Thinning Response in Eucalypt Regrowth

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Abstract

Stand and tree thinning response is analysed for three Tasmanian eucalypt thinning trials. Significant and lasting response was found for trees in thinned fifty year old regeneration. Smaller 'intermediate' trees tend to have a larger response in DBH increment than larger 'dominant' trees at all thinning intensities. Results from these and other trials are generalised to form a stand density diagram which can be used to determine optimum thinning strategies.

Introduction

In the current climate of uncertain future sawlog availability in Tasmania, thinning of native regrowth forest is being considered as a means of shortening sawlog rotation length. Although it is well known that thinning can induce trees to grow more quickly in diameter, Tasmanian foresters are uncertain about the size and duration of thinning response. Perhaps one of the reasons for this is that few thinning trials have been documented, and those that have generally span a period much shorter than rotation length. Furthermore, results from these thinning trials seem not to have been jelled into generalised thinning models. The notable exception is the thinning model in STANDSIM (Opie 1972, Incoll 1974, Campbell *et al.*, 1979), the Victorian stand growth simulator which has been used with limited success in Tasmania to assess the feasibility of thinning.

This paper examines three of the Forestry Commission's thinning trials and highlights some of the fundamental principles of thinning in eucalypt regrowth. It also presents a simplified thinning model in the form of a stand density diagram which can be used to determine optimum thinning strategies.

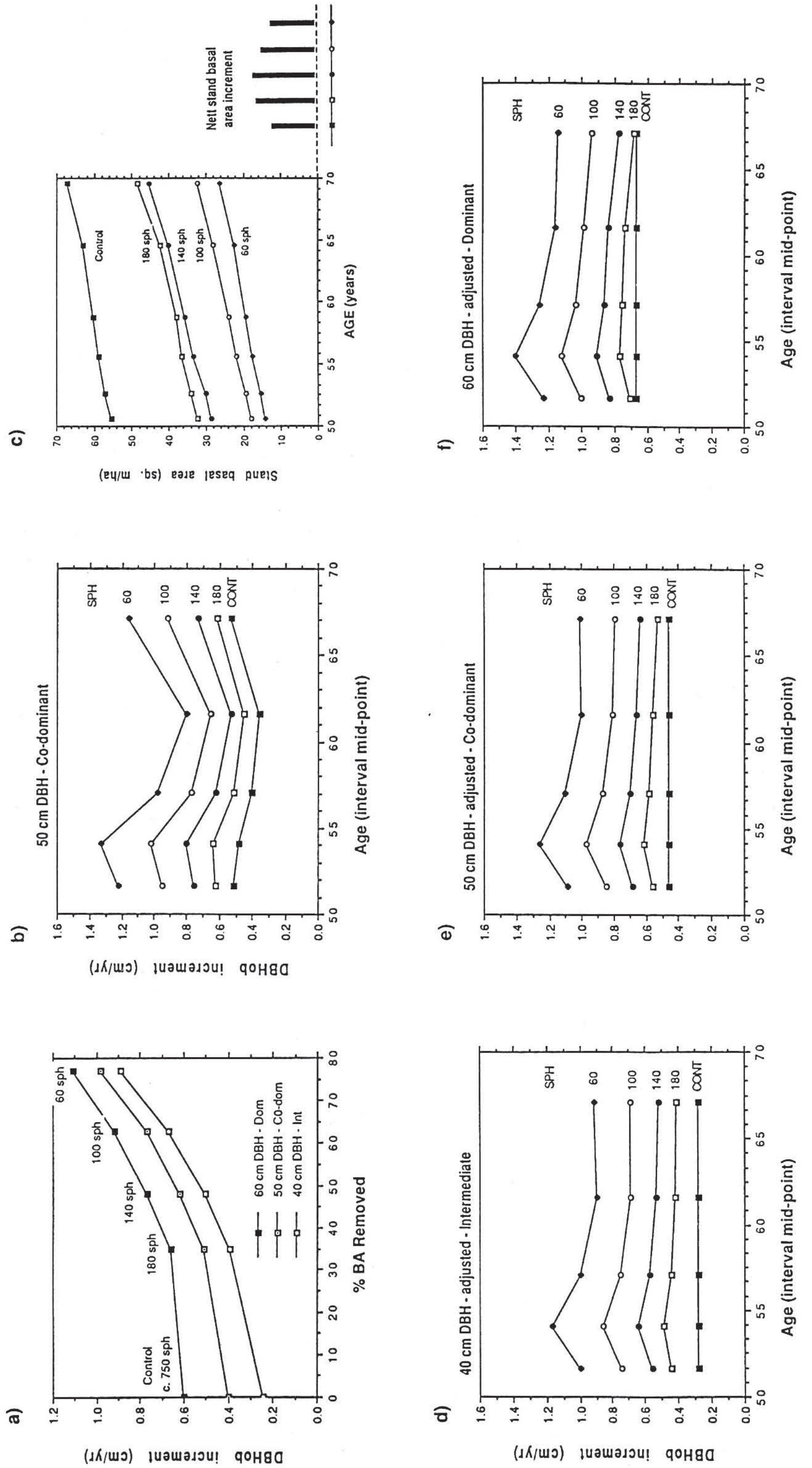
Description of Trials

i) *ETYPs* (Eucalypt Thinning Yield Plots) is the oldest surviving thinning trial in regrowth in Tasmania. It was established on Riawunna Road (Geeveston) in 1964 (pre-thinning measurements had been made in 1960 and 1963) in 50 year old *Eucalyptus obliqua*. The stand is of good quality with a mean site index of 40m (mean dominant height at age 50 years), and appears not to have been seriously affected by Southern Forest Dieback (Podger *et al.*, 1980). The trial comprises four replications of five treatments: an unthinned control, and retention rates of 180, 140, 100 and 60 stems per hectare (sph). Plots are approximately 45x45m with a 7.2m buffer.

ii) The *Young Regrowth Thinning Series* (YRTS) comprises five thinning experiments in 15-25 year old eucalypt regrowth. They were established in the period 1982-84 over a range of species and site qualities. The pattern of response has been similar for all five sites, so the results for only one of them (Lovetts Road, Geeveston) are presented here. The Lovetts Road trial is most similar to ETYPs in site quality and species composition, and therefore allows us to compare the effects of age on thinning response.

The Lovetts Road trial was established in 16 year old *E.obliqua* regrowth which has a site index of 42m. It has five replicated treatments on buffered 40x40m plots, with nominal stocking retention rates of 150, 250, 350, 500 sph, and an unthinned control.

Fig. 1. ETYPs stand and tree growth over twenty years since thinning.



iii) The *Edwards Road and Hartz Road* plots (Geeveston) were established in 1976 in 10 year old *E.regnans* regrowth. The primary purpose of these thinnings was for Australian Paper Manufacturers to assess the pulping qualities of young ash regrowth. For operational convenience, thinnings came from roadsides and no regard was given to site variability. Nevertheless, the Forestry Commission used it opportunistically to establish a series of research plots. Although their value is limited, they are the longest running set of plots in young thinned regrowth in State forest and provide information that is currently not available from the Young Regrowth Thinning Series.

The Edwards-Hartz series comprises three plots (250 and 440 sph, and control) on Edwards Road and two plots (400 sph and control) on Hartz Road. Plots range in size from 0.02 to 0.08 ha and are not buffered. Site index averages about 45m.

Stand Basal Area Growth

The most authoritative work on thinning in ash regrowth is by Webb (1966), who analysed a series of thinning trials in *E.regnans* near Toolangi (Victoria). These experiments were established in 1947 in even-aged regrowth ranging in age from 7 to 42 years. Webb concluded that:

> *An acre of land provides a given amount of plant food and water and receives a given quantity of solar radiation. The total volume produced per acre per year (excluding mortality) is constant over a range between 50 percent to nearly 100 percent of ...(unthinned) density. This volume may be decreased but it cannot be increased.*

Because height growth is fairly insensitive to stand density, what is true for volume should also to be true for basal area. Using the same set of data, Webb and Incoll (1969) reported that gross basal area increment (which does not deduct mortality) in stands older than 30 years was not reduced by more than 10 percent until the basal area removed by thinning exceeded 50 percent. They found that younger stands could be thinned more heavily than 50 percent without reduced basal area increment.

Data from ETYPs and the Young Regrowth Thinning Series concur with these findings. For ETYPs, nett basal area increment, (which deducts basal area lost through mortality), is highest over twenty years for 140 sph; i.e. about 50 percent basal area reduction although it appears the peak may be relatively broad and flat (Fig. 1c). Unthinned plots grew a similar amount, but lost basal area through mortality. Stands more heavily thinned had reduced basal area increment and appeared unable to fully utilise their sites. Furthermore, the 16 year old regrowth in the YRTS.- Lovetts Road trial attained its highest increment on plots where about 55 percent of the basal area had been removed (Fig. 2a).

Assmann (1961) defined *critical basal area* (CBA) as the basal area for which gross basal area increment is 95 percent of maximum. Stand densities greater than this do not significantly increase production, but lower densities result in a marked reduction in basal area increment. Competition between trees continues to occur until the retained basal area is reduced to about half the CBA. Below this point, individual tree growth is maximised, but at the cost of sub-maximal stand production.

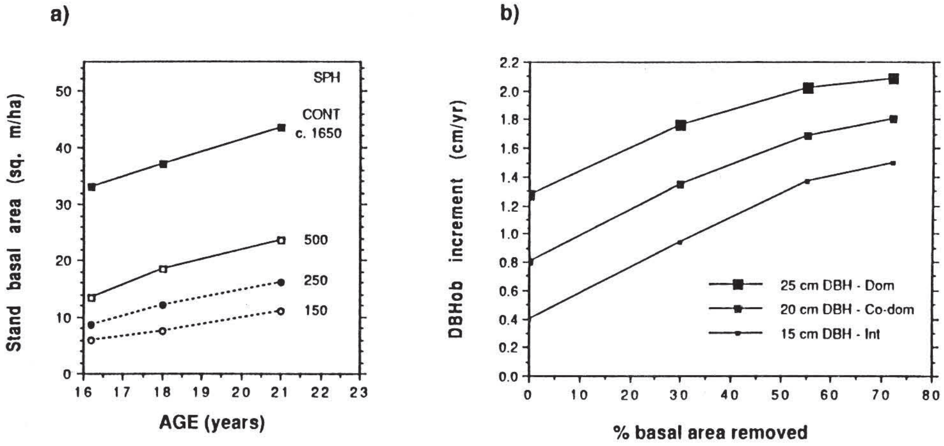
From the point of view of stand management, knowledge of its CBA is extremely useful. Nett basal area production will always be maximised in the vicinity of the CBA and forest managers intending to maximise total yield can minimise the frequency of thinning by always cutting down to the CBA.

Furthermore, CBA can be used as a reference point to give meaning to terms such as 'under-stocked' and 'over-stocked'.

Stand Density Diagram

CBA can be estimated for any even-aged

Figure 2. Lovetts Rd. trial: a)gross stand basal area versus age for the range of treatments, and b) DBHob increment versus percentage basal area removed for three tree dominance classes.



stand using a 'stand density diagram' (Curtis 1970) of the type shown in Fig. 4. Stand density diagrams often relate mean tree size to stocking, and can be based on the following empirical relationship of Reineke (1933),

$$D_{mean} = k.S^{-0.625} \qquad \text{Equation (1)}$$

where D_{mean} is quadratic mean tree diameter*, S is stocking (sph) and k is a species related constant. The relationship gives the maximum mean diameter for a given stocking and is similar in nature to one called the '-3/2 Power Law' or 'Self Thinning Rule' (Drew and Flewelling 1979, West and Borough 1983, Hutchings 1983) which relates mean tree volume to stocking. The '-3/2 Power Law's' various names give the impression that the relationship is an infallible natural law. Unfortunately, this is not the case, because some even-aged plant communities do not appear to comply with the relationship (Zeide 1987). However, the '-3/2 Power Law' and Equation (1) ought to be sufficiently good approximations to be of use as management tools.

Equation (1) can be re-written as,

$$BA_{mean} = k'.S^{-1.25}$$

$$\text{or} \quad BA_{stand} = k'.S^{-0.25} \qquad \text{Equation (2)}$$

where BA_{mean} is mean tree basal area, BA_{stand} is stand basal area, and k' is a constant. When Equation (2) is plotted on a log-log graph, it is a straight line with a slope of -0.25 and an intercept of log(k'). This line is called here the 'maximum density' line.

An important property of stand density diagrams is that lines running parallel to the maximum density line represent a fixed relative density. Thus, the combinations of basal area and stocking for which full site occupancy occurs with the minimum basal area (i.e. critical basal area) should fall on a straight line parallel to the maximum density line. Data from ETYPs, YRTS and Toolangi did not contradict the assumption that the slope of the CBA line was -0.25. The intercepts for the maximum density and CBA lines in Fig. 4 were estimated using available data to be 5.98 and 4.54 respectively.

The maximum density and CBA lines are linked by 'thinning' lines, which are pathways taken by stands thinned from below. The shape of these curves was determined from the limited data and ought only to be regarded as approximate guides. Computer simulated thinning of hypothetical stands from below indicated that these curves are probably 'parallel' across the range of stocking.

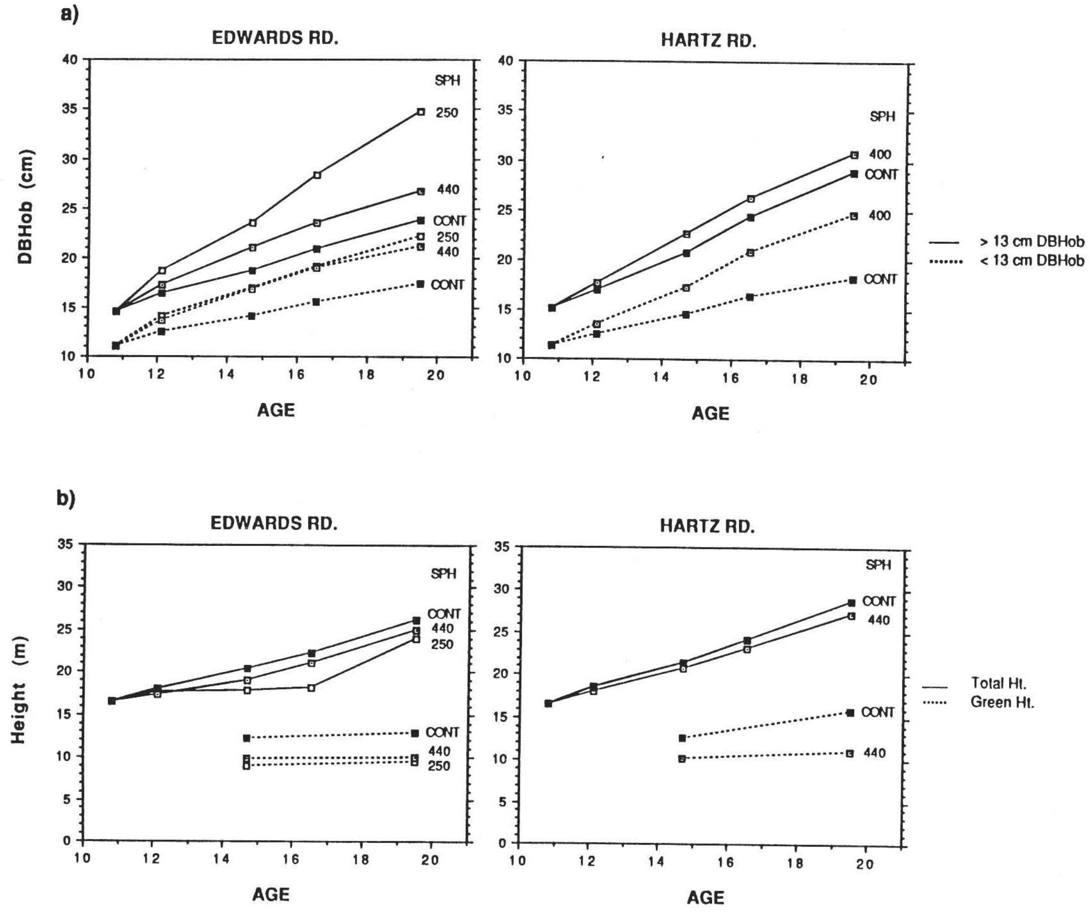
Quadratic diameter is equivalent to the diameter of the (notional) tree of mean basal area.

Diameter Increment

An effective way of demonstrating thinning response of individual trees (if one exists), is to compare growth of 'typical' trees over a range of thinning intensities and tree vigour classes. Diameter increment models were developed for ETYPs and YRTS - Lovetts Road trials in order to account for non-treatment effects due to site quality, pre-thinning basal area and stocking, and also to simplify the task of estimating growth for 'typical' trees. These models are not shown here because they are specific to individual trials and are likely to be erroneous outside the range of data for those trials. It is sufficient to say that the amount of variability accounted for in each case was about 75 percent and residuals were well-behaved. The models for these trials are represented graphically in Figs. 1 and 2b where dominant, co-dominant and intermediate pre-thinning vigour classes are presented. Suppressed trees were not retained in any of the thinnings.

The Edwards-Hartz data did not warrant the development of a model because of the small number of trees on some plots. Trees were grouped into pre-thinning diameter classes of 10.0-13.0cm and >13.0cm which can be considered to be intermediate and dominant vigour classes.

Fig. 3. Edwards - Hartz Rd. trial: a) DBHob versus age for two diameter classes, and b) Total height and green height versus age, for a range of treatments.



'Response' is defined here as additional increment due to thinning. All vigour classes in the three trials responded to all thinning intensities. Fig. 1a shows that over the 20 year span of the ETYPs trial, intermediate trees have responded marginally better than co-dominants and dominants. In terms of relative growth, the heaviest thinning (60 sph) resulted in a three-fold increase in the diameter growth rate of intermediate trees and only a two-fold increase for dominant trees. The pattern is similar for YRTS - Lovetts Road (Fig. 1b), although response has been larger. The Edwards-Hartz data show a relatively large response for the intermediate class in the 400 and 440 sph treatments (Fig. 3a). However, the pattern for the heavy thinning treatment at Edwards Road (250 sph) is not consistent with the other two trials, since the removal of further basal area appears to have had no additional effect on the growth of intermediate trees.

Webb (1966) found that diameter increment of dominant *E.regnans* was not significantly increased until stand basal area was reduced by 40 to 50 percent. ETYPs results do not support this, because significant (albeit small) response was found for dominant trees with only 35 percent of basal area removed. These results are consistent with the opinion of Lemon and Schumacher (1962), who consider that thinning does not have a significant effect on diameter growth until the dominant crown class is partly thinned, which, according to Webb (1966), begins to occur when more than 30 percent of basal area is removed.

Tree growth can be related to the management density diagram (Fig. 4) by marking on it lines that signify growth thresholds for trees in various vigour classes. The 'dominant response' line signifies the threshold of dominant tree response. Dominant tree response appears to be roughly proportional to the distance the stand lies below the 'dominant response' line, until the 'free growth' line is reached. Beyond the 'free growth' line, no trees in the stand experience competition and tree response is maximised.

Fig. 4 also shows an 'imminent mortality' line, the position of which is speculative and was estimated using CFI permanent plots. It is thought that this may also double as the 'intermediate response' line, but this could not be verified with available data.

Healthy and vigorously competing stands of a single species will generally lie somewhere between the 'imminent mortality' and 'maximum density' lines. The unthinned ETYPs plots, for instance, completely spanned this zone. If we define *relative basal area density* as the ratio of actual to maximum basal area for a given stocking, then the 'average' fully-stocked stand probably has a relative density of about 0.75.

Fig. 4 shows the path taken by a hypothetical stand. Its growth path meanders within the mortality zone until thinning reduces its density to below the critical basal area. Without mortality, the path rises vertically to the 'imminent mortality' line, whereby the stand resumes its meandering in the mortality zone.

For 'average' density 25 year old stands on good sites (site index 40-45), Fig. 4 gives the following 'rule-of-thumb' estimates of basal area reductions for critical thresholds:

• imminent mortality	18%
• dominant response	37%
• critical basal area	56%
• free growth	77%

Effect on Clear Bole Length

Clear bole length is an important consideration when the primary goal of thinning is accelerated sawlog production. Work by Webb (1966) in *E.regnans* indicates that green levels in stands over 20 years old do not rise appreciably when they have been thinned to below the 'dominant response' line (Fig. 4). This is supported by ETYPs and the Edwards-Hartz trial (Fig.3b), where 'green height' is taken to be the height of the lowest, healthy branch forming part of the main crown (Wood 1988). Even if green level does rise after a long time in a fixed position, it is

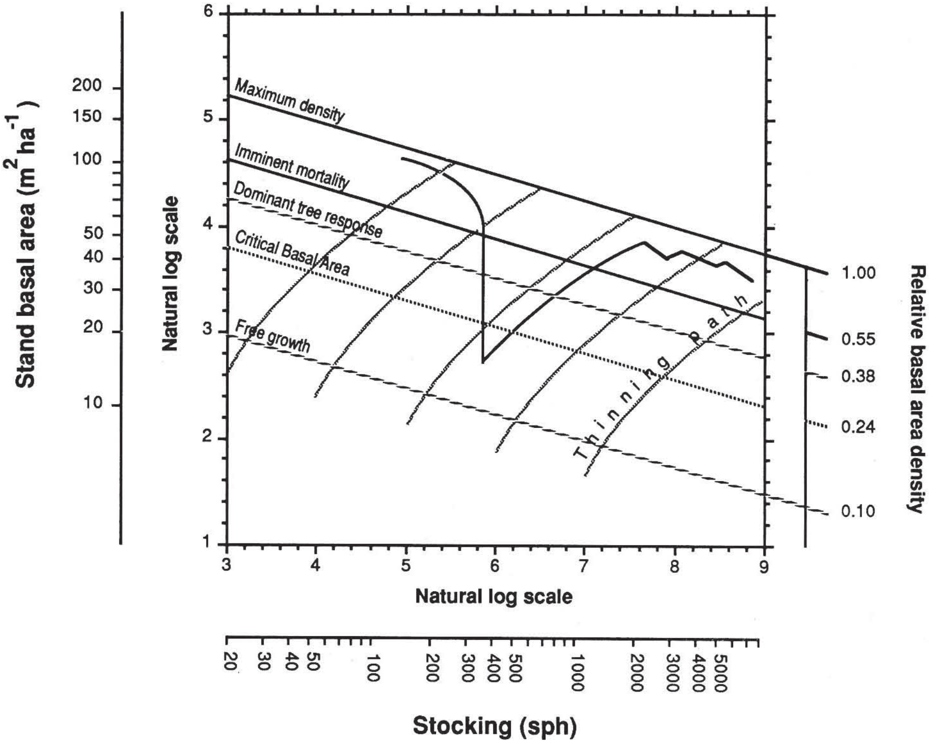


Fig. 4. Stand Density Management Diagram for basal area versus stocking, showing critical density thresholds and a hypothetically thinned stand. Relative Basal Area Desity is an index of stand density, which, for a given stocking, expresses basal area as a proportion of maximum basal area. Each of the threshold lines has a slope of -0.25 and a fixed relative basal density.

likely that sawlog quality in the upper bole will be degraded by large dead branches.

It is strongly recommended that unless manual pruning is contemplated, thinning should not occur until there is a satisfactory length of clear bole.

Effect of Woody Understorey Species

Clear bole length is less likely to be a major concern where tall woody understorey species occur because green level will be at least as high as the understorey canopy. However, a vigorous understorey is likely to have a detrimental effect on thinning response. This is indicated in a trial established by the Forestry Commission near Smithton in 1962 to study the effect of *Pomaderris apetela* competition on the growth of *E.obliqua*. Treatments comprised two eucalypt stockings (1235 sph and control) in combination with three *Pomaderris* stockings (0, 2470 and ∞ clumps per ha). The stand was thinned at age 2, and by age 18 the mean diameters of dominant thinned eucalypts with and without *Pomaderris* was 27 and 31 cm respectively, mean heights were 22 and 26 m respectively, and the ratio of tree volumes was 2:3. Thinned *Pomaderris* had the same effect on eucalypt growth as unthinned *Pomaderris*, indicating that *E.obliqua* may be a poor competitor for the niche occupied by *Pomaderris*. Similar trends have been reported by Oliver (1984), who looked at the effect of a woody understorey on the growth of planted ponderosa pine. He found that ponderosa pine only increased growth significantly when the understorey was maintained at very low densities.

Unfortunately, a woody understorey will, in many instances, be practically unavoidable since the cost of its eradication will be prohibitive. Interpretation of the density diagram will also be affected by a thick understorey, but the way in which it is affected is not speculated upon here.

Effect of Age

The comparison of ETYPs with YRTS - Lovetts Road has already shown that diameter increment before thinning, and response to thinning, is larger at younger ages. Relative increases, however, appear to remain similar. The more rapid growth of younger trees will be compensated by a response of shorter duration. Age, or more correctly, tree size, is likely to affect the rapidity with which maximum response is attained because gaps created by thinning will be larger in older stands and thus more time will be required to regain full site occupancy. In addition, the rate of crown and root expansion of retained trees may decline as they age (Jensen and Long 1983).

Conclusions

The trials analysed showed that trees respond to thinning. Smaller retained trees tend to respond better than larger dominant trees to all thinning intensities, but particularly to light thinnings. The duration of response was at least 20 years for all ETYPs treatments and it appears that trees on the most heavily thinned plots will continue to show a thinning response for many years to come.

Crude estimates of the duration of response can be gauged from the density management diagram (Fig. 4) using estimates of future basal area increment. Since thinned stands progress vertically up the diagram. Future progress can be mapped to the 'dominant response' line and higher. Estimation of future basal area increment ought not to be a major problem, since it will be almost constant between the 'critical basal area' line and the 'imminent mortality' line, declining only slowly with age.

The density management diagram can be used to prescribe thinning treatments appropriate to management objectives. Where the objective is maximization of wood production, the stand is simply thinned to its critical basal area. Where the management aim is to minimise the time required to produce a certain number of sawlogs, then various combinations of stocking versus response size and duration can be explored. However, this latter use of the diagram is stretching its utility and is an investigation better suited to a computer model.

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