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Comparison of a Fully Mapped Plot Design to Three Alternative Designs for Volume and Area Estimates Using Maine Inventory Data

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Abstract

A fully mapped plot design is compared to three alternative designs using data collected for the recent inventory of Maine's forest resources. Like the fully mapped design, one alternative eliminates the bias of previous procedures, and should be less costly and more consistent. There was little difference in volume and area estimates or in sampling errors among the four procedures.

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Introduction

The recent inventory of Maine's forest resources by the Northeast Station's Forest Inventory and Analysis (FIA) project was the first completed using a fully mapped plot design (Hahn et al. 1995). With this design, when an inventory subplot straddles two or more distinct conditions, the boundaries between these conditions are mapped. Prior to implementing the mapped plot design, most FIA units moved subplots so that all subplots would be in the same condition or ignored different conditions that occurred on the plot.

The mapped plot design eliminates the bias inherent in these two procedures (Hahn et al. 1995), but also results in increased time and cost. Azimuth to each plot border/ boundary intersection and distance and azimuth to each boundary corner need to be determined. In addition to the ecotype defining conditions, all plot-classification variables, such as physiographic class and slope, need to be determined for each distinct ecotype.

Another problem with the fully mapped design occurs when classifications requiring tree measurements have too few trees on ecotypes occupying small slivers of the plot. When this happens, the options include: (1) having field crews call the classifications with observation of characteristics of the ecotype not restricted to the plot; (2) taking additional data for classification purposes only; (3) assigning "not determined" classifications.

This paper presents comparisons of estimates and sampling errors for the fully mapped design and three additional procedures to handle straddle plots. It should be noted that the fully mapped plot design was initially implemented nationally by FIA without specification of a particular plot layout. More recently it has been mandated that the Forest Health Monitoring (FHM) plot layout would be used[1] (Scott 1993). The Maine inventory, begun prior to this more recent mandate, uses a single 1/5-acre plot for trees larger than 5 inches in diameter at breast height (dbh).

The three procedures compared with the fully mapped design on this single 1/5-acre plot are:

1. Ignore boundaries on a plot; measure and use all trees to determine plot classifications. This is the Fuzz approach presented in Hahn et al. (1995).
2. Record and use the trees in the condition at plot center only (call this condition 1).
3. Map all forest land-use conditions; measure all trees on the plot but base plot classifications on the condition at plot center only. Tree characteristics such as volume of all trees on the plot are assigned to the class determined for condition 1. Call this a "modified mapped" design.

[1]Bechtold, W.A.; LaBau,V.J.; McLain,W.; Rogers, P. 1992. Site classification, growth, and regeneration. In: Forest health monitoring field methods guide (national guide). Internal report on file at U.S. Environmental Protection Agency, Office of Research and Development, P.O. Box 12254, Research Triangle Park, NC.

Methods

The data used in this analysis were collected using the fully mapped design with a single 1/5-acre circular plot for trees at least 5 inches dbh, and five circular microplots positioned around plot center for trees less than 5 inches dbh. The field procedures used were essentially those presented in Scott and Bechtold (1995). When the field crew determined a distinct difference in condition on a plot, the boundaries between conditions were mapped and trees were assigned to the appropiate condition class. In Maine, four stand attributes were used to determine plots to be mapped; land use (forest-nonforest), forest type, stand size (seedling-sapling, poletimber, sawtimber), and stand origin (planted, natural). The boundaries were mapped by determining azimuth from plot center to each condition/plot boundary intersection. When a corner occurred, distance and azimuth from plot center to each corner were determined. With these measurements, the area of each condition can be calculated using the procedure outlined in Scott and Bechtold (1995).

In addition to the four condition defining stand attributes, all plot variables recorded by FIA, e.g., physiographic class, were determined for each condition that was mapped. For tree-based classifications, if a condition had fewer than 10 trees, the field crew assigned a value based on observation not restricted to the plot.

The sampling design used in Maine was double sampling for stratification (Cochran 1963) where a large sample of photo points were interpreted to assign strata for a smaller sample of ground plots. For the fully mapped design, the variable used for population estimates of area for a stand attribute classification is the proportion of the plot occupied by the stand attribute class to be estimated. Estimates of tree-based characteristics, e.g., volume, are determined using the individual-tree volume weighted by the inverse of the proportion of an acre of the original plot design (this value is 5 for trees 5+ inches dbh). Note that the condition proportion is used with tree-based characteristics only to adjust site occupancy classifications such as stand density. The condition proportions are not used for population estimates of tree attributes. For example, the density of a condition occupying half of a plot is determined by dividing the density value calculated using the trees in the condition by 0.5. However, the volume used to estimate population totals is not adjusted.

Differences between the fully mapped design and the three alternative procedures are as follows.

1. Fuzz. Boundaries need not be mapped. All trees on the plot are measured and used to determine tree-based classifications. As implemented for this analysis, all stand-based classifications such as land use and physiographic class are assigned the value at plot center. Also, when there are fewer than 10 trees on the whole plot, condition 1 classifications assigned by the field crew are used for tree-based attributes such as forest type.

2. Condition 1 only. Record and use the trees in the condition at plot center only. Conditions different from that of

plot center need to be determined by the field crew and boundaries delineating condition 1 need to be mapped. All classifications are based on condition 1 only. For population estimates of tree attributes such as volume, adjust the values by multiplying by the inverse of the proportion of the plot that is condition 1. This is the “direct weighting” procedure of Beers (1966) that was one of the biased procedures considered by Gregorie and Scott (1990).

3. Modified mapped. All forest land-use conditions need to be noted by the field crew, mapped, and assigned a land-use class, including those not at subplot center. Measure all trees on the plot but assign plot classifications using the trees on condition 1 only. For area estimates, the plot is considered to represent the value of condition 1. For population estimates of tree attributes such as volume, use all trees on the plot. With one exception, the value used is that of the tree attribute weighted by the tree-expansion factor of the original plot design (for Maine this is 5 for trees at least 5 inches dbh).

The exception is to assign a value of zero to the tree attribute on nonforest conditions if summaries are for forested land uses only. For summaries using classifications based on tree attributes, such as number of trees on forest land by forest type, a “not determined” class needs to be included that contains the tree-attribute total of forested land-use conditions on plots classified as nonforest. This will be added to the plot total for all forest types to compensate for plots assigned a forest land use based on condition 1 that include nonforest sections.

To compare the four procedures, estimates and sampling errors for each procedure were calculated using data collected for the most recent inventory of Maine. Portions of several of the standard area and volume tables found in the statistical report (Griffith and Alerich 1996) are presented.

Results

Table 1 contains the estimates and sampling errors (standard error expressed as percent of the estimate) of area of timberland by forest type group. Timberland is forest land producing or capable of producing crops of industrial wood (more than 20 cubic feet per acre per year) and not withdrawn from timber utilization (Griffith and Alerich 1996). The differences in both the estimates and sampling errors among the four procedures are small for most forest types. Only for the smallest classes are the differences substantial. The sampling errors for the three alternative procedures are slightly larger than those for the fully mapped design. Note that the area estimates for the condition 1 only and the modified mapped design are the same since both use condition 1 for classification of the plot. Also, the total for Fuzz is the same as that for the condition 1 only and the modified mapped design since land use is based on condition 1 for this analysis.

Table 2 presents estimates of area by stand-size class for the four procedures. The results are similar to those for forest type. Except for the smallest stand size, the sampling errors for the three alternative procedures are only slightly larger than those for the fully mapped design.

Estimates of cubic-foot volume on timberland by forest type group and stand size are presented in Tables 3 and 4, respectively. Here, too, the differences in estimates and sampling errors are small. Note that the total volume is the same for the fully mapped and modified mapped design since all trees are measured and used. Also, note the volume in the “not determined” class for both the Fuzz and modified mapped designs. For the modified mapped design, this is the timberland volume on noncondition 1 portions of straddle plots classified as nontimberland based on condition 1.

For the Fuzz procedure, this “not determined” class includes volume from both noncondition 1 sections that have a forested land use and condition 1 sections that have a forest but nontimberland land use. The latter volume was included to account for volume on timberland sections of these plots.

Tables 5 and 6 present the cubic-foot volume for two tree-based classifications: species and diameter class. Note that the estimates and sampling errors are the same for the fully mapped and modified mapped designs since all trees are used by the two procedures. The slight difference for the Fuzz procedure results from including volume from forested but nontimberland sections of straddle plots.

Of the 2,981 plots measured in Maine, 246 had more than one ecotype. Table 7 contains a cross-classification matrix of cubic-foot volume for stand size of condition 1 by condition other than one for these straddle plots. The volumes off the diagonal are the volumes from other stand sizes that would be included in the condition 1 classification by the modified mapped procedure. For instance, the total volume from nonpoletimber stands that would be included in poletimber stands is 16,180,000 cubic feet (21,586,000 – 5,406,000), or 0.17 percent of the total cubic-foot volume estimated to be in poletimber stands (9,260.2 million cubic feet, Table 4).

Discussion

For the Maine inventory, the differences among the four plot designs and estimation procedures are small for both estimates and sampling errors. Although we would expect greater differences for smaller populations or finer classification breakdowns, for instance, summaries for county of forest type by stand size, the sampling errors also would be proportionately larger for all designs. We also might expect greater differences in regions that are more fragmented so that multiple ecotype plots are more frequent. The Fuzz procedure can result in bias in classification of the plot. For instance, a straddle plot with distinct pine and oak forest type sections could be classified incorrectly as oak-pine. The estimate of total volume on timberland also is biased because there is no differentiation of nontimberland forest and timberland land use on noncondition 1 sections. Without this distinction, including or excluding these volumes would result in biased estimates. The condition 1 only design is unbiased for estimates of area, such as area by forest type, but biased for estimates of tree attributes, e.g., volume by diameter class. Adjusting of the tree-expansion factor by multiplying by the inverse of the proportion of the plot that is condition 1 should reduce the bias. The use of this “direct weighting” procedure by Gregorie and Scott (1990) resulted in small biases for their examples. However, the possibilty of unknown and potentially large bias is a major reason why the fully mapped design has been implemented nationally.

The modified mapped procedure is unbiased for both estimates of area for stand classifications, such as area by forest type, and estimates of tree characteristics for individual-tree classifications, such as volume by species. However, estimates of tree attributes for plot classifications could include values from other classes. For instance, volume of poletimber stands could include volume from sawtimber stands. Also, for tables such as volume on timberland by forest type, a “not defined” class would be needed to account for the volume of trees on timberland that is not condition 1. The estimates for total area of timberland, total volume, and other tree attributes are unbiased. As for the fully mapped and Fuzz procedures, all trees on the plot are measured using the modified mapped design. This avoids the inefficiency of recording only a small portion of the tree information after incurring the expense of reaching a plot. Also, summaries by tree characteristics such as volume by species use all information collected. For the modified mapped design, plot attributes other than land use would not be needed for conditions other than at plot center. This design should take less time and result in more consistent estimates than the fully mapped design by reducing the number of field-crew classifications. If it is thought that additional measurements are needed to classify small sections, the modified mapped design would require fewer supplemental plots than the fully mapped design.

The Maine inventory was begun before the forest health monitoring plot design was mandated. The increased area coverage of the FHM design should result in more frequent multiple-condition plots. Although it will not be necessary to establish boundaries when they occur between subplots, a value for all plot-characteristic variables is needed for each condition. It is uncertain whether the FHM and the single 1/5-acre plot would result in different numbers of boundaries that actually need to be mapped. The 1/5-acre plot is larger but there are 4 times as many subplots in the FHM design.

With the FHM plot design, implementation of the modified mapped procedure could be done in several ways. The plot classification could be determined using the ecotype of plot center of the central subplot; or each subplot could be classified using the ecotype of subplot center. When the inventories for the next states using the FHM design are completed, these options will be investigated and comparisons similar to those in this report will be made.

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Table 1.—Estimates and sampling errors of timberland area by forest type group for Maine using four procedures on data collected with a fully mapped design

Forest type group	Estimate				Sampling error[a]			
	Fully[b] mapped	Fuzz	Condition 1 only	Modified mapped	Fully mapped	Fuzz	Condition 1 only	Modified mapped
	Thousand acres				*Percent*			
White-red pine	1245.9	1263.0	1249.5	1249.5	6.75	6.81	6.85	6.85
Spruce-fir	6011.2	6001.2	6020.1	6020.1	2.38	2.40	2.39	2.39
Loblolly-shortleaf pine	6.7	6.7	6.7	6.7	100.00	100.00	100.00	100.00
Oak-pine	127.6	139.9	133.5	133.5	22.22	21.61	22.26	22.26
Oak-hickory	453.2	461.3	454.7	454.7	11.78	11.83	11.93	11.93
Elm-ash-red maple	434.7	445.6	439.1	439.1	12.17	12.11	12.20	12.20
Northern hardwoods	6408.8	6387.4	6401.1	6401.1	2.33	2.35	2.35	2.35
Aspen-birch	2249.6	2236.8	2237.5	2237.5	4.97	5.04	5.04	5.04
All forest type groups	16937.7	16942.1	16942.1	16942.1	0.44	0.46	0.46	0.46

[a]Sampling errors are standard errors expressed as percent of estimate.
[b]From Table 2 in Griffith and Alerich (1996).

Table 2.—Estimates and sampling errors of timberland area by stand-size class for Maine using four procedures on data collected with a fully mapped design

Stand size	Estimate				Sampling error[a]			
	Fully[b] mapped	Fuzz	Condition 1 only	Modified mapped	Fully mapped	Fuzz	Condition 1 only	Modified mapped
	Thousand acres				*Percent*			
Saw	5770.0	5790.0	5757.2	5757.2	2.66	2.69	2.69	2.69
Pole	6934.6	6934.0	6927.0	6927.0	2.28	2.31	2.31	2.31
Seedling-sapling	4215.7	4197.6	4237.5	4237.5	2.97	3.02	3.01	3.01
Nonstocked	17.3	20.4	20.4	20.4	54.00	58.36	58.36	58.36
All stand size classes	16937.7	16942.1	16942.1	16942.1	0.44	0.46	0.46	0.46

[a]Sampling errors are standard errors expressed as percent of estimate.
[b]From Table 6 in Griffith and Alerich (1996).

Table 3.—Estimates and sampling errors of net cubic-foot volume on timberland by forest type group for Maine using four procedures on data collected with a fully mapped design

	Estimate				Sampling error[a]			
Forest type group	Fully[b] mapped	Fuzz	Condition 1 only	Modified mapped	Fully mapped	Fuzz	Condition 1 only	Modified mapped
	Million cubic feet				*Percent*			
White-red pine	2683.9	2662.0	2727.9	2653.3	7.58	7.66	7.79	7.68
Spruce-fir	7352.0	7312.3	7340.3	7316.9	3.28	3.30	3.31	3.30
Loblolly-shortleaf pine	18.8	18.8	18.8	18.8	100.00	100.00	100.00	100.00
Oak-pine	215.0	233.0	220.4	215.0	25.65	24.46	25.31	25.65
Oak-hickory	620.7	614.8	628.0	611.7	13.89	14.01	14.10	14.07
Elm-ash-red maple	264.9	268.1	268.6	267.9	16.98	16.85	16.91	16.87
Northern hardwoods	7520.4	7447.4	7473.4	7471.0	2.96	2.98	2.98	2.97
Aspen-birch	2214.0	2209.7	2225.8	2208.5	6.89	6.91	6.95	6.91
Not determined	0.0	183.3	0.0	126.5	0.00	21.27	0.00	21.79
All forest type groups	20889.7	20949.3	20903.0	20889.7	1.29	1.28	1.33	1.29

[a]Sampling errors are standard errors expressed as percent of estimate.
[b]From Table 20 in Griffith and Alerich (1996).

Table 4.—Estimates and sampling errors of net cubic-foot volume on timberland by stand size class for Maine using four procedures on data collected with a fully mapped design

	Estimate				Sampling error[a]			
Stand size	Fully[b] mapped	Fuzz	Condition 1 only	Modified mapped	Fully mapped	Fuzz	Condition 1 only	Modified mapped
	Million cubic feet				*Percent*			
Saw	10548.2	10483.1	10533.5	10454.2	3.05	3.07	3.11	3.08
Pole	9355.1	9289.0	9371.7	9260.2	2.67	2.69	2.71	2.70
Seedling-sapling	982.7	992.0	992.7	1046.9	5.43	5.42	5.52	5.44
Nonstocked	3.7	1.9	5.1	1.9	65.37	84.66	93.93	84.66
Not determined	0.0	183.3	0.0	126.5	0.00	21.27	0.00	21.79
All stand size classes	20889.7	20949.3	20903.0	20889.7	1.29	1.28	1.33	1.29

[a]Sampling errors are standard errors expressed as percent of estimate.
[b]From Table 20 in Griffith and Alerich (1996).

Table 5.—Estimates and sampling errors of net cubic-foot volume on timberland by species for Maine using four procedures on data collected with a fully mapped design

Species	Estimate				Sampling error[a]			
	Fully[b] mapped	Fuzz	Condition 1 only	Modified mapped	Fully mapped	Fuzz	Condition 1 only	Modified mapped
	Million cubic feet				*Percent*			
Balsam fir	2184.0	2185.6	2189.7	2184.0	3.56	3.56	3.60	3.56
Tamarack	166.9	166.9	164.9	166.9	14.97	14.97	15.17	14.97
White spruce	461.2	461.4	447.7	461.2	7.97	7.97	8.14	7.97
Black spruce	318.5	318.5	318.8	318.5	12.81	12.81	12.93	12.81
Red spruce	3166.7	3170.1	3170.1	3166.7	4.02	4.02	4.06	4.02
Red pine	63.7	63.7	64.1	63.7	27.66	27.66	27.67	27.66
White pine	2067.8	2075.0	2095.5	2067.8	6.70	6.67	7.02	6.70
N. white-cedar	1937.9	1937.9	1932.8	1937.9	5.34	5.34	5.37	5.34
Hemlock	1286.4	1301.0	1287.5	1286.4	6.27	6.29	6.39	6.27
Other softwoods	27.1	27.1	26.9	27.1	62.75	62.75	63.27	62.75
Red maple	2328.0	2333.2	2327.0	2328.0	3.21	3.21	3.26	3.21
Sugar maple	1583.5	1584.3	1573.1	1583.5	5.05	5.05	5.08	5.05
Yellow birch	940.5	941.3	940.0	940.5	4.34	4.34	4.35	4.34
Paper birch	1101.8	1104.8	1095.8	1101.8	4.73	4.72	4.75	4.73
Gray birch	67.5	68.4	67.6	67.5	11.42	11.32	11.45	11.42
Beech	928.5	935.3	921.6	928.5	5.92	5.90	5.95	5.92
White ash	327.5	332.6	326.8	327.3	8.43	8.41	8.52	8.44
Black ash	71.1	71.1	71.7	71.1	13.70	13.70	13.66	13.70
Aspen	1225.1	1226.9	1241.2	1225.1	6.70	6.69	6.75	6.70
White oaks	17.4	17.4	17.6	17.4	28.31	28.31	28.04	28.31
Red oaks	519.3	527.1	521.2	519.3	8.18	8.13	8.33	8.18
Basswood	33.7	33.7	34.4	33.7	19.87	19.87	19.73	19.87
Elm	16.9	14.0	14.5	16.9	18.63	18.24	19.01	18.63
Other hardwoods	48.7	52.1	52.5	48.7	16.02	15.42	16.28	16.02
All species	20889.7	20949.3	20903.0	20889.7	1.29	1.28	1.33	1.29

[a]Sampling errors are standard errors expressed as percent of estimate.
[b]From Table 19 in Griffith and Alerich (1996).

Table 6.—Estimates and sampling errors of net cubic-foot volume on timberland by diameter class for Maine using four procedures on data collected with a fully mapped design

Diameter class (inches)	Estimate				Sampling error[a]			
	Fully[b] mapped	Fuzz	Condition 1 only	Modified mapped	Fully mapped	Fuzz	Condition 1 only	Modified mapped
	Million cubic feet				*Percent*			
5-8.9	7761.7	7778.0	7774.7	7761.7	1.50	1.49	1.53	1.50
9-12.9	7267.8	7287.4	7286.8	7267.8	1.60	1.60	1.65	1.60
13-16.9	3591.9	3609.1	3584.0	3591.9	2.48	2.47	2.54	2.48
17-20.9	1386.0	1387.5	1384.7	1386.0	4.59	4.59	4.61	4.59
21-24.9	564.3	567.5	562.7	564.3	6.92	6.88	6.95	6.92
25-28.9	192.4	194.4	185.0	192.4	13.18	13.07	13.58	13.18
29+	125.5	125.5	125.1	125.5	20.39	20.39	20.57	20.39
All diameter classes	20889.7	20949.3	20903.0	20889.7	1.29	1.28	1.33	1.29

[a]Sampling errors are standard errors expressed as percent of estimate.
[b]From Table 19 in Griffith and Alerich (1996).

Table 7.—Cubic-foot volume of straddle plots assigned to condition 1 stand-size class from noncondition 1 class using modified mapped procedure

Condition 1 stand size	Nontimberland	Sawtimber	Poletimber	Seedling-sapling	Nonstocked	All classes
	Thousand cubic feet					
Nontimberland	0	58,487	61,542	6,155	0	126,484
Sawtimber	0	8,064	15,923	57	0	23,544
Poletimber	0	14,308	5,406	1,872	0	21,586
Seedling-sapling	0	36,745	34,048	3,952	1,810	76,555
Nonstocked	0	0	0	0	0	0
All classes	0	117,604	116,419	12,336	1,810	248,169

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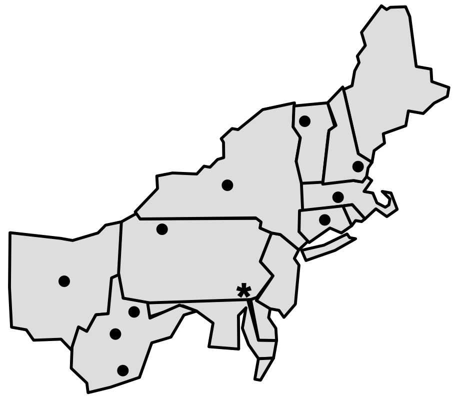
Keywords: Mapped plot design; Maine inventory; bias of estimates.



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