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APPENDIX A

Descriptions of selected uneven-aged forests in Britain

ABBERLEY HALL

Location: Great Whitley, Worcestershire
Area: 15.5 ha.
Management Objectives: To maintain continuous tree cover in a sensitive landscape and to produce valuable timber.

Management History: These broadleaved woods are in the grounds of a preparatory school and Abbey forestry have managed them since the 1950's. Up until 1964, only single trees were felled, but then small groups were removed, particularly in response to favourable timber prices in the early 1970's. The main species planted are *oak,* ash, and beech. Harvesting operations need to be temporally well-spaced in order to minimize disruption to the school. It is acknowledged that income from the woodlands will not be continuous, mainly because there are very few larger trees left. Natural regeneration of beech, ash and *oak* is abundant. There is no formal control of growing stock.

CAWDOR

Location: Nairn
Area: 305 ha.
Management Objectives: Original objectives at the start of the Anderson trial.

1. To bring all parts of the wood into maximum value production.
2. To maintain the existing æsthetic and protective amenities so far as they are compatible with good management.
3. To develop the wood in such a way as to provide the maximum experimental and instructional value from the broadest point of view.

Management History: In 1954 Lord Cawdor agreed to the setting up of an Anderson mal in Cawdor wood. The intention was to transform the wood (mostly mature oak) over a 120-year period, using a group size of approximately 0.1 ha. (Taylor, 1967). In 1962 the management plan was revised because the ageing wood was suffering from windblow. Also, the original group size was too small, plant spacing was too close and too many species were being planted in each group. The transformation period was reduced to 60 years and the group size increased to 0.4 ha.

In 1967 another management plan was produced, because it was felt that the potential of the wood was not being fully realised and the wood was subsequently divided into two parts. An eighth of the area was to be managed primarily for amenity and the remaining area for production. In 1970 the Anderson trial was discontinued and several years of fairly ad hoc management followed (Newton, 1986).

Currently, approximately 100 ha. is being managed by a group system, with group sizes ranging from **0.4** to 2.0 ha.. *Oak* and European larch are the main production species and natural regeneration of various species is abundant.

CORROUR

Location: Highland region
Area: 54 ha. in the Anderson trial
Management Objectives: Original objectives at the start of the Anderson trial.

1. To achieve a balanced growing stock of exotic coniferous species capable of continuous production.
2. To test the application of the Check method as a means of following stand development and prescribing yields in Scottish conditions.
3. To maintain the Corrour woodlands as a source of forestry knowledge through research, education and historical interest.

Management History: Afforestation was begun by Sir John Stirling Maxwell in 1892, using mainly Scots pine (Malcolm, 1971). Other species (mainly spruces) were gradually introduced, producing a patchwork of different species and size classes. In 1952, an Anderson mal was initiated. As with the other Anderson trials, the initial group sizes (0.04 ha. to 0.2 ha.) proved to be too small and they were subsequently increased to 0.1 to 2.5 ha., with a mean of 0.4 ha. (Malcolm, 1978). The early years of the trial were disrupted by heavy deer browsing and the trial was suspended for a while until a deer fence could be erected. Ownership of the land was transferred to the Forestry Commission in 1965 and thinning operations were suspended until a new road could be constructed. A new management plan was produced in 1978 but was never adopted. When ownership passed back into private hands in 1983, much of the mature timber was clearfelled.

DALMENY

Location: South Queensferry, W.Lothian
Area: 292 ha.
Management Objectives: To maintain a hardwood park with a high amenity value.

Management History: Broadleaved woodlands and shelterbelts were established on the estate during the 18th and 19th centuries and some of the 19th century plantings were specifically for amenity purposes (Taylor, 1973). Until 1956, when Anderson trials were initiated, the woodlands were mainly used for sporting purposes. The early group sizes were approximately 0.05 ha., but for silvicultural and administrative reasons the group size was increased to 0.20 ha. or more. Severe gales in 1968 and 1964, and attack by Dutch Elm Disease in 1977/78, disrupted the trials and led to even larger felling areas. Currently, felling area size is between 1.60 and 2.00 hectares and the dead elm trees are still being removed. Sycamore is now the main species being planted, along with beech and *oak.* The broadleaves are planted in a mixture with Norway spruce, which is removed early on for sale as Christmas trees and fence posts.

DARTINGTON NORTH WOOD

Location: Dartington, Devon
Area: 6.7 ha.
Management Objectives: To develop and maintain the irregular structure of the wood for timber production and amenity.

Management History: In 1943 Wilfred Hiley experimented with a selection system in the North wood at Dartington. He began by introducing Douglas fir, Japanese larch and Sweet chestnut into small gaps created by a heavy thinning in a plantation of mixed ages and mixed species. In the 1950's further group plantings, of mainly Douglas fir, were carried out. However, by the early 1960's Hiley appeared to reject the selection system (Howell et al, 1983) and it was not until 1980 that selection management was reintroduced into the woods. Species now being planted include Western hemlock, Douglas fir, Lawson cypress, red *oak,* sycamore, and beech.

Hiley considered the method of control ("check" method) to be appropriate for regulating the yield (Howell et al, Ibid) and regulation is still by volume rather than area. Felling operations are generally carried out every five years, in order to minimize disturbance to visitors and ensure a reasonable volume of timber for sale. Group size is of the order 0.075 - 0.125 ha.. Natural regeneration has not, until recently, played a part in management, but it is now appearing in some of the heavily thinned stands.

EDINBURGH UNIVERSITY EXPERIMENTAL AREA, GLENTRESS

Location: Peebles, Borders
Area: 117 ha.
Management Objectives: Original Objectives, as formulated by M.L. Anderson

1: To create mixed stands of irregular structure "best adapted to the natural conditions" in order to maintain and increase soil fertility.
2: To maximize value production by achieving the highest possible volume increment and timber quality.
3: To determine the optimum growing stock composition, avoiding the use of clearfelling, for the provision of sustained yield.
4: To obtain experience in the management of irregular stands.
5: To improve access within the forest to ensure satisfactory harvesting.

Further objectives adopted in recent years include recreation, conservation, and education.

Management History: In 1952 Anderson initiated trials of irregular working in 30-year old conifer stands at Glentress. His intention was to transform the existing stands, over a 60-year period, into a mixed forest of irregular or uneven-aged structure, using Norway spruce, European silver fir, and beech (Blyth, 1987). A six year felling period was chosen, based on the initial increment measures to determine Current Annual Increment and Time of Passage (Blyth and Malcolm, 1988). Also, in accordance with the Gurnaud-Biolley check method, 100% enumeration was to be carried out in the year of treatment.

A transformation period of 60 years requires annual fellings of approximately ***2*** ha. (117÷60=1.95ha.) and during the early stages of the transformation this was removed in rectangular groups of 0.01 to 0.02 ha. However, these groups proved to be too small because the young trees were badly shaded as the surrounding crop trees grew. Also, the original species choice had to be reconsidered because European silver fir and beech were heavily browsed by deer, sheep, rabbits, and hares. Consequently, additional species such as Western hemlock, Grand **fir** and various broadleaves (e.g. sycamore) were introduced.

In 1964 the system was reviewed and several changes made. First, the group size was increased to between 0.02 and 0.20 ha. and second, the 100% enumeration was discontinued, with the intention of reintroducing it once the irregular structure became well developed. Since 1964, there have been more modifications, particularly in the choice of species. Sitka spruce, Douglas fir, noble fir and hybrid larch are now included in new plantings and the species composition aimed for is 50% Sitka spruce, 40% other conifers and 10% broadleaves, by area (Blyth and Malcolm, 1988). Groups are now roughly circular and the aim is to have a group diameter of at least twice the height of the surrounding trees. Also, an annual 10% sample enumeration is being introduced to obtain information on increment and yield with a manageable amount of work. Finally, it is encouraging to note the appearance of natural regeneration of sycamore (sufficient to maintain the broadleaved component) and Sitka spruce.

FASKALLY WOODS

Location: Faskally, Perthshire
Area: 51 ha.
Management Objectives:

1: To preserve and enhance, where possible, the structure and species diversity of the area, to provide **a** recreational forest of high amenity.
2: To provide adequate essential visitor facilities to meet present and future recreational demand.
3: To conserve the environment in the forest primarily as a means of enhancing its amenity value and visitor enjoyment.
4: To provide high quality timber as efficiently as the above mentioned objectives permit.

Management history: Faskally woods were originally planted as policy woodlands for Faskally house. The estate was bought by the North of Scotland Hydro-electric board, in 1947, and for a few years the woods formed part of a public relations campaign mounted by the hydro-elecmc board to convince the public that the board was sensitive to environmental concerns (Newton, 1985). The woods were then bought by the Forestry Commission in 1953 and in 1955 Anderson-style group selection management was initiated. Group sizes ranged from 0.02 to 0.05 ha. and a transformation period of 120 years was chosen (Tsintides, 1987). **As** in other Anderson trials the group size proved too small and was gradually increased to between 0.05 and 0.10 ha.

Throughout the 1950's and 1960's the plan was generally followed, but during the 1970s management was apparently neglected when the woods were incorporated into the Tummel Forest administration. **A** new plan was prepared in 1977 with two primary objectives:

1: To conserve the structure and species diversity of the wood and maintain a high standard of visual amenity.
2: To stimulate public interest in the use of the wood for informai recreation.

The secondary objective was to produce timber of high quality within the constraints of the primary objectives. Group size crept up again to between 0.25 and 1.25 ha., but the plan was only partially followed and little new planting was carried out.

In 1987 Takis Tsintides surveyed the woods and prepared a management plan as part of his M.Sc. dissertation and this plan has been adopted by the Forestry Commission. He recorded 23 tree species, with Scots pine, European larch, Douglas fir, birch and beech occupying the largest area, but also including sycamore, poplar, Norway spruce, oak, alder, lime, and rowan. Abundant natural regeneration of Douglas fir, sycamore, and birch was also noted. Tsintides recommended continuation of the group management, but with a reduced group size of 0.05 to 0.50 ha..

GRIZEDALE

Location: Grizedale, Cumbria

Area: A) 2.75 ha. "Broad Piece"
B) 300 ha.

Management Objectives (A):

1: To maintain continuous cover for landscape purposes and to minimize æsthetic impacts of harvesting.
2: To create a diverse habitat for wildlife.
3: To provide a better environment for growing trees.

Management history: A Forestry Commission wood managed by uneven-aged group selection. Species include Douglas fir, Japanese larch, Norway spruce, and mixed broadleaves. Management involves gradually enlarging groups of regeneration which has come into the wood in patches where windthrow has occured.

Management Objectives (B):

1: To perpetuate the broadleaved woodland within the designated area and to obtain a more balanced age class distribution.
2: To produce high quality broadleaved timber on a long rotation wherever soil depth permits.
3: To encourage growth of species native to the Lake District.
4: To increase the diversity of native broadleaves.
5: To increase wildlife values.
6: To manage and develop existing stands of non-native broadleaves in order to obtain maximum silvicultura1information from them.

Management history: From 1954 to 1965 the management plan objectives included conversion of the existing coppice and clearfelling system to uneven-aged group selection forest, testing of new hardwoods, natural regeneration of boatskin larch, study of the economics of the selection system and demonstration of the methods employed. After 12 years the plan was discontinued due to high costs of enumeration, damage by deer, trespassing by sheep and declining markets for the produce. However, with the developments in broadleaved silviculture over the past 20 years

(e.g. tree shelters, broadleaved grant schemes and designation of broadleaved woodland zones in the Lake District National Park) the plan has been resurrected. Oak regeneration is by groups of 0.10 to 0.20 ha. using tree shelters and supplemented by natural regeneration. The woods are typical lakeland oak, ash, hazel woods, but also include other species such as wych elm, alder, birch, sycamore, small-leaved lime, holly, rowan, gean, blackthorn, hawthorn, bird cherry, guelder rose, yew, juniper, and aspen. The objective is to produce quality saw and veneer sizes whenever possible.

LONGLEAT

Location: Warminster, Wilts.
Area: 22%ha.
Management Objectives: Timber production with amenity considerations

Management history: For the past 15 years the Longleat estate woodlands have been managed using an irregular system. Species include Douglas fir, Western redcedar, Lawson cypress, larch, Wellingtonia, and spruce. Natural regeneration is encouraged by carrying out heavy crown thinnings and the overstory is removed once the regeneration is well established. Some of the biggest trees are retained to become "monarchs". Natural regeneration is prolific and relied on almost entirely.

POWDERHAM

Location: Powderham Castle, Devon
Area: 182 ha.
Management Objectives: To perpetuate the broadleaved woodland for landscape, amenity and shooting purposes and for commercial timber production.

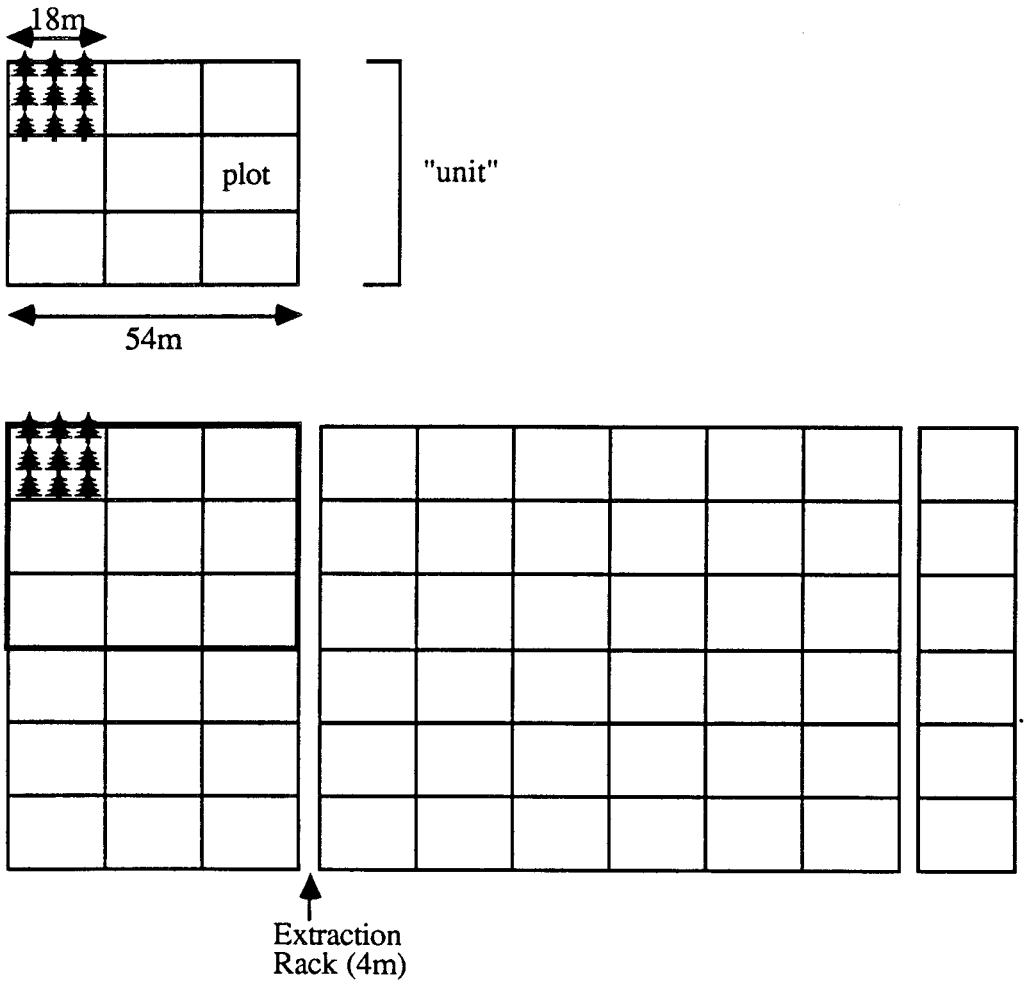
Management history: Felling of mature broadleaves (approximately 120-years old) is carried out in small blocks (0.50 - 1.00 ha.) for reasons of landscape and amenity. The main part of the wood is visible from several directions and the aim is to maintain the appearance of continuous tree cover. Broadleaves include oak, ash, beech, chestnut, sycamore, Nothofagus, and red oak and are planted with conifer nurses.

TAVISTOCK

Location: Tavistock, Devon
Area: 200 ha.
Management Objectives: To produce high quality stress-graded timber with 4-6 growth rings per inch.

Management history: The estates at Tavistock were bought in 1959 and the "Bradford Plan System" ("Bradford-Hutt scheme) was initiated (Collin, 1986). Under this sytem, the converted forest is made up of a number of "units" as shown in Figure A1 below.

Figure A1: Arrangement of Plantings at Tavistock

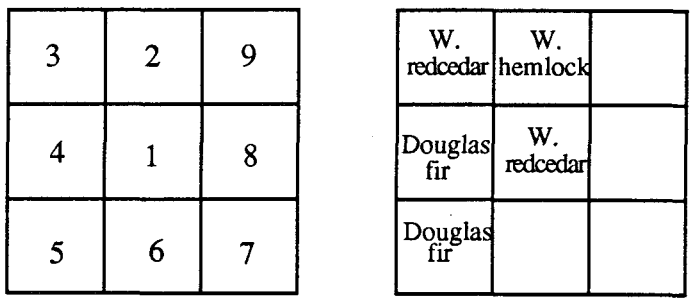


Each "unit" contains nine "plots" and each "plot" is planted with nine trees, although at final harvest the "plot" will contain only one final crop tree (Wigston, 1976). Each "plot" contains a single species, but adjacent plots in the unit may contain different species.

The plot size was chosen because Hutt calculated that this was the area neededto grow one 54-year old Douglas fir (Hutt, 1974). During the conversion phase a plot is felled every six years using a spiral arrangement for the felling sequence (See Figure **A2)** and the surrounding trees are thinned.

In the early years of the conversion shade-bearers are used and Douglas fir is introduced at a later stage. Several other species have also been included, such as Nothofagus and California redwood.

Figure **A2:** Felling Sequence and Species at Tavistock



TRAWSCOED HALL

Location: Welshpool, Powys
Area: 37 ha.
Management Objectives: To produce timber with conservation and amenity considerations

Management History: These are broadleaved woodlands managed on a single tree basis. The main species is oak, but other species include sycamore, wild cherry, beech, ash, grand fir, and Douglas fir. These woods have won a Siver medal for commercial forest with conservation and amenity considerations. One of the main philosophies here is to spend as little as possible on regeneration and to only thin when trees have reached a stage when they can be sold as firewood. The woods have prolific but sporadic natural regeneration.

YEALAND MANOR

Location: Yealand Conyers, Lancashire
Area: 12 ha.
Management Objectives: To maintain an amenity woodland whilst producing some timber and firewood.

Management history: Yealand Manor is owned by the Provincial Insurance Company and is used as a training centre for employees. Since 1958 the woodlands have been managed by single-tree felling. Only dying, defective and broken trees are felled and the rest of the wood is thinned when these trees are removed. Species present and regenerating naturally include sycamore, ash, elm and cherry. Fellings are carried out when there are enough suitable trees to make the operation commercially viable.

APPENDIX B

Branch diameters of trees in the Anderson Groups at the University of Edinburgh Experimental Area, Glentress

Douglas Fir Groups

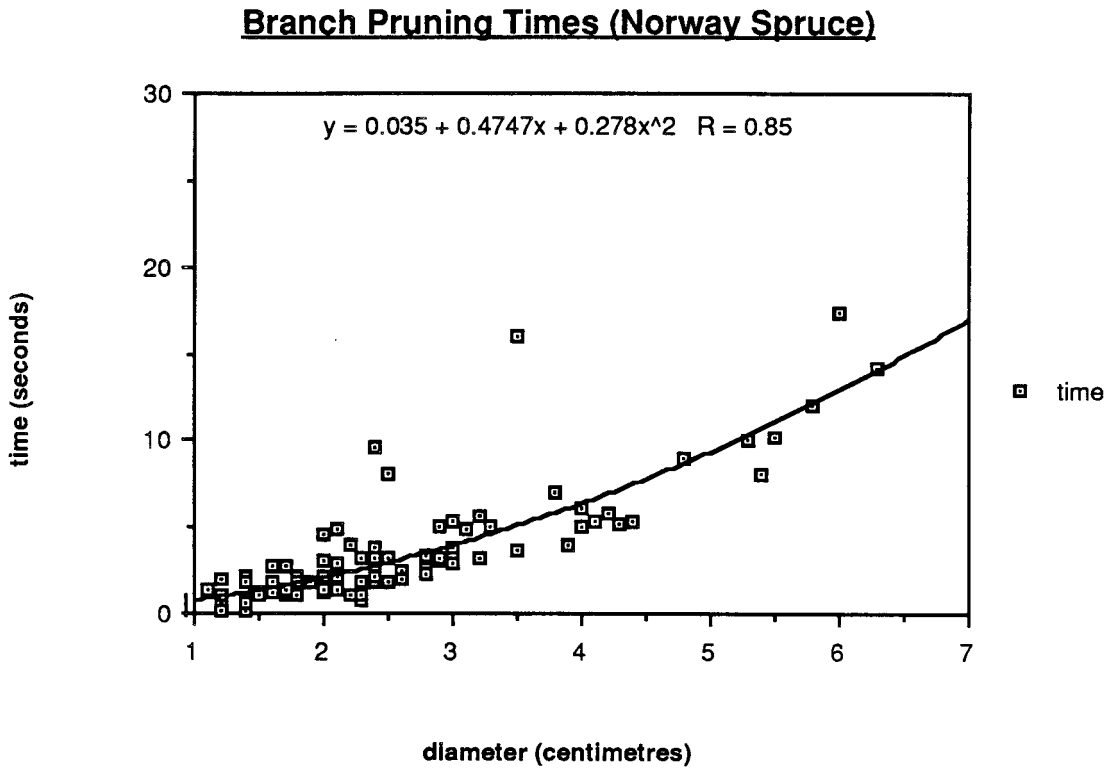
	"Edge" Trees							"Inner" Trees						
Diam cms	1	2	3	4	5	6	7	8	9	10	11	12	13	14
0.90									I				I	
0.95									I		I			
1.00		I	I		I		II		I				I	
1.05												I	II	
1.10									I	I		II		
1.15										I				
1.20		I							I					
1.25			I									I		
1.30													I	
1.35														
1.40				I				I		I	I		II	
1.45					I	I								
1.50	I	I	I								I		I	
1.55													I	
1.60				I								I		I
1.65														
1.70														
1.75														
1.80	II	I		III		I		I		I				I
1.85														I
1.90														
1.95								I						
2.00														
2.05														
2.10	I							I						
2.15														
2.20		I			I									
2.25														
2.30	I													I
2.35														
2.40														I
2.45							I							
2.50							I							
2.55														
2.60					I	I								
2.65														
2.70	I													
2.75														
2.80							I							
2.85														
2.90					I									
2.95														
3.00				I										
3.05	I	I												

Silver Fir Groups

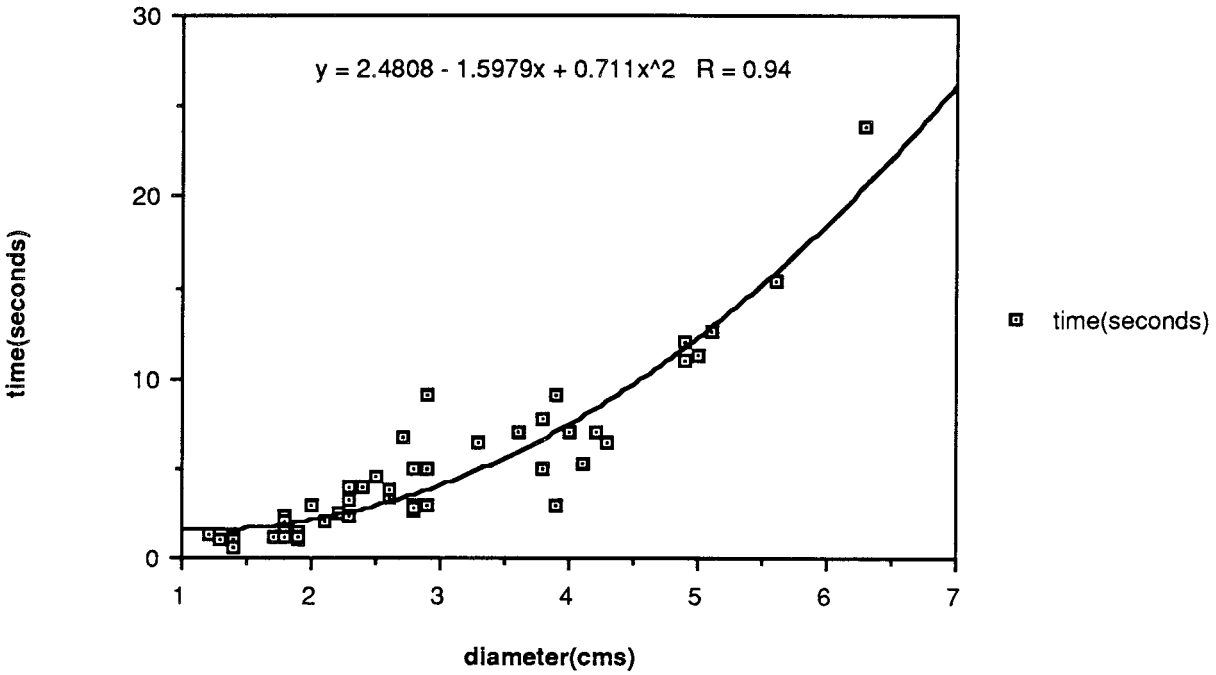
"Edge" Trees								"Inner" Trees						
Diam cms	1	2						3	4	5				
0.90	I							I		I				
0.95														
1.00		II												
1.05									I					
1.10								I						
1.15														
1.20														
1.25														
1.30										I				
1.35														
1.40								I						
1.45														
1.50									II					
1.55									I					
1.60	I							I						
1.65														
1.70														
1.75														
1.80		I							I	I				
1.85														
1.90										I				
1.95														
2.00									I					
2.05	I	I												
2.10														
2.15														
2.20														
2.25														
2.30										I				
2.35														
2.40														
2.45														
2.50														
2.55														
2.60	I													
2.65														
2.70														
2.75														
2.80														
2.85														
2.90														
2.95														
3.00		I												
3.05	I													

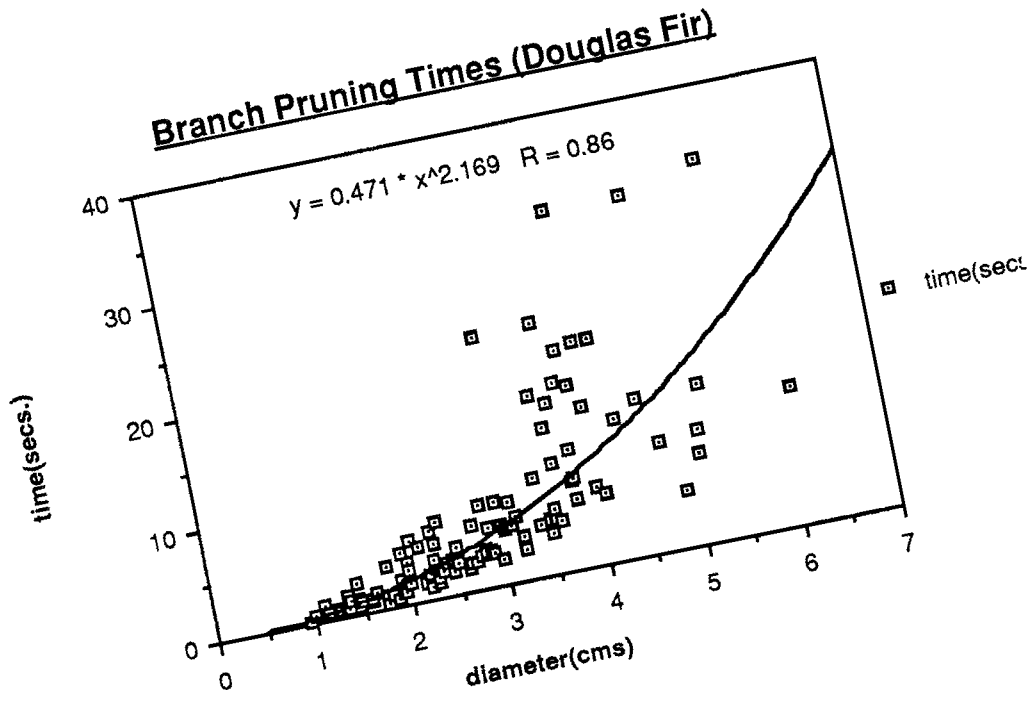
APPENDIX C

Branch Pruning Data

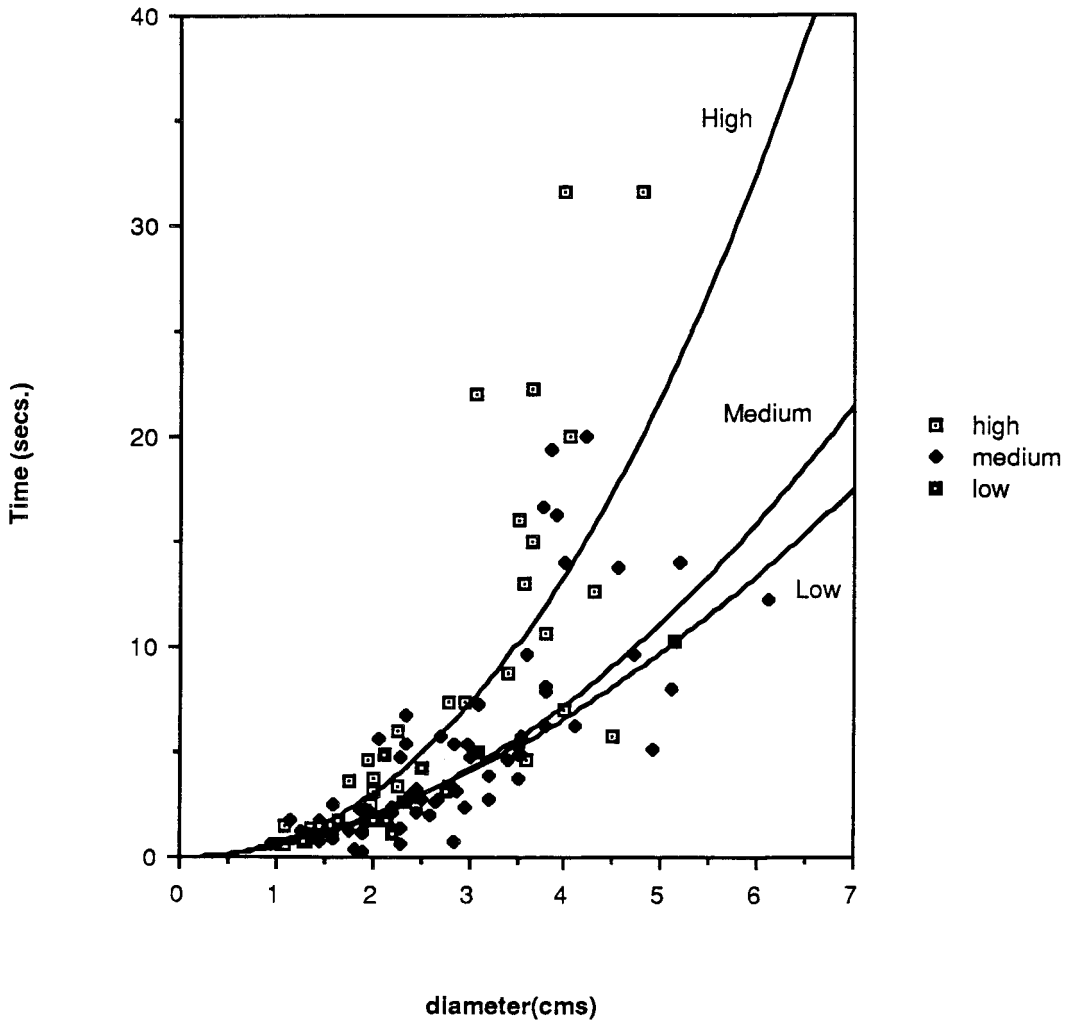

Branch Pruning Times (Norway Spruce)
y = 0.035 + 0.4747x + 0.278x^2 R = 0.85
time (seconds)
30
20
10
0
1
2
3
4
5
6
7
diameter (centimetres)
time

Branch Pruning Times (Sitka Spruce)




Branch Pruning Times (Douglas Fir)
y = 0.471 * x^2.169 R = 0.86
time(secs.)
diameter(cms)
time(sec
0
10
20
30
40
0
1
2
3
4
5
6
7

Pruning Times by Branch height (Douglas fir)



APPENDIX D

Extrapolation of Forestry Commission Yield Tables

Extrapolation of the Yield Tables was started by plotting the MAI curves for each species and Yield Class used in the model and these MAI curves were then extrapolated by eye. MAI curves for these same species obtained from other countries (e.g. Denmark, Norway, southern Germany and Austria) where the Yield Tables cover a greater age range were used to judge the shape of the curves beyond the end points of the Forestry Commission curves. Once the new MAI values were found, they were used to calculate the other values in the Yield Tables.

Expansion of the Description of the Statistical Approach

The number of runs used to calculate the results had to be restricted, because generating the random arrangements of groups was very time consuming, particularly for the smallest group size where there were **256** elements in the array. Initially, average values were calulated for **only** five runs and the standard deviations calculated. **A** sixth run made little difference to the results, and the seventh even less and therefore seven runs were judged to be sufficient. The arrangement of the groups and the order of felling appears to have little effect on operating times when final fellings and thinnings are combined.