



New Height Growth and Site Index Models for Pacific Silver Fir in Southwestern British Columbia

Introduction

Pacific silver fir (*Abies amabilis* (Dougl. ex Loud.) Forbes) is an important timber crop species in coastal forests of B.C. Its range extends from sea-level to almost timberline, and from the hypermaritime region on the west coast of Vancouver Island to the subcontinental region on the leeward side of the Coast Mountains. With this relatively wide climatic amplitude, a large variability in the height growth pattern of Pacific silver fir can be expected, since climate is considered to be the most influential determinant of the trajectory of height over age of forest trees. This variability, however, is not reflected in the height growth curves and site index tables used to estimate Pacific silver fir site index, since the curves and tables were developed from low-elevation stands on Vancouver Island. Consequently, when these curves and tables are applied to high-elevation or submaritime stands, we get biased estimates of site index. Accurate estimates of site index are necessary for accurate yield predictions. Furthermore, they are essential for making rational decisions about whether to cut the forest in situations where potential tree growth is marginal, such as in high-elevation forests.

Study Stands and Procedure

To account for climatic variability, the coastal forest was stratified into two continentality strata: (1) maritime and less-maritime (MLM) (including west Vancouver Island, east Vancouver Island and the windward side of the Coastal Mountains, respectively), and (2) submaritime and subcontinental (SS) (including the leeward side of the Coastal Mountains). Dominant, non-suppressed trees were sampled in relatively even-aged second-growth stands across the entire elevation range on Vancouver Island and south of the line extending from Port McNeill to Lillooet. Three trees were felled and sectioned in each of 98 stem analysis plots. Average height growth curves, height-age data at 5-year intervals, and site indices were determined for every plot. We used data from 67 of the plots for calibration, and from 31 of the plots for testing. Since there was a negative correlation between age and site index, the calibration range was restricted to 100 years to provide for a more balanced data set. The test data set contained trees up to 160 years breast height age. To obtain climate-specific curves, the MLM and SS continentality strata were used as additional variables in polymorphic height and site index functions, allowing different curve shapes for different site indices as well as for the continentality strata.

Results and Discussion

The climate-specific models developed showed differences in height growth pattern between the continentality strata as well as between site index classes (Figure 1). When tested against the independent data, these models improved estimates of height growth (Equation 1, Figure 1) and site index (Equation [2], Tables 1 and Table 2), when compared to conventional polymorphic models. Application of the models is recommended in stands within the breast height age range of 15 to 160 years in southwestern BC.

Height growth model (Equation 1)

$$H = 1.3 + MLM \left\{ (S - 1.3) \frac{1 + e^{[8.704 - 1.306 \ln(50) - 0.980 \ln(S - 1.3)]}}{1 + e^{[8.704 - 1.306 \ln A - 0.980 \ln(S - 1.3)]}} \right\} + SS \left\{ (S - 1.3) \frac{1 + e^{[9.761 - 1.549 \ln(50) - 1.109 \ln(S - 1.3)]}}{1 + e^{[9.761 - 1.549 \ln A - 1.109 \ln(S - 1.3)]}} \right\}$$

Site index mode (Equation 2)

$$S = 1.3 + MLM \left\{ 0.694 (50 - A) A^{-0.558} + 0.368 (H - 1.3) + 31.771 (H - 1.3) A^{-1} \right\} + SS \left\{ 0.592 (50 - A) A^{-0.578} + 0.183 (H - 1.3) + 41.659 (H - 1.3) A^{-1} \right\}$$

where: H = top height (m); S = site index (top height at 50 years breast height age); A = breast height age (years); e = the base of ln; ln = natural logarithm; MLM (maritime and less maritime) and SS (submaritime and subcontinental) = 0 and 1, respectively.

Table 1. Site index table for naturally established, unmanaged, Pacific silver fir stands in the maritime and less-maritime region of southwestern BC.

Age @ bh	Top Height (m)																																Age @ bh
	4.0	6.0	8.0	10.0	12.0	14.0	16.0	18.0	20.0	22.0	24.0	26.0	28.0	30.0	32.0	34.0	36.0	38.0	40.0	42.0	44.0	46.0	48.0	50.0	52.0	54.0	56.0	58.0	60.0	62.0			
12	16.0	22.1	28.1	34.1	40.2																											12	
14	14.1	19.4	24.7	30.0	35.2	40.5																										14	
16	12.7	17.4	22.1	26.8	31.5	36.2	40.9																									16	
18	11.5	15.7	20.0	24.3	28.5	32.8	37.1	41.4																								18	
20	10.5	14.4	18.3	22.2	26.1	30.1	34.0	37.9	41.8																							20	
22	9.7	13.3	16.9	20.5	24.2	27.8	31.4	35.0	38.7																							22	
24	8.9	12.3	15.7	19.1	22.5	25.9	29.2	32.6	36.0	39.4																						24	
26	8.3	11.5	14.7	17.8	21.0	24.2	27.4	30.6	33.7	36.9	40.1																					26	
28	7.7	10.7	13.7	16.8	19.8	22.8	25.8	28.8	31.8	34.8	37.8	40.8																				28	
30	7.2	10.1	12.9	15.8	18.7	21.5	24.4	27.2	30.1	32.9	35.8	38.6	41.5																			30	
32	6.8	9.5	12.2	14.9	17.7	20.4	23.1	25.8	28.6	31.3	34.0	36.7	39.4																			32	
34	6.4	9.0	11.6	14.2	16.8	19.4	22.0	24.6	27.2	29.8	32.4	35.0	37.6	40.2																		34	
36	6.0	8.5	11.0	13.5	16.0	18.5	21.0	23.5	26.0	28.5	31.0	33.5	36.0	38.5	41.0																	36	
38	5.6	8.1	10.5	12.9	15.3	17.7	20.1	22.5	24.9	27.3	29.7	32.1	34.6	37.0	39.4																	38	
40	5.3	7.6	10.0	12.3	14.6	17.0	19.3	21.6	23.9	26.3	28.6	30.9	33.2	35.6	37.9	40.2																40	
42	5.0	7.3	9.5	11.8	14.0	16.3	18.5	20.8	23.0	25.3	27.5	29.8	32.0	34.3	36.5	38.8	41.0															42	
44	4.7	6.9	9.1	11.3	13.5	15.7	17.8	20.0	22.2	24.4	26.6	28.7	30.9	33.1	35.3	37.5	39.6															44	
46	4.5	6.6	8.7	10.8	13.0	15.1	17.2	19.3	21.4	23.6	25.7	27.8	29.9	32.0	34.1	36.3	38.4	40.5														46	
48	4.2	6.3	8.4	10.4	12.5	14.5	16.6	18.7	20.7	22.8	24.8	26.9	29.0	31.0	33.1	35.2	37.2	39.3														48	
50	4.0	6.0	8.0	10.0	12.0	14.0	16.1	18.1	20.1	22.1	24.1	26.1	28.1	30.1	32.1	34.1	36.1	38.1	40.1													50	
52		5.8	7.7	9.7	11.6	13.6	15.5	17.5	19.5	21.4	23.4	25.3	27.3	29.3	31.2	33.2	35.1	37.1	39.0	41.0												52	
54		5.5	7.4	9.3	11.2	13.2	15.1	17.0	18.9	20.8	22.7	24.6	26.5	28.5	30.4	32.3	34.2	36.1	38.0	39.9												54	
56		5.3	7.1	9.0	10.9	12.7	14.6	16.5	18.4	20.2	22.1	24.0	25.8	27.7	29.6	31.5	33.3	35.2	37.1	38.9	40.8											56	
58		5.0	6.9	8.7	10.5	12.4	14.2	16.0	17.9	19.7	21.5	23.4	25.2	27.0	28.9	30.7	32.5	34.3	36.2	38.0	39.8											58	
60		4.8	6.6	8.4	10.2	12.0	13.8	15.6	17.4	19.2	21.0	22.8	24.6	26.4	28.2	30.0	31.8	33.5	35.3	37.1	38.9	40.7										60	
62		4.6	6.4	8.1	9.9	11.7	13.4	15.2	16.9	18.7	20.5	22.2	24.0	25.7	27.5	29.3	31.0	32.8	34.6	36.3	38.1	39.8										62	
64		4.4	6.1	7.9	9.6	11.3	13.1	14.8	16.5	18.2	20.0	21.7	23.4	25.2	26.9	28.6	30.4	32.1	33.8	35.5	37.3	39.0	40.7									64	
66		4.2	5.9	7.6	9.3	11.0	12.7	14.4	16.1	17.8	19.5	21.2	22.9	24.6	26.3	28.0	29.7	31.4	33.1	34.8	36.5	38.2	39.9									66	
68		4.0	5.7	7.4	9.1	10.7	12.4	14.1	15.7	17.4	19.1	20.8	22.4	24.1	25.8	27.4	29.1	30.8	32.5	34.1	35.8	37.5	39.1									68	
70			5.5	7.2	8.8	10.4	12.1	13.7	15.4	17.0	18.7	20.3	22.0	23.6	25.2	26.9	28.5	30.2	31.8	33.5	35.1	36.8	38.4	40.1								70	
72			5.3	6.9	8.6	10.2	11.8	13.4	15.0	16.7	18.3	19.9	21.5	23.1	24.8	26.4	28.0	29.6	31.2	32.9	34.5	36.1	37.7	39.3								72	
74			5.1	6.7	8.3	9.9	11.5	13.1	14.7	16.3	17.9	19.5	21.1	22.7	24.3	25.9	27.5	29.1	30.7	32.3	33.9	35.5	37.0	38.6	40.2							74	
76			5.0	6.5	8.1	9.7	11.3	12.8	14.4	16.0	17.5	19.1	20.7	22.3	23.8	25.4	27.0	28.6	30.1	31.7	33.3	34.8	36.4	38.0	39.6							76	
78			4.8	6.3	7.9	9.4	11.0	12.5	14.1	15.7	17.2	18.8	20.3	21.9	23.4	25.0	26.5	28.1	29.6	31.2	32.7	34.3	35.8	37.4	38.9	40.5						78	
80			4.6	6.2	7.7	9.2	10.8	12.3	13.8	15.3	16.9	18.4	19.9	21.5	23.0	24.5	26.1	27.6	29.1	30.7	32.2	33.7	35.2	36.8	38.3	39.8						80	
82		4.5	6.0	7.5	9.0	10.5	12.0	13.5	15.0	16.6	18.1	19.6	21.1	22.6	24.1	25.6	27.1	28.7	30.2	31.7	33.2	34.7	36.2	37.7	39.2							82	
84		4.3	5.8	7.3	8.8	10.3	11.8	13.3	14.8	16.3	17.8	19.2	20.7	22.2	23.7	25.2	26.7	28.2	29.7	31.2	32.7	34.2	35.7	37.2	38.7	40.2						84	
86		4.2	5.6	7.1	8.6	10.1	11.5	13.0	14.5	16.0	17.4	18.9	20.4	21.9	23.3	24.8	26.3	27.8	29.3	30.7	32.2	33.7	35.2	36.6	38.1	39.6						86	
88		4.0	5.5	6.9	8.4	9.9	11.3	12.8	14.2	15.7	17.2	18.6	20.1	21.5	23.0	24.4	25.9	27.4	28.8	30.3	31.7	33.2	34.7	36.1	37.6	39.0						88	
90			5.3	6.8	8.2	9.7	11.1	12.5	14.0	15.4	16.9	18.3	19.8	21.2	22.6	24.1	25.5	27.0	28.4	29.9	31.3	32.7	34.2	35.6	37.1	38.5	40.0					90	
92			5.2	6.6	8.0	9.5	10.9	12.3	13.7	15.2	16.6	18.0	19.5	20.9	22.3	23.7	25.2	26.6	28.0	29.4	30.9	32.3	33.7	35.2	36.6	38.0	39.4					92	
94			5.0	6.4	7.9	9.3	10.7	12.1	13.5	14.9	16.3	17.7	19.2	20.6	22.0	23.4	24.8	26.2	27.6	29.0	30.5	31.9	33.3	34.7	36.1	37.5	38.9	40.3				94	
96			4.9	6.3	7.7	9.1	10.5	11.9	13.3	14.7	16.1	17.5	18.9	20.3	21.7	23.1	24.5	25.9	27.3	28.7	30.1	31.5	32.9	34.3	35.7	37.1	38.5	39.9				96	
98			4.7	6.1	7.5	8.9	10.3	11.7	13.1	14.4																							

Table 2. Site index table for naturally established, unmanaged, Pacific silver fir stands in the subarctic and subcontinental regions of southwestern BC.

Age @ bh	Top Height (m)																														Age @ bh
	4.0	6.0	8.0	10.0	12.0	14.0	16.0	18.0	20.0	22.0	24.0	26.0	28.0	30.0	32.0	34.0	36.0	38.0	40.0	42.0	44.0	46.0	48.0	50.0	52.0	54.0	56.0	58.0	60.0	62.0	
12	16.5	23.8	31.1	38.4																											12
14	14.5	20.8	27.1	33.4	39.7																										14
16	12.9	18.5	24.0	29.6	35.2																										16
18	11.6	16.6	21.6	26.6	31.6	36.6																									18
20	10.6	15.1	19.6	24.2	28.7	33.2	37.8																								20
22	9.7	13.8	18.0	22.1	26.3	30.4	34.6	38.8																							22
24	8.9	12.8	16.6	20.4	24.3	28.1	32.0	35.8	39.6																						24
26	8.3	11.9	15.4	19.0	22.6	26.1	29.7	33.3	36.8																						26
28	7.7	11.1	14.4	17.7	21.1	24.4	27.8	31.1	34.4	37.8																					28
30	7.2	10.3	13.5	16.6	19.8	22.9	26.1	29.2	32.3	35.5	38.6																				30
32	6.7	9.7	12.7	15.7	18.6	21.6	24.6	27.5	30.5	33.5	36.4	39.4																			32
34	6.3	9.2	12.0	14.8	17.6	20.4	23.2	26.0	28.9	31.7	34.5	37.3																			34
36	6.0	8.6	11.3	14.0	16.7	19.4	22.0	24.7	27.4	30.1	32.8	35.4	38.1																		36
38	5.6	8.2	10.7	13.3	15.9	18.4	21.0	23.5	26.1	28.6	31.2	33.8	36.3	38.9																	38
40	5.3	7.8	10.2	12.7	15.1	17.6	20.0	22.4	24.9	27.3	29.8	32.2	34.7	37.1	39.6																40
42	5.0	7.4	9.7	12.1	14.4	16.8	19.1	21.5	23.8	26.2	28.5	30.9	33.2	35.6	37.9																42
44	4.7	7.0	9.3	11.5	13.8	16.0	18.3	20.6	22.8	25.1	27.3	29.6	31.9	34.1	36.4	38.6															44
46	4.5	6.7	8.9	11.0	13.2	15.4	17.6	19.7	21.9	24.1	26.3	28.4	30.6	32.8	35.0	37.2	39.3														46
48	4.3	6.4	8.5	10.6	12.7	14.8	16.9	19.0	21.1	23.2	25.3	27.4	29.5	31.6	33.7	35.8	37.9														48
50	4.0	6.1	8.1	10.1	12.2	14.2	16.2	18.3	20.3	22.3	24.4	26.4	28.4	30.5	32.5	34.5	36.6	38.6													50
52	5.8	7.8	9.7	11.7	13.7	15.6	17.6	19.6	21.5	23.5	25.5	27.5	29.4	31.4	33.4	35.3	37.3	39.3													52
54	5.5	7.5	9.4	11.3	13.2	15.1	17.0	18.9	20.8	22.7	24.6	26.5	28.5	30.4	32.3	34.2	36.1	38.0	39.9												54
56	5.3	7.2	9.0	10.9	12.7	14.6	16.4	18.3	20.1	22.0	23.8	25.7	27.6	29.4	31.3	33.1	35.0	36.8	38.7												56
58	5.1	6.9	8.7	10.5	12.3	14.1	15.9	17.7	19.5	21.3	23.1	24.9	26.7	28.5	30.3	32.1	33.9	35.7	37.5	39.3											58
60	4.9	6.6	8.4	10.1	11.9	13.6	15.4	17.1	18.9	20.7	22.4	24.2	25.9	27.7	29.4	31.2	32.9	34.7	36.4	38.2											60
62	4.7	6.4	8.1	9.8	11.5	13.2	14.9	16.6	18.3	20.0	21.8	23.5	25.2	26.9	28.6	30.3	32.0	33.7	35.4	37.1	38.9										62
64	4.5	6.1	7.8	9.5	11.1	12.8	14.5	16.1	17.8	19.5	21.1	22.8	24.5	26.1	27.8	29.5	31.2	32.8	34.5	36.2	37.8	39.5									64
66	4.3	5.9	7.5	9.2	10.8	12.4	14.1	15.7	17.3	18.9	20.6	22.2	23.8	25.5	27.1	28.7	30.3	32.0	33.6	35.2	36.8	38.5									66
68	4.1	5.7	7.3	8.9	10.5	12.1	13.7	15.2	16.8	18.4	20.0	21.6	23.2	24.8	26.4	28.0	29.6	31.2	32.7	34.3	35.9	37.5	39.1								68
70	5.5	7.1	8.6	10.2	11.7	13.3	14.8	16.4	17.9	19.5	21.1	22.6	24.2	25.7	27.3	28.8	30.4	31.9	33.5	35.1	36.6	38.2	39.7								70
72	5.3	6.8	8.3	9.9	11.4	12.9	14.4	16.0	17.5	19.0	20.5	22.1	23.6	25.1	26.6	28.1	29.7	31.2	32.7	34.2	35.8	37.3	38.8								72
74	5.1	6.6	8.1	9.6	11.1	12.6	14.1	15.6	17.0	18.5	20.0	21.5	23.0	24.5	26.0	27.5	29.0	30.5	32.0	33.5	34.9	36.4	37.9	39.4							74
76	4.9	6.4	7.9	9.3	10.8	12.2	13.7	15.2	16.6	18.1	19.6	21.0	22.5	23.9	25.4	26.9	28.3	29.8	31.3	32.7	34.2	35.6	37.1	38.6							76
78	4.8	6.2	7.6	9.1	10.5	11.9	13.4	14.8	16.2	17.7	19.1	20.5	22.0	23.4	24.8	26.3	27.7	29.1	30.6	32.0	33.4	34.9	36.3	37.7	39.2						78
80	4.6	6.0	7.4	8.8	10.2	11.6	13.0	14.5	15.9	17.3	18.7	20.1	21.5	22.9	24.3	25.7	27.1	28.5	29.9	31.3	32.7	34.2	35.6	37.0	38.4	39.8					80
82	4.4	5.8	7.2	8.6	10.0	11.4	12.7	14.1	15.5	16.9	18.3	19.6	21.0	22.4	23.8	25.2	26.6	27.9	29.3	30.7	32.1	33.5	34.8	36.2	37.6	39.0					82
84	4.3	5.7	7.0	8.4	9.7	11.1	12.4	13.8	15.2	16.5	17.9	19.2	20.6	21.9	23.3	24.7	26.0	27.4	28.7	30.1	31.4	32.8	34.2	35.5	36.9	38.2	39.6				84
86	4.1	5.5	6.8	8.2	9.5	10.8	12.2	13.5	14.8	16.2	17.5	18.8	20.2	21.5	22.8	24.2	25.5	26.8	28.2	29.5	30.8	32.2	33.5	34.8	36.2	37.5	38.8				86
88	4.0	5.3	6.6	7.9	9.3	10.6	11.9	13.2	14.5	15.8	17.1	18.4	19.8	21.1	22.4	23.7	25.0	26.3	27.6	28.9	30.3	31.6	32.9	34.2	35.5	36.8	38.1	39.4			88
90	5.2	6.5	7.7	9.0	10.3	11.6	12.9	14.2	15.5	16.8	18.1	19.4	20.7	21.9	23.2	24.5	25.8	27.1	28.4	29.7	31.0	32.3	33.6	34.9	36.2	37.4	38.7	39.0			90
92	5.0	6.3	7.6	8.8	10.1	11.4	12.6	13.9	15.2	16.5	17.7	19.0	20.3	21.5	22.8	24.1	25.3	26.6	27.9	29.2	30.4	31.7	33.0	34.2	35.5	36.8	38.1	39.2			92
94	4.9	6.1	7.4	8.6	9.9	11.1	12.4	13.6	14.9	16.1	17.4	18.6	19.9	21.1	22.4	23.6	24.9	26.1	27.4	28.7	29.9	31.2	32.4	33.7	34.9	36.2	37.4	38.6			94
96	4.7	6.0	7.2	8.4	9.7	10.9	12.1	13.4	14.6	15.8	17.1	18.3	19.5	20.8	22.0	23.2	24.5	25.7	26.9	28.2	29.4	30.6	31.9	33.1	34.3	35.6	36.8	38.0			96
98	4.6	5.8	7.0	8.2	9.4	10.7	11.9	13.1	14.3	15.5	16.7	18.0	19.2	20.4	21.6	22.8	24.0	25.3	26.5	27.7	28.9	30.1	31.3	32.5	33.8	35.0	36.2	37.4			98
100	4.4	5.6	6.8	8.0	9.2																										

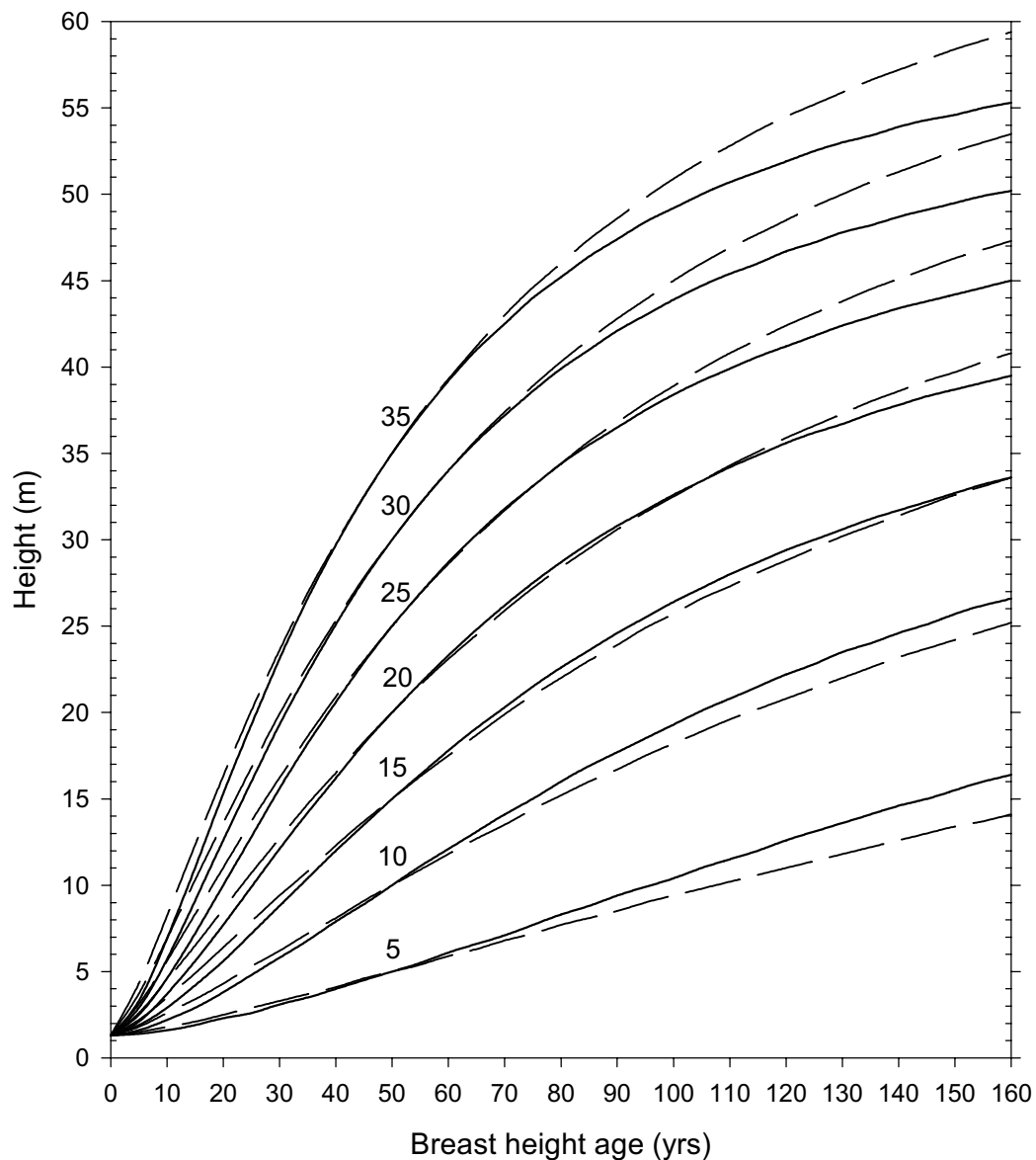


Figure 1. Climate-specific height growth curves (Eq. [1]) for naturally established, unmanaged, Pacific silver fir stands in the maritime and less-maritime region (dashed lines) and subarctic and subcontinental region (solid lines).

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