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RMYLD update: new growth and yield relationships for aspen

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RMYLD UPDATE: NEW GROWTH AND YIELD RELATIONSHIPS FOR ASPEN

Carleton B. Edminster and H. Todd Mowrer

ABSTRACT: Whole stand growth and yield relationships have been developed for even-aged stands of aspen in the central Rocky Mountains and incorporated into a new species-specific subroutine of the RMYLD model. Potential production is estimated for various combinations of site quality, rotation age, and initial thinning intensities. Merchantable cubic-foot volume is maximized at relatively high stand densities. Early precommercial thinning produces fewer but larger trees at rotation with relatively small decreases in total yield compared to unthinned stands.

INTRODUCTION

There are 3.78 million acres of commercial aspen (Populus tremuloides) forest in Colorado, Utah, and Wyoming (Green and Van Hooser 1983). More than 75 percent is in Colorado. The net bole volume of aspen growing stock in these three States was more than 3.25 billion cubic feet in 1977.

The potential of aspen for wood production and management has been relatively neglected. In recent years the wide distribution of aspen, concerns for timber supplies and stand conditions, and improved utilization have increased interest in its growth and yield characteristics and management potential (USDA Forest Service 1976). Baker (1925) studied the growth and yield of aspen in central Utah and felt his results would be generally applicable throughout the central Rocky Mountains; however, his yield tables are limited to narrow ranges of stand density and geographic distribution of growth plots. Although estimates of future growth and yield of aspen have been made by reference to these early tables or by reference to stock tables of similar stands, both methods have serious limitations. The early yield tables are not representative of a wide variety of stand densities, and the use of stock tables is limited by the accuracy of expectations about future conditions of the subject stand.

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MODEL DEVELOPMENT

Silvical characteristics of aspen make it an ideal species for a whole stand, even-aged growth and yield model such as RMYLD (Edminster 1978). In 1979 in cooperation with Colorado State University, a study was begun to collect growth data and develop whole stand growth and yield relationships for aspen stands in Colorado, southern Wyoming, and northeastern Utah. Data were collected from 101 temporary plots located in single, even-aged clones. The clones were purposively selected to represent a wide variety of stand conditions (table 1).

Table 1.--Summary of stand conditions sampled in the aspen growth study

Characteristic	Mean	Minimum	Maximum
Site index (feet)	63.3	29.0	111.0
Average age at b.h. (years)	68.6	17.0	131.0
Trees per acre	1,088.0	128.0	5,469.0
Basal area per acre (ft^2)	160.5	12.0	351.0
Average diameter (inches)[1]	6.6	1.6	15.0
Average dominant and codominant height (feet)	48.6	14.8	100.7
Total volume per acre (ft^3)	3,551.4	97.2	12,879.2
Merchantable volume per acre (ft^2)[2]	4,498.0	187.2	12,311.6
Sawtimber volume per acre (board feet)[3]	22,724.1	2,238.0	61,031.0

[1]Average diameter is the diameter of the tree of average basal area.
[2]Values for merchantable volume based on 57 plots with average diameter 5.0 inches and larger. Merchantable volume computed for trees 5.0 inches d.b.h. and larger to a 4-inch top.
[3]Values for sawtimber volume based on 36 plots with average diameter 7.0 inches and larger. Sawtimber volume computed for trees 7.0 inches d.b.h. and larger to a 6-inch top.

Relationships to project average stand diameter, average dominant and codominant height, and periodic stand basal area growth were developed, as were relationships to estimate changes in average tree characteristics and numbers of trees per acre due to thinning from below to various levels (Edminster and Mowrer in preparation). Stand volume equations are used to compute total and merchantable cubic-foot and board-foot volumes per acre. These relationships were incorporated into a new species-specific subroutine for RMYLD. Growth and yield estimates contained in this paper are based on these relationships.

STAND CONDITIONS SIMULATED

Yield simulations were made for the following range of initial stand conditions and management controls:

1. Site indexes at 80 years of age at breast height (b.h.) are 40, 50, 60, 70, 80, and 90 ft. (Edminster and others 1985).
2. Average b.h. is 20 years.
3. Average stand diameter (d.b.h.) is related to site index as follows (average stand diameter is the diameter of the tree of average basal area):

Site index (ft)	Initial d.b.h. (in)
40	2.0
50	2.2
60	2.4
70	2.6
80	2.8
90	3.0

4. Stand density is 2,000 trees per acre.
5. No catastrophic mortality occurs during the rotation.
6. Single precommercial thinnings are made at b.h. age 20 to growing stock levels 80, 100, 120, 140, 160, and 180. (Growing stock level [GSL] is defined as the residual square feet of basal area when average stand diameter is 10 inches or more. Basal area retained in a stand with an average diameter of less than 10 inches is less than the designated level [Edminster 1978]). Stands are also left unthinned for the rotation.
7. Maximum rotation age at b.h. is 120 years, with a clearcut regeneration method.
8. Minimum size for inclusion in merchantable cubic volume is 5.0 inches d.b.h. to a 4-inch top.

The precommercial thinnings produced a range of numbers of trees retained, depending on GSL and site index as shown in the following tabluation:

Site index (ft)	Trees per acre retained after precommercial thinning	
	GSL 80	GSL 180
40	515	1,198
50	494	1,159
60	473	1,116
70	452	1,073
80	432	1,030
90	413	988

Only precommercial thinnings were examined due to increased incidence of decay and mortality in partially cut pole-sized stands (Walters and others 1982). In addition, partial cutting results in inferior replacement stands (Jones 1976); therefore, only regeneration by clearcutting is considered.

MODEL RESULTS AND DISCUSSION

Diameter Growth

Periodic diameter growth of aspen is related to stand density, as represented by stand basal area and site quality. Ten-year periodic diameter growth averaged 0.7 inch for all stands sampled in the growth study. At low site indexes, periodic diameter growth averaged 0.6 inch, and at high site indexes the growth rate averaged 0.8 inch. Periodic diameter growth is a linear function of site index, but the effect of site index appears to be much less than for conifers in even-aged stands in the central Rocky Mountains. As with most species that are suited to even-aged management, diameter growth of aspen is greatest at low stand densities, but these low stand densities result in reduced volume yields per unit area. Determination of desirable stand density for managed stands involves consideration of both average tree size and volume production. To achieve appreciable increases in diameter growth, stand basal area must be reduced below 100 ft²/acre.

Periodic growth rates and changes in diameter resulting from precommercial thinning were examined to determine average tree sizes relative to rotation age and initial stand density. For the range of stand densities and site indexes examined, trees reach average diameters of 5.7 to 9.0 inches at 80 years, and 8.1 to 12.3 inches at 120 years (table 2). On lands of moderately good site index 70, average stand diameters reach 5 inches at 37 to 54 years of age, 7 inches at 64 to 83 years, and 9 inches at 91 to 111 years (fig. 1). Average diameters ranged from 9.6 to 11.3 inches at the maximum rotation age tested, which was 120 years on site index 70 lands. The number of decades required to reach an average stand diameter of at least 5.0 inches for computation of merchantable cubic volume ranged from 4 on thinned site index 90 lands to 7 on unthinned site index 40 to 60 lands (table 3).

Height Growth

Periodic height growth of aspen increases with site index and decreases with age and stand density. Average dominant and codominant height growth follows the site index curves (Edminster and others 1985) with adjustments downward to account for average codominant as well as dominant height (fig. 2). Differences in average dominant and codominant height due to initial stand densities tested are relatively minor. The maximum difference between stands initially thinned to GSL 80 and unthinned stands was 3 ft at 120 years of age across the range of site indexes.

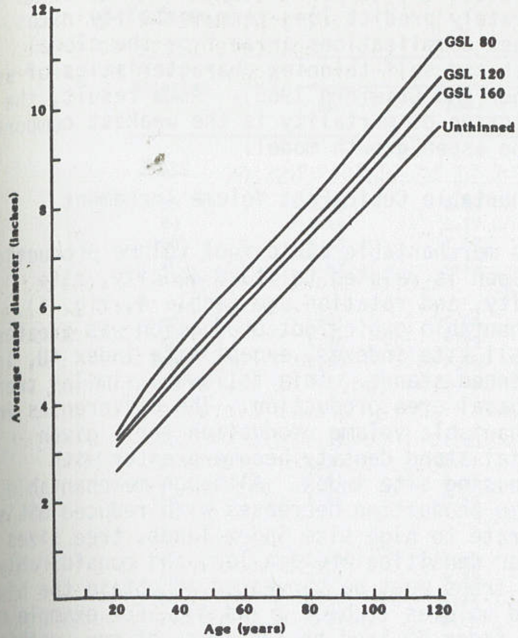

Figure 1.--Estimated average stand diameter of aspen in relation to age and initial stand density on site index 70 lands.

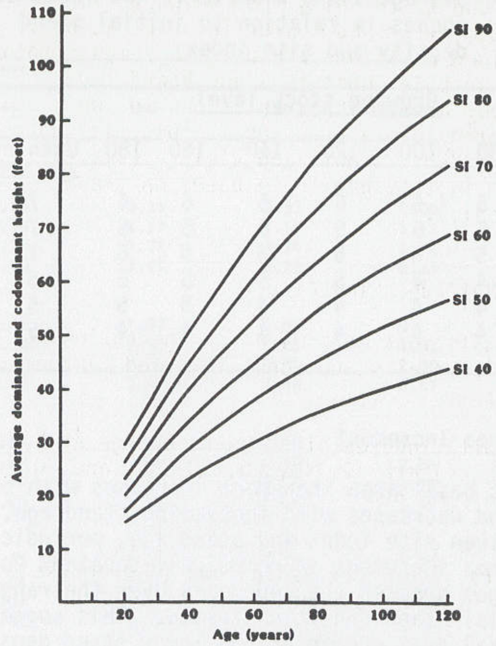

Figure 2.--Estimated average dominant and codominant height of aspen in relation to age and site index.

Table 2.--Estimated average stand diameter (in) and number of trees per acre of aspen at final harvest in relation to initial stand density, site quality, and rotation age

	Growing stock level													
	80		100		120		140		160		180		Unthinned	
Rotation age	Diameter	No. of trees	Diameter	No. of trees	Diameter	No. of trees	Diameter	No. of trees	Diameter	No. of trees	Diameter	No. of trees	Diameter	No. of trees
							Site Index 40							
60	5.9	410	5.6	479	5.4	553	5.2	617	5.1	655	5.0	704	4.5	923
80	7.3	333	7.0	381	6.6	450	6.4	496	6.3	517	6.2	553	5.7	688
100	8.7	271	8.4	304	7.9	361	7.6	399	7.5	417	7.4	438	6.9	527
120	10.1	222	9.8	246	9.3	284	9.0	312	8.9	321	8.7	343	8.1	416
							Site Index 50							
60	6.1	428	5.8	501	5.7	553	5.6	608	5.4	660	5.2	745	4.7	987
80	7.5	358	7.2	406	7.1	443	7.0	478	6.7	530	6.4	599	5.9	758
100	8.9	300	8.6	334	8.5	357	8.4	381	8.1	416	7.7	473	7.1	592
120	10.3	250	10.0	275	9.9	291	9.8	307	9.5	333	9.1	371	8.4	462
							Site Index 60							
60	6.3	429	6.1	497	5.9	563	5.8	615	5.8	648	5.6	713	4.9	1046
80	7.7	371	7.5	417	7.3	464	7.2	498	7.2	519	7.0	561	6.1	813
100	9.1	316	8.9	349	8.7	382	8.6	406	8.6	423	8.4	446	7.5	612
120	10.6	264	10.3	293	10.1	316	10.0	335	10.0	346	9.8	364	8.9	476
							Site Index 70							
60	6.7	412	6.4	496	6.2	553	6.1	620	6.0	667	5.9	721	5.4	974
80	8.1	366	7.8	424	7.6	463	7.5	508	7.4	542	7.3	578	6.8	741
100	9.7	307	9.2	363	9.0	391	8.9	423	8.8	445	8.7	472	8.2	583
120	11.3	258	10.8	298	10.6	318	10.4	347	10.3	362	10.1	388	9.6	467
							Site Index 80							
60	7.0	396	6.8	467	6.5	546	6.4	599	6.2	672	6.2	701	5.6	1011
80	8.6	342	8.4	389	8.0	452	7.8	503	7.6	552	7.6	574	7.0	785
100	10.2	297	10.0	330	9.6	376	9.4	410	9.1	453	9.1	469	8.4	623
120	11.8	255	11.6	279	11.2	312	11.0	337	10.7	368	10.7	379	9.9	493
							Site Index 90							
60	7.4	388	7.1	458	7.0	508	6.8	563	6.8	610	6.4	707	5.8	1051
80	9.0	339	8.7	387	8.6	423	8.4	459	8.4	493	8.0	555	7.2	820
100	10.6	300	10.3	355	10.2	361	10.0	386	10.0	410	9.6	455	8.7	645
120	12.3	259	11.9	288	11.8	308	11.6	327	11.6	343	11.2	375	10.3	508

Table 3.--Estimated number of decades to reach an average stand diameter of at least 5.0 inches in relation to initial stand density and site index

	Growing stock level						
Site Index	80	100	120	140	160	180	Unthinned
40	5	6	6	6	6	6	7
50	5	5	5	6	6	6	7
60	5	5	5	5	5	6	7
70	4	4	5	5	5	5	6
80	4	4	4	4	5	5	6
90	4	4	4	4	4	4	5

Basal Area Increment

Periodic basal area increment increases with site index and decreases with increasing stand age. For a given site index and stand age, periodic basal area increment is relatively constant for stand ages greater than 40 years over the range of initial stand densities tested. This suggests that basal area growth at the lower stand densities was not redistributed on the fewer residual stems. The pattern of basal area development in relation to age and site index for unthinned stands is shown in figure 3. At a stand age of 120 years, basal area production per acre varied from 149 ft² on site index 40 lands to 294 ft² on site index 90 lands.

Basal area growth relationships in the model predict growth based on estimated 10-year periodic plot performance. Since mortality is often a clustered event, in both location and time,

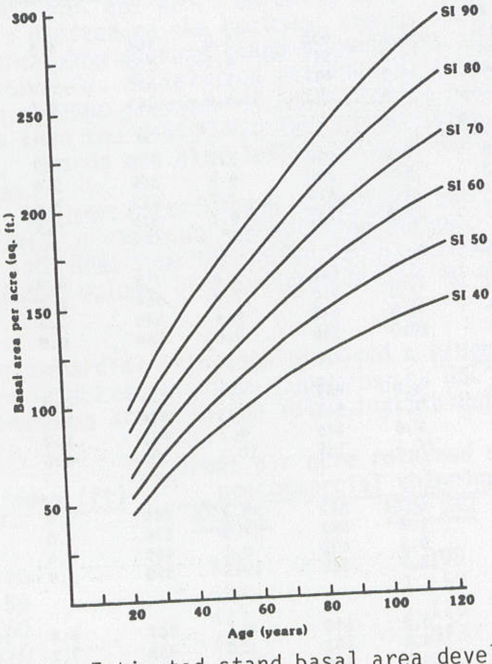

Figure 3.--Estimated stand basal area development in unthinned stands of aspen in relation to age and site index.

samples from a relatively small number of stands over a short time period may not be adequate to accurately predict long-term mortality rates. Further complications arise from the clonal growth and self-thinning characteristics of aspen (Zahner and Crawford 1965). As a result, the prediction of mortality is the weakest component in the aspen growth model.

Merchantable Cubic-Foot Volume Increment

Gross merchantable cubic-foot volume production of aspen is related to stand density, site quality, and rotation age (table 4, fig. 4). Merchantable cubic-foot production was greatest for all site indexes, except site index 40, in unthinned stands. This follows a similar trend for basal area production. The differences in merchantable volume production for a given initial stand density become greater with increasing site index. Although merchantable volume production decreases with reduced GSL's on moderate to high site index lands, tree sizes at higher densities are smaller, and considerably more trees must be harvested to obtain the higher stand volumes (tables 2 and 4). For example on site index 70 land at 120 years of age, unthinned stands produce 6.5 percent more merchantable volume than stands initially thinned to GSL 180, but the unthinned stand contains 20.4 percent more trees which are 0.5 inch smaller in average diameter.

Compared to earlier estimates for aspen in central Utah (Baker 1925), predicted merchantable yields from this study are considerably higher, with differences increasing with increasing site quality. Although direct comparisons are not possible due to different site curves used to index productivity, the following approximate comparisons at stand age 120 years for unthinned stands on a per-acre basis can be made:

Baker Site Class (index height)	Merchantable cubic-foot yields: Baker	Current study
1 (77)	4,600	8,680
2 (67)	3,400	6,540
3 (55)	2,300	4,520
4 (44)	1,700	2,740

Only a small portion of the difference can be explained by the larger utilization standards in Baker's study, where cordwood cubic-foot volume was calculated for trees 6.0 inches d.b.h. and larger to a 5-inch top.

Mean annual increment (MAI) of merchantable cubic-foot volume provides an objective criterion for evaluting growth consequences of different precommercial thinning levels and unthinned stands (Assman 1970). Gross merchantable cubic-volume MAI is related to age, site quality, and initial stand density (fig. 5). For each initial stand density, merchantable cubic-foot volume MAI is greater at each higher site index, and differences become greater with increasing site index. Mean annual increments are increasing through stand age of 120 years. Site indexes 50 and

Table 4.--Estimated gross merchantable cubic-foot volume production per acre of aspen in relation to initial stand density, site quality, and rotation age (trees 5.0 inches d.b.h. and larger to a 4-inch top)

Rotation age	Growing stock level 80	100	120	140	160	180	Unthinned
Years	Thousand cubic feet						
	Site Index 40						
60	0.63	0.61	0.61	0.58	0.56	0.55	0.00[1]
80	1.16	1.17	1.18	1.18	1.17	1.18	1.12
100	1.65	1.68	1.71	1.71	1.71	1.74	1.72
120	2.09	2.13	2.18	2.20	2.19	2.22	2.23
	Site Index 50						
60	1.01	1.00	1.04	1.06	1.03	1.01	0
80	1.76	1.79	1.86	1.92	1.90	1.91	1.91
100	2.50	2.55	2.64	2.72	2.72	2.74	2.80
120	3.17	3.24	3.34	3.42	3.44	3.48	3.57
	Site Index 60						
60	1.39	1.45	1.50	1.55	1.62	1.60	0
80	2.39	2.51	2.59	2.69	2.79	2.79	2.86
100	3.41	3.56	3.67	3.79	3.92	3.93	4.12
120	4.36	4.53	4.66	4.80	4.93	4.95	5.21
	Site Index 70						
60	1.86	1.98	2.02	2.16	2.21	2.28	2.39
80	3.14	3.32	3.40	3.61	3.70	3.82	4.10
100	4.49	4.71	4.81	5.07	5.18	5.33	5.72
120	5.79	6.04	6.15	6.42	6.56	6.72	7.16
	Site Index 80						
60	2.32	2.52	2.64	2.77	2.86	2.98	3.27
80	3.89	4.16	4.35	4.53	4.69	4.85	5.42
100	5.58	5.91	6.15	6.41	6.58	6.78	7.50
120	7.05	7.44	7.78	8.11	8.34	8.57	9.38
	Site Index 90						
60	2.92	3.11	3.34	3.43	3.70	3.71	4.29
80	4.83	5.09	5.40	5.55	5.92	5.99	6.93
100	6.93	7.25	7.62	7.81	8.27	8.38	9.56
120	8.62	9.01	9.42	9.66	10.14	10.37	11.92

[1] Stand merchantable cubic-foot volume is not computed when average stand d.b.h. is less than 5.0 inches.

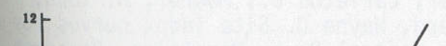

Figure 4.--Estimated gross merchantable cubic-foot volume production per acre of aspen in relation to age, initial stand density, and site index.

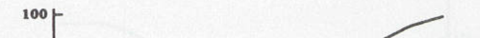

Figure 5.--Estimated gross mean annual merchantable cubic-foot volume increment per acre in relation to age, initial stand density, and site index.

above produce more than 20 ft³/acre annually. Mean annual increment in unthinned stands on site index 90 lands approaches 100 ft³/acre.

A pathological rotation of 90 to 120 years for sawtimber production of aspen in Colorado has been suggested by Hinds and Wengert (1977). Deductions in cubic-foot volume for decay (Davidson and others 1959) were applied to the gross MAI values in figure 5 to determine a reasonable rotation for merchantable cubic-foot volume. Results of the decay study were based on Baker's site classification, and application of the results to the current study is an approximation. Decay deductions for site class 1 were applied to site indexes 80 and 90, class 2 to site index 70, and class 3 to site index 60 and below. Estimates of net merchantable cubic-foot volume MAI's are shown in figure 6. Culmination of net MAI generally occurs between 100 and 120 years, most often at 100 years of age. These results support the recommendations for sawtimber production. Cull resulting from decay varies greatly in stands of comparable age and site quality (Davidson and others 1959; Hinds and Wengert 1977). As a result, the estimates reported here should only be applied to a specific stand with care.

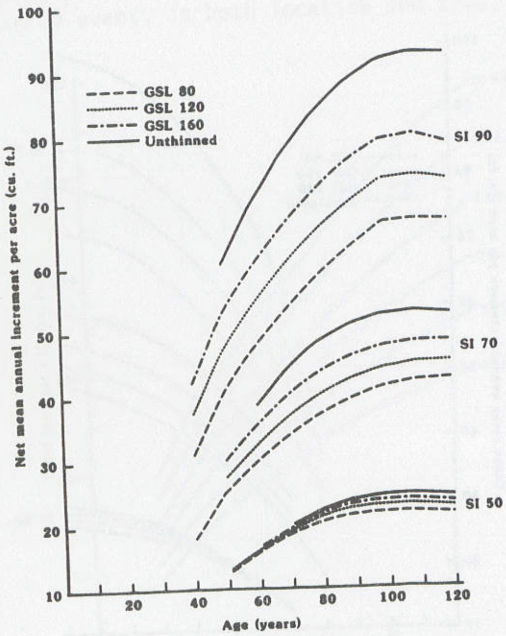

Figure 6.--Estimated net mean annual merchantable cubic-foot volume increment per acre in relation to age, initial stand density, and site index.

MANAGEMENT CAUTION

The growth and yield estimates presented appear reasonable and consistent within the limits of current knowledge based on sampling even-aged natural stands of aspen at a wide variety of stand age, density, and site quality. Comparisons of estimates with actual values from permanent plots in managed and unthinned stands are needed to validate growth relationships and estimates. Thinning studies in a pole-size stand and juvenile stands on three site quality lands are currently underway to provide some of this information.

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