and because its roots are generally finer and more numerous.

The differences between ridge and furrow planting were investigated. In the case of larch, it was found that root differences between ridge and furrow planted trees were small, indicating a possible reason for the overall stability of the species. The species was able to
attain the same balance of root and top growth in both positions. However, the stable and unstable pine had almost exactly the same top-root weight ratio but there did appear to be a greater proportion of widely-spread roots among the ridge-planted trees. In the case of trees planted in the furrow, the roots rarely penetrated the channel made by the tine and lay mostly on a level with, or even above, the planting position. A further reason for the greater tendency of pines to loosen when furrow-planted might be the holding power of the rooting medium. The few top inches of soil in the furrow were loose, whereas the rooting zone on the ridge was held together by numerous roots and stems of the vegetation. There were some indications that more intensive ploughing and sub-soiling aided root development. A suggestion that the loosening of trees had been facilitated by bad planting practice was unsubstantiated, as was the idea that phosphate application affected tree development in a way that decreased stability. The authors gave, as the primary reason for wind-loosening, the unsuitable and inadequate cultivation of soils which were impermeable to roots. Amongst other recommendations, it was felt that tree stability should be tested by a measured pull to determine whether differences in direction of root growth between furrow-planted and ridge-planted pines might explain the
differences in stability.

Andersen (1954) thoroughly discussed the effects of the wind-storm of 31st. January, 1953, in the north-east of Scotland, during which more than 45 million cubic feet, mainly of coniferous species, were windblown. Considering the wind climate of Scotland it appeared to him that, although gale risk was a serious factor in forestry in the region, very few gales during the previous 250 years had attained a violence comparable to that of the 1953 storm. The principal cause of the varying degree of damage was considered to be the local distribution of extreme gusts, modified by topographical features. A marked co-relation was found between the height of trees and incidence of wind-throw, few stands of less than forty feet in height having been damaged. Although the susceptibility of tree species was not assessed quantitatively, Andersen felt that the performance of Scots pine was discouraging. Species of larch proved to be generally resistant and species of spruce were unstable, although there were instances of spruces not being more severely damaged than pine, on similar sites. Douglas fir showed some instances of being wind-firm to a surprising degree. Of the edaphic factors, the effect of compacted soil horizons on depth of rooting was clearly important and, on the question of stand layout and tending, it was concluded that wind-resistant margins
were important in the prevention of gale damage.

It is interesting to note that 16 gales, almost all exceeding 90 m.p.h. in wind-speed and all damaging to forests, have occurred in Scotland and northern England from 1838 to 1958. The two of 1953 and 1958 blew down approximately 85 M.M.H.F. (108 M.M.c.f.), a very large volume considering the size of Scottish forests and the available outlets for wood.

k. Rusts and Fungi:

Gladman and Low (1963) have described the five most important conifer heart rots occurring in Scotland and their causative fungi - *Fomes annosus*; *Polyporus Schweinitzii*; *Armillaria mellea*; *Trametes pini* and *Stereum sanguinolentum*. In management it was common to paint stumps with creosote to prevent infection by *Fomes annosus*. An important consideration for management lay in the question of crop succession. Where one crop succeeded another the problem was not one of keeping out new infection, as in first rotation crops, but of dealing with that already established in the existing stumps and providing a direct source of infection for the new crop. Apart from small, special areas having an alkaline soil reaction, pine might continue to succeed pine without serious risk of crop deterioration from *Fomes*, even though the fungus became
well established in the stumps. If, however, pine was replaced by another genus (as was common with Scots pine, the economics of which were widely questioned), the question of rot fungi became important since the pine, resistant to attack itself, readily provided in its stumps excellent sources of infection for the succeeding, susceptible species.

*Armillaria* was important as a root-rot fungus, causing little stem decay but producing increased susceptibility to windblow, particularly if heavy thinning was employed. *Thuja plicata* and *Tsuga heterophylla* were susceptible tree species. Killing by *Armillaria*, however, seldom caused more than irregularity of stocking.

The *Trametes* and *Polyporus* could be ignored from a management point of view. *Stereum sanguinolentum* was only important as a coloniser of wounds but required care to be taken in extraction operations, to avoid damage permitting its entry.

The authors stressed that the existing low incidence of these decays in Britain was closely linked with the immature condition of the majority of conifer crops and was not a static condition. However, the choice of rot resistant species, where possible, coupled with judicious crop management, regular stump treatment and good extraction practice could materially reduce the
incidence of decays. The tendency towards shorter rotations itself did much to reduce the problem.

1. Forest Thinning:

Unlike British Columbia, where thinning practice is virtually non-existent, British conifer forestry almost invariably involves the practice of periodic thinning. Taylor (1964) has given an historical review of, and an account of research into, thinning and has emphasised that advances in thinning practice are expected to be associated with increased knowledge of tree physiology.

Matthews (1963) has noted the trend, in Britain, toward rather heavier thinnings made less frequently, a trend which made necessary careful choice of the trees retained. The trees to be favoured were those that produced the greatest quantity of wood for the space they occupied and, based upon genetical and physiological knowledge, Matthews suggested that close attention should be paid to crown length and width, density of foliage and seed production in attempting to select the most efficient trees.

Thom (1964) has emphasised the necessity of basing thinning policy upon an appreciation of the economics of certain courses of action combined with an appreciation of
efficient silviculture. It was also necessary to have adequate forecasts of forest produce in advance so that they could be matched with likely demands from new wood-using industries throughout Great Britain. On the basis of likely markets, Thom pleaded for "intensive" and "extensive" forestry within definite production zones, which would allow the planning of thinning policy, accordingly.

Crowther (1964) has briefly examined the main factors that the results of work study suggested had the greatest influence on the efficiency of the thinning operation. A larger pole size would increase output and reduce costs and the Scottish eclectic thinning produced a larger pole in first thinnings. Wider spacing of plants would be expected to produce trees of larger size in the early thinnings, although heavier branching in the earlier stages and loss of increment by delayed closing of the canopy could be expected to result. However, the branching problem could be overcome by pruning. The increase in volumes cut per acre and an increase in the total volume cut at any one place, at any one time would reduce costs. The layout of extraction racks and trackways was of prime importance in the efficient conduct of early thinning operations. The end-product had an affect on costs and a price length range of from 10 to 15 feet.
appeared, under British conditions, to be the best compromise between long poles which caused damage in extraction and short pieces of, say about four feet, which tended to be more expensive because of the extra handling involved with large numbers of small pieces. Mechanisation promised some improvements of method but relatively slow progress had been made. Tree felling occupied 10 to 15 percent of the total production time, limiting the savings that the power saw could achieve. The removal of branches remained a problem, even though power saw techniques could be used. In thinning extraction, the double drum winch was proving to be promising and, on easier ground where a wheeled tractor could operate, a combination of tractor and Hiab Elefant Grab loader was promising. The provision of production incentives and the training of young forest workers would improve costs and production.

MacMillen (1964) referred to some aspects of extraction engineering with reference to thinnings. The optimum road density, of particular importance in large-scale planning, could be calculated by means of the formula developed by Grayson (Empire Forestry Review, September, 1958), which provided a useful guide, although its results should not be rigidly applied. Topography remained an important factor in influencing the extraction equipment to be used and thus modifying the theoretical
road spacing. The road standards employed should permit the use of vehicles with a high pay-load direct to the market from the nearest point of extraction, particularly where the timber was to be transported a considerable distance to its market. Extra costs were involved in reloading or using small vehicles. MacMillen stressed that consideration of axle load and the extent to which that load was applied repetitively would lead to structural decisions on sub-grade surfacing and drainage, including culvert, specifications. If the surface was not sealed, it might lend itself readily to mechanical maintenance.

Stirling (1964) has dealt with the silviculture of thinnings in young and middle-aged crops. The quality of the crop and the need to overcome economic objections by a flexible approach to thinning were recognised. The importance of light as a major factor in photosynthetic efficiency, the role of smaller trees in the crop, tree selection and qualitative aspects of thinnings were discussed. Stirling held that much evidence pointed silviculturally and economically to a higher intensity of thinning, at least to the point of light saturation in stands within the period of increasing current annual increment. Heavier, early thinnings were needed in the faster-growing conifers if good proportionate crowns were to be maintained. The development of an increasingly
large crown was a condition for existence in the stand. Some form of crown thinning was indicated and low, light, early thinning, removing the smaller, most suppressed trees did not help the crop to grow any better. A heavy thinning from below was, in effect, a form of crown thinning. The use of sub-dominants in a stand, branch thickness, canopy depth, flexibility in thinning treatment and best tree selection at the first thinning were all considered. As a result, Stirling believed that the Scottish eclectic thinning method, although not fully developed, provided a most practicable, positive and dynamic approach to thinning, giving a flexible, progressive method of selection and with positive economic advantages in early thinnings. To reduce windblow risk, drainage maintenance must be carried out as an integral part of the thinning operation.

Dickson (1964) felt that further research was needed into provenance, planting distances and pruning, so as to obtain the highest net returns from thinnings. The net discounted revenue position of crops grown with the objective of making no thinning could be investigated and compared to normal treatment. The effects of new extraction methods on increment and thinning methods, as well as the economics of each type of thinning over a
crop rotation needed more research coupled with a better knowledge of how increment was laid on in relation to thinnings of different grades. Tree physiology, the thinning of older crops in relation to the formation of the subsequent crop needed investigation and the planning of future industry developments should be aided by producing statistics of yield under the Scottish eclectic thinning method.

Cooper (1963) discussed the difficulties in the marketing of thinnings due to over-production in the five years preceding 1963 and recommended control both of the quantities supplied and of prices. He wanted to see, firstly, the creation of a Committee, at the highest level, of representatives of the Forestry Commission, Timber Growers' Organisation, producers and wood-using industries to agree what products could be taken from the woods each year and the minimum prices for each market. Secondly, the Timber Growers' Organisation should be a collecting pool for information on produce coming forward from private estates and, thereby, Regional Marketing Agencies should be set up to offer services to both the wood-using industries and the estates to agree quotas and allocate them to individuals to ensure a regular flow of produce into the mills and collieries.

This concludes the review of literature for Scotland.
CHAPTER 7

PROBLEMS AND POSSIBILITIES FOR THE FUTURE

1. Forest Ownership and Tenure:
   a. Structure of the State Forest Authorities:

   The forests of British Columbia are almost all vested in the Crown in right of the Province. The policies which govern them are developed by the Government and controlled by the Provincial Legislature in quite a direct way. A Standing Committee of the Legislature investigates forestry questions directed to it by the Minister of Lands, Forests and Water Resources. The revenues received from and expended upon forestry are controlled by the Provincial Legislature and, in certain fields, by the Government of Canada. The Forest Service regulates and administers the forests within these legislative and monetary bounds and its management is extensive in form. This form of policy making requires relatively frequent amendments to the "Forest Act", so as to allow the Forest Service administration to meet changing circumstances. Also, it has led, along with staff and money shortages, to an extraordinary complexity of forest regulatory and administrative control measures.

   The State authority in Britain, the Forestry Commission, is a different form of authority. About one-half of the British forests are vested in the Commission-
ers. Whilst the use of the Commission lands is governed by other Departments of Government, such as the Department of Agriculture, once it has been determined to use land for forests, the Forestry Commissioners themselves become the policy makers and managers of it, and control all of their expenditures within the limits imposed by Treasury loans, and receipts. The management of Forestry Commission forests is intensive and they conduct many of the operations with their own personnel, unlike the British Columbia Forest Service which tends to rely upon supervision of the forest industry, which normally conducts the logging operations. The British Columbia Forest Service does, however, maintain a fire suppression organisation and grows virtually all of the seedlings and transplants used in the Province. There has been a strong tendency, however, for the Forest Service to delegate forest management and operations, under a variety of tenures, to industry, retaining to itself the right of approval and ensuring compliance to agreed or approved measures by means of its own supervisors.

In addition to the management of their own forests, the Forestry Commissioners have powers, derived from Parliament, to regulate the cutting of produce in private woodlands and, through the Dedication and Approved Woodlands schemes, to pay grants to private woodland
owners for planting and maintenance. The Parliamentary Legislation governing the Commissioners is relatively small in volume and has not, in the past, been subject to frequent legislative amendment, as has been the case in British Columbia. In considering the problems and possibilities for Scotland and British Columbia, it is important that the differences in the structures of the State authorities are recognised. The Forestry Commission, in theory at least, is a body possessing more direct power of policy-making and management and financial decision than is the Forest Service.

b. The Management of State Lands:

(1) The vast Crown forests of British Columbia, by their very size, present great difficulties to management, particularly when the low density of population of the bulk of the Province is taken into account. It is clearly impossible for the Forest Service to intensively manage all of the Crown forests itself at the present day and there are considerable difficulties for the Forest Service to manage them extensively. This is particularly the case when British Columbia Government, wishing to restrain the growth of the Provincial Civil Service, have not permitted rapid growth of the Forest Service. In addition, as has been described, both the Canadian and Provincial Governments have diverted sub-
stantial funds derived from the Provincial forests and the dependent forest industry to purposes other than forestry. Under these circumstances and because the policies of successive Provincial Governments have aimed at fostering the development of forest industries, there has been devised a succession of forms of tenure. In general, these have ranged from earlier forms, providing simply for liquidation of standing timber with a royalty payable to the Province by the holder of the tenure to recent, more sophisticated and complex forms, in which licencees are required to manage fully the units of tenure on a sustained yield basis, under supervision of the Forest Service. It is of interest to comment on some of these tenures.

(2) Timber Berths:

Timber berths were originally granted by the Canadian Government within the Railway Grants ceded to it by the Provincial Government. These lands and administration of the Berths were returned to the Province in 1930. The berths provided that the owner could cut all timber above 10 inches d.b.h.o.b., upon payment of a specified royalty per unit of volume. It was provided that a berth owner must operate a conversion plant of a certain size to utilise the produce from the berth at a stated rate.
Also, logged lands or areas of young growth were to be returned to the Province. In practice, some of the provisions were not enforced by Government and many of the Berths were held for speculative reasons, in hopes of capital gain. With the advent of sustained yield, the Provincial Government decided, upon recommendation of a Select Standing Committee of the Legislature, to endeavour to recover the berth lands to add to public sustained yield units and thereby bring them under the sustained yield policy. To this end, it was argued that the berth holders were only granted the right to cut timber which was ten inches d.b.h. and above, at the time at which the berth was granted i.e. they were not entitled to subsequent growth. Also, certain provisions of the berths were enforced, such as a requirement that, upon order of the Minister, berth holders were required to survey the berth boundaries at their own expense. Rates of taxation on the berths were raised to discourage speculation and accelerate liquidation. In some instances, requests by industry to convert the berths into tree farm licences or equivalent arrangements which would permit sustained yield management of them were not accepted. It is not the purpose of the author to comment upon the merits and demerits of this policy, except to note that the return of the logged lands to the Province
will presumably increase the already heavy backlog of forest lands which are not satisfactorily restocked, since the Timber Berth tenures contained no provisions for reforestation by the holder and the Forest Service appears to be unwilling to enter into other arrangements under which industry, in return for modification of the tenure, would reforest and manage the lands.

(3) Tree Farm Licences:

The position of tree farm licences has been described at some length in the Review of Literature. Their issue has been stopped by Government policy changes, stemming from pressure from the public and sectors of the forest industry and it seems to be unlikely that more will be issued. The author has not changed his views of 1956 that this form of tenure has the potential to provide the best and most intensive form of forest management to be found in the Province. There will presumably continue to be difficulties where some licencees endeavour to carry out minimum contract requirements only, rather than aiming for rational management. There are also problems with Working Plans. In the author's view, once a plan has been prepared by the licencee and approved by the Forest Service, it forms the legal basis of management and ought not to be subject to continuing controversy at the field inspection level. Thus, the forest manager must be required to adhere
to the approved plan and the Forest Service inspector must not be permitted to impose his own views, where they differ from the provisions of the approved plan. Part of this problem may be solved, in the future, by a greater concentration, through educational means, on the purpose, structure and intent of Working Plans. The frequent amendment of Tree Farm Licence Working Plans to conform to frequent changes in Forest Service policy should be avoided as much as possible in favour of amending the plan at the planned time of revision. This permits policy changes to be properly co-ordinated into existing management practices without introducing the confusion which accompanies frequent amendments and which tends to remove the stability of management provided by a detailed Working Plan.

(4) Public Sustained Yield Units:

As pointed out in the Review of Literature, the Public Sustained Yield Units, which normally supply a number of industrial plants with raw material, are managed by "remote control". The administrative control of the units consists of the setting of an annual allowable cut which is distributed by means of a quota system to logging operators or industrial plants. The complexities of the close utilisation policy are included in the quota system, although where pulpwood harvesting areas overlie public sustained yield units, the rights conferred by the latter take
precedence over the public sustained yield unit operators' opportunity to practise close utilisation. There will, in all likelihood, be future problems with these overlapping tenures and policies but it is too early to predict in what direction these will arise.

There are no working plans, equivalent to those in operation on Tree Farm Licences, for the Public Sustained Yield Units, but they are under preparation. Part of the reason for delay in preparation of these plans lies in the difficulties of applying the Provincial Inventory to individual Public Sustained Yield Units and the position should be corrected when present work to intensify the inventory in areas of high forest produce demand, is completed. It is of interest to note that Forestry Commission plans for its own forests are incomplete pending the development of satisfactory inventory data.

The problem of management of Public Sustained Yield Units at the local level has been mentioned and it is clear that a decision should be reached in the near future on this problem. There are a number of possible approaches. One is to increase considerably the number of Forest Districts in the Province and place sustained yield unit management staffs at the District Headquarters, managing a number of units and accounting for them financially.
Another approach would be to form Forest Service management staffs for large, individual units and groups of smaller units. If neither of these courses is adopted, the Provincial Government should consider arrangements whereby the industry dependent on produce from a given unit would make a working plan for approval of the Forest Service, to similar standards of those presently required for tree farm licences and covering the same scope of operations.

The latter approaches would permit a more logical, planned approach to the allocation of timber for cutting and to the construction of capital works, since the approach could be a joint one rather than an individual one, as at present. In this case, the Government should require reforestation and fire protection provisions to be conducted by industry to be specified, although proper financial arrangements will be necessary to compensate industry.

At the present time, the management of public sustained units appears to consist largely of complex administrative rules to regulate and distribute the cut, efforts to obtain close utilisation and measures such as slash disposal. Fire fighting and reforestation provisions do not appear to be co-ordinated to the cutting provisions, nor do there appear to be financial criteria applicable to individual units. Until these problems are corrected,
doubts must remain as to whether the sustained yield policy of the Province is actually being applied on the ground to the individual public sustained yield units.

(5) Pulpwood Harvesting Areas:

The pulpwood harvesting area is the most recent major form of tenure, devised for stimulating the growth of the pulp industry so as to increase the Province's share of world pulp production. The mills constructed to date have been built in the Interior of the Province and are the first to be so located. The prediction by Clyne of over-production up until 1972 in relation to increasing world demand, has so far proved to be substantially correct and the situation appears to have slowed down the construction of some mills, although guarantees have been placed with the Government. There is little doubt, however, that the policy of stimulating the growth of the pulp industry by the issue of Pulpwood Harvesting Areas is proving to be successful.

The Pulpwood Harvesting Area overlies a number of public sustained yield units and the pulp company is granted an option to purchase sufficient pulpwood from these units to ensure a sufficient supply to sustain the pulp mill. The pulpwood is part of the sustained yield allowable cuts of the Public Sustained Yield Units. One of the questions
which affects the Pulpwood Harvesting Area deals with the ability or desire of the pulp company to use the pulpwood volume allocated to it. In some cases, the Harvesting Areas have been issued to cover not only the initial plant capacity but, also, planned future development which is guaranteed to be created by a certain date, by the pulp company. Clearly, in these cases, the Pulpwood Harvesting Area is larger than the existing capacity and will remain so until increases in plant capacity occur. Also, because of the forest inventory data available, some Pulpwood Harvesting Areas may be considerably too large for the planned future plant capacity. This kind of problem can be corrected by the Minister who has powers to reduce the size of the area, if excess pulpwood volume is present.

As pointed out in the Review of Literature, sawmill chips are a cheaper source of wood supply for a pulp mill than is round wood. Consequently, the mills will normally buy these chips in preference to logging round wood. The desire to secure this source of supply has led to the purchase of sawmills by the pulp companies, a process also leading to a degree of integration. The pulpwood on which the pulp mill has a first option was calculated on the basis of the usual minimum size of log which the industry in a given area was using. It is perhaps coincidental that, at the time when these policies were being evolved,
technological advances in the sawmilling industry were permitting that industry to use smaller logs. Within Pulpwood Harvesting Areas, the sawmilling industry was placed at the disadvantage in that it could not count on an increase in supply, by utilising smaller logs, except in those cases where the pulp company did not exercise its option. This is perhaps the more remarkable in view of the much higher stumpages which the sawmills were paying for logs than were the pulp companies in Pulpwood Harvesting Areas. With the technological advances in sawmilling, it is quite possible that pulp companies will process much of their log supply, through profiling machines to recover their lumber content and then use the chips for pulp manufacture. These are potential problems, the extent of which cannot be predicted at this time. It is clear, however, that the pulp companies have been placed in a powerful position vis-a-vis the sawmilling industry and it is to be expected that they will continue, in some cases, to consolidate their position by the purchase, or construction, of sawmills.

The major weakness of the Pulpwood Harvesting Area agreements is their lack of detailed reference to fire protection and silvicultural measures, including reforestation. It is true that, for each sale of pulpwood to the pulp company by the Government, the timber sale licence concerned will contain such terms and conditions as the
Chief Forester may consider to be necessary or desirable but these must be consistent with the Pulpwood Harvesting Area agreement. Certainly, the requirements for fire protection and reforestation are far less specific than they are for a Tree Farm Licence. Whether or not means can be found under which pulp companies with Pulpwood Harvesting Areas will assume some responsibility for fire protection and reforestation, it would appear to be advisable to arrive at a detailed understanding on those questions at the time of negotiating the Pulpwood Harvesting Area agreement.

In the final analysis, a number of potential problems which may arise with Pulpwood Harvesting Areas may have to be corrected at the end of the 20-year term for which they are issued.

(6) Dedicated Woodlands and Approved Woodlands:

In Britain, the Forestry Commission manages and operates its own woodlands and the problems of devising tenures is limited to the relatively simple process of short-term timber disposal. Thus the question of large and/or long-term tenures does not arise. For example, under an agreement between the Commission and Scottish Pulp and Paper Limited at Fort William, the Forestry Commission has contracted to supply the pulp mill with a specified
volume of pulp logs but the question of how these logs are produced and where, rests with the Forestry Commission directly and does not involve the pulp mill in a direct sense.

In Britain, however, the area of private woodlands presents some difficulties which are relatively greater in importance than they are in British Columbia. The policy of encouraging private landowners to plant, maintain and upgrade their forests, through the Dedicated and Approved Woodlands Schemes, with their planting and maintenance grants and taxation incentives, has been largely successful and an important acreage has been planted. There are, however, some problems remaining which have received the attentions of British authors. These include the variable standards of management and forestry staffs of the private sector, as well as the lack of adequate commercial experience in some quarters in the area of timber disposal. Also, the co-ordination of woods supplies to the industry from the Commission and private forests presents problems in which the Commission has readily accepted the need to reconcile the marketing to best advantage of their own produce, with their duty to do anything possible to encourage suitable conditions in which the marketing of production from the private woodlands can also flourish. The author noted, when in Scotland, that the Forestry Commission
had concluded a supply agreement with Scottish Pulp and Paper Limited and that negotiations, after initial set-backs, were continuing for bulk supply from the private sector. As against the supply of small sawmills which are fairly readily supplied by individual negotiations, it is apparent that with pulp mills and sawmills upgraded to high speed production, and requiring larger volumes, group bargaining by private owners will be more effective in achieving a fair price level. To the author, a free bargaining basis is much preferable to price controls or other devices which attempt to remove normal economic pressures from both forestry and the commercial developments dependent upon it. Clearly, also, there will normally be a need for co-operation between the Commission and the private woodland owners to establish a division of supply to a particular plant with the concomitant advantages of being able to plan supply both as to volume, economic haulage distances and the various facets of management which must be co-ordinated to achieve maximum success in the enterprise.

It is worthy of mention that the financial operations of the Forestry Commission are separated into its activities as a forestry enterprise and its administrative functions as the national forest authority. Thus, whilst as the forestry enterprise, it is charged with interest on the grants-in-aid providing its source of capital, in its
role as the forest authority it simply records the trans-
actions made, mostly expenditures, and is not charged
interest, presumably because there is no direct source of
revenue available to the Commission from these expenditures.
Thus, no financial return is expected from grants under
the Dedication and Approved Woodlands Schemes, which in
1966, were 1,533,788 pounds sterling, nor from research
and special services, on which 799,220 pounds were expend-
ed. These expenditures are presumably regarded as being
in the national interest and amongst other considerations,
will provide greater opportunity for the establishment of
industry, producing taxation revenues and other benefits
for the country.

2. Policy Problems Posed by Workers in British
Columbia and Possibilities for the Future:

a. The Close Utilisation Policy

The desirability of closer utilisation within the
British Columbia forests is obvious, yielding greater rev-
enues to Government and reducing the waste left from log-
ging, thereby reducing fire risk and the amount of site
preparation necessary for reforestation. Because the annu-
al allowable cut would be increased, the Forest Service
offered those who practised close utilisation an increase
in their quota, the increased volume to be sold at a lower
stumpage. Unfortunately, the incentives were quite inad-
quate to attract the wide-scale support of industry for the policy. Industry objected that the logging and conversion of small diameter trees and logs was uneconomic and that the large volumes of narrow-width lumber which would result would be difficult to sell except at reduced prices. The Government has removed the voluntary aspects of the policy in some public sustained yield units, such as the Okanagan Public Sustained Yield Unit, by announcing that those purchasing the trees from the Government will be required to cut to close utilisation standards. The particular Public Sustained Yield Units which are to be involved are those in which a substantial proportion of the standing volume is present in the form of small-diameter trees. The different close utilisation standards chosen for the Coast and Interior are probably partly due to the smaller volumes of small diameter timber in the former forests and were chosen to correspond to specific figures available in the Provincial Inventory, corresponding to the close utilisation standards adopted for the taking of the Inventory. It is visualised that operators opting or required to practise close utilisation must have chipping facilities to produce pulp chips but it is difficult to envisage that this provision could be enforced outside of the economic hauling range of a pulp mill. Also, should the Government enforce close utilisation on a large scale in the Interior, it will
presumably result in a lower amount of pulpwood being utilised by the pulp companies in the Pulpwood Harvesting Areas. It is difficult to visualise what the outcome of the close utilisation policy will be in the short term, although it is realistic to assume that it will be fully applied at some time in the future. By and large, the industry opposes the application of the policy at the present time and Government is endeavouring to apply it as widely as possible. Another aspect of the problem lies in the cyclic nature of lumber prices to Interior sawmills. It has been a rule of thumb that good profits may be made in approximately one year in five, with marginal profits or losses being likely in the other four years. At periods of good lumber prices, the resistance to close utilisation is perhaps likely to be less, for economic reasons than in periods of low prices. Another factor affecting close utilisation is the very rapid increase in costs, particularly labour and machinery costs, experienced since the Second World War, increases which have offset, to a great extent, lumber price increases. These inflationary trends make the small log only a little more attractive to industry at the present day than it was twenty years ago. The trend toward close utilisation has been assisted by the automated profiling machines and other technological advances in the industry and it is these trends which hold
the best promise of achieving close utilisation. The Government's changed views to permit the weigh-scaling and ratio sampling for the measurement of log volumes should be of material assistance to close utilisation, although as Moss (1966) has pointed out, the methods are more costly in some circumstances.

b. The British Columbia Continuous Forest Inventory:

The British Columbia Continuous Forest Inventory, in the initial phase of 1957, forms an excellent tool for the formulation of policy and the difficulties of applying it to management units, by reason of the limits of accuracy which apply to it, have been described. There are certain obvious reasons why these difficulties should arise. The Inventory was conducted under joint Federal/Provincial financing and the costs of conducting an inventory programme to reach a level of accuracy of, say, 95 percent, 19 times out of 20, in each management unit in the Province within a reasonable period of time would have been very costly indeed and it is doubtful if the requisite number of men could have been found. Nevertheless, it has clearly become essential to intensify the inventory in those public sustained yield units where the current annual allowable cut is fully committed to the industry so as to ensure that the development or sustaining of industrial output is not limited by inaccuracies in the inventory. The Provincial
Government is pursuing this policy. Where the estimated annual allowable cut is not being used fully by the industry, a lower level of accuracy can be accepted, at least until further industrial use occurs. Eventually, it will be necessary to conduct the taking of inventory on a management unit basis and, for reasons of economy, it seems likely that this will influence the size of management units, tending to keep them large, for at least several decades. Indeed, instances have occurred where public sustained yield units have been joined together to form a single, large unit.

The costs of the inventory, particularly since it is designed as a progressive, periodic inventory, are continuing and these costs may be expected to increase as the general level of cutting in the Province increases and the pressure of demand on the public sustained yield units increases.

The tree farm licences conduct their own inventory, to standards approved by the Forest Service, and these inventories have usually proved to be of great value by revealing that previous inventory estimates were usually considerably too low. The effect upon the economics and management of the tree farm licences where this has occurred has usually been most favourable. In addition, logical
planning for the size of the dependent plant and knowledge of the material which would be supplied to it, were facilitated.

c. Sustained Yield and Allowable Cut:

The strongest objections to the sustained yield policy of British Columbia have been made by Pearse (1967), primarily on economic grounds. He held it to be unlikely that equal annual harvests would result in maximum financial returns so long as the demand for forest products fluctuated over time and that the small variations permitted from the prescribed annual sustained yield cut were unlikely to help the situation very much. The large economic costs of carrying old growth inventory was also most serious and the value of the second-growth crops to replace the old growth was foregone. It is not clear what Pearse proposed as an alternative to sustained yield, other than adherence to economic principle, but it may be surmised that he visualised some form of highly accelerated cutting, with a view to liquidating the old stock in good market periods and replacing it with new growth. The use of Hanzlik's formula was also criticised on the grounds that it did not contain economic variables. As noted previously, the author has found it difficult to assess the value of Pearse's remarks, since they do not present cogent alternatives to the sustained yield policy. When Sloan
(1956) recommended the policy he had in mind some social objectives, amongst them the stabilisation of communities and continuity of employment based on the stabilisation of existing industry. The rate of expansion of industry in British Columbia must be considered healthy and it seems doubtful that the economy could sustain more rapid increases in view of shortages of capital and current manpower limitations. This point of view is, perhaps, supported by the marketing difficulties experienced by the pulp industry after recent British Columbia and world expansion. In addition, sustained yield has had the desirable effect of dispersing industry, thereby assisting in the development of under-developed parts of the Province. In the developed parts of the Province, the restriction of cut has encouraged the industry to attend to questions of more complete utilisation, product quality and intensification of silvicultural practice to make the best economic use of the products of the forest and of the forest land. Without these incentives, the strong tendencies of industry to expand in terms of acquiring more timber and building larger plants would probably continue, absorbing energies which are now directed to some extent, toward the questions mentioned.

Pearse has supported, as do many economists, the use of short rotations as being the economic optimum in most cases. However, he has also criticised the purely
technological consideration of aiming for the maximum growth in volume, and not value, of wood. The author, as emphasised elsewhere, supports the latter criticism but has serious doubts about a large-scale current reliance upon short rotations. In any event, there is nothing in the sustained yield policy which precludes the use of short rotations, where management considerations indicate its desirability, nor is there anything in the policy, to narrow the yield calculation to the use of Hanzlik's formula. Indeed, yield calculations by other methods are in use in some management units in the Province. Pearse also disputed the technological principle that fuller utilisation was always desirable and maintained that the quality of wood which it was desirable to move was determined by well-known economic constraints. It should be the lowest grade or size, the value of which, when harvested, would cover the cost of harvesting it. With deference, the skilled forest manager seldom employs the so-called principle of fuller utilisation as a simple, unqualified rule. There are, of course, obvious advantages to close utilisation where it can be practiced economically. The economic principle of cutting only the lowest grade or size which can be paid for as an individual item is usually with good reason, also much qualified in practice. It is seldom, for example, that the requirements of forest industry
plants are very closely balanced with potential forest output, in terms of quality and quantity. There is a point at which it is more economic to operate an existing plant at a nominal loss rather than not operate it, at the cost of a greater loss. Under these circumstances and a variety of others, there may be justification in viewing inputs to plants on an average basis. Also, the logging operation, where it is to be followed by silvicultural or fire protection operations, is not the sole criterion of cost and, where an integrated view of costs is taken, closer utilisation may be desirable, contradicting the indications of simple logging cost and plant conversion cost indicators. As discussed in other parts of this thesis, the author has serious doubts about some methods of applying the sustained yield policy but the policy itself appears to be well-established and, in all likelihood, will remain so.

d. Forest Protection:

(1) Fire Protection:

The problem of fire protection in British Columbia is an extremely serious one and the indications are that it will continue to be so. Whilst some improvement has been apparent over time, the number, scale, damage and costs of fighting fires are a heavy burden upon the Province. The increasing use of sophisticated fire-fighting tools, including water-bombers and helicopters, a substantial radio
communications system, the use of forest fire simulators for fire control training and the use of measures such as slash-burning, forest closures and early shift working have been reviewed. These are measures involving the detection, early reporting and suppression of fires in the first instance and in the prevention of forest fires in the second, although slash-burning is itself a cause of forest fires. If present policies are continued and as population and pressures on the forest increase, the present trends may be expected to escalate, in terms of increases in the number of fires, fewer large fires and heavily increased expenditures, consuming a substantial proportion of the total forest expenditures. One avenue which the author believes must receive much more attention is the question of public use of the forests. The question is fraught with political complications resulting from pressures for increased multiple use and other factors. There has been a strong tendency to react to public access and use questions in a fragmented way, dealing with problems as they arise. The Select Standing Committee of the Legislature has dealt with some of the problems but, with deference, the author believes that the subject of forest fire in all its direct and related considerations is worthy of investigation at a Royal Commission level, in order to change policies to combat the evident trends.
The efforts of Government and Industry under existing policies are substantial but do not appear to be enough, in spite of heavy expenditures, and other means must be sought to intensify preventive measures.

Reference to the statistical tables dealing with forest fires, which are annexed to this thesis, clearly demonstrates the problem faced by the Province and give reason for doubt that real improvement in the forest fire situation is occurring.

(2) Forest Insect Pests and Disease:

At the present time, the position of forest insects in the Province is reported by annual survey by the Canadian Government Forest Entomological Branch. It may be anticipated, subject to the factors affecting the cyclical nature of insect populations and, in the presence of mature and overmature trees, that a series of periodic epidemics of damaging epidemics will continue to occur. The establishment of a large-scale organisation to combat these epidemics by sustained aerial spraying techniques is a questionable development since, in many cases, the main cause of having timber of declining vigour in the forests remains uncorrected. Also, there are pollution problems connected with chemical sprays. Management can take measures to combat the effects of epidemics and it appears
likely that these measures will gain greater recognition in the future. The cutting plan in a forest should normally aim at the removal of the oldest and least vigorous stands first. The procedure may be difficult to correlate with the recommended practice of laying down areas of contiguous logging slash in succeeding years, so as to attract bark beetles from old slash into new slash but some compromise can usually be made in practice to arrive at a workable solution. The development of a good road system is an essential which permits access to the various stands to be logged and gives improved access to areas of insect attack which may arise, to permit countermeasures or facilitate the salvage of the attacked timber. There is a great need for research into counter-measures which can economically be employed by management when insect outbreaks do occur and objectives need to be clarified. For example, in the case of the Douglas fir bark beetle (*Dendroctonus pseudotsugae*), the peeling of stumps and burning or removal of all material suitable for breeding, after logging, is a very expensive process. Spraying of stumps and other material with chemical sprays is of doubtful efficiency at the present time and trap tree programmes have shown some promise. The question of attractants to entice beetles to traps is under research. Research into these management tools should be increased
in an attempt to find practical ways to keep populations at endemic levels at low cost.

As the reduction of the old forests progresses, the emphasis may be expected to change toward young growth problems, many of which are not apparent at the present time. It appears that future progress, therefore can best be made by the development of low-cost methods of control to be employed by management, and the development of long-term cutting plans and road systems to reduce the opportunities for epidemics to occur and improve accessibility to deal with them when they do.

In a somewhat similar vein, the presence of the large areas of forests of low vigour is an important factor in the level of disease and decay which is encountered. In some species, such as western red cedar and western hemlock, it may well be that, in the future, pathological rotations will be employed. In the meantime, the presence of decay is regarded as an endemic factor which must be dealt with in the normal course of forest operations.

In areas of very severe decay occurrence, such as the old western red cedar-western hemlock forests of the Columbia Region, the current Forest Service policy is
to require all trees left standing after logging to be felled and, along with the voluminous quantities of unusable logging waste, to be burned so as to clear the site for reforestation. In this Region, the industry has frequently objected to the level of stumpage which has to be paid, claiming that the amount of work to be done in relation to the volume of sound wood recovered makes the logging and burning operations of questionable economic value. To date, the Forest Service has generally maintained the position that it will not dispose of timber at zero or negative stumpages, although the recently introduced policy of rebates of stumpage for silvicultural operations may eventually lead to a solution of this problem. An apparent difficulty exists in the application of these economic principles to stands so degraded by decay that industry has no desire to utilise them. Since industry chooses the location of its application for timber sales, these areas may have been by-passed without official identification. Also, timber which was at one time considered to be uneconomic to utilise has since been utilised. It should be possible, however, by survey to identify those areas which, in all likelihood would not be attractive to industry prior to the time of heavy stand mortality. Stands of this nature
clearly ought to be removed and new, young growth established as soon as possible. Thus, in the management units concerned, a conversion programme at some cost to Government should be considered, with sale of any logs recovered to the highest bidder, as a means of partially defraying costs. A different kind of problem exists in Timber Berths. These have usually been high-graded or logged only for those trees which contain merchantable timber, leaving the low value trees standing. Moreover, under the existing terms of tenure, the process is likely to continue. As has been described, Government is pressing for utilisation of the berths so as to remove their use for a speculative holding and to place the lands in the public sustained yield units. However, the lands will be useless to forestry unless the wrecked stands are replaced by young, vigorous growth and it appears that programmes at Government expense will be necessary to accomplish this. An alternative, which appears to have been rejected, lies in re-drawing the terms of timber berths in negotiation with the owners under terms which would provide an extended tenure, provided that the owner carried out the conversions himself. Such an arrangement would presumably provide a better incentive for closer utilisation of timber remaining on the berths. These aspects of policy ought to be decided and active rehabilitation of very low value stands commen-
Again, as the old stands are progressively reduced in area, the emphasis on diseases and decays may be expected to change, with problems associated with young growth moving into prominence.

e. Reforestation:

The problems of reforestation have been given close attention in the Review since it is clearly a critical problem in terms of achieving full productivity in British Columbia. Sloan (1956) and the Forest Service, in evidence before Sloan, disagreed to a remarkable extent on the backlog of acres, not satisfactorily restocked following logging and fire, requiring reforestation. Sloan (1956), Wright (1966), Hoffmeister (1965) and the Vancouver Section of the Canadian Institute of Forestry (1967) have all emphasised the need for greatly increased reforestation programmes. Actually, the exact amount of backlog is, to some extent, unimportant, once it is recognised that it is very large indeed and quite beyond the financial capability of Governments to plant in a short-term programme. If brush-clearing operations on lands of high growth potential and conversion of non-commercial cover are included, a very rough estimate would place the necessary expenditures at not much less and quite possibly more than, one thousand
million dollars. This has led some authors to surmise that low-site lands may have to be abandoned following logging. In addition to forest which can be recognised as needing reforestation without too much difficulty, there are large areas of the Interior which have been selectively logged purely to recover trees of high commercial volume, in the belief that the residual, suppressed stand would recover and grow into the position of the former stand. In a great many cases, this process has not occurred and trees of low vigour and advanced age have been left to occupy the sites. Added to the areas classified as not satisfactorily restocked, the losses in potential growth are very large indeed. These losses must, in retrospect, be attributed as the cost of Provincial and Canadian development in which capital has been and is being directed from forestry to other requirements.

It is evident that the process of deforestation is still in progress and presents the Provincial Government with a serious problem. The Forest Service has commenced to expand its nursery facilities under a programme which has been restricted by both the availability of trained personnel and, initially, of seed supply and with increases of financial support which, if the restrictions mentioned had not been present, would have been inadequate. It is planned to reach a level of nursery
plant production of 75 million plants by 1975, from a level in 1966 of about 19 million plants.

In addition, a variety of automated planting techniques, such as bullet planting, tube planting and others are under trial to determine their suitability. If these or similar techniques are suitable for adoption, they will greatly assist progress in reforestation.

One of the reasons for the difference in the areas of land which were not satisfactorily restocked, as estimated by Sloan and the Forest Service, was that Sloan included lands occupied by brush and non-commercial cover, whereas the Forest Service did not, stating that the cost of reforestation of these areas would make the enterprise uneconomic.

The very variable figures quoted for land requiring planting make it difficult to assess the adequacy of the Provincial reforestation programme in relation to the problem. The Department of Lands and Forests (1957) in the Provincial Forest Inventory has probably given the most accurate estimate. According to the Inventory, there are 12 million acres of non-commercial forest, consisting of selectively logged areas which have become badly degraded by logging and areas of stagnant lodgepole pine, poorly formed aspen or well established brush. On the
Coast, decadent, highly defective stands and stands of stunted, limby western red cedar growing on poorly drained, exposed sites comprise a large portion of the forests classed as non-commercial. In addition, there were 6.4 million acres of forest land classified as not satisfactorily restocked, 2.9 million acres of which were considered to be unplantable, due to topography or the presence of excessive debris or brush. Of the remaining 3.5 million acres, 1.5 million acres were expected to restock naturally, leaving 2.0 million acres which is considered to be plantable and to need planting. In effect it appears that the Government are planning for the Forest Service and industry to plant only about 2.0 million acres out of the 18.4 million acres of non-commercial forest and land not satisfactorily restocked, as well as providing for current needs. This is no small programme, when one considers that British forests are about 2 million acres in extent and, although they have on two occasions undergone heavy fellings, have taken almost 50 years to establish. As has been mentioned in connection with diseased and decayed stands, it is desirable that a rehabilitation programme should be initiated. However, it seems likely that the Provincial planting programme for some time will follow a policy of obtaining the most value for the least expenditure and that the easiest areas
to plant will receive priority. The Forest Service is undoubtedly endeavouring to plant the highest quality sites, under the policy described, first but has wisely modified this approach to develop its nursery programme on a regional basis. Thus, for example, although the Coastal sites are generally much better than the Northern Interior sites both will be replanted on a concurrent basis, a policy which should avoid extensive regional de-forestation.

The present planning of the Provincial Government, to achieve a production of 75 million plants by 1975, would, at that time, permit the planting of about 75,000 acres per annum, as against 47,000 acres planted in 1966, a heartening increase. However, when it is appreciated that the annual area logged, mostly by clear felling, will probably be in excess of 200,000 acres and that the average annual acreage of forest burned during the decade 1957-66, was 126,000 acres (the nett area of merchantable and immature timber killed), there is considerable doubt as to the adequacy of the programme. As stressed elsewhere, the reduction of forest fire occurrence is a pressing need. In addition, it is apparent that much reliance must remain on natural regeneration and the silvicultural systems of felling designed to obtain it. Even so, it appears that it will be necessary to continue the expansion of the reforestation programmes beyond
1975. Until the pressing problems of reforestation are overcome, the sustained yield policy will not be fully operative and the forest productivity will continue to decline. Much may depend upon the results of the experiments into planting one-year old seedlings by mechanised methods.

f. Forest Utilisation:

The development of the pulp and paper industry in British Columbia is rapid and has been stimulated by the guarantee, to most new pulp mills, of ample supplies of timber with low rates of stumpage and royalty applicable for twenty years. The development of the lumber industry has been more in the direction of utilisation improvements, such as the installation of chipping plants and lumber profiling machines. The production level of plywood has undergone moderate growth, with the bulk of production at the Coast where sanded grades are made from the high-grade, large diameter Douglas fir. The Interior plywood plants utilise a variety of species, including spruce, and their production is unsanded because of the absence of sufficient clear wood to economically justify sanding. The shingle industry has declined from its early position, largely due to competition from other forms of roofing. The chipboard and flakeboard industries remain relatively small, chiefly because the market prices and economics of
operation require a low cost raw material but also because the market demand is limited. The production of poles and piling has remained relatively stable in recent years. Forest industry statistics are appended to this thesis. The industry as a whole relies upon exports for its continued existence and inflationary pressures continue to pose a threat to the competitive position in some markets. The author noted, for example, when in Europe that Scandinavian pulp had a lower quoted price than did British Columbia pulp. In some products, such as plywood and Coastal lumber, the factor of quality gives a competitive advantage to the industry in overseas markets, an advantage which will remain until the virgin forests have been cut. At the present time, all coniferous species occurring in the Province are utilised by the industry, with the exception of those of minor occurrence.

Research into and development of mechanical logging has been described and is a continuing process. The most recent introduction in the Interior is the tree shear, a set of mechanical shears mounted on the front of the tractor which snip off the tree at the bases, leaving a very low stump. The economics of logging have been revolutionised by mechanical logging and its continued development is largely unquestioned. A number of authors have discussed the effects of mechanisation
upon silviculture, protection and the economics of management with most favouring clear-cutting and a major reliance upon artificial regeneration. However, in British Columbia, the problems of mounting a sufficiently large programme of reforestation to follow this course have been pointed out and it appears that partial cutting methods including clear-cutting in strips, designed to obtain natural regeneration, will continue to be used.

g. Forest Research:
The position of Forest Research, by the Canadian and British Columbian Governments, has been reviewed. There has been a marked tendency, on the part of the Provincial Government, to restrict the allocation of funds to the Forest Service Research Division on the grounds that the Canadian Government are active in the field. However, in the author's view the Forest Service Research Division should substantially increase its activities. Whilst the Canadian research groups do conduct applied research, there is a tendency for them to emphasise the more fundamental, long-term research activities. There is a great need for research of a kind that can provide forest managers, in the field, with quick answers to current problems, even though the answers may not be comprehensive and may refer to local problems, and this need can best be filled, in the author's view, by the
Provincial Forest Service Research Division which has created a good record in the past with this kind of investigation. Also, the programmes currently being conducted by the Forest Service Research Division ought to be expanded considerably. The obvious need to continue to develop knowledge of the factors of natural regeneration, to which the Research Division currently gives high priority, has been mentioned and the programme needs expansion. The tree breeding programme is currently restricted to Coastal species and, in view of the level of Interior utilisation and the artificial regeneration needs resulting from it, should be expanded to include the Interior species.

The preliminary research into site classification by the landform-vegetation-soil method and involving four workers, was conducted under the Canadian Government A.R. D.A. scheme but further funds were not allocated to this work. The importance of this site classification, in terms of management decisions on silvicultural systems of felling, methods of regeneration and other decisions relating to site was indicated, as was the need to relate research and experience to site. This programme of research ought to be revived and continued by one of the two Governments, or both acting jointly.
There is a need, in the Interior, to study the effects of slash-burning in relation to its effects on the soil and site productivity. Also, studies into the compatibility of multiple uses of land are needed. For example, the Department of Lands and Forests (1957) have estimated that there are 15.9 million acres of forest in the Province in which grazing is possible but studies into the compatibility of forestry and grazing in these areas have been very limited. It is essential to have a clear understanding of the effects of cattle grazing upon natural regeneration, to know what densities of grazing are permissible and what degree of range management is necessary to achieve compatibility and to maintain the grazing potential. The degrade of lowland ranges by overgrazing and lack of management have been common in British Columbia in the past and are increasing the pressures for forest grazing at a time when its effects are not well understood. In addition, studies of the economic benefits to be derived from particular multiple use situations are necessary.

h. Multiple Use of Forests:

It is Government policy in British Columbia to encourage the multiple use of forest lands. Unrestricted public access into the forest, with the exception of
periods of fire closure, has come to be regarded as a public right, whether or not the access routes are publicly or privately owned. The fire closure system itself tends to be inflexible, operating on a regional, rather than a local basis. The author has suggested, above, that, in spite of recent decisions to the contrary, a full review of factors contributing to the occurrence of forest fires should be made and particularly the question of public access in the light of a rapidly increasing population.

Hatter, giving evidence before Sloan (1956) has generally supported the sustained yield policy, as leading to a closer fulfilment of good land use principles and conducive to the maintenance of stable wildlife and fish populations. He did stress, however, that access to lakes, streams and hunting territory was an important problem in managing the wildlife resource for maximum yield, since wildlife could not be stockpiled but must be harvested. The forest industry has been charged, on occasion, with poor road building and logging practices which have contributed to the silting of salmon spawning beds. Management planning to prevent these abuses would be greatly assisted by a landform-vegetation-soil site classification, as mentioned above to provide information
on the erosion and slump potential along projected access routes and logging areas. The indiscriminate use of chemical sprays has been much moderated in management practise by the threat that the sprays pose to fish life in a country such as British Columbia and, undoubtedly, their use will continue to be much restricted by this and other considerations.

The problems presented to forestry by mining and vice-versa are not great. Land is removed from forestry by open-pit mining, road and power right-of-way, and mill sites. There is a problem in some areas with the large, speculative holding of mining claims, a process which is regarded in the mining industry as normal practise but which poses investment and right-of-way problems to forest management. The miner is concerned with having free access over forest access roads during the prospecting phase of his operations.

The question of water yield has received attention, from authors such as Golding, in the Okanagan Valley where water supply for irrigation and domestic purposes is entering a critical phase. In this and other areas, water pollution is a subject receiving much attention and possible solutions, at least in the Okanagan, including a feasibility study for canalised diversion of
water from the Shuswap River system into the Okanagan drainage. The use of short rotations, for the purpose of increasing water yield has been suggested but, in areas where water supply is critical, there is little probability of establishing pulp mills because of pollution problems.

Generally, British Columbia has recognised the growing need for multiple use of forest lands and Government policy will, in all probability, continue to foster it. As has been pointed out, however, it is essential that economic and ecological investigation into the integrated economic benefits which might result and into the compatibility or otherwise of the various uses in given localities, should be made.

i. Forest Education:

The University of British Columbia is the educational centre for professional foresters and recently, the establishment of well-equipped technological training schools has permitted the formal training of forest technologists. The Forest Service Ranger Training School, long established, is the in-service training centre for Forest Service Rangers. In the author's view, as mentioned previously, there is a pressing need for professional forest managers in excess of those currently practis-
ing. If the public sustained yield units are provided with local management staffs in the manner suggested above, it seems certain that a greatly increased demand for managers will arise. However, the existing educational facilities should be well able to meet the need.

j. Forest Finance:

As noted in Chapter 4 and elsewhere large sums of money are received from the forest resource and from forest industry taxation. It is a moot point whether or not the taxation of the forest industry should be regarded as forest revenue in the same way as stumpage and royalty receipts. Nevertheless, the two are clearly inter-related. The Provincial Government sets the upset stumpage figures, the minimum that the industry must pay for the privilege of logging timber, on which Provincial forest revenues largely depend. The raising of stumpage and royalty levels under a given, fixed set of economic conditions would increase Provincial revenues, and reduce corporate profits, thereby reducing Canadian Government corporate taxation receipts. The tendency for the Provincial Government to do this is modified by the desire to maintain a healthy, expanding forest industry. The Canadian Government's need for revenues also produces a tendency to increase corporate taxation, a tendency which is modified by the same desire to maintain a
healthy, expanding industry and to create an expanding
tax base. The expansion of industry itself, given a fixed
set of economic conditions, will result in increases of
revenues to the two levels of Government. Clearly, how-
ever, the past and current losses of productive forest
from logging and fire will have the reverse effect and
will reduce the revenues which may be anticipated from
the forest and the dependent industry. The losses are
contrary to the best interests and policies of both
Governments.

The reason that the losses have been allowed to
continue, appear to lie in the pressing need for finan-
cial expenditures on public works and other social needs,
resulting in the diversion of large amounts of capital
to other endeavours.

At a more pragmatic level, it is perhaps signifi-
cant that the political parties forming the two govern-
ments have seldom been the same at the same time and a
common policy towards British Columbia forestry has not
emerged. There has been frequently expressed in recent
years, some dissatisfaction with the British
North America Act which grants to the Provinces the rights of natural resources and to the Canadian Government certain other rights and responsibilities.

Agreement between the two Governments for the comprehensive financing of forestry in British Columbia has not occurred, although particular fields such as those included in the Federal-Provincial and Forestry Agreements, have been the subject of agreement. The latter Agreements, now in the process of expiring, present an interesting example of the kind of problem which is encountered under Canada’s Governmental system. From discussions which the author held with the Canadian Government officials, it seems to be likely that the Canadian Government became disenchanted with the Agreements, under which it was making payments to the Provinces, partly because its officials did not gain a direct participation or supervisory role in Provincial Forestry. Based on the British North America Act, the Provincial Government continued to exercise its right fully to control the forest resources. The termination of the Forestry Agreements was announced by the Canadian Government as an anti-inflationary measure, although it was also announced, at about the same time, that Canadian Government forest and forest products research facilities in British Columbia, which were under the sole jurisdic-
tion of the senior government, were to be expanded. Whether or not the expansion of research facilities were areas in the forest economy in which expenditures were most needed is not clear. At the same time, the Provincial Government had expressed the view that it was dissatisfied with grants from the Canadian Government which were earmarked for particular purposes and that it would prefer lump sum allocations which it would expend at its own discretion. Under the system, it is not clear whether or not the Provincial Government would have allocated an appropriate proportion of the funds provided by the Canadian Government to forestry to achieve the substantial increases in expenditures which are clearly needed in the Province. It is a remarkable fact, in this connection, that the total of about 43.9 million dollars expended on British Columbia forests, including research, during 1966, compares with Forestry Commission expenditures of about 55 million dollars (converting from pounds sterling at one pound = $2.80). The amounts are not comparable because of the different nature of the expenditures but do point up the low level of expenditure in British Columbia forest by Governments. The Forestry Commission, at least for the time being, does not have receipts to meet expenditure. The reverse is true in British Columbia.
At the present time, the British Columbia Government is increasing its allocations of funds to forestry but the rate of increase is inadequate to meet pressing needs. Industry is also increasing its contributions, although the actual amounts are unpublished. Clearly, a problem of financing exists and, until a better solution is found, it is difficult to see the needed programmes and the sustained yield policy succeeding to the extent that they ought. The author is not such an idealist as to suppose that all of the moneys needed will be readily forthcoming and it may be necessary to draw public attention to the minimum needs for maintaining the British Columbia forest estate in a productive state before Governments fully appreciate the need for their greater co-operation in this field. The questions of constitutional legality are, no doubt, of great importance but should not be premitted to lead to an impasse in which the Canadian Government does not contribute adequately to one of its sources of revenue, at least to the extent that the revenue source, which is renewable, can be co-operatively maintained. British Columbia is a Province contributing, through taxation, to programmes designed to assist less well-developed and wealthy Provinces. However, to do this its own
prosperity must clearly continue. With forestry as its major industry, that prosperity, in the future, will rest heavily on the adequacy of the work now being done to maintain the forest land in a productive condition.

3. Problems in Management Practice Posed by Workers and Possibilities for the Future:

a. The Interior Subalpine Forests

(1) The Interior Spruce Forest Cover Types:

In these forests, a number of authors have expressed the need for the development of a system of site classification to rate the productivity of the forest associations and to which research management experience and engineering aspects could be related. The approaches suggested have included plant indicator, ecological and landform-plant indicator-soil systems. To date, a number of valuable research projects have been completed but they have not been of a comprehensive nature and usually have not leant themselves to site mapping of large areas. The A.R.D.A. system of land mapping is primarily designed for land-use planning at the Governmental level and does not lend itself particularly well to forest unit management because it is not detailed enough. It does assist in assessing the use to which land areas should be put.

From a forest management viewpoint the landform-plant indicator-soil system holds the most promise for
providing a management tool which can be economically applied to site mapping of large areas, since, once the range of sites has been established, sites can be identified from aerial photographs with a limited amount of ground control. It is quite possible that mapping of this kind would remove much of the need for repeated random sampling of management units to determine the forest inventory. At the management unit level and at the accuracy of inventory normally required, the use of average site productivity for the various age classes could well give equivalent results at less cost, after the initial site mapping.

However, it is premature to apply the technique at this stage since more pilot projects and research are needed to confirm present indications. A good approach, in the author's view, would be to classify the sites of a few management units, selected to represent the various forest cover types. Preferably, these units should have a local manager who could test the effectiveness of the systems in his plan of management and its execution.

A great deal of research, particularly by the British Columbia Forest Service Research Division is directed toward reforestation problems but, it is most important to relate this research to site in a way which will indicate to the manager whether or not the findings relate
to the sites under his control.

The development of silvicultural systems applicable to the Interior Subalpine Forest has been reviewed in some detail and it appears to be likely that clear-strip cutting in its various forms, along with site scarification to obtain spruce natural regeneration, forming an appropriate percentage of the new stand will continue to be used and developed. Artificial reforestation by planting will provide an alternative, where natural regeneration fails, where site quality is high and/or where the site is unsuitable, by reason of moisture or topography for machine scarification. It is most likely that a better knowledge of site will influence the method of obtaining regeneration quite markedly. However, it is unlikely that clear cutting, as a logging method will be changed in the old-growth stands. These stands are generally unsuitable for manipulation by partial cutting methods because of their instability when the canopy is opened, the significant degree of mortality which occurs from exposure and insolation and the damage which results from mechanical logging. The clear-cutting, of necessity, should be to as close a standard of utilisation as is economically possible, taking into account the fact that site preparation for regeneration, including falling of residual trees, slash burning and mechanical scarifica-
tion can be carried out at reduced cost, where close utilisation is practised. The incentive towards relating the standard of utilisation not only to logging and conversion plant economics but also to questions of site preparation, protective measures and reforestation is strongest in the tree farm licence and tree farm tenures, where all these practices are related to one management.

In the Public Sustained Yield Units, the industry is primarily responsible for logging economics and the subsequent operations, in theory, at least, are paid for by the Government. In spite of the tenure arrangements, it is clearly more efficient to view the logging operation not in isolation, but as the start of a process of converting the old stand into a new one, the costs of the process being inter-related.

Considerably more research is needed before the clear-strip logging and scarification system can be regarded as a satisfactory silvicultural system. It is apparent, for example, that in areas of great summer heat there is a considerable risk of mortality of the young spruce seedlings during their first summer of growth. In some instances, for example, the author has noted that natural regeneration has only succeeded after the exposed, scarified site has been occupied by herbaceous growth other than grasses, presumably because of
the shade and better soil moisture regime which results. Again, there is some question whether wet areas, which are difficult to machine scarify and are liable to be invaded by brush, should be scarified at all. In this case, the use of planting is indicated.

It is most likely that attempts to change species will not occur and that spruce will continue to be the most valuable commercial species of these stands. In this connection, as has been mentioned, nursery facilities for spruce are being expanded in the Interior and attention is being paid to seed quality. However, a tree-breeding programme for spruce and lodgepole pine is highly desirable and will probably occur within the next decade, when the value of the programme being conducted for Coastal Douglas fir is more readily appreciated. The increasingly strong position of lodgepole pine as a commercially valuable species should undoubtedly result in its nursery production which has been minor up to the present time. It is quite likely that the drier spruce sites, where the admixture of lodgepole pine is frequently considerable, will be reforested, when artificial means are used, with mixed planting instead of the pure spruce planting which is the standard current practice.

The practice of tending young stands has scar-
cely occurred at all in the past and its future is difficult to predict. It is clear that the new stands from natural regeneration or in plantations where natural regeneration has followed can be extremely dense. It may be that a form of early cleaning, designed to achieve a suitable spacing and balance of species and carried out at a time when the trees are small enough to be easily slashed, will occur. The existing amounts of timber surplus to demand and the amounts which can be made available by practising close utilisation make it likely that periodic thinning practice will not come into use in the near future, although good sites within short distances from utilisation plants may be thinned. One of the problems resulting from the economic position is that the new young stands of the present will, by the time thinning practice is economically attractive, probably not be suitable for manipulation by partial cutting and will not be as productive as they would, had they been thinned. Stem diameters will not be so large as they would be under thinning regimes and rotations will be longer than would otherwise be the case. Nevertheless, the current climate of forest industry and forestry opinion makes it likely that periodic thinning will be deferred until such time as economic considerations favour its introduction.
The Interior Lodgepole Pine Forest Cover Type:

The silviculture and management of lodgepole pine forest cover type are not well understood or developed in British Columbia since it is only recently that it has come to be regarded as a desirable commercial forest. The pulp industry was absent from the Interior and the pure, or almost pure, stands of the pine usually contained most of their volume in stems of too small a diameter for use by the existing sawmilling industry. A limited use did, however, exist in the manufacture of railroad ties (sleepers). An understanding of lodgepole pine seed production and characteristics of its cones was developed by Crossley and others in Alberta, the economics of its use are quite well developed and its colonisation behaviour following forest fires is quite well understood. Some sites have been identified as probably being permanent lodgepole pine sites and others as sites on which the pine is a sub-climax species but sufficient knowledge to determine when management should attempt to convert the stands to the climax forest or continue with the sub-climax, is lacking and a decision must usually rest on an "educated guess". Although, logically, one might expect that lodgepole pine cone-bearing boughs scattered over a scarified site close to the ground could lead to natural regeneration, this is
not always the case. The pine seedlings withstand exposure on a hot site better than do spruce and scarification of Engelmann spruce-lodgepole pine sites may lead to an increase in the proportion of lodgepole pine stems.

The density of lodgepole pine stands established following a forest fire is frequently very high indeed, as a result of a high accumulation of serotinous cones containing seed of long viability on the ground at the time of a fire. The regeneration in the past has not been cleaned to obtain more appropriate densities and, because of even growth, the stands frequently enter a period of stagnation in which the diameter growth of individual stems is extremely slow. It has been shown that, in any event, the vigour of lodgepole pine drops sharply at about 30 to 40 years of age and that late thinning to open the stand is of little value. Also, the stand is frequently composed, at this stage, of whips which are affected by snow bend, snow break and damage, in a wind, to each others' crowns. In this connection, it appears to be essential that cleaning programmes should be introduced, early in the life of the stand, to improve tree size and quality in the future and to shorten the rotation. It is not known whether, if the stand were to be reduced early in its life to an open stocking, the
period of rapid growth could be extended beyond the age of 30 to 40 years, but it does seem likely that the rapid early growth could be exploited to much better effect by avoiding stagnation.

From the work conducted, the partial cutting of mature lodgepole pine stands is not generally favoured, particularly since the maximum physical life is relatively short (about 150 years). Little response can be expected from the residual stand and physical damage from mechanical logging is frequently heavy. The thin bark of the species also makes exposure, after a lifetime of protection by the closed canopy, a risk factor. The potential of attack of the residual stand by the Mountain Pine Beetle is also present. Generally clear-cutting is favoured.

A major difficulty of employing clear-cutting is the standard of utilisation. At any level short of close utilisation (7 inches d.b.h. to a 4 inch top) and, even at a close utilisation standard, large numbers of undersized trees are frequently left standing. Generally, these are of no current or potential value and, although they are sometimes left standing, in the mistaken belief that they will grow into a commercial stand and/or provide a good seed source, it is likely that they will be pushed
down in the scarification process and, probably, burned.

The question of converting lodgepole pine stands, on suitable sites, to the climax forest has been mentioned and the decision making process has been assisted by Illingworth's (1958) identification of four site types, based on plant indicators on which the forest succession is to the climax forest. On these sites, the lodgepole pine stand has generally been established following a fire. There is little information on the effects of fire on, and recovery periods for, the soils and the growth potential of a given site, after conversion to the climax forest, can only be inferred from such factors as the gross volume of the lodgepole pine and the condition of plant indicators. As mentioned in the section dealing with the Interior Spruce Forest Types, research into and application of a landform-plant indicator-soil system of classification would provide a useful management tool.

Where the aim of management is to obtain natural regeneration, it appears that, as with the Interior Spruce Forest Types, clear-strip and clear-group logging systems, accompanied by scarification, will be employed, using short distances to the marginal seed source. In the case of conversion to the climax stand, seed source restrictions would not apply and large scale clear-cutting
followed by planting of the appropriate species, possibly after slash burning, will probably be the major silvicultural system employed.

Illingworth (1961) has recommended studies of the character of pine seed sources and their relative importance; thinning studies and, where an understorey of spruce and alpine fir was present, the removal of the lodgepole pine to the smallest economic diameter. However, where mills had made large investments in specialised equipment, he suggested that the question of conversion to the climax forest should be investigated as an economic problem and its effects on management determined. Also, he recommended that his ecological classification of lodgepole pine (Illingworth (1958) should be improved and extended to other zones. Armit (1966), in the north-central Interior has recommended that the Forest Service Research Division should start a ten-year programme of research to investigate site scarification; improvement of the quantity and dispersal of seed released from serotinous cones in slash; slash burning effects; direct seeding and planting trials; species trials; cleaning and spacing trials; provenance trials and methods of consistently producing high quality seed from seed production areas. He also recommended silvical (autoecology) studies to include annual seedfalls and disposal patterns
in relation to the environment; seasonal and zonal variation in serotiny of pine cones and the effect of environmental factors upon germination, survival and phenology of pine, including seedbed condition, soil, nutrient requirements microclimate and aspect. Lastly, the Research Division should produce an ecological forest site classification, developed from vegetation and factors of the environment and it should, by means of a tree-breeding programme, develop superior crosses or strains of the pine. For other research organisations, Armit proposed a classification and investigation of soils; soil environment; interactions and relationships of stand densities and stand treatments with soil properties, snow and moisture conditions, radiation intensities, plant activity, foliage development and energy assimilation; influences of the natural economic community and its phenological development.

These long lists and wide variety of subjects for research reflect the current lack of scientific knowledge of the pine, a position which causes considerable difficulties for management. The inadequacy of research programmes in relation to the needs of management has been described and, needless to say, only a few of the recommended subjects have been incorporated into the research programmes.
Lodgepole pine will, in all probability, be grown on the shortest possible rotation to achieve a size suitable for utilisation and this will provide an incentive to apply, at least, early cleaning operations. The pathological rotation in many areas is quite short, owing to the activities of *Cronartium stalactiformae* and *Atropellis piniphila*, the potential of attack by *Dendroctonus monticola* and the occurrence of red heart. The growth pattern, however shows that longer rotations are possible if pathological factors are not limiting. In the Okanagan Valley, for example, the periodic annual increment falls below the mean annual increment, on the average, at about 110 years of age, when the virgin stand volume is about 2,600 cubic feet per acre and the mean annual increment is 24 cubic feet per acre. Where pulp utilisation is unlikely to occur, as in the Okanagan Valley, longer rotations, up to 110 years plus the regeneration period, may well be justified.

b. The Montane Forest Region:

The situation of the Montane Forest Region is very varied. It contains pure ponderosa stands at the northern limits of the range of the species, mixed ponderosa pine and Douglas fir, pure Douglas fir, pure western larch and mixed Douglas fir and western larch
stands. The sites are frequently of rapidly varying quality. Also, since they have been quite readily accessible for logging, in contrast to the Interior Subalpine Forests, they frequently have a long history of logging, possibly up to about four cuts, which in many cases have simply removed the most valuable stems and degraded the stands. In some areas, natural regeneration appears to establish itself quite readily without site preparation, although in others regeneration is difficult to obtain. A factor clearly established by the workers is that, on hot sites, natural regeneration can only be expected where a degree of shade is provided and, if these sites are open, planting with special means of site preparation, such as ploughing, is the only known satisfactory way of obtaining reforestation within a reasonable period. The classification of sites, by ecological means, has not produced results related to productivity which can be applied by forest management in a comprehensive way, although information on the succession indicates the desirability of retaining the pioneer ponderosa pine, rather than the climax Douglas fir on many sites, because of the better timber production and grazing forage yield. The forest cover type is favoured for grazing, although the effects of grazing are not thoroughly understood, as described previously.
The Forest Service have generally favoured a method of reserving seed trees and removing as much of the rest of the stand as economically possible, although the need for prescription of the silvicultural system by individual areas has been stressed. In all areas, there is a considerable risk attached to planting and costs are higher than normal planting costs. Experiments in direct seeding in the Montane forest, as a low-cost method of obtaining regeneration have not met with marked success.

The author employed the Periodic Selection System with Improvement Thinnings in stands in the Okanagan Valley. Logging aimed at maintaining a balance between large wood, medium wood and small wood somewhat along the lines of the Swiss check system and with cutting priorities which removed badly formed and diseased trees first. In general, the aim was to upgrade the stands, increase their increment and ensure a good ground cover, to provide shade of assistance to natural regeneration. The cutting cycle was planned to be thirty years. Whilst the economics of the first cut will suffer somewhat from the removal of poor trees, it was hoped that high planting costs could be avoided. In some stands the amount of small wood below the economic cutting diameter was very
high and thinning of thickets up to a maximum of 100 acres per year (for cost reasons) was conducted. It appears that this system, which also favoured ponderosa pine, is applicable to the ponderosa pine-Douglas fir complexes. It is unlikely to be satisfactory for western larch which tends to form even-aged stands. Where, however, the seed-tree system or clear-cutting has been employed, even-aged stands have been created and, since the large scale application of economic periodic thinning does not appear to be likely, at least for a few decades, it appears that these systems will continue to apply in the future.

It will be necessary, in these stands, to collect more information on insects and diseases. The control of _Dendroctonus pseudotsugae_, the Douglas fir beetle is particularly important and requires trap tree programmes, reduction of incubator trees and material and the maintenance of thrifty stands. Shoestring root rot, _Armillaria mellea_, is a particular threat to pole size trees and has been noted, on occasion, to occur on an increased scale in thinned areas, where it propagates from the dead root systems of trees removed in the thinning. The dwarf mistletoe _Arceuthobium douglassii_ is common in some areas and can best be controlled by cutting priorities, which ensure the removal of diseased trees and burning of the witches brooms. Other bark beetles and cone insects can
inflict heavy damage and methods of control for the latter have not yet been suggested. Windblow does not appear to be a general problem in the Montane Forests and the species are better able to survive forest fires, unless they are crown fires, because of their thick bark. The bark, also, is more resistant to damage during mechanical logging, but damage does occur. The intensity of cut applied in selection logging must generally be modified to allow for some damage and the subsequent removal of the damaged trees. The selection systems do have an advantage in that logging will produce a proportion of large diameter, good quality trees.
c. The Columbia Forest Region:

The major problems in this region, reflected in the work of almost all authors, are the pathological ones of extensive decay in the western red cedar and western hemlock trees and the heavy mortality of the valuable western white pine from pole blight and white pine blister rust. Studies of the white pine diseases mentioned have not resulted in the development of solutions for economic control. The silvicultural system most frequently employed for stand utilisation is clear-felling, followed by slash burning, with a view to conversion into thrifty even-aged stands. The natural regeneration results from the practice are variable and regeneration practice is in need of closer investigation, from a management point of view. It seems to be quite likely that artificial regeneration will need to be substantially increased to ensure that the acres logged are regenerated, particularly since many of the Columbia Forest Region sites are susceptible to invasion by brush species.

Following logging, it is usual to cut down all remaining trees of 8 inches d.b.h. and over to broadcast burn them, along with slash and waste from trees logged for their commercial wood content. Many of the poles which remain standing are killed or burned down in the process. The results of these slash burns have been very variable
(a situation which undoubtedly has a bearing on the results of natural regeneration) and Muraro (1964) has emphasised the need for more research to accurately delineate previous and current weather regimes. The objective of this research would be to arrive at satisfactory estimates of the slash hazard and to evaluate successful burning prescriptions.

The logging of the overmature and mature western red cedar-western hemlock stands usually covers large areas of clear-cutting, in spite of the finding of Illingworth (1962) that the majority of seed falling into the area, fell within 100 feet of the residual stand. The natural regeneration results have been variable and the sites are liable to invasion by brush within a few years after logging. Also, where natural regeneration occurs, a very high percentage of it is western red cedar and western hemlock. On many of these sites, Douglas fir is a species of minor occurrence but shows good growth and good quality, and can attain large size without having the severe pathological problems affecting the other species. There is a possibility that planting of the logged and burned areas with Douglas fir may be a suitable system of conversion.

The problems surrounding the artificial regeneration programmes of British Columbia have been discussed and
there is a distinct possibility that large-scale planting programmes in the Columbia Forest Region will be restricted for a period well in excess of the next decade by the nursery production of plants. However, the Region should probably receive priority in the planting programme since it contains some of the best growing sites in the Interior. The latter consideration also lends support to the proposal that, where the existing stands are of little or no commercial value, a Government sponsored rehabilitation scheme should be conducted.

d. The Coast Forest Region:

The evolution of research into reforestation questions in the Coastal Region has been described in considerable detail in the Review of Literature. The chief influence upon this work was probably the continuing and developing practice of clear-felling which, in practice, has generally shown itself to be the most economic method of removing the overmature and mature stands. The areas of the individual clear-fellings, as compared to those of the early days has generally been reduced but, even so, corresponds closely to the physical ability of high-lead extraction equipment to extract timber to the location of the central spar. The governing factor has thus been the logging method, rather than the silvicultural requirements
for natural regeneration. It must be borne in mind, however, that selective logging in the old Coastal stands, particularly by mechanical methods, is of doubtful application because of the damage which results from the felling and extraction of large-size timber in dense, virgin stands.

Over a period of time, research by workers has gradually concentrated on the regeneration of settings of the general size described. Another important factor has been the obligation, by Government regulation, to burn most of the logged settings to remove the fire hazard presented by logging slash. The evidence as to whether or not slash burning assists the establishment of natural regeneration tends to be mixed but appears to indicate that it favours natural regeneration and delays site re-invasion by ground and shrub vegetation.* Whether or not the chances for natural regeneration are improved in these ways, it has become clear that very considerable areas of the logged Coastal forest, whether slash burned or not, have not regenerated naturally and this had led some authors to recommend immediate re-planting of the logged and burned sites. The statistical evidence presented on

* Slash burning does pose problems, however, by the extent to which fires "escape" and damage adjacent timber.
sites not satisfactorily restocked is sufficient to demonstrate the inadequacy of relying upon natural regeneration to the extent that has occurred in the past.

The measures being taken in terms of increased planting programmes have been discussed. Research and field trials undertaken to determine the feasibility of direct seeding by artificial means have not yet established that the method is reliable under a sufficiently wide range of conditions to establish it as a management tool. The more recent research has concentrated to a considerable extent on the evolution of cheaper planting techniques, such as bullet, tube and bare-root planting. Some of these techniques might, also, greatly ease plant production and greatly increase the man-hour rates of planting, indicating a possibility of much larger planting programmes within the existing financial restrictions.

The Coastal Forest Region has long been the most intensively utilised by the forest industry, contains the best growing sites in the Province and has the heaviest concentration of integrated forest industry. The importance of maintaining maximum productivity on these sites has led to the introduction of genetical studies and a tree-breeding programme in order to produce seed and plants of superior growth and other desirable characteristics.
In the past, Douglas fir has always been a desirable species and has been cut at a rate well above its rate of replacement and growth. This species was selected for the tree-breeding programme for these reasons and because a more extensive programme was and is beyond the research capability, in terms of finances and staff. The forest industry have made important contributions to the programme.

The question of the introduction of tending operations, particularly thinning, into the Province's forests has been discussed. However, it does appear that the southern portion of the Coastal Forest Region will be the area of the Province into which thinning operations will be introduced first, since the incentives to practice intensive forestry are greatest there. Indeed, further growth of the industry may well depend, in the near future, upon thinning practices and the accompanying increases in productivity. Because of a lack of practical experience, the techniques most suited to the Region and their economics are not yet well understood but the range of equipment and skills which are available should greatly assist in finding appropriate solutions.

In connection with productivity, the use of fertilisers is being investigated and could well prove to be
economically feasible.

As with other forest regions, the problems of pathology as they relate to overmature and mature timber stands are quite well understood and more costly control operations have occurred because of the high value of some of the standing timber. It remains to be seen what problems will arise and to what extent and degree of severity in the new, young stands.

Although some authors have recommended the use of financial rotations in the Coastal Forest Region, based on economic calculations, they have generally employed lower rates of interest than those currently in effect in money markets. If the current rates of interest are employed the rotations become so short, under these calculations, as to indicate that forestry is uneconomic. These indications are somewhat similar to those in Britain in relation to the finances of the Forestry Commission for its own forest estate. In the author's view, the economics of the forestry enterprise and the forest industry dependant upon it are closely inter-related and, logically, should not be treated in isolation from each other since it is obvious, in a modern economy, that neither could possibly be economic without the other. There is a
strong possibility that the economist should approach rotation and management economics on an integrated basis. The joint enterprises can frequently obtain better overall economic success than could be achieved if practice in the two sectors is conducted on separated economic calculations. Also, in terms of forest policy, it is clear that the forest and the industry together constitute the major economic and social objectives. The most potent obstacle to integrated economic planning rests, both in British Columbia and Scotland, in the separate ownerships and managements of the forest and the forest enterprise. This division of ownerships need not, in the author's view, prevent integrated economic analyses of benefit to the owners and management. In other words, the sale of standing timber (which does not always reflect its true value) may not be the logical end-point of an analysis but, rather, the finished forest product. Certainly, the adverse indications afforded by most economic analyses of the forest enterprise treated alone merits more study of the validity of the integrated approach.

4. Policy Problems Posed by Workers in Scotland and Possibilities for the Future:

The pattern of land use in Scotland, particularly in the Highlands and Border country, has presented severe policy problems. For example, the decline of hill farming
and crofting as industries, and the accompanying de-
population of the Highlands have created economic and
social problems which have led to considerable political
controversy. The upgrowth of exotic plantation forestry
in Britain was initially based, after 1919, on the econo-
mics of national emergency but, even so, its social as-
pects, particularly the provision of employment, were
stressed. Even at the present day, although policy now
aims at growing wood to aid the current economy, rather
than an emergency economy, the social aspect of providing
employment is still stressed.

In theory, at least, the establishment of forests and
their dependent industries in the Highlands and Borders
will lead to a healthier employment situation in these
areas, leading to a relative stability of the population
and social and economic benefits. The better use of the
land would be one of the economic benefits. The major
problems which face Scottish forestry in achieving the
afforestation of the Highlands, in particular, are complex.
They include the technical problems of afforestation and
growth of exotics under physical conditions that are freq-
ually harsh, the problems of establishing an utilisation
industry which can thrive on the kind of wood that is
being produced, the creation of a forest-oriented populat-
ion from a population whose traditions and occupation, for the last century at least have not been closely related to large scale economic forestry* and the financial questions surrounding the combined forestry and utilisation industry enterprises.

a. Financial Policies:

The provisions for taxation and subsidy incentives designed to encourage afforestation and maintenance by the private landowner have been described. The measures have been successful insofar as widespread private planting has occurred. They will not necessarily lead to good standards of forest management or to good marketing practices. The landowner, in many cases, is naturally more concerned that he should place his land under trees, obtaining grants to do so and increasing the value of his estate as well as abandoning to some extent the less economic use to which it may be put. Also, afforestation is a means of sustaining the estate as an entity for the heirs by avoiding, to some extent, the heavy burden of succession duty upon it. In some cases, with large estates and enlightened ownership, good forest management is practiced but in other cases it is not. Particularly on the small estates, where the land available for afforestation is very

*With the possible exception of the great land owners and their estate staffs.
limited, it is difficult to envisage that economic forestry, can be practised, even with the aid of grants.

The relatively recent phenomenon of private forestry syndicates has attracted private capital primarily for the opportunity to invest in an enterprise which is subsidised and which offers estate duty advantages. There has been some opposition to the syndicates in that they compete in the acquisition of land, to some extent, with the Forestry Commission, the State authority which then subsidises their operations. The syndicates have introduced the phenomenon of private enterprise purchasing low quality land, in considerable acreages in Britain, an unusual state of affairs in recent times. Nevertheless, the syndicates do demonstrate a progressive attitude toward forestry and employ professionals to direct their management. Since their motivation is profit from the enterprise, as well as taxation relief and since they propose to develop utilisation industries it appears that they are forwarding the Government policy of encouraging private afforestation and will also provide sound economic forest management, including good marketing practices.

A problem of the first magnitude facing British forestry has been illustrated by Mathur (Mathur, R.S. 1967. Ecological and economic considerations in land use plann-
ing. M. Sc. Thesis. Edinburgh University.) and Mutch. Primarily, their observations relate to the rates of interest which the Forestry Commission estimates that the investments in its own forests will earn, as related to the Treasury borrowing rate which is applied to the Commission's loans. Part of the question devolves into the justification of crediting the difference between the actual borrowing rate and the estimated return from the forest enterprise to the social attributes of forestry, to the provision of rural employment, recreation opportunities and other indirect benefits. It is not the purpose of this thesis to investigate or comment upon the quantitative financial attributes of these social benefits. What does appear to be unusual, in the author's view, is the existence of a method of accounting, as applied to the Commission's operations, in which it is required to pay for these benefits without, apparently, receiving financial credit for them. If, in the Government's view, the financial assessment of the social benefits is correct and justified, this should surely be reflected in a borrowing rate of interest reduced by the Treasury to allow for it or by a method of annual debt write-off. It is hardly logical for the Commission to be practising economic forestry for a profit when there is little opportunity to demonstrate in a practical way what the actual profit or
loss is, in money terms. Mutch has pointed out that, in his view, the size of the Commission's loan from Treasury can only increase since it is unrealistic to assume that the borrowing rate will fall as low as 3 percent. In the author's view, the situation presents a very real problem for the Commission and for British forestry. As suggested previously, it is possible that the situation should be re-examined from the point of view of estimating the overall benefit to the British economy of the forestry and the dependent present and future forest industries in a combined sense. These benefits should at least be capable of more accurate assessment than are the social benefits, the financial value of which do not accrue to the Forestry Commission.

The remarks of Openshaw (1967) upon the effects on forestry of the proposed British entry into the European Economic Community are of special interest to British Columbia. In essence, the resultant imposition of tariffs upon timber imports into the United Kingdom would favour the position of British forestry and the British pulp industry but would deter the sales of Canadian produce in Britain. Openshaw has conjectured that one of the results of British entry into E.E.C. might be that Canada would invest in pulp and paper mills in Britain. Also, Openshaw noted that a good case might be made to extend the
British forest area up to 10 million acres. Some pressure has already been exerted upon the British Government from within Britain, to impose tariffs on wood imports but, emergency tariffs apart, the Government has reasoned that this would invite tariffs on Britain's exports and has resisted the suggestion. However, should Britain enter E.E.C. there would presumably be an obligation to adopt the Community's import regulations.

b. Land Use Policy:

The plans of the Forestry Commission to plant a further 450,000 acres in upland areas where population is declining have been noted in the Review of Literature and this acreage will lie mostly in the Scottish Highlands. The restrictions on land use by the Commission, by decision of the Minister of Agriculture and from other causes, have also been mentioned. The Land Use Study Group of the Department of Education and Science (1966) has reported that no complete land use capability surveys are in existence and the author, on inquiry, found that the latest complete air photograph coverage of Scotland was taken during the Second World War. Air photography would not only provide a good basis for classifying land use capability but is also a proven forest management tool for both planning the taking of inventory and operations. To be of
use it would appear that a new coverage should be photographed, at a scale of 1 inch = 20 chains or less. Such a programme would, of course, be of use in fields other than land use capability studies and forestry. The comments of Mathur (Mathur, R.S. 1967. Ecological and economic considerations in land use planning. M.Sc. Thesis. Edinburgh University) and Edwards (1966) point up the need for further research to arrive at a more satisfactory system of land use capability definition than exists at the present time.

c. **General Policy:**

The new Forestry Commission policy for State forests has been reviewed, entailing a change from the use of forests as a simple defence measure to the pursuit of efficient and cheap forestry so as to compete with world prices and earn a proper return on the money invested. The question as to what constitutes a proper return has been discussed above and suggestions made for revision of the accounting method. In spite of these reservations, the author believes that the change of policy toward managing the forests on a commercial basis is a healthy one and provides economic aims and yardsticks to govern management. Along with the policy aim of achieving the highest possible return on the capital invested is the
aim of achieving an orderly expansion of timber production by extending the areas of forest at a steady rate by means of new planting and by managing all State forests in accordance with the principles of sustained yield. The latter aim should, presumably, be commensurate with the first and to achieve this ought to be planned. The author has noted planning toward establishing the preferred extent and locations of future forest planting. In turn, these findings should relate to such factors as average hauling distance from plant and other transportation factors, leading to an assessment of the anticipated value of standing timber grown at various locations. Under this form of planning, the value of land considered for purchase for planting will vary according to its location, as well as its production capability, leading to an economic policy for land purchase. The suggestion here is that the Commission should establish a land purchase policy in which higher prices may be justified to buy the more desirable land and land distant from planned centres of plant utilisation would be purchased at a lower price or, possibly, not at all. If a variation of price were to be rejected as being discriminatory to land owners wishing to sell to the Commission, at least a priority could be assigned to purchase of the lands. The need for such a policy will be strengthened should land purchase
competition from other sources, such as the forestry syndicates, increase or should the proposed plant locations become general knowledge. In the latter case, the landowner close to a proposed plant location would be provided with a good incentive not to sell his land, but, rather, to practice forestry in his preferred location, whereas the Commission and other prospective buyers might find themselves in a position where only the less desirable lands, from an economic viewpoint, were being offered for sale. These considerations will be of particular importance in the Highlands, where road transportation problems make transportation costs a factor of unusual importance and where the possibilities for large-scale forestry and industrialisation appear to be greatest.

Another aim of the new policy is to provide employment in rural areas, especially where the need is greatest, and to build up and maintain a thriving body of forest workers and their families. Fundamentally, this aim appears to be a social one and its influence on the economics of the situation must, in the author's view, be treated with some care. The Commission, as the employer, offers to its established workers a considerable range of benefits, which include continuous employment provided performance is satisfactory, pension at a stated retire-
ment age and, in some cases, rental housing. The author noted, in Scotland, that a considerable percentage of the work force, particularly in some forests, were of an age when it was doubtful that they could perform the more arduous forms of forest work efficiently. Certainly, as compared to British Columbia, the attitude toward the worker was, possibly, paternalistic. With the transfer of policy emphasis, it appears that forest working may become more extensive, for economic reasons, and opportunities for mechanisation, to effect cost savings, will be taken. Efficient machine operation requires not only good training and experience, but also the physical ability to achieve maximum output. The problems of attracting forest labour to outlying points are difficult ones but their best solutions may lie in incentives such as better rates of pay, either basic or through piece-work, the promotion of a mobile labour force, rather than a static, resident one through the use of mobile homes and other methods and in the creation of greater opportunities for contract work. Whatever is done, it appears to the author that the problem of providing employment in rural areas deserves serious consideration in relation to the aim of economic forestry, to determine if a more suitable compatibility of the two aims cannot be achieved.

Returning to the question of what is a fair return on
the investment, it appears that distinct benefit to the balance of payments can accrue to the British economy by home-production of wood, thereby reducing or stabilising to some extent the cost of Britain's wood imports. This is a point frequently made to support the extension of British forestry, as for example, by Beresford-Peirse (1963). It would greatly assist the assessment of the worth of British forestry to the economy if the point were to be investigated in a quantitative manner and the factor should be more readily assessed than is the value of social benefits which have been discussed previously. Holtam (1964) has assessed the British industrial requirements of home-grown wood as compared to potential production, for the period 1965-75, and this study could possibly be enlarged into a total demand and supply forecast for Britain, as a basis for estimating the effect of British forestry on future wood imports. Holtam has pointed out that, based on his estimates, imports will continue to contribute such a big proportion of Great Britain's needs for wood and wood products that prices for home-grown wood were likely to continue to follow imported prices.

d. Marketing Policy:

The Watson Committee (Forestry Commission (1956)) has
reported on the marketing of home-grown timber and has described the agencies involved in it. It noted that the Forestry Commission was to dispose of their timber in the round and in the most remunerative markets. The private sector presented a more complex situation and the Committee concluded that the marketing of produce from the privately owned sector should be integrated with the output from the State woodlands and this total home-grown output integrated into the total pattern of British timber consumption. Various objectives to be achieved by these integrations were stated and the Committee proposed that they should be achieved, in part, by a private Woodland Owners' Association for all of Britain. In practice, the Scottish Woodland Owners' Association was formed separately from the body for England and Wales. In addition, a central consultative body was also required, representative of all the principal interests concerned in the marketing of home-grown timber. MacGregor (1957) commented that, although the diagnosis of the Watson Committee was generally agreed to be excellent, there had been no suggestions for the detailed marketing machinery to be employed. He felt, also, that the main weakness in marketing home-grown timber was associated with the small scale and scattered nature of most private woodlands since this, in the absence of co-operative or organised
marketing, led to irregular and insignificant output.

The question of the extent to which the private woodland owners will adopt co-operative marketing procedures in co-ordination with Forestry Commission marketing remains to be seen, although it is clear that there is interest in accomplishing this. In the author's view, the fixing of prices by regulation, as a means of ensuring a fair return should be avoided in favour of free marketing procedures by mutual bargaining. In the case of small sales of a local nature there is probably merit in permitting their exclusion from co-operative arrangements but in dealing with large scale supplies, such as pulp mill supplies, there can be little doubt that co-operative bargaining without regulatory restriction is the best approach and the most likely to strike economic price levels. In the case of the Fort William pulp mill, the Forestry Commission reached a separate supply agreement with the company as a necessary part of encouraging the mill's construction. Agreement between private woodland owners and the company has taken longer. This is probably only natural since the woodland owners are dealing with an established pulp mill and both groups have yet to find by experience what a realistic commercial price level will be. The author believes that marketing procedures will take a number of
years to develop but that, apart from this delay, they will develop best under a free marketing system, albeit a co-operative one. In consequence, it seems to be advisable not to treat the marketing situation as an urgent problem but, rather, to continue to encourage its development along the general lines recommended by the Watson Committee.

e. Forest Tenures:

(1) Forestry Commission Lands and Holdings:

The importance of developing a new land use capability survey for Scotland has been mentioned. In this connection, the land use of Commission lands in North Scotland Conservancy, as given by the Forestry Commission (1966a) are striking. In 1966, out of a total Commission area of 597,518 acres, 313,356 acres were classed as agricultural and other land and were thus not considered suitable for forestry. These lands have accrued from land purchases, leases and feus of estates, all of which are not suitable for forestry. It is a moot point whether the Commission, which is designed to be a forest authority practising economic forestry should try to divest itself of some of these lands, particularly those whose use capability indicate that they are suitable for agriculture. In many cases, the lands under agriculture are leased back
to tenant farmers and may not be attractive enough to sell to new owners. The agricultural authorities, who define for the Commission which lands must be reserved for agriculture, rather than planted, do not own substantial land areas and the administration of the land remains with the Commission. In addition to agricultural lands, the Commission is concerned with game management, particularly in the deer forests, an activity which seems to be more compatible with its main role than does the administration of agricultural land. Possibly, the development of a land use capability survey will assist in defining more closely the land use of Commission lands and provide a basis for a decision on the most appropriate method of managing them. In the author's view, the method of accounting for these lands should be reviewed since receipts and expenditures connected with them might better be separated from the accounting for woodlands. The joining of them into a general account tends to obscure the position of the forestry operations.

The Forestry Commission is also a substantial owner of housing, partly from purchase and partly by the necessity of providing accommodation in outlying areas where none exists and private enterprise is not attracted to invest in housing. Whilst ownership of some of these
properties is unavoidable, it may be that a re-consideration of the policy aim of providing employment in rural areas, a subject discussed above in its relation to economic forestry, would provide a basis for revision of the Commission's housing policy.

The increased scale of planting proposed for North Scotland, particularly the crofting counties, indicates the need for accelerated land acquisition. In the author's view the Commission has been wise in not utilising its compulsory powers of acquisition to any great extent but, rather, depending upon negotiation and offers to purchase as a means of expanding its land areas. The author has suggested above that a suitable basis for the planning of land acquisition would be an economic evaluation of potential forest land based on its relationship to planned industrial locations. Accelerated land acquisition might then be possible by increasing the prices offered for land possessing higher economic value, even though the offers for land of lower economic value might thus become less attractive.

(2) Dedicated and Approved Woodlands:

The grants and taxation advantages available to the owners of dedicated and approved woodlands have been reviewed and they have generally proven to be a good
incentive for the afforestation and tending of private lands. It is of significance that the Watson Committee (Forestry Commission (1956)) has noted that the attitude of owners toward forestry varied from keen professional interest to apathy. The variety of arrangements made for management of their forests by private landowners was brought out. These are of particular interest to a British Columbia Registered Forester whose professional scope of activity is both defined and protected, to some extent, by the British Columbia Foresters' Act. The general effect of this Act in terms of forest management is that a registered professional forester must usually supervise, at least, or direct the management of forests. In tenures such as Forest Management Licences where the British Columbia Government pays part of the costs of forestry, it is a requirement of the contract that the licencee must employ at least one registered forester, either full-time or in a consulting capacity. The author noted when in Britain, that University-trained foresters were tending to favour the idea of a professional association of the type that would both regulate professional standards of work and ethics and, at the same time, define the fields of forestry in which it considered professional foresters should be employed, as a pre-requisite of successful forestry. The Forestry Commission, which
encourages private forestry, might consider whether it would be advisable to require, as a part of the schemes for dedicated and approved woodlands, that private owners should employ a professional forester for direction and/or supervision of the operations to which grants are applicable and for direction and/or supervision of an approved plan of operations or management. Acceptance of the requirement could be accelerated by financial consideration, within the grant, of a portion of the additional costs involved. The formation, by the professional foresters, of a regulatory association would ensure that the standards of performance of the profession would provide good forest management and assist in the acceptance, by the forest owners, of such a provision. The position of the professional firms of land agents engaged in forestry would not be jeopardised by this arrangement, although they themselves would need to employ professional foresters, as many of them now do. Estate technician foresters would take their part in management under the direction and/or supervision of the professional forester. The demands of modern economic forestry are such that it is difficult to envisage wide-spread economic success of private forestry unless professional management is introduced.
a. **Afforestation:**

The scale of afforestation and reforestation in Scotland have been reviewed and, although McNeill (1962) suggested that more research was needed into the subject of natural regeneration, it appears likely that British forestry will continue to rely heavily upon planting for regeneration.

Neustein (1962), in considering whether more productive species could be used for second rotation crops, has emphasised that, in the successful Sitka spruce areas, the species continued to outgrow all other species with the exception of *Tsuga heterophylla*, but that certain other species of doubtful value as a first crop showed some promise. Growth rate was not the only criterion, since Neustein suggested that a degree of increment loss would be acceptable in a second rotation species where stand stability could be improved by deeper rooting or improved micro-flora and fauna. Neustein also felt that larger transplants would be needed to overcome suppression by weeds, a problem that was dealt with by site preparation during afforestation operations. However, where site preparation was necessary to establish regeneration, the ploughing of wet sites for drainage and turf planting
would need new designs of equipment, particularly to overcome damage from stumps. The interest shown in the question of second rotation crops and the possibilities for a change of species strengthens the view that forestry in Scotland will continue to rely very heavily on planting for crop establishment. Henman (1963) also emphasised the severe limitations of ploughing in achieving a depth of drainage in excess of 20 inches in heavy mineral soils. New, deep drainage ploughs were being developed and on stump-covered ground the hydraulically operated, tractor mounted digger had a good potential. Yeatman (1955), discussing the Upland Heaths and Peats has pointed out a number of influences, including degree of fertilisation, hard pans, aeration and waterlogging, and application of phosphatic fertiliser which influence root development, growth rates and long-term stand stability. Zehetmayr (1960) reviewed the planting experimental work carried out in the field from 1921 and 1957 and commented upon the roles of various exotic and native species in afforestation experiments. Whilst he concluded that planting on ploughed ground presented little difficulty, he asserted that the initial cultivation represented the first steps towards improvements of soil structure and fertility. The major silvicultural problem of the future was likely to be the continuation of this improvement and the
possible lines of approach lay in further cultivation, manuring and the use of soil-improving species, particularly broad leaved trees. Jack (1965), in a thorough review of Northern Irish experience in site preparation and planting on deep peat concluded that it was possible to grow a crop of trees, noted that it appeared to be possible to give trees a good burst of initial growth by ploughing to a depth of 24 inches, but stated that it was not clear what intensity of ploughing or draining treatment was required for maintenance and stability of older stands. Both Yeatman (1955) and Jack (1965) noted that response to fertilisers tended to be much lower in stands which were growing reasonably well. In Yeatman's case, he stated that the response of vigour of the tree root system to the application of phosphatic fertiliser varied inversely with the degree of cultivation and, also, inversely with the inherent level of fertility of the site in question. It appears that the initial site cultivation affects both the growth rate and future stability of the crop, the latter being a problem of major importance to British forestry.

Fundamentally, the achievement of deeper ploughing is a physical problem which is beyond the capability of the machinery presently employed. Deeper ploughing may involve problems of penetrating and breaking up hard pan
in heath soils, the penetration by the plough, on peats, into zones of debris such as the remains of ancient forest and the problem of increasing the tendency for the drain wall to slump. It appears to the author, however, that by the adoption of an aggressive research approach, these problems should be capable of solution, at least to a substantial degree, on a reasonable cost basis. Deeper ploughing would involve more powerful machinery, with the necessary weight (possibly variable to obtain deep penetration in peat and hard pan) and adequate flotation characteristics to carry it on wet ground. Speed of ploughing should be maintained or increased for cost reasons and arrangements to vary furrow cross-section as well as depth, so as to reduce slump would seem to be necessary. An alternative is to consider the development of high-speed chain and bucket digging, although the furrow cross-section would be more difficult to vary. Recognising that the capital cost of designing and building special equipment would be high, the future area planned for planting and the annual rates of planting envisaged appear to justify a feasibility study of this approach. Other possibilities which might bear investigation include the disturbance of deep layers, such as hard pan, by hard steel rippers projecting below a plough and the laying of perforated plastic pipe at depth in peat through a tubular hardened steel
ripper. The use of low pressure balloon tyres as well as wider tracks might be considered to maintain flotation characteristics of the heavier equipment. The equipment should also be designed for the more difficult task of reestablishing the drainage pattern, where necessary, for reforestation with second rotation crops. A further feature of such a machine would be the need to move it from point to point by road or rail, a feature which entails the stripping down of accessories for a move. It appears to the author that a study of this approach merits a high priority since, should it be feasible, it will create a different set of silvicultural circumstances from those created by current techniques. The indicated benefits of improved root penetration, improved growth rates, improved long-term and short-term crop stability and the possibilities of a reduced need for fertiliser applications merit a high priority.

b. Lodgepole pine:

The position of lodgepole pine in the forest economy of Scotland, particularly Northern Scotland have resulted in a detailed review of the literature about it. The major problem surrounding it in Britain is that of selection of provenance. The next chapter of this thesis deals with a study into some aspects of the provenance problem and a
discussion of them is deferred to that chapter. The species appears to have a good potential for both pulp and lumber use in Britain, provided that the form of the tree is good.

c. Sitka spruce:

Sitka spruce is probably the most favoured species for planting in Scotland at the present time, in that it is planted on sites of good enough quality, with lodgepole pine being planted on sites which are considered to be of too low a quality to support the spruce. Some authors, particularly Davies (1967), have urged that the use of Sitka spruce, with its faster growth rate, should be extended to the more infertile sites for which lodgepole pine has usually been favoured, on the basis that an adequate application of phosphate results in the species withstanding exposure better than any other species in the Conservancy and that it has a superior growth rate. Given routine manuring, it appeared that it was the species most likely to repay the costs of intensive silviculture. Whether or not these proposals are adopted, Sitka spruce is easily the most important species, in terms of current rates of planting, in Scotland. However, there is a considerable support in Forestry Commission opinion for the extensive use of lodgepole pine in North Scotland Conser-
vancy. Problems of provenance of the spruce appear to be minor as compared with the pine, although Burley (1966) has noted that there is a broad interaction of genotype with environment that should be evaluated before planting the species at any given site. The species appears to be considerably more susceptible to wind-throw than is lodgepole pine and although this can possibly be corrected in a number of situations by improvement of initial drainage of site, it may eventually prove to be a considerable deterrent to the continued large-scale use of the species. It is also important that, whilst the spruce is suitable for pulp and board manufacture, its use and value as lumber is considerably restricted by its grade, the need to use preservatives on building components, the difficulties of obtaining preservative penetration and the difficulties of obtaining a smooth finish when planing.

In considering the relative growth rates of Sitka spruce and lodgepole pine it is most advisable to extend questions of their relative growth rates into questions of the value of the resulting wood per unit of volume. An important factor for pulp is the relative volume per bone-dry ton of chips derived from the spruce and the pine and, in lumber, of the widths and, particularly, the grade of the product. In terms of lumber grades, the pine appears to be superior.
It is of interest to note that the very rapid increase in the use of small diameter lodgepole pine which has occurred in recent years in British Columbia has resulted, to a considerable extent, from the good grades of lumber which have resulted.

d. Site Productivities, Rotations and Yields:

There has been a considerable interest in Britain in the development of long-term production forecasting techniques. In the case of the work by Sinden (1964 and 1965), short-term forecasting was used to determine the best financial age at which a mature crop should be felled. The generally accepted technique for forecasting involves the use of Faustmann's concept of nett discounted revenue. The need for long-term forecasting, as pointed out by Johnston and Bradley (1964), is particularly evident where industry is considering the construction of expensive, wood-using mills and must have estimates of quantities and specifications of the raw material coming onto the market for many years ahead.

It is a moot point whether it is worthwhile to carry estimates of this kind to a high degree of refinement. Faustmann's formula is subject to the well-known weakness that the prevailing market prices at the end of a rotation cannot be predicted with any assured degree of accuracy.
from many years beforehand, even in a so-called controlled economy. Also, it is difficult to predict the relative demands and values of the various end-products for which the wood might be required. In any economy, there is no guarantee that the produce of the forest will be put to its optimum economic use since the supply of large existing plants of social, as well as economic, importance will normally take precedence over the transfer of supply to a new plant, even though the new plant may be considered to be more economic. Forecasting is clearly necessary for certain purposes but it is important that forecasts be treated as such, rather than viewing them as a fixed aim of management. It follows that guarantees to supply plants in order to encourage industrial development, should be made as flexible as is mutually acceptable so that advantage may be taken by management of attractive economic opportunities and changes of practice as they arise.

The possibilities of increased growth rates by manuring appear to be most attractive and the further intensification of forest practice to take advantage of them appears to be likely in Britain. Some suggestion has been made, however, that a reversion to extensive forestry might be more economic in terms of reducing the work force per acre and in abandoning early uneconomic thinnings.
An economic analysis comparing the two approaches would be of value as a decision-making tool. However, the attraction of manuring lies in the fact that it appears that the plantation forestry can be made more profitable and the actual levels of wood production per annum from the Scottish forests could be substantially increased, making increased industrialisation possible. It appears to the author that the proposals of Davies (1967) and (1967a) for aerial fertilisation will be followed to an increasing extent. Binns and Grayson (1967) have also favoured increased manuring of the forest. They have pointed out that the lower the stumpage price that was expected or the higher the costs of manuring, the less was the justification for treatment. In certain stands it would be better to practice extensive forestry. But there would be some sites and conditions of crop where the response to fertilisers would transform the crop's potential and the sort of management applied. Reports to date have favoured the use of helicopters over fixed wing aircraft, apparently because of the flight distance from airports to the forests and restrictions of operations by weather. The situation should be subjected to close analysis. Helicopters are considerably more expensive to operate than are fixed wing aircraft and are more restricted in load-carrying capacity. The construction of air
strips by the Forestry Commission to facilitate fixed-wing operations may provide a lower cost solution to aerial fertiliser dusting. The anticipated increase in the use of fertilisers should be accompanied by careful cost analyses and a research programme to gauge crop response and duration of response.

With reference to the points made about long-term production forecasting, the possibilities of introducing manuring on a large scale is an example of a new technique which could materially change existing forecasts.

e. Plant and Forest Utilisation Standards:

It has been of considerable interest to the author to compare the logging techniques in use in Scotland with those of British Columbia. Log preparation in the woods is considerably more precise in Scotland. Although Zehetmayer (1965) used the premise that the carrying-out of any operation in the forest was more expensive than doing it at a mill or landing and concluded that the debarking operation was the most obvious one at the mill, he felt unable to transfer cross-cutting from the woods to the mill, where the possibilities of mechanisation and lower unit costs are better. He recommended instead, an optimum length of pulpwood of from 10 to 12 feet. Tree length skidding, as commonly practised in British Columbia
is restricted by the damage likely to be caused to the residual trees in the thinned stand and, in part, by the power of the extraction equipment. Considerable amounts of extra work are involved. The logger cross-cuts the logs, often on difficult ground and then man-handles them over short distances into bundles large enough to give efficient skidding operation. The conversion to short pieces at this point increases the amount of handling which is necessary to load the vehicle. Cross-loading has been avoided and the truck design is such that lengths over 12 feet, loaded lengthwise, could only form one stack. The taper of British thinnings generally exceeds 1 inch in 7 feet and this requires piling of top to butt to some extent, to avoid awkward loads. The trucks have a solid bed with bunks - a rather surprising arrangement since it increases vehicle weight and increases the difficulty of stacking curved pieces. The author felt the North American truck with its pole extension, rather than a fixed bed might have features which could be advantageously adopted. The pole extension lightens the vehicle itself and permits the length of the vehicle to be adapted to the length of the load. Thus it could be possible to load pieces considerably longer than 12 feet. The absence of a solid deck would ease loading. Also, on the return trip, the trailer wheels are hauled up off the road onto the back
of the truck making the vehicle of much shorter length and greatly assisting traffic flow and turning capability in the forest. A major advantage in Scotland, by reason of lightening the vehicle itself, could lie in the possibility of carrying larger loads of wood. The cost of transportation of wood in Scotland in which load limitations are involved, is high and critical in relation to the overall forest economics. On this basis, the possibilities of specialised vehicles are considered to be worthy of investigation.

The advances made in mechanisation of logging in Scotland are most striking, particularly insofar as the use of power saws, the Isachsen double drum winch and mobile log loading equipment are concerned. It appears to be inevitable and necessary that the process will continue. The author felt that a good potential exists to develop more powerful skidding equipment along the lines of the Isachsen. Mobile skidding equipment is difficult to employ on many Scottish sites because of wet ground conditions. In this connection, it would be worthwhile to conduct of a study of the diversified types of rubber-tyred skidding equipment which are operating successfully in Canadian spruce swamps. A major feature which might be incorporated successfully into British equipment is the
use of large diameter, wide tread, low pressure rubber tyres. The marked trend in the Interior of British Columbia away from tracked skidding equipment to rubber-tyred equipment is based on the lower investment, faster skidding speeds, greater manoeuvrability and overall lower operating costs of the latter.

The question of road spacing and standard is receiving considerable attention in Scotland at the present time. In many instances, roads constructed at the time of planting to provide access, were not laid out to provide future optimum spacing for double-drum winch extraction. It seems that the problem may recur, if roads are now laid out at the time of planting for optimum economic extraction by a particular means, since there is always the strong possibility that a given mechanical system will be superceded by another with the passage of time. It appears to the author that there are considerable advantages in taking a practical approach and maintaining the level of road construction at a minimum. At the time of planting, the widest practical spacing and the minimum standard of construction should be adopted. The increase in planting cost should be more than offset by the saving in road construction cost. The first thinning should be deferred as long as is silviculturally possible and the
deferment might be lengthened by adopting wider planting distances. This approach would mean the acceptance of only moderate access for personnel during the period from planting to first thinning but could result in substantial savings of initial capital expenditure and interest. At the time of the first thinning, a decision would be necessary on road spacing and alignment, based on the optimum economic balance between truck hauling costs for loads of various sizes and the cost of road construction for the particular locality. Higher truck hauling costs for smaller loads might be justified in some localities by savings in road construction capital and interest charges. As the value of the timber stand increases the standard of the roads could be improved. The principle here is to defer the capital expenditures on roads as long as possible and, when expenditures are made, to recover as high a proportion of them as possible by a concurrent cut, recognising that practical restraints will apply to the principle. This approach does not solve the problem of having to re-locate or abandon roads to conform to changing extraction systems but it would avoid such changes being made in a high-cost road system, involving heavy losses of invested capital.

The difficulties encountered in the location of
stacking spaces (landings) in some Scottish forests are also common in Canada and there is no standard solution to provide the best financial results. In one location a landing would be preferable to stacking along the roadside and in another location, the reverse may be true. Even where it is preferable to locate a landing, control of its cost of construction is most important. For example, in British Columbia, certain kinds of mechanised log handling on a landing demands a large flat area because of the turning radius of the machines employed. These large landings are costly to construct and only the flow of a large volume of logs over such a landing would justify its construction. Thus the decision as to the method of stacking (decking) logs after extraction should be a local one. To arrive at a proper solution for this kind of problem of which there are many, it seems to be most desirable that foresters in charge of logging should have training in the economics of logging.

f. Road Transportation:

A number of points affecting the transportation of forest products have been made. A major problem which was faced by the industry lay in the standard of the public (Government) roads system of Scotland, which in many areas were not of a suitable standard for the carriage
of economic loads. The work of Davidson (1967) has provided a logical approach to the problem and improvement of certain categories of road to a 24 ton gross load standard is proceeding. The decision was a compromise one, based on costs. Nevertheless, it may be necessary, at the conclusion of present improvements, to proceed with further improvements. The road system of the Scottish Highlands has been well below the standards needed not only for forestry but for the establishment of industry and for the strengthening of the increasingly important tourist industry. In the case of British Columbia, it has been the policy in recent years to build roads in anticipation of industrial development and to improve facilities for tourists and, to some extent, considerations of this kind may well justify the continued development of a major road system in the Highlands.

g. Forest Utilisation:

As described by Hart (1962a), the Forestry Commission regulates the felling or sale for felling of privately owned growing trees, under the provisions of the "Forestry Act, 1951." The important exceptions are dedicated woodlands, in which the owner may fell in accordance with the agreed plan of operations, without a licence. The Forestry Commission is empowered to include replanting conditions
in a licence and the owner may claim appropriate planting grants. The power to regulate private fellings was undoubtedly important when forest policy aimed at building a reserve of timber for use in wartime. Under the new policy of practising economic forestry and since a large area of private woodland is now dedicated or approved, the importance of the licensing system has declined, although it still has a role in the preservation of the beauty of the countryside. The practice of economic forestry will not necessarily lead to the planting of every available productive acre with trees, indeed it is quite likely that small isolated forests may be placed into an amenity, rather than economic category. Whether or not the preservation of aesthetic beauty will be considered a sufficient reason to retain the licensing system, it appears that its value, from an economic viewpoint, will continue to decline in the future and the cost of its administration may be questioned.

The Forestry Commission has stated that it does not foresee that it would enter into the field of forest products manufacture and the author views this policy as most wise. The policy of encouraging forest industrial development, including the possibility of obtaining Government loans, is a necessary one to deal with the
growing output of wood volume from the forest and its effectiveness is demonstrated by the establishment of the pulp mill at Fort William. More pulp plant developments may be anticipated. The attractiveness of chipboard and softboard manufacture is limited by their economics and this position is quite similar to that in British Columbia where very low cost wood is a pre-requisite for profitable operation of the plant. The opportunities for plywood manufacture from home-grown timber are limited by rapid growth rates, which produce fewer than the desirable 8 rings per inch of radius, and by the presence of frequent knots. A great opportunity exists for the modernisation of the sawmilling industry and its integration with the pulp and board industries in terms of chip supply. The future developments in sawmilling will probably demand larger plants with a considerably higher man-hour productivity and higher investment than is the case at the present time. Study and discussion on the reorganisation of the industry have been proceeding.

Mention has been made of the fact that the Forestry Commission does about one-half of the logging on its own lands and that the Trade Associations favour the sale of standing timber to merchants. The Commission has not committed itself to increasing the sales of standing tim-
ber but has held that the proportion would be variable, depending on a variety of factors. The author has commented upon the difficulties of achieving the economic aims of forestry where permanent labour forces are employed and it seems likely, in the future, that there will be a greater trend toward contract logging, particularly as a forest-oriented community, possessing logging skills, develops. Contractors themselves should develop mobility of their crews as well as their equipment, possibly to the extent of providing mobile trailer housing, so as to take advantage of logging opportunities throughout Scotland, as they arise. There is also a large field for contract logging in the privately owned forests. The continued development of a healthy independent contract logging industry will serve to maintain a competitive situation suited to the economic aims of the forest policy. There is a tendency to equate the Commission policy of providing rural employment with the maintenance of a given level of employment within the Commission itself. However, contract logging is also a means of executing the policy.

The tendency of the Commission toward the allocation of timber and away from sale to the highest bidder by competitive auction or tenders bears some resemblance to the trend of Government policy in British Columbia, where
ruinously high bidding, aimed at capturing the volumes normally logged by another party, had a strong influence. As with the Forest Service, the Forestry Commission relies heavily on its own appraisal of the value of standing timber but appears to be planning to avoid the subsequent auction or tender bidding in favour of direct negotiation with the party to whom the timber is allocated. This possible system will probably be restricted to 80 percent of the party's requirements with competitive bidding applying to the other 20 percent. It is of particular interest that the Commission sells its timber on a lump-sum basis, a system which is frequently advocated by the forest industry in British Columbia. However, the estimate of timber volumes to be sold by the Commission are generally more accurate than those of the Forest Service, for reasons of cost and available staff and the Forest Service continues to favour the scale of timber removed as a basis of payment, rather than a lump-sum sale based on the estimate of standing volume. The Commission, although incurring a higher cruising cost, does avoid the considerable administrative expense of collecting scale returns from the industry and the billing and receipt procedures. Where the volume cut falls short of the estimate, the Commission is usually prepared to negotiate with the purchaser to reach a settlement. In the author's view
there is much merit in the Commission procedures.

h. Forestry Commission Management Plans:

Little comment need be made on the progress of Commission Conservancy and Forest Management Plans, the latter of which are in process of preparation. The system of preparation is well organised and will eventually contribute greatly to rational management. The present position is quite similar to that in the British Columbia forests managed by the Forest Service, for which plans are in the course of preparation.

i. Effects of Wind:

The severe problems posed by wind to British forestry have been reviewed in some detail. Much of the investigation into cause and effect has been directed toward analysis of rooting development and the effects of tree height in stands on various soils but where standard ploughing techniques have been employed. The author has suggested that research into methods of achieving improved soil drainage and penetration of hard pans, so as to possibly improve the rooting structures could lead to substantial reductions in wind-blow. These measures alone, if feasible, will not prevent future damage from wind-blow and stem break and cutting systems are another area in which more investigation is necessary. There are
indications that tree height may prove to be a limiting factor, requiring the adjustment of rotation length. The increase in plant utilisation capacity which will almost certainly occur will reduce the impact of large-scale damage by wind by providing a faster means of processing of damaged trees, with normal fellings being deferred. The effects of wind on the stem form of certain provenances of lodgepole pine are quite marked and these effects are discussed in more detail in the next chapter. Wind damage in Scotland, although opportunities for its reduction exist, will continue to be a problem to which management and the forest industry must adapt to arrive at the best current economic solution possible.

j. Forest Thinning:
The economic problems of thinning practice have been discussed by several authors. Matthews (1963) emphasised the need to choose the residual stems carefully, particularly in view of the trend towards heavier thinning. Thom (1964) wanted to see the definition of zones for "intensive" and "extensive" forestry, based on the economics of zones. Crowther (1964) and Stirling (1964) have favoured the Scottish eclectic thinning method, because it produces larger poles and greater volumes in the early thinnings. Dickson (1964) wanted to have more research
into provenance, planting distances and pruning, so as to obtain the highest nett returns from thinnings.

For many years past, it has been recognised that first thinnings and, frequently, second and third thinnings, seldom result in a profit. Although certain desirable silvicultural results accrue to the residual stand and the total production of wood per acre over a rotation is substantially increased, the problems of economics have, if anything, increased and made profitable thinning increasingly difficult to accomplish. However, much of the current wood production in Scotland is in the form of thinnings and to maintain existing plants in a number of areas, thinning is a necessary operation. The author has already suggested that a logical approach to forest economics may lie in considering the forestry and plant operations as an economic whole, rather than treating with forestry alone, and this concept would include thinning operations. The deferment of the first thinning and the reduction of initial forest establishment costs by the adoption of wider initial plant spacing is an attractive possibility for improvement of the cost structure but may have the drawback that suppression of heather and competing vegetation would be delayed, slowing tree growth. Nevertheless, the author believes that it ought to be tested, employing spacings of 7, 8 and 9 feet.
The author is unable to comment on the effectiveness of eclectic thinning since, although the three examples which were examined did not appear to give desirable silvicultural results, this small sample was not considered to be an adequate one to arrive at an informed opinion. The suggestion of Thom (1964) holds much merit since it would permit a less intensive thinnings regime in those areas, the geographic location of which, in relation to plant location, are of lower economic value and/or in those stands in which the productive capacity does not merit intensive silviculture.

The general conclusion is that thinning must clearly continue to play a major role in Scottish forestry, if the establishment of additional manufacturing capacity is to become a reality and maximum volume production is to be achieved. The major problems are economic and the various proposals of the authors mentioned ought to be pursued in an effort to improve the economic position.
CHAPTER 8

AN INVESTIGATION OF BASAL SWEEP OF LODGEPOLE PINE IN BRITAIN

1. General:

It has been well recognised in Britain that plantations of lodgepole pine of South Coastal origin (Washington and Oregon Coasts) in Britain have been subject to basal bowing. The seed of South Coastal origin has been largely favoured in Britain because, in addition to displaying the qualities of tolerance to site and exposure which are common qualities of the pine, it exhibits the fastest growth rate of any region of origin. It has a proven ability to grow on poor peats. In visiting the older plantations of lodgepole pine, the author formed an adverse impression of the commercial value of the stands affected by basal bowing and, with the approval of Professor Black and Doctor Taylor, subsequently undertook an investigation of the phenomenon.

The potential importance of the problem is readily appreciated when it is noted that the Forestry Commission, in the four years from 1963 to 1966, imported 7,148 lb. of lodgepole pine seed, of which 3,460 lb. were of South Coastal origin, or almost 50 percent of the total. During the same four years, 81 million lodgepole pine trees were
planted in Great Britain, of which 58 million were planted in Scotland. If the proportion of trees of South Coastal origin were to be 50 percent, this would mean that, during the four year period, almost 29 million trees known to be subject to basal sweep were planted in Scotland. The Forestry Commission have reported on the incidence of the basal sweep on 23,374 acres of South Coastal lodgepole pine contained in a number of sample forests in Scotland. There were 13,800 acres (59 percent) estimated to have an amount of basal sweep not worthy of special consideration. Another 6,000 acres (26 percent) were estimated to have a proportion of crooked stems no greater than could be removed as thinnings, i.e. under 50 percent. The other 3,500 acres (15 percent) had over 50 percent of stems with sabre butt. To the author, these estimates suggest a serious economic situation for the future. The 6,000 acres from which the crooked stems would be removed by thinning are likely to be costly and probably uneconomic to thin because of low returns and additional handling costs, where the wood can be used. Thinnings, in any event, are more costly to utilise per unit of volume than is the final crop stand. Also, the tendency of sweep to "grow out" without increasing diameter might possibly justify the retention of trees without excessive sweep where the economics indicate this. Based upon the estimates and
taking a realistic management viewpoint, it appears that about 40 percent of South Coastal lodgepole pine plantations in Scotland will present a serious problem to profitable management.

There is an unfortunate trend in present-day forestry, noticeable in both Great Britain and British Columbia, to base forest management decisions upon economic analyses of a quantitative nature, giving inadequate weight to qualitative considerations. With attention concentrated upon the financial success of the forest, as a separate enterprise, the quantitative analyses based on fast-growing species, short rotations and average overall or average product group prices, offer attractive justification for management decisions. The process is sometimes defended by the viewpoint that the forester, faced with rapid technological changes, cannot foresee or adequately forecast, the end use for which the forest is being grown. In consequence, it is sometimes concluded that the objective of management should be to grow the greatest volume of wood in the shortest possible time on the premise that the technical ingenuity of the industrial plant designers will successfully overcome any quality or size problems which might arise. Whilst it is most difficult, if not impossible, to disprove these hypotheses, present trends give cause to doubt them. The actual trend in industry,
for almost all conversion processes, is to demand more, rather than less quality in the forest produce supplied to it. The mechanisation and centralisation of production processes, such as debarking by machine at the plant, rather than by hand in the woods and, in British Columbia, the practice of cutting to maximum length in the woods, leaving most of the bucking (cross-cutting) to a cut-off plant at the mill, have led to an increasing demand for straight logs. The new processes of profiling logs converting the outside of the logs directly into pulp chips have proved to be economic since they represent a relatively high degree of automation. However, the processes basically require straight logs and lose much efficiency when dealing with logs containing sweep. In view of these trends, the author believes that quality, including stem straightness, is an important consideration for the future. It appears that a proper management decision, so long as present actual trends continue, will aim at the production of wood of reasonable quality as well as rapid growth. From discussion with British foresters and researchers it appears that current opinion tends to favour the continuation of planting of South Coastal lodgepole pine, because of its higher growth rate and to treat the problem of basal sweep as a silvicultural challenge. The author reasoned that, if it were shown that the loss of quality
and cost increases attributable to basal bowing negated the advantages of rapid growth then it would become important to actually plant seed of other origin until such time as a satisfactory silvicultural solution to the sweep problem could be found. Visual observation of young plantations of South Coastal and British Columbia Interior provenances at Wykeham and in other areas indicated that basal bowing of South Coastal provenances was occurring in an extensive way, whereas the Interior provenances were retaining straightness of stem.

The work of Edwards, Atterson and Howell (1963), in their efforts to determine the causes of basal bowing, has been cited in the Review of Literature for Scotland. Fundamentally, they concentrated on the rooting characteristics of trees blown over at an angle and trees remaining upright and found that trees on ridge tops showed better root development than did trees planted in the furrow bottom. The Forestry Commission researchers have continued to investigate the problems and are currently conducting further investigations into rooting characteristics and susceptibility to windthrow. To date, it appears that a satisfactory solution, to prevent basal bowing, has not been reached. There has been some thought that basal sweep seemed to be related to very rapid early growth of trees and a series of experiments, not two years old, have
been initiated by the Commission. Whilst it is too early to judge results conclusively, there are certain indications of interest. The reduction of phosphate fertilizer, applied at the time of planting to $\frac{1}{2}$ oz. and 1 oz. per tree (as against the normal 2 ozs.) does not appear to have reduced sweep significantly. Application of phosphate 3 years after planting and not before, appeared to reduce sweep but this result may have been due to wind shelter from the surrounding stand. The dipping of roots into a phosphate/soil paste, using about $\frac{1}{2}$ oz. phosphate per tree appeared to reduce bowing but is inconclusive at present. The use of very large plants, which also increases planting costs slowed the initial growth and reduced bowing and appears so far to have been successful. In addition, massive doses of potash have been applied in an attempt to stimulate root growth but it is too early as yet to assess results.

The problem of basal bowing appears to be a result basically, of physical factors. Lodgepole pine is planted, to a considerable extent, on the Upland Heaths or peats. The depth of ploughing for drainage is quite limited. In the case of the Upland Heath, a hard pan at about two feet depth or lower may not be broken by ploughing and will form a barrier to root penetration, in addition to impeding downward drainage and possibly, thereby, further affecting
root development. In the case of the peats, root penetration is directly limited by the extent to which the water table is lowered by ploughing and attendant drainage. There are current mechanical limitations on the depth of ploughing which is practicable and deeper ploughing on peats, for example, would present problems such as slumping of the sides of deep drains and subsequent drainage maintenance. Edwards, Atterson and Howell (1963) found little evidence of trees blowing over when planted on the ridge top and extensive blowing over when planted in the bottom of the furrow and attributed this to better cultivation and a more stable rooting medium on the ridge top and it appears likely that better aeration on the better drained ridge-top contributed to better root development in terms of root spread. It is notable that step-planting on the side of the furrow is favoured in many locations at the present time.

When the lodgepole pine is planted, it is nowadays frequently fertilized with 2 ozs. of phosphate to overcome check and permit initial rapid growth. It is usual, after about 3 to 5 years of growth, for the young pine of South Coastal provenance to blow over at an angle of some 20 to 70 degrees away from the direction of the prevailing wind. It is most unusual for Interior provenances to suffer from this effect. Whilst there is no direct evidence to
support the opinion, the author has little doubt that the much denser crown of the South Coastal provenances, regarded as a biological advantage, in relation to that of the Interior provenances, provides a much more effective "sail" with which the wind levers over the young tree. The remarkably uniform angle adopted by blown-over trees in a given location, suggests a level of force resulting from a given maximum wind-speed and "sail" areas of relatively uniform density. The phenomenon is particularly striking when alternate rows of South Coastal and Inland types are viewed and it is seen that the Coastal type have all adopted a fairly uniform lean and the Inland types have not. There are, of course, provenances which demonstrate intermediate reactions but these are generally intermediate in type, including crown form.

With further development, the tree will correct its lean to re-assume its vertical growth and, in some instances, it will over-correct so that the stem re-assumes its position vertically above the root collar, or nearly so. In only a few instances, from the author's observations, will the stem over-correct more than this. Some of the butt sweeps are very long, extending for some fifty feet and others very short.

As will be seen from the results of the investigation,
described below, there is a possible relationship between the number of trees with sweep and the degree of sweep and the prevalence of windfall in the stand. This phenomenon may be attributable to the crown density and area, in the same way that the young tree is susceptible to the effects of excessive leverage. However, it also appears to be at least possible that part of the phenomenon is due to the presence of sweep. As noted, the young trees generally lean away from the prevailing wind and the sweep develops accordingly. In consequence, the wind force upon the crown is translated by an effective, flexible lever into a force which has a generally upward direction on the root system to windward. The author observed this effect in a plot of South Coastal provenance at Wykeham (Upland heath), when moderate winds were blowing. Portions of the root systems to windward of trees with heavy sweep rose upwards into the air from cracks opening in the ground surface when gusts of wind occurred and descended into the cracks which then closed, in periods of calmer winds. The angle at which the stem reaches the ground surface would appear to have an important influence on the effective application of an uprooting force.

Reverting to questions of quality, the author has been unable to find any studies into the wood quality of basal sweep in the pine. However, there appears to be little
doubt and this has been confirmed in discussion with wood technology specialists, that reaction wood occurs extensively in the swept portion of the stem. In British Columbia and the United States, the occurrence of sweep in Interior lodgepole pine is a rare occurrence. The shore pine is frequently contorted in form but then, so are many species occupying exposed sites close to the Pacific Ocean and it may be that the cause is environmental, rather than genetic in origin. The Inland pine was not used in British Columbia until relatively recently because of its relatively small diameter. Its subsequent, burgeoning use has been based to a considerable extent upon its excellent form, its relatively uniform, if small, size and the good lumber grades of its wood. Its form and size have permitted a degree of mechanisation and automation which have permitted economic plant conversion. These advantages would be largely negated if extensive sweep existed and, indeed, it is doubtful whether the species would have come into commercial use to anything like the extent it has, had this condition prevailed.

2. Hypothesis:

Based upon the foregoing considerations the author formed the hypothesis:

a. That the sweep occurring in the South Coastal provenances materially reduced the stand value
for existing end uses and would result in added thinning and logging costs from handling and loading difficulties, where the sweep could be used at all.

b. If the reduction in stand value and cost increases were sufficiently large to nullify the advantages of faster growth and since effective means of preventing sweep in the Coastal types have not been developed, then there would be reason to review the policy of large-scale planting of these types with the possible selection of another provenance.

c. The occurrence of sweep had a possible relationship to the incidence of windfall.

3. Areas of Investigation:

   a. Wykeham Forest:

   Upon the recommendation of the Forestry Commission silviculturist for Scotland, the initial and detailed portion of the investigation was undertaken at Experiment No. 55, Wykeham Forest, Map reference on 1" Sheet 93-44/950875. The experiment is situated on Wykeham Low Moor, North Riding, Yorkshire, 5½ miles west of Scarborough. The area is about 600 feet above sea level and lies on top of a ridge with a deep dale half a mile to the west. The ground rises very steadily towards the north to
end in a deep dale within one mile. The aspect is south, south west and the area is sheltered on the south by an old wood and is moderately to fully exposed elsewhere. The topography is practically flat apart from a slight convexity and there is a slight natural drainage towards the south, south east. The geological formation is Lower Calcareous Grit of the Middle Oolite series and the soil has 1" - 4" of raw heather humus on 8" - 10" of leached grey sand. Below this is a thin pan of varying hardness over a red-brown, sandy loam which changes to orange colour at 12" - 15" depth. Small stones are present in all layers, increasing in size as the depth increases.

The experimental area was ploughed in an approximate north-south direction to a moderate depth, employing a double-furrow plough, in 1933 and planted in 1938 with a variety of lodgepole pine provenances, all plants being 2 + 1, except for provenance 35/54 (Oregon) which was 1 + 1. Planting was done by a vertical notch in the 5 year old furrow, after cutting away the heather. Prior to planting, the area appears to have carried isolated Scots pine trees and it was used as a grouse moor. It was burnt over in about 1920. The prevailing wind is W.S.W.

The provenances to be tested consisted of 3 coastal seed lots, 2 intermediate (Skeena River) seed lots and 11
inland seed lots, usually with 3 replications each in randomised blocks and with a plot size of 0.1 acre and narrow plot surrounds between plots. The plot layout is shown on the accompanying diagram.
The provenances and their distribution to plots were:

<table>
<thead>
<tr>
<th>Provenance</th>
<th>Source Elevation Feet</th>
<th>Plot Numbers</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Coastal</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>34/25 Sonora Island and New Westminster</td>
<td>10-50</td>
<td>24 37 10</td>
</tr>
<tr>
<td>34/40 Olympic Peninsula (believed Shelton)</td>
<td>300-500</td>
<td>34 14 11</td>
</tr>
<tr>
<td>34/10 S.W. Lincoln County, Washington</td>
<td>100</td>
<td>20 22 --</td>
</tr>
<tr>
<td><strong>Skeena River</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>35/18 Smithers, B.C.</td>
<td>2000</td>
<td>15 46 2</td>
</tr>
<tr>
<td>35/22 Hazelton, B.C.</td>
<td>1150</td>
<td>40 18 6</td>
</tr>
<tr>
<td><strong>Inland</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>34/24 Prince George, B.C.</td>
<td>1870</td>
<td>36 28 9</td>
</tr>
<tr>
<td>35/17 Prince George, B.C.</td>
<td>1870</td>
<td>26 39 1</td>
</tr>
<tr>
<td>35/19 Williams Lake, B.C.</td>
<td>1750</td>
<td>35 23</td>
</tr>
<tr>
<td>35/20 Clearwater, B.C.</td>
<td>1500</td>
<td>41 27 4</td>
</tr>
<tr>
<td>34/23 Shuswap Lake, B.C.</td>
<td>2000-2700</td>
<td>30 17 16</td>
</tr>
<tr>
<td>35/21 Shuswap Lake, B.C.</td>
<td>1200</td>
<td>31 47 5</td>
</tr>
<tr>
<td>34/69 Priest River, N. Idaho</td>
<td>2380</td>
<td>21 33 12</td>
</tr>
<tr>
<td>35/53 East Washington</td>
<td>Unknown</td>
<td>14 38 7</td>
</tr>
<tr>
<td>34/68 East Yellowstone, Montana</td>
<td>6700</td>
<td>29 -- --</td>
</tr>
<tr>
<td>35/54 Oregon</td>
<td>Unknown</td>
<td>25 42 8</td>
</tr>
<tr>
<td>35/59 Williamson River, Klamath, Oregon</td>
<td>3400-5000</td>
<td>19 32 --</td>
</tr>
</tbody>
</table>

Growth and yield data for the plots (Sample Plot Form No. 9) were supplied by the Forestry commission and portions of the data have been employed in the investigation, where applicable.
The following average data were also supplied by the Forestry Commission and shows the percentage of the crop that was unstable and windblown at the age of 26 and 29 years respectively. The data also show the average mean annual increments per annum for each provenance, it being thought that a correlation could possibly exist between crop instability and mean annual increment.
<table>
<thead>
<tr>
<th>Provenance</th>
<th>Plot Nos.</th>
<th>M. A. I.</th>
<th>% Crop Unstable</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>26yrs</td>
<td>29yrs</td>
</tr>
<tr>
<td><strong>Coastal:</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>34/25</td>
<td>Sonora Island and New Westminster</td>
<td>10, 24, 37</td>
<td>70</td>
</tr>
<tr>
<td>34/40</td>
<td>Olympic Peninsula (believed Shelton) Washington</td>
<td>11, 13, 34</td>
<td>94</td>
</tr>
<tr>
<td>34/10</td>
<td>S.W. Lincoln County, Oregon</td>
<td>20, 22, --</td>
<td>92</td>
</tr>
<tr>
<td><strong>Skeena River:</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>35/18</td>
<td>Smithers, B.C.</td>
<td>2, 15, 46</td>
<td>76</td>
</tr>
<tr>
<td>35/22</td>
<td>Hazelton, B.C.</td>
<td>6, 18, 40</td>
<td>80</td>
</tr>
<tr>
<td><strong>Inland:</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>34/24</td>
<td>Prince George, B.C.</td>
<td>9, 28, 36</td>
<td>74</td>
</tr>
<tr>
<td>35/17</td>
<td>Prince George, B.C.</td>
<td>1, 26, 39</td>
<td>74</td>
</tr>
<tr>
<td>35/19</td>
<td>Williams Lake, B.C.</td>
<td>3, 23, 35</td>
<td>82</td>
</tr>
<tr>
<td>35/20</td>
<td>Clearwater, B.C.</td>
<td>4, 27, 41</td>
<td>74</td>
</tr>
<tr>
<td>34/23</td>
<td>Shuswap Lake, B.C.</td>
<td>16, 17, 30</td>
<td>87</td>
</tr>
<tr>
<td>35/21</td>
<td>Shuswap Lake, B.C.</td>
<td>5, 31, 47</td>
<td>90</td>
</tr>
<tr>
<td>34/69</td>
<td>Priest River, N. Idaho</td>
<td>12, 21, 33</td>
<td>87</td>
</tr>
<tr>
<td>35/53</td>
<td>East Washington (Unknown)</td>
<td>7, 14, 38</td>
<td>85</td>
</tr>
<tr>
<td>34/68</td>
<td>West Yellowstone, Montana</td>
<td>29, --, --</td>
<td>43</td>
</tr>
<tr>
<td>35/54</td>
<td>Oregon (Unknown)</td>
<td>8, 25, 42</td>
<td>56</td>
</tr>
<tr>
<td>35/59</td>
<td>Williamson River, Klamath, Oregon</td>
<td>19, 32, --</td>
<td>73</td>
</tr>
</tbody>
</table>
The thinning treatment of the plots had been standard Forestry commission C/D grade at three year intervals. It is important that the Chief Forester in charge of the experiment confirmed that thinning had aimed at removing the worst trees subject to reasonable spacing of residual trees. The plots appear to have received careful silvicultural treatment which has improved the stand on them.

b. Achnashellach Forest:

The results obtained by detailed measurements at Wykeham Forest were such that it was felt to be advisable to test them by a counting procedure, rather than by further detailed measurements, at other Forestry Commission lodgepole pine trials, preferably in different conditions from those encountered at Wykeham Expt. 55. The provenance trial areas selected were at Achnashellach and Millbuie.

(1) Achnashellach 24 P.37 Ext. 38, 39, 31:

The trials at Achnashellach are large and this section of them contained three trials which were used for the investigation. The trials planted in 1937, consisting of plots of approximately 0.1 acre in size, contained 5 replicates of each of 11 provenances, 1 replicate being randomly assigned within each of five contiguous blocks. One provenance only had four replicates, two of these being in half-size (0.05 acres) plots and the provenance was not used for the purposes of the investigation.
Another block, planted in 1939 occupied an exposed position higher up the slope than the other blocks and consisted of 0.1 acre plots. Two plots were rejected because of heavy exposure damage and third was rejected since its provenance was not replicated elsewhere. Two plots were found to be in juxtaposition on the ground as against the map. There were 5 replicates of each of 7 provenances which were used and these replicates were assigned randomly to each of 7 blocks which were not always, however, contiguous.

The trials are located close to the west coast of Scotland, at an elevation of 120 - 150 feet above mean sea level, on a north-facing slope of 15 to 40 degrees. The site carried a variable depth of peat overlying morainic drift and had a main vegetation before planting of *Trichophorum, Molinia, Calluna, Erica tetralix* and *Sphagnum*. Sitka spruce, planted on the site in 1924, had failed. The average precipitation for the area is 80 inches per annum. The plots were all established at a spacing of 5 ft. x 5 ft., after hand turfing and draining, and were fertilized at the time of planting, with an application of 2 ozs. of ground mineral phosphate per plant.

(2) Achnashellach 29 P.57:

The provenance trials planted in 1957 at Achnashellach were designed with the objective of comparing the survival,
growth, yield and other characteristics of 14 provenances of
lodgepole pine, all collected from trees in Britain and 2
provenances of seed imported direct from North America.
Of these, 5 of the former provenances and 2 of the latter
were examined in the study to amplify the range of proven-
ances investigated in the P.37 and P.39 blocks at
Achnashellach. The site, again, is morainic drift on
schist, with an overlying peat depth of 6 - 24 inches. The
vegetation before planting was poor *Trichophorum* and *Calluna*
and the plantings lie on a steep slope with northern aspect
at an elevation of 225 - 300 ft. The rainfall averages
approximately 80 inches per annum. In this case, the area
was drained by ploughing with a double mould board Cuthbert-
son plough, with furrows about 5½ ft. apart. The plants
were spaced 4½ feet apart along the furrow and 1½ ozs. of
ground mineral phosphate were applied to each plant. The
design of the planting was a balanced 4 x 4 lattice with 5
replications. The plots each contained 6 x 6 plants, with
one blank line between plots.

The Forestry Commission Research Branch have expressed
the opinion that site variations occur within the Achnashel-
lach trials and have a tendency to confound results. This
possible tendency has not been taken into account in this
investigation, other than to observe that the variations
which did occur were possibly those created by natural
drainage routes. The final outcome of the investigation did not appear to be materially affected by possible site variations.

c. Millbuie Forest: (Millbuie 1 P.38 - 42):

The Millbuie provenance trials, comparing the growth of Pinus contorta provenances of different origins, are located on the Black Isle, on the east coast of Scotland at grid reference NH/672631. Two inches of peat overlay a leached sandy clay soil on an area previously used as a grouse moor and for sheep grazing. The main vegetation was Calluna, Scirpus and Erica tetralix. The area is flat, lies at an elevation of 500 ft. and experiences a rainfall of 30 to 35 inches. The area was ploughed with a shallow single furrow, using a Solotrac type plough and planting was conducted at a spacing of 4½ x 4½ ft., without the use of fertiliser. For purposes of the investigation, the "intensive" (small) plots of 30 plants each (5 x 6) were used in three sets of irregular, randomised blocks. All provenances had 5 replicates.

(1) Plot 1:

Plot 1 was planted in 1938, contains 14 provenances and was used fully for the purposes of the investigation. The plots were brashed and cleaned during 1956 and were thinned during the spring and summer of 1959. In addition,
climatically damaged trees were removed in 1951, 1957 and 1960.

(2) Plots 19 and 26:

Plots 19 and 26 were planted in 1939, 1940, 1941 and 1942. Six provenances of P39, of P41 and 3 of P42, the latter from British seed collections, were used to enlarge the range of provenances covered in Plot 1. For purposes of the investigation, these ten provenances were grouped to form one section. The P39 plots were brashed and cleaned during 1956, the P41 plots, probably, in 1959 and the P42 plots in February 1962 and February 1963. All were subsequently thinned in the spring and summer of 1959, except for the P42 Section which was thinned in the spring of 1963. In addition, climatically damaged trees were removed in 1951, 1957 and 1960. It was surmised that these differences in plot histories would not materially affect the relative incidence of basal sweep.

4. Method of Investigation:
   a. Evaluation of Basal Sweep:
      (1) Basic Considerations:

      The actual method of measuring basal sweep at Wykeham Forest is described below. The basic considerations of how to evaluate it are of importance and are dealt with at this point.
A practical analysis of log value is usually based on a particular set of conditions. The owner of timber and the forest manager will normally analyse the value of the possible range of produce in relation to stand location; local logging and extraction costs; haulage distances; local and general road or rail standards and restrictions; the availability of conversion facilities to his potential customers; the conversion, sales and other costs; the market prices available at the mill, to the manufacturer, for his end-product; local as well as general taxation; as well as a variety of other normal and special factors of the enterprise from stump to sale of the end-product. The cost of growing timber is not, in itself, a criterion of its value except insofar as it can be assumed that all succeeding, related enterprises could thrive economically after paying the costs, with accompanying profit. Under normal circumstances, it is preferable to first determine the product outlets and the economics concerned, to arrive at a level of cost which is reasonable to the total of the operations.

It is recognised that, in Britain and Scotland, this approach has not usually been possible for forestry, since many timber-growing areas have and are being established in the belief that, when they enter a state of production, appropriate industrial outlets will be created and will provide markets adequate for the economic viability of the
forestry enterprise. It does not follow, of course, that this will occur without difficulties. Should the costs being expended on the forestry enterprise be too great for the industrial plant to absorb, a counter-effect upon forestry is likely to result, requiring lower wood production costs for overall financial success. The Fort William pulp mill is an example of a plant endeavouring to achieve profitable operation and, as a part of the process, asking for reduced sales values of wood. Some sales below cost levels are already made to the pulp mill where haulage distances approximately in excess of 80 miles are involved and certain other factors, such as pulp mill wage cost levels are recognised as affecting the wood cost which the mill can afford to pay. Thus, the prices of woodland produce may be appropriately treated as a variable dependant on a variety of economic variables, assuming that prices are not arbitrarily fixed by price controls. In some areas, where future industrial plant developments may occur, it is difficult to forecast what woodland produce prices will apply.

With this general background in mind, considerable thought has been given to arrive at an appropriate evaluation of financial losses which are incurred by the presence of basal sweep in lodgepole pine. It was decided to treat the problem in relation to modern log conversion
practice, whether or not the facilities exist in Britain at the present time but which have possible application. In a sense, the approach is arbitrary but the method can be applied, possibly with further refinement, to specific local circumstances.

Log diameter is of fundamental importance to the price and cost structure of both the forestry and wood conversion enterprises. In general, for example, logging and extraction costs increase as tree and log diameters decrease. Similarly, in the sawmill, the handling and conversion of logs and, in the pulp mill, the conversion of logs up to the point of chips leaving the chipper are normally higher per unit volume of small diameter logs, than they are per unit volume of large diameter logs. Log length also has a definite bearing on costs. These and similar factors, however, are frequently qualified in practice. Whilst the marginal tree and log calculations indicate the point at which profitability ceases, there is a strong tendency to disregard these criteria in favour of total volume input considerations and their effect on the overall economics. Also, forest policy and management will frequently aim at maximum utilisation, demanding the purchase of small and large logs from the stand as a package purchase. Frequently, therefore, from the industrial plant viewpoint, there is a tendency to treat with averages of diameter and length,
rather than with individual log sizes. In the case of a number of plants and processes costs and prices cannot be related to logs of different sizes because of lack of data, unless broad assumptions as to cost and price distribution are made. In view of these various factors, it was decided to employ average prices in this thesis, as being more directly related to current practice.

(2) Assumed Products and Prices:

(a) Lumber Recovery:

Reference to the illustration "Product relationships employed in the study" will serve to demonstrate the approach taken to determine lumber recovery. The illustrations shows the end view of a straight log in which the small end diameter, underbark, is just large enough to permit the recovery of 2 pieces of 2 inches x 4 inches cross-section. It has been assumed that the slabs have been chipped off to produce pulp chips. The waste consists of sawdust produced by sawing the profiled cant into 2 pieces of 2 inch x 4 inch lumber. As the top diameter increases, a point will be reached at which it is possible to recover larger sizes of lumber.

In essence, this form of recovery is that which is carried out by the modern profiling lumber machines. The occurrence of sweep may be visualised as introducing a
The two circles represent the end cross-sections of a log from which 2-2\(\times\)4\(\text{"}\) pieces can be recovered. The shaded portion represents pulp chips, the clear portion lumber and the solid black portion sawdust.
third cross-section between the log small end cross-section and the log large end cross-section. If the latter 2 cross-sections are imagined to remain in the same positions as illustrated in "Product relationships employed in the study", i.e. with the centres of the cross-sections superimposed, then the cross-section at the point of maximum sweep or deflection will have a centre which does not coincide with the centres of the other two cross-sections.

The illustration "Diagramatic illustration of lumber recovery being unaffected by simple sweep under certain conditions" shows a small-end cross section and a cross section of maximum sweep or deflection. The large-end cross-section is omitted from the illustration since it does not affect lumber recovery. Basically, the illustration shows that the external sweep or deflection alone does not determine changes in lumber recovery but that the diameter or radius at the point of maximum sweep must also be taken into account. If, in the illustration, r 1 is of sufficient length to permit the recovery of, say, 2 pieces of 2 inch x 4 inch lumber, then so long as r 2 is equal to or greater than r 1, recovery is unaffected.

Based on these simple relationships and, in the knowledge that almost all of the basal sweep encountered was simple sweep (i.e. one plane of curvature), the
DIAGRAMMATIC ILLUSTRATION OF LUMBER RECOVERY BEING UNAFFECTED BY SIMPLE SWEEP UNDER CERTAIN CONDITIONS. (REFER TO TEXT).

- Maximum sweep or deflection of log.
- $r_1$: Radius at top cross-section of sweep.
- $r_2$: Radius at point of max. deflection.
- $p$: Horizontal distance between centres of cross-sections.
- $x$: Corner point of lumber to be recovered.

When $r_1$ & $r_2$ reach $x$
Then $p = \frac{r_2}{r_1}$.

DIAGRAM BY A.M.
DRAWN BY L.H.B.
potential of a variety of situations was tested by a process of trial and error.

The profiles which were selected for recovery from a single log were:

- 2 pieces 2" x 4"
- 2 pieces 2" x 6"
- 1 piece 2" x 6" and 2 pieces 1" x 4"
- 1 piece 2" x 6" and 2 pieces 2" x 4"
- 2 pieces 2" x 6" and 2 pieces 1" x 4"
- 1 piece 2" x 8" and 2 pieces 2" x 4"
- 1 piece 2" x 8" and 2 pieces 2" x 6"

This range was adequate to cover the range of diameters encountered at Wykeham. Taking, for example, 2 pieces of 2" x 4", they were drawn to scale and, by applying different values of p in horizontal and vertical planes, the varying top diameters necessary to produce 2 pieces of 2" x 4" lumber at varying values were determined. British sawing practice allows for shrinkage during drying and the dimensions of lumber quoted above were increased by adding 0.125 inches of thickness and .062 inches for each 2 inches of thickness and width, approximately to the normal trade practice.

Where the horizontal and vertical applications of a given value of p produced different diameter values for the production of the same lumber, it was assumed in each case that the maximum recovery occurred and the smallest diameter value
was taken. The following table resulted.

<table>
<thead>
<tr>
<th>Minimum diameter underbark necessary to produce the given lumber combinations</th>
</tr>
</thead>
<tbody>
<tr>
<td>P  2-2&quot;x4&quot; 2-2&quot;x6&quot; 1-2&quot;x6&quot; 1-2&quot;x6&quot; 2-2&quot;x6&quot; 1-2&quot;x8&quot; 1-2&quot;x8&quot; 2-1&quot;x4&quot; 2-2&quot;x4&quot; 2-1&quot;x4&quot; 2-2&quot;x4&quot; 2-2&quot;x6&quot;</td>
</tr>
<tr>
<td>---------------------------------</td>
</tr>
<tr>
<td>Nil 6.0 7.5 6.4 6.7 7.6 8.9 8.4</td>
</tr>
<tr>
<td>1  6.7 8.1 6.8 8.2 8.3 9.6 8.7</td>
</tr>
<tr>
<td>2  7.5 8.8 7.6 8.8 9.2 10.4 9.4</td>
</tr>
<tr>
<td>3  8.3 9.6 8.6 9.5 10.0 11.3 10.3</td>
</tr>
<tr>
<td>4  9.2 10.3 9.4 10.4 11.0 12.2 11.2</td>
</tr>
<tr>
<td>5  10.1 11.2 10.3 11.3 11.9 13.0 12.1</td>
</tr>
<tr>
<td>6  11.0 12.0 11.2 12.3 12.8 13.9 13.1</td>
</tr>
</tbody>
</table>

Diameter values for values of p in excess of 6 were worked out individually. The application of this table to the Wykeham plots will be described later.

(b) Lumber Prices:

There was some difficulty in obtaining prices for lodgepole pine lumber ex-sawmill, in view of trade inexperience with the species, resulting from the low supply of sawtimber available in Britain to date. However, prices were kindly supplied by the trade*, based on prices for Scots pine. These were:

*From T.H. Woolridge, Riddoch's Sawmills.
<table>
<thead>
<tr>
<th>Item</th>
<th>Price per H.F. (Pence)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1&quot; x 4&quot;</td>
<td>122</td>
</tr>
<tr>
<td>2&quot; x 4&quot;</td>
<td>116</td>
</tr>
<tr>
<td>2&quot; x 6&quot;</td>
<td>116</td>
</tr>
<tr>
<td>2&quot; x 8&quot;</td>
<td>119</td>
</tr>
</tbody>
</table>

There was no variation in prices per H.F. for lengths below 20 feet. The trade also recommended that the potential use of lodgepole pine for mining timber should be ignored since the market was very marginal in Scotland.

*(c) Pulp Chip Recovery:*

The method of arriving at the total volume underbark of basal sweep is described below. The total volume of lumber which could possibly be recovered was determined by multiplying the lumber cross-section(s) by the direct distance from the butt to the top of the sweep. To this was added the related volume of sawdust, based on a one-eighth inch saw kerf. These volumes were then deducted from the total volume to give the theoretical maximum pulp chip recovery.

*(d) Pulp Chip Value:*

The pulp chip value at mill, less haulage, was taken to be 17 pence per cubic foot of solid wood upon the advice of Scottish Pulp and Paper Company Ltd. at Fort William.
The Fort William pulp mill specifies that sweeps only up to a maximum of 1.5 inches in 10 feet are acceptable but, in practice, if the wood is well cut to length, there is a tendency to allow a greater maximum. The major factors placing a limitation on using logs with sweep for chips are mechanical limitations of the de-barking equipment and considerations of safety. In de-barking, the log with sweep will tend to move and presents a hazard to the worker.

b. Measurement of Basal Sweep:

The diagram "Measurement of Basal Sweep" illustrates the measurements taken on trees with sweep. A simple device consisting of an extensible rod with a second extensible rod at right angles to it was made for measuring purposes.

The instrument was placed with its lower end at stump height c, a distance of 2 inches above the highest point of contact with the ground surface with the tree. The top of the instrument was then extended to the point where the tree assumed straightness above the sweep, giving the distance d. The rod at right angles to d, was then moved to the point of maximum sweep or deflection and the distances e and f were measured, the latter being the distance from stump height to the rod, along d. With the aid of a carpenter's level, the instrument was then placed in a
MEASUREMENT OF BASAL SWEEP.

SEE TEXT FOR EXPLANATION.

DIAGRAM BY A.M.
DRAWN BY LHB.
vertical position and the distances a and b were measured. The diameters overbark g, h and i were then measured by means of a diameter tape and bark thicknesses taken at j, k and l with a bark borer. All measurements were made from the outer bark surface, care being necessary to accomplish this on coastal type trees with heavily fissured bark.

The presence or absence of sweep in a tree was determined by viewing the tree from two directions approximately at right angles to each other. In some cases, butt flare, a slight lean to the tree and other factors could give an impression of sweep. All such cases were measured and in the cases where e was less than 0.8 inches, the tree was considered to be straight. In almost all cases of this kind, the increase in stem diameter from g to h and from h to i was such that lumber recovery would be unaffected.

In certain instances the basal sweep was short, the tree having assumed upright growth quite rapidly. It would be normal commercial practice in such instances to cut off the butt ("long-butting") and discard it, so as not to spoil the quality of the lowest log in the tree. In these instances, the lower and upper diameters and the length of the sweep were measured, allowing for stump height c.

In the case of very long sweeps, and there were some in excess of forty feet, an extensible survey sighting
pole, marked red and white alternately for each foot of its length to measure d and to estimate e, f, g, h, a and b. k and j were also estimated.

Windfalls with sweep found lying on the ground were measured in situ, using the methods described. A number of trees were noted to have a severe crook at about 3 feet to 6 feet above ground level, the tree being straight below. Whilst the effect will undoubtedly affect the tree quality and value it was unrelated to normal basal sweep and appeared to arise from the killing of the terminal bud, possibly by insects. Consequently, these defects were not measured and the tree, unless otherwise affected by basal sweep, was counted as sound.

As mentioned previously, the measurement of sweep was only conducted at Wykeham, on approximately 2,000 trees. At Achnashellach and Millbuie, trees were classified as having measurable sweep or as straight by visual observation, although the instrument was used in cases where the presence of sweep was in doubt, employing the same criterion (i.e. a tree was recorded as having sweep where e was 0.8 inches or greater) as at Wykeham. Also, at Achnashellach and Millbuie, an assistant was employed who conducted independent checks on the author's visual estimates without finding errors.
At Wykeham, notes were made on the cardinal direction of sweep and windfall and position of the stem in relation to the furrow.

C. Results:

(1) Numbers of Trees with Measurable Sweep:

(a) Wykeham Expt. 55:

As was to be expected, the Coastal provenance plots at Wykeham, owing to their faster individual growth, contained fewer, larger trees than did the Inland provenance plots. The tables below show the percentages of the total number of trees in each plot which had measurable sweep and the average of plots for each provenance. Each provenance is allocated to a regional grouping, to demonstrate the effect of geographical grouping of provenances. A column is added showing the windfall history of the provenances on these plots.
## Wykeham Experiment 55. (P38)

### Percentages of Trees with Basal Sweep

<table>
<thead>
<tr>
<th>Provenance</th>
<th>Provenance Region</th>
<th>Percentage of Trees with Sweep</th>
<th>Percentage of stand windblown by 29 yrs. age.</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Block I</td>
<td>Block II</td>
<td>Block III</td>
</tr>
<tr>
<td>34/40 Olympic Peninsula</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>35/21 Shuswap Lake</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>34/10 S.W. Lincoln County</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>34/23 Shuswap Lake</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>35/53 East Washington</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>35/20 Clearwater</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>35/59 Williamson River</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>34/69 Priest River</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>34/68 E. Yellowstone, Montana</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>35/18 Smithers</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>34/25 Sonora Island and New Westminster</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>35/17 Prince George</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>34/24 Prince George</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>35/54 Oregon</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>35/22 Hazelton</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>35/19 Williams Lake</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*N.P. = No Plot
### (b) Achnachellach (P39 and P41):

<table>
<thead>
<tr>
<th>Provenance</th>
<th>Provenance Region</th>
<th>Percentage of Trees with Sweep by replicates</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>I</td>
</tr>
<tr>
<td>36/505 Washington Coast ex Auchterawe</td>
<td>P39 South Coast</td>
<td>77.8</td>
</tr>
<tr>
<td>36/506 U.S. Coast ex Inchnacordoch</td>
<td>P39 South Coast</td>
<td>N.P.</td>
</tr>
<tr>
<td>38/510 U.S. Coast ex Inchnacordoch</td>
<td>P41 South Coast</td>
<td>N.P.</td>
</tr>
<tr>
<td>36/42 Queen Charlotte Island</td>
<td>P39 North Coast</td>
<td>21.8</td>
</tr>
<tr>
<td>36/43 Hazelton</td>
<td>P39 Skeena River</td>
<td>17.6</td>
</tr>
<tr>
<td>37/56 Gray's Harbour</td>
<td>P41 South Coast</td>
<td>N.P.</td>
</tr>
<tr>
<td>36/40 Terrace</td>
<td>P39 Skeena River</td>
<td>8.0</td>
</tr>
<tr>
<td>36/22 Prince George</td>
<td>P39 North-Central Interior</td>
<td>8.0</td>
</tr>
<tr>
<td>36/41 Smithers</td>
<td>P39 Skeena River</td>
<td>0.0</td>
</tr>
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</table>
(d) Achnashellach (P57):

<table>
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<tr>
<th>Provenance</th>
<th>Provenance Region</th>
<th>Replicates</th>
<th>I</th>
<th>II</th>
<th>III</th>
<th>IV</th>
<th>V</th>
<th>Average</th>
</tr>
</thead>
<tbody>
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<td>South Coast</td>
<td></td>
<td>51.4</td>
<td>69.7</td>
<td>57.1</td>
<td>64.7</td>
<td>81.2</td>
<td>63.8</td>
</tr>
<tr>
<td>ex Forth, Eire</td>
<td></td>
<td></td>
<td>58.7</td>
<td>48.7</td>
<td>48.3</td>
<td>72.7</td>
<td>50.0</td>
<td>55.9</td>
</tr>
<tr>
<td>55/227 Queen Charlotte Island</td>
<td>North Coast</td>
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<td>0.0</td>
<td>22.2</td>
<td>17.2</td>
<td>5.9</td>
<td>9.4</td>
<td>11.0</td>
</tr>
<tr>
<td>ex Kirroughtree</td>
<td></td>
<td></td>
<td>9.7</td>
<td>9.4</td>
<td>20.0</td>
<td>9.4</td>
<td>3.2</td>
<td>10.2</td>
</tr>
<tr>
<td>55/258 Shuswap Lake</td>
<td>Southern Interior</td>
<td></td>
<td>3.0</td>
<td>3.8</td>
<td>9.1</td>
<td>5.9</td>
<td>3.1</td>
<td>5.1</td>
</tr>
<tr>
<td>ex Roseisle Compt. 44</td>
<td>Wet Belt</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>55/247 Terrace</td>
<td>Skeena River</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ex Millbuie</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>55/253 Prince George</td>
<td>North-Central Interior</td>
<td></td>
<td>0.0</td>
<td>5.9</td>
<td>8.3</td>
<td>9.1</td>
<td>8.6</td>
<td>6.3</td>
</tr>
<tr>
<td>ex Harwood Dale</td>
<td></td>
<td></td>
<td></td>
<td></td>
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<td></td>
</tr>
</tbody>
</table>
### Millbuie Plot 1 (P38):

<table>
<thead>
<tr>
<th>Provenance</th>
<th>Provenance Region</th>
<th>Percentage of Trees with Sweep by replicates</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>I</td>
</tr>
<tr>
<td>34/39 Coast, U. S. A.</td>
<td>South Coast</td>
<td>81.8</td>
</tr>
<tr>
<td>34/40 Olympic Peninsula</td>
<td>South Coast</td>
<td>80.0</td>
</tr>
<tr>
<td>34/23 Shuswap Lake</td>
<td>Southern Interior Wet Belt</td>
<td>57.2</td>
</tr>
<tr>
<td>35/21 Salmon Arm, Shuswap Lake</td>
<td>Southern Interior Wet Belt</td>
<td>57.2</td>
</tr>
<tr>
<td>34/25 Sonora Island and New Westminster</td>
<td>North Coast</td>
<td>46.7</td>
</tr>
<tr>
<td>34/69 Priest River, N. Idaho</td>
<td>U. S. Interior</td>
<td>50.0</td>
</tr>
<tr>
<td>35/20 Vavanby, Clearwater</td>
<td>North-Central Interior</td>
<td>15.4</td>
</tr>
<tr>
<td>35/17 Prince George</td>
<td>North-Central Interior</td>
<td>50.0</td>
</tr>
<tr>
<td>35/22 Hazelton</td>
<td>Skeena River</td>
<td>18.2</td>
</tr>
<tr>
<td>35/24 Prince George</td>
<td>North-Central Interior</td>
<td>23.1</td>
</tr>
<tr>
<td>35/59 Williamson River</td>
<td>U. S. Interior</td>
<td>7.1</td>
</tr>
<tr>
<td>35/19 Williams Lake-Quesnel</td>
<td>North-Central Interior</td>
<td>9.1</td>
</tr>
<tr>
<td>35/18 Telkwa, Smithers</td>
<td>North-Central Interior</td>
<td>8.3</td>
</tr>
<tr>
<td>*35/53 East Washington</td>
<td>U. S. Interior</td>
<td>41.7</td>
</tr>
</tbody>
</table>

* Replicate V is actually seed lot 37/55.
<table>
<thead>
<tr>
<th>Provenance</th>
<th>Provenance Region</th>
<th>Percentage of Trees with Sweep by replicates</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>I</td>
</tr>
<tr>
<td>36/505 U.S. Coast ex Auchterawe</td>
<td>South Coast</td>
<td>71.4</td>
</tr>
<tr>
<td>39/530 Inchnacardoch ex Ruttle Wood</td>
<td>Probably South Coast</td>
<td>84.6</td>
</tr>
<tr>
<td>39/531 Coast U. S. A. ex Inchnacardoch</td>
<td>South Coast</td>
<td>81.8</td>
</tr>
<tr>
<td>39/530 Inchnacardoch ex Inchnacardoch</td>
<td>Probably South Coast</td>
<td>82.4</td>
</tr>
<tr>
<td>36/506 Inchnacardoch ex Ruttle Wood</td>
<td>Probably South Coast</td>
<td>N.P.</td>
</tr>
<tr>
<td>39/528 Mount Ida ex Inchnacardoch</td>
<td>Southern Interior Wet Belt</td>
<td>31.2</td>
</tr>
<tr>
<td>36/42 Queen Charlotte Island ex Inchnacardoch</td>
<td>North Coast</td>
<td>50.0</td>
</tr>
<tr>
<td>36/40 Terrace ex Inchnacardoch</td>
<td>Southern Interior Wet Belt</td>
<td>26.3</td>
</tr>
<tr>
<td>37/42 Salmon Arm, Shuswap Lake ex Teindland</td>
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<td>N.P.</td>
</tr>
<tr>
<td>39/547 Alberta ex Teindland</td>
<td>Alberta</td>
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</tr>
<tr>
<td>36/43 Hazelton ex Inchnacardoch</td>
<td>Skeena River</td>
<td>6.2</td>
</tr>
</tbody>
</table>
(g) Statistical Analysis of Enumeration Results:

An analysis of variance of the data, including the calculation of variance ratio was carried out by KDF9 computer. In the case of all six areas enumerated, the variance ratio F was above the 1 percent level. In addition, comparisons between each of the individual treatment means were conducted within the same computer programme including calculations of Student's T. From these figures, levels of probability of significant differences were derived, as follows (all levels of probability higher than .4 are omitted).
The following table may be read horizontally or vertically.

<table>
<thead>
<tr>
<th>Average Percentage of trees with sweep</th>
<th>Provenance</th>
<th>Prov. No.</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
<th>11</th>
<th>12</th>
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Note: The other 3 provenances in the trial were omitted because of incomplete replications.
(ii) Achnashellach (P39 and P41):

Six provenances were tested, the others being omitted because of incomplete replicates.

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(iii) Achnashellach (P37):

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(iv) Achnashellach (P57):

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Employing the criteria already described, the sweep volumes were analysed, by a computer programme, to determine product recoveries from basal sweep volumes and their estimated values per acre. In the following table, the plot values have been averaged to give the values for each provenance.

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<th>Volume Unsuitable for Lumber or Chips (cu.ft.)</th>
<th>Volume Sawdust (cu.ft.)</th>
<th>Total Wood Volume of Basal Sweep (cu.ft.)</th>
<th>Product Value (Shillings)</th>
<th>Value of Basal Sweep Wood Volume per Cubic Foot (Shillings)</th>
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*Variations between figures which obviously should be the same e.g. 34/68 and 35/19 are due to mathematical error from accumulation.
(vi) Millbuie, Plots 26 and 19 (P39, P40, P41 and P42):

<table>
<thead>
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<th>Average percent of trees with sweep</th>
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</table>
The foregoing probabilities have been listed in rather tedious detail but for a purpose. Taken in conjunction with the analysis of variance and conditions which are apparent on the ground they provide a remarkable demonstration of the fact that, given a few minor aberrations from causes which the author is unable to define, the occurrence of basal sweep does have a very close co-relation with provenance. The co-relation is made the more remarkable by the varying site conditions and planting treatments which have been afforded to the species. These matters are considered in more detail in the discussion which follows later. It is now appropriate to turn to the quantitative results of measurement of basal sweep at the Wykeham trial.

(2) Quantitative Results of Basal Sweep Measurement at Wykeham, Expt. 55:

The enumeration of trees with or without sweep is not, in itself an economic criterion, since the greater the degree of sweep, the less is the value of its wood content for current, or normal foreseeable, commercial use. It is apparent at once, for example, from a study of the data given for percentages of trees containing measurable basal sweep, that south coastal provenances may be relied upon to have a significantly higher percentage and, also, a very high percentage, as compared to British Columbia Inland provenances, other than those from Shuswap Lake, which
appear to show a low, but variable percentage, of basal sweep. Not only this, but also, the degree of sweep in a log is influenced as to commercial use by the diameter characteristics of the log. The south coastal provenances, for example, have greater individual tree diameters at a given age than do the slower growing Inland provenances and this is an ameliorating influence in terms of commercial use, although it may not be so in terms of volume of sweep per acre.

Reference is made to the diagram above "Measurement of Basal Sweep." The volume of sweep $V$, was taken to be, by the Smalian formula,

$$ V = \frac{(\text{Area } g + \text{Area } h)m}{2} + \frac{(\text{Area } h + \text{Area } i)n}{2} $$

The lengths $m$ and $n$ being derived from the measurements $d$, $e$ and $f$, being the sides of right-angled triangles.

The actual volumes of sweep measured, overbark and underbark and the volumes per acre, overbark and underbark were calculated by computer programs. Primarily, these were intended for final checking of sweep money values but it is of interest to record the volumes per acre.
<table>
<thead>
<tr>
<th>Provenance</th>
<th>Cubic Feet</th>
<th>Replicates I</th>
<th>Replicates II</th>
<th>Replicates III</th>
<th>Average of Replicates</th>
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<td>49.26</td>
<td>-</td>
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<td>UB</td>
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<td>43.69</td>
<td>-</td>
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</table>
In the foregoing table, the provenances are arranged in the order that they assumed from the numerical percentage of trees with basal sweep. A disruption of order is noticeable when the quantitative values are translated into volumes, although the general order established by the numerical assessment is not unduly disturbed. The change is, of course, due to diameter and growth rate considerations.

The trees suffering most from basal sweep, in a very general sense, are those of the south coastal provenances but there is an opinion, albeit qualified, that sweep may be related to growth rate. If this should be so, a comparison of basal sweep volume with total plot volume is of interest. A computer programme was run to obtain the percentage of basal sweep volume to Forestry Commission total standing volume figures, overbark, for each plot.
The results were:

<table>
<thead>
<tr>
<th>Provenance</th>
<th>Replicates</th>
<th>% of Sweep Volume to Total Volume</th>
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<td>I</td>
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</tr>
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Again, the enumeration order is somewhat disturbed, but nowhere seriously.
This last table was subjected to an analysis of variance and the probabilities of significant difference, on the same lines as previous probability tables, are as follows:

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<td>.01</td>
<td>.02</td>
<td>.05</td>
<td>.05</td>
<td>.2</td>
<td>.2</td>
<td>.3</td>
<td>.4</td>
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As might be anticipated, the significance of differences has been reduced by the application of sweep volumes to standing plot volumes but it is considered that statistically, the differences are real and well supported.
It is worthwhile to comment on this table at this point, since it is not simple to read. The amount of lumber which can be recovered and which commands a price better than that of wood for pulp chips is low by comparison with pulp chips at the age of 32 years. It can be expected, at a greater age, that the lumber recovery will be greater. However, the degree of basal sweep intervenes with pure diameter considerations to the extent, in the faster growing provenances, that the unit value of sweep wood is lower than in the slower growing and, consequently, small diameter provenances to the extent that the higher lumber recovery from the faster growing provenances is overcome by the amount of unusable wood. At the age of 32 years, it is apparent that it is the amount of unusable wood that is important, to the extent that sweep wood in the faster growing species may be of considerably lower value than is sweep wood in the slower growing species, even though the latter is of value only for pulp chips at 32 years of age.

(4) Windfall, Lean and Sweep:

At Wykeham, some fresh windfall lay on the ground, all in the plots of the South Coastal and Shuswap Lake provenances and, in addition to basal sweep, a considerable number of trees showed varying degrees of lean. The latter, again, occurred in larger numbers in the South Coastal and
Shuswap Lake provenances than in the others. Whilst the primary interest of the study lay in the question of basal sweep, the author formed the opinion that all three phenomena were inter-related. All three categories were noted, over almost all of the plots investigated, with information as to the direction of fall, lean or sweep. In addition, a note was made as to whether they fell, or leant into, the north-south furrow or away from it. The following three diagrams show the direction of fall or lean into or away from the furrow and the direction of fall or lean of all the trees.

The indications are that the major influence is direct pushing by the prevailing wind, irrespective of the influence of the furrow. It is interesting to note, however, that a number of trees fell or leant in the opposite direction and it was inferred that this was due to the influence of the furrow and/or the effects of easterly gales from the North Sea, which occur on this coast. Very few trees fell or leant in line with the furrows.

(5) Discussion:

The results giving the percentages of numbers of standing trees having basal sweep have clearly indicated the heavy incidence of the sweep occurring in both the South Coastal and Shuswap Lake provenances at Wykeham.
DIRECTION OF BASAL SWEEP AND/OR LEAN AND DIRECTION OF EXISTING WINDBLOW WHERE THE DIRECTION IS AWAY FROM THE CENTRE OF THE FURROW, OF 196 LODGEPOLE PINE TREES.

EXPERIMENT 55. WYKEHAM.
DIRECTION OF BASAL SWEEP AND/OR LEAN AND DIRECTION OF EXISTING WINDBLOW WHERE THE DIRECTION IS TO THE CENTRE OF THE FURROW, OF 285 LODGEPOLE PINE TREES.

EXPERIMENT 55. WYKEHAM.

DIAGRAM BY A.M. DRAWN BY LHB.
DIRECTION OF BASAL SWEEP AND/OR LEAN AND DIRECTION OF EXISTING WINDBLOW OF 503 TREES: (LODGEPOLE PINE.)

EXPERIMENT 55: WYKEHAM.

DIAGRAM BY A.M.
DRAWN BY LKB.
Unfortunately, records of basal sweep in thinnings removed from the plots at Wykeham have not been kept but it appears to be most likely, from a study of early photographs of the plots that most of the thinnings from the South Coastal and Shuswap Lake provenances had basal sweep. The enumeration results at both Achnashellach and Millbuie confirm the results at Wykeham, although the Shuswap Lake provenances show considerably lower amounts of sweep at Achnashellach and at Millbuie, Plots 19 and 26.

In general, the South Coast provenances show the highest percentage of sweep followed by the Shuswap Lake and North Coast provenances. These tend to be followed in turn by the U. S. Interior and, finally, the North-Central Interior provenances. The Skeena River provenances are intermediate between the North Coast, U. S. Interior and North-Central Interior provenances.

The following diagram summarises the results by provenance groups:
Trees with basal sweep as a percentage of standing trees at Wykeham, Achnashellach and Millbuie, by provenance groups.

Diagram by A.M. 
Drawn by L.H.B.
The variations within groups are attributed to site variations, differences in thinning regimes and the variations inherent in grouping individual provenances into regional provenance groups. In spite of these variations, there is a clear trend as was indicated by the results of the individual experiments and the statistical tests applied to them.

There appears to be a possible correlation between the percentage of trees with sweep and the windfall history, as well as with the number of trees that are leaning.

The quantitative results at Wykeham are summarised by regional provenance groups in the following diagram:
PERCENTAGE OF STANDING VOLUME, OVERBARK, AFFECTED BY BASAL SWEEP AT WYKEHAM, EXPERIMENT 55.

REGIONAL PROVENANCE GROUP

1. SOUTH COAST
2. SHUSWAP LAKE
3. NORTH COAST
4. U.S. INTERIOR
5. SKEENA RIVER
6. NORTH - CENTRAL INTERIOR.

DIAGRAM BY A.M.
DRAWN BY L.H.B.
The diagram reflects the position at Wykeham only. It also refers to standing volume only and does not take into account the volumes of thinnings removed, since although these volumes are available from records, the volume of basal sweep in them is not. The North Coast provenance shows the lowest percentage of basal sweep by volume but is less well represented than the other regional provenance groups. The South Coastal and Shuswap Lake provenances are clearly the most affected groups, the U. S. Interior provenances are intermediate and the Skeena River and North-Central Interior provenances are the least affected.
The mean annual increments for the provenances at Wykeham have been recorded by the Forestry Commission, as follows:

<table>
<thead>
<tr>
<th>Provenance</th>
<th>M.A.I. at 26 yrs. c.f.</th>
<th>M.A.I. at 29 yrs. c.f.</th>
</tr>
</thead>
<tbody>
<tr>
<td>34/40 Olympic Peninsula</td>
<td>94</td>
<td>99</td>
</tr>
<tr>
<td>35/21 Shuswap Lake</td>
<td>90</td>
<td>97</td>
</tr>
<tr>
<td>34/69 Priest River, N. Idaho</td>
<td>87</td>
<td>97</td>
</tr>
<tr>
<td>34/10 S. W. Lincoln County</td>
<td>92</td>
<td>96</td>
</tr>
<tr>
<td>35/53 E. Washington (Unknown)</td>
<td>85</td>
<td>94</td>
</tr>
<tr>
<td>35/19 Williams Lake</td>
<td>82</td>
<td>93</td>
</tr>
<tr>
<td>34/23 Shuswap Lake</td>
<td>87</td>
<td>92</td>
</tr>
<tr>
<td>35/22 Hazelton</td>
<td>80</td>
<td>92</td>
</tr>
<tr>
<td>35/18 Smithers</td>
<td>76</td>
<td>86</td>
</tr>
<tr>
<td>35/17 Prince George</td>
<td>74</td>
<td>85</td>
</tr>
<tr>
<td>34/24 Prince George</td>
<td>74</td>
<td>82</td>
</tr>
<tr>
<td>35/20 Clearwater</td>
<td>74</td>
<td>82</td>
</tr>
<tr>
<td>35/59 Williamson River, Klamath, Oregon</td>
<td>73</td>
<td>81</td>
</tr>
<tr>
<td>34/25 Sonora Island and New Westminster</td>
<td>70</td>
<td>79</td>
</tr>
<tr>
<td>35/54 Oregon (Unknown)</td>
<td>56</td>
<td>61</td>
</tr>
<tr>
<td>34/68 West Yellowstone, Montana</td>
<td>43</td>
<td>43</td>
</tr>
</tbody>
</table>

The volumes of sweep in each provenance which are unsuitable for either lumber or pulp, on the basis of the criteria adopted in this investigation, have been given above. It is of interest to relate them to M.A.I.'s at 29 years of age. As an example, if one compares provenances 34/40 Olympic Peninsula to 35/18 Smithers, the difference in M.A.I.s is 13 cu. ft. per acre per year. The former provenance at Wykeham has a volume unsuitable for use as lumber and pulp in the basal sweep of 64.3 cubic feet and
in the latter provenance, all the wood can be used for lumber or pulp. At the 29 year MAI, it would take 4.6 years of growth to make good this difference, assuming that all of this growth was in the form of usable wood. By comparison with 35/53 E. Washington, the provenance 34/40 Olympic Peninsula would need 13.7 years of growth to make good the difference. Unfortunately, the investigation did not include an assignment of value to the volumes, other than those affected by basal sweep, in the stand so that a direct comparison of stand value is not available.

In terms of a management decision on which provenance ought to be grown, there are certain important factors which have not been investigated. The amount of waste caused by basal sweep in the thinnings removed at Wykeham is unrecorded but, obviously, a high proportion of the stems removed in the South Coastal and Shuswap provenances must have been badly affected and would presumably give a lower nett utilisable growth rate than is indicated by the gross volume figures. The difficulties of handling sweep material in the woods and at the plant, as well as the losses in the volume that could be loaded on a given lorry are presumably important. The values assigned to the wood may be too high, particularly for lumber, since they are prices that the sawmiller would pay for straight logs. Also, in the faster growing provenances, there are
indications of heavier continuing windfall than occurs in the slower growing species. The salvage of windfall, if it is not to be abandoned, is very expensive, involving the movement of equipment at frequent intervals to recover low volumes per acre, by comparison with the normal thinning or logging operations. Also, the faster growing provenances have a greater number of leaning stems than do the slower-growing ones and the effects of tension wood in these and in the basal sweep volumes have not been taken into account.

(6) Conclusions:

It is concluded:

(a) The fastest growing provenances examined show the greatest percentage by number of stems, of basal sweep, in all areas of investigation.

(b) The basal sweep lowers the potential values of these provenances and, if the effects of other factors which have not been examined or on which information is not available are taken into account, makes the present widespread use of these provenances highly questionable from management and plant utilisation viewpoints.

(c) There is a good possibility that basal sweep, tree lean and windfall are inter-related and stem from the same basic causes on the sites examined. Whilst root development under given site and drainage conditions is undoubtedly a factor, the denser tops of the Coastal
provenances probably have an important bearing.

(d) whilst the author is unable definitely to recom-
mend on the basis of the investigation alone, what proven-
ances other than South Coastal ones, should be planted,
further studies should be made to determine more suitable
ones of slower growth rate but higher overall values.

(e) It appears that the present tendency to treat
provenances by regional groupings is not entirely satis-
factory and contains a number of uncertainties.

(7) Recommendations:

It is recommended:

(a) That the widespread use of South Coastal proven-
ances in afforestation should be discontinued in favour of
provenances yielding better quality wood, at the expense of
accepting somewhat lower growth rates.

(b) Along with a., that an intensive research pro-
gramme should:

(1) Examine as many other sites as possible
to enlarge upon this investigation with a view to
obtaining a large statistical base to compare as
many provenances as possible under a variety of
site and drainage conditions.

(2) Conduct a detailed examination of plant
capability to utilise basal sweep so as to obtain
more accurate data on end product values and the
added costs of utilisation of basal sweep.

(3) Develop data on operational cost increases, if any in the logging, extraction and haulage of logs containing sweep. If possible, these data should relate to specific areas so as to arrive at local values in given areas of the Highlands.

(4) In the course of recording research stand histories, to enter estimates of basal sweep and other defects to provide a guide to product quality as well as quantity.

(5) Investigate the possibilities and economics of substantially deeper ploughing to determine whether South Coastal and other fast-growing provenances which are subject to heavy sweep, lean and windfall cannot be provided economically with better root development opportunities to achieve initial stability. In this connection, a research development grant for the design of a ploughing machine with considerably more power and high flotation adequate to support such a machine on deep peat might be considered. Presumably, different furrow configurations would be involved if furrow slumping is not to occur at greater depths.
(6) Continue to investigate the growth of lodgepole pine. A feature of the pine in pure stands in British Columbia is a sharp decline in current annual growth rates during the age bracket of about 30 to 40 years.

(7) Improve knowledge of the provenances of lodgepole pine by intensifying research collections of seed in British Columbia over smaller, selected areas such as Shuswap Lake and the Skeena River. In this connection, although not a research project, the Forestry Commission is recommended to arrange seed collections under the supervision of a graduate forester who should be required to certify the seed source. Whilst this procedure would increase seed costs, the high costs of afforestation in Britain merit a high degree of certainty of the seed source.
CHAPTER 9

CONCLUSIONS

The comparison of forest policy and management practices in the two areas reveals many divergencies and some similarities, the latter occurring mostly at the policy level. Scotland, where the primeval forest was largely destroyed and extensive areas of degraded soils, especially peat areas, were formed, embarked five decades ago upon a programme of intensive plantation forestry. A growing emphasis upon the use of exotics has appeared and Scots pine has lost much of its popularity. Initially, the plantation programme, which is still in a state of expansion, was designed to provide a reserve of timber which Britain with its vulnerable sea-borne supply system would need in time of war and the reserve was, in fact, extensively exploited during the Second World War. The advent of nuclear weaponry led to a change of policy and the emphasis has been placed upon economic forestry on a sustained yield basis and the development of an industry to utilise the products of the forest.

In British Columbia, the primeval forest was used, in the early days, as a means of stimulating railroad construction and as a source of capital which was employed to develop roads and social services in the Province. A consis-
tent feature of British Columbia forest policy has been the emphasis upon the economic use of forests and the continual evolution of forms of tenure, with the objective of stimulating the expansion of industry. The process has been accompanied by the development of foreign markets upon which British Columbia forestry and the forest industry rely very heavily, unlike British forestry which mainly competes in the home markets, with large volumes of timber imports. As the forest industry has developed, the Canadian Government has become a major beneficiary of Provincial forestry, through corporate and personal income taxes and, although re-investment has occurred in forest research and through a number of joint programmes, the major portion of the revenues has been diverted to other purposes. A feature of modern policy is the administration of the forests on a sustained-yield basis. Substantial increases in the reforestation programme of British Columbia have occurred but it appears that further expansion is essential if the forest area is not to be reduced.

Comparatively, Scottish forestry is very intensive and includes the use of frequent periodic thinnings, whereas British Columbia forestry is extensive in nature.

Both areas have major pathological problems, those of British Columbia being forest fires, the control of
which absorbs major sums of money, insects and disease, although the latter two are closely connected with the declining vigour of mature and overmature stands. The major pathological problems in Scotland are those connected with wind damage.

In this thesis, particular emphasis has been placed upon the role of lodgepole pine which is indigenous to British Columbia and which is widely used as an exotic species in Scotland, as the only species which can grow on low quality, exposed, peat sites, to provide commercial produce on a short rotation.

A considerable variety of recommendations have been made in Chapter 7 which the author believes would result in improvements in forestry practice in Scotland and British Columbia. Also, in Chapter 8, recommendations have been made which, it is felt, ought to lead to greater success with lodgepole pine in Scotland. In particular, a more thorough investigation of provenances, both as to their source in British Columbia and the United States and as to their employment in Scotland, and an investigation of the possibilities of achieving better site drainage have been recommended. The latter investigation, it is felt, could lead to an important reduction in the wind-blow hazard in Scotland.
The author does not pretend that the recommendations which are made are comprehensive and that they cover all aspects of forest policy and management. They are the ones that emerged as being the more obvious ones to follow, based on a number of years of forestry experience in British Columbia, an exposure to modern British forestry and the possibilities of concentrated consideration of the evidence accumulated by workers in both areas. The author hopes that the recommendations will be given close consideration by those in a position to implement them and that they will be adopted.