Quantification of thinning and fertilization treatment response for forest stands in Northern Idaho

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ABSTRACT

Two separate methodologies were employed to quantify the effect, magnitude, and duration of silvicultural treatments (i.e., thinning and nitrogen fertilization) on the growth of forest stands in Northern Idaho. The first methodology employed standard statistical procedures (i.e., analysis of covariance) to provide estimates of average plot basal area, height, and cubic volume growth following thinning and fertilization treatments.

It was shown that the application of one fertilization treatment (200 lbs. of nitrogen per acre) to thinned stands of grand fir (<u>Abies grandis</u> [Doug L.] Lindel) and Douglas-fir (<u>Pseudotsuga menziesii</u> [Mirb.] Franco) in Northern Idaho resulted in higher average basal area growth when compared to those stands not receiving a thinning treatment. Additionally, fertilization of unthinned stands of similar composition resulted in a significant height increment increase during the same six-year post treatment period. Fourteen years after treatment, fertilization had increased average tree size (cubic volume) by 14 percent in unthinned and by 23 percent in thinned stands.

The second methodology employed individual tree analysis to investigate the effect of the aforementioned silvicultural treatments on the diameter growth of trees in the specified stands.

Two alternative individual-tree, distance-independent, diameter increment models for thinned and fertilized stands were developed using data from the same permanent research plots. The first model resembled that of the PROGNOSIS (Wykoff, et. al. 1982) in terms of stand, site, and tree variables comprising the diameter growth prediction equation. The second model utilized stand site index in place of site factors, such as elevation, slope, aspect, and habitat type used in the PROGNOSIS-type model. The results indicated that contingent upon knowledge of site index and availability of the proper site index equation and conversion factors, the second specification of the diameter increment model would yield comparable projection results, more sensitivity to density effects, and superior statistical properties. It was concluded that while thinning was influential in increasing diameter growth for lower stand densities, and also altered the pattern of stand structure, further diameter growth was realized as the result of fertilization treatment.

Key words: Growth models, site index, diameter increment, Douglas-fir, grand fir, model validation.

CHAPTER I

INTRODUCTION

Generally speaking, intermediate silvicultural treatments such as cleaning, liberation cuts, thinning, and fertilization are conducted to enhance growth performance as well as to ensure desired composition, spacing, and stem quality of developing forest stands. Thinning operations are most often performed to achieve, among other objectives, an increase in merchantable yields (by redistributing volume growth), and a higher economic value. Fertilization is used in order to produce more quality wood, intensify culture, achieve wider choice of species, enhance vegetative cover, and improve food and cover for wildlife (Stone 1973). Depending on a stand's site quality (productive capacity of the site), amount of nutrient applied, and nutritional demands, fertilization generally results in accelerated growth through time, leading to higher stand volumes and reduction in rotation length (Miller 1981).

Forest fertilization continues to be an important silvicultural practice in forest lands in the Pacific Northwest. The nature of height, volume, and basal area growth response following single and/or multiple applications of fertilization treatments has been investigated by many researchers through regional forest nutrition projects (i.e.: IFNTC 1986-1987; RFNRP 1987). Results of individual and cooperative research studies in the region indicate: i) accelerated height, basal area, and volume growth through time as the result of fertilization treatments and a significant response to nitrogen fertilization (especially for Douglas-fir, grand fir, and western hemlock species), ii) accelerated mortality of trees in the smaller size classes of natural (unthinned) stands (specifically at higher levels of nitrogen fertilizer), iii) changes in stand development following fertilization treatment and alteration in the distribution of added increments due to nitrogen fertilizer across size classes within a stand, and iv) a higher priority given in the region to fertilization of thinned stands, although fertilization of unthinned stands is regarded as a biologically and economically feasible managerial option.

Since fertilization tends to alter the dynamics of all food chains and trophic levels, the impacts of fertilizer treatments are not always easy to predict. Nevertheless, many researchers have determined the magnitude, duration, and distribution of nitrogen fertilizer responses in forest stands (e.g., Waring and Youngberg 1972; Cochran 1979; Brix 1981), and many studies have successfully investigated the managerial consequences of forest tree nutrition and fertilization programs (e.g., Jorgensen and Wells 1987; IFTNC 1987).

Thinning improves the growth of forest stands by capturing merchantable mortality and concentrating growth on to (residual) trees that will reach merchantable size. While thinning operations normally reduce cubic volume per acre, they are shown to be effective in improving height growth (site index) and diameter growth for various species in the Pacific Northwest (Reukema and Bruce 1977; Seidel 1987). Changes in the volume increment distribution are often observed as the result of thinning treatments. However, gains in volume production from thinning regimes depend, among other things, on the age, site quality, and density of stand, as well as the timing, type, and intensity of the thinning treatments applied. Hence, while thinning may consistently enhance height and diameter growth of forest stands under specified conditions in a particular region (NCSFFC 1980), for other situations it may result in inconsistent growth and yield responses related to factors such as thinning intensity or stand density (Graham, et. al. 1985; Ronco, et. al. 1985).

In the first phase of this study, an "average" growth response analysis for Northern Idaho grand fir and Douglas-fir stands to nitrogen fertilization and thinning is presented, using plot-based analysis of variance procedures. Here, the objectives are i) to investigate six-year gross and net basal area and height growth response of thinned vs. unthinned stands following fertilization treatments, and ii) to compare the periodic (two-year) basal area growth response through time and to determine the duration of response to fertilization treatment for thinned and unthinned stands. In addition, the average fourteen-year net volume for both thinned and unthinned stands are computed and the effect of fertilization on volume increment distribution within a stand is further discussed.

In the second phase of the study, individual-tree analysis and diameter increment models are employed to further investigate the effect of thinning and nitrogen fertilization on the diameter growth of trees in the specified stands.

In general, growth models involving explicit prediction of yields in forest stands can be divided into two categories: stand-level and tree-level models. Stand-level growth models (such as those presented in the first part of this analysis) employ stand variables such as age, basal area per acre, site index, etc., as inputs, while tree-level growth models are normally constructed utilizing both stand and individual tree variables, such as diameter, height, crown dimensions, and between-tree distances. The tree-level (component) models are further classified as distance-dependent and distance-independent models (Munro 1974). Distance-dependent, individual-tree models require information concerning the spatial arrangement and distribution of the trees involved to predict individual tree growth within a stand (Clutter et. al. 1983). Distance-independent, individual tree models, on the other hand, do not require information on between-tree distances, and predict individual tree growth using conventional measures of competition (crowding) such as basal area per acre or crown competition factor.

Stand-level models have been developed by many investigators (e.g., Bennett 1970; Smalley and Bailey 1974; Chambers 1980; Curtis et. al. 1981) to enable quantitative determination of growth and yield (i.e., basal area, height, volume) on a unit land area basis. However, for the most part, these models are unable to fully account for the variation in forest stands caused by species composition, tree size, competition status, soil type, and other factors. Therefore, adjustments for stand structure variation are not normally provided, as they are for individual tree models.

Distance-dependent, individual-tree models such as those suggested by Hegyi (1973), Mitchell (1975), and Tennent (1980) maintain a closer approximation to the stand structure (by considering spatial variation within a stand) and may be appropriate for simulating silvicultural practices. Nevertheless, the cost associated with obtaining extremely detailed data, lack of sufficient observations in stem-mapped plots, and specific computing requirements can result in empirical limitations and disadvantages for their application.

Recently, the use of the individual-tree, distance-independent growth models has been emphasized (e.g., STEMS, Belcher et. al. 1982; PROGNOSIS, Wykoff et. al. 1982; SPS, Arney 1984) in the Northwest. Models of this form employ conventional stand table data (along with some stand-level statistics) and can provide for mixed size and age classes and species. Since spatial patterns of trees are not considered, some researchers may regard such specification of distance-independent models as being limited in growth analysis applications. However, these models are not necessarily inferior to those of distance-dependent models, since the inclusion of various competition indices may contribute little or no improvement in growth prediction (Clutter et. al. 1983), although recent results by Daniels et al. (1986) suggest that this may not always be the case.

The main objective in the second phase of this study is to develop individual-tree, distance-independent diameter increment models for forest stands in northern Idaho. It is also intended to use the specified functional forms of the diameter increment model to ascertain the impact and the duration of thinning and fertilization treatment response in these stands.

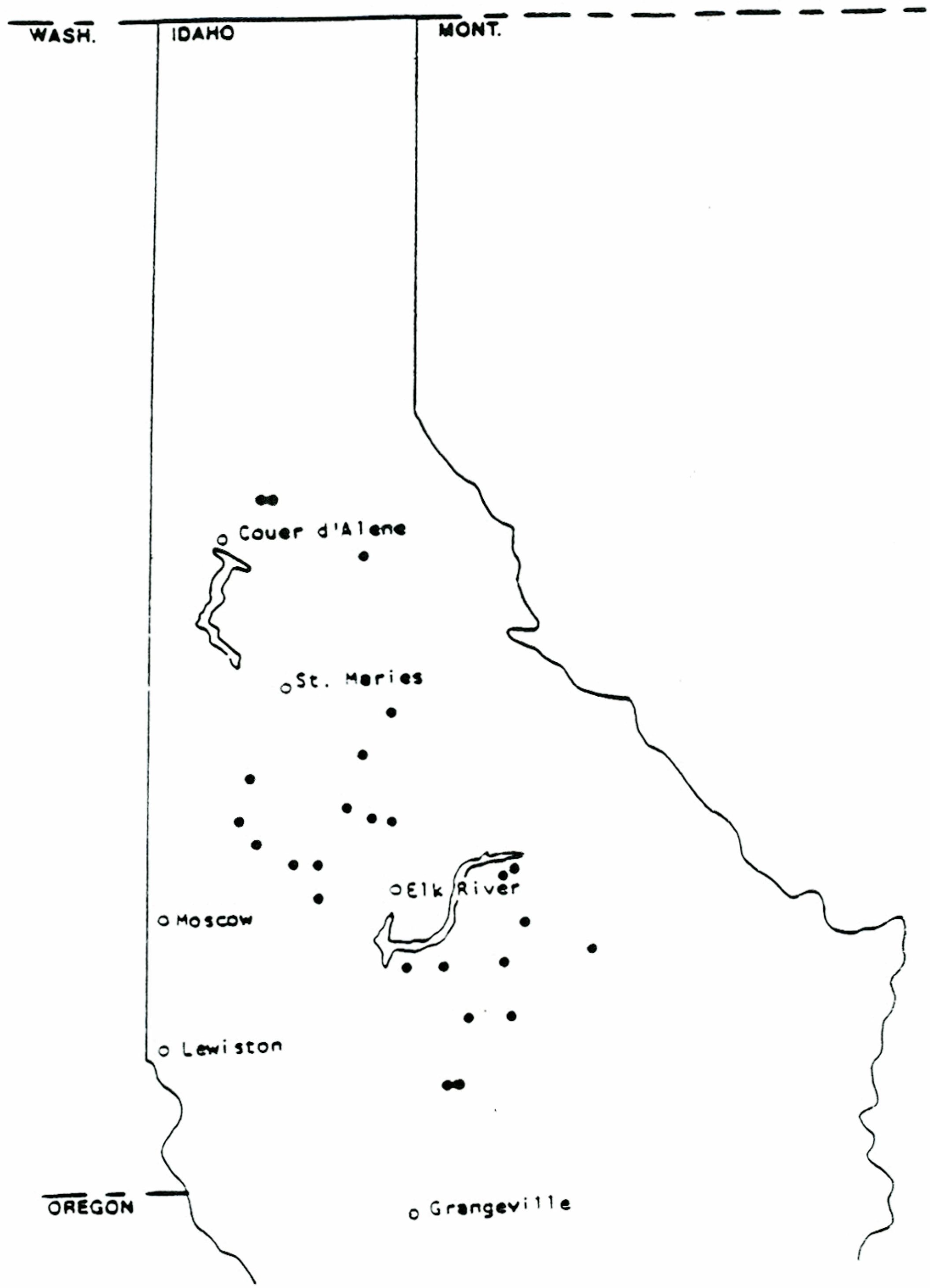

Figure 1. The Location of Thinning and Fertilization Experiments in Northern Idaho (• denotes installation)

CHAPTER IV

DISCUSSION AND CONCLUSIONS

Douglas-fir and grand fir stands located in Northern Idaho appeared to respond well to nitrogen fertilization as evidenced by the strong average basal area growth response in both thinned and unthinned stands six years following treatment. The four-year basal area response estimates were actually higher than those reported for the IFTNC (1986) Douglas-fir trials located in the same region. However, at least on a per acre basis, duration of basal area response was short-lived (only four years) in unthinned stands most likely due to over stocking (high density). Results of this study suggest that fertilization continues to influence stand dynamics beyond the four-year period. For example, nitrogen fertilization in unthinned Douglas-fir and grand fir stands reduced average density by about 100 trees per acre over the 14-year post treatment period. This contributed to an increase in the average tree size as compared to untreated stands, since additional treatment-related mortality was concentrated in the smaller size classes.

Nitrogen applied to thinned plots produced both lower average absolute and relative response during the first four years following treatment compared to fertilized unthinned plots. However, duration of response appeared to be longer in thinned stands and remained significant after six years. Some of these differences in the average growth response were the result of thinning methods applied. It is clear that thinning type (crown versus low versus spacing, etc.) and intensity differed both within and between installations studied. Some stands were only lightly thinned while others were thinned heavily, and some actually received mechanical thinning while others were thinned either from below or from above in order to achieve a target 15'x15' post treatment spacing. Obviously, the type of thinning treatment impacts the average stand diameter shortly after the thinning application. These factors may confound standard plot based analytical approaches to quantify fertilization response in these stands.

The small though positive fertilization response noted in unthinned plots during the later periods (9-14) may be related to initial differences in stand structure. Such structure differences could influence mortality, as well as the rate of crown differentiation, and consequently, the tree size distribution of a stand. In fact, shifts in volume increment distribution across diameter classes (from lower to upper diameter classes) were observed quite frequently within individual installations. Results indicate that the combination of thinning and fertilization treatments increased mortality of trees in lower crown classes, redistributed volume increment within stands, and altered the pattern of stand development.

The individual-tree growth response analysis clearly showed the impact of thinning treatments in changing the distribution of diameter increments across tree size classes within a stand, and hence resulting in a long-term alteration of stand structure. Larger trees showed more growth response to both thinning and fertilization than smaller trees, and the greatest fertilization response occurred for trees in thinned stands of low density. Stands that were lightly thinned (i.e., those with high basal area after thinning) produced much less tree growth response than those of low density after thinning. Similar patterns were evident for the fertilization treatment.

The average net volume response analysis indicated a progression of average cubic foot volume per tree as a result of thinning and fertilization treatments. For example, in fourteen years post treatment period, fertilization increased average tree size by 14 percent in unthinned and by 23 percent in thinned stands (Table 10). This would imply that if rotation age remained constant, more volume per tree or larger trees could be harvested at that time. On the other hand, if harvest age were to be determined by tree size, then rotation length could be reduced via fertilization treatment, as evident by the individual-tree diameter increment model (Table 12), i.e.: a grand fir tree of average DBH (6.3 inches for MS-16 data) is expected to grow approximately 5.5 inches in diameter fourteen years following fertilization treatment as compared to a diameter growth of 4 inches for an untreated tree, keeping all other site and density factors constant (at their mean level). This would result in an increase of about 15 percent in the average stand diameter due to the fertilization treatment (11.8 inches versus 10.3 inches), and could consequently result in reduction of the rotation age in the specified stands. In addition, when adjusted for density variables, further increase in the average stand diameter was observed as a result of thinning and fertilization combined [6.6 inches diameter growth in fourteen years, representing an increase of 9 percent over fertilized only (12.9 inches versus 11.8 inches) and 25 percent over control treatment (12.9 versus 10.3 inches), respectively]. The above conclusions concerning the impacts of fertilizer treatment (i.e., accelerated growth through time, higher individual tree volumes, and reduction in rotation length) are similar to those suggested by other researchers (e.g., Miller 1981; Jorgensen and Wells 1987).

It should be emphasized that the applicability of the proposed diameter increment model given in (5) is dependent on the availability of site index equations for a given species in a specified region, and suitable sample trees in a specified stand. Hence, contingent upon knowledge of site index, the given specification may be used in predicting the diameter growth of individual trees and ascertaining the effect of thinning and fertilization treatments. However, because of various practical and technical problems involved in site index calculations such as selection of sample trees for determination of height and age, number of sample trees to include and measure for a given stand, and choice of method for calculating the final site index estimates, the use of the specified model may be limited for certain applications. Under these circumstances, the PROGNOSIS-type specification of the diameter increment model could be used to accomplish the same objectives. While both models provided many desirable statistical properties, the proposed model avoided the inherent collinearity among the site factors (see Appendix C), reduced the ill conditioning effect between site and density variables, and demonstrated more sensitivity to density effects.

The diameter growth predictive models produced meaningful projection results and performed well in tests with independent data sets. The new equations, when incorporated into existing individual-tree growth and yield simulation models, could provide useful tools to forest managers in the region.

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