Appalachia-Science in the Public Interest
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ASPI TECHNICAL SERIES TP 32

THE PRACTICE OF ECOFORESTRY

PART 1. INVENTORY AND DESCRIPTION

Introduction

Healthy **ecosystems** (the totality of living and non-living things, and the forces and processes that operate among them) are the foundations of healthy and sustainable human communities. The three-part series THE PRACTICE OF ECOFORESTRY is intended to provide technical direction to individuals who believe that it is both biologically and morally imperative that we restore and protect the health of native ecosystems. This implies that ecological restoration and protection are the transcendent goals of forestry, and that production and harvest of forest produce for human use are subordinate goals. Forest management founded on these principles may be called "ecoforestry." This series of papers may also serve as a primer on forestry and an introduction to forestry jargon. Key terms and concepts are presented in **bold-face**.

Maps

Your forest land should be delineated on a map that is at least as detailed as the standard 1:24,000 **topographic quadrangle maps** produced by the U.S. Geological Survey (USGS) and sold locally (check under "maps" in the Yellow Pages of your phone book) for $3 to $5. Ask the map distributor to see the **index map** for your state. This will allow you to determine the name of the USGS topographic quadrangle that includes your land. To obtain a useful scale it is usually necessary to enlarge portions of the map with a photocopy machine. Note that the scale of the map will change on enlargement such that, for example, whereas 1 inch represents 2,000 feet on a standard USGS quadrangle, it will represent 1,000 feet if the map size is doubled (i.e. enlarged 100%).

Once your land is located on a topographic map and the map scale is enlarged, you should subdivide the land into **management units.** These are normally based on differences in **bedrock**, **land-use history**, and **topography** and are drawn to delineate land areas that are internally uniform. For example, management units may be based on whether the land is underlain by sandstone, limestone or shale bedrock, or on whether the land has ever been cultivated. In mountainous areas, useful management units may also be formed by classifying land as 'flat' (if average slope steepness is less than 20%, i.e. rise <20 feet per 100 feet horizontal distance) or as 'sloping'; as facing north (if most slopes face to the north side of a line running from northwest to southeast) or as facing south; and as occurring on ridges, stream bottoms, noses, side-slopes or coves (Fig. 1).

Ecosystem characteristics within a management unit are usually sufficiently uniform to consider the trees a **stand** (a group of trees occupying an area of land and treated as a single unit) in terms of management.

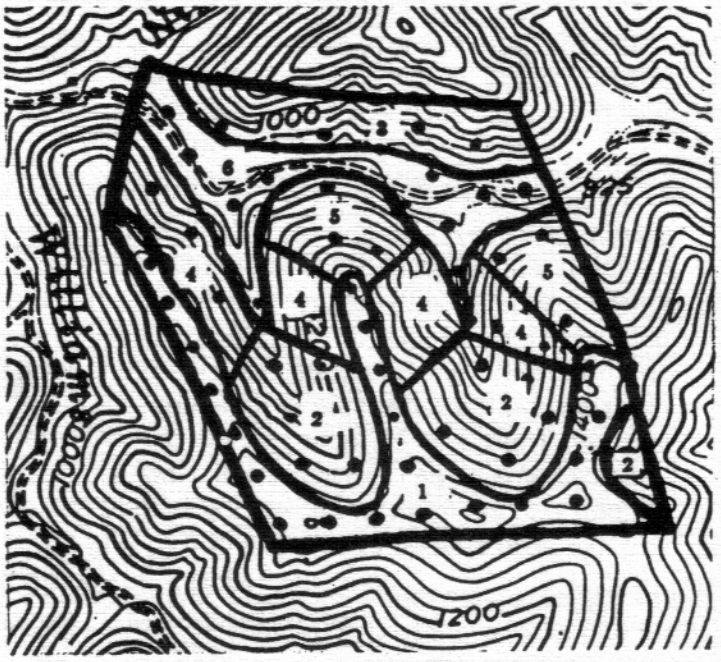

Figure 1. Portion of a USGS topographic map showing an 80-acre forest divided into six management units: 1=ridge; 2=cove; 3=south side slope; 4=north side slope; 5=nose; 6=stream bottom. Dots represent locations for 60 inventory plots.

The acreage in each management unit should next be estimated, and the approximate number and spacing of **inventory plots** should be determined from Table 1. Inventory plot centers may be marked on the map using the spacing guidelines in Table 1 and the scale provided on the map (e.g. 1 inch equals 2,000 feet for a standard USGS map) or plots may simply be located in the field without ever marking them on the map. To do the latter, begin at an identifiable land mark and randomly locate the first plot center, then locate the other plot centers in a square grid pattern of the appropriate spacing (Fig. 1; Table 1) . In the mountains, lines of plot are easily run by going up-and-down the slope, but in flat country a **compass** may be needed to run straight lines.

Table 1. Number and spacing of plots.

ACREAGE	NUMBER OF PLOTS	SPACING (ft)
1	10	70
5	10	150
10	10	210
25	25	210
50	50	210
100	75	240
200	100	300
300	125	320
400	150	340
500	175	350
600	200	360
1000	300	380

Books

Books provide information on hard-to-measure ecosystem characteristics such as geology, soils and animal populations. Field guides available at libraries and bookstores cover nearly every topic imaginable, and are useful for understanding local conditions, for constructing **species lists** and for identifying unusual organisms or conditions. Since identification of tree species is an essential part of a forest inventory, a tree guide is indispensable if you are not familiar with the local trees. **Soil survey reports** written by the USDA Natural Resources Conservation Service (formerly called the Soil Conservation Service) are good starting points since they provide introductions to local climate, geology, and human-history, while presenting detailed coverage of soils. Soil surveys usually cover one or two counties, and may be examined in libraries or obtained free from county agriculture extension agents. In addition to published material, federal agencies such as the USDA Forest Service; state divisions of nature preserves, forestry, water and geology; and non-governmental organizations such as Appalachia - Science in the Public Interest and The Nature Conservancy can often provide useful unpublished information regarding forest ecosystems in your locality.

Inventory Stick

The **inventory stick** (Fig. 2) is the only tool needed to collect **cruise** data (data characterizing individual trees and stands of trees). The inventory stick is the basis of an inventory method called **point sampling** or **plotless cruising** that allows all stand information to be collected from a point, without having to establish sample plots of known area. Although the theory behind the method is complicated, the inventory stick itself is simple to construct and use. First, obtain a 38-inch piece of tobacco stick or lattice wood, or a yard stick, and sand or plain both sides smooth. Marks will be put on one side of the stick to measure tree **DBH** (diameter at breast height, or 4.5 feet high) and on the other side to measure tree height. Starting from the left side of the stick, mark DBH in 2-inch intervals from 2 to 70 inches at the distances shown in Table 2. Note that the interval between DBH marks becomes smaller as DBH increases. Now turn the stick over and mark tree height in units of **logs** (one log equals 16 feet) with the mark for the first log located $6^1/_{16}$ inches from the left end of the stick, and successive marks up to 5 logs also spaced at intervals of $6^1/_{16}$ (Fig. 2).

Table 2. Location of marks on inventory stick.

DBH --in---	Distance From Left End ---in & sixteenths ----	DBH ---in---	Distance From Left End ----in & sixteenths----	DBH ---in---	Distance From Left End ----in & sixteenths----
2	1-14/16	26	18- 3/16	50	28-13/16
4	3-11/16	28	19- 3/16	52	29- 9/16
6	5- 6/16	30	20- 3/16	54	30- 5/16
8	6-15/16	30	20- 3/16	56	31- 1/16
10	8- 7/16	32	21- 3/16	58	31-13/16
12	9-13/16	34	22- 2/16	60	32- 8/16
14	11- 3/16	36	23	62	33- 3/16
16	12- 7/16	38	23-14/16	64	33-14/16
18	13-11/16	40	24-12/16	66	34- 9/16
20	14-14/16	42	25-10/16	68	35- 3/16
22	16	44	26- 7/16	70	35-13/16
24	17- 2/16	46	27- 4/16		
		48	28- 1/16		

An **angle gauge** is added to the stick to allow measurement of an important stand characteristic called **basal area**, which is measured in units of square-feet per acre and represents the cross-sectional area at breast height of all trees occurring on an acre of land. To make the angle gauge, drill a hole near the right end of the stick, place a 1-inch metal washer on an 18-inch long piece of nylon line, thread the line through the hole, and tie a knot to allow the washer to dangle from the stick. Now put a notch, about $^1/_4$ inch deep and wide enough to tightly hold the washer, on one edge of the stick at a point exactly 33 inches from the left side (Fig. 2). Your inventory stick is now complete and ready to be used in the field.

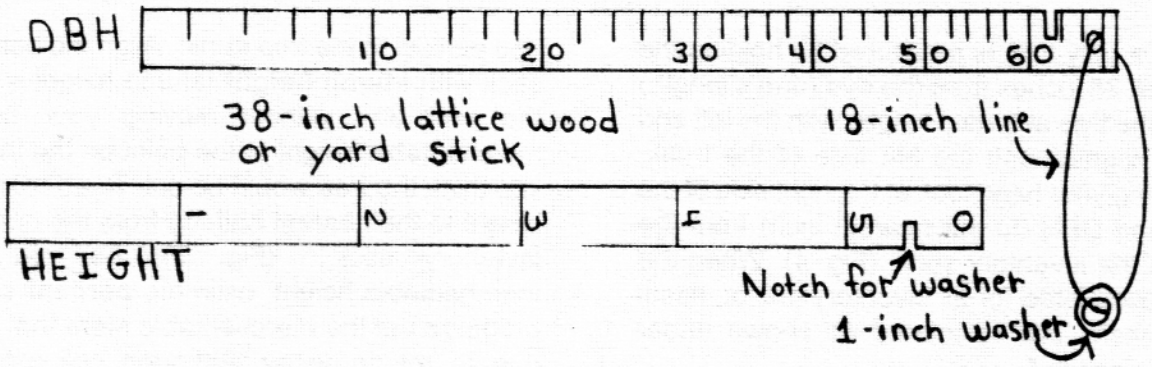

Figure 2

Data Collection

General Ecosystem Properties. Data describing the local ecosystems may be collected at each inventory point. Given the complexity of ecosystems, it is obvious that not all properties can be described. Effort should be directed to collecting information concerning rare or sensitive species, unique conditions, or ecologically important features such as **caves**, **cliffs**, and **cavity trees** (large living trees that are hollow and used as dens by many animal species). As time and ability allow, useful information may also be collected regarding animals, non-woody plants, soils, bedrock, human land-use history, and climate. In most locations the construction of simple species lists (wild flowers, birds, butterflies, ferns, etc.) in itself represents a major contribution to understanding of the local ecosystems.

Snags (standing dead trees), **logs** (fallen dead trees), and **treefall mounds-and-pits** (small hillocks and depressions that form when a tree uproots) are three features that are unique to forest ecosystems and are of special importance in terms of their contributions to biological diversity. Due to their ecological importance, the density of snags, logs, and mounds-and-pits should be estimated at each point. This is most easily done by counting the number of these features that occur within a $^1/_{20}$-acre (approximate radius = 25 feet) circular plot surrounding each inventory point. The number of these features per acre may then be estimated by calculating the average numbers per plot (total number counted at all the points divided by the number of points) and multiplying by 20. Snags, logs, and mounds-and-pits will be discussed in more detail in Part 2 ("Ecological Restoration") of this series of papers. Note also that the inventory stick may be used to estimate horizontal distances. Hold the zero end of the stick near you leg and note where the dangling washer "points" to the ground at a spot 3 feet away (Fig. 2). Step to this spot and continue to point with the stick and pace. For example, 8 sticks plus 1 foot will approximately delineate the radius of the $^1/_{20}$-acre plot.

Forests. Data describing forests are collected at each inventory point. Using the angle gauge, **tally trees** at each point are recorded by species and 2-inch DBH class (see sample tally sheet). Insert the washer into the notch on the inventory stick. Hold the inventory stick with the zero end at your eye and sight all trees as you turn a complete circle while keeping your head over the plot center. Move slightly off center to ensure that no trees are obscured from view by other trees, and that you sight all trees. Trees are tallied if, when viewed at breast height with one side of the washer aligned with one side of the trunk, the other side of the trunk projects beyond the limits of the washer (trees A and D in Fig. 3). If the sides of the trunk exactly fit the width of the washer, the tree is a **border tree** (tree E in Fig. 3); tally only every other border tree at a point. Trees that are entirely within the angle of the washer are not tallied (trees B and C in Fig. 3).

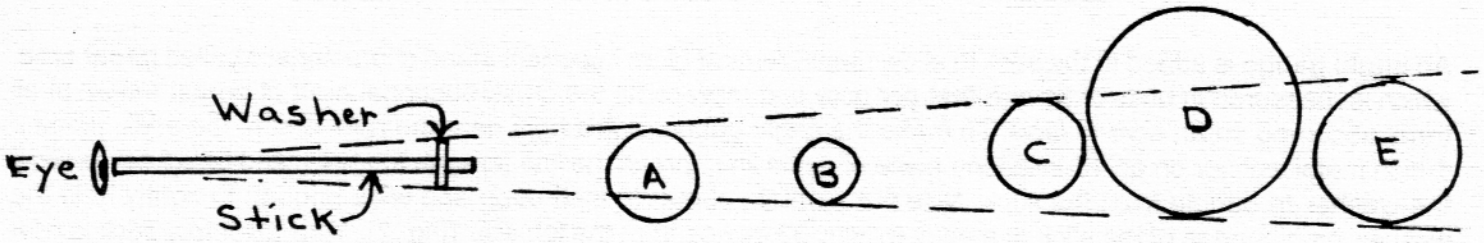

Figure 3

The DBH of a tally tree is measured by holding the inventory stick 25 inches from the eye (arm's length) and against the tree at breast height, with the left end of the stick aligned with the left side of the trunk. Without moving your head look at the right side of the trunk and read DBH (to the nearest inch) from the markings on the inventory stick (Fig. 4). When the tree tally is completed for all inventory points, basal area and density are calculated as shown under "Sample Calculation."

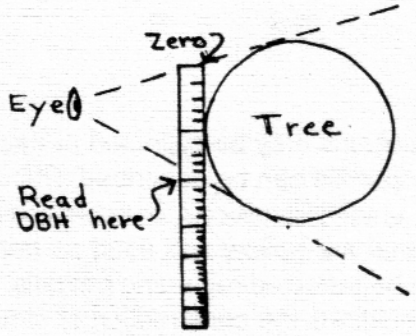

Figure 4

Merchantable height should be recorded at a subset (at least 50%) of all the inventory points to provide an estimate of **sawtimber** (trees greater than 10 inches DBH) and **poletimber** (trees 5.0 to 9.9 inches DBH that yield **pulpwood** or **cordwood**) volumes, and for use in making management decisions as described in Part 3 ("Tending and Harvest) of this series of papers. Merchantable height for poletimber trees is defined as the height to the point where the **upper stem diameter** is 4 inches. Merchantable height for sawtimber trees is defined as the height to the point where the upper stem diameter is 8 inches, or to a fork, major branch, or visible defect like a hole. The merchantable sawtimber height of hardwoods (except yellow-poplar) is usually limited by branching and forking before the upper stem diameter decreases to 8 inches. Merchantable height is measured standing on the same level as the base of the tree at a distance of 66 feet while holding the inventory stick 25 inches from the eye and parallel to the tree trunk. Align the bottom of the stick with **stump height** (stump height = 1 foot) on the tree and without moving your head sight merchantable height at the point on the trunk where you think the tree would be cut. Read merchantable height to the nearest half-log from the marks on the inventory stick (Fig. 5). As you measure merchantable height, estimate **percent cull**, or the proportion of the merchantable stem that is useless due to rot or decay. Although cull estimates on standing trees are difficult to make even for experienced individuals, look for wounds, bark distortions, holes, and bumps as indicators of internal defects, and make your best guess. As shown under "Sample Calculations," DBH and merchantable height estimates may be used to calculate **gross volumes** of sawtimber and cordwood, while cull estimates may be used to reduce the gross volumes to **net volumes**.

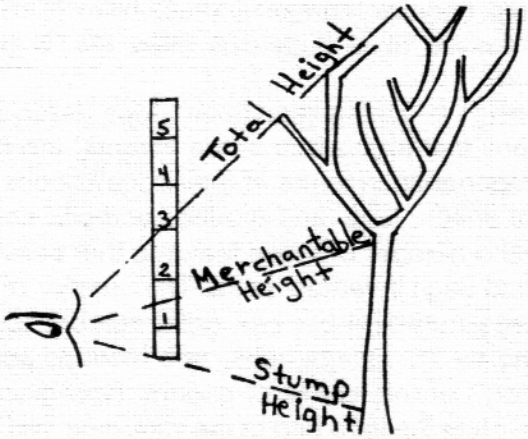

Figure 5

Sample Calculations

Sample calculations are illustrated using a set of inventory data on the following pages. Blank field sheets are also provided for duplication.

Basal Area. The inventory stick was designed to have a **basal area factor** (**BAF**) of 10. This means that each tally tree contributes a basal area of 10 sq.feet/acre. To estimate the average basal area for a stand, count the total number of trees recorded on

the dot tally sheet, divide by the total number of sample points, and multiply by 10. In this case:

(73 ÷ 7) X 10 = 104 sq.ft/ac basal area

The basal area may be determined in the same way for any DBH-class or species. For example, the basal are of white oak is:

(34 ÷ 7) X 10 = 49 sq.ft/ac or 47% of the total

Date 5/20/94 Number of Plots 7 Stand ASPI- COVE

DBH -CLASS LIMITS (inches)

SPECIES	2-4.9	5-9.9	10-11.9	12-13.9	14-15.9	16-17.9	18-19.9	20-21.9	22-27.9	28-33.9	34-53.9	54-69.9	TOTAL
White oak	::	⊠ ::	::	:.	:	•			•				34
Hickory	•	::	:	•	•	•							11
Dogwood	•			•									2
Black Gum		:	•		:.								6
Scarlet oak	•		•		:	•							5
Sourwood	::	•											5
Yellow-poplar	•	::	:										8
Beech	•												1
Red Maple	•												1
	16	29	11	5	8	3			1				73

Number of Trees. A BAF of 10 means that each tally tree represents 10 sq.ft/ac of basal area. Small tally trees must therefore represent many more trees/ac than large tally trees. To determine the number of trees/ac, multiply the number of tally trees in each DBH-class by the number listed in the following table for that DBH-class, then divide by the number of sample points. In this example, there are 630 trees/ac, and in the 2-4.9 inch DBH-class there are:

(16 X 204) ÷ 7 = 466 trees/ac

DBH Class(in)	Trees per Acre
2- 4.9	204
5 -9.9	29
10-11.9	15
12-13.9	11
14-15.9	8
16-17.9	6
18-19.9	5
20-21.9	4
22-27.9	3
28-33.9	2
34-53.9	1
54-69.9	0.5

Volume. Volume is calculated from the DBH - height -%cull data listed on the second field sheet (above). Poletimber trees and sawtimber trees too poor to be sawn into boards are considered pulpwood, and volumes are calculated in units of **cords** (a cord is a 4 X 4 X 8 foot stack of wood containing about 85 cubic feet of solid wood).

Date 5/20/94

Stand ASPI - COVE Number of Plots 7

Species	D.B.H.	HEIGHT	CULL	VOLUME	S/P
White OAK	5	1/2	10	.01	P
Hickory	7	1	10	.04	P
Scarlet OAK	10	1/2	25	.04	P
Scarlet Oak	14	1/2	10	38	S
Sarlet Oak	14	1	25	.12	P
Scarlet OAK	17	1	15	73	S
White OAK	11	1	15	19	S
Sourwood	8	1 1/2	10	.06	P

Sawtimber trees with merchantable lengths of at least ½ log are calculated in units of **board feet** (abbreviated, BF; MBF = 1,000 BF).

Gross volume in cords

Dbh (inches)	1/2 Log	1 Log	1 1/2 Log	2 Log
5	0.012	0.019	0.027	—
6	.017	.028	.039	0.049
7	.023	.039	.053	.067
8	.030	.051	.070	.087
9	.039	.064	.089	.111
10	.048	.080	.111	.138
11	.058	.097	.135	.168
12	.070	.116	.161	.201
13	.082	.137	.190	.237
14	.096	.160	.221	.276
15	.111	.184	.255	.318
16	.127	.211	.292	.364
17	.144	.239	.331	.413
18	.162	.270	.373	.465
19	.181	.302	.417	.521
20	.202	.336	.465	.580
21	.223	.372	.515	.642
22	.246	.410	.568	.708
23	.270	.451	.623	.777
24	.296	.493	.682	.851

For example, consult the correct **volume table** to find that the gross volumes for a tree with DBH = 10 inches and height = 1 log is 0.08 cords as pulpwood and 14 BF (Doyle scale) as sawtimber. If the cull deduction is 20%, the net volumes for this tree are 0.08 X 0.8 = 0.06 cords, and 14 X 0.8 = 11 BF. Note that volumes are not calculated for trees smaller than 5 inches DBH. Note also that a number of board-foot volume tables exist, and that the one used must be specified by name.

DOYLE LOG RULE, FORM CLASS 78

GROSS TREE VOLUME

VOLUME (BOARD FEET) BY NUMBER USABLE 16-FOOT LOGS

Tree Diameter (inches)	1	1 1/2	2	2 1/2	3	3 1/2	4	4 1/2	5
10	14	17	20	21	22	-----	-----	-----	-----
11	22	27	32	35	38	-----	-----	-----	-----
12	29	36	43	48	53	54	56	-----	-----
13	38	48	59	66	73	76	80	-----	-----
14	48	62	75	84	93	98	103	-----	-----
15	60	78	96	108	121	128	136	-----	-----
16	72	94	116	132	149	160	170	-----	-----
17	86	113	140	161	182	196	209	-----	-----
18	100	32	164	190	215	232	248	-----	-----
19	118	156	194	225	256	276	297	-----	-----
20	135	180	225	261	297	322	346	364	383
21	154	207	260	302	344	374	404	428	452
22	174	234	295	344	392	427	462	492	521
23	195	264	332	388	444	483	522	558	594
24	216	293	370	433	496	539	582	625	668
25	241	328	414	486	558	609	660	709	758
26	266	362	459	539	619	678	737	793	849
27	292	398	505	594	684	749	814	877	940
28	317	434	551	650	750	820	890	961	1,032
29	346	475	604	714	824	902	980	1,061	1,142
30	376	517	658	778	898	984	1,069	1,160	1,251
31	408	562	717	850	983	1,080	1,176	1,273	1,370
32	441	608	776	922	1,068	1,176	1,283	1,386	1,488
33	474	654	835	994	1,152	1,268	1,385	1,497	1,609
34	506	700	894	1,064	1,235	1,361	1,487	1,608	1,730
35	544	754	964	1,149	1,334	1,472	1,610	1,743	1,876
36	581	308	1,035	1,234	1,434	1,583	1,732	1,878	2,023
37	618	860	1,102	1,318	1,534	1,694	1,854	2,013	2,172
38	655	912	1,170	1,402	1,635	1,805	1,975	2,148	2,322
39	698	974	1,250	1,498	1,746	1,932	2,118	2,298	2,479
40	740	1,035	1,330	1,594	1,858	2,059	2,260	2,448	2,636

INTERNATIONAL LOG RULE - 1/4 INCH, FORM CLASS 78

GROSS TREE VOLUME

VOLUME (BOARD FEET) BY NUMBER USABLE 16-FOOT LOGS

DBH (inches)	1	1 1/2	2	2 1/2	3	3 1/2	4	4 1/2	5
10	36	48	59	66	73	--	-	--	-
11	46	61	76	86	96	--	-	--	-
12	56	74	92	106	120	128	137	--	-
13	67	90	112	130	147	158	168	--	-
14	78	105	132	153	174	187	200	--	-
15	92	124	156	182	208	225	242	--	-
16	106	143	180	210	241	263	285	--	-
17	121	164	206	242	278	304	330	--	-
18	136	184	233	274	314	344	374	--	-
19	154	209	264	311	358	392	427	--	-
20	171	234	296	348	401	440	480	511	542
21	191	262	332	391	450	496	542	579	616
22	211	290	368	434	500	552	603	647	691
23	231	318	404	478	552	608	663	714	766
24	251	346	441	523	605	664	723	782	840
25	275	380	484	574	665	732	800	865	930
26	299	414	528	626	725	801	877	949	1,021
27	323	448	572	680	788	870	952	1,032	1,111
28	347	482	616	733	850	938	1,027	1,114	1,201
29	375	521	667	794	920	1,016	1,112	1,210	1,308
30	403	560	718	854	991	1,094	1,198	1,306	1,415
31	432	602	772	921	1,070	1,184	1,299	1,412	1,526
32	462	644	826	988	1,149	1,274	1,400	1,518	1,637
33	492	686	880	1,053	1,226	1,360	1,495	1,622	1,750
34	521	728	934	1,119	1,304	1,447	1,590	1,727	1,864
35	555	776	998	1,196	1,394	1,548	1,702	1,851	2,000
36	589	826	1,063	1,274	1,485	1,650	1,814	1,974	2,135
37	622	873	1,124	1,351	1,578	1,752	1,926	2,099	2,272
38	656	921	1,186	1,428	1,670	1,854	2,038	2,224	2,410
39	694	976	1,258	1,514	1,769	1,968	2,166	2,359	2,552
40	731	1,030	1,329	1,598	1,868	2,081	2,294	2,494	2,693

Total pulpwood or sawtimber volumes are calculated by multiplying the volume of each tallied tree by the "trees per acre" number (see table on preceding page) for the appropriate DBH-class, adding the results together for all the trees, and dividing by number of inventory points. For example, for the two pulp and two sawtimber scarlet oaks recorded in the sample data:

Pulpwood (0.04 cords/tree X 15 trees/ac) ÷ 7 = 0.09 cords/ac in 10 inch DBH trees
(0.12 cords/tree X 8 trees/ac) ÷ 7 = 0.14 cords/ac in 14 inch DBH trees
0.23 cords/ac

Sawtimber (38 BF/tree X 8 trees/ac) ÷ 7 = 43 BF/ac in 14 inch DBH trees
(73 BF/tree X 6 trees/ac) ÷ 7 = 63 BF/ac in 17 inch DBH trees
106 BF/ac

Application of Inventory Results

You are now ready to use the inventory results to restore or maintain ecological health, and to sustainably tend the forest to provide wood products. More detailed descriptions of the practical applications of the information you have collected thus far can be found in Part 2 ("Ecological Restoration") and Part 3 ("Tending and Harvest") of this three-part series on the PRACTICE OF ECOFORESTRY.

Suggested Reading

The following publications are available from: Forestry Extension, Department of Forestry, University of Kentucky, Lexington, KY 40546-0073. FOR-1 costs $1; FOR-9 and FOR-15A are free.

1. Graves, Donald H. 1986. A LANDOWNER'S GUIDE. MEASURING FARM TIMBER. University of Kentucky, Cooperative Extension Service. FOR-9. 22 pp.
2. Hill, Deborah H. 1993. SMALL WOODLOT MANAGEMENT IN KENTUCKY. University of Kentucky, Cooperative Extension Service. FOR-15A. 24 pp.
3. Hill, Deborah H. And Diana L. Olszowy. 1991. KENTUCKY TREES. HOW TO KNOW THEM. University of Kentucky, Cooperative Extension Service. FOR-1. 112 pp.

*Funded by a grant from the **W. Murray Fund***

Text, layout & Design – **Paul Kalisz**

Printed on Recycled Paper

Project Director – Al Fritsch