Stand growth and natural regeneration development following selection harvesting of dry-belt Douglas-fir – 15 Year Results

FIA-FSP Project Y102033 Final Technical Report

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April 23, 2010

STAND GROWTH AND NATURAL REGENERATION DEVELOPMENT FOLLOWING SELECTION HARVESTING OF DRY-BELT DOUGLAS-FIR – 15 YEAR RESULTS

ABSTRACT

Partial cut logging is of considerable importance throughout the dry-belt areas of British Columbia's central and southern interior. However, lack of good long term data continues to be the major impediment to improved growth and yield estimates for residual stands. One of the few existing well-designed studies of the effects of different levels of growing stock and stand structure on growth and yield was established in 1993 in an uneven-aged stand of interior Douglas-fir near Westwold in the Okanagan-ShuswapForest District. Fifteen years post-establishment, we remeasured the overstorey and understorey permanent plots. In addition, the understorey plots were re-visited three of the four years between the 10- and 15-year assessments to check seedling survival. Individual tree growth has responded to the thinning treatments, with those stems in the more heavily harvested plots and lower 'q' value growing faster. However, no clear treatment effects on relative growth at the stand level have yet emerged and the maximum productivity cutting cycle is still unknown. Conifer seedling recruitment is continuing to increase despite a 15-year period since the last disturbance. However, the tree distribution is patchy, germinant mortality high, and height growth slow. While unstocked openings in Layers 3 and 4 may need to be addressed at some point, recruitment of understorey trees from Layer 2 to the canopy Layer 1 is more important in the near term and will be the subject of further study.

INTRODUCTION

BACKGROUND

This project is part of a longer term research program engaged in improving growth and yield modelling for complex managed stands, such as mixed-species and multi-cohort stands created by retention silviculture systems. Practitioners and policy makers responsible for ensuring that the value and benefits derived from BC's forests are sustained must address the impact of a bewildering array of biological, environmental and economic factors, for which there is little or no experience, data or models. We incorporate detailed growth relationships into dynamic models that are flexible and capable of addressing new issues. Growth and yield projections should conform to existing data, be reasonable, intuitive and consistent with current knowledge. The tools, reports and service provided by this program support effective policy development and improved stewardship, and reduce uncertainty in forest management decisions by integrating the best available data and knowledge to address problems related to tree growth and yield. The results will allow managers to choose among alternatives or at least discard alternatives that are not viable. The accuracy of the predictions will improve as more data become available. Therefore, ensuring the ongoing collection of good quality permanent plot measurements, especially in complex stands such as EP987.04 is essential.

OBJECTIVES

The objectives of this field project were:

- to contribute to scientific knowledge about dry Douglas-fir stand growth and regeneration after partial cutting in order to support policy development, stand management decision-making, and the application of improved partial cutting practices for sustainable forest management,

- to strengthen growth and yield modelling capability for projecting IDF uneven-aged stands by adding to the permanent growth and yield plot database. The data will be used for model development, calibration and testing.

- To determine the effects of different levels of residual growing stock and stand structure on the growth and development of overstorey trees and regeneration in a dry-belt Douglas-fir stand after single-tree selection harvesting

STUDY SITE AND DESIGN

Selection harvesting is well suited for areas with visual, wildlife and watershed constraints, where there are concerns about regeneration success after conventional clearcut logging, and where there is a desire to create or maintain certain wildlife habitats. The existing Experimental Project (EP987.04) was established in 1993-94, with the cooperation of the former Vernon Forest District (now Okanagan-Shuswap Forest District), to provide information on the response of uneven-aged drybelt Douglas-fir (*Pseudotsuga menziesii* var. *glauca* (Bessin) Franco) to different selection harvesting regimes. Funding for the establishment of the trial was provided by the Canada-British Columbia Forest Resources Development Agreement (FRDA II). The stem-mapping, and 5th-year measurements were funded by Forest Renewal British Columbia. The 10th-year was funded by the Forestry Innovation Investment (FII) program.

The trial is located on a level to gently sloping, northwest-facing slope, at an elevation of 1100 m, approximately 6.0 km north of Westwold, in the Okanagan-Shuswap Forest District. This site (50°32'N, 119°44'W) is ecologically classified as the Douglas-fir-Feathermoss (04) site series of the Cascade Dry Cool Interior Douglas-fir (IDFdk2) biogeoclimatic subzone (Lloyd et al. 1990). The soil is a well- to moderately well-drained, sandy loam Brunisol, with a rooting depth of 28 cm. The moisture regime is mesic to subhygric, and the nutrient regime, medium. Prior to study establishment, the site was occupied by a multi-aged stand of Douglas-fir (*Pseudotsuga menziesii* var. *glauca* (Bessin) Franco), with minor components of lodgepole pine (*Pinus contorta* Dougl. var. *latifolia* Engelm.), hybrid white spruce (*Picea glauca* x *engelmannii*), trembling aspen (*Populus tremuloides* Michx.) and paper birch (*Betula papyrifera* Marsh.). Some of the pine trees had been attacked by mountain pine beetle (*Dendroctonus ponderosae* Hopkins), and there was evidence of spruce budworm (*Choristoneura* spp.) in the stand. There were no signs of previous logging activity but cattle had grazed the site and continue to do so (Johnstone 2000). Before treatment, the site was divided into three blocks, based on differences in stem density and species mix (Figure 1).

The installation consists of a full factorial experiment established using a randomized, complete-block design. The first factor examined was residual basal area ('B') with three levels (15, 20 and 25 m^2ha^{-1}), and the second factor examined was the negative exponential constant between 5-cm diameter classes ('q') with two levels (1.3 and 1.5). For all of the treatments, the maximum tree-size goal ('D') was 50 cm, and the treatments were applied to that portion of the stand between 7.50 and 52.49 cm in diameter. Each block contains six partial cutting treatments, plus an untreated control. All of the treated and control plots are 0.25 ha (50 m x 50 m) (Johnstone 2000).

After treatment (spring, 1994) and in the fall of 1998, all trees 7.5 cm diameter at breast height (DBH) and larger were tagged and mapped within local Cartesian coordinate systems, and the following measurements taken:

- Diameter at 1.30 m (dbh) of all tagged trees in the treated and untreated (control) plots.

- Total height, and crown length of approximately 21 Douglas-fir trees (7 trees randomly sampled from each third of the diameter distribution) in each plot. These samples were used to create height prediction functions for the remaining trees. In addition, the total heights of 21 pine and 28 spruce trees in the entire installation were measured.

- Age at breast height, from increment cores, of all height-trees.

- Presence of damage.

Compilation of the establishment data confirmed that, while the residual basal area treatment targets were achieved, the "q" targets were not, especially in the "q=1.3" treatments, where there were not enough large trees in the stand to meet the residual growing stock targets. Since the initial diameter distributions were unbalanced, it proved impossible to achieve both targets in one harvest (Table 1).

TREATMENT NO.	TARGET		BEFORE CUTTING		AFTER CUTTING	
	Basal area (B) (m²/ha)	'q'-value	Basal area (B) (m²/ha)	'q'-value	Basal area (B) (m²/ha)	'q'-value
1	15	1.3	39.58	1.983	14.86	1.559
2	20	1.3	37.26	1.586	20.43	1.383
3	25	1.3	39.01	1.890	24.96	1.757
4	15	1.5	34.73	1.745	15.03	1.590
5	20	1.5	35.70	1.767	19.75	1.573
6	25	1.5	40.24	1.708	24.79	1.579
0	Control		37.25	1.843	-	-

TABLE 1: Treatment prescriptions, based on 5-cm diameter classes, for the 10- to 50-cm diameter stand component

To assess regeneration, a study was initiated at the site in the fall of 2002. A five-metre buffer was measured around the inside perimeter of each 50 x 50 m treatment plot to establish an inner 40 x 40 m square regeneration sampling area with firm, straight boundaries. The boundaries of the inner plot were established and surveyed by a professional survey crew using a transit. The purpose of this buffer was to reduce the influence of trees located in the untreated surround on the area within the regeneration sampling frame. The inner plot was divided into four square quadrants within which the centre of one circular 0.005-hectare subplot was established at random coordinates. This semi-random approach was a compromise between the desires for both a random sample and one that would represent the range of conditions across the treatment plot (Figure 2). The sample plots were allowed to overlap each other and the 40 x 40 m sampling area boundary (provided the plot centre remained within the sampling area) in order to ensure equal probability of selection for any point within the sampling frame. The "mirage" method of edge correction was used for plots that overlapped the sample area boundaries, whereby an area equal in shape and size to that projecting beyond the boundary is reflected back onto the sampling area and recounted (Gregoire 1982).

The centre of each regeneration subplot was permanently marked with a metal pipe inserted with a flag on which was written the treatment and plot number. We recorded the location of each subplot centre stake within the coordinate system established for the treatment plot stem map. All ingress, including first year germinants, and advanced regeneration up to 7.49 cm DBH within the regeneration subplots were numbered with an aluminum tag, assessed for species, quality (good or poor), height class, and age where possible by counting internodes. Two-thirds of the subplots were established in this way in 14 of the 21 treatment plots for a total of 56 subplots, before onset of winter weather halted further work. The remaining 28 regeneration subplots were completed in September of 2003. We observed that overwinter mortality of the first year germinants had been high and that it was difficult to attach tags securely to such small seedlings without damaging them, so the tagging limit was changed to include only those seedlings that had survived at least two growing seasons. We then revisited all 84 subplots to record height and crown length for trees at least 10 cm tall, and DBH for trees taller than 1.3 m. This provided an establishment data set that is coordinated with a remeasurement of the overstorey trees. Overwinter mortality in the subplots installed last year was assessed as well, so that data from all 84 plots would be comparable.

METHODS

REMEASUREMENT OF EP987.04

Data collection

To estimate and compare the fifteen-year growth and yield response to the range of single-tree selection treatments, the measurements carried out at plot establishment, five and ten years later were repeated. In some cases, new height sample trees of the same species and size had to be chosen to replace those that had died or suffered damage. Furthermore, to make the height sample more representative of the test trees within the 40m x 40m test area, sample trees in the 5-m buffer were replaced with similarly-sized trees in the test area. Trees that had reached the 7.5 cm dbh threshold since the last assessment were tagged and mapped. The data was checked for errors, reformatted and entered into the Ministry of Forests corporate EP data base.

Analysis

Individual tree and basal area data was compiled by block and by treatment. Statistics on individual tree and net growth (i.e., excluding mortality), by block and treatment, were calculated for the 15-year observation period.

REGENERATION ASSESSMENT

Data collection

The regeneration subplots were visited in the fall of 2005, 2006, and 2007 to check seedling and small tree survival. At each visit, tagged seedlings were relocated by careful, systematic searching of successive sectors in each subplot, and with frequent use of a metal detector (White PRIZM IV). The status of each seedling was recorded as “Live”, “Dead” or “Not Found”. Those not found were occasionally located on a subsequent visit; if not, they were assumed “Dead” at the time the loss was first noted.

In September of 2008, survival status was again recorded for all tagged seedlings and live seedlings re-measured for total height, height of lowest live branch, and diameter at 1.3 m height (dbh) if applicable. Age and condition of live seedlings was also updated; condition was assessed as 'good', 'poor' or 'ongrowth', the latter category applying if the tree had attained 7.5 cm dbh or larger since the last measurement and, therefore, was considered ingrowth to the larger overstory experimental treatment plot. Notes were recorded on conditions that directly affected seedling height growth, such as browse, dieback, terminal bud damage, broken tops, multiple leaders, and defoliation. Each subplot was also searched for new seedlings that had attained a height of 10 cm or more since 2003. These were tagged, measured and assessed as above, except that species was also recorded.

Analysis

The subplot establishment data was compiled in 2003-04 to produce seedling and sapling frequency distributions by treatment, species, age, quality, and height class. The results were compared among the harvesting treatments using analysis of variance, based on a full factorial, randomized complete block design. The factor "q" was initially treated as a covariate, using the actual values. When "q" was found to have no significance ($p<0.05$) in the model, it was dropped from the analysis and the two plots within each block that had the same residual stocking level, but different q levels, were simply treated as two replications of the stocking level in subsequent analysis. The ultimate model used is displayed in Table 2. (Bealle Statland and Johnstone 2004).

The 2008 subplot data was similarly compiled and compared both qualitatively and analytically with those compiled in 2003. The analysis of variance tests were not repeated; instead, more emphasis was placed on qualitative comparisons and survival modelling.

SOURCE	DF	EMS	ERROR
Block, B	2	$4\sigma^2_{RBT} + 32\phi_B$	R(BT)
Residual Basal Area, T	3	$4\sigma^2_{RBT} + 24\phi_T$	R(BT)
B*T	6	$4\sigma^2_{RBT} + 8\phi_{B*T}$	R(BT)
Replicate, R(BT)	9	$4\sigma^2_{RBT}$	
Total	20		

TABLE 2: Variance components for analysis of regeneration assessment data

OVERSTOREY GROWTH AND DEVELOPMENT

All growth and yield compilations were based on the test trees within the 40 x 40 m subplot only, to reduce edge effects. Figures 3 and 4 show the effects of partial cutting on bole diameter growth and mean tree diameter, respectively, for each of the three 5-year measurement periods. The results indicate that there was an immediate and direct response by the residual trees to harvesting intensity and that this response has been maintained over the 15-year period. The highest increments were observed in the most heavily harvested plots (Treatments 1 and 4) and lowest in most lightly harvested plots (Treatments 3 and 6). All of the harvested plots outgrew the unharvested control plots by almost 2 to 1 or more. This improvement in diameter growth is reflected in mean diameter development. Although smaller at the time of treatment, diameters in the most heavily harvested plots have now equalled or surpassed their more lightly harvested counterparts.

In contrast to the mean tree response, the response on an area basis is less clear (Figures 5 and 6). Obviously, the treated plots outgrew the controls. The low growth in treatment "BA 25, Q 1.5" during the first 5 years was due to loss of several large spruce and fir to windthrow. A lot of the pine in Block 3 have been attacked by the mountain pine beetle and an outbreak of western spruce budworm is increasing. It appears that, with the exception of the 25 m^2ha^{-1} residual treatments, it will be quite a while longer before the more heavily cut stands catch up to the control stocking levels.

Figures 7 and 8 show overstorey tree survival and ingrowth, respectively. Survival has been about the same for most of the treated plots at just over 80% and about 6% higher than the control plots. The more heavily harvested treatments have more ingrowth into the small diameter classes (tagging threshold 7.5 cm dbh). These trees originate from advanced regeneration that was preserved at the time of treatment.

UNDERSTOREY RECRUITMENT

Reasonably high numbers of good quality seedlings have established within most of the treated plots since the partial cutting. Average values for each treatment across all of the blocks are presented in Figure 9 to summarize the results of the survey to 2008 and compare them to the results of 2003. These totals (means of three blocks, ± std. errors) include all live seedlings and saplings taller than 10 cm and smaller than 7.5 cm dbh, all species combined. Despite 15 years since disturbance and dense pinegrass growth, seedling establishment is still continuing. Plot-to-plot variation is very high, however, a reflection of the very patchy spatial distribution. Douglas-fir dominates the understorey, but some lodgepole pine, spruce and smaller amounts of aspen and birch are also present. In 2008, 50-70% of the seedlings were rated good quality and 30-50% were taller than 50 cm (data not shown). There is a general trend of decreasing recruitment with increasing initial residual overstorey stocking.

The rest of the regeneration results are reported in the draft paper "Understorey recruitment and development in an interior Douglas-fir partial cutting experiment in southern British Columbia" to be submitted for publication this year.

DISCUSSION

The most important growth and yield result is the addition of another measurement to the database. Fifteen years of growth in itself can not yield any significant answers with respect to the treatments, but without this incremental measurement and maintenance of the plots, obtaining significant results in the future and, thus, capitalizing on the investment would not be possible.

The mean diameters in the most heavily harvested plots are increasing faster than those in the lightly treated plots. This is not unexpected, as the trees are responding to the greater increase in growing space created by the treatments. However, there are no clear differences at the stand level. Total stand net growth is not expected to show a parallel pattern, because fewer trees yield less volume and less growing stock. This has not yet been fully compiled because of the difficulties surrounding the reduction of the plot size by the buffer and the need to apply new height prediction curves that produce consistent results across measurements. It isn't possible to make any definitive comments regarding the effects of stand structure on growth because we weren't able to achieve the 1.3 'q' targets. However, it is interesting that trees in Treatment 2, where we came closest to achieving our goal, outgrew their 1.5 counterparts (Treatment 5), because a higher proportion of the residual growing stock is in larger trees. For a given level of residual basal area, the higher response generally occurred in the plots with the lower 'q'-value. The main causes of mortality have been the continued loss of pine to mountain pine beetle, uprooting and the breakage of tops of the smaller pine and fir trees by wind, and uprooting of large spruce. The cutting cycle length required for maximum production is, as yet, unknown.

New germinants are continuing to establish at the site, even as the overstorey continues to develop. However, very few seedlings were found in the untreated control plots, indicating that these plots are fully stocked. Canopy disturbance is required for understorey reinitiation to commence. Some small gaps have appeared in the controls due to snow and wind breakage. The few seedlings found were mostly in these gaps and less than five years old. Douglas-fir dominates the understorey; lodgepole pine is a distant second. Spruce recruits were very rare—almost all of the understorey spruce are present as advanced regeneration. High within-treatment variation in recruitment suggests that several more replications of the treatments would be required to demonstrate any stocking effects.

Significant regeneration events have been episodic. Forest floor conditions favourable to the establishment of natural regeneration may not persist sufficiently long after ground disturbance to take advantage of good seed crop years.

CONCLUSIONS AND MANAGEMENT IMPLICATIONS

This study was established to determine the effects of partial cutting on the growth, yield and development of uneven-aged, dry-belt Douglas-fir trees and stands. Individual tree growth has responded to the thinning treatments, with those stems in the more heavily harvested plots and lower 'q' value growing faster. However, we can report no clear treatment effects on growth at the stand level and the maximum productivity cutting cycle has yet to become apparent. Continued periodic measurement and analysis will be required.

Although germinant mortality after mast years is high, there are sufficient numbers and quality of Douglas-fir recruits in Layers 3 (1.3m height to 7.49cm dbh) and 4 (<=1.3 m height) to eventually provide future crop trees. However, the seedlings are relatively small, slow growing and irregularly distributed. Given that the most important cohort for near-future stand development will be the ingrowth to Layer 2 (7.5 to 12.5cm dbh), unstocked openings and slow seedling growth are probably a concern only for the lower retention plots and those with the most windthrow damage. We will next evaluate the recruitment levels and dispersal in comparison with the quality and growth rate of stems in Layer 2 in more detail, to produce a more comprehensive analysis of the stand understorey dynamics. Deciding on what constitutes a sufficient level and spacing of natural regeneration to preclude intervention is difficult in these stand types. Alternative stocking survey methods for dry partial cut stands are currently being explored to account for this.

It is clear that a wide range of recruitment results can be expected within these levels of residual stocking after fifteen years. Regeneration is influenced by many factors other than those controlled in this study. The future measurement of additional site or tree variables in this experiment could elucidate significant factors or significant patterns related to initial stocking may emerge as the overstorey continues to develop. These understorey subplots are intended to be permanent for future measurement of seedling growth and mortality. This data will be very important for testing models that project the development of uneven-aged stands.

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Lloyd, D., K. Angove, G. Hope, and C. Thompson. 1990. A guide to site identification and interpretation for the Kamloops Forest Region., B.C. Min. For., Res. Br., Victoria, B.C.

FIGURES

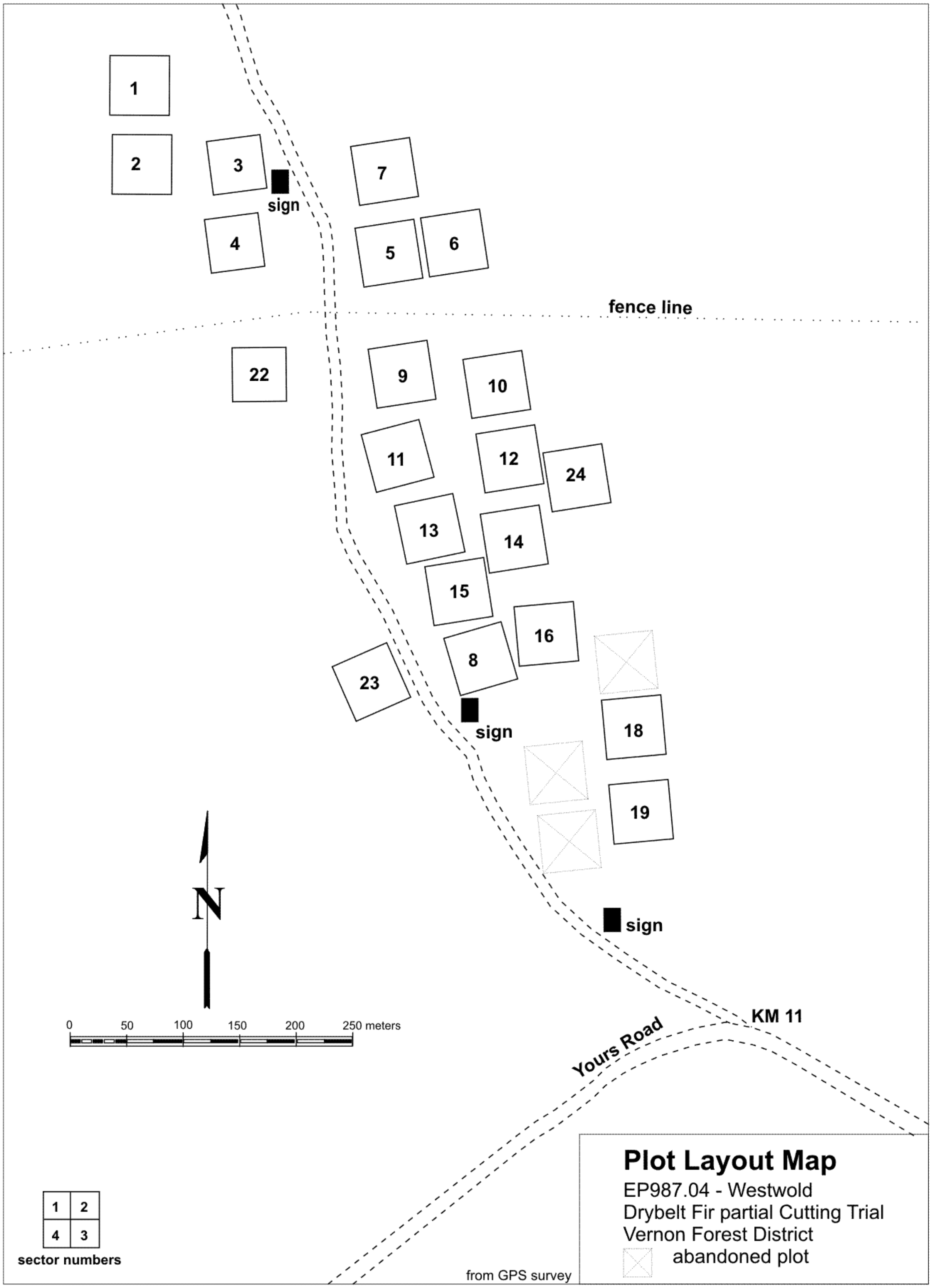

Figure 1: Layout of treatment plots at the Westwold study site.

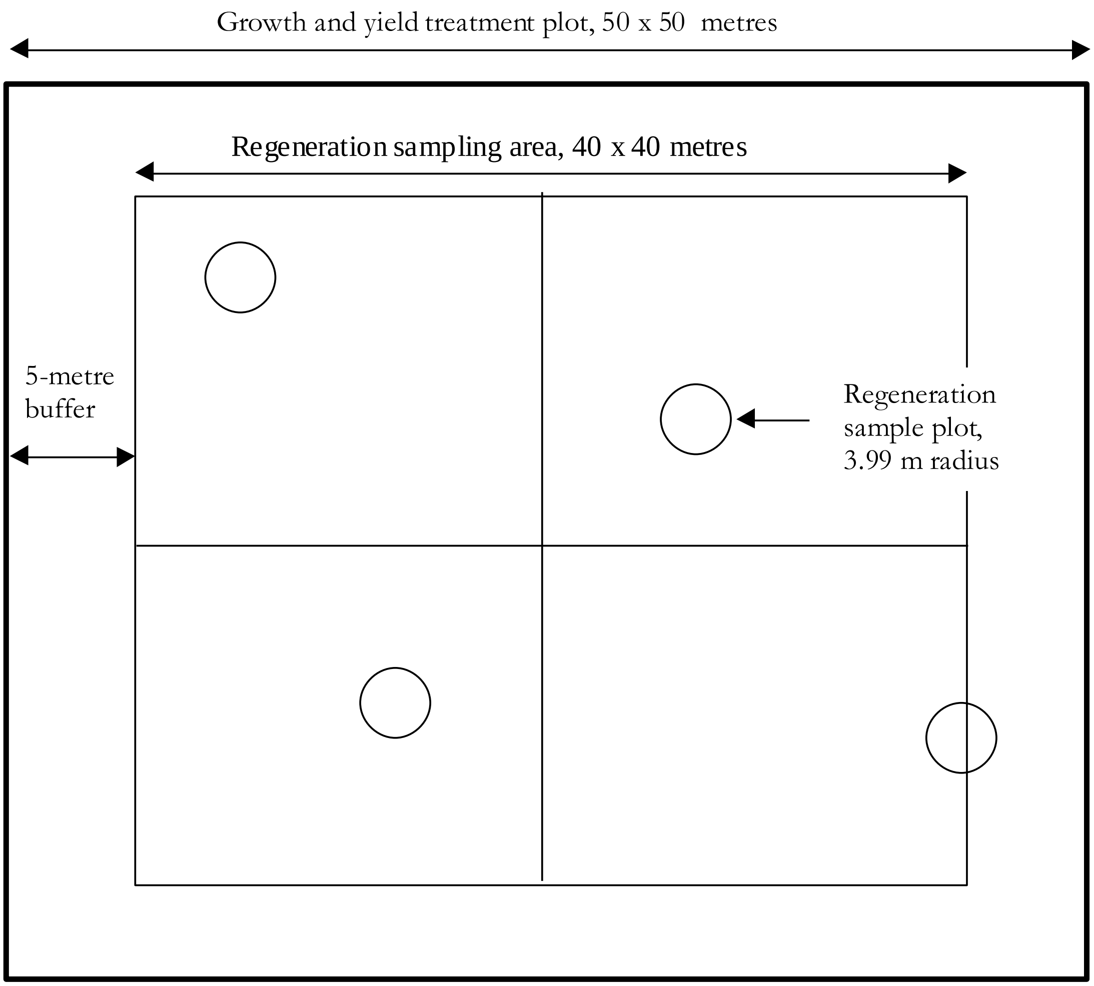

FIGURE 2: Schematic diagram of regeneration sample plot layout within each treatment plot (not to scale).

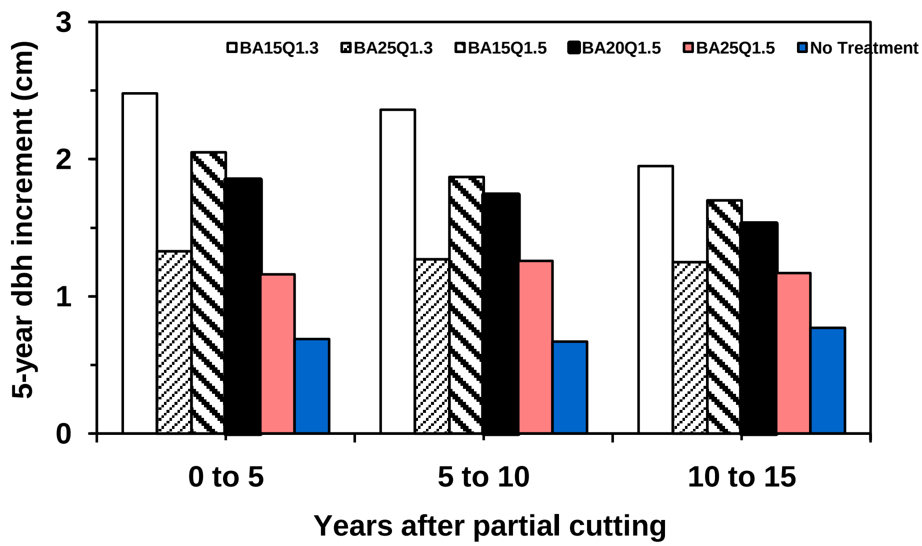

FIGURE 3: Diameter growth by treatment, following partial cutting (all species combined).

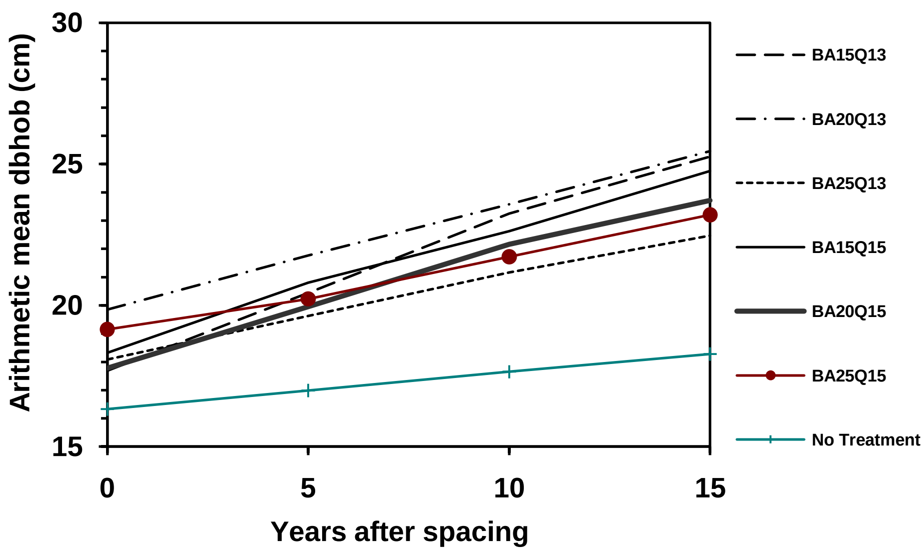

FIGURE 4: Diameter development by treatment, following partial cutting.

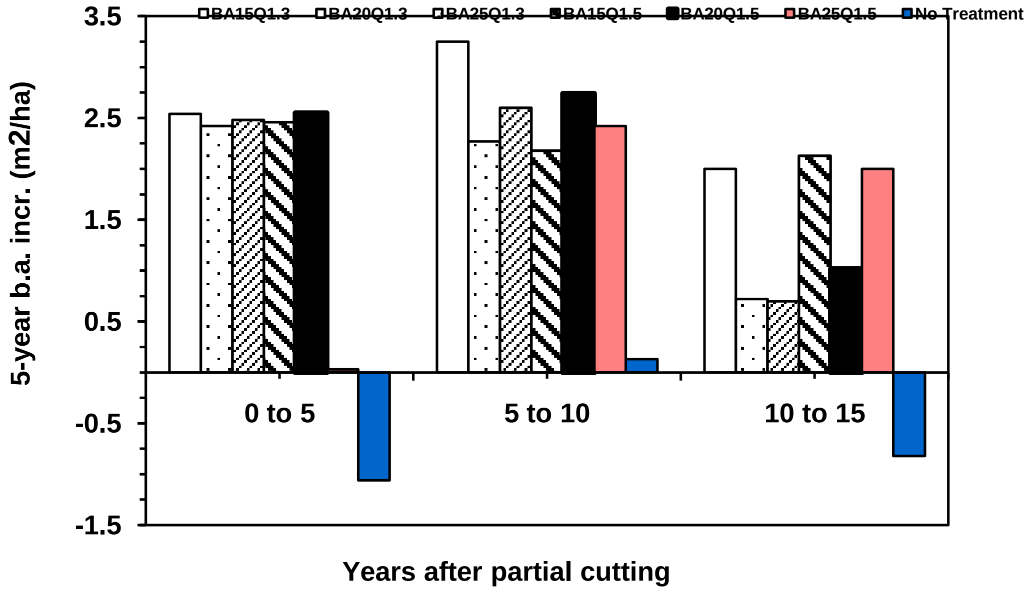

FIGURE 5: Overstorey basal area growth by treatment following partial cutting.

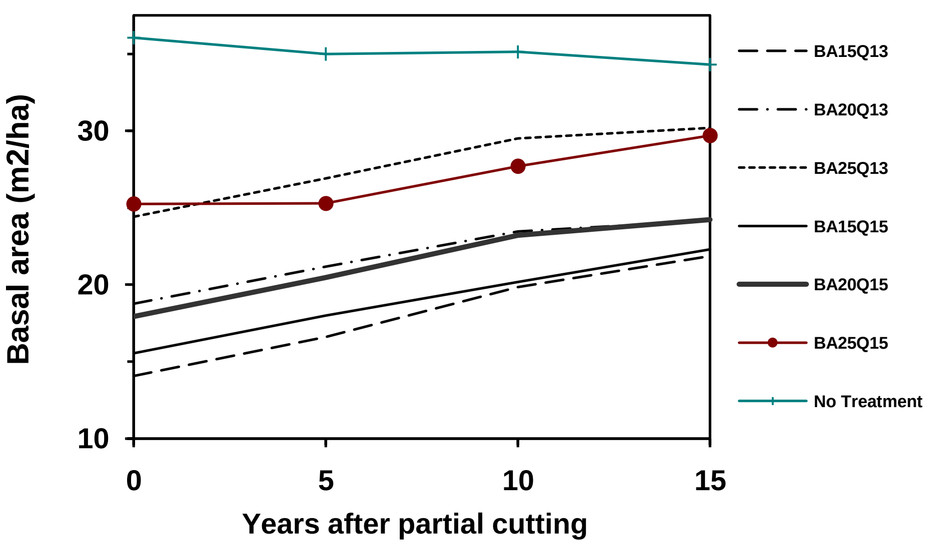

FIGURE 6: Overstorey basal area development by treatment, following partial cutting.

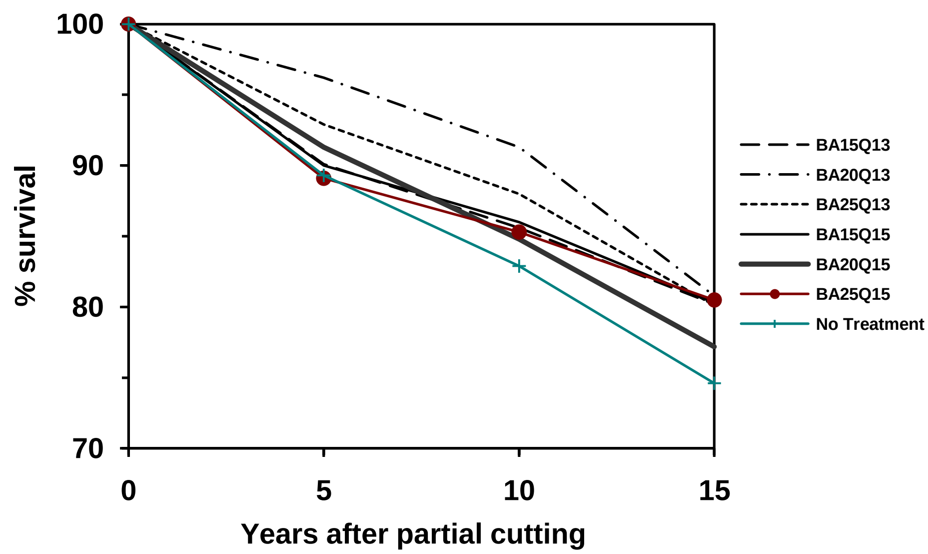

FIGURE 7: Overstorey survival by treatment, following partial cutting.

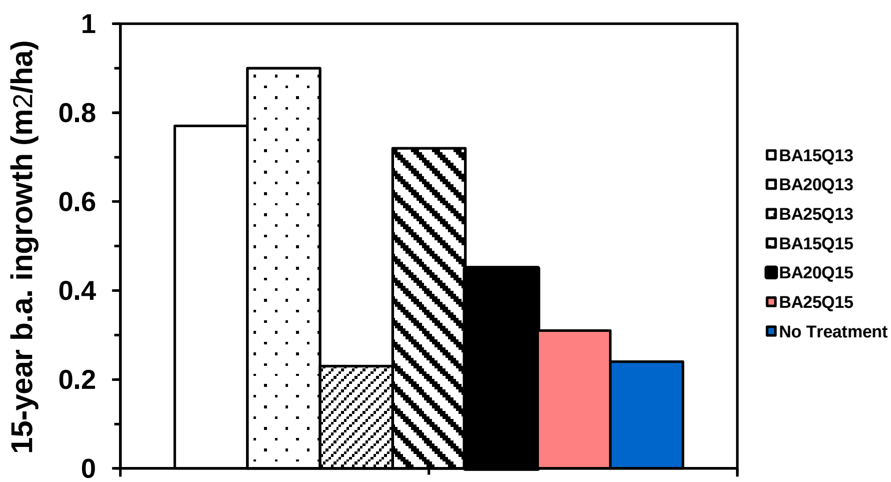

FIGURE 8: Ingrowth basal area by treatment, 15 years following partial cutting.

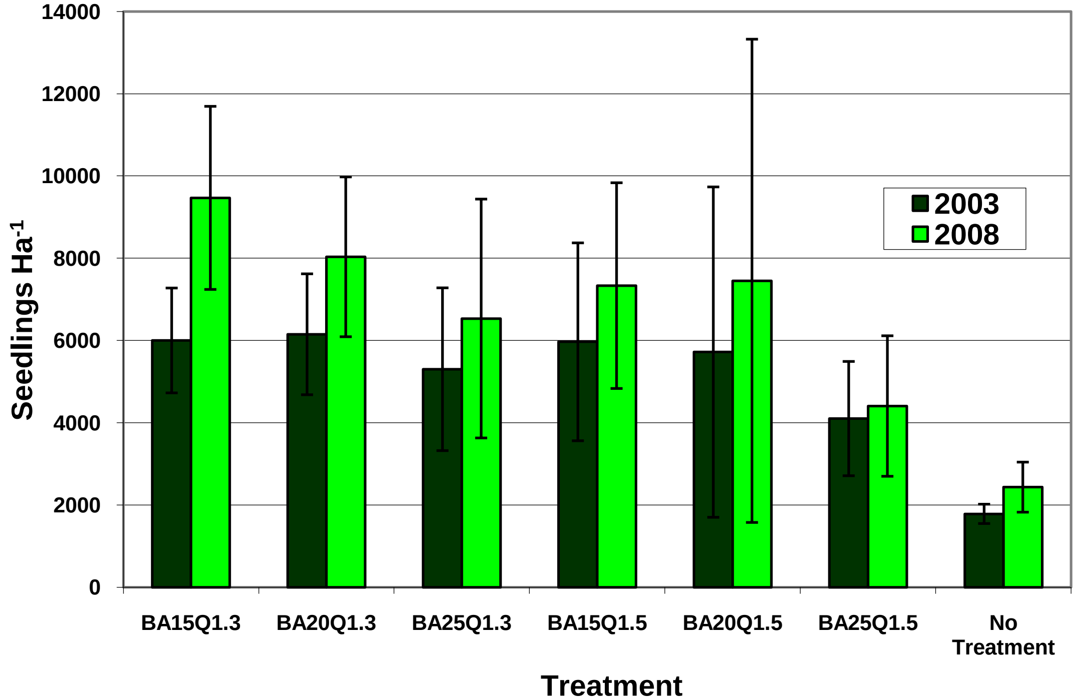

FIGURE 9: Regeneration counts ten years (2003) and 15 years (2008) after treatment, all species combined.