Fourth Annual Report

Intermountain Forest Tree Nutrition Cooperative

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College of Forestry, Wildlife, and Range Sciences

University of Idaho

Moscow

SUMMARY

Results based on analysis of two-year basal area per acre growth response for 45 test sites treated in 1981 indicate:

A) A majority of the installations showed a substantial (greater than 25%) growth response to both treatments.

B) There were significant differences in response between geographic regions.

C) Except for the Central Washington region, there was no significant response difference between treatments of 200 and 400 lbs nitrogen per acre.

D) Stand density at the time of treatment strongly influenced treatment response. As density increased response decreased.

E) The installations were not correctly classified as to response based on foliar nitrogen and needle weight changes in new foliage one year after treatment. Further analysis of other foliar nutrients suggests that for many non-responding installations other elements may limit growth or perhaps the nitrogen treatments created nutrient imbalances.

Two-year growth response of the 1981 test sites:

Forty-five installations were established and treated in the fall of 1981. Each installation consists of six one-tenth acre plots, some plots are larger to include a sufficient number of sample trees. Treatments were assigned to the plots randomly. The treatments consisted of: 1) two plots with applications of 200 lb. per acre actual nitrogen, 2) two plots with applications of 400 lb. per acre of actual nitrogen, and 3) two control plots. Urea was the nitrogen source. The diameters of all sample trees were measured before treatment and again after the 1983 growing season. Thus, this analysis is based on diameter (basal area) growth for two years after treatment.

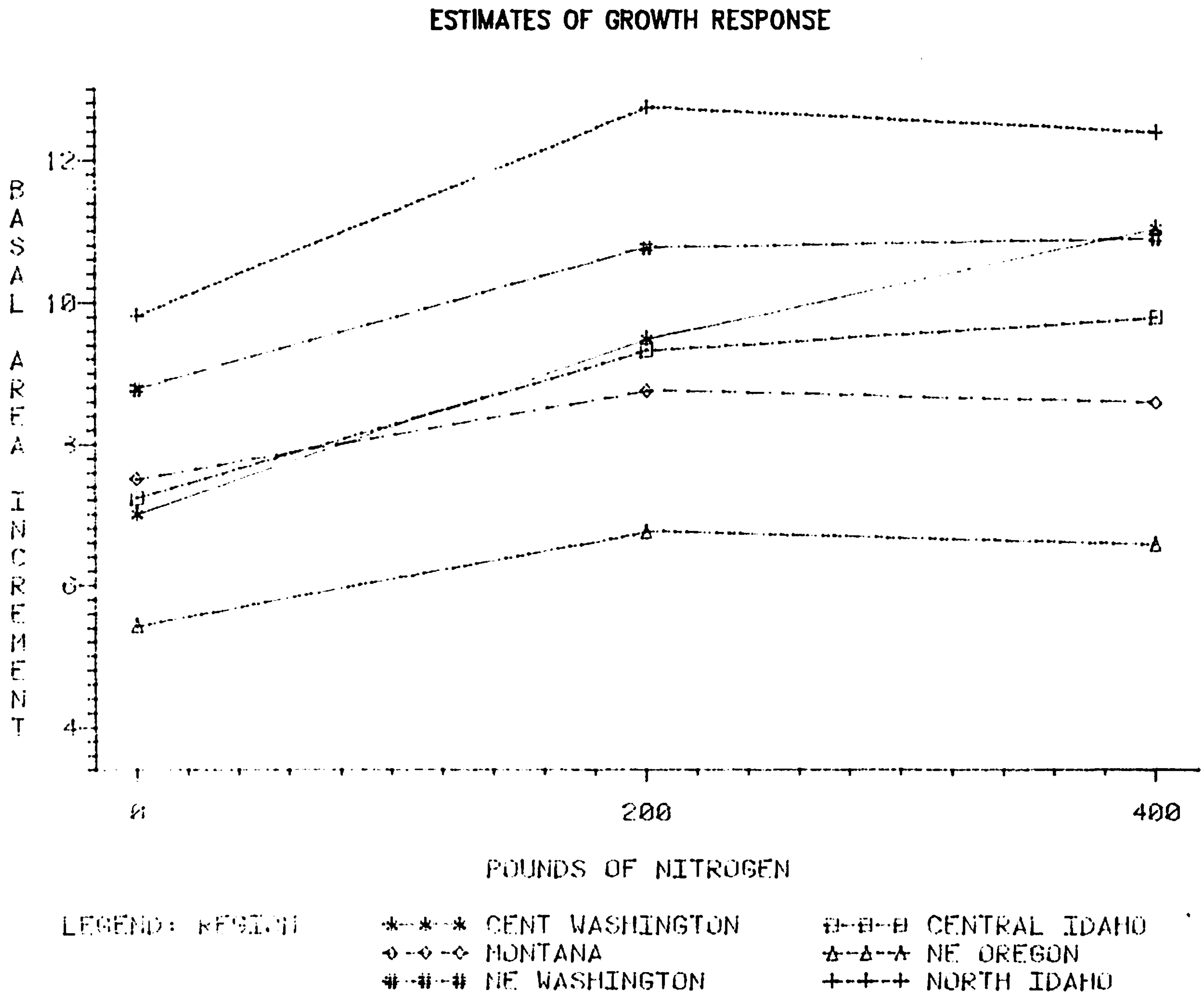
Basal area response data are presented as smoothed estimates throughout this portion of the report. The estimates are derived from the statistical model indicated in Table 1 (The Analysis of Variance Table) of the Technical Documentation Report.

Table 1. Two-year average adjusted basal area per acre increment by treatment and IFTNC geographic region.

REGION	TREATMENT		
	CONTROL ($Ft.^2/A$)	200 lb./A ($Ft.^2/A$)	400 lb./A ($Ft.^2/A$)
North Idaho	9.81	12.73	12.37
Montana	7.51	8.75	8.58
Central Idaho	7.24	9.31	9.78
Northeast Oregon	5.42	6.75	6.56
Central Washington	7.00	9.49	11.04
Northeast Washington	8.79	10.77	10.90

The two-year basal area per acre (BA/A) increment for both the 200 and 400 lb. treatments were statistically different from the controls across all geographic regions. However, except for Central Washington, there was no difference between the 200 and 400 lb. treatments. The adjusted means (to a common initial basal area) for BA/A increment are given for each treatment by region in Table 1 and are shown graphically in Figure 1.

FIGURE 1. THE EFFECT OF NITROGEN FERTILIZATION RATE ON TWO-YEAR BASAL AREA INCREMENT FOR THE SIX GEOGRAPHIC REGIONS OF THE IFTNC.



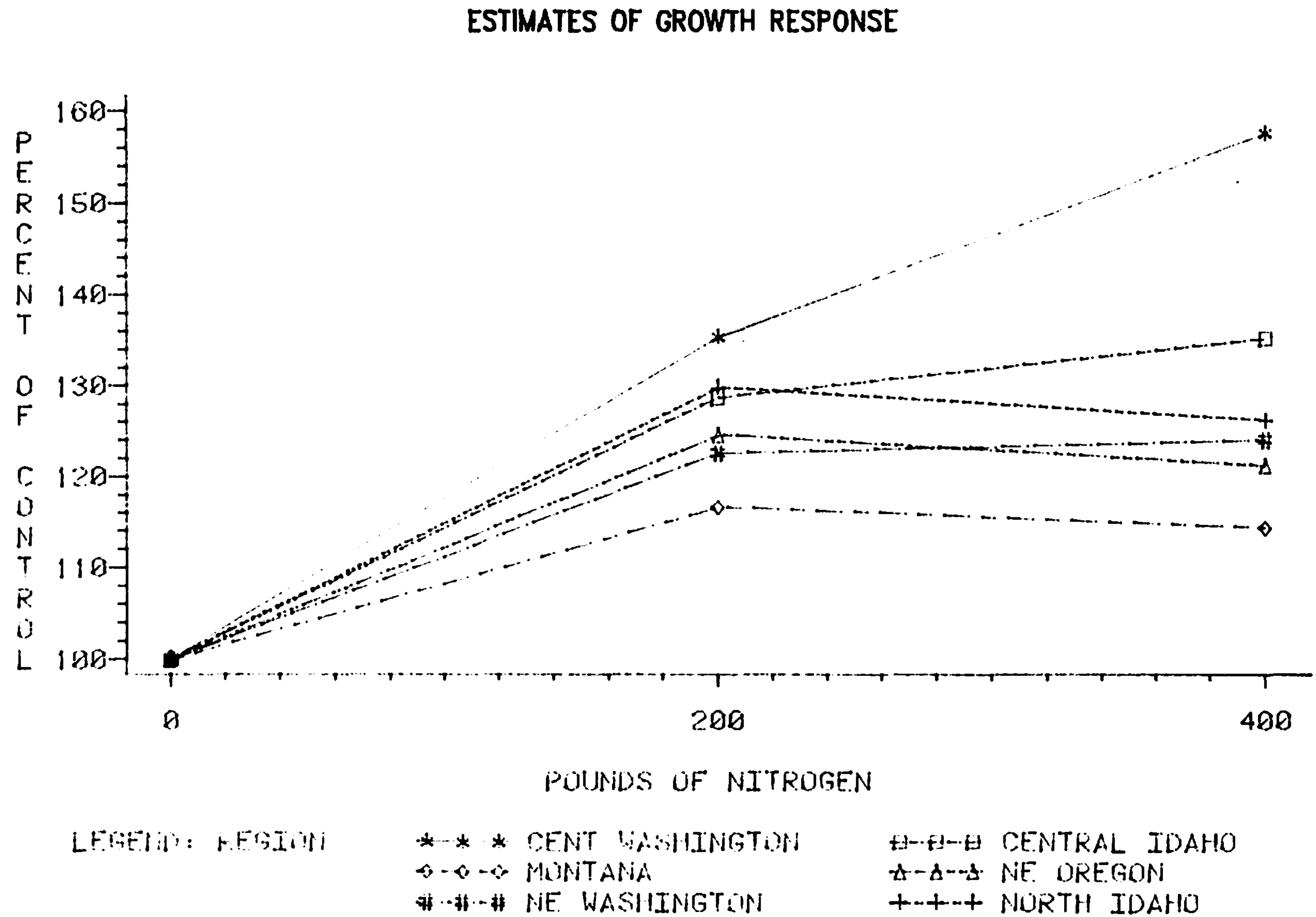
The adjusted differences between average treated growth rates and average untreated growth rates are provided in Table 2. There were significant differences in treatment response between the geographic regions. The North Idaho region showed the largest absolute response to the 200 lb. treatment with an average increase of 2.92 ft^2/A in the two year period. Central Washington produced the largest average relative response (36%) to the 200 lb. treatment. Central Washington also had both the largest absolute (4.04 $ft.^2$/A) and relative (58%) response to the 400 lb. treatment. Montana showed the lowest average absolute and relative responses to both nitrogen treatments. These regional response differences are clearly shown by Figure 2. By comparison, the average two-year BA/A responses reported for thinned stands of Douglas-fir west of the Cascades were 3.74 and 4.02 $ft.^2$/A for 200 and 400 lb. treatments respectively (Regional Forest Nutrition Research Project, Biennial Report 1980-1982; College of Forest Resources, University of Washington, Seattle). It is surprising to note that the average absolute BA/A responses to 400 lb. of nitrogen are almost identical for Central Washington and the "west-side".

Table 2. Two-year average adjusted basal area per acre response by treatment and IFTNC geographic region.

Region	Treatment			
	200 lb./A		400 lb./A	
	$Ft.^2$/A	Percent	$Ft.^2$/A	Percent
North Idaho	2.92	30	2.56	26
Montana	1.24	16	1.07	14
Central Idaho	2.07	29	2.54	35
Northeast Oregon	1.33	24	1.14	21
Central Washington	2.49	36	4.04	58
Northeast Washington	1.98	23	2.11	24

Although there are significant differences in treatment response among regions, there is substantial variation within each region. That is, some installations responded very well and others little or not at all in every region. This can be seen in Table 3 which provides

FIGURE 2. THE EFFECT OF NITROGEN FERTILIZATION RATE ON TWO-YEAR RELATIVE BASAL AREA INCREMENT FOR THE SIX GEOGRAPHIC REGIONS OF THE IFTNC.



the maximum and minimum response value for each treatment by region. In addition, both the adjusted and unadjusted response values are provided for all 45 installations in Section 1 of the Technical Documentation Report. The results for selected individual installations will also be provided to area managers who have been involved in selection of these test sites. Although there is substantial variation in treatment response, much of the variation can be explained by physical and biological factors that differ between installations. Many differences become obvious from the "Weetman" Diagnostic Technique that is discussed in a later section of this report.

Table 3. Maximum and minimum adjusted two-year basal area per acre response by treatment and IFTNC geographic region.

Region	Maximum ($ft.^2/A$)		Minimum ($ft.^2/A$)	
	200 lb/A	400 lb/A	200 lb/A	400 lb/A
North Idaho	4.04	3.63	1.19	0.93
Montana	2.35	2.22	0.48	0.35
Central Idaho	2.57	3.08	1.69	2.04
Northeast Oregon	2.03	1.84	-0.12	-0.33
Central Washington	3.51	5.60	1.99	3.22
Northeast Washington	3.41	3.63	1.28	1.36

Another important factor that determines the magnitude of response to nitrogen fertilization is stand density. Plot density at the time of treatment is expressed in the statistical model as basal area per acre. Initial basal area is included as a covariate in the model as a separate variable and as an interaction of treatment and basal area (Table 1, Technical Documentation Report). The effect of initial basal area on relative growth response by region is shown in Figures 3 thru 8 and on absolute growth in Figures 9 thru 14. As stand density increases growth response decreases. At very high stand densities, growth response is predicted to be zero. Although all basal area values shown on the graphs are within the range of our data, very few plots exceeded 225 ft^2/A. The average

FIGURE 3. THE EFFECT OF INITIAL BASAL AREA PER ACRE ON TWO-YEAR RELATIVE BASAL AREA RESPONSE FOR NORTH IDAHO.

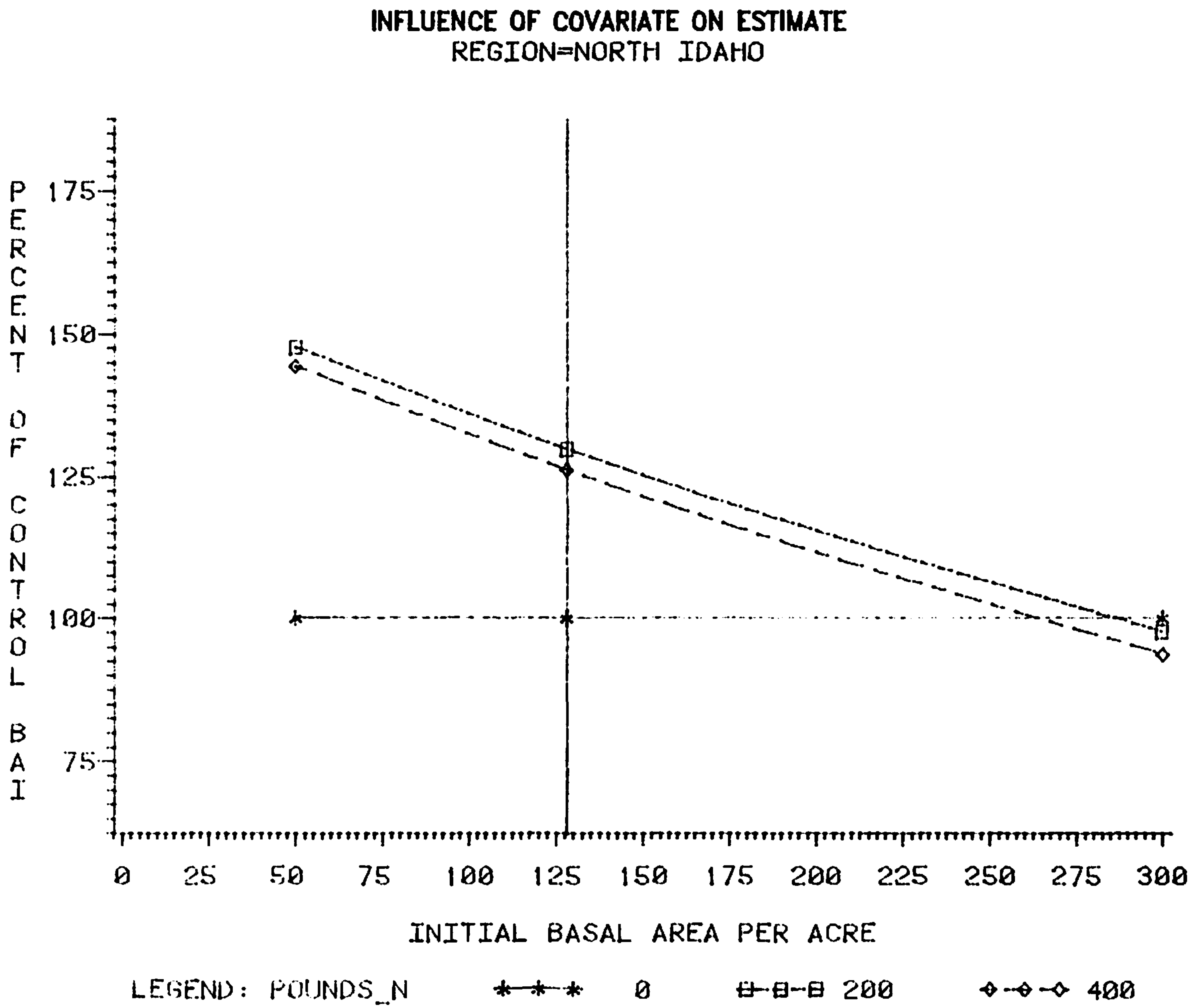


FIGURE 4. THE EFFECT OF INITIAL BASAL AREA PER ACRE ON TWO-YEAR RELATIVE BASAL AREA RESPONSE FOR MONTANA.

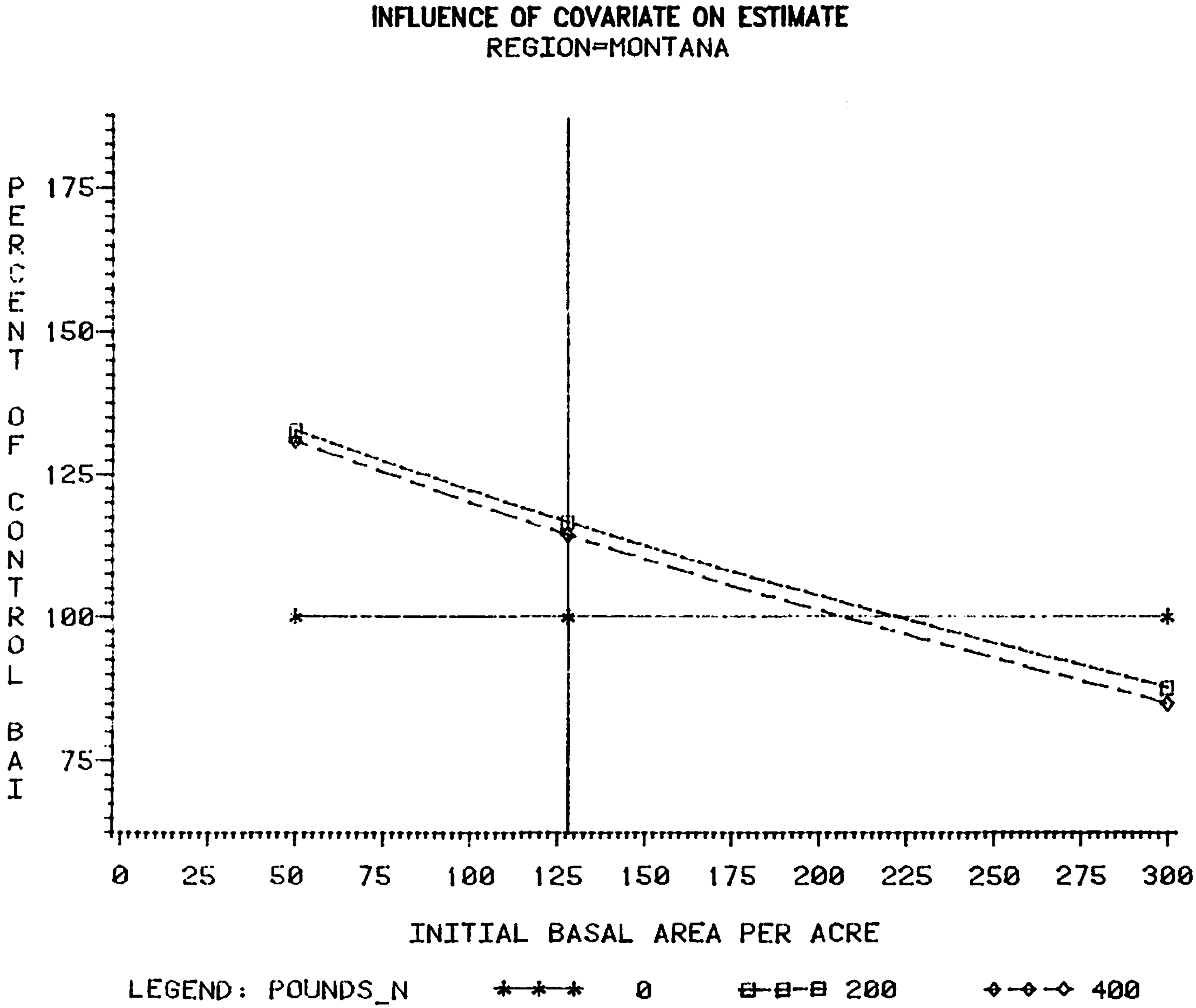


FIGURE 5. THE EFFECT OF INITIAL BASAL AREA PER ACRE ON TWO-YEAR RELATIVE BASAL AREA RESPONSE FOR CENTRAL IDAHO.

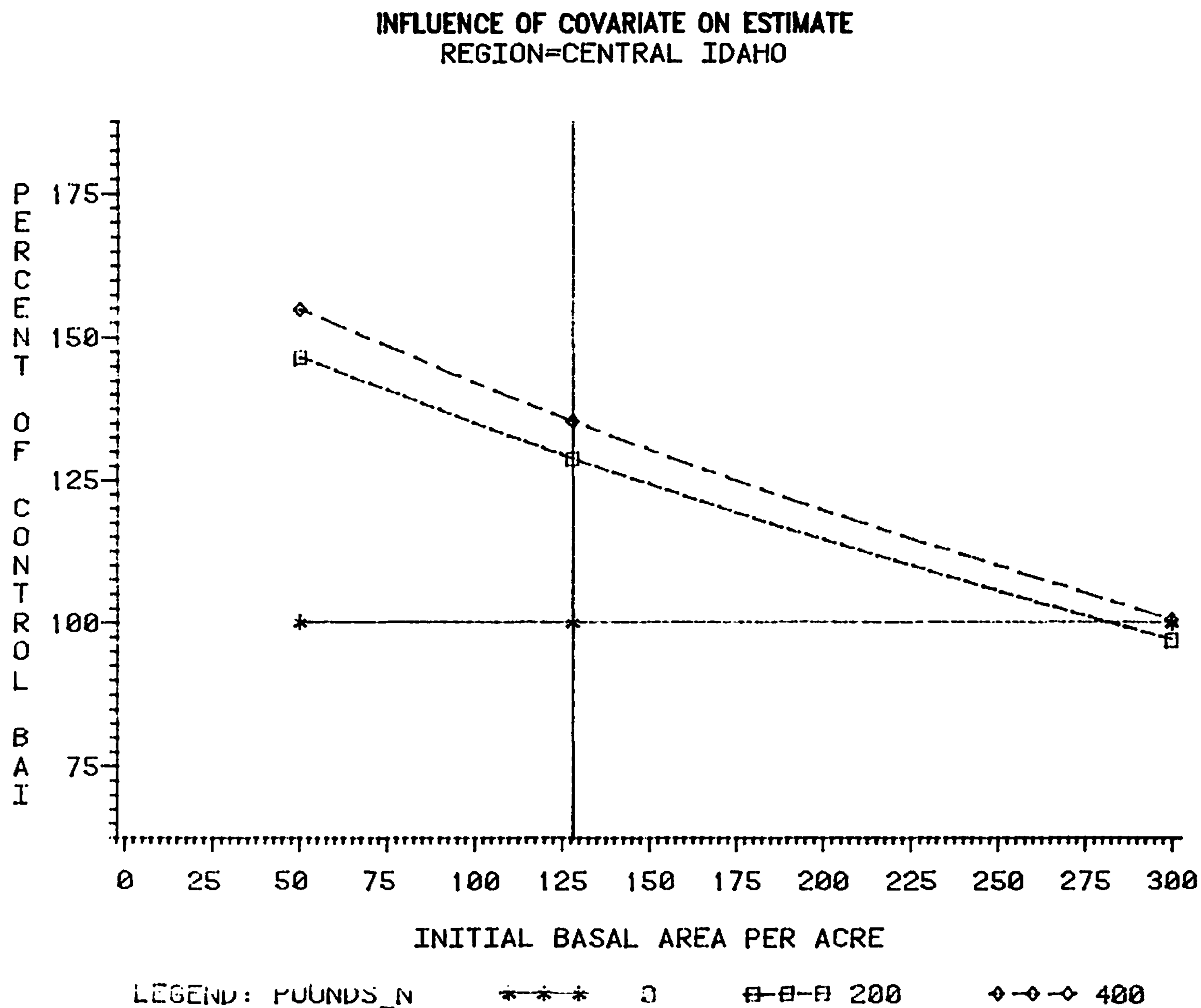


FIGURE 6. THE EFFECT OF INITIAL BASAL AREA PER ACRE ON TWO-YEAR RELATIVE BASAL AREA RESPONSE FOR NORTHEAST OREGON.

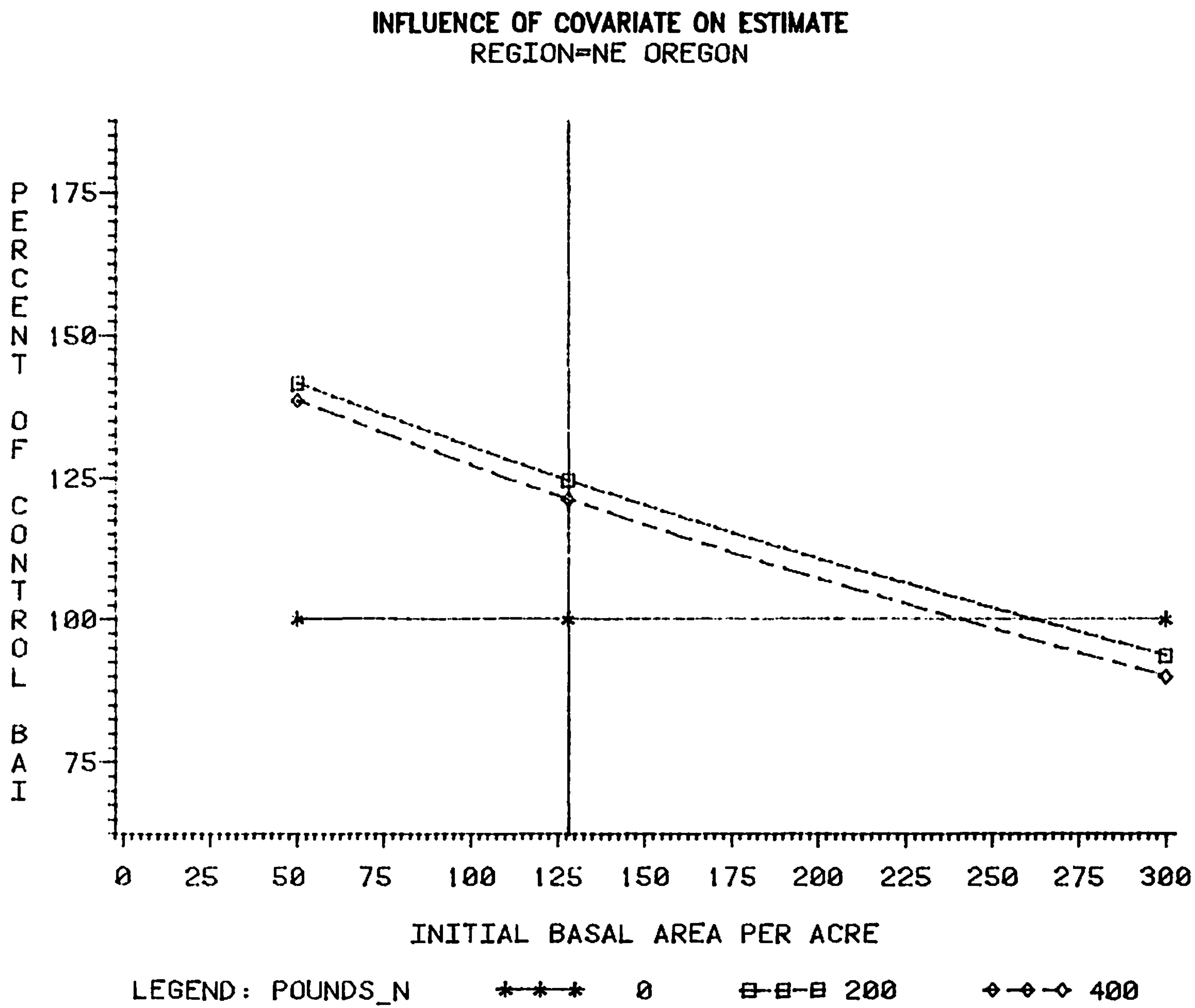


FIGURE 7. THE EFFECT OF INITIAL BASAL AREA PER ACRE ON TWO-YEAR RELATIVE BASAL AREA RESPONSE FOR CENTRAL WASHINGTON.

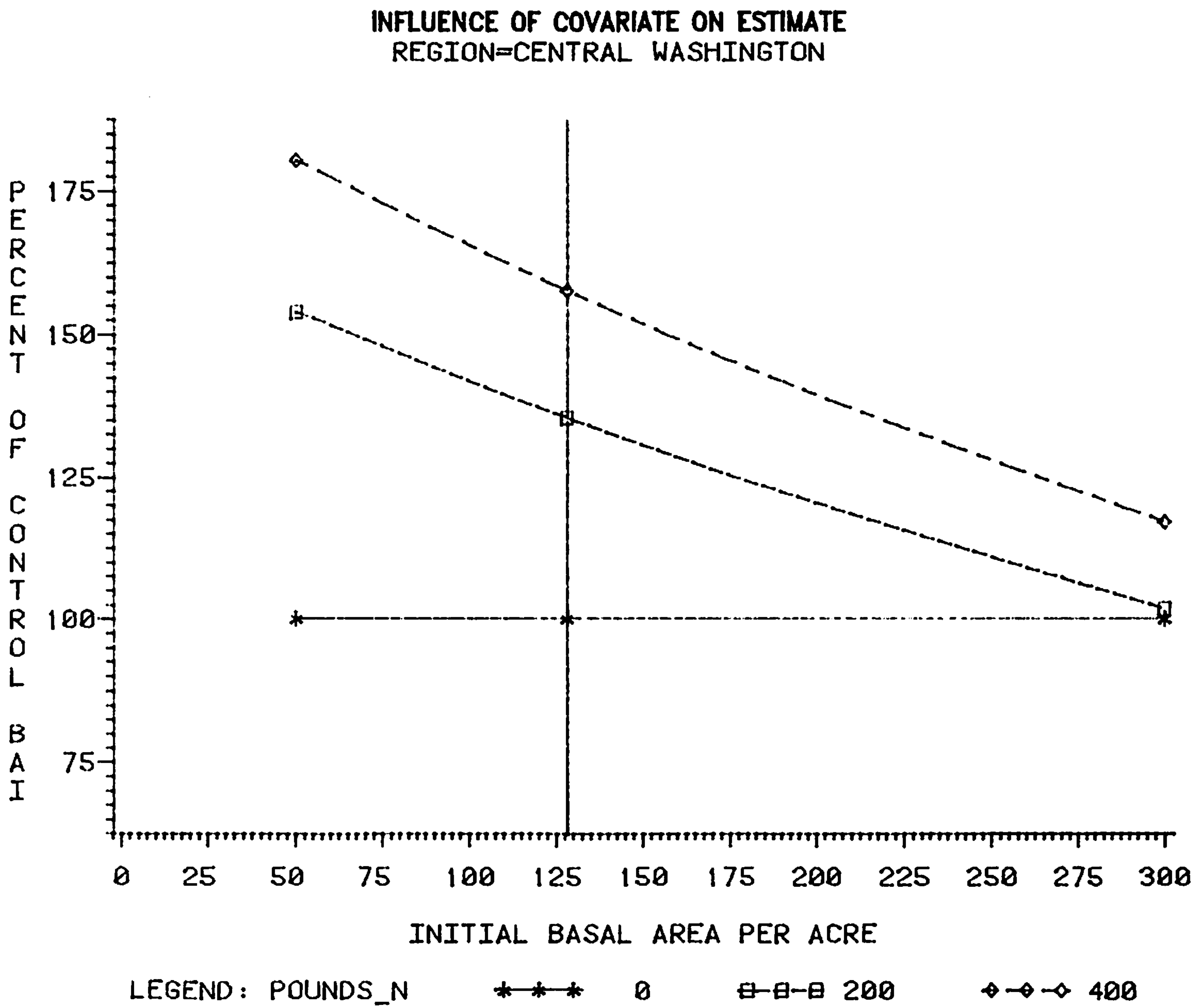


FIGURE 8. THE EFFECT OF INITIAL BASAL AREA PER ACRE ON TWO-YEAR RELATIVE BASAL AREA RESPONSE FOR NORTHEAST WASHINGTON.

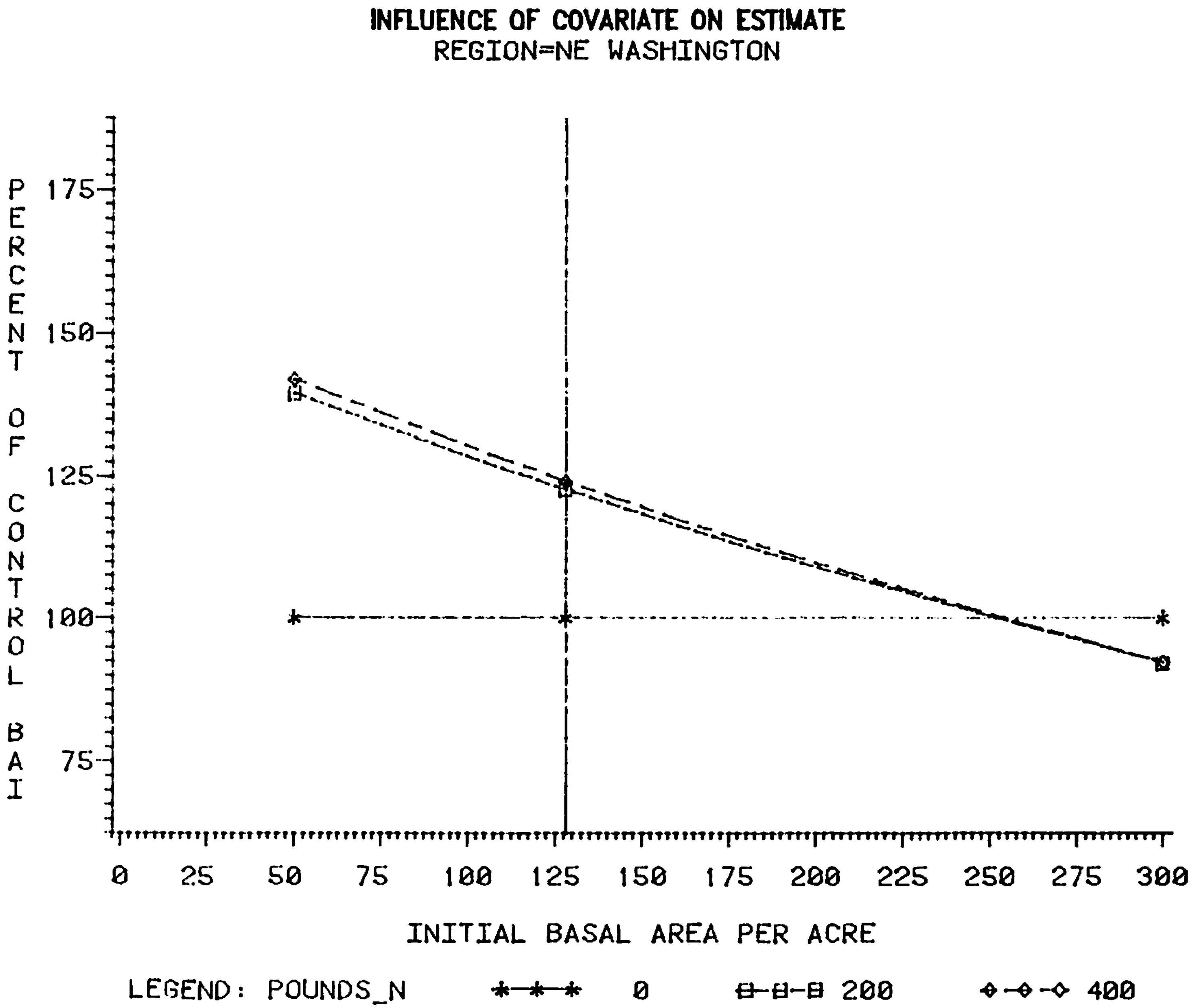


FIGURE 9. THE EFFECT OF INITIAL BASAL AREA PER ACRE ON TWO-YEAR ABSOLUTE BASAL AREA RESPONSE FOR NORTH IDAHO.

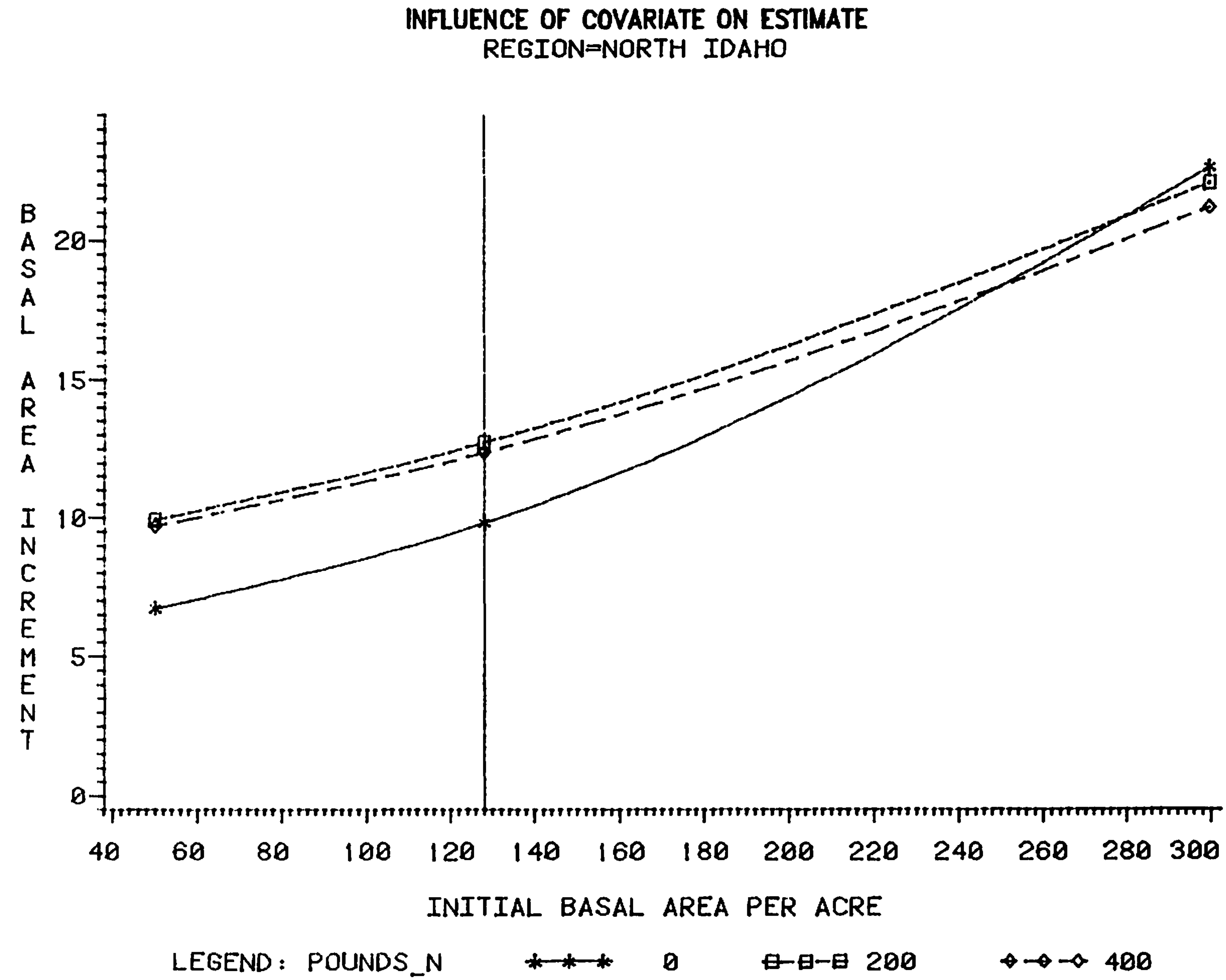


FIGURE 10. THE EFFECT OF INITIAL BASAL AREA PER ACRE ON TWO-YEAR ABSOLUTE BASAL AREA RESPONSE FOR MONTANA.

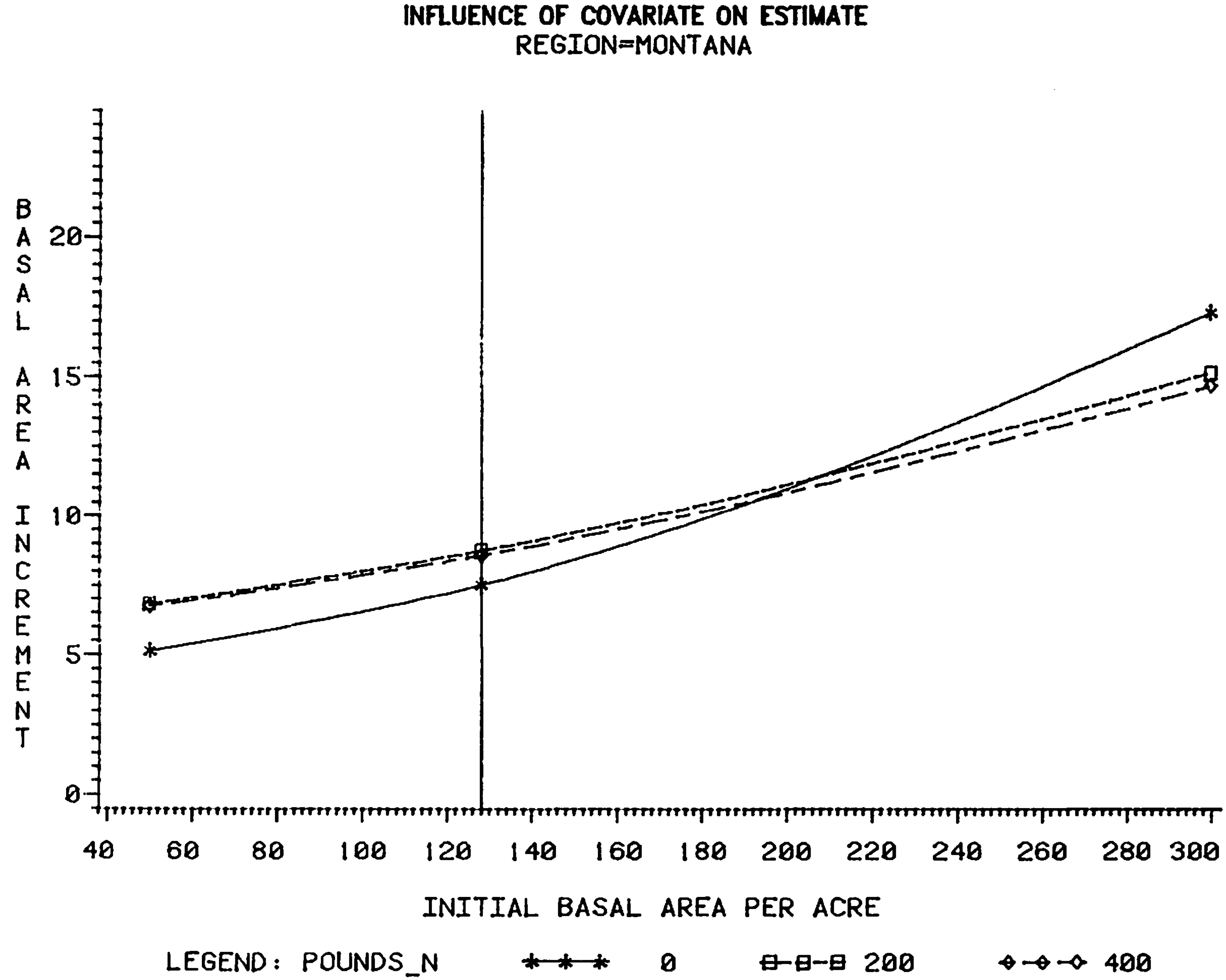


FIGURE 11. THE EFFECT OF INITIAL BASAL AREA PER ACRE ON TWO-YEAR ABSOLUTE BASAL AREA RESPONSE FOR CENTRAL IDAHO.

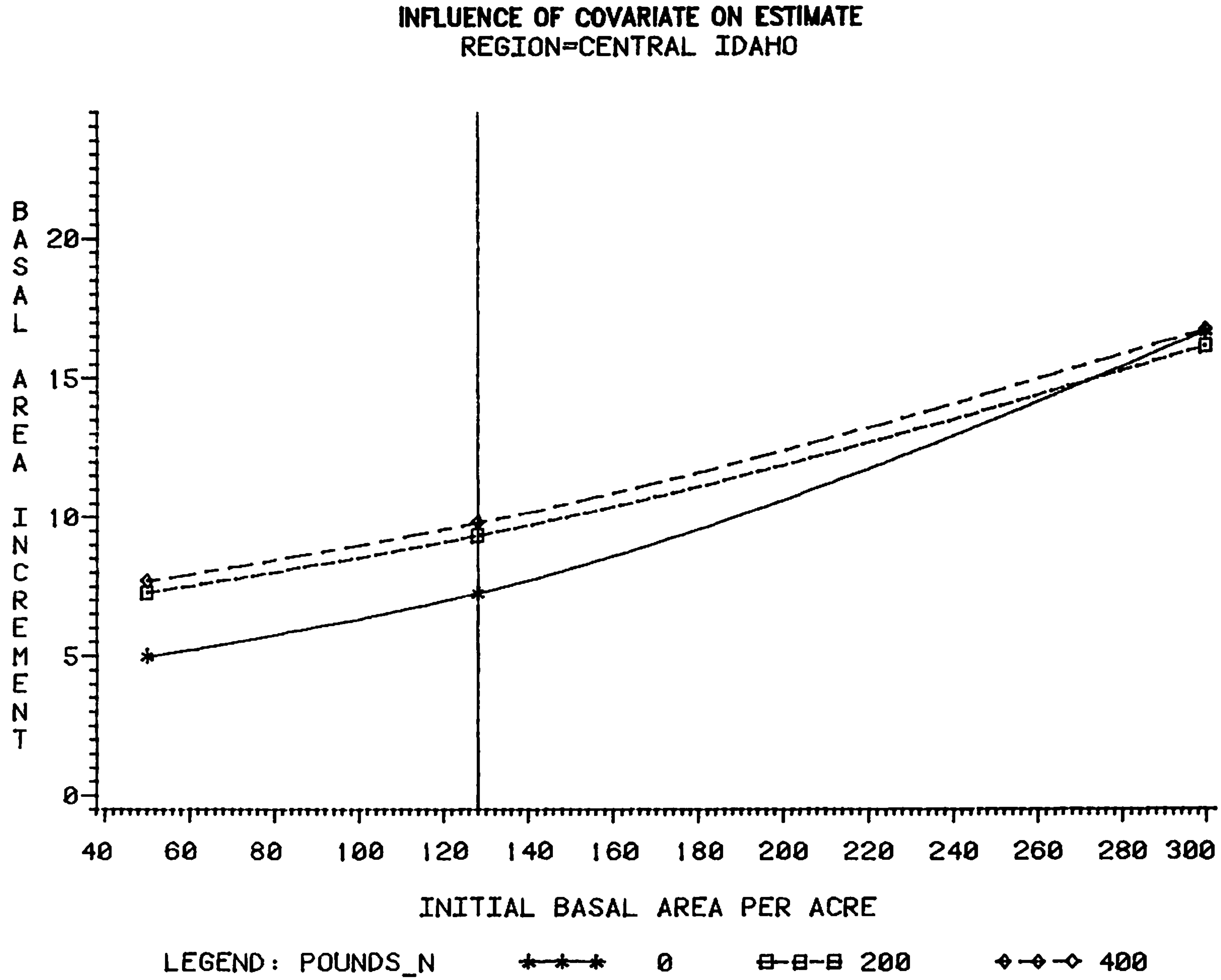


FIGURE 12. THE EFFECT OF INITIAL BASAL AREA PER ACRE ON TWO-YEAR ABSOLUTE BASAL AREA RESPONSE FOR NORTHEAST OREGON.

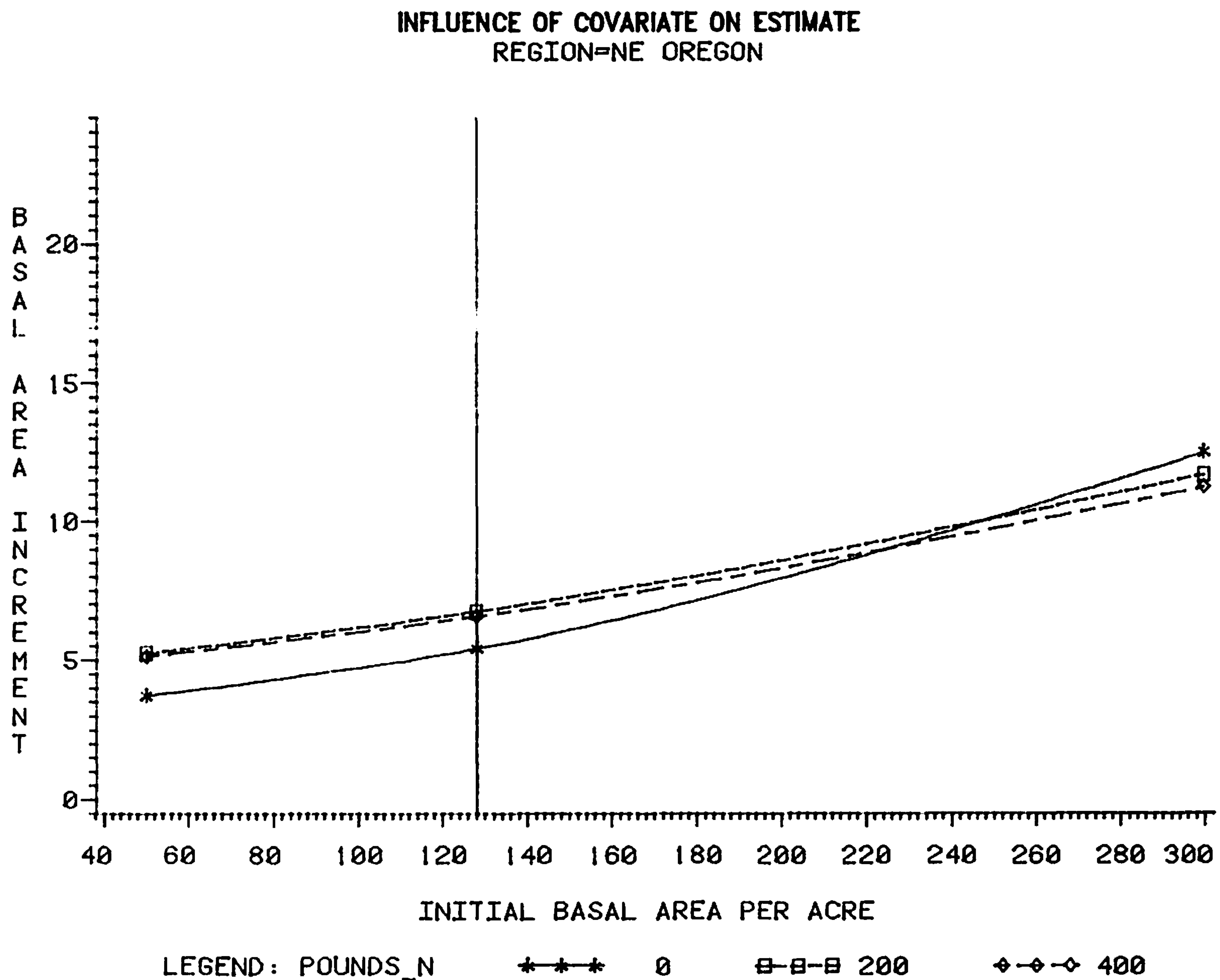


FIGURE 13. THE EFFECT OF INITIAL BASAL AREA PER ACRE ON TWO-YEAR ABSOLUTE BASAL AREA RESPONSE FOR CENTRAL WASHINGTON.

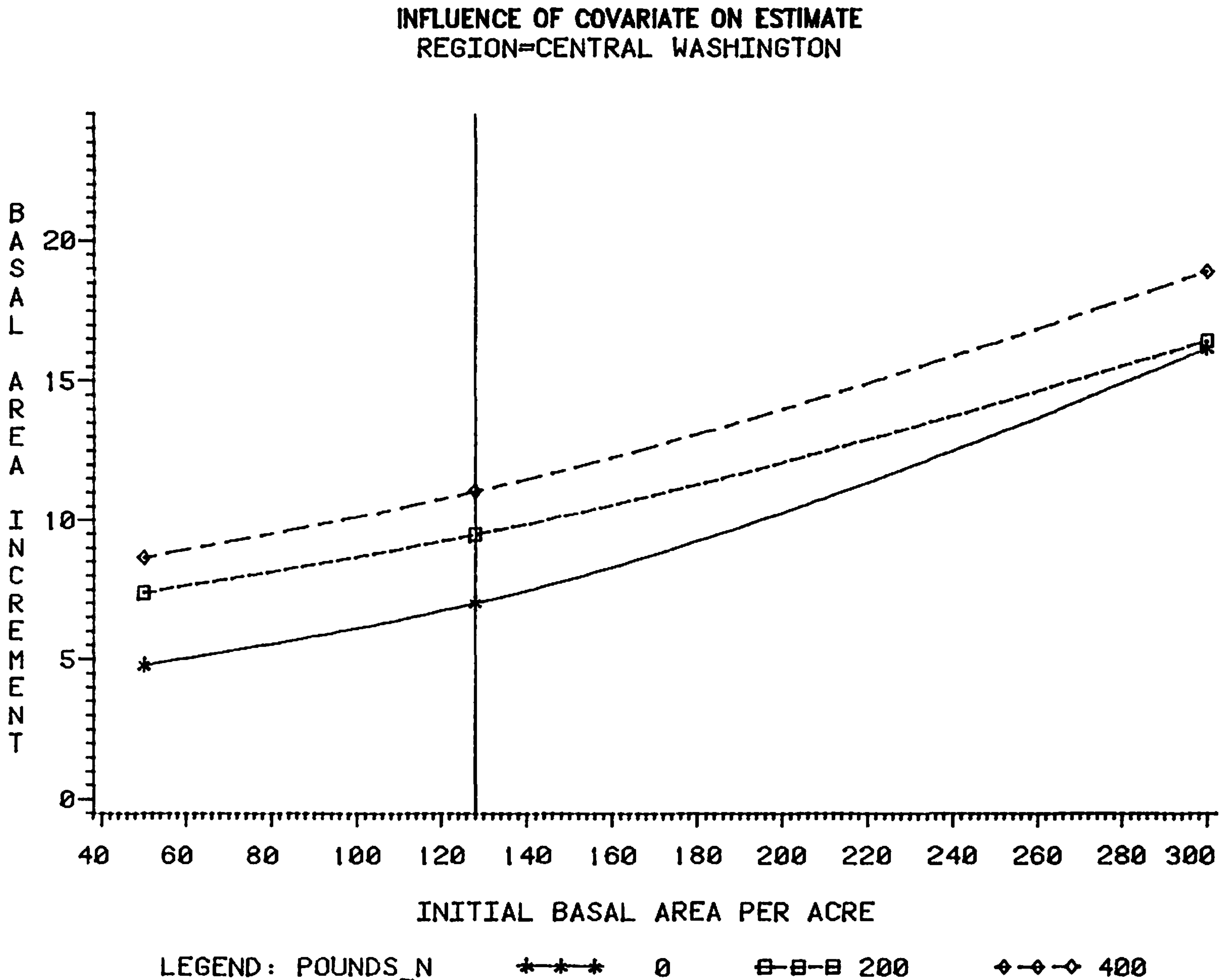
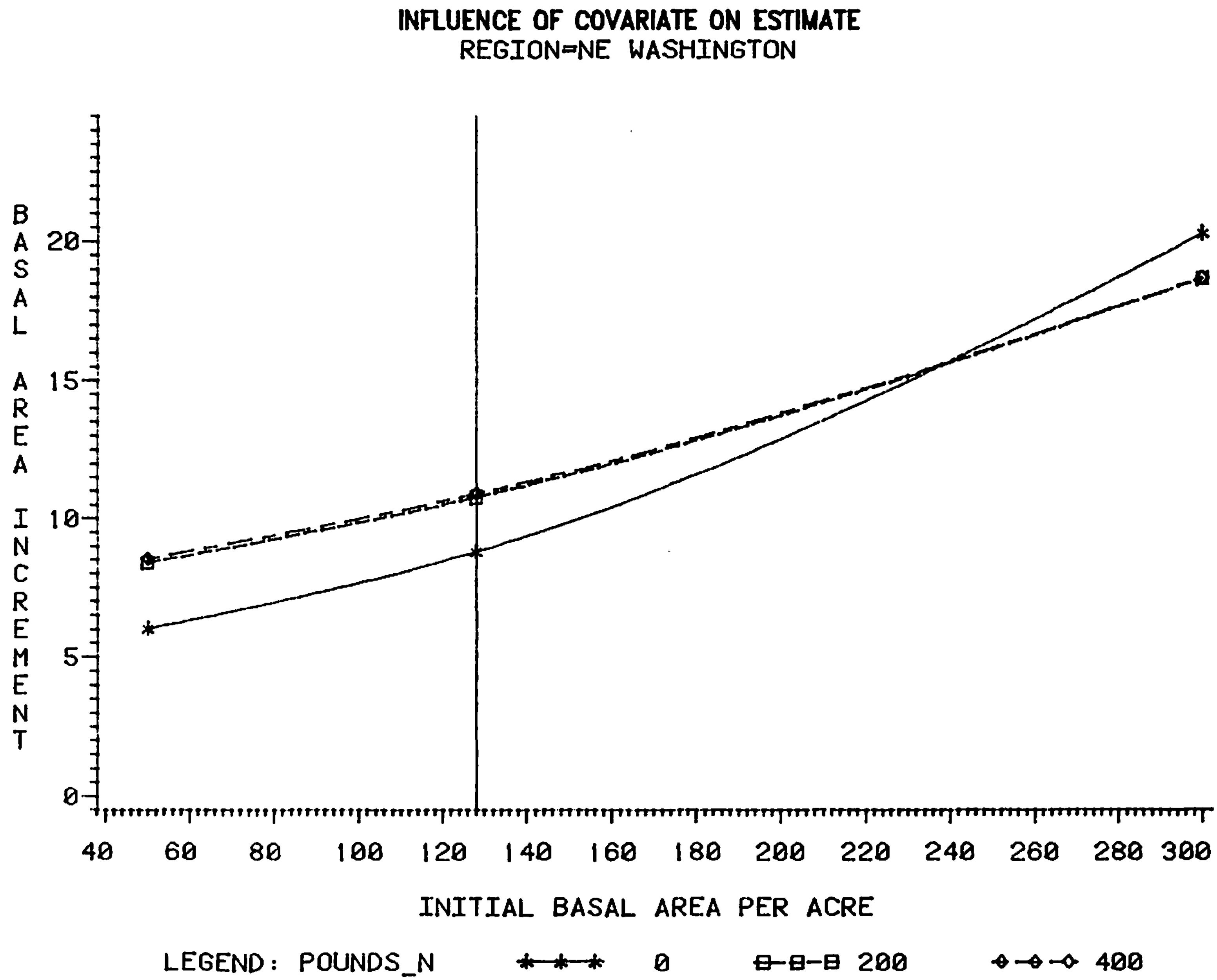


FIGURE 14. THE EFFECT OF INITIAL BASAL AREA PER ACRE ON TWO-YEAR ABSOLUTE BASAL AREA RESPONSE FOR NORTHEAST WASHINGTON.



basal area for all installations was 128 ft^2/A and this point is denoted by the vertical line in Figures 3 thru 14.

Based on these results, *tentative* stand density guidelines can be recommended for nitrogen fertilization for each region of the IFTNC. One danger in doing so is that factors in addition to stand density also affect the magnitude of growth response to nitrogen fertilization. Some of these factors are discussed in the "Weetman" Foliar Diagnostics section of this report. Even so, stand density is clearly important in determining response and preliminary density guidelines should be useful to cooperators.

The BA/A values given in Table 4 are those that predict a "substantial" (25%) growth response to 200 lb/A of nitrogen by region. That is, relative responses exceeding 25% would not be expected in stands of greater density. When comparing these values between regions, remember that a 25% response is above average for Montana, about average for Northeast Oregon and Northeast Washington, and below average for North Idaho, Central Idaho, and Central Washington. The relationship is clear for all regions: BA/A response declines with increasing density, and for very high basal areas no response at all is predicted.

Table 4. Stand Densities that predict a twenty-five percent two-year basal area per acre growth response by geographic region of the IFTNC.

REGION	INITIAL BASAL AREA (Ft^2/A)
North Idaho	155
Montana	88
Central Idaho	150
Northeast Oregon	128
Central Washington	175
Northeast Washington	121

We can not yet assess the effect of fertilization on stand dynamics. There was essentially no mortality during the measurement period, and two years is insufficient time for significant changes in diameter distributions to occur. These effects will be examined when the four-year data are available.

Initial plot basal area per acre was the only statistically significant (α=.05) covariate in the analysis. Many other plot variables were tested as possible covariates in the analysis. These were: Douglas-fir site index (Monserud 1982); slope percent; an interaction of slope and aspect (Stage 1976); stand density index (Curtis 1982); initial trees per acre; initial cubic foot volume per acre; quadratic mean diameter at breast height; and total soil nitrogen and phosphorus (from the upper 10 inches of the mineral soil).

Overall, managed Douglas-fir stands in the Intermountain Northwest showed a substantial growth response to nitrogen fertilization. Twenty-seven of the 45 installations had basal area growth increases of more than 25% for both fertilizer treatments after two growing seasons. If we assume that the pattern of response over time is about the same as for thinned Douglas-fir stands west of the Cascades, response should increase to a peak at four years and then begin to decline. The "west-side" stands still showed a significant treatment effect after 8 years (Regional Forest Nutrition Research Project, Biennial Report 1980-1982; College of Forest Resources, University of Washington, Seattle).

The 400 lb/A treatment was not significantly different from the 200 lb/A treatment, except for the Central Washington Region. Perhaps the higher rate will result in a longer response duration or large future differences in the magnitude of response. However; based only on two-year results, 200 lbs./A is the preferred rate for 5 of the 6 geographic regions.

Three-year growth response of the 1980 test sites:

Boise Cascade Corporation supported the installation of four test sites on their lands in the fall of 1980. There is one installation each in the Central Idaho, Northeast Oregon, Central Washington, and Northeast Washington regions. Each installation consists of eight one-tenth acre plots. Treatments were assigned to the plots randomly and were applied in the fall of 1980 or the spring of 1981. These test sites contained several additional treatments not tested in other installations of the cooperative. The treatments consisted of two control plots and one plot for each of the following: 1) 200 lbs./A of nitrogen applied in the fall; 2) 400 lbs./A of nitrogen applied in the fall; 3) 200 lbs./A of nitrogen and 50 lbs./A of sulphur applied in the fall; 4) 200 lbs./A of nitrogen applied in the spring; 5) 400 lbs./A of nitrogen applied in the spring; and 6) 200 lbs./A of urea and sulphur-coated urea were the sources for nitrogen and sulphur. The diameters of all sample trees were measured before treatment and again after the 1983 growing season. Thus, this analysis is based on diameter (basal area) growth for three years after treatment. Basal area response for the 1980 data are presented as smoothed estimates derived from the statistical model indicated in Table 2. (The Analysis of Variance Table) of the Technical Documentation Report.

The three-year BA/A increment for all the treatments, except nitrogen and sulphur applied in the fall, were significantly different (α=.05) from the controls. There was no difference (α=.05) between the fertilizer treatments. The adjusted means (to a common initial basal area, percent slope and site index) for absolute and relative BA/A increment for each treatment are given in Table 5.

The results of this limited experiment suggest that there is no difference in growth response from fall or spring fertilizer applications as conducted in this study. That is, the spring treatments were applied in early April and substantial precipitation probably occurred after the treatments were applied. If the material were applied later in the spring, nitrogen losses due to volatilization and nitrification may have occurred (Otchere-Boateng 1979). There was no difference in growth response between the urea and sulphur-coated urea treatments for these four installations.

Table 5. Three-year average adjusted basal area per acre response by treatment for four 1980 installations.

TREATMENT	INCREMENT ($Ft.^2/A$)	RESPONSE ($Ft.^2/A$)	PERCENT
Control	12.91	–	–
200 lb N/A-Fall	15.12	2.21	17
400 lb N + 50lb S/A-Fall	15.43	2.52	20
200 lb N + 50lb S/A-Fall	13.90	0.99	8
200 lb N/A-Spr.	14.33	1.42	11
400 lb. N/A-Spr.	15.48	2.57	20
200 lb N + 50lb S/A-Spr.	15.09	2.18	17

Results of the "Weetman" Foliar Diagnostic Technique for the 1981 installations:

In 1983 we made growth response predictions for individual installations based on new foliage collected one year after the fertilizer treatments were applied. These predictions are included in the 1983 annual report of the IFTNC. The nitrogen/needle weight graphs are also included in Section III of the Technical Documentation Report. The predictions are based on interpreting graphs showing change in needle weight versus change in nitrogen content of the needles. Based on these graphs, each installation was categorized as: yes—a responder to treatment; no—a nonresponder; or maybe. The average adjusted (for density) two-year basal area growth response of installations predicted to be in the three response classes were compared. There was no statistically significant difference in the average basal area response for the three predicted classes. The average adjusted responses (combined for both 200 and 400 lb. treatments) for the three classes were: predicted responders=2.05 $ft.^2/A$; predicted nonresponders=2.80 $ft.^2/A$; and maybe=1.96 $ft.^2/A$. Even though there is no significant difference, the average actual response of the predicted nonresponders was higher than the predicted responders. The trends were exactly the same when the 200 lb. and 400 lb. treatments were analyzed separately. Based on two-year growth response, the stands were not correctly classified using the "nitrogen/needle weight" graphs. Why did the diagnostic technique fail? The answer(s) could prove valuable to the cooperative.

The technique is based on two factors, the change in foliar nitrogen concentrations and change in needle weight. Responding stands should theoretically have both an increase in nitrogen and in needle weight. Essentially all of the installations showed substantial increases in foliar nitrogen concentrations, including the stands that did not respond. This suggests that a failure of the trees to take up the nitrogen is not a factor in explaining the nonresponse.

There were large differences between installations in needle weight change. This factor was the most important in the prediction of response. That is, the prediction technique is based on a direct relationship between increasing needle weight for first year foliage collected one year after treatment and increasing growth response to treatment. Our results indicate that there is no relationship between change in first-year needle weight and adjusted (for initial basal area) two-year basal area growth response! Numerous statistical models were tested to relate response to change in needle weight. The results merely confirmed what was evident from the scatter of data points on a graph of response versus change in needle weight, that there is no relationship. Many of the installations showing the largest growth response had no change in needle weight. The converse was also true, many installations had large increases in needle weight and showed no growth response.

There are several possible explanations for these results. In the case of large growth responses with no change in needle weight, perhaps foliar "efficiency" increased or maybe the nitrogen was stored the first year after treatment and then allocated to both increased needle numbers and size the second year. Currently we have no information that would help answer these questions.

For those installations that showed large increases in needle weight with no corresponding growth response, a careful inspection of the levels of other nutrients is very revealing. The change in relative foliar concentrations of nine elements are displayed in "Weetman Type II" graphs for each installation in Section III of the Technical Documentation Report. Many of the installations that had large increases in needle weight showed concurrent large reductions in foliar concentrations for other elements. This was particularly true for those installations that showed no growth response. As of this writing, we haven't had time to statistically analyze the many possibilities. However, the implications are that on some sites nutrients other than or in addition to nitrogen were limiting growth or that the nitrogen treatments created some sort of nutrient imbalance.

The foliar nutrient diagnostics will be the subject of substantial discussion at the annual meeting of the cooperative and hopefully additional results will be presented. It certainly seems that the "Weetman" Foliar Diagnostics Technique will be a productive investment by the IFTNC and the Forest Service Intermountain Forest and Range Experiment Station.

LITERATURE CITED

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