Resource Inventory Notes

BLM 13 Sept. 1978

Inplace, Multiple Resource Inventories at Budget Prices [1/]

by

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I. Introduction

There is a wealth of resources on the lands we (the public agencies) administer and/or manage. Each resource specialist requires a set of information for management of the resource. Management must have accurate information in order to make intelligent decisions concerning the use, manipulation, etc., of those resources. Inventories collecting the data for these resource activities (such as forestry, range, wildlife) are often conducted separately.

While the management of each activity has individual information requirements, they also have much in common. Because management decisions are often based on evaluation of trade-offs between resources, a data base capitalizing on the commonality of information between resources is highly desirable, if not an absolute necessity. Such a data base may be built through multi-resource and multi-purpose inventories.

II. Levels of Inventories

There are several degrees or levels of inventories. For purposes of discussion, however, we'll only consider two--extensive or broad based inventories and intensive or inplace inventories.

Extensive inventories are usually used for general program development. Tables and reports are the general outputs. They have the advantage of being very low cost and fast to conduct. Because they employ sampling, large areas are covered with relatively few field samples. The cost per acre usually is below 10¢. The disadvantage of extensive inventories is they generally do not provide the location - specific information that the manager needs for day-to-day work.

1/ Paper presented at the SAF Mile-Hi Chapter Meeting, October 1977.

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Intensive inventories, on the other hand, do provide the inplace data the manager requires. Vegetative type maps and summary tables are the primary products. These types of inventories are very costly to conduct and require large amounts of manpower to cover large areas. Costs of $2-7/acre are common.

The ideal inventory would be one that rapidly provides inplace data at a low cost. Therefore, we need to design a multiple resource inventory that produces location maps and employs a type of sampling that keeps costs to a minimum.

Before designing any inventory system, it is necessary to spell out in detail, the objectives, the products, the precision and the data required. After this is done, we can commence designing a sampling system.

III. Definitions

A. Inventory Unit

The first step in building our ideal system is to define our inventory unit. This inventory unit is an area delineated on a map which outlines the area and population(s) to be sampled. Generally speaking the inventory unit boundary should correspond with some piece of terrain upon which management decisions, plans or programs are normally based. Usually this is some type of administrative unit such as a Ranger District in the USDA Forest Service or a Planning Unit in the USDI Bureau of Land Management.

B. Sampling Frame

The next step is to divide our inventory unit into sampling units. These units must cover the whole inventory. They must not overlap in the sense that every element in the population (inventory unit) belongs to one and only one sampling unit (Cochran, 1963). The construction of the list of sampling units is called the sampling frame.

As we want to provide the manager with the location of the resources, the frame will consist of mapped areas of terrain. Most of our resources are related to vegetation; therefore the mapping units will also depict various aspects of vegetation. Since vegetation is generally directly related to soil, soil mapping units can also be overlayed.

Our sampling frame will therefore consist of mapped vegetation and soil sampling units. Generally 10 acres (4.05 Hectare) units are adequate for most of our management needs. To keep our cost to a minimum, the mapping may be done primarily through photo interpretation.

C. Sampling Frame Data Base

To keep costs to a minimum, these sample units or cells will be mapped and constructed from remote sensing (generally aerial photography).

To have the greatest utility, one should endeavor to extract as much information about each sample unit from the imagery. This should include estimates of the type, height, density and crown diameter of the vegetation, as well as information about the terrain such as aspect, slope, elevation physiography. Also to be included in this data base would be locational information such as the coordinates of the center of each sampling unit and/or digitized boundaries as well as some type of identifier.

IV. Sampling Methods

Much data that will be required by the manager can only be obtained in the field. Again to keep costs to a minimum, we'll use some type of sampling design to collect this data. If we did not use some type of sampling, we'd be back to the high costs of the intensive inventories. When we do use sampling, we are giving up some of the information that we normally would obtain through a 100% enumeration, i.e. - not all sample units will have data that was measured in the field.

There are many different ways of selecting which map cells will be sampled in the field. The more common methods include (1) random, (2) systematic or (3) stratified sampling or combinations thereof.

1. Simple random sampling consists essentially of indiscriminately selecting cells. One method of random sampling would be to number all cells from 1 to 10, put the numbers in a hat and draw out a sample. The random selection is the purest form of sampling but has the disadvantage of not assuring a good distribution of field plots throughout the inventory unit. Because too much is left up to chance, the simple random sample is seldom used.

2. In systematic sampling, sample cells are selected for measurement based on a predetermined spacing between cells. Field measurements for example may be taken at points located at every half mile across the inventory unit. This provides good distribution but one may end up oversampling some types of cells and undersampling others.

3. Stratified sampling is one of the more common methods used in resource inventories. Cells are grouped into like categories (called strata) and then cells within each stratum are either randomly or systematically selected for field measurement. Every cell must fall into a strata and each cell can only fall into one strata. Stratified sampling creates good dispersion throughout the inventory unit and also forces samples to be selected within areas of prime interest.

Generally speaking, stratified sampling for forestry is usually twice as efficient as systematic sampling - this means that we can get as precise information using only half the number of field plots using stratified sampling as we would get if we used systematic sampling (MacLean 1972).

Whatever selection method is used, it is important that it is not biased. Biased selection of sample units seriously limits what can be "legally" said of the population as a whole.

V. Expanding the Data

When using sampling techniques, only a small portion of the sampling frame will be visited and measured in the field. Most of the sampling frame will not have field measurements attached to each sample unit. Therefore, some way of assigning field data to each sample unit is needed. Assuming a stratified sample is used, we can use either of three procedures for assigning values to the "non-visited" sample units.

1. Assign each the mean values from all the field samples.

2. Assign each the mean values from all the field samples within the strata.

3. Develop correlations between the photo interpreted variables and field variables; then assign predicted field values to each non-measured sample unit.

Each of the above has its merits and limitations, but each progressively accounts for more variation associated with specific types of sample units. If meaningful correlations cannot be developed, the only course of action would be to fall back on the next broader level (i.e. using stratum means, etc.).

VI. Steps in Ideal System

First of all, assuming objectives have been clearly stated, we need to establish the sampling frame. Our sampling frame, as mentioned earlier, is going to consist of mapped pieces of terrain showing differences in soil and vegetation, such as a forest type map. To keep cost to a minimum, this mapping may be done directly from photo interpretation.

A. Photo Interpretation. As the mapping is done, quantitative information about the appearance of the vegetation and soil should be recorded on a photo record. This may include, but is not limited to, vegetation height, cover, crown diameter and type.

The homogeneous areas delineated on the photos are numbered for identification purposes. These site delineations are transferred to orthophoto quads and/or topgraphic maps where additional data is extracted such as aspect, slope, elevation, landform, and acreage of site.

This recorded information is edited and stored on a computer photo file for use in developing sampling strata, regression equations and predicted values.

If access to a digitizer is available, the mapped sites can be digitized for later automated mapping.

B. Stratification. After all mapping and intepretation is completed, we need to sort our photo file (sampling frame) into relative homogeneous listings. The strata may be formed for each resource separately or for combinations of closely related resources. The strata formed should:

1. be logically related to items of information sought

2. exist either naturally or artifically

3. represent a relatively homogenous condition defined in specific terms.

4. represent a grouping that is meaningful to the manager and that he definitely wants sampled.

Each and every site must fall into one and only one sampling strata for each resource or combination of resources.

Once the sites are grouped into sampling strata the next step is to determine the sampling intensity and select sites for field measurement for each resource or combination of resources.

C. Site Selection. If a multi-resource inventory is being conducted, several related resource values pertaining to forestry, range, wildlife etc. will be measured on all sample sites.

However, if there are varying needs between resources, then perphaps only some data needs to be collected on some of the sampled sites. If this is the case, then some efficiency can be gained by selecting samples from the stratified sites for the resources requiring the least intensity first then forcing these sites as sampled sites for each progressively intense resource.

For example - watershed might stratify the sites within an inventory unit into two categories--vegetated and non-vegetated. Perhaps only two vegetated sites and four non-vegetated sites need to be sampled to meet watershed needs.

Forestry may require the vegetated sites be broken down into forested area and non-forested areas. Perhaps four samples need to be measured in each of the forestry strata. If the 2 watershed sample sites both fell within the forested stratum then these 2 sites would be part of the 4 forestry samples.

If no more resources are involved, the watershed and forestry plots would be established on 2 sites, forestry plots only on 4 sites and 2 watershed plots established on the non-vegetated area.

We eventually have a series of single purpose inventories being conducted from a common sampling frame while collecting multi-resource data only where needed.

D. Field Measurements. Field measurements on the sampled sites would be taken according to standard methodology for each resource. In areas where more than one resource is being measured, field procedures should be streamlined to reduce any redundancy. If possible multi-resource data should be measured at the same places on the ground to develop correlations. The forcing of samples illustrated above will help insure multi-use data being collected at the same locations.

The field data is of course, recorded on an input form edited and stored on a master file along with the photo data for each sample site.

E. Data Analysis and Computations. After all field work is completed, data is transformed into usable information. Summary tables are developed to present the inventory data. There are many programs such as FINSYS (Barnard 1978) available for generating reports.

After all normal calculations are finished, we still only have summaries for the inventory unit as a whole. We do not at this point have the site by site information. Our next step is to build regression equations which correlate field data with corresponding photo data. If significant correlations exist then we can build prediction equations to assign field values to sites not visited in the field (Lund 1974).

If significant correlations do not exist, then one can fall back on the stratum means.

Once the prediction equations and/or structure means are developed, it is a simple matter to run the photo file through the equations and assign "field" values for each site.

F. Mapping. The final step in our "ideal" inventory would be to merge the photo file and predicted values with the digitized site boundaries to produce crude computer generated maps. The maps could display any of the data or combinations of data on the files.

VII. Summary

The procedures outlined above takes advantage of the speed and low cost of the extensive inventory and the inplace utility of mapped areas for intensive inventories. Portions of this system have been successfully tested by the Bureau of Land Management (Lund 1975 and 1977). The system described above will provide a replacement for or a simulation of an in-place inventory at budget prices.

It should be pointed out that no inventory system is universal nor will provide all the information needed for all situations. The system described in this paper uses the advantages of several types of inventories. At best it will provide a firm resource foundation and a means of prioritizing areas where additional inventories are needed.

Literature Cited

Cochran, William G.
1963. Sampling Techniques. 2nd edition. John Wiley & Sons, Inc. New York, NY. 413 p.

Barnard, Joseph E.
1978. FINSYS - A Tool for the Processing of Integrated Resource Inventory Data. In Integrated Inventories of Renewable Natural Resources: Proceedings of the Workshop. USDA For. Serv. Gen. Tech. Report RM-55. p. 332-335.

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1975. Multiple-Resource Inventory System. In. Proc. Systems Analysis and Forest Resource Management. Athens, Georgia. p. 433-441.

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1977. Field Trip Report, Las Cruces, New Mexico. DSC 1382-2, dated 11 Nov. 1977. 7p.

MacLean, Colin D.
1972. Photo Stratification Improves Northwest Timber Volume Estimates. USDA For. Serv. Res. Paper PNW 150. 10p.

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SAMPLING FOR WEIGHT IN APPALACHIAN HARDWOODS 2/

by

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ABSTRACT: The standard deviations of per-acre dry weights of mixed Appalachian hardwoods were approximately proportional to basal areas determined by point sampling, indicating the possible usefulness of a double sampling scheme with a mean-of-ratios estimator for weight estimations.

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Weight tables have recently been developed for the major timber species in northern West Virginia, facilitating the prediction of weights using dbh along (Wiant et al. 1977). Using those tables, per-acre estimates of total dry weight, excluding leaves, stumps, and roots, were determined for 397 point samples (BAF 10) on a 36-year-old mixed hardwood stand near Morgantown, West Virginia. Sawtimber volume is 52% oak, 21% yellow-poplar, 10% black cherry, 6% hickory, and 8% miscellaneous species. Oak site index averages 73.

An examination of standard deviations of weights (Y) by basal area classes (X) in Table 1 indicates standard deviations tend to be approximately proportional to X, as is appropriate in the mean-of-ratios estimator of the form: $Y = \frac{1}{n}\left(\Sigma \frac{Y}{X}\right)X.$ Standard deviations were less strongly proportional to the square root of X, as appropriate in the ratio-of-means estimator of the form: $Y = \left(\frac{\bar{y}}{\bar{x}}\right) X;$ and are obviously not constant for all values of X, as assumed in using linear regression of the form: $Y = a + bX$ (Freese 1962). For these estimators a straight-line fit is appropriate; this was indicated by a linear regression of Y on X (r = 0.88; d.f. = 395). Also, the ratio estimators are appropriate if the line passes through the origin, a hypothesis accepted (t = 1.88, d.f. = 395) using the test suggested by Snedecor and Cochran (1967).

These results indicate, at least for hardwood stands similar to the one studied here, and possibly in many stands, that a double sampling scheme for weight estimations, measuring basal area (X) on a large number of point samples and weight (Y) on a smaller randomly selected subsample, using the mean-of-ratios estimate might be useful.

2/ Published as West Virginia University Agricultural Experiment Station Scientific Paper 1516.

Table 1. Statistics for per-acre estimates of dry weight (lbs.) by basal area classes.

Square feet of basal area per acre (X)	Number of point samples	For per-acre dry weights (Y) Standard deviation (S)	S/X	$S/\sqrt{X}$
20	10	4370	219	977
30	15	7512	250	1371
40	15	8124	203	1285
50	30	14212	284	2010
60	32	15360	256	1983
70	42	17096	244	2043
80	49	14610	183	1633
90	53	18065	201	1904
100	52	20165	202	2016
110	44	23170	211	2209
120	27	18508	154	1690
130	20	23778	183	2085
140	8	27436	196	2319

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Freese, F. 1962. Elementary forest sampling. USDA For. Serv. Agri. Handbook 232.

Snedecor, G.W., and W.G. Cochran. 1967. Statistical methods. Iowa State Univ. Press, Ames.

Wiant, Jr., H.V., C.E. Sheetz, A. Colaninno, J.C. DeMoss, and F. Castaneda. 1977. Tables and procedures for estimating weights of some Appalachian hardwoods. West Virginia Univ. Agri. & Forest. Exp. Stn. Bul. 659T.

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Current Literature

Please order publications directly from addresses given below:

General

Gen. Tech. Rept. WO-3 "Proceedings of the Symposium on the Environmental Consequences of Fire and Fuel Management in Mediterranean Ecosystems"

Res. Note PSW-322 "Computation of Times of Sunrise; Sunset and Twilight in or Near Mountainous Terrain".

Res. Note PSW-324 "Interpolation of Unevenly Spaced Data Using a Parabolic Leapfrog Correction Method and Cubic Splines".

All from Pacific Southwest Forest and Range Experiment Station, P.O. Box 245, Berkeley, CA 94701.

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Paper No. 625 "Simulation Methods As An Aid to Designing Market Map Studies: A Managerial Review"

Paper No. 638 "On Continuous Review (s,S) Inventory Systems: An Application of Regenerative Stochastic Processes".

Paper No. 639 "A Method For Analyzing Interdependent Decisions Via the Principal of Optimality".

All from Purdue University, Krannert Graduate School of Management, Krannert Building, W. Lafayette, IN 47907.

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Circular 549 "New Approaches to Land-Use Planning" from Agricultural Extension Service, NC State University, Raleigh NC 27607.

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"Mini-Courses in Statistics: Descriptive Statistics and Probability Distributions" - This is a series of 16 Audio-Tutorial Modules. Contact Educulture,3184 "J" Airway Ave., Costa Mesa, CA 92626 for details and pricing.

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"Multivariate Analysis of Physical Site Data For Wildland Classification" by Radloff and Betters in Forest Science 24(1):2-10, March 1978 - at your local conservation library.

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No. 69-1977 "Environmental Design - Coping With Limited Resources Challenges Native Wit" from: Agricultural Extension Service, University of Minn., St. Paul, MN 55108.

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Georgia Forest Res. Paper 89, "Probability Level, Accuracy and Sample Size in Forest Sampling" from: Georgia Forest Research Council, Box 828, Macon, GA 31202. Tables are given presenting sample size required to achieve a given accuracy when the percent accuracy desired, the coefficient of variation and population size are known.

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"Techniques for Vegetation Measurements and Analysis for a Pre-And Post-Mining Inventory" is available at a cost of $1.50 each. Order from Dept. of Range Science, Colorado State University, Fort Collins, CO 80523.

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Drop us a line for a copy of "Multiple Resource Inventories in the U.S.A." by Gyde Lund. This paper was presented in Bucharest, Romania at the IUFRO Workshop on National Forest Inventories.

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FORESTRY

Gen. Tech. Rept. RM 56 "Producer-Consumer Biomass in Arizona Ponderosa Pine".

Reprint "A Method of Evaluating Impacts of Timber Harvests on Nontimber Forest Resources" by Sassaman & Randall.

Gen. Tech. Rept. RM 50 "Forecasting Seed Crops and Determining Cone Ripeness in Southwestern Ponderosa Pine".

All from Rocky Mountain Forest and Range Experiment Station, 240 West Prospect, Ft. Collins, CO 80521.

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"Common Regressions to Estimate Tree Biomass in Tropical Stands" by Crow in Forest Science, 24(1):110-114, March 1978 at your local conservation library.

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Georgia Forest Research Paper 74 "An Illustration of Wood Color Measurement" from Georgia Forest Research Council, Box 828, Macon, GA 31202.

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Technical Report No. TR-18 "Logging Trucks: Comparison of Productivity and Costs", price $2.00. Order from F.E.R.I.C., 201-2106 W. Broadway, Vancouver, B.C. V6K 2C8 Canada.

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"Technicas de Muestreo Usadas en Mexico en Inventarios Forestales. Desarrollo Historico" in Ciencia Forestal, Depto. de Servicios Tecnicos de Apoyo., Av. Progreso No. 5, Coyoacan 21, D.F. Mexico.

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"Inventario Forestal Nacional Estimaciones Comarcales y Mapas Cuaderno No. 2" from Servicio De Publicaciones Agrarias, Paseo de Infanta Isabel, 1, Madrid - 7, Spain.

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Copies of the proceedings of "Canadian Forest Inventory Methods - 1975" are still obtainable by sending $6 (Canadian) to: School of Continuing Studies, Attn: Dr. P.L. Aird, University of Toronto, Toronto, Ontario, Canada M5S 1A1.

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"Forest Resources of the TARCOG Region": Alabama Forestry Commission,

"Analysis of Forest Values for Comprehensive Planning": Florida Division of Forestry,

"North Carolina Forestry Council Report-Long Range Program": North Carolina Forest Service,

"Report to Coordinate Planning Activities Between Savannah River National Environmental Research Park and State or Substate Agencies in South Carolina and Georgia": USDA-Forest Service,

"The Last Tree": USDA Forest Service.

These publications were produced either independently by or jointly with the US Forest Service. Available from USDA Forest Service, SA S&PF, 1720 Peachtree Rd. NW, Atlanta, GA 30309.

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"Metric Handbook for Softwood Lumber".

FMR-X-101 "Sensitivity Ratings as a Guide in Locating and Evaluating Transportation Routes and Corridors".

FMR-X-107 "Application of Large-Scale Photos to a Forest Inventory in Alberta".

FMR-X-102 "Forest Management in Canada - Volume 1".

All from Forest Management Institute, Canadian Forestry Srv., 396 Cooper Street, Ottawa, Ontario, Canada K1A 0W2

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Res. Paper Int-197 "Weight & Density of Crowns of Rocky Mountain Conifers". From Intermountain Forest & Range Experiment Station, 507 25th St., Ogden, UT 84401.

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Note 267 "Direct and Indirect Estimation of Height Distributions in Even-Aged Stands" and Note 268 "Generalized Biomass Estimation Equations for Jack Pine". From College of Forestry, 1530 North Cleveland Ave., St. Paul, MN 55108.

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RANGE & WILDLIFE

Technical Note TN-316 "Nesting Habitats and Surveying Techniques for Common Western Raptors". Drop us a line - Attn: D-360 for a copy.

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FS 579 "Measuring Forage and Grain in Storage" from Cooperative Extension Service, South Dakota State University, Brookings, SD 57007.

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RECREATION

Res. Paper NE 389 "Trail Transect: A Method For Documenting Trail Changes" from Northeast Forest Experiment Station, 370 Reed Rd., Broomall, PA 19008.

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FMR-X-105 "Fundy National Park, N.B. and the Proposed Western Extension Integrated Resource Survey" from Forest Management Institute, Canadian Forestry Srv., 396 Cooper St., Ottawa, Ontario, Canada K1A 0W2.

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SOILS

State Forest Notes No. 67 "Soil Erosion Definitions" from California Dept. of Forestry, 1416 Ninth St., Sacramento, CA 95814.

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Pub. 750 "Layman's Guide to Evaluating Soil Potential for a Septic Tank Drain Field" from Cooperative Extension Service, VPI & State University, Blacksburg, VA 24061.

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Engineering Technical Rept. ETR 7100-4 "Measurement of Soil Creep by Inclinometer".

Res. Note PSW-323 "Estimating Sedimentation from an Erosion - Hazard Rating"

Both from: Pacific Southwest Forest & Range Experiment Station, P.O. Box 245, Berkeley, CA 94701.

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G-74-126 "Understand Your Soil Test: Zinc, Iron and Sulfur" from Cooperative Extension Service, University of Nebraska, Lincoln, NE 68583.

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WATER QUALITY & FISHERIES

Tech. Bull. 93 "Population and Biomass Estimates of Fishes in Lake Wingra".

Tech. Bull 75 "Survey of Lake Rehabilitation Techniques and Experiences".

Tech. Bull. 100 "Use of Arthropods to Evaluate Water Quality of Streams".

All from Dept. of Natural Resources, Box 7921, Madison, WI 53707.

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Bull. No. 11 "Evaluating Riparian Habitats from Aerial Color Photography" from Forest, Wildlife & Range Experiment Station, University of Idaho, Moscow, ID 83843.

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Meetings and Workshops

Workshop on State of the Art in Forest Measurements. September 14-15, Hotel Roanoke, Roanoke, Virginia. Sponsored by the Biometrics Working Group, SAF, and the School of Forestry and Wildlife Resources, Virginia Polytechnic Institute and State University. The purpose of the workshop is to update practitioners on the state of the art in selected areas of biometrics-mensuration. This workshop is aimed at technology transfer for foresters working with mensurational problems. Topics to be covered include tree and product measurement, stand projection methodology, and management planning models. Contact: Harold E. Burkhart, School of Forestry and Wildlife Resources, Virginia Polytechnic Institute and State University, Blacksburg, VA 24061 (phone 703-951-6952).

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Eighth World Forestry Congress. October 16-28, Jakarta, Indonesia. Contact Robert E. Buckman, Dep. Chief for Research, USDA Forest Service, P.O. Box 2417, Washington, D.C. 20013.

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SAF National Convention. October 22-26, St. Louis, MO. Contact SAF, 5400 Grosvenor Lane, Washington, D.C. 20014. The SAF Inventory, Biometrics and Remote Sensing Working Groups will be holding a joint technical meeting on "Measurements: Gateway to Knowledge" at the convention. Plan now to attend.

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Utilizing Urban Wood Wastes, Oct. 30-31, 1978, University of Wisconsin - Madison, Fee - $130. Contact Fred Werren, Dept. of Engineering, University of Wisconsin - Extension, 432 North Lake Street, Madison, WI 53706.

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National Urban Forestry Conference. November 13-16, Washington, D.C. Registration fee $30. Contact School of Continuing Education, S.U.N.Y., College of Environmental Science & Forestry, Syracuse, NY 13210.

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Forest Growth and Yield Workshop. Sponsored by the SAF Inventory Working Group and University of New Hampshire will be held Nov. 29 thru Dec. 1, 1978 at Durham, NH. The regional workshop designed as an introductory course for forest managers and analysts who need to implement growth and yield methodology in a decision-making role. Enrollment will be limited to 25 on a first-come basis. Registration and fees will be between $50-100. For details contact Dr. James Barrett, INER, James Hall, University of New Hampshire, Durham, NH 03824.

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Get these in your Annual Work Plan for 1979.

July 16-20. "Sampling Designs for Successive Inventories". A workshop sponsored by the Colorado State University Dept. of Forest and Wood Sciences and the SAF Inventory Working Group. Registration for this workshop will be $300.

The following week, July 23-27 will be the 1979 Forest Inventory Workshop - sponsored by the SAF and IUFRO, also in Ft. Collins. This will be on the magnitude of the 1978 Tucson and the 1974 Ft. Collins meetings. Make plans now to attend both sessions.

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Miscellaneous

International Workshop a Success.

The IUFRO Workshop on "National Forest Inventories" was held in Bucharest, Romania this past June. Over 80 papers were heard by 100 participants from over 35 countries. The proceedings have been published. We'll keep you abreast of their availability in a future issue of the "Notes".

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