Resource Inventory Notes

BLM 17 January 1979

VARIABLE RADIUS PLOT AND 3P[1/] TIMBER SAMPLING

by

J. David Estola[2/]

ABSTRACT: This paper describes multi-stage sampling with two efficient sampling methods; (1) variable radius plot offers a fast way to select samples and (2) 3P offers the option to precisely measure relatively few variable plot sample trees.

Introduction: The Bureau of Land Management's (BLM) Denver Service Center and Wyoming State Office recently conducted training in the use of combined variable plot and 3P sampling. The class objective was to test an efficient way to sample and measure densely stocked timber stands for timber sale purposes. The class project consisted of eleven designated clearcut areas totalling 82 acres.

Phase I - Sample Design. Before the desired number of variable plots and 3P samples could be computed, it was necessary to assume sampling precision standards and anticipated timber variability. The following equations and assumptions were used.

$$E_{total} = \sqrt{E^2_{plot} + E^2_{3P}} \qquad (1)$$

$$n = \frac{(t^2)(CV^2)}{E^2_{plot}} \qquad m = \frac{(t^2)(CV^2)}{E^2_{3P}} \qquad (2)$$

where:

E = Standard Error
n = Number of plots
m = Number of 3P samples
t = Students "t" factor
CV = Coefficient of variation

1/ 3P is an acronym for probability proportional to prediction

2/ Forester, Bureau of Land Management, Denver Service Center, Denver Federal Center, Bldg. 50, Denver, Colorado 80225

Published by:
USDI, Bureau of Land Management, D 340
Denver Service Center, Denver Federal Center, Bldg. 50
Denver, Colorado, 80225

Givens: E_{total} = 10% (at two standard deviations)

E_{3P} = 4% (at two standard deviations)

t = 2 (approximately)

Assumptions: CV_{plot} = 60%

CV_{3P} = 20%

Substituting in equations (1) and (2):

$$10 = \sqrt{E^2_{plot} + 4^2_{3P}}$$

$$E_{plot} = 9.54$$

$$n = \frac{(2^2)(60^2)}{(9.54^2)} = 171 \qquad m = \frac{(2^2)(20^2)}{(4^2)} = 100$$

Information required for generating 3P random numbers (Estola 1978) include:

K = Pre-estimate of the largest KPI (total height was used for KPI)

Σkpi = Pre-estimate of the sum of the KPI's

ESN = Desired number of 3P samples

M = Pre-estimate of number of variable plot trees

Assumptions:

K = 70 (tallest tree)

Σkpi = 51,300 (6 trees per point x 171 points x 50 average height per tree)

ESN = 100

M = 1026 (6 trees per point x 171 points)

Phase 2 - Data Collection. Variable plots were allocated to each clearcut area on the basis of the size of each area. A systematic sample was used to establish the location of each plot. The height of each variable plot sample tree was estimated and compared to a 3P random number to determine which plot trees would be 3P samples. Field tally books were set up as follows:

Sample Field Tally Book Format

Variable Plot				3P Samples			
Clearcut No.	Plot No.	Tree No.	KPI (Total Height)1/	Sample No.	DBH	Height	Recovery2/
1	1	1	45				
1	1	2	60	1-1-1	13.3	54	.95
1	1	3	50				
1	1	4	40	1-1-2	11.3	37	.95
Plot Totals		4	195	2			

1/ Rounded to nearest 5 feet
2/ Net over gross volume ratio

Phase 3 Data Processing. Volume equations (Meyers 1969) were used to compute the Scribner (16 foot board foot) volume of each 3P sample tree. 3P data expansion factors were computed as follows:

Individual Clearcut Areas = Stratum

$$F_{stratum} = \left[\frac{BAF}{(.005454)(DBH^2)(n_{stratum})}\right]\left[\frac{\Sigma KPI_{stratum}}{(m_{stratum})(KPI)}\right] \quad (3)$$

Total Clearcut Areas (All Strata)

$$F_{strata} = \left[\frac{BAF}{(.005454)(DBH^2)(n_{strata})}\right]\left[\frac{\Sigma KPI_{strata}}{(m_{strata})(KPI)}\right] \quad (4)$$

Where: $F_{stratum}$ = Stratum expansion factor

F_{strata} = All strata expansion factor

BAF = Basal Area Factor

$n_{stratum}$ = Stratum number of plots

n_{strata} = All strata number of plots

$\Sigma KPI_{stratum}$ = Sum of the KPI in the stratum

ΣKPI_{strata} = Sum of the KPI in all strata

$m_{stratum}$ = Stratum number of 3P samples

m_{strata} = All strata number of 3P samples

COMPUTATIONS USED TO CALCULATE STAND CHARACTERISTICS ARE SHOWN SYMBOLICALLY IN THE TABLE BELOW.

STAND CHARACTERISTICS COMPUTATIONS

STAND CHARACTERISTICS	STRATUM	ALL STRATA
TREES PER ACRE (T/A)	$\sum_{i=1}^{k} F \text{ stratum}$	$\sum_{k} F \text{ strata}$
HEIGHT PER TREE	$\dfrac{\sum_{i=1}^{k} \left[(F \text{ stratum})(\text{Height})\right]}{\text{Stratum T/A}}$	$\dfrac{\sum_{k} \left[(F \text{ strata})(\text{Height})\right]}{\text{Strata T/A}}$
VOLUME PER ACRE	$\sum_{i=1}^{k} \left[(F \text{ stratum})(\text{Volume})\right]$	$\sum_{k} \left[(F \text{ strata})(\text{Volume})\right]$
VOLUME PER TREE	$\dfrac{\sum_{i=1}^{k} \left[(F \text{ stratum})(\text{Volume})\right]}{\text{Stratum T/A}}$	$\dfrac{\sum_{k} \left[(F \text{ strata})(\text{Volume})\right]}{\text{Strata T/A}}$
VARIABLE PLOT STAND ERROR (E plot)	$\sqrt{\dfrac{\left(\sum_{i=1}^{k} X^2\right) - \dfrac{\left(\sum_{i=1}^{k} X\right)^2}{n \text{ stratum}}}{n(n-1) \text{ stratum}}}$	$\sqrt{\dfrac{\left(\sum_{k} X^2\right) - \dfrac{\left(\sum_{k} X\right)^2}{n \text{ strata}}}{n(n-1) \text{ strata}}}$
3P STANDARD ERROR (E_{3P})	$\sqrt{\dfrac{\left(\sum_{i=1}^{k} R^2\right) - \dfrac{\left(\sum_{i=1}^{k} R\right)^2}{m \text{ stratum}}}{m(m-1) \text{ stratum}}}$	$\sqrt{\dfrac{\left(\sum_{k} R^2\right) - \dfrac{\left(\sum_{k} R\right)^2}{m \text{ strata}}}{m(m-1) \text{ strata}}}$
COMBINED STANDARD ERROR (E total)	$\sqrt{(E \text{ plot})^2 + (E_{3P})^2_{\text{stratum}}}$ *	$\sqrt{(E \text{ plot})^2 + (E_{3P})^2_{\text{strata}}}$ *

* A COVARIANCE TERM, CONSIDERED INSIGNIFICANT, WAS EXCLUDED.

WHERE: $\sum_{i=1}^{k}$ = SUM OF THE 3P SAMPLES WITHIN A STRATUM

$\sum_{k}$ = SUM OF THE 3P SAMPLES WITHIN A STRATA

X = BASAL AREA PER VARIABLE PLOT

R = RATIO OF MEASURED VOLUME OVER KPI PER 3P SAMPLE TREE

RESULTS OF THE CLASS PROJECT ARE SHOWN ON THE FOLLOWING TABLE.

COMBINED VARIABLE PLOT - 3P SAMPLE SUMMARY

Strata	#Plots	3P Samples	Trees/Acre	Height/Tree	DBH/Tree	Gross Volume/Tree	Gross Volume/Acre	Net Volume/Acre	Plot* Standard Error	3P* Standard Error	Combined* Standard Error
No. 1	9	3	515	48 ft.	8.9 in.	40 bd. ft.	20,656 bd. ft.	20,370 bd. ft.	16.2 %	29.0 %	33.2 %
2	18	12	367	53	8.8	43	15,649	15,514	18.8	5.4	19.6
3	25	18	189	53	11.0	71	13,470	13,027	17.6	4.4	18.1
4	16	7	260	48	10.5	57	14,701	14,601	24.6	11.2	27.0
5	15	9	195	58	11.6	88	17,212	16,933	13.2	8.6	15.8
6	11	9	151	63	13.4	129	19,424	17,514	25.8	4.0	26.1
7	6	5	411	59	11.3	85	34,966	34,574	33.0	9.6	34.4
8	35	25	234	55	10.8	71	16,581	16,127	10.6	2.6	10.9
9	11	7	317	47	10.1	52	16,508	16,127	14.4	5.2	15.3
10	8	8	452	47	8.2	32	14,550	13,560	22.2	8.6	23.8
11	24	15	378	47	8.4	34	12,799	12,059	13.4	5.6	14.5
All Strata	178	118	282	52	10.0	56	15,754	15,254	5.6	2.2	6.0

*Two Standard Deviations

Conclusions: Combined variable radius plot and 3P sampling did prove to be effective. Compared to standard 3P procedures, the use of variable radius plot sampling saved field time. Rather than visit the estimated 24,600 total number of trees, 1,305 variable radius plot trees were visited. Since a volume table cruise was applied to the 118 3P sample trees, projected volume estimates will reflect the biases that may be present in the volume table. For achieving the most accurate results, a destructive sample (fall, buck and scale) is recommended for estimating the volume of 3P sample trees.

LITERATURE CITED

Estola 1976. 3P Random Numbers and a Handheld Programmable Calculator. Resource Inventory Notes. BLM 11, May, 1978. p. 1-3.

Myers 1969. Board-Foot Volumes to a 6-Inch Top for Lodgepole Pines in Colorado and Wyoming. USDA Forest Service Research Note RM-157. p. 2.

* * * * * * * * * *

HEIGHT ACCUMULATION FOR PROGRAMMABLE CALCULATORS

by

Gerald D. Hansen[1/]

ABSTRACT: The height accumulation method of tree volume determination is transformed into an algorithm which is compatible with programmable calculators.

Wiant (1976) suggested that the height accumulation method developed by Grosenbaugh (1954) can be used to measure volumes of trees in 3P sampling systems. The computation of many individual tree volumes, however, can be very time consuming: distances between taper steps must be converted into 4-foot units, DIB/DOB ratios must be calculated and coefficients used in volume computations must be identified. This report describes a method for transforming the same height accumulation procedure into an algorithm which is compatible with many programmable calculators.

1/ G.D. Hansen is a graduate student at the SUNY College of Environmental Science and Forestry, Syracuse, N.Y. Work reported here was done while the author was a graduate student in the Division of Forestry at West Virginia University, Morgantown.

Computations of Coefficients

Grosenbaugh (1954) presented tables of the coefficients A, B and C which are used in the following formula to compute volume.

$$\text{Volume} = A(\Sigma H') + B(\Sigma H) + C(\Sigma L)$$

The coefficients to be used for calculating cubic foot and board foot volumes are grouped according to DIB/DOB ratios.

Regression equations which predict the coefficients A, B and C with respect to DIB/DOB ratios are shown below. These equations are applicable when 4-foot height units and 2-inch taper steps are used.

Cubic Volume (ft^3)

$A = 0.32800(DIB/DOB) - 0.15340$ $R^2 = 0.9991$

$B = 0$

$C = 0.05400(DIB/DOB) - 0.02495$ $R^2 = 0.9997$

International 1/4-inch (board feet)

$A = 2.94000(DIB/DOB) - 1.352$ $R^2 = 0.9997$

$B = -(1.46000(DIB/DOB) + 0.02200)$ $R^2 = 0.9989$

$C = -(0.25200(DIB/DOB) + 0.05640)$ $R^2 = 0.9985$

Scribner (board feet)

$A = 2.94000(DIB/DOB) - 1.36200$ $R^2 = 0.9997$

$B = -(1.72000(DIB/DOB) + 0.05900)$ $R^2 = 0.9995$

$C = -(0.40000(DIB/DOB) + 0.68000)$ $R^2 = 1.0000$

Doyle (board feet)

$A = 3.72000(DIB/DOB) - 1.72600$ $R^2 = 0.9993$

$B = -5.00000(DIB/DOB)$ $R^2 = 1.0000$

$C = 5.87900 - 1.88000(DIB/DOB)$ $R^2 = 0.9995$

Computation of Height Accumulation Volume

The data processing required to compute volume using the height accumulation method is represented by the flow chart in Figure 1. This algorithm incorporates the previously described prediction equations along with a procedure for computing $\Sigma H'$, ΣH and ΣL. Fractions of 4-foot height units are rounded to whole units as described by Enghardt and Derr (1963).

Data which are required include DBH, average bark thickness and height of taper steps. A Spiegel Relaskop or Wheeler Pentaprism with an attached hypsometer can be used to locate taper steps and measure heights. Topographic scale readings recorded at a distance of 33 or 66 feet can be used by designating the appropriate data format code.

A product code directs the calculator to compute volume for sawtimber of pulpwood to a specified DOB. Sawtimber volume plus total pulpwood volume to a smaller DOB can be computed simultaneously for the same tree.

This suggested algorithm is compatible with calculators which have approximately 1000 program steps and 25 storage locations. Modifications in the number of data format of product volume options can be made to adapt the program to the capabilities of other calculators.

LITERATURE CITED

Enghardt, H. and H. J. Derr. 1963. Height accumulation for rapid estimates of cubic volume. J. For. 61:134-137.

Grosenbaugh, L. R. 1954. New tree-measurement concepts: height accumulation, giant tree, taper and shape. USDA Southern For. Experiment Station, Occ. Paper 134. 32 p.

Wiant, H. V. 1976. Elementary 3P Sampling. West Virginia University Agric. and For. Experiment Station. 31 p.

\- - - - - - - - - - -

Figure 1. Flow Chart for Height Accumulation.

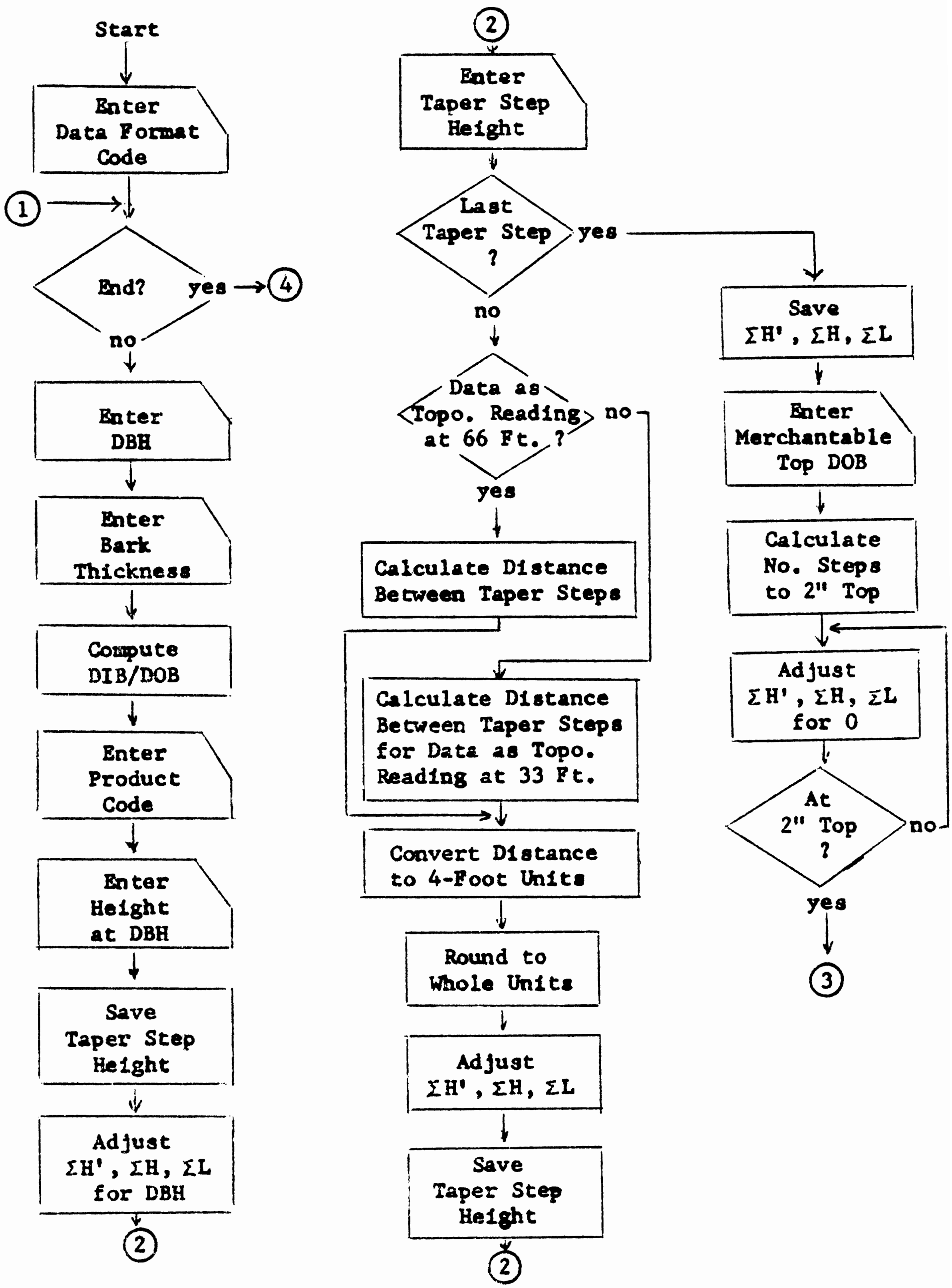
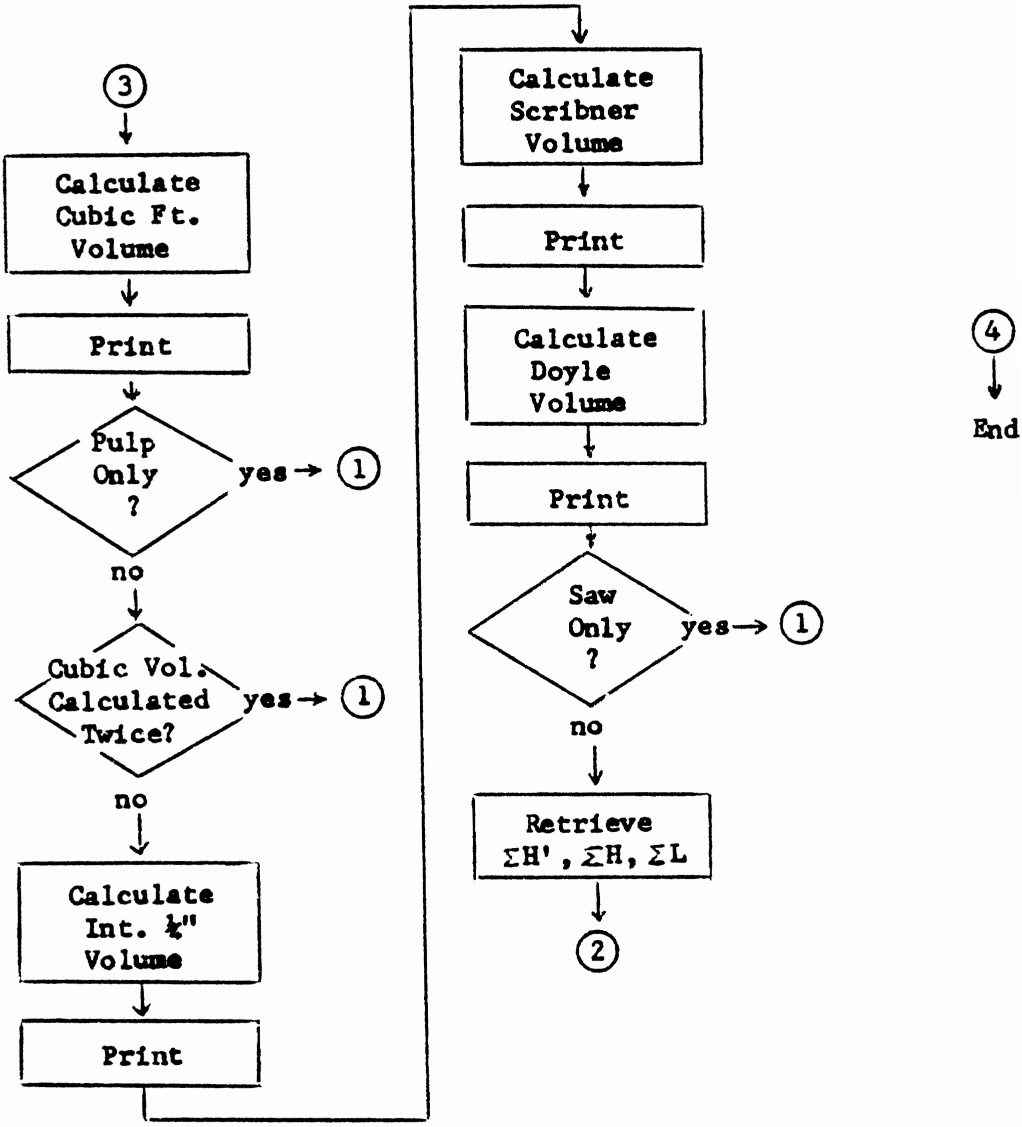


Figure 1. Flow Chart for Height Accumulation (cont.).



CURRENT LITERATURE

Please order directly from address given below.

General

"Description of the Ecoregions of the United States" from Forest Service Regional Office, 324 25th St., Ogden, Utah 84401.

- - - - - - - - - - -

The October 1978 issue of the Journal of Forestry is devoted to Land Classification. Check your local conservation library for this monumental issue.

- - - - - - - - - - -

A pamphlet and poster on "Forest Resource Planning Program" from USDA Forest Service, Information Center, Room 816, 1720 Peachtree Road, NW, Atlanta, Georgia 30309.

- - - - - - - - - - -

FORESTRY

Reprint "Stammzahlinventur in Kunstlich Bergrundeten Jungen Bestockungen", by Ulbricht, (English summary).

Reprint "Taxatorische Zustanderfassung und Einzeplanung im Waldgebiet Cajalbana Kuba-ein Lehrbeispiel" by Kurth and Ulbricht. (English summary).

Reprint "Kieferninventur, Harznutzungspotenz und Prognose der Harznutzungspotenz im Nordosten der Sozialistischen Republik Vietnam" by Ulbricht. (English summary).

Reprint "Zur Genauigkeit der durch die Foresteinrichtung erhobenen Grundflachen, Hohen und Durchmesser" by Ulbricht. (English summary).

Discussion Paper - "Data Memory Containing the Forest Fund of the GDR and Its Use" by Ulbright. (English summary).

Reprint "Kybernetics - A General Introduction and Special Problems of Forestry" by Ulbright. (English summary).

Reprint "A System of Models for Intepreting Forest Inventories" by Kurth and Ulbricht. (English summary).

Reprint "The Estimation of Volume Distribution and Kinds of the Beechen and Utilization Stands" by Ulbricht. (English summary).

Reprint "Simulation Models for Sustained - Yield Regulation" by Kurth and Gerold. (English summary).

Reprint "Regressions Between Current Increment and Statistical Data of Stands" by Ulbricht.

Reprint "Forschritte in der Nachhaltregelung" by Deltuvas, et al.

All from Tech. University Dresden, Sektion Forstwirtschaft, Pienner Str. 8, 8223 Tharandt, German Democratic Republic.

- - - - - - - - - - -

"El Mensajero Forestal" a monthly newsletter is available by subscription from Apartado Postal 113, Durango, Dgo, Mexico. The rates are $50 (Mexican).

- - - - - - - - - - -

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

Gen. Tech. Report RM-55 "Forecasting Seed Crops and Determining Cone Ripeness in Southwestern Ponderosa Pine".

Res. Paper RM-199 "RMYLD; Computation of Yield Tables for Even-Aged and Two-Storied Stands".

All from Rocky Mountain Forest and Range Experiment Station, 240 West Prospect, Fort Collins, Colorado 80526.

- - - - - - - - - - -

Res. Paper PSW-128 "Site Classification of Ponderosa Pine Stands Under Stocking Control in California".

Gen. Tech. Report PSW-24 "Tree Failures and Accidents in Recreation Areas: A Guide to Data Management for Hazard Control".

Both from Pacific S.W. Forest and Range Experiment Station, P.O. Box 245, Berkeley, California 94701.

- - - - - - - - - - -

G2950 - "Measuring Firewood --- To Get Your Money's Worth" from University of Wisconsin-Extension, Agricultural Bulletin Bldg., 1535 Observatory Drive, Madison, Wisconsin 53706. Price is 5¢ plus postage for out-of-state orders.

- - - - - - - - - - -

"How to Calculate Size-Class Distribution For All-Age Forests".

Res. Note NC-234 "Three Tools For Measuring Height Growth in Field Plantings Compared".

Res. Note NC-232 "A System For Predicting the Amount of <u>Phellinus (Fomes) Igniarius</u> Rot in Trembling Aspen Stands".

Res. Paper NC-156 "Estimating Aspen Crown Fuels in Northeastern Minnesota".

"Forest Atlas of the Midwest" by Merz.

All from Northcentral Forest Experiment Station, 1992 Folwell Avenue, St. Paul, Minnesota 55108.

- - - - - - - - - - -

REMOTE SENSING

The Optronics Journal - available from Optronics International Inc., 7 Stuart Road, Chelmsford, Massachusetts 01824.

- - - - - - - - - - -

Proceedings "Vegetation Damage Assessment Symposium" - available from The American Society of Photogrammetry, 105 N. Virginia Avenue, Falls Church, Virginia 22046. The price for the 556 paged document is $12 for ASP members and $18 for non-members.

- - - - - - - - - - -

Res. Report 1197 "Effectiveness of a Map Interpretation and Terrain Analysis Course on NAP-of-the Earth Navigation Training of Crew Chief/ Observers".

Res. Report 1199 "Evaluation of the Singer Night Visual System Computer-Generated Image Display Attached to the UH-1 Flight Simulator".

Both available from U.S. Army Research Institute for the Behavioral and Social Sciences, 5001 Eisenhower Avenue, Alexandria, Virginia 22333.

- - - - - - - - - - -

"P.B. Wrapper" is a free - bimonthly publication from NASA's Western Regional Applications Program. To get on the mailing list, write Rita Pless, M/S 242-4 NASA Ames Research Center, Moffett Field, California 94035.

- - - - - - - - - - -

SOILS AND WATER

P-44 "Soil Sampling" is available from Distribution Office, Cooperative Extension Service, University of Alaska, Fairbanks, Alaska 99701.

- - - - - - - - - - -

Chapter A4 "Methods For Collection and Analysis of Aquatic Biological and Microbiological Samples". Book 5 - Laboratory Analysis - IN Techniques of Water-Resources Investigations of the United States Geological Survey. Contact Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402.

- - - - - - - - - - -

EPA-600/4-78-012 "Methods For Measuring the Acute Toxicity of Effluents to Aquatic Organisms". Contact National Technical Information Service, Springfield, Virginia 22161 for price and availability.

* * * * * * * * * * *

MEETINGS and WORKSHOPS

Aerial Photography/Aerial Photo Interpretation Workshop sponsored by the College of Forestry, Wildlife and Range Sciences and Office of Continuing Education, University of Idaho, February 5-9, 1979.

The course is for those land resource managers who have not had or who need a refresher on such topics as: Obtaining aerial photography, small format camera systems, preparing and viewing aerial photos stereoscopically, determining scale, distances, heights, slopes, and area, making simple maps, and interpreting vegetation and landform. Cost $140.

Contact Dr. Joseph J. Ulliman, College of Forestry, Wildlife and Range Sciences, University of Idaho, Moscow, Idaho 83843.

- - - - - - - - - - -

Introduction to Renewable Resource Inventory Methods, will be presented March 5-9, 1979, at the University of California, Berkeley.

The course focuses on the inventory design process, emphasizing sampling and measurement systems and the integration of aerial photography, satellite spectral data and conventional ground data into such systems. Forest and rangeland inventory problems will be used to illustrate the principles and techniques discussed in lecture and workshop sessions.

Workshop exercises will cover sampling skills, aerial photography and satellite imagery for stratification, and measurement techniques applicable to large and medium-scale photography.

Enrollment is limited, and participants will be selected on the basis of their field of inventory interest and their job responsibilities. For details write: Division of Letters and Sciences, University of California Extension, 2223 Fulton St., Berkeley, California 94720, or call (415) 642-1061. The fee will be $350.

- - - - - - - - - - -

The Biennial Workshop on Color Aerial Photography in Plant Sciences and Related Fields will be held in May 1979 at Davis, California. For details contact William M. Ciesla, WO-FI&DM Methods Application Group, Forest Service, USDA, 2810 Chiles Road, Davis, California 95616.

- - - - - - - - - - -

Sampling on Successive Occasions - A workshop sponsored by Department of Forest and Wood Sciences, Colorado State University, S.A.F. Inventory Working Group and IUFRO S4.02-03 will be held July 17-20, 1979. The workshop is designed for resource managers and researchers engaged in sampling projects such as national and state timber surveys, multi-resource inventories, timber inventories on industry-owned lands, etc. A knowledge of basic sampling technique is assumed. The course will be limited to 40 people and will cover expected values, probability sampling, best linear unbiased estimates, independent estimates, remeasurement, sampling with partial replacement, optimum sample sizes and sampling on more than two occasions. The fee is $250. Contact Office of Conferences and Institutes, Residential Conference Center, Colorado State University, Fort Collins, Colorado 80523.

- - - - - - - - - - -

1979 Forest Inventory Workshop. Don't let the name fool you. 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 will be about $75. The dates are July 23-26, 1979, at Colorado State University. For details contact Office of Conference and Institutes, Residential Conference Center, Colorado State University, Fort Collins, Colorado 80523.

- - - - - - - - - - -

Remote Sensing for Natural Resources - An international view of problems, promises and accomplishments sponsored by the University of Idaho, IUFRO and SAF. Dates are September 10-14, 1979.

* * * * * * * * * * *

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.

- - - - - - - - - - -

Change of Address? Be sure to send us your old label. If you want to get on our mailing list, drop us a line.

* * * * * * * * * * *

GPO 848-529

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF LAND MANAGEMENT
DENVER FEDERAL CENTER
BUILDING 50
DENVER, COLORADO 80225

OFFICIAL BUSINESS
PENALTY FOR PRIVATE USE $300

POSTAGE AND FEES PAID
U. S. DEPARTMENT OF THE INTERIOR
Int 415

U.S.MAIL

J C SPACE DIRECTOR 02 000252
COMPUTER APPL STAFF
FOREST SERVICE
PO BOX 2417
WASHINGTON DC 20013