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CLOQUET FORESTRY CENTER FOREST STAND STRUCTURE AND GROWTH ESTIMATES DERIVED FROM PERMANENT PLOTS AND A MULTIPLE RANDOM START SAMPLING DESIGN

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In 1959 a continuous forest inventory system was initiated on the Cloquet Forestry Center forest (1). The inventory system, based on a method of sampling described by Shiue (6), consisted of a systematic sample with four random starts of approximately 86 plots each. Non-productive land, experimental plantations, administrative areas, and the main highway were eliminated from the survey. Three hundred and forty-five permanent 1/7-acre circular plots were established on 2749.1 acres of productive land (5). The office and field procedures used in locating these plots are described in detail by Swenson (7). The plots were remeasured in 1964 and 1969.

Data Collection

Diameter and merchantable height measurements were collected for all trees five inches and larger in diameter at breast height on each 1/7-acre plot. Square feet of basal area was computed for each sample tree. The Lake States Composite Cord Volume Table No. 6 was used to obtain the cord volume of each sample tree (4). Cubic foot volume was computed by multiplying the cord volume for each tree by a factor of 79 and applying a species correction factor.

This information was used to derive volume per acre, basal area per acre, and number of trees per acre estimates for each 1/7-acre plot. These estimates were tabulated for the productive land and summarized by the following cover types: red pine, jack pine, white spruce-balsam fir, black spruce, tamarack, northern white cedar, and aspen-birch. Complete stock and stand tables for the productive land and these cover types are on file at the Cloquet Forestry Center.[2/]

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[2/] Hatch, C. R. 1973. Stand structure and growth estimates for the Cloquet Forestry Center forest. Typewritten tables. College of Forestry, University of Minnesota, 34 pp.

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Statistical Design

The use of a systematic sample with multiple random starts makes it possible to compute a valid sampling error in addition to a point estimate of the mean. Sampling error is defined as the half-width of the 95% confidence interval expressed as a percent of the mean. Since the four random starts did not have an equal number of systematically located plots, ratio estimates were used (2). It should also be noted that with four random starts estimates of sampling error are based on three degrees of freedom and, therefore, may be of large magnitude.

Stand Structure Estimates

In 1969 the productive land on the Cloquet Forestry Center forest contained an estimated 3,814,069 cubic feet of volume, 183,807 square feet of basal area, and 484,495 trees. The respective sampling errors for each of these estimates are 7, 9, and 7 percent. Jack pine, red pine and birch accounted for 25, 21, and 13 percent of the total basal area, respectively. The percentage contribution to total volume by each of these species was similar to that of basal area. Twenty-two percent of the total number of trees were jack pine. Red pine, birch, aspen, and spruce each accounted for approximately 13 percent of the total number of trees.

Table 1 gives estimates of volume per acre, basal area per acre, and number of trees per 10-acres by cover type. Sampling errors are given for each of these estimates.

Growth Estimates

Growth was obtained from periodic remeasurement of all sample trees on each 1/7-acre plot. Four growth components were recognized in this analysis:

Survivor growth -- Trees present in the 1959-1964 period and/or the 1964-1969 period

Ingrowth -- Trees 5-inches or larger in diameter in 1964 but not in 1959 or trees 5-inches or larger in diameter in 1969 but not in 1964

Mortality -- Trees that were alive in 1959 and dead in 1964 or trees that were alive in 1964 and dead in 1969

Cut -- Trees recorded in 1959 and harvested prior to 1964 or trees recorded in 1964 and harvested prior to 1969

Net change is defined as survivor growth plus ingrowth minus mortality minus cut.

Survivor growth and ingrowth are biased since ingrowth includes both the growth of trees 5-inches in diameter entering the stand between measurements - actual ingrowth - and the growth on those trees from the time they entered the stand until they were measured - actual survivor growth (3). Combined, these two components of growth provide an unbiased estimate of gross growth.

Table 2 gives estimates of the four growth components by cover type. Only plots which remained in the same cover type during the entire 10-year period were used in the analysis. Thus, plots which were clearcut were eliminated from the growth computations.

Summary

A systematic sample with multiple random starts was used to compute point estimates of stand structure and growth on the Cloquet Forestry Center forest. In addition, valid estimates of sampling error were computed for each of the point estimates.

Sampling errors were of reasonable magnitude for point estimates of total volume, total basal area, and total number of trees on the productive land. However, when the productive land was stratified by cover type, the sampling errors became excessive.

If this procedure is to be used to derive cover type point estimates, it is necessary to increase the number of random starts. Otherwise, sampling errors become excessive.

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Table 1. Estimates of volume per acre, basal area per acre, and number of trees per 10-acre and their respective sampling errors for major cover types on the Cloquet Forestry Center forest in 1969.

	Stand Structure Estimates					
Cover Type	Volume/ Acre (Cu. Ft.)	Sampling Error (Percent)	Basal Area/ Acre (Sq. Ft.)	Sampling Error (Percent)	No. of Trees/ 10-Acres (Freq.)	Sampling Error (Percent)
Red Pine	2170	25	92.8	22	1935	29
Jack Pine	2129	6	96.4	7	2279	9
White Spruce-Balsam Fir	1146	25	63.1	26	1997	29
Black Spruce	1028	37	58.5	37	2293	38
Tamarack	851	63	41.4	52	1268	47
Northern White Cedar	1393	34	90.7	25	3059	17
Aspen-Birch	1078	22	54.1	20	1449	19

Table 2. Annual growth and respective sampling errors by growth components for major cover types on the Cloquet Forestry Center forest during the period 1959-1969.

	Cover Type													
	Red Pine		Jack Pine		White Spruce-Balsam Fir		Black Spruce		Tamarack		Northern White Cedar		Aspen-Birch	
Growth Component	Esti-mate	SE (%)	Esti-mate	SE (%)	Esti-mate	SE (%)	Esti-mate	SE (%)	Esti-mate	SE (%)	Esti-mate	SE (%)	Esti-mate	SE (%)
	Cubic Foot Volume Growth/Acre/Year													
Survivor	91.1	13	78.5	13	43.9	22	33.7	43	25.9	80	43.6	24	45.3	20
Ingrowth	9.7	45	5.5	11	11.3	59	10.1	19	2.7	75	8.9	82	9.2	38
Mortality	6.2	84	15.9	45	17.1	92	10.4	58	6.6	35	9.2	61	7.6	59
Cut	8.3	86	5.8	76	1.4	307	1.1	331	5.9	300	0.0	0	7.0	112
Net Change	+86.3	23	+62.3	21	+36.7	51	+32.3	50	+16.1	192	+43.3	23	+39.9	28
	Square Feet of Basal Area Growth/Acre/Year													
Survivor	2.42	10	2.09	16	1.46	34	1.02	42	0.73	59	1.60	20	1.34	28
Ingrowth	0.92	47	0.50	10	1.05	60	0.91	20	0.24	80	0.90	81	0.80	30
Mortality	0.30	78	0.88	42	0.91	48	0.65	45	0.38	12	0.60	61	0.47	45
Cut	0.42	74	0.33	76	0.09	307	0.07	331	0.34	300	0.00	0	0.35	102
Net Change	+2.62	32	+1.38	38	+1.51	76	+1.21	38	+0.25	527	+1.90	26	+1.32	37
	Change in Number of Trees/10-Acres/Year													
Ingrowth	56	46	32	10	67	59	61	23	16	80	60	82	48	28
Mortality	9	95	29	29	30	15	28	45	12	60	22	88	17	39
Cut	13	95	14	71	4	307	3	331	12	300	0	0	9	103
Net Change	+34	90	-11	81	+33	97	+30	35	- 8	479	+38	113	+22	54

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