United States
Department of
Agriculture

Forest Service

**Southern Forest
Experiment Station**

New Orleans,
Louisiana

General Technical Report
SO-77

Stocking, Forest Type, and Stand Size Class—The Southern Forest Inventory and Analysis Unit's Calculation of Three Important Stand Descriptors

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SUMMARY

The procedures by which the Southern Forest Inventory and Analysis unit calculates stocking from tree data collected on inventory sample plots are described in this report. Stocking is then used to ascertain two other important stand descriptors: forest type and stand size class. Inventory data for three plots from the recently completed 1989 Tennessee survey are used to illustrate the computation procedures.

July 1990

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INTRODUCTION

The Forest Inventory and Analysis unit of the USDA Forest Service, Southern Forest Experiment Station conducts continuing surveys and reports on the forest resources in seven Midsouth States (Alabama, Arkansas, Louisiana, Mississippi, Oklahoma, Tennessee, and Texas). Data are collected from trees occurring on sample plots spaced across each State on a 3- by 3-mile grid. From these tree data, additional variables are generated that describe the forest stands in which the sample trees are located. The generation of three of these stand-description variables—stocking, forest type, and stand size class—is the focus of this paper. Data from the recent Tennessee survey are used to help illustrate the generation procedures. Stocking will be discussed first because it is essential to the generation of the other two stand-description variables.

STOCKING

Stocking, as defined by the Southern Forest Inventory and Analysis unit (SO-FIA), is a measure of the extent to which the growth potential of the site is utilized by trees or is preempted by other vegetation. It is expressed as the ratio (in percent) of actual stand density to a specified standard density at which the growth capacity of the site is fully utilized. The stocking standard currently in use has its origins in the Timber Resources for America's Future study (USDA FS 1958), in which stocking standards were developed for all major forest types in the United States. This was accomplished by reducing stand densities in normal yield tables for uncut natural stands to average densities that were based on the number of undamaged, free-to-grow, commercial tree species in previously cut stands on ownerships that were judged to be well managed. For sawtimber-sized trees, the 100-percent stocking standard was set at approximately 60 percent of the stocking in normal stands. For seedlings and sapling-sized trees, the stocking standard was set to provide sufficient initial stocking to insure satisfactory timber quality and provide for timber yields from intermediate harvests. The stocking standard originally developed for the South was based on 1,000 seedlings per acre, but was later reduced to reflect a basis of 600 seedlings per acre. This reduction was applied only to trees 6 inches in diameter at breast height (d.b.h.) and smaller in order to account for changes in southern forest management since 1958 (table 1). This stocking standard is used in the derivation of each plot's relative stocking percentage. Each live tree tallied contributes a relative stocking percentage to the plot total based on its size, its corresponding specified stocking standard, and the sampling design under which it was selected (tables 2, 3, 4).

The SO-FIA tallies trees 5 inches in d.b.h. and larger on a cluster of 10 horizontal prism points (basal area

Table 1.— *Original and current stocking standard for the South, by tree size*

Diameter class	Stocking standard	
	Original	Current
	Trees per acre	
<1	1,000	600
2	800	560
4	590	460
6	400	340
8	240	240
10	155	155
12	115	115
14	90	90
16	72	72
18	60	60
20	51	51
22	42	42
24	36	36
26	31	31
28	27	27
30+	24	24

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Table 2.—*Example plot consisting of an overstocked stand of seedling to sapling-sized loblolly pines**

Prism point	Species	Crown class	D.b.h.	Tree class	Relative stocking percentage
			Inches		
1	Yellow-poplar	Intermediate	1.1	Growing-stock	4.709
	Loblolly pine	Intermediate	1.0	Growing-stock	4.690
2	Yellow-poplar	Intermediate	0.1	Growing-stock	4.600
	Dogwood	Intermediate	0.1	Growing-stock	4.600
	Dogwood	Intermediate	0.1	Growing-stock	4.600
	Yellow-poplar	Intermediate	0.1	Growing-stock	2.200
3	Northern red oak	Intermediate	0.1	Growing-stock	4.600
	Yellow-poplar	Intermediate	0.1	Growing-stock	4.600
	Yellow-poplar	Intermediate	0.1	Growing-stock	4.600
	Yellow-poplar	Intermediate	0.1	Growing-stock	2.200
4	Dogwood	Intermediate	1.0	Growing-stock	4.690
5	Loblolly pine	Intermediate	1.3	Growing-stock	4.753
	Loblolly pine	Intermediate	1.3	Growing-stock	4.753
	Loblolly pine	Intermediate	1.0	Growing-stock	4.690
6	Loblolly pine	Intermediate	1.7	Growing-stock	4.859
	Loblolly pine	Intermediate	1.3	Growing-stock	4.753
7	Loblolly pine	Intermediate	1.6	Growing-stock	4.830
	Loblolly pine	Intermediate	1.4	Growing-stock	4.777
	Loblolly pine	Intermediate	1.4	Cull	4.777
8	Loblolly pine	Intermediate	1.4	Growing-stock	4.777
	Loblolly pine	Intermediate	1.1	Growing-stock	4.709
9	Loblolly pine	Intermediate	0.1	Growing-stock	4.600
	Blackgum	Intermediate	0.1	Growing-stock	4.600
	Loblolly pine	Intermediate	0.1	Growing-stock	4.600
	Loblolly pine	Intermediate	0.1	Growing-stock	2.200
10	Loblolly pine	Intermediate	0.1	Growing-stock	4.600
	Blackgum	Intermediate	0.1	Growing-stock	4.600
	Blackgum	Intermediate	0.1	Growing-stock	4.600
	Yellow-poplar	Intermediate	0.1	Growing-stock	2.200

*Plot summary: Stocking (all live) 125.767 percent
Stocking (growing-stock) 120.990 percent

Forest typing	All live stocking (%)
Softwoods	54
Pines	54
Loblolly pine	54
Yellow-poplar	20
Dogwood	11
Blackgum	11
Northern red oak	4

Tree-size class	
Seedling/sapling	100

Table 3.—*Example plot consisting of an optimally stocked stand of pole-sized white oak on an upland site**

Prism point	Species	Crown class	D.b.h.	Tree class	Relative stocking percentage
			Inches		
1	White oak	Codominant	6.0	Growing-stock	5.600
2	White oak	Codominant	8.8	Growing-stock	4.500
3	Post oak	Codominant	11.1	Growing-stock	4.200
	White oak	Codominant	8.8	Growing-stock	4.500
	White oak	Intermediate	2.8	Growing-stock	1.534
4	White oak	Dominant	10.2	Growing-stock	4.400
	White oak	Codominant	12.0	Growing-stock	4.200
	White oak	Codominant	9.5	Growing-stock	4.400
	White oak	Codominant	8.3	Growing-stock	3.000
	White oak	Intermediate	6.3	Growing-stock	0.000
5	White oak	Dominant	12.1	Growing-stock	4.200
	Hickory	Intermediate	2.8	Growing-stock	1.534
6	White oak	Codominant	7.3	Growing-stock	4.500
	Black oak	Codominant	6.2	Growing-stock	5.600
7	White oak	Codominant	7.5	Growing-stock	4.500
	White oak	Intermediate	4.8	Growing-stock	4.508
	Sourwood	Intermediate	3.2	Cull	2.004
	White oak	Intermediate	1.3	Cull	0.331
8	Sourwood	Intermediate	6.6	Cull	5.600
	Black gum	Intermediate	1.9	Cull	0.706
	Black gum	Intermediate	1.5	Cull	0.440
9	Hickory	Dominant	13.6	Cull	3.900
	White oak	Intermediate	7.1	Growing-stock	4.500
	White oak	Intermediate	6.6	Growing-stock	5.600
	Sourwood	Intermediate	5.0	Cull	2.000
10	White oak	Codominant	9.3	Growing-stock	4.400

*Plot summary: Stocking (all live) 90.657 percent
Stocking (growing-stock) 75.676 percent

Forest typing	All live stocking (%)
Hardwoods	100
White oak	71
Sourwood	11
Hickory	6
Black oak	6
Post oak	5
Black gum	1

Tree-size class	
Seedling/sapling	12
Pole	70
Sawtimber	18

Table 4.—*Example plot consisting of an understocked stand of sawtimber-sized cottonwood on a bottomland site**

Point	Species	Crown class	D.b.h.	Tree class	Relative Stocking percent
			Inches		
1	Cottonwood	Dominant	22.7	Growing-stock	3.400
	Osage-orange	Intermediate	12.4	Cull	4.200
2	Sugarberry	Intermediate	3.7	Cull	5.776
	Sugarberry	Intermediate	1.8	Cull	4.889
3	Osage-orange	Intermediate	7.6	Cull	4.500
4	Cottonwood	Dominant	31.3	Growing-stock	3.200
	Cottonwood	Codominant	24.3	Growing-stock	3.300
5	Cottonwood	Dominant	31.3	Growing-stock	3.200
	Cotton wood	Codominant	29.4	Growing-stock	3.200
	Cottonwood	Codominant	24.7	Growing-stock	3.300
	Willow	Intermediate	17.6	Cull	3.500
6	Cottonwood	Codominant	30.4	Growing-stock	3.200
	Cottonwood	Codominant	27.3	Growing-stock	3.300
7	Cottonwood	Dominant	29.8	Growing-stock	3.200
	Hickory	Intermediate	1.3	Cull	0.331
8	Cottonwood	Codominant	23.3	Cull	3.300
	Cottonwood	Codominant	22.9	Growing-stock	3.400
	Honeylocust	Intermediate	7.0	Growing-stock	4.500
9	Osage-orange	Intermediate	12.8	Cull	4.200
10	Sycamore	Intermediate	10.9	Cull	4.400
	Osage-orange	Intermediate	10.3	Cull	4.400

*Plot summary: Stocking (all live) 76.693 percent
Stocking (growing-stock) 37.200 percent

Forest typing	All live stocking (%)
Hardwoods	100
Cottonwood	47
Osage-orange	23
Sugarberry	14
Sycamore	6
Honeylocust	5
Willow	4
Hickory	1
Tree-size class	
Seedling/sapling	14
Pole	23
Sawtimber	63

factor 37.5) and tallies trees less than 5 inches in d.b.h. on ten 1/275-acre circular fixed plots associated with each prism point. As a consequence, relative stocking percentages can be calculated from the following formulas:

Relative stocking percentage for a prism point tree=[(37.5 square feet per acre) ÷ (basal area of the tally tree) ÷ (number of points per sample plot) ÷(appropriate size-class stocking standard)](100).

For example, relative stocking percentage for a 6-inch tally tree=[(37.5) ÷ (0.1963) ÷ (10) ÷ (340)](100)=5.6 percent.

Relative stocking percentage for fixed-plot tree=[(trees per acre represented by each tally tree) ÷(number of fixed plots per sample plot) ÷ (appropriate size-class stocking standard)] (100).

For example, relative stocking percentage for a 4-inch tally tree=[(275) ÷ (10) ÷ (460)](100)=6.0 percent.

These general formulas and the stocking standards in table 1 have been used to calculate relative stocking percentages for different-sized tally trees collected under the SO-FIA sample design (table 5). Only data for the 2- and 4-inch classes are shown in table 5, but tally trees from 1.0 to 4.9 inches in d.b.h. are actually assigned relative stocking percentages by 0.10-inch classes using the following formula: $(4.5865)+(0.0229)(\text{d.b.h.})+(0.0807)(\text{d.b.h.})^2$.

This procedure for calculating relative stocking percentages is modified in certain special circumstances. Seedlings, which are defined as trees with a d.b.h. of less than 1.0 inch, are tallied and assigned a stocking percentage only if they occur on sample points where no trees are larger than seedlings (table 2). Also, in the early 1970's it was determined that smaller trees, which are assigned relative stocking percentages that are greater than those assigned to larger trees, were given disproportionate weight in the determination of forest type. This caused some pine stands to be typed by the hardwood understory and not by the softwood overstory. To alleviate this problem, the stocking percentages assigned to sapling-sized trees (d.b.h. between 1.0 and 4.9 inches) on sample points with at least one tree whose d.b.h. is 5.0 inches or larger are discounted using the following formula, which was proposed by the Southeastern Forest Experiment Station:

Discounted stocking percentage=$(0.1957)(\text{d.b.h.})^2$. The discounting procedure was applied in table 3, sample points 7 and 8. Finally, points having no live tally trees are assigned a percentage that refers not to the relative stocking of trees but to the proportion of the plot preempted from tree growth by other vegetation or other conditions. With a 10-point sample cluster, this percentage is 10. This percentage is not used in the calculation of relative plot stocking.

In the next step, relative tree stocking at each point is summed to yield point occupancy. Point occupancy is allowed to accumulate to 16 percent per point and to a maximum of 160 percent per plot. As the current 100-percent stocking standard was set at approximately 60 percent of normal stocking, the 160-percent maximum can be regarded as the proportional equivalent of stocking levels represented by normal yield tables. Actually, the maximum percentage should be 167 percent, but has been reduced down to the "160 percent plus" category shown in the Forest Survey Handbook (USDA FS 1972). Allowing each point to contribute no more than a given maximum to point occupancies ensures that no one point or group of points has a disproportionate weight in determining stocking, forest type, or stand size class. This is especially important when the sample plot consists of a cluster of 10 prism points that cover approximately 1 acre.

In the summation of point occupancy, preference is given to the most open-grown and largest trees. This is accomplished by sorting the tally trees by crown class and d.b.h. (tables 2, 3, 4). Tally trees less than 5 inches in d.b.h., which are not assigned to crown classes in the field, are subsequently assigned to the intermediate crown class. The stocking percentage of the tally tree that causes the point occupancy to exceed 16.0 percent is reduced until point occupancy equals 16.0 percent (table 2, sample points 2, 3, 9, 10). The relative stocking percentages for trees dropped from the point occupancy accumulation are set at zero (table 3, sample point 4). The relative stocking percentages of the trees that contribute to point occupancies are summed to determine relative stocking for each plot. Relative plot stocking is commonly based only on tallies and measurements of

Table 5.—*Relative stocking percentages assigned to tally trees in given diameter classes*

Diameter class	Relative tree stocking
Inches	*Percent*
<1	4.6
2	5.0
4	6.0
6	5.6
8	4.5
10	4.4
12	4.2
14	3.9
16	3.8
18	3.5
20	3.4
22	3.4
24	3.3
26	3.3
28	3.3
30+	3.2

Table 6.—*General species groupings used in the determination of forest type*

Timber types	Managements types	General forest types	Detailed forest types
Softwood	Pine	White pine-hemlock	Jack pine
			Red pine
			White pine
			White pine-hemlock
			Hemlock
			White-red-jack pine
		Longleaf-slash pine	Loneleaf-slash pine
			Longleaf pine
			Slash pine
		Loblolly-shortleaf pine	Loblolly-shortleaf pine
			Loblolly pine
			Shortleaf pine
			Virginia pine
			Sand pine
			Eastern redcedar
			Pond pine
			Spruce pine
			Pitch pine
			Table-mountain pine
	Other softwood	Spruce-fir	Spruce-fir
			Balsam fir
			Black spruce
			Red spruce
			Northern white-cedar
			Tamarack
			White spruce
Mixed softwood/hardwood	Mixed pine/hardwood	Oak-pine	White pine-northern red oak- white ash
			Eastern redcedar-hardwood
			Longleaf pine-scrub oak
			Shortleaf pine-oak
			Virginia pine-southern red oak
			Loblolly pine-hardwood
			Slash pine-hardwood
			Other oak-pine
Hardwood	Upland hardwood	Oak-hickory	Oak-hickory
			Post-black-bear oak
			Chestnut oak
			White-red oak-hickory
			White oak
			Northern red oak
			Yellow-poplar-white oak-northern red oak
			Southern scrub oak
			Sweetgum-yellow-poplar
			Mixed hardwoods
		Maple-beech-birch	Maple-beech-birch
			Sugar maple-beech-birch
		Aspen-birch	Aspen-birch
			Aspen
			Birch
	Bottomland hardwood	Oak-gum-cypress	Oak-gum-cypress
			Swamp chestnut-cherrybark oak
			Sweetgum-Nuttal oak-willow oak
			Sugarberry-American elm-green ash
			Overcup oak-water hickory
			Atlantic white-cedar
			Cypress-tupelo
			Sweetbay-swamp tupelo-red maple
		Elm-ash-cottonwood	Elm-ash-cottonwood
			Black ash-American elm-red maple
			River birch-sycamore
			Cottonwood
			Willow
			Sycamore-pecan-American elm
		Nontyped	

growing-stock trees, but can also be based on tallies and measurements of live trees (growing-stock trees plus rough and rotten cull trees). The relative plot stocking is then used to place the plot in one of several broad stocking classes:

Relative plot stocking	Stocking class
<16.7 percent	Nonstocked
16.7 to 60 percent	Understocked (table 4)
60 to 100 percent	Optimally stocked (table 3)
>100 percent	Overstocked (table 2)

FOREST TYPE

Determinations of forest type are not made in the field. Instead, they are made on the basis of computations that involve the use of tally-tree data. This assures consistency in forest type classifications over time, which in turn make it possible to assess trends accurately.

In general, a forest type takes its name from the species or species group that forms the plurality of relative plot stocking. In the actual typing process, forest types are named by determining the proportions of relative plot stocking in increasingly detailed species groupings, which are shown in table 6. First it is determined whether softwood species (excluding cypress) comprise at least half of the plot stocking. If so, then classification of the plot as a pine or other softwood type depends on whether pine species (including red cedar) comprise the majority of the softwood stocking. The specific species of pine or other softwood that forms the plurality of the pine or other softwood plot's stocking then determines the general and detailed forest type classifications. For example, in table 2 softwoods comprise 54 percent of relative plot stocking, pines comprise 100 percent of softwood stocking, and loblolly pines comprise all of the pine stocking, resulting in a loblolly-shortleaf general forest type and loblolly detailed forest type classifications.

If softwoods fail to comprise the majority of relative plot stocking, but pines still comprise 25 to 49 percent, then a mixed forest type will be assigned by determining which pine species has the largest proportion of stocking. If pine stocking is less than 25 percent of relative plot stocking, then a hardwood type is assigned. Whether a plot is classified as an upland or bottomland hardwood type depends entirely on the physiographic class assigned by the forester in the field. When a plot is located on a upland physiographic site, an upland hardwood type is assigned; when a plot is located on a bottomland physiographic site, a bottomland hardwood type is assigned. Beyond this point, the general forest type and detailed forest type are named for the hardwood species or species grouping that forms the plurality of stocking (tables 4, 5). Forested plots lacking live tally trees, recent clearcuts for example, are classified as nontyped.

STAND SIZE CLASS

Stand size class is also generated from the relative stocking percentages assigned to live tally trees. For plots containing enough live tally trees to have a relative plot stocking of at least 16.7 percent, each live tally tree is assigned to one of the following tree-size classes based on its d.b.h.:

1. Seedling/sapling (trees less than 5 inches in d.b.h.),
2. Pole (softwood trees from 5.0 to 8.9 inches in d.b.h. and hardwood trees from 5.0 to 10.9 inches in d.b.h.), and
3. Sawtimber (trees greater than pole-size).

Relative stocking percentages for all trees in each size class are summed, and the proportion of total plot stocking represented by the size class is calculated. If trees in the seedling/sapling size class comprise at least half of the plot stocking then the plot is classed as seedling/sapling (table 2). If not, then the plot's size class will depend on whether the pole-sized trees or sawtimber-sized trees comprise the greater proportion of the plot's stocking (tables 3, 4). Plots with relative stocking percentages below 16.7 are classified as nonstocked.

CONCLUSIONS

A clear understanding of the procedures used to calculate stocking, forest type, and stand size class is essential to correct understanding, interpretation, and use of SO-FIA forest resource data. The SO-FIA procedures for computation of these stand descriptors from tree-level inventory data were developed to reflect real-world conditions. However, the assumptions upon which the techniques are based will not hold true in every situation. Fortunately, these occasional misrepresentations of existing conditions are compensated for by the consistency these computational techniques lend to assessments of long-term trends.

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May, Dennis M. 1990. Stocking, forest type, and stand size class—the Southern Forest Inventory and Analysis unit's calculation of three important stand descriptors. Gen. Tech. Rep. SO-77. New Orleans, LA: U.S. Department of Agriculture, Forest Service, Southern Forest Experiment Station. 7 p.

Data from three forest inventory plots collected in the 1989 survey of Tennessee are used to demonstrate how the Southern Forest Inventory and Analysis unit calculates plot stocking, forest type, and stand size class from forest inventory sample tree data.

Keywords: Forest inventory, sample plot, stocking class, stocking percentage, stocking standard.