Resource Inventory Notes

BLM-23 July 1979

SAMPLING NATURAL RESOURCE POPULATIONS: MUTUALLY EXCLUSIVE FIXED-AREA SAMPLING UNITS

by

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ABSTRACT: The two conceptual populations of sampling units formed by dividing a physical population into a finite number of mutually exclusve (non-overlapping) fixed-area square and circular plots, respectively, were compared by examining three completely enumerated forest populations. The conceptual population of circular plots yielded a biased representation of each of the forest populations. The bias is unpredictable and depends on the spatial and size distribution and density of trees. Forest size and plot size appear to have little effect on the bias. The natural resource sampler should be aware that the bias is large for irregular forests and negligible for homogeneous forests.

INTRODUCTION

Two concepts must be kept in mind when sampling a population contained in some fixed land area using mutually exclusive fixed-area plots as sampling units (Palley and O'Regan 1961). The first is the physical population of interest-the set of physical objects such as all of the trees in a forest area. The second is the conceptual population of all sampling units obtained by dividing the fixed land area (e.g., forest) into N mutually exclusive (non-overlapping) equal-area plots. For the purposes of this paper, we will assume that the land area associated with the physical population can be divided exactly into N equal-area sampling units.

Each sampling unit has some known probability (usually 1/N) of being chosen in a random sample. The conceptual population of sampling units and associated probabilities form the fundamental probability set (FPS). Sampling from the FPS is known as probability sampling (Cochran 1965).

The conceptual population of equal-area square plots covers the entire fixed land area. Estimates of population characteristics (parameters) (e.g., basal area, number of trees, or volume per acre for forest populations) based on samples from the conceptual population are unbiased.

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Published by:
USDI, Bureau of Land Management, D 460
Denver Service Center, Denver Federal Center, Bldg. 50
Denver, Colorado, 80225

A hypothetical land area divided into 81 square-plots is shown in Figure 1. Estimates based on equal-area rectangular or triangular plots are also unbiased when they cover exactly the entire fixed land area.

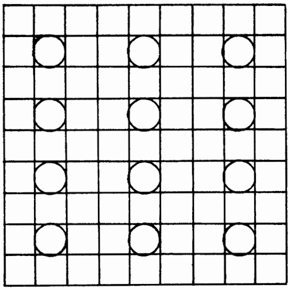


Figure 1. A hypothetical square land area divided into a population of 81 equal-area square plots. Circles inscribed inside the square plots represent a systematic sample of 12 circular plots.

Some of the forest mensurational literature appears to define the conceptual population of equal-area circular plots as all possible mutually exclusive circular plots (Brister and Schultz 1977). Estimates of population characteristics based on samples from such a conceptual population are biased since only 78.54% of the land area is covered by the mutually exclusive circular plots. This can be seen by imagining a circular plot inscribed inside each of the square plots in Figure 1. Each circular plot covers 78.54% of the area inside each square plot. Thus, 21.46% of the land area is not covered in the conceptual population.

In forest inventory, a systematic sample of circular plots is usually taken from a forest area. A systematic sample of 12 circular plots is shown in Figure 1. This type of sampling procedure is one of the reasons why many people think in terms of sampling a population of mutually exclusive circular plots.

The objective of this paper is to examine the bias associated with the conceptual populations of mutually exclusive circular plots by comparing the conceptual populations of square and circular plots for three completely enumerated rectangular forest populations.

BIAS ASSOCIATED WITH CIRCULAR PLOTS

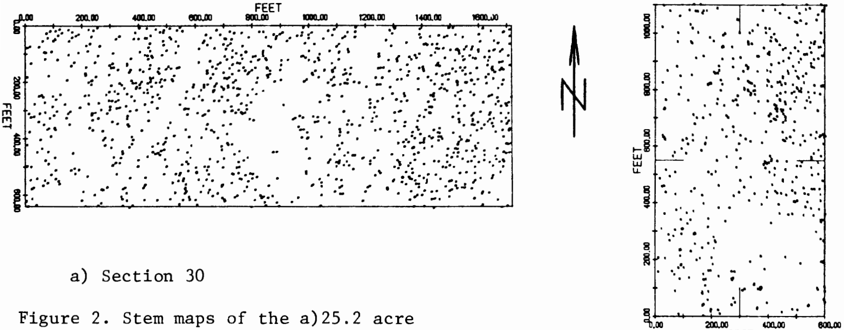
Conceptual populations of mutually exclusive square plots and circular plots inscribed inside the square plots were obtained for three completely enumerated and stem-mapped forest populations:

1. 15.2 acre (600'X 1100') rectangular eastside pine stand from the Blacks Mountain Experimental Forest located within the Lassen National Forest in northeastern California.[2/]

[2/] The data for this stand were kindly provided by Dr. William G. O'Regan, Mathematical Statistician, Pacific Southwest Forest and Range Experiment Station, Berkeley, California.

2. 3.8 acre (300'X 550') rectangular eastside pine stand that is the southwest one quarter of the 15.2 acre stand.
3. 25.2 acre (1716' X 640') rectangular eastern white pine stand located in the Ottawa National Forest (Section 30, T46N, R36W) in the western upper peninsula of Michigan.

The spatial distribution of trees in each of these forests is shown in Figure 2.



a) Section 30

b) Blacks Mountain

Figure 2. Stem maps of the a) 25.2 acre Section 30 white pine forest and b) 15.2 acre Blacks Mountain eastside pine type forest. Fiducial marks on stem map b divide the forest into four smaller quarter forests.

Conceptual populations of .025, .05, .10, .20, and .25 acre square plots were obtained from the 15.2 acre and 25.2 acre forest populations. The dimensions of each forest were reduced for each plot size so that the forest could be divided exactly into N sampling units. The dimensions of the square plots were rounded to the nearest foot. The areas of the circular plots were 78.54% of the areas of the square plots. The areas of the square and circular plots and the areas and number of square and circular plots making up the conceptual populations (N) for the two forests and five plot sizes are shown in Table 1.

Table 1. Areas of the square and circular plots and areas and conceptual population sizes (N) for the two forests and five plot sizes.

Plot Size (Acres)		Forest			
		Blacks Mountain		Section 30	
Square	Circular	Area (Acres)	N	Area (Acres)	N
.025	.020	14.85	594	24.70	988
.05	.040	14.00	276	23.73	464
.10	.079	14.40	144	23.40	234
.20	.156	13.10	66	21.44	108
.25	.195	12.42	50	23.84	96

The population means (μ_s and μ_c) and standard deviations (σ_s and σ_c) for basal area (BA) and number of trees (NOT) per acre for the conceptual populations of square and circular plots for the two forests and five plot sizes are shown in Table 2. The bias ($\mu_c-\mu_s$), the relative bias ($100(\mu_c-\mu_s)/\mu_s$), and the ratio of the two standard deviations (σ_c/σ_s) are also given in Table 2.

Since the conceptual population of square plots covers the entire forest, the population means for square plots are equal to the population means for the forests. The population means for circular plots are, of course, biased representations of the population means for the forests. The bias is variable and shows little relationship to plot size. The bias is not the same for BA and NOT for any given square plot size, but the general trends for the 5 plot sizes are similar for these two characteristics. In

Table 2. Population means and standard deviations for BA/acre and NOT/acre for the conceptual populations of square and circular plots, two forests, and five plot sizes. The bias for circular plots and the ratio of the two standard deviations are also given.

Forest	Variable	Plot Size (Acres)	Type of Plot						
			Square		Circular				
			μ_s	σ_s	μ_c	Bias	Rel. Bias(%)	σ_c	σ_c/σ_s
BLACKS MOUNTAIN	BA/ACRE	0.025	123.0	179.4	118.5	-4.5	-3.7	191.8	1.07
		0.05	117.0	117.1	127.1	10.1	8.6	141.1	1.20
		0.10	122.1	97.7	121.9	-0.2	-0.2	109.0	1.12
		0.20	117.9	68.5	116.0	-1.9	-1.6	72.6	1.06
		0.25	117.0	63.7	121.7	4.7	4.0	72.8	1.14
	NOT/ACRE	0.025	32.7	41.3	31.2	-1.5	-4.6	44.2	1.07
		0.05	30.9	31.5	32.8	1.9	6.1	35.7	1.13
		0.10	32.3	25.9	32.4	0.1	0.3	27.9	1.08
		0.20	31.4	22.8	31.5	0.1	0.3	24.7	1.08
		0.25	30.6	19.5	31.1	0.5	1.6	20.1	1.03
SECTION 30	BA/ACRE	0.025	87.3	88.5	85.6	-1.7	-1.9	98.4	1.11
		0.05	86.7	65.3	85.7	-1.0	-1.2	69.3	1.06
		0.10	86.3	49.8	87.1	0.8	.9	56.8	1.14
		0.20	86.2	36.2	84.1	-2.1	-2.4	39.2	1.08
		0.25	86.7	36.1	85.4	-1.3	-1.5	38.6	1.07
	NOT/ACRE	0.025	45.2	45.3	43.9	-1.3	-2.9	48.3	1.07
		0.05	44.8	36.2	44.5	-0.3	-0.7	37.7	1.04
		0.10	44.7	28.5	44.8	0.1	0.2	31.9	1.12
		0.20	44.2	22.0	43.5	-0.7	-1.6	23.9	1.09
		0.25	44.6	21.6	44.1	-0.5	-1.1	22.3	1.03

most cases, the relative bias of the 15.2 acre Blacks Mountain stand was larger than that of the Section 30 stand. Biases for the Blacks Mountain stand varied from 8.6% to -4.6%, and biases for the Section 30 stand varied from 0.9% to -2.9%.

The standard deviations for circular plots were, of course, larger than the standard deviations for square plots since the circular plots were only 78.54% as large as square plots. The ratio of the standard deviation for circular plots (σ_c/σ_s) varied from 1.06 to 1.20 for the Blacks Mountain stand and 1.03 to 1.14 for the Section 30 stand. Standard deviations, in general, decreased as plot size increased.

Conceptual populations of .025, .05, .10, .20, and .25 acre square plots were obtained from the 3.8 acre forest population. Conceptual populations of .031, .064, .126, .253, and .314 acre square plots were also obtained from the same forest so as to yield conceptual populations of .025, .05, .10, .20, and .25 acre circular plots. Thus, a total of 10 different square or circular plot sizes are defined. The areas of the square and circular plots and the areas and number of square and circular plots making up the conceptual populations (N) for the 3.8 acre forest and 10 plot sizes are shown in Table 3.

Table 3. Areas of the square and circular plots and areas and conceptual population sizes (N) for the 3.8 acre forest and 10 plot sizes.

Plot Size (Acres)		Forest Size		Plot Size (Acres)		Forest Size	
Square	Circular	Area (Acres)	N	Circular	Square	Area (Acres)	N
.025	.020	3.60	144	.025	.031	3.52	112
.05	.040	3.35	66	.05	.064	3.22	50
.10	.079	3.20	32	.10	.126	3.52	28
.20	.156	2.98	15	.20	.253	2.53	10
.25	.195	2.48	10	.25	.314	2.51	8

The population means and standard deviations for BA and NOT per acre for the conceptual populations of square and circular plots for the 3.8 acre forest and the 10 plot sizes are shown in Table 4. The bias, relative bias, and the ratio between the two standard deviations are also given in Table 4.

Table 4. Population means and standard deviations for BA/acre and NOT/acre for the conceptual populations of square and circular plots for the 3.8 acre forest and 10 plot sizes. The bias for circular plots and the ratio of the two standard deviations are also given.

Type of Plot	Variable	Plot Size (Acres)	Type of Plot						
			Square		Circular				
			μ_s	σ_s	μ_c	Bias	Rel. Bias(%)	σ_c	σ_c/σ_s
SQUARE	BA/ACRE	.025	143.2	219.7	139.2	-4.0	-2.8	237.3	1.08
		.05	148.9	130.1	160.0	11.1	7.5	151.8	1.17
		.10	140.5	113.3	134.4	-6.1	-4.3	136.5	1.20
		.20	154.1	60.9	137.7	-16.4	-10.6	70.7	1.16
		.25	169.0	71.4	185.2	16.2	9.6	71.0	0.99
	NOT/ACRE	.025	26.9	34.3	25.1	-1.8	-6.7	36.5	1.06
		.05	28.1	24.0	30.4	2.3	8.2	28.2	1.18
		.10	26.6	18.8	26.3	-0.3	-1.1	23.8	1.27
		.20	29.2	10.9	28.2	-1.0	-3.4	11.2	1.03
		.25	31.4	11.6	35.4	4.0	12.7	13.5	1.16
CIRCULAR	BA/ACRE	.025	141.6	197.8	165.8	24.2	17.1	243.3	1.23
		.05	143.8	131.1	141.9	-1.9	-1.3	150.3	1.15
		.10	141.6	98.8	138.3	-3.3	-2.3	111.9	1.13
		.20	165.8	69.9	181.6	15.8	9.5	69.6	1.00
		.25	157.3	63.6	165.4	8.1	5.1	67.9	1.07
	NOT/ACRE	.025	26.7	31.7	30.8	4.1	15.4	38.8	1.22
		.05	27.3	23.5	27.2	-0.1	-0.4	24.9	1.06
		.10	26.7	18.3	25.4	-1.3	-4.9	19.3	1.05
		.20	30.8	12.0	34.7	3.9	12.7	13.2	1.10
		.25	30.2	11.2	31.4	1.2	4.0	12.6	1.12

Once again, the bias related to circular plots is variable and shows little relationship to plot size. The bias is not the same for BA and NOT for the same square plot size, but the general trends for the 10 plot sizes are similar for these two characteristics. The relative biases varied from -10.6% to 12.7% for the square plot sizes of .025, .05, .10, .20, and .25 acres, and the relative biases varied from -4.9% to 17.1% for the circular plot sizes of .025, .05, .10, .20, and .25 acres.

σ_c/σ_s varied from .99 to 1.27 for the 10 plot sizes. Standard deviations, in general, were larger for circular plots inscribed inside square plots and decreased as plot size increased. Standard deviations for circular plots were not consistently higher or lower than standard deviations of the same size square plots. These differences were due to the different forest areas constructed for the same size equal and square plots (Table 3) and the juxtaposition of the conceptual populations and the forest populatio

DISCUSSION

The conceptual population of equal-area circular plots gives a biased representation of the physical population because it does not cover the entire population. For forests, this bias is variable and shows little relationship to plot size. The bias varies with forest characteristic, and forest size appears to have little effect on the bias. Bias is a function of the size and spatial distribution of trees in and the density of the forest. The bias is determined by the difference between the part of the forest that is covered by the circular plots and the part that is not covered.

The precision of circular plots inscribed inside square plots is less than that of the square plots. The difference in precision between equal size square and circular plots depends on the juxtaposition of the conceptual population and the forest population.

The natural resources sampler should be aware of the bias associated with a conceptual population of mutually exclusive equal area circular plots. This bias is unknown and unpredictable since its sign and size depend on the size and spatial distribution of trees in and the density of the forest. Such a sampling method should be used with care. If the forest is homogeneous (e.g., a plantation), the bias will be relatively small; however, if the forest is irregular (e.g., a partially cutover stand), the bias can be very large. The accuracy of a biased estimator may be compared with that of an unbiased estimator by comparing their mean square errors (Cochran 1965).

The natural resource sampler should be aware that bias due to plot shape is only one of many errors that affects the accuracy of sample estimates. Statistical sampling error, edge effect bias, and a multitude of measurement errors also affect accuracy. Measurement error may be the largest source of error in many cases.

LITERATURE CITED

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COMPUTING OPTIMUM PLOT SIZE FOR WILDLAND INVENTORIES

by

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ABSTRACT

The paper presents an example, using real data from a reconnaisance inventory of the Paraguayian Chaco, of how to compute the theoretical sample plot size that will minimize field work while meeting a given precision. This example would be of use in inventories of wildland areas, where the effect of plot size on the amount of field work is not known. The discussion following demonstrates how to use the analysis in choosing the proper plot size, while considering other factors as well.

INTRODUCTION

In wildland resource inventories, better use of available resources can be made, if we select the proper sample plot size. Often, the optimum sample plot size for a given inventory is not known, such as is the case when this forest type has never been inventoried before. In this case, the sample plot size is selected dogmatically, without concern for the population variation. This can lead to oversampling in the case of large plots, to compensate for higher statistical error, or inaccurate results in the case of very small plots, when bias due to sampling error becomes a problem. But, if a relationship between Coefficient of Variation (C.V.) and plot size for the sample population is determined, the resource manager can select the plot size which will minimize the cost of an inventory while meeting a given precision.

The following is an example of how the optimum plot size is determined, using real data from a reconaissance inventory of the "Quebrachales" in the Paraguayian Chaco,[1] and how the information can be used.

PROCEDURE

1. Coefficient of Variation

Within every sample population, there is a relation between plot size and its corresponding coefficient of variation (Wensel, 1976). This is done by

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[1] Quebrachales - forest type whose dominant species are Quebracho blanco (<u>Aspidosperma Quebracho blanco</u>) and Quebracho colorado (<u>Schinopsis balansae</u>). The latter is used as raw material for the tannin industry. The data comes from this inhouse document: "Parcelas de Muestreo en el Departamento Alto Paraguay" (Huespe, Taaffe, Periera, 1978.)

calculating the C.V. for a given plot size (for example, 0.1 hectare) and repeating this calculation for other plot sizes of the same population. Then a graph is made of C.V. versus plot size.

In our case the inventory data was taken on one hectare plots (10m x 1000m), but was grouped into tenth hectare subplots on the data sheet (10m x 100m). Plots of a tenth to one hectare were compiled to demonstrate the relationship between C.V. and plot size. At random, 10 subsamples, consisting of 10 subplots each, of 4 different plot sizes were compiled (one tenth hectare two tenth hectare, 3 tenth hectare, and five tenth hectare). Also, one subsample of 8 tenths hectare[2/] and the original data were entered into the analysis. For each of these 42 subsamples, a corresponding C.V. was calculated. Then, the curve of C.V. versus plot size was plotted on graph paper (see graph 1) and a power curve fit analysis was utilized to give the best fitting curve. In this example C.V. = 0.05 plot size $^{-0.27}$, $r^2 = 0.46$.

2. <u>Number of Necessary Plots</u>

Using this relationship, the number of necessary plots of different plot sizes that gave the same precision was computed. Suppose we accept the precision that a sample of 10 plots of one hectare each, will give (after Wensel, 1976).
the same precision, use this formula:

$$n_s = \left[\frac{C.V._s}{C.V._{\text{one hectare}}} \right]^2 \times n_{\text{one hectare}}$$

n_s = number of plots of plot size s.

$C.V._s$ = Coefficient of Variation of sample plot size s.

s = size of sample plot.

For example:

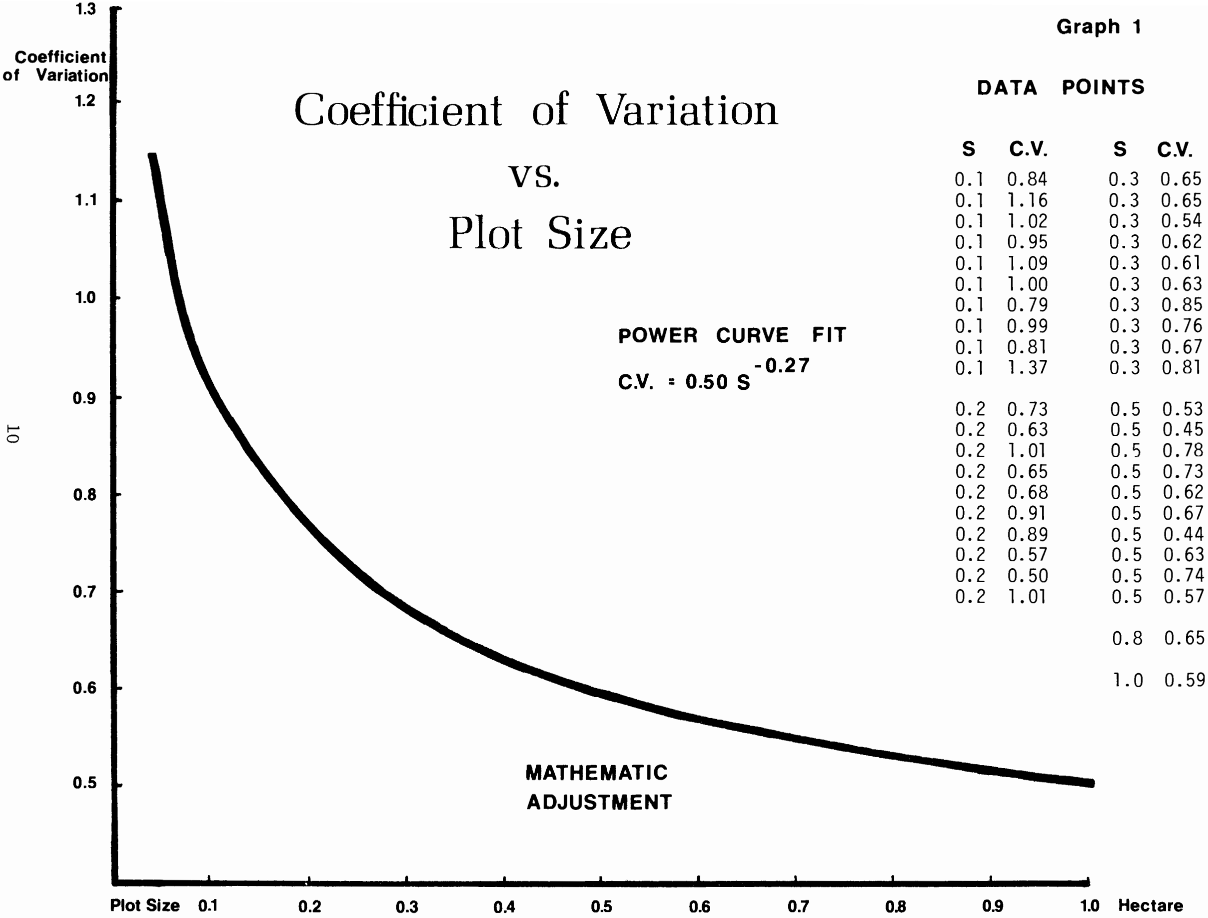
$$n_{0.1\ \text{hectare}} = \left[\frac{C.V._{0.1\ \text{hectare}}}{C.V._{1.0\ \text{hectare}}} \right]^2 \times n_{1.0\ \text{hectare}}$$

$$= \left[\frac{.93}{.50} \right]^2 \times 10 = 35 \text{ plots.}$$

[2/] More subsamples of larger plot sizes were not used, since in the original inventory, 6 plots of one hectare each were inventoried. Thus, subsamples of larger plots would give duplicating data.

Graph 1

Coefficient of Variation vs. Plot Size



DATA POINTS

S	C.V.	S	C.V.
0.1	0.84	0.3	0.65
0.1	1.16	0.3	0.65
0.1	1.02	0.3	0.54
0.1	0.95	0.3	0.62
0.1	1.09	0.3	0.61
0.1	1.00	0.3	0.63
0.1	0.79	0.3	0.85
0.1	0.99	0.3	0.76
0.1	0.81	0.3	0.67
0.1	1.37	0.3	0.81
0.2	0.73	0.5	0.53
0.2	0.63	0.5	0.45
0.2	1.01	0.5	0.78
0.2	0.65	0.5	0.73
0.2	0.68	0.5	0.62
0.2	0.91	0.5	0.67
0.2	0.89	0.5	0.44
0.2	0.57	0.5	0.63
0.2	0.50	0.5	0.74
0.2	1.01	0.5	0.57
		0.8	0.65
		1.0	0.59

x or in general form:

$$n_s = \left[\frac{C.V._s}{0.5}\right]^2 \times 10 = \left[\frac{.5\ s^{-0.27}}{.5}\right]^2 \times 10 = 10s^{-0.54}$$

To compute total area sampled for a specific plot size s:

$$\text{Area sampled}_{0.1\ \text{hectare}} = s\ (^{n}0.1\ \text{hectare})$$

$$= (0.1\ \text{hectare/plot})\ (35\ \text{plots})$$

$$= 3.5\ \text{hectare}$$

Or in general form:

$$\text{Area sampled}_s = s(n_s) = 10\ s^{0.46}$$

To summarize in tabular form:

Plot Size	C.V.	n_s	Area Sampled
1.0 hectare	0.50	10	10 hectares
0.8	0.53	11	8.8
0.5	0.60	14	7.0
0.3	0.69	19	5.7
0.2	0.77	20	4.0
0.1	0.93	35	3.5
0.05	1.12	50	2.5
0.01	1.74	121	1.2

Clearly, this shows that with smaller plots, the area necessary to sample is less. But, this analysis does not consider sampling error or a cost estimate.

3. Optimum Plot Size

The optimum plot size is the plot size that minimizes cost of the inventory while adhering to a given precision. In forest inventory there are two types of costs, fixed and variable, i.e., Total cost = Fixed cost + Variable cost. Clearly, fixed cost cannot be minimized by plot size, thus, one must try to minimize variable costs. These variable costs as a whole, have to deal with the field work, or the time spent collecting the data. So, suppose that variable costs can be defined as a function of time (i.e., variable cost - f (time)) Thus, the objective is to minimize the time spent collecting data, while collecting enough meaningful data to meet a specified precision. As with cost, time can be divided into fixed time and variable time (total time - fixed time + variable time). Fixed time is the time spent on all activities of a forest inventory other than actual field work, while variable time includes time spent in field work, such as the time spent traveling between sample plots and the time spent making the measurements on a plot. These times will vary due to plot size. Thus, to minimize cost, we must minimize variable time. This can be defined as:

$$T_v = n(bs + a)$$

Where:

T_v = variable time
b = time spent making measurements
a = time spent traveling between sample plots

Substituting for n $(n = 10s^{-0.54})$

$$T_v = 10s^{-0.54}(bs + a)$$

$$= 10\,bs^{0.46} + 10as^{-0.54}$$

To minimize the function, take its first derivative.

$$\frac{dT_v}{ds} = 4.6\,bs^{-0.54} - 5.4\,as^{-1.54}$$

Set it equal to zero.

$$0 = 4.6\,bs^{-0.54} - 5.4as^{-1.54}$$

Solve for s.

$$s = \frac{5.4\,a}{4.6\,b}$$

From inventory experience in the Chaco, with one hectare plots,[3] estimates for "a" and "b are one hour and eight hours, respectively.

Thus, $s = \frac{5.4\,a}{4.6\,b} = \frac{5.4\ (1)}{4.6\ (8)} = 0.15$ hectare

Or the optimum plot size, with these given parameters, is between a tenth and two-tenths hectares. (See graph 2.)

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[3] At this point, estimates for "a" and "b" must be in terms of one hectare plots, since n was defined in terms of a one hectare plot.

DISCUSSION

The example shows that a better plot size for the Quebrachales would be between 0.1 hectare and 0.2 hectares. The the inventory used 1.0 hectare plots instead, and we had to accept an error of the estimate of greater than 50%. (Error of the estimate - $\frac{C.V. \times t}{n} = \frac{.5 \times 2.6}{6} = 52\%$).

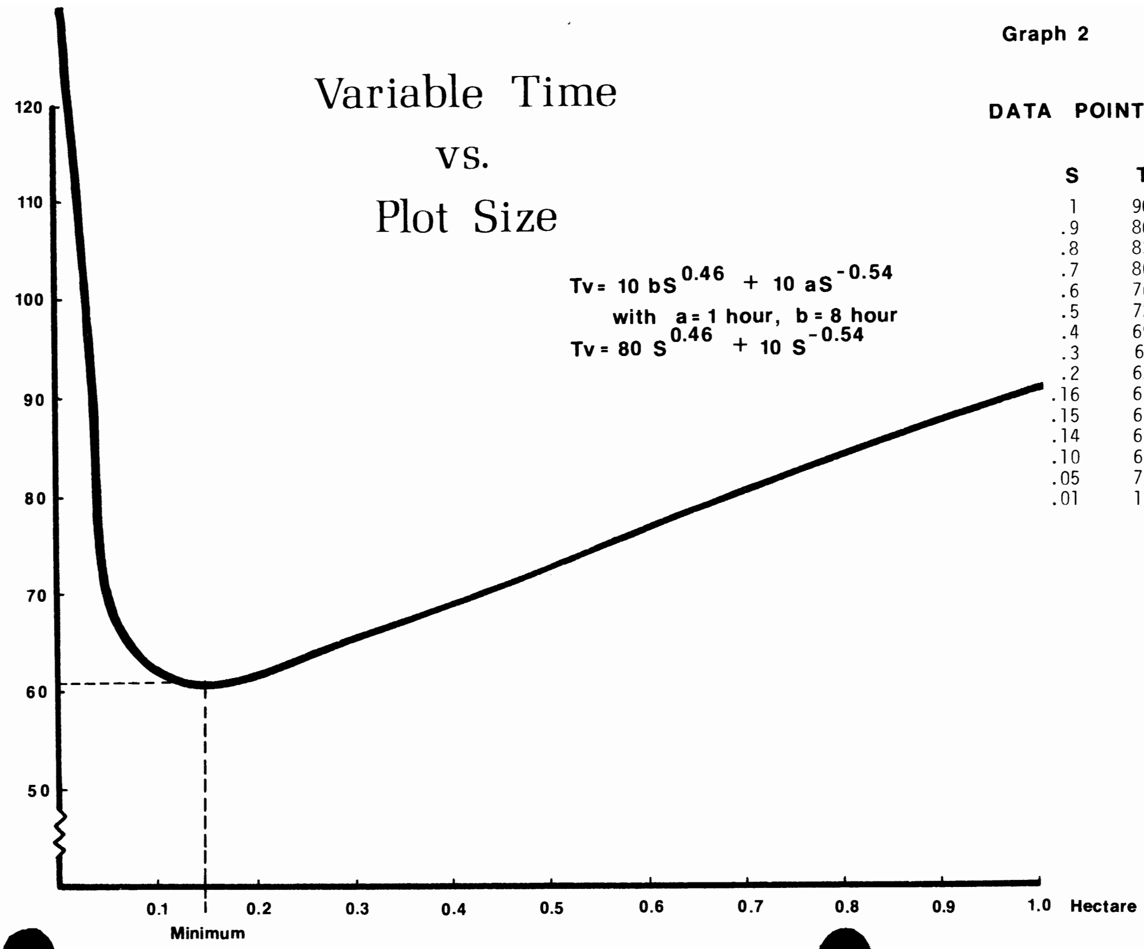
But suppose that we had used a sample plot of 0.2 hectares, and we had the same amount of time in which to do the field work as the original inventory, or time enough to take 6, 1.0 hectare plots. From field estimates, it took 8 hours to take measurements on a 1.0 hectare plot and one hour traveling time between plots. Thus, the total time in actual field work was 54 hours. (8 hours, 1 hour) 6 plots - 54 hours. Now assume that to measure a 0.2 hectare plot, it takes 20% of the time to measure a hectare plot. Thus, the time spent making the measurements on a 0.2 hectare plot would be 1.6 hours. Let's assume that the time spent between plots is the same (i.e., 1 hour), so to measure one 0.2 hectare plot and get to the next takes 2.6 hours. Dividing the number of hours theorectically spent taking a 0.2 hectare plot into the 54 hours available for field work allows us about 20, 0.2 hectare sample plots. Let's now determine the error of the estimate of a 0.2 hectare plot with 20 sample plots. Error of the estimate = $\frac{C.V. \times t}{n} = \frac{0.77 \times 2}{20} = 34\%$. This is within the acceptable range (30 to 40% error) for reconnaisance inventories. Thus, we could have gotten results within the acceptable range by using a more optimum sample size.

But a more important use of this procedure, is what Graph 2 shows us. Here, we have actual time values for the field work versus plot size. The resource manager can see whether the amount of field work is dependent on plot size, to what extent, and what plot size theoretically minimizes field work.

Obviously, there are other factors which determine the optimum use of available resources in a forest inventory. Available manpower, vehicles, work day, etc., could make a plot size other than the optimum more economical to use. For instance, suppose in our case that there is only one vehicle, which serves several inventory parties. Then the plot size should be of such a size that an inventory party does not have to be moved often during a day. A party should be dropped off in one area, or at most, two areas a day. Thus, a large plot size of a half to a full hectare would have to be used and not our theoretically optimum 0.15 hectare plot. Now by looking at graph 2, we can compare the extra field work necessary to use larger plots. For example, we see that the variable time value for a one hectare plot is 90, the Tv value for a 0.5 hectare plot is 73, and the minimum Tv value is 61 for a 0.15 hectare plot. Thus, to use a one hectare plot, we must perform almost 50% more field work ($\frac{Tv\ 1\ hectare}{Tv\ minimum} = 90/61 = 48\%$) than with our optimum plot size of 0.15 hectares, to meet the same precision. And to use a 0.5 hectare plot, we must perform about 20% more field work ($\frac{Tv\ 0.5\ hectare}{Tv\ minimum} = \frac{73}{61} = 20\%$).

Graph 2

Variable Time
vs.
Plot Size



$$T_v = 10\,bS^{0.46} + 10\,aS^{-0.54}$$

with a = 1 hour, b = 8 hour

$$T_v = 80\,S^{0.46} + 10\,S^{-0.54}$$

DATA POINTS

S	Tv
1	90.0
.9	86.8
.8	83.3
.7	80.0
.6	76.4
.5	72.7
.4	69.1
.3	65.1
.2	62.0
.16	61.3
.15	61.3
.14	61.3
.10	61.4
.05	70.6
.01	129.8

Accordingly, if the choice of plot sizes was between a half hectare and a one hectare plot, we would choose to use a half hectare plot. Thus, the resource manager can see the effect plot size has on the use of available resources and toward what size plot he should tend to optimize the use of these resources.

SUMMARY

This paper presents an example of how the optimum plot size for a wildland inventory can be calculated, using real data from a reconnaisance inventory of the Paraguayian Chaco. The analysis uses a derived relationship between coefficient of variation and plot size whcih, in this example, is C.V. $= 0.05\ s^{-0.27}$, with $r^2 = 0.46$. Then substituting this equation into a theoretical formula for variable time, $(TV = n\ (bs\ a))$ an equation for Tv was determined as $Tv = 10bs^{0.46}\ 10as^{-0.54}$. Next taking its first derivative, and setting $\frac{dTv}{ds}$ equal to zero, the plot size which for a given precision minimizes time spent in field work, was determined. This plot size is $s = \frac{5.4a}{4.6b}$. From inventory experience values of one hour and eight hours respectively were estimated for "a" and "b". Thus, the optimum plot size for this forest type is 0.15 hectares.

In the preceding discussion, the author has shown how more precise estimates of the population are obtained by using optimum plot size. Also, it has been shown how this procedure, especially the graph of variable time versus plot size, can be valuable in determining the optimum use of available resources in a wildland inventory.

LITERATURE CITED

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1978. Parcelas de Muestreo en el Departamento Alto Paraguay. In-house document, Servicio Forestal Nacional del Paraguay.

HUSCH, MILLER, BEERS
1963. Forest Mensuration. Second Edition. The Ronald Press Company, New York. p. 204-206.

WENSEL, LEE C.
1976. Wildland Resource Sampling. Draft Copy. p. 41-43.

THE SATELLITE PROGRAM IN STATISTICAL ECOLOGY

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The Pennsylvania State University, University Park, Pennsylvania USA

INTRODUCTION AND SUMMARY

The Second International Congress of Ecology was held in Jerusalem, Israel, during September 1978. A Satellite Program in Statistical Ecology was planned in this connection by the International Statistical Ecology Program. The emphasis was on research, review, and exposition concerned with creative interface between quantitative ecology and relevant quantitative methods. The emphasis was on both theory and application, coupled with synthesis of both ecological and methodological aspects of the problem. The program consisted of instructional coursework, seminar series, thematic research conferences, and collaborative research workshops in the modern setting.

The 1977 and 1978 Satellite Program in Statistical Ecology consisted of NATO Advanced Study Institutes at College Station, Berkeley, and Parma; NATO Advanced Research Institute at Parma; ISEP Research Conferences, Seminars, and Workshops at College Station, Berkeley, Parma, and Jerusalem; and Research Conference at the Second International Ecological Congress at Jerusalem.

The Satellite Program in Statistical Ecology has been supported by Army Research Office, USA; Commission of the European Communities, Belgium; Environmental Protection Agency, USA; Fish and Wildlife Service, USA; Italian Society of Ecology, Italy; National Marine Fisheries Service, USA; National Research Council, Italy; NATO Advanced Study Institutes Program; NATO Ecosciences Program; The University of Parma; The Pennsylvania State University; The Texas A&M University; The University of California at Berkeley; and the Participants and their home institutions and organizations.

Carefully refereed and edited research-review-expositions and research papers have been specially prepared for the program by concerned experts and expositors. These valuable materials have been processed for publication in a series of volumes to appear in mid 1979.

SCIENTIFIC CONTENT, COORDINATION, AND PUBLICATION

The following summary information on the subjects and corresponding coordinators and co-editors of the satellite program may be of interest here in the following format. The details of each subject content and its publication volume will be reported later or can be available now from the program headquarters.

1. SCIENTIFIC MODELING AND QUANTITATIVE THINKING WITH EXAMPLES IN ECOLOGY, edited by G. P. Patil, D. Simberloff and D. Solomon.

2. STATISTICAL DISTRIBUTIONS IN ECOLOGICAL WORK, edited by J. K. Ord, G. P. Patil and C. Taillie.

3. SPATIAL AND TEMPORAL ANALYSIS IN ECOLOGY, edited by R. M. Cormack and J. K. Ord.
4. QUANTITATIVE POPULATION DYNAMICS, edited by D. G. Chapman, V. Gallucci, and F. M. Williams.
5. SAMPLING BIOLOGICAL POPULATIONS, edited by R. M. Cormack, G. P. Patil, and D. S. Robson.
6. ECOLOGICAL DIVERSITY IN THEORY AND PRACTICE, edited by F. Grassle, G. P. Patil, W. Smith and C. Taillie.
7. MULTIVARIATE METHODS IN ECOLOGICAL WORK, edited by L. Orloci, C. R. Rao, and W. M. Stiteler.
8. SYSTEMS ANALYSIS OF ECOSYSTEMS, edited by George Innis and R. V. O'Neill.
9. COMPARTMENTAL ANALYSIS OF ECOSYSTEM MODELS, edited by James H. Matis, Bernard C. Patten, and Gary C. White.
10. ENVIRONMENTAL BIOMONITORING, ASSESSMENT, PREDICTION, AND MANAGEMENT - CERTAIN CASE STUDIES AND RELATED QUANTITATIVE ISSUES, edited by J. Cairns, G. P. Patil and W. E. Waters.
11. CONTEMPORARY QUANTITATIVE ECOLOGY AND RELATED ECOMETRICS, edited by G. P. Patil and M. Rosenzweig.
12. ANALYSIS WITH STANDARD CONTAGIOUS DISTRIBUTIONS, by J. B. Douglas.

Two more subjects were organized in the program.

1. CONCEPTUAL FOUNDATIONS OF ECOLOGICAL THEORY AND APPLICATIONS.
2. OPTIMIZATIONS IN ECOLOGICAL THEORY AND MANAGEMENT.

It would be fruitful to reorganize these subjects and add a few more for the next satellite program.

For purposes of convenience at this time, the Proceedings are formulated in twelve volumes in the Statistical Ecology Series published by the International Co-operative Publishing House, Fairland, Maryland. Altogether, they consist of estimated 4,000 pages of research, review, and exposition, in addition to a common preface in each followed by individual volume introductions. Subject indexes are also prepared at the end.

CONCLUDING REMARKS

The satellite-like-programs help create and sustain enthusiasm, inward strength, and working efficiency of those who desire to meet a contemporary social need in the form of some interdisciplinary work. It should be only proper and rewarding for everyone involved that such programs are planned from time to time.

Comments, suggestions, and further inquiries on the program and its publications may be sent to: Dr. G. P. Patil, Chairman, International Statistical Ecology Program, 318 Pond Laboratory, University Park, PA, 16802, USA.

* * * * *

ERRATUM.

The following corrections should be made in Resource Inventory Notes BLM 20 in the article by Chevrou.

Page 4.

Second line should read: $CV\ (\hat{S})\ \% = 50\ p^{0.5}\ N^{-0.75}$

Fourth line should read:

and $\hat{S}$ its estimation ($S = Na^2$. a = distance between dots), N number of dots in

Last line formula (22) should read:

uniformly distributed in (0,1).

Page 5.

Formula (31) should read:

$$(31)\quad E(2n) = \frac{2L}{\pi a} = 4p \sqrt{\frac{b}{a}}\ \frac{1}{\sqrt{\pi}}\ \sqrt{N}$$

Formula (51) should read:

$$(51)\quad E(\mathrm{Var.}\ \hat{S}) = 2\ a^2\ b^2\ p \frac{1}{\sqrt{\pi}}\ \sqrt{N} \left[\frac{1}{6\sqrt{u}} + g\ (n)\ \sqrt{u^3} \right]$$

Formulas (61) and (62) should read:

$$(61)\quad \hat{S} = Na^2 \text{ and } E(\hat{S}) = S$$

$$(62)\quad \mathrm{Var}\ \hat{S} = \frac{4}{9\sqrt{\pi}}\ pa^4 \sqrt{N} \text{ or } = \mathrm{Var}\ \hat{S} = \frac{2}{9\ \pi}\ a^3\ L = \frac{2}{9}\ na^4$$

Formula (64) should read:

$$(64)\quad \log CV\ (S)\% = 1.70 + 0.5 \log p - 0.75 \log N,$$ to be compared to Zöhrer's formula (1979).

Page 6 line 2 should read:

$$\hat{S} = Na^2 \simeq (N_1 + \frac{N_2}{2})\ a^2 \text{ and } E(\hat{S}) = S$$

▽▽▽▽▽▽▽▽

Current Literature

Please order directly from sources given.

General

Report 0-X-275. "Sample Size Estimation Made Easy" from Information Office, Great Lakes Forest Research Ctr., Canadian Forestry Service, Dept. of Environment, Box 490, Sault Ste. Marie, Ont., P6A 5M7, Canada.

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Misc. Series No. 45 "Users Guide to PRCLUSTR - Cluster Analysis of Comparison Rankings." Available from Idaho Agric. Exp. Sta., Univ. of Idaho, College of Agriculture, Moscow, ID., 83843.

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Res. Note PSW - 329. "Herbs and Brush on California Fir Regeneration Sites: A Species and Frequency Sampling," from Information Service, PSW Forest and Range Exp. Stn., P. O. Box 245, Berkeley, CA., 94701.

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Environmental Assessment and Land Use Planning

"The Impact of Pipeline Construction on Stream and Wetland Environments." From Office of Policy, Michigan Public Service Commission, 6545 Mercantile Way, Lansing, MI., 48910. Price is $6.00.

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Research Report PSW-30. Mystic Mountain: An Educational Alternative Futures Wildland Planning Game"

Reprint: "Forest Environmental Impact Analysis - A New Approach" by Thor Chal.

Both from Information Service, PSW Forest and Range Exp. Sta., P.O. Box 245, Berkeley, CA., 94701.

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Forestry

Res. Paper No. 43. "A Guide to Urban Tree Inventory Systems" by Sacksteder and Gerhold. Available from Urban Forestry Specialist, USDA Forest Service, State and Private Forestry, P. O. Box 2417, Washington, D.C., 20013.

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"A Guide to Canadian Forest Inventory" Reprint "The Error of Area Estimates from Dot Grids". FMR X-122 "Pilot Study for Canadian Forest Resource Data System" from Petawa National Forestry Institute, Brunswick Bldg., 3rd Floor, 240 Bank St., Ottawa, Ont., K1G 3Z6 Canada.

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FO:DP/BRA/76/027. Technical Report No. 8 "Forestry Development and Research - BRAZIL - Inventories for Amazonian Forestry Development". Contact Forest Resource Div., Food and Agr., Org. of the UN, Via Delle Terme di Caracalla, 00100 - Rome, Italy for availability.

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Research Report P-775 "Application of Timber RAM and ECHO - an Oklahoma Example" from Agricultural Experiment Station, Oklahoma State Univ., Stillwater, OK. 74074.

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Reprint: "Assessment of Forest Resources for Forest Management" by Aarne Nyyssonen

and

ACTA Forestalla Fennica. Vol. 163, 178 "Estimation of Stand Increment" (English Summary)

are available from University of Helsinki, Inst. of Forest Mensuration and Management, Unioninkatu 40B, Helsinki, Finland.

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Land Classification

Canada Committee on Ecological (Biophysical) Land Classification. 1979. Canada's Northlands (Second Edition). Proceedings of a Technical Workshop -- To develop an integrated approach to base data inventories for Canada's Northlands, 17-19 April 1974, Toronto, Ontario. Compiled and edited by M. J. Romaine and G. R. Ironside. Ecological Land Classification Series, No. 0, Lands Directorate, Environment Canada, Ottawa. 124 p. Cat. No.: EN 73-3/0. Available free of charge from: Ecological Land Classification Series, Lands Directorate, Environment Canada, 20th Floor, Place Vincent Massey, Ottawa, Ontario, Canada, K1A OE7.

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Canada Committee on Ecological (Biophysical) Land Classification. 1979. Applications of Ecological (Biophysical) Land Classification in Canada: Proceedings of the Second Meeting of the Can.Comm. on Ecol. (Biophys.) Land Classif., 4-7 April 1978, Victoria, B.C. Comp. and ed. by C.D.A. Rubec. Ecological Land Classification Series, No. 7, Lands Directorate, Environment Canada, Ottawa. 396 p. Cat. No.: EN73-3/7. Available by mail from: Printing and Publishing, Supply and Services Canada, Ottawa, Ontario. K1A OS9. Price $7.00 (Canada); $8.40 (other countries).

Remote Sensing

"Remote Sensing and Image Interpretation" by Lillesand and Kiefer. A new text to be published June 15, 1979, by John Wiley and Sons, Inc., 605 3rd Ave., New York, NY 10016. The tenative price for the 640 paged book is $24.95.

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Meetings

1979 Forest Inventory Workshop. This workshop is designed to appeal to land managers, inventory specialists, practitioners, data analysts and biometricians. This national meeting is sponsored by the SAF Inventory and Biometrics Working Groups, IUFRO Subject Groups S4.02 and S6.02 and by Colorado State University. Over 84 papers will deal with such subjects as Multi-Resource inventories, Biometrics, Inventory Projection and Growth, Inventories on Successive Occasions, Sampling Techniques, Sampling Aspects of Aerial Photography, Computer Uses in Resource Inventories, Tropical Inventories, Biomass Measurement, Biomass Inventory, Metric Conversion Strategies, Product Estimation and a series of contributed papers. Registration fee $75. The dates are July 23-27, 1979, at Colorado State University. For details contact Office of Conference and Institutes, Residential Conference Center, Colorado State University, Fort Collins, Colorado, 80523.

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Soil Conservation Society of America Annual Meeting. July 29 - August 1, Ottawa, Ontario. Theme "Resource-Constrained Economics: The North American Dilemma". Contact SCSA 7515 N.E. Ankeny Rd., Ankey, IA. 50021.

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A Symposium on "Remote Sensing for Natural Resources -- An International View of Problems, Promises and Accomplishments". Sponsored by IUFRO, Society of American Foresters (Remote Sensing WG), American Society of Photogrammetry, and Geological Society of America. September 10-14, 1979, at the University of Idaho, Moscow, Idaho. Papers will be presented by 40 International leaders in remote sensing of natural resources. One day is reserved for tours, one of which is a jet boat trip up the Snake River. For more information, write or call: Continuing Education, University of Idaho, Moscow, Idaho, 83843. Ph (208) 885-6486.

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The Midwest Mensuration Meeting will be held at Atwood Lake Lodge Resort, Dellroy, Ohio, October 3-5, 1979. Space will be limited. Those wanting to attend should contact Martin Dale or Don Hilt at USFS Northeastern Forest Exp. Stn., P.O. Box 365, Delaware, OH 43015 or call (614) 369-4471.

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Coming in 1980! Arid Land Resource Inventories. Nov. 30 - Dec. 6. Sponsored by the Mexican Forest Service, SAF Inventory Working Group, IUFRO Subject Group S4.02, the U. S. Forest Service and the Bureau of Land Management. The tenative topics to be discussed include inventory planning, classification schemes, economical mapping system, cost efficient sampling and measurement techniques and resource data anaylsis systems. Watch the Notes for further developments.

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Also coming in 1980 - The 14th International Congress of the International Society of Photogrammetry to be held in Hamburg, Germany. For additional information write The Secretariate, ISP Congress 1980, c/o Hamburg Messe and Congress GmbH, Congress - Organization, P.O. Box 30 23 60, D-2000 Hamburg 36, Federal Republic of Germany.

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Wanted! Lead articles, current literature and meeting announcements for publishing in the "Notes". If announcing a meeting, please allow at least a four month lag time.

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