BASELINE OVERSTORY CONDITIONS IN FOUR WATERSHEDS OF VARYING MANAGEMENT INTENSITY IN THE EASTERN OUACHITA MOUNTAINS

James M. Guldin and Thomas Foti[1]

Abstract—Baseline tree data were collected in four watersheds in the eastern Ouachita Mountains during 1996-98. By watershed, average basal area ranged from 71 to 102 square feet per acre, average tree density ranged from 234 to 295 trees per acre, and quadratic mean diameter of trees ranged from 7.41 to 8.22 inches. Variables for which the largest values were associated with the unmanaged South Alum Creek watershed and the smallest values were associated with the most intensively managed Little Glazypeau Creek watershed include basal area for all trees, stem density for all trees, basal area and stem density of the white oak-southern red oak species group and for all hardwoods, and basal area and stem density of shortleaf pine and for all conifers. Conversely, variables for which the largest values were associated with the Little Glazypeau watershed, and the lowest values were associated with the South Alum Creek watershed, were loblolly pine basal area and stem density. The data suggest that it may be possible to relate management intensity to descriptive mensurational variables at the landscape scale in the eastern Ouachita Mountains.

INTRODUCTION

The phase III landscape study in the Ouachita Mountains Ecosystem Management Research Project is designed to describe changes in baseline conditions among four watersheds under different intensities of management. The four watersheds under study and their attributes are listed in table 1. An overall description of the study design is presented in Guldin (in press).

Experimental replication of watersheds of substantial size is impractical; it is impossible to achieve uniformity of topographic, edaphic, and physiographic conditions in such watersheds. Some other approach to the development of experimental error is needed if it is necessary to apply parametric statistical tests in this situation. We tackled this question with a study design that used time, rather than space, as an experimental replicate. Thus, 4 years of measurements were taken in these areas, and comparisons among watersheds included variation by year to determine whether treatment or year was the more significant variable.

The objectives of the research reported here are to quantify existing vegetation conditions of pine, pine-hardwood, and hardwood stands in the four watersheds; to compare differences in stand structure by watershed and year; and to describe the range of variation in forest conditions among watersheds by year and treatment.

METHODS

Sample Grid

The baseline overstory vegetation data was collected by systematic sampling over a 4-year period (1995-98). Sampling was conducted using plots on a rectangular grid, with offsets in the grid by year (fig. 1). The grid used as a basis for sampling in 1995 and 1996 consisted of north-south transects 400 m apart. To facilitate access, each transect was flagged and numbered wherever it crossed as road. Additional north-south transects, offset 200 m from those employed in 1995 and 1996, were used in 1997 and 1998.

Sample points were located at 200-m intervals along the first set of transects in the first year. In the second year, the sample points were offset 100 m from the first set of sample points along the same transects. In the third year, sample points were located at 200-m intervals along the second set of transects. In the fourth year, sample points were offset 100 m from the third set of sample points along each of the second set of transects.

Table 1—Attributes of the four watersheds under study

	Ownership		Management	
Watershed	FS	Industry	intensity	Area
	- - *percent* - -			*ha*
Alum Creek	100	0	None	1460
Bread Creek	95	5	Low	1255
North Alum Creek	50	50	Moderate	3080
Little Glazypeau Creek	5	95	High	2450

FS = Forest Service.

[1] Research Forest Ecologist and Project Leader, USDA Forest Service, Southern Research Station, Hot Springs, AR; and Director of Research, Arkansas Natural Heritage Commission, Department of Arkansas Heritage, State of Arkansas, Little Rock, AR, respectively.

Citation for proceedings: Guldin, James M., tech. comp. 2004. Ouachita and Ozark Mountains symposium: ecosystem management research. Gen. Tech. Rep. SRS–74. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southern Research Station. 321 p.

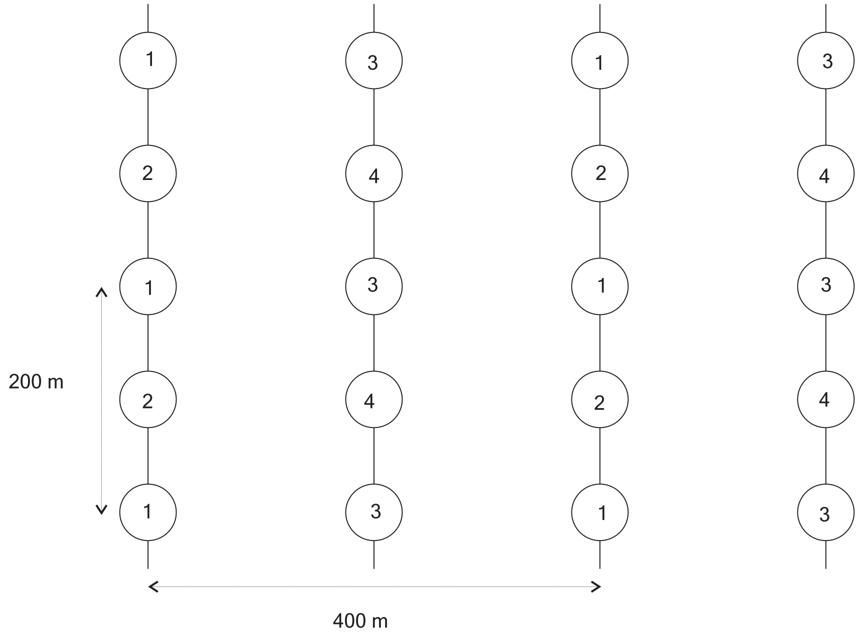


Figure 1—Layout of transects from 1995-98. Plots labeled 1 were sampled in 1995, 2 in 1996, 3 in 1997, and 4 in 1998.

These grid points became the plot centers for the plot-based measurements of vegetation. Approximately 500 plots were sampled annually.

Plot Layout

Two different sampling methods were used. In 1995, stands were sampled using variable radius plots, with a basal area factor (BAF) 10 square-feet-per-acre prism (fig. 2a). All trees 3.0 inches in diameter at breast height (d.b.h.) and larger that were sampled were recorded by species and 2-inch diameter classes. Examination of the data after the first year of sampling suggested that this sampling might not yield data that adequately characterize the vegetation in the watersheds. Because of this concern, sampling in 1996-98 was done using a nested plot design (fig. 2b). Circular 0.1-acre fixed-radius plots were used to sample all trees having d.b.h. from 3.6 to 9.5 inches inclusive, and a BAF 5 square-feet-per-acre prism was used to sample all trees with d.b.h. 9.6 inches and larger. Species and d.b.h. to the nearest 0.1 inch were recorded for all sampled trees.

Statistical Analysis

Two statistical questions arise. First, because two sampling schemes were employed, we have to ask whether the 1995 data can be combined with 1996-98 data. Second, we have to ask whether the replication approach employed was sensitive enough to yield useful results.

Statistical tests suggest that the total basal area variable is not normally distributed under either sample design (the Shapiro-Wilks W statistic was significant at the 0.0001 level for both). For this reason, comparisons of data obtained by different sample methods were conducted using nonparametric analysis of variance, using the Wilcoxon statistic to test significance of mean comparisons. Descriptive baseline information (basal area per acre, trees per acre, and quadratic mean diameter) will be useful to the research team and others.

RESULTS

Comparison of Sampling Methods

The 1995 sample gives a basal area distribution sensitive only to the nearest 10 square feet of basal area (fig. 3a). This is an artifact of the expansion of a prism sample to a per-acre basis. Each tree sampled counts as 10 square feet of basal area per acre in trees of that size class. Therefore, the prism sample taken in 1995 produces a distribution of basal area that is obviously discontinuous. Conversely, the 1996-98 sampling scheme, which combined prism sampling and the use of fixed-radius plots, produces a more continuous distribution (fig. 3b). The shape of the distribution is similar to that of the 1995 sample, but the nested design results in a more uniform distribution of observations across the range of basal areas.

Discontinuities in data, such as that found in the 1995 sample, can violate underlying assumptions in parametrical statistical tests. One such test suggests that total basal area variable is not normally distributed under either sample design (the Shapiro-Wilks W statistic was significant at the 0.0001 level for both). For this reason, comparisons between variable means for data obtained by different sample methods were conducted using nonparametric analysis of variance. The Wilcoxon statistic was used to test significance of mean comparisons. Using this test, significant differences in variable means by sample design were detected for virtually all summary variables of basal area and stem density (table 2). Four of the six species groups show significantly higher basal area in the 1996-98 sample design than the 1995 sample design.

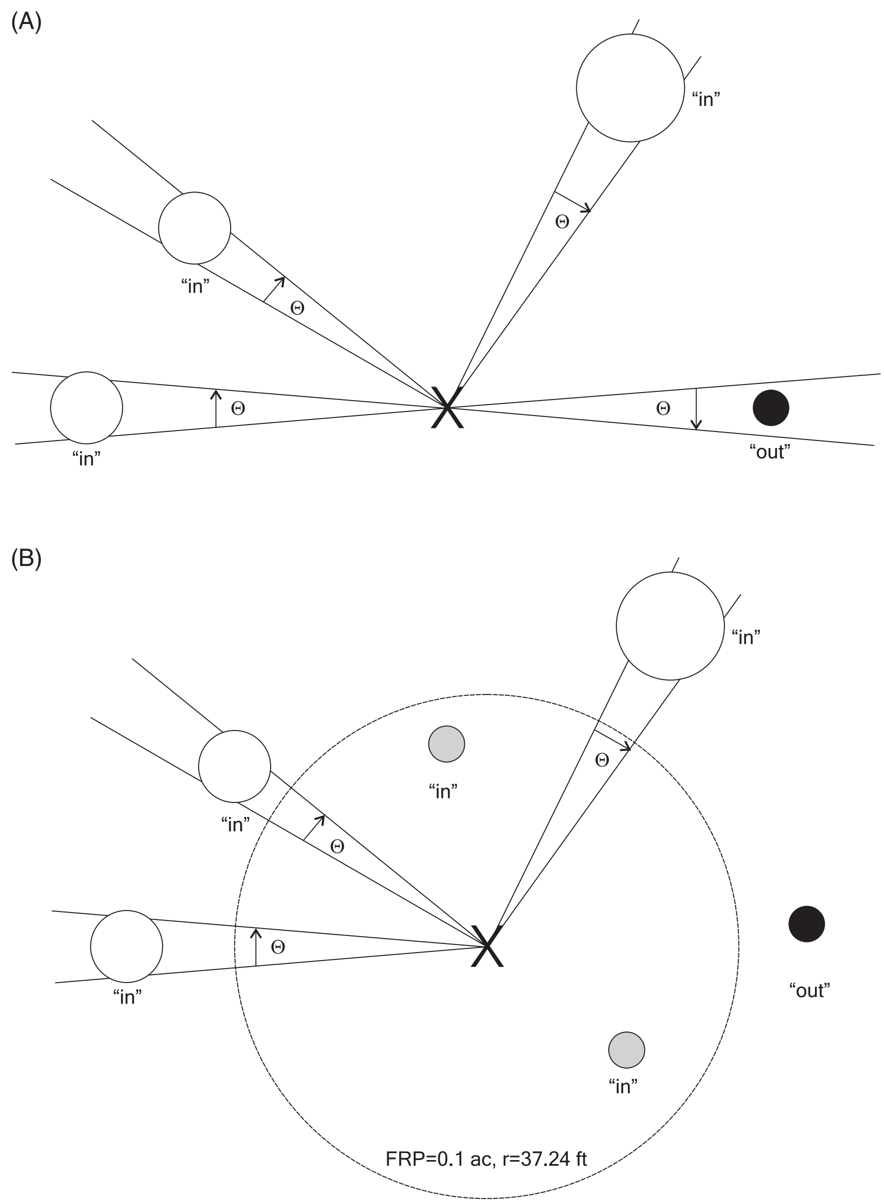
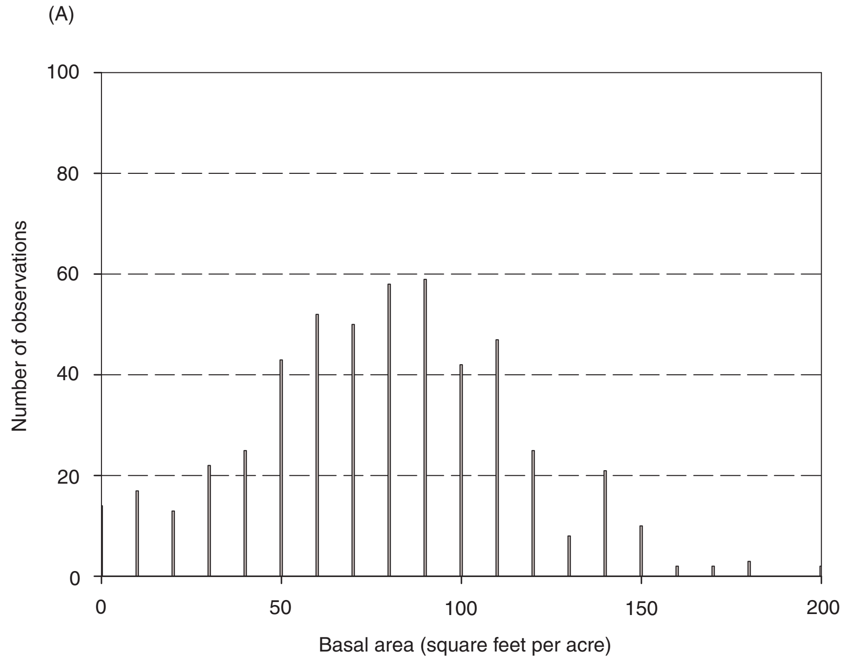


Figure 2—Overstory vegetation sampling methods used in (A) 1995, and (B) 1996-98. (A) 1995 sampling. Sampling is conducted using a variable radius prism where Θ corresponds to a basal area factor (BAF) of 10 square feet per acre, which marginally samples a tree with diameter at breast height (d.b.h.) 12.0 inches at 33 feet; and (B) 1996-98 sampling. Sampling is based on use of a nested fixed radius plot (FRP) of 0.1-acre to sample midstory trees having d.b.h. 3.6 and 9.5 inches inclusive, combined with use of a prsim where Θ corresponds to a BAF of 5 square feet per acre to sample trees with d.b.h. greater than or equal to 9.6 inches. A BAF 5 prism marginally samples a 12.0-inch tree at 46.67 feet.

The largest difference is in the sample for loblolly pine, which is found exclusively in plantations in these watersheds. Loblolly pine accounts for only 10 percent of the basal area in the 1995 sample, but the difference in the loblolly pine basal area between the two samples is 68 percent of the total difference between the samples. These loblolly pine plantations are often very dense and difficult to see through, which may contribute to inaccuracy in the prism sample.

Of the three broad species groups (all conifers, all hardwoods, and all species), the all conifers and all species groups show significantly higher basal area in the 1996-98 sample than in the 1995 sample (table 2). Four of the six species groups show significantly higher stem density in the 1996-98 sample than in the 1995 sample, as do three broad summary variables.



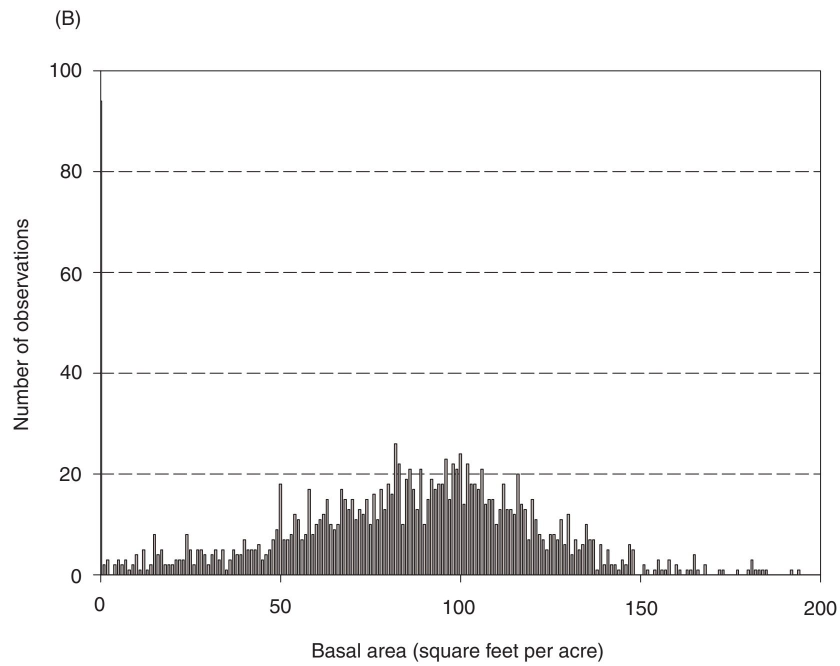


Figure 3—Number of observations by 1-foot basal area increments, 1995 sample design versus 1996-98 sample design. (A) 1995 sample design, and (B) 1996-98 sample design.

To determine the effect of sample design on variable means, we randomly selected and remeasured eighty-one 1995 plots in 1997 according to the 1996-98 sample design. In all instances, broad summary variables have higher means and lower coefficients of variation in the 1996-98 sample design than in the 1995 sample design (table 3). Results for two important species or species groups are consistent with these findings—shortleaf pine (fig. 4a) and the white oak-southern red oak group (fig. 4b).

Based on these results, it is difficult to justify pooling the 1995 data with the 1996-98 data for future analyses. For the balance of this paper, only the 1996-98 data will be used as a basis for discussing the conditions in the watersheds.

Overall Stand Conditions

The mean basal area (all species combined) across all watersheds over 1996-98 was 86.4 square feet per acre. Conifer basal area across all watersheds averaged 49.5 square feet per acre, of which 35.8 square feet per acre was shortleaf pine and 13.7 square feet per acre was loblolly, with

Table 2—Differences in mean species group summary variables, by sample design, across all watersheds[a]

	Sample design 1995	1996–98	Prob > lZl
	- - - ft^2 per acre- - -		
A. Basal area			
Shortleaf pine	34.32	35.75	NS
Loblolly pine	8.28	13.74	0.001
Other conifers	0.00	0.05	0.005
White and southern red oak	16.32	17.53	0.0001
Other oaks	10.12	9.31	0.01
Other hardwoods	9.40	10.02	0.0001
All conifers	42.60	49.54	0.0001
All hardwood	35.83	36.86	NS
All species	78.43	86.39	0.0001
	Trees per acre		
B. Stem density			
Shortleaf pine	94.97	95.26	0.05
Loblolly pine	40.52	46.16	0.01
Other conifers	0.00	0.21	0.01
White and southern red oak	60.22	58.97	0.0001
Other oaks	31.03	30.01	0.0001
Other hardwoods	41.04	47.84	0.0001
All conifers	135.48	141.64	0.0001
All hardwoods	132.28	136.82	0.001
All species	267.77	278.46	0.0001

[a] Differences between means are shown by Prob > lZl, the nonparametric Wilxocon 2-sample test statistic with normal approximation; the value shown is the probability level at which the null hypothesis of no difference between means is rejected.

Table 3—Mean and coefficient of variation for summary basal area and stem density variables for subset of 1995 sample design plots that were remeasured in 1997 using the 1996–98 sample design

	Sample design 1995 Mean	1995 C.V.	1996–98 Mean	1996–98 C.V.
	ft^2/ac	*percent*	*ft^2/ac*	*percent*
A. Basal area				
All conifers	48.89	69.1	58.29	61.7
All hardwoods	31.72	80.8	40.32	60.9
All species	80.62	43.3	98.61	33.4
	trees/ac	*percent*	*trees/ac*	*percent*
B. Stem density				
All conifers	139.2	109.4	138.2	82.6
All hardwoods	122.4	83.2	161.4	50.8
All species	261.5	63.5	299.7	37.0

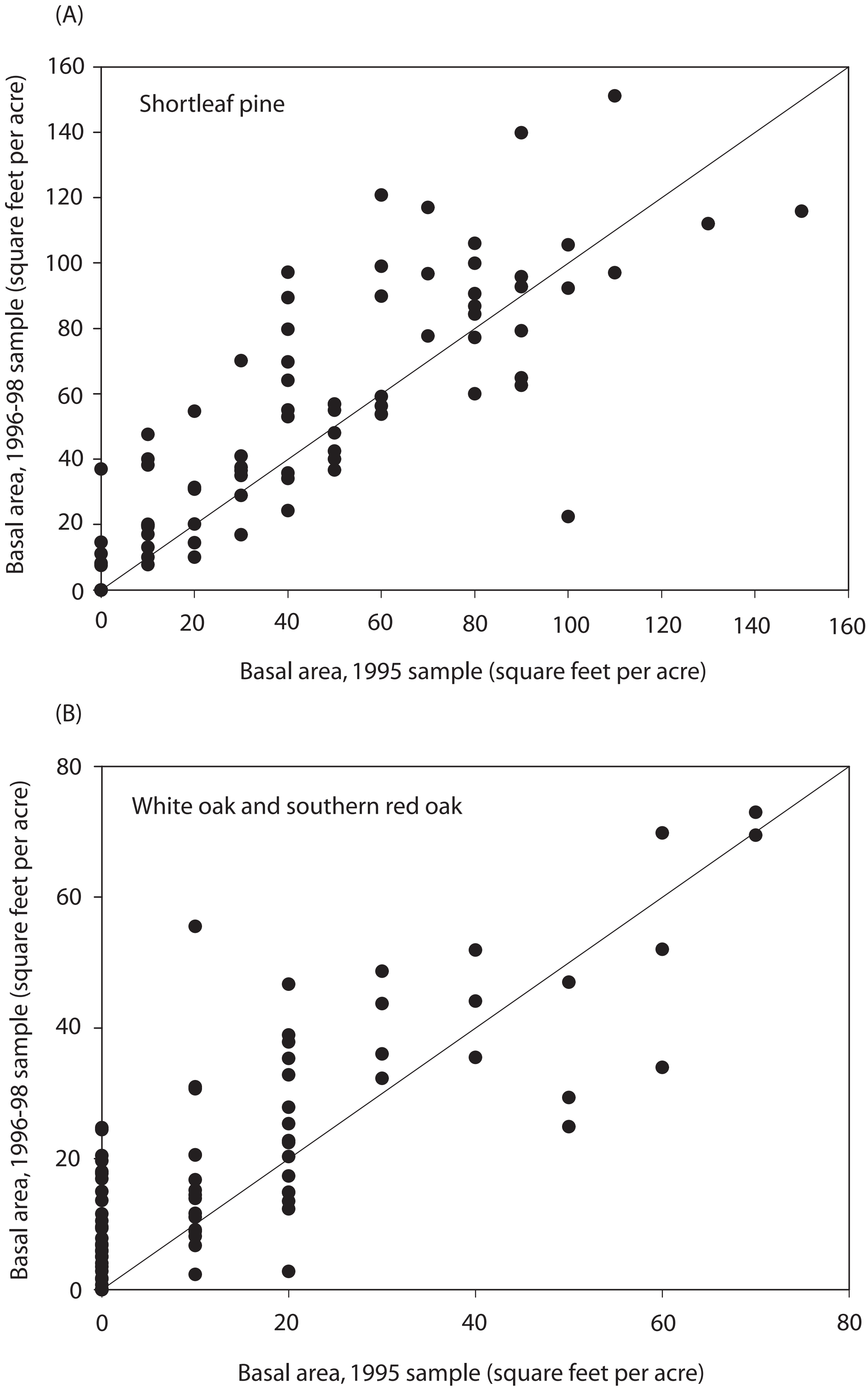


Figure 4—Basal area by plot, for the 81-plot subset of 1995 sample design plots that were remeasured in 1997 using the 1996-98 sample design. (A) shortleaf pine, and (B) white oak and southern red oak.

the small balance in eastern redcedar. The mean hardwood basal area across all watersheds was 36.9 square feet per acre, of which nearly half (17.5 square feet per acre) was in white and southern red oak, and the balance more or less equally split between other oaks (9.3 square feet per acre) and other hardwoods (10.0 square feet per acre).

Mean stem density (all species combined) across all watersheds over 1996-98 was 278.5 trees per acre, nearly equally split between conifers (141.6 trees per acre) and hardwoods (136.8 trees per acre). Shortleaf pine was most numerous, with 95.3 trees per acre, followed by white and southern red oaks (59.0 trees per acre), other hardwoods (47.8 trees per acre), loblolly pine (46.2 trees per acre), other oaks (30.0 trees per acre), and eastern redcedar (0.2 trees per acre).

South Alum Creek

The unmanaged South Alum Creek watershed had, on average, 295 trees per acre (table 4). Of these, 174 trees per acre were hardwoods and 121 trees per acre were conifers. Almost all of the conifers that were present were shortleaf pine.

Basal area (all species combined) was higher (102.5 square feet per acre) than it was in the other watersheds studied (table 4). Of this, 55.4 square feet per acre was in conifers and 47.1 square feet per acre was in hardwoods. Shortleaf pine made up more than 99.9 percent of the conifer basal area in the South Alum Creek watershed. The remaining 0.1 percent was loblolly pine, recorded in a handful of research plots that were planted to loblolly in the 1970s and 1980s. No eastern redcedar was sampled during the 3 years of data collection.

Over half (56.6 percent) of the hardwood basal area in the South Alum Creek watershed was in white and southern red oaks. The remaining basal area consisted almost equally of other oaks (primarily black and post oaks) and hardwoods other than oak.

Quadratic mean diameter (qdbh) is the diameter calculated from the mean basal area per tree. In the South Alum Creek watershed, the qdbh for all species combined during 1996-98 was 8.23 inches. Conifers were, on average, larger than hardwoods in this watershed; the qdbh for conifers was 10.59 inches, whereas that for hardwoods was 7.06 inches.

Bread Creek

The Bread Creek watershed, characterized by general Forest Service management, supported an average of 292.0 trees per acre (table 4), exactly divided between hardwoods and conifers. Of the total, over 70 percent of stems were shortleaf pine, white oak, or southern red oak. More than 97 percent of the conifers present were shortleaf pine, and more than 70 percent of the hardwoods present were oaks.

Basal area averaged 86.2 square feet per acre (table 4), of which 49.7 square feet per acre was in conifers and 36.5 square feet per acre was in hardwood. Shortleaf pine accounted for 97.1 percent of the conifer basal area. Loblolly pine, in plantations, made up 2.8 percent of conifer basal area. White oak and southern red oak constituted 52.4 percent of hardwood basal area, with an additional 26.6 percent in other oak species and the balance in other hardwoods.

In the Bread Creek watershed, qdbh for all trees sampled was 7.4 inches, which was smaller than qdbh in the other watersheds. Conifer qdbh was 8.5 inches. The qdbh of

Table 4—Mean basal area and stem density by species or species group and watershed, 1996–98

	South Alum Creek	Bread Creek	North Alum Creek	Little Glazypeau Creek
A. Basal area				
Shortleaf pine	55.43	48.26	35.54	15.92
Loblolly pine	0.02	1.39	14.26	29.01
Other conifers	0.00	0.03	0.09	0.01
White oak-southern red oak	26.64	19.11	18.54	8.88
Other oaks	11.28	9.72	9.82	6.90
Other hardwoods	9.14	7.65	10.57	11.02
Total	102.51	86.15	88.82	71.75
B. Stem density				
Shortleaf pine	120.61	142.18	107.32	30.90
Loblolly pine	0.20	3.52	42.46	107.36
Other conifers	0.00	0.28	0.37	0.05
White oak-southern red oak	94.33	67.31	61.82	25.98
Other oaks	39.05	36.83	30.50	19.28
Other hardwoods	41.05	41.85	50.92	50.47
Total	295.24	291.96	293.39	234.04

shortleaf pine in this watershed, 8.5 inches, was a full inch less than qdbh for shortleaf in any of the other watersheds. The mean qdbh of hardwoods in the Bread Creek watershed, 6.6 inches, was less than qdbh of hardwoods in any other watershed; and qdbh of white and southern red oaks, 7.4 inches, was 0.1 inch less than qdbh for these species in any other watershed.

North Alum Creek

Industry owns half of the North Alum Creek watershed, and the Forest Service owns the other half. Tree density averaged 293.4 trees per acre during 1996-98 (table 4). Density of conifers was 150.1 trees per acre, and density of hardwoods was 143.2 trees per acre. The industry presence accounts for the importance of loblolly pine, which constituted 28.3 percent of conifer stem density in the watershed.

Basal area in the North Alum Creek watershed averaged 88.8 square feet per acre (table 4). Of this, 49.9 square feet per acre was in conifers and 38.9 square feet per acre in hardwoods. Shortleaf pine accounted for 71.2 percent, and loblolly for 28.6 percent, of conifer basal area. Oaks constituted 72.8 percent hardwood of basal area, with white and southern red oak accounting for nearly two-thirds of the oak basal area.

The qdbh of trees in the North Alum Creek watershed was 7.8 inches. Conifer qdbh was 9.5 inches and hardwood qdbh was 7.1 inches. The quadratic mean diameters of shortleaf and loblolly pine were 9.6 and 8.4 inches, respectively. The quadratic mean diameters of the white oak-southern red oak group and the other oak group were 8.0 and 8.3 inches, respectively.

Little Glazypeau Creek

The Little Glazypeau watershed, managed largely by forest industry, had 234.0 trees per acre (table 4), about 20 percent fewer stems per acre than were present in the other three watersheds. The reduction was in hardwood density, where declined by more than one-third as density of white and southern red oaks declined by nearly two-thirds.

Basal area in the Little Glazypeau Creek watershed averaged 71.7 square feet per acre (table 4); of this, 44.9 square feet per acre was in the conifer component and 26.8 square feet per acre was in the hardwood component. Conifer basal area in this watershed was about 12 percent lower than that in the other three watersheds. Loblolly pine constituted two-thirds of conifer basal area in this watershed (compared to one-sixth of average conifer basal area across the other three watersheds). The proportion of hardwood basal area to total basal area was 33 percent lower than in the other watersheds, and basal area in white and southern red oaks was also 33 percent lower in Little Glazypeau than in the other watersheds.

The qdbh of trees in the Little Glazypeau watershed was 8.0 inches. As in the other watersheds, conifer qdbh (9.9 inches) was greater than hardwood qdbh (6.9 inches).

DISCUSSION

We believe that differences between the sample designs employed in 1995 and 1996-98 are significant, and we conclude that the two designs should not be combined. All of the 1995 data were collected by sampling with a BAF 10 square-feet-per-acre prism, and are discontinuous. This discontinuity has adverse implications for conducting statistical analysis that would not apply to the 1996-98 data. More importantly, mean values of stem density and basal area for important species and species groups from the 1995 sample are typically lower than corresponding values for the 1996-98 data, a difference greater than that likely to be explained by normal forest growth. For both of these reasons, summary statistics reported here were prepared only on the basis of the nested sample design used in 1996-98.

By watershed, average basal area ranged from 71 to 102 square feet per acre, with the lowest basal area in the most intensively managed Glazypeau watershed and the highest in the unmanaged South Alum Creek watershed. Average tree density varied from 234 to 295 trees per acre, again with the lowest tree density in the Little Glazypeau Creek watershed and the highest in the South Alum Creek watershed. Quadratic mean diameter varied from 7.41 to 8.22 inches. Quadratic mean diameter was least in the Bread Creek watershed, and largest in the South Alum Creek watershed.

Values of other variables discussed here follow a similar pattern of association. The variables for which the largest values are associated with the unmanaged South Alum Creek watershed and the smallest values are associated with the most intensively managed Little Glazypeau Creek watershed include the following

- basal area of shortleaf pine
- basal area of all conifers
- basal area of the white oak-southern red oak group
- basal area of the other oak group
- basal area of all hardwoods
- basal area of all trees
- stem density of the white oak-southern red oak group
- stem density of the other oak group
- stem density of all hardwoods
- stem density of all trees.

Conversely, the variables for which the smallest values are associated with the unmanaged South Alum Creek watershed the largest values are associated with the Little Glazypeau Creek watershed are

- basal area of loblolly pine
- stem density of loblolly pine
- quadratic mean diameter of loblolly pine.

These associations are not unexpected, and reflect the common silvicultural practices one would conduct in managed landscapes. For example, thinning in the conifer component improves the condition of retained conifers by cutting the poorer and less vigorous trees, and reduces density-dependent mortality. Timber stand improvement cutting in the shortleaf pine-hardwood forest type removes hardwoods to release pines, and is often done in conjunction with thinning of pines. The result of these management actions is to reduce both stem density and basal area in the conifer and hardwood component relative to unmanaged stands. Reproduction cutting in the managed watersheds would result in removal of the larger conifers, which would reduce quadratic mean diameter in the managed watersheds. Finally, the most intensive silvicultural practice is to completely remove the shortleaf pine component and replant with loblolly pine, which grows more rapidly than shortleaf pine but which is not naturally found in these watersheds.

In conclusion, these data give some interesting clues about the effects of varying intensities of management on descriptive mensurational statistics used to characterize average stand conditions. More comprehensive analysis of the data is needed to better indicate the robustness of these trends, and to show whether the trends are statistically significant. However, this subjective analysis suggests that it may be possible to quantify landscape attributes associated with increasing management intensity for the woody plant component in the Ouachita Mountains.

LITERATURE CITED

Guldin, James M. [In press]. Landscape-scale research in the Ouachita Mountains of west-central Arkansas: general study design. In: Guldin, James M., tech. comp. Ouachita and Ozark Mountains symposium: ecosystem management research. Gen. Tech. Rep. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southern Research Station.