1986

Using Site Factors to Predict Douglas-fir Site Index

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Objective:

To develop equations for predicting the Douglas-fir site index of a site based on the physical and soil characteristics of the site. The equations were to be ranked according to the ease of acquisition of any necessary data.

Data base:

All data for this analysis were collected on research plots established by the IFTNC. Data sets on 414 plots were complete with regards to site index and site characteristics information. The associated plots cover six geographic regions: central Idaho, northern Idaho, Montana, northeast Oregon, central Washington and northeast Washington.

Douglas-fir site index for each plot was obtained from site-specific height-age equations developed by Jim VanderPloeg. These equations were evaluated at breast height age 50 to obtain the plot site index.

Site characteristics considered for predicting site index are listed in Table 1. The variables are broken into five groups based on the theoretical ease of acquisition of the data. Information about the first group of variables--elevation, slope, aspect, and vegetation series--should be readily available. Vegetation series is the potential dominant climax tree species (in the sense of Daubenmire, Pfister, Steele, etc.). The second group includes soil parent material--information which is becoming more available with the increase in soil mapping. This information can be easily obtained by a qualified observer making a visual examination of the site. The third group includes soil depth and depth of any ash cap. These require on-site evaluation but are fairly easy to measure. The fourth group consists of soil chemical characteristics requiring soil sampling and laboratory analysis for determination. The last group includes soil moisture holding capacity whose measurement requires intensive soil sampling and a laborious analysis.

Analysis approach:

Standard regression analysis was used to develop the predictive models. All candidate predictor variables were entered and the least significant ones were eliminated one-by-one. A significance level greater than 0.05 for the partial F statistic was used as the elimination criterion.

Rather than develop separate models for each geographic region, a single model was fit using all 414 observations. The influence of geographic region was modeled directly by including region interaction terms and testing for significance.

Five models were developed, each corresponding to a given level of difficulty in obtaining the data necessary to drive the model. Thus, the first model could only use variables easily obtained--those in group 1 of Table 1. The second model could involve any variables from the first or second group, the third model could use any from the first three groups and the fourth model could use any variable from the first four groups. The fifth model could use any variable from any of the groups.

Results:

Analysis of the variables in group 1 indicated that each contributed significantly to explaining the variation in site index. The shape of the relationship was also determined to vary significantly across geographic regions. Thus the model formed from group 1 variables includes elevation, slope, aspect and vegetation series; parameter estimates (given in Table 5A) change with geographic region.

The model for the second level of data availability--groups 1 and 2--includes parent material along with all the variables. Coefficients (Table 5B) again all vary with geographic region. The third level model adds ash depth information to the previous model. Soil depth was found to be non-significant. Coefficients (Table 5C) remain dependent on region.

The model for the fourth level includes information on mineralizable nitrogen levels in the soil in addition to these variables in the preceeding model. The coefficient for mineralizable nitrogen was not found to be regionally dependent. Coefficients are presented in Table 5D.

The model for the fifth level of data availability (all possible variables considered) is shown in Table 2 with coefficients given in Table 5E. The model adds soil moisture holding capacity information to that present in the fourth level model. The coefficient for moisture holding capacity was found to vary significantly with geographic region.

Statistical fit for each model is presented in Table 3. Included are the sum of squares explained by the particular model, the percentage of the total sum of squares explained, the standard error of the estimate for the model and the standard error expressed as a percentage of the overall mean site index. By proceeding from top to bottom through the table, one can see the improvement afforded in site index prediction by collection of more site information. The mean and standard deviation of the site index sample are also shown to provide reference standards.

Tables 4A through 4F provide similar model for data broken down by geographic region; the tables indicate the importance of various terms in the model for explaining the pattern of variation in site index within each region. Thus one can see that information on soil parent material was not very useful in central Idaho, northeast Oregon or northeast Washington. To contrast that, knowledge about soil parent material was very helpful in predicting site index in Montana and central Washington, while information about other soil characteristics was useful in northern Idaho. Measurement of soil moisture holding capacity gave greatest improvement of fit in central Idaho and northeast Oregon.

Certain parameter estimates raise questions as to how "good" the estimates really are. For example, the negative slope associated with soil moisture holding capacity in central Idaho is both counter intuitive and contrary to the simple correlation between site index and moisture holding capacity. This could result from collinearity and/or overfitting. These questions will be addressed in future analysis.

The general form of the various models are illustrated in Figures 1 through 4. Figure 1 depicts the behavior of site index with respect to changes in elevation and vegetation series (Figure 1A), and percent slope and aspect (Figure 1B) for model 1 in northeast Washington. In Figure 1A aspect and slope are held constant at 258 degrees and 30 percent, respectively. Figure 1B shows a grand fir series at 3000 foot elevation. Figure 2 shows site index behavior with respect to varying elevation and parent material for model 2 in Montana; aspect, slope and vegetation series are 258 degrees, 30 percent and Douglas-fir, respectively. Figure 3 illustrates the behavior of model 4 in northern Idaho. Figure 3A shows how site index varies with respect to mineralizable nitrogen and ash depth, while Figure 3B depicts the influence of elevation and vegetation series. When held constant, values for aspect, slope, elevation, vegetation series, parent material, ash depth and mineralizable nitrogen are 258 degrees, 30 percent, 3000 feet, grand fir, ash over meta sediments, deep, and 45 ppm, respectively. Figure 4 shows the relationship of site index to soil moisture holding capacity and parent material in northeast Oregon. Constant conditions are an aspect of 258 degrees, a slope of 30 percent, an elevation of 5000 feet and 45 ppm of mineralizable nitrogen on a Douglas-fir series with no deep ash layer.

Predicting DF Site Index

Table 1 Candidate Variables

Group 1:	Elevation (feet)
	Slope (percent)
	Aspect (degrees)
	Vegetation series
	Douglas-fir
	Grand fir
	Western redcedar or western hemlock
Group 2:	Soil parent material
	Alluvium
	Ash mixed with loess
	Ash over metasediments
	Basalt
	Colluvium
	Glacial till
	Granite
	Sandstone
	Valley fill
Group 3:	Soil depth
	Shallow (<12 inches)
	Moderate (12 to 24 inches)
	Deep (>24 inches)
	Ash depth
	Deep (>12 inches)
	Not deep
Group 4:	Mineralizable nitrogen (ppm)
	Total nitrogen (ppm)
	Total phosphorus (ppm)
	Carbon (percent)
Group 5:	Soil moisture holding capacity (inches of water)

Predicting DF Site Index

Table 2 Model Form

$$
\begin{aligned}
\text{DF Site Index} = {} & B_{0i} \\
& + B_{1i} \times \text{Elevation} \\
& + B_{2i} \times \text{Elevation}^2 \\
& + B_{3i} \times \text{Slope} \\
& + B_{4i} \times \frac{\text{Slope}}{100} \times \cos(\text{Aspect} - B_{5i}) \\
& + B_{6ij} \times \text{Vegetation series indicator} \\
& + B_{7ik} \times \text{Parent material indicator} \\
& + B_{8i} \times \text{Ash depth indicator} \\
& + B_9 \times \text{Mineralizable nitrogen} \\
& + B_{10i} \times \text{Moisture holding capacity}
\end{aligned}
$$

where $i = 1$ to 6 indicates the geographic region

$j = 1$ to 3 indicates the vegetation series

and $k = 1$ to 9 indicates the parent material

Predicting DF Site Index

Table 3 Model Fit Across All Regions

Variables in model	Variation explained: Sum of squares	Variation explained: % of total	Std Error	% of mean
Model 1: elevation, slope, aspect, vegetation series	46,768	81.03	5.45	7.89
Model 2: Model 1, parent material	51,591	89.39	4.15	6.01
Model 3: Model 2, ash depth	51,779	89.72	4.09	5.93
Model 4: Model 3, mineralizable nitrogen	52,097	90.27	3.99	5.78
Model 5: Model 4, moisture holding capacity	52,890	91.64	3.73	5.40

Corrected total 57,713 Mean site index 69.01

n = 414 Standard deviation 11.82

Predicting DF Site Index

Table 4A — Model Fit For Central Idaho

Variables in model	Variation explained: Sum of squares	Variation explained: % of total	Std Error	% of mean
Model 1: elevation, slope, aspect, vegetation series	1,010	42.34	4.40	7.67
Model 2: Model 1, parent material	1,075	45.06	4.33	7.54
Model 3: Model 2, ash depth	1,075	45.06	4.33	7.54
Model 4: Model 3, mineralizable nitrogen	1,016	42.60	4.45	7.77
Model 5: Model 4, moisture holding capacity	1,350	56.59	3.87	6.75

Corrected total 2,385 — Mean site index 57.35

n = 78 — Standard deviation 5.57

Predicting DF Site Index

Table 4B

Model Fit For Northern Idaho

Variables in model	Variation explained: Sum of squares	Variation explained: % of total	Std Error	% of mean
Model 1: elevation, slope, aspect, vegetation series	873	51.54	3.58	4.29
Model 2: Model 1, parent material	914	53.95	3.55	4.25
Model 3: Model 2, ash depth	970	57.25	3.45	4.13
Model 4: Model 3, mineralizable nitrogen	1,142	67.41	3.03	3.64
Model 5: Model 4, moisture holding capacity	1.195	70.56	2.88	3.46

Corrected total 1,694

n = 72

Mean site index 83.44

Standard deviation 4.88

Predicting DF Site Index

Table 4C

Model Fit For Montana

Variables in model	Variation explained: Sum of squares	Variation explained: % of total	Std Error	% of mean
Model 1: elevation, slope, aspect, vegetation series	913	26.92	6.84	10.22
Model 2: Model 1, parent material	2,475	73.01	4.28	6.39
Model 3: Model 2, ash depth	2,475	73.01	4.28	6.39
Model 4: Model 3, mineralizable nitrogen	2,485	73.32	4.30	6.42
Model 5: Model 4, moisture holding capacity	2,501	73.77	4.26	6.37

Corrected total 3,390

n = 60

Mean site index 66.92

Standard deviation 7.58

Predicting DF Site Index

Table 4D

Model Fit For Northeast Oregon

Variables in model	Variation explained: Sum of squares	Variation explained: % of total	Std Error	% of mean
Model 1: elevation, slope, aspect, vegetation series	2,568	85.74	3.49	5.27
Model 2: Model 1, parent material	2,607	87.02	3.38	5.10
Model 3: Model 2, ash depth	2,607	87.02	3.38	5.10
Model 4: Model 3, mineralizable nitrogen	2,683	89.57	3.08	4.64
Model 5: Model 4, moisture holding capacity	2,963	98.92	0.99	1.49

Corrected total 2,996

n = 42

Mean site index 66.34

Standard deviation 8.55

Table 4E Model Fit For Central Washington

Variables in model	Variation explained: Sum of squares	Variation explained: % of total	Std Error	% of mean
Model 1: elevation, slope, aspect, vegetation series	10,054	71.48	7.26	10.02
Model 2: Model 1, parent material	13,078	92.98	3.70	5.11
Model 3: Model 2, ash depth	13,210	93.92	3.47	4.79
Model 4: Model 3, mineralizable nitrogen	13,213	93.94	3.49	4.82
Model 5: Model 4, moisture holding capacity	13,285	94.45	3.34	4.61

Corrected total 14,065 Mean site index 72.47

n = 84 Standard deviation 13.02

Predicting DF Site Index

Table 4F Model Fit For Northeast Washington

Variables in model	Variation explained: Sum of squares	Variation explained: % of total	Std Error	% of mean
Model 1: elevation, slope, aspect, vegetation series	3,757	67.20	5.12	7.68
Model 2: Model 1, parent material	3,850	68.87	5.06	7.59
Model 3: Model 2, ash depth	3,850	68.87	5.06	7.59
Model 4: Model 3, mineralizable nitrogen	3,965	70.92	4.93	7.39
Model 5: Model 4, moisture holding capacity	4,004	71.62	4.87	7.30

Corrected total 5,591

n = 78

Mean site index 66.67

Standard deviation 8.52

Table 5A Coefficients for Model 1 by Region

Model Parameter	Geographic Region					
	Central Idaho	Northern Idaho	Montana	Northeast Oregon	Central Washington	Northeast Washington
Intercept	-352.18	34.23	-116.21	108.53	-122.54	6.45
Elevation	0.16730	0.02772	0.01633	-0.01489	0.12610	0.05826
Elevation^2(x10^{-6})	-16.9210	-4.4445	1.6772	0.8146	-19.0709	-11.3089
Slope	-0.0438	0.1976	-0.1503	0.0938	-0.0259	-0.0335
$B \times \frac{Slope}{100} \times \cos(A-0)$						
B	9.2600	8.9415	6.9960	12.8377	9.2534	16.8606
0	77.37	106.22	192.81	186.26	131.82	38.22
Series						
Douglas-fir	1.86	2.47	-8.05	5.55	-7.82	-14.63
Grand fir	0.0	0.0	0.0	0.0	0.0	0.0
Cedar/hemlock	NA	5.03	NA	NA	-1.75	2.67

Table 5B Coefficients for Model 2 by Region

Model Parameter	Central Idaho	Northern Idaho	Montana	Northeast Oregon	Central Washington	Northeast Washington
	Geographic Region					
Intercept	-323.98	31.11	-210.67	104.18	-130.47	19.39
Elevation	0.15797	0.02975	0.13610	-0.00448	0.12212	0.05212
$\text{Elevation}^2 (\times 10^{-6})$	-16.1433	-4.6053	-16.7148	-0.7628	-17.1160	-10.0369
Slope	-0.0525	0.1847	-0.0405	0.1030	-0.1774	-0.0689
$B \times \frac{\text{Slope}}{100} \times \cos(A-0)$						
B	10.9529	10.0543	2.7231	13.2824	11.3792	17.7464
0	74.13	101.84	78.30	159.59	353.17	58.77
Series						
Douglas-fir	1.72	2.85	0.50	5.51	-2.45	-14.89
Grand fir	0.0	0.0	0.0	0.0	0.0	0.0
Cedar/hemlock	NA	5.30	NA	NA	28.49	1.43
Parent Material						
Alluvium	NA	NA	22.68	NA	NA	NA
Ash/Loess	NA	-2.46	0.0	NA	8.93	NA
Ash/Meta	NA	-0.89	NA	NA	NA	NA
Basalt	-2.80	NA	NA	-10.72	3.52	-6.48
Colluvium	NA	NA	4.78	NA	NA	NA
Glacial till	NA	0.0	16.51	NA	-19.00	-5.73
Granite	0.0	NA	NA	0.0	19.80	0.0
Sandstone	NA	NA	NA	NA	0.0	NA
Valley fill	NA	NA	0.0	NA	NA	NA

Table 5C Coefficients for Model 3 by Region

Model Parameter	Central Idaho	Northern Idaho	Montana	Northeast Oregon	Central Washington	Northeast Washington
Intercept	-323.98	43.06	-210.67	104.18	-60.95	19.39
Elevation	0.15797	0.02335	0.13610	-0.00448	0.07305	0.05212
$Elevation^2 (x10^{-6})$	-16.1433	-3.9210	-16.7148	-0.7628	-8.5555	-10.0369
Slope	-0.0525	0.1674	-0.0405	0.1030	-0.1509	-0.0689
$B \times \frac{Slope}{100} \times \cos(A-0)$						
B	10.9529	2.7231	2.7231	13.2824	8.9165	17.7464
0	74.13	78.30	78.30	159.59	30.38	58.77
Series						
Douglas-fir	1.72	2.85	0.50	5.51	0.17	-14.89
Grand fir	0.0	0.0	0.0	0.0	0.0	0.0
Cedar/hemlock	NA	4.55	NA	NA	52.60	1.43
Parent Material						
Alluvium	NA	NA	22.68	NA	NA	NA
Ash/Loess	NA	-1.47	0.0	NA	8.23	NA
Ash/Meta	NA	0.82	NA	NA	NA	NA
Basalt	-2.80	NA	NA	-10.72	-1.17	-6.48
Colluvium	NA	NA	4.78	NA	NA	NA
Glacial till	NA	0.0	16.51	NA	-44.12	-5.73
Granite	0.0	NA	NA	0.0	8.11	0.0
Sandstone	NA	NA	NA	NA	0.0	NA
Valley fill	NA	NA	0.0	NA	NA	NA
Ash depth						
Deep	NA	2.54	NA	NA	22.50	NA
Not deep	0.0	0.0	0.0	0.0	0.0	0.0

Table 5D Coefficients for Model 4 by Region

Model Parameter	Central Idaho	Northern Idaho	Montana	Northeast Oregon	Central Washington	Northeast Washington
	Geographic Region					
Intercept	-381.43	16.61	-232.24	64.72	-66.31	-15.67
Elevation	0.17091	0.02650	0.13858	0.00515	0.06841	0.05904
$\text{Elevation}^2 (\text{x}10^{-6})$	-17.4120	-4.1730	-17.0532	-2.0434	-8.0702	-11.4407
Slope	-0.0460	0.1396	-0.0324	0.0764	-0.1232	-0.0591
$B \times \frac{\text{Slope}}{100} \times \cos(A-0)$						
B	12.1502	7.9409	3.7276	12.2966	8.6745	17.2417
0	70.94	119.50	116.35	150.54	1.50	65.37
Series						
Douglas-fir	1.36	2.73	-2.89	5.56	-1.60	-13.76
Grand fir	0.0	0.0	0.0	0.0	0.0	0.0
Cedar/hemlock	NA	3.07	NA	NA	52.61	3.77
Parent Material						
Alluvium	NA	NA	23.33	NA	NA	NA
Ash/Loess	NA	-0.96	0.0	NA	10.52	NA
Ash/Meta	NA	1.28	NA	NA	NA	NA
Basalt	-4.61	NA	NA	-15.53	2.17	-6.31
Colluvium	NA	NA	6.27	NA	NA	NA
Glacial till	NA	0.0	16.50	NA	-41.12	-6.65
Granite	0.0	NA	NA	0.0	13.03	0.0
Sandstone	NA	NA	NA	NA	0.0	NA
Valley fill	NA	NA	0.0	NA	NA	NA
Ash depth						
Deep	NA	2.99	NA	NA	24.78	NA
Not deep	0.0	0.0	0.0	0.0	0.0	0.0
Mineralizable N	0.0721	0.0721	0.0721	0.0721	0.0721	0.0721

Table 5E Coefficients for Model 5 by Region

Model Parameter	Geographic Region: Central Idaho	Northern Idaho	Montana	Northeast Oregon	Central Washington	Northeast Washington
Intercept	-317.53	9.67	-166.00	92.03	-13.02	37.01
Elevation	0.15777	0.04164	0.11533	0.00262	0.03503	0.02971
$Elevation^2 (x10^{-6})$	-16.0923	-5.6600	-14.2688	-1.5351	-1.9788	- 6.2576
Slope	-0.1022	0.1039	-0.0321	-0.0356	-0.1241	-0.0507
$B \times \frac{Slope}{100} \times \cos(A-0)$						
B	13.8325	9.4493	5.2788	9.7467	10.6727	15.7942
0	65.85	116.19	122.88	128.94	359.6600	62.68
Series						
Douglas-fir	0.08	1.07	-2.16	1.00	-2.01	- 9.77
Grand fir	0.0	0.0	0.0	0.0	0.0	0.0
Cedar/hemlock	NA	0.82	NA	NA	71.64	4.18
Parent Material						
Alluvium	NA	NA	21.58	NA	NA	NA
Ash/Loess	NA	0.31	0.0	NA	2.45	NA
Ash/Meta	NA	4.83	NA	NA	NA	NA
Basalt	-4.32	NA	NA	-15.52	- 1.91	-7.71
Colluvium	NA	NA	5.09	NA	NA	NA
Glacial till	NA	0.0	15.94	NA	-60.66	-7.02
Granite	0.0	NA	NA	0.0	7.71	0.0
Sandstone	NA	NA	NA	NA	0.0	NA
Valley fill	NA	NA	0.0	NA	NA	NA
Ash depth						
Deep	NA	2.22	NA	NA	32.93	NA
Not deep	0.0	0.0	0.0	0.0	0.0	0.0
Mineralizable N	0.0333	0.0333	0.0333	0.0333	0.0333	0.0333
Soil Moisture holding capacity	-1.0247	-0.5243	-0.2135	1.1042	0.7417	1.2902

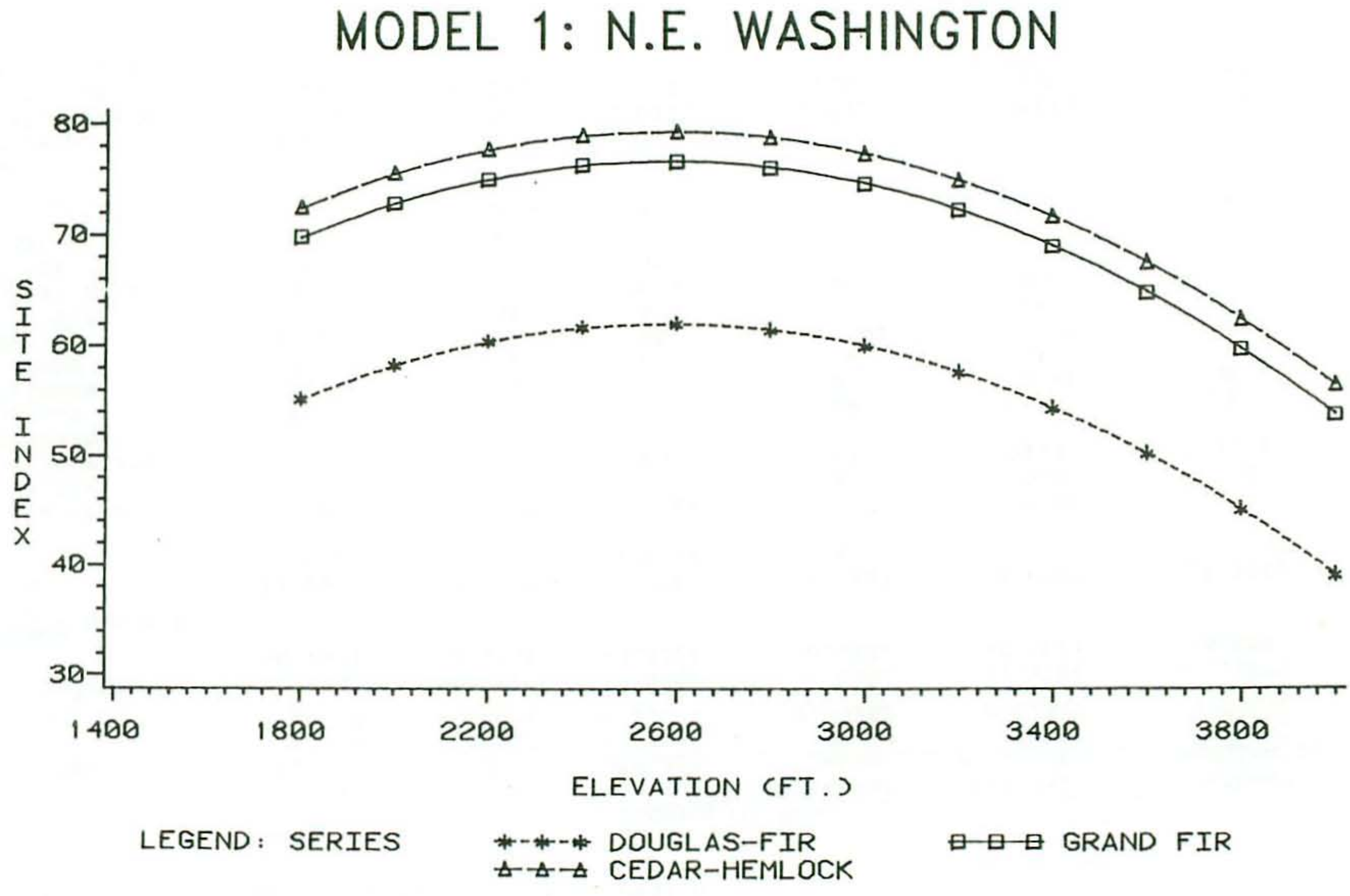

Figure 1A. Site index behavior relative to changes in elevation and vegetation series for model 1 in northeast Washington.

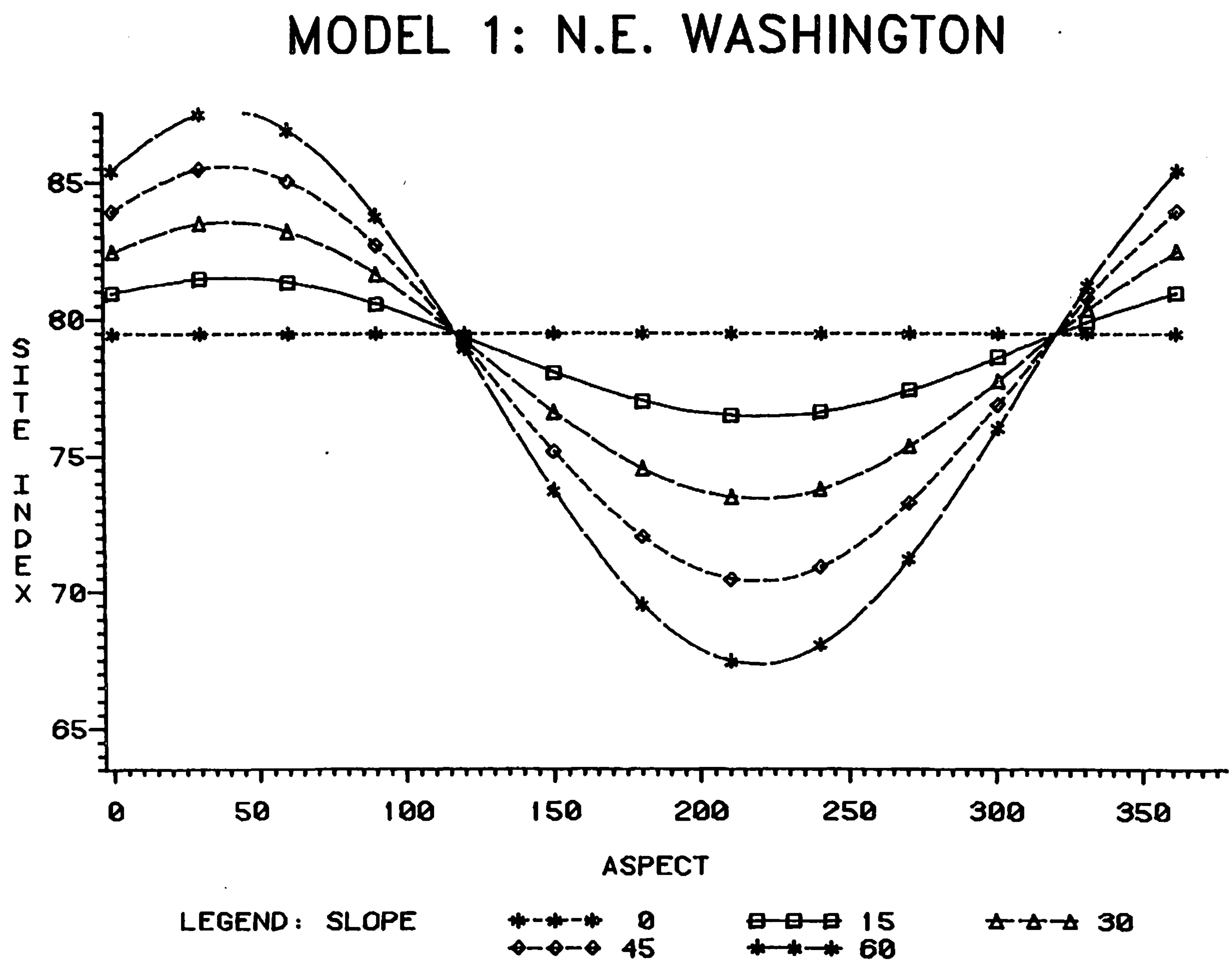

Figure 1B. Site index behavior relative to changes in percent slope and aspect for model 1 in northeast Washington.

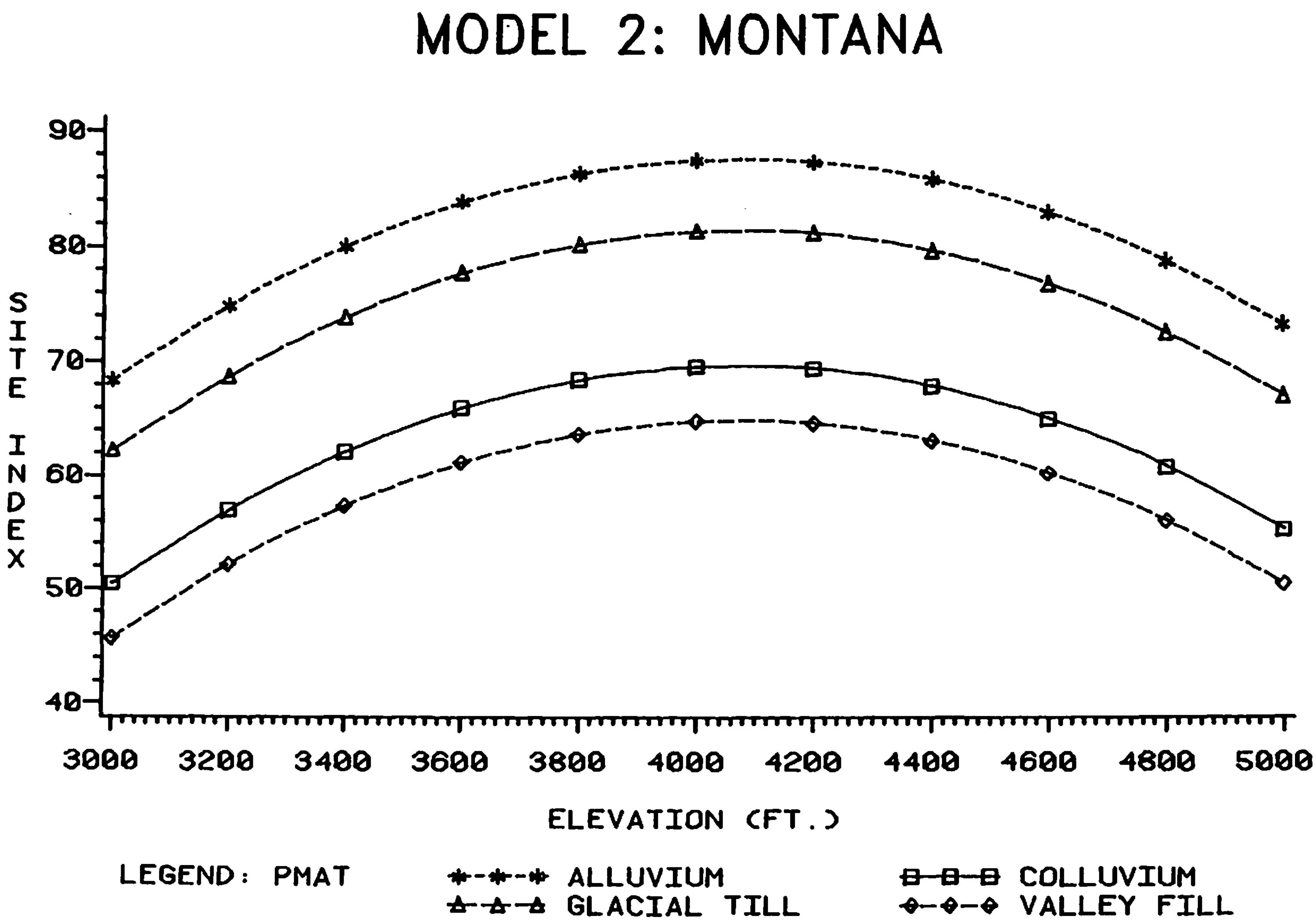

Figure 2. Site index behavior relative to changes in elevation and parent material for model 2 in Montana.

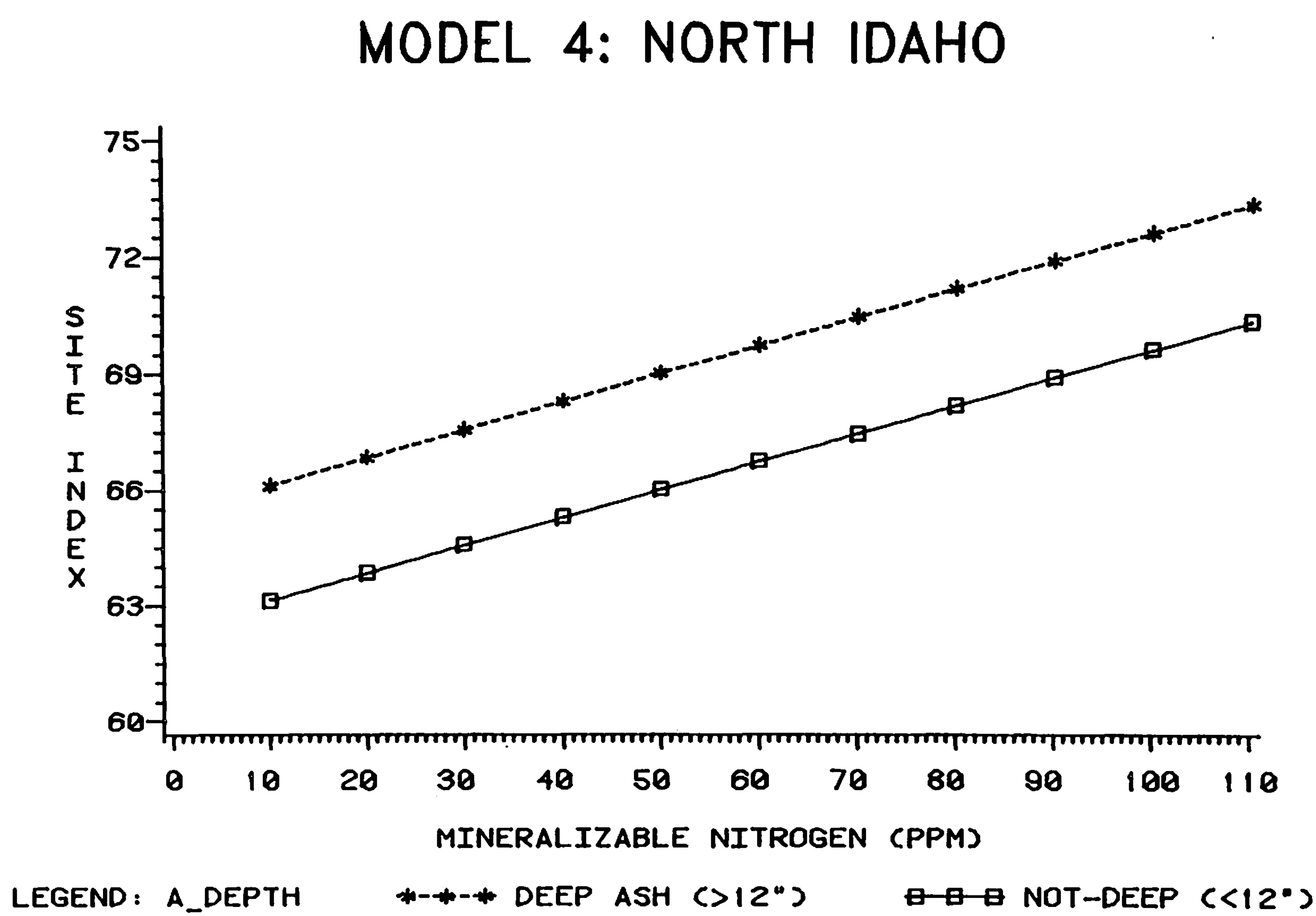

Figure 3A. Site index behavior relative to changes in mineralizable nitrogen and ash depth for model 4 in northern Idaho.

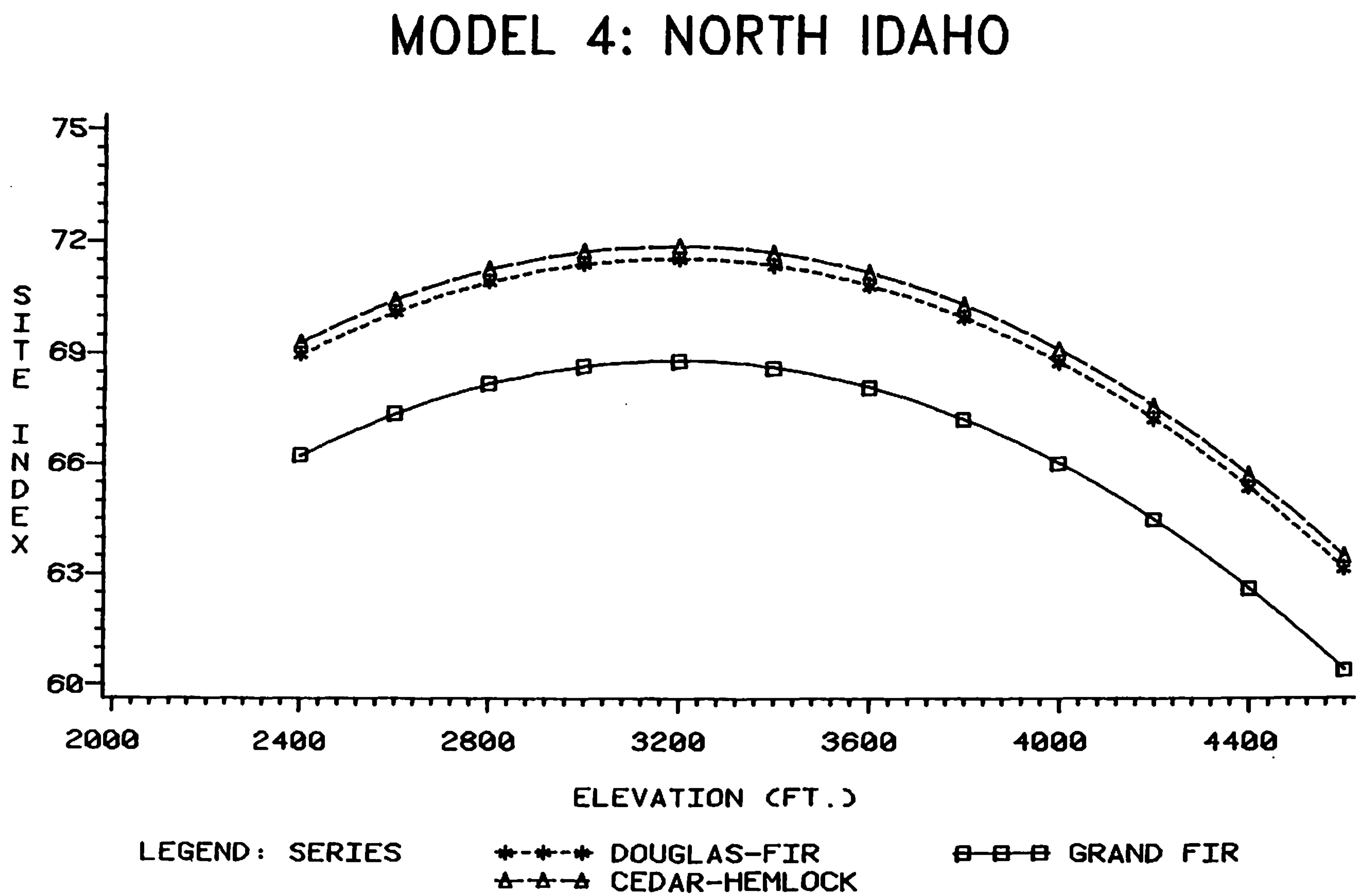

Figure 3B. Site index behavior relative to changes in elevation and vegetation series for model 4 in northern Idaho.

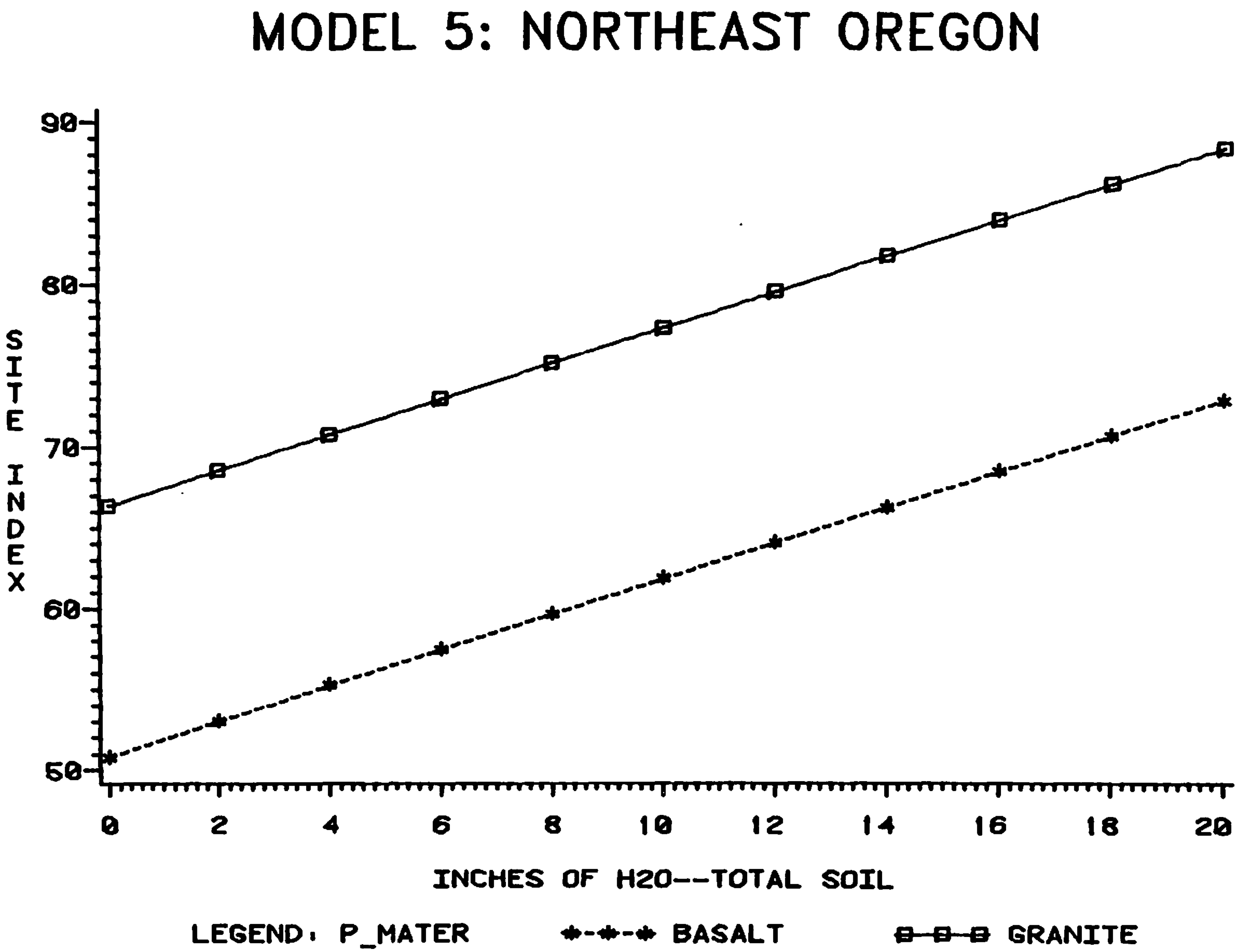

Figure 4. Site index behavior relative to changes in soil moisture holding capacity and parent material for model 4 in northeast Oregon.