UPLAND HARDWOOD FORESTS AND RELATED COMMUNITIES OF THE ARKANSAS OZARKS IN THE EARLY 19TH CENTURY

Thomas L. Foti[1]

Abstract—Historic accounts of the 19th Century Arkansas Ozarks mention such communities as oak forests, pine forests, barrens and prairies. I document the region-wide distribution of these types based on data from the first land survey conducted by the General Land Office (GLO). Structural classes used here include closed forest, open forest, woodland, savanna, open savanna and prairie or herbaceous-dominated. The analysis is based on subsections of the Ozark Mountains within Arkansas. These provide areas small enough to represent the landscape level diversity of the Ozark ecoregion, but large enough to encompass a relatively large number of GLO corners, the basic unit of analysis. As of the 1820s and 1830s, there were differences in the proportion of structural classes within these subsections: the Boston Mountains had more closed forest than the Ozark Highlands to the north, but communities were more open than today, probably as a result of recent fire suppression.

INTRODUCTION

Understanding the composition, structure and processes of natural communities of the past may provide valuable perspectives for developing appropriate forest management approaches and understanding of current issues such as oak decline and red oak borer. This does not mean that the goal of management today must be the restoration of past conditions; accomplishing that goal may be impossible given current social, economic or ecological constraints. Knowledge of past conditions may simply inform managers and decision makers about how much change has occurred in the landscape and what some of the implications of that change may be.

The presettlement character of the Ozark Mountain region has been the subject of considerable and sometimes acrimonious debate. A central issue has been the structure of the wooded areas, specifically whether they were open woodlands with herbaceous ground cover or whether they were closed-canopy forest. A further question involves the processes that may have led to a previously more open condition, especially fire frequency. These issues have substantial implications today for deciding on "appropriate" management for public lands, for achieving silvicultural objectives such as oak regeneration, and for understanding current forest health problems.

The typical view of the vegetation of the Ozark region that dominated the scientific literature of the first half of the 20th Century was that most of the non-prairie areas were dense forest (e.g., Braun 1950). This view was challenged by Beilmann and Brenner (1951), who presented historic descriptions and notes of the first land surveyors from the early 19th Century that provided evidence that much of the non-prairie area of the Missouri Ozarks was not closed forest but rather was open woodland often termed "barrens." Such areas had trees spread widely enough to allow sunlight to reach the ground, dramatically increasing the density and diversity of vegetation in that stratum. In many cases, particularly in the most open woodlands, the ground-layer flora was comprised of species typically found in prairies. Steyermark (1959) issued a spirited and devastating rebuttal, also quoting from historic sources and surveyor's notes to argue his position that the patterns of vegetation structure in Missouri had changed little from the early historic time to the present. Many later researchers (Ladd 1991, Nigh and Pallardy 1983, Schroeder 1981) have provided more support for the Beilmann and Brenner view than that of Steyermark, and have provided considerable insight into the role of fire in maintaining the open condition.

Most of the debate over historic condition of oak woodlands of the Ozarks has been limited to the Missouri portion of the region. The conclusions reached there may apply to the Arkansas Ozarks as well, but there may be differences. While the physiography of part of the Arkansas Ozarks is the same as that of adjacent areas of Missouri, the Boston Mountains Subdivision (Foti 1974) does not extend into Missouri. The Boston Mountains and the Ozark Highlands have been recognized as separate sections (Foti and Bukenhofer 1998, Foti and Bukenhofer 1999, Keys and others 1995) as a result of the significant differences between them. In turn each of these sections has been subdivided into subsections, each of which varies somewhat from the others, in terms of both physical and biological features (fig. 1). Therefore the descriptions and analyses presented here will be stated in terms of these finer geographic regions. Subsections are still large enough to contain many of the GLO survey section corners, but are small enough to reduce the landscape and plant community variation within each.

HISTORIC DESCRIPTIONS OF THE ARKANSAS OZARKS

The most comprehensive map of the vegetation of Arkansas including the Ozarks in the 19th Century was provided by Sargent (1884) who mapped pine forest, hardwood forest and prairie. However, he did not map structural differences of the forest types.

[1] Chief of Research, Arkansas Natural Heritage Commission, Little Rock, AR 72201.

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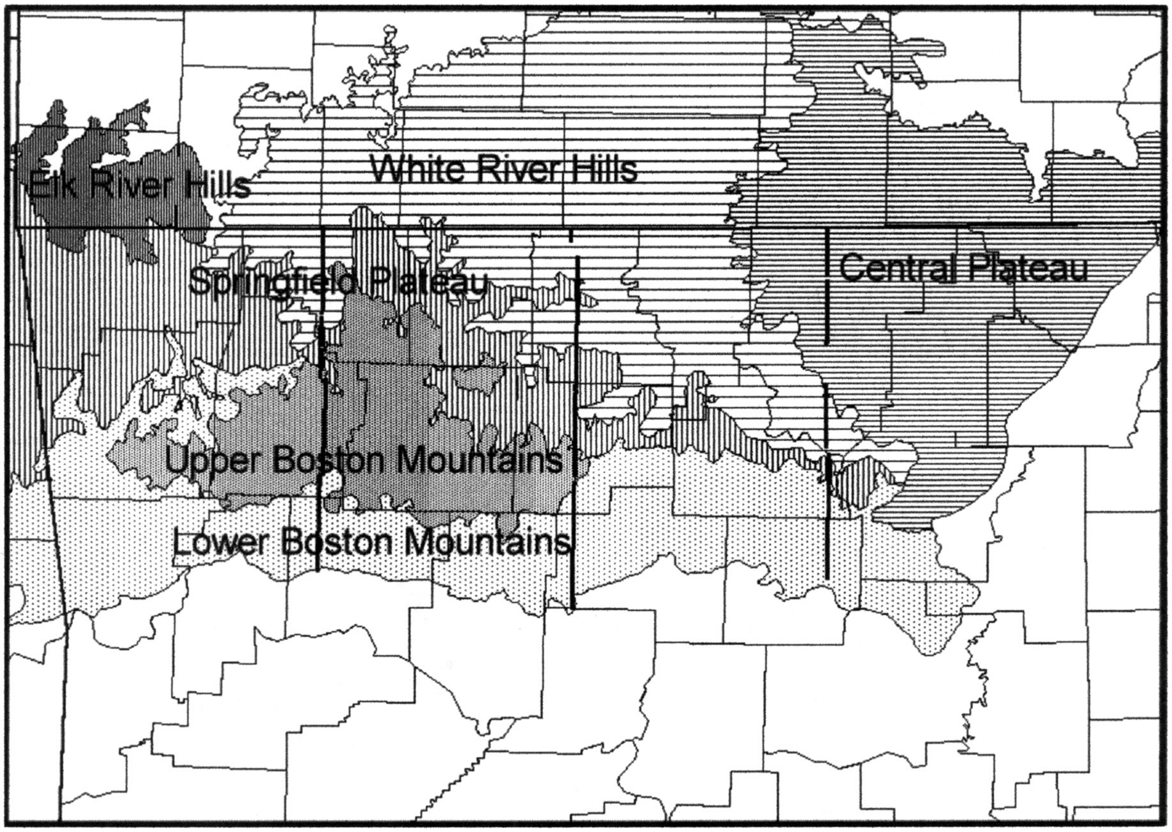

Figure 1—Subsections of the Arkansas Ozarks referred to in this study, along with the locations of GLO corners analyzed.

In the White River Hills Subsection of the Ozark Highlands Section Schoolcraft in 1818 found cane thickets and forests of oak, ash, maple, walnut, mulberry, sycamore, hickory, and elm on alluvial soils. He found prairies of coarse grass and "scanty" timber on the limestone hills and "bald mountains" (Rafferty 1996).

Owen (1858) described traveling north from Huntsville, Madison County, through the Boston Mountains and Springfield Plateau, saying one travels first through barrens and then prairie (p. 103). He described the land between the White River and Bentonville (Benton County) in the Springfield Plateau as being mainly barrens interspersed with prairies. He expressed the opinion that the prairies there had been of much greater extent and had been reduced by human activity.

Near the White River in the Upper Boston Mountains Subsection, Gerstacker (1881) described forest rather than barrens: "There was no trace of fir [cedar]; the mountains were covered with oak, beech, and hickory . . . It struck me as extraordinary that the best and most fertile land was on the hill tops, where in other places, it is generally the worst; here grew black walnut, wild cherry, with stems sometimes twenty inches in diameter, black locust, and sugar maple, trees which generally grow only on the richest soils" (p. 282).

PREVIOUS STUDIES BASED ON GLO SURVEY NOTES

General Land Office (GLO) notes of the original land survey of the Ozarks from 1818 to the 1850's provide quantitative data on forest composition at that time. Surveyors traversed the east and south sides of each 6 mile by 6 mile township and then the east and south sides of each mile-square section within each township. Direction and distance from each section corner and quarter-section corner (that is, halfway along each section side traversed) to two or four bearing trees were measured and species were identified (Bourdo 1956). Diameter of each tree was also recorded. Location of additional line trees and qualitative descriptions of the topography, soil, forest, and undergrowth along each mile line surveyed were also recorded. Although there were no doubt biases in the selection of bearing trees and sometimes errors in measurements, these surveys are the most complete quantitative data set on vegetation in the early 19th Century.

These surveys offer several ways to characterize vegetation: (1) Compilation of numbers of trees by species can provide information on composition, (2) Diameters of bearing trees can provide estimates of size, (3) Distances to bearing trees can provide estimates of total density and density by species, (4) Diameter and distance combined can provide estimates of basal area or dominance, (5) Mile notes can provide qualitative assessment of land, timber and undergrowth, and (6) Plat sheets of each township provide maps of notable features such as streams, prairies, fields and ridgelines.

Prairies are often well delineated both in the notes and on plat sheets because these were considered valuable in land selection decisions. Other measures must be determined from the written data and notes.

Of particular interest in the present study is the density of trees in the non-prairie areas. Most previous studies have used methods developed in Illinois to characterize the openness of the areas with trees based on average distance of bearing trees from the corner (Anderson and Anderson 1975, Rodgers and Anderson 1979). According to these studies, savanna is defined as having less than 50 percent canopy cover of trees, a density of 1 tree per 5 acres to 19 trees per acre, and average distance from the corner greater than 32 feet (48 links). Open forest varies from 19 to 40 trees per acre, average distance from 22 feet (33 links) to 32 feet, and closed forest has a greater density. This definition of savanna as having an arboreal crown cover of less than 50 percent follows Curtis (1959). Curtis defined the lower limit of tree density for savanna at 1 tree per acre rather than 1 tree per 5 acres as Anderson and Anderson did.

As in Missouri, the notes have been used to characterize the vegetation of the Arkansas Ozarks. In most instances, these studies were conducted by anthropologists and archeologists to examine settlement patterns, and therefore forest composition and structure were secondary to the main interest.

The dominant trees in the Lee Creek watershed of Crawford County in the Lower Boston Mountains Subsection in 1837-1843 were white oak, black oak and post oak, with appreciable numbers of hickory. White oaks most commonly occurred on steep slopes and higher elevations. Post oaks were most common on high elevations, upper stream valley floodplains and intermediate flat uplands. Black oak and hickories were distributed across all landform types (Harmon and others 1996, Lockhart and others 1995).

Tree species distribution and density were characterized within three townships along War Eagle Creek in Madison County (Upper and Lower Boston Mountain subsections and Springfield Plateau Subsection) by Joyce (1981). The study area was mapped into SCS (now NRCS) land capability classes and average density, dominance and frequency of all trees within each class were calculated. Trees of all capability classes except one were classed as closed forest using criteria of Rodgers and Anderson (1979). Trees of Class III, having severe limitations that reduce the choice of crops or require conservation practices or both, had an average density (18.4 trees per acre) that classed them as savanna. Approximately 18 percent of the study points fell within this class. Using a different approach, the instances in which the surveyor used such terms as “very little timber” or “no timber of any value or size” in the mile notes were mapped. This occurred in 20 of the 216 total miles surveyed, but all of these occurred on the 52 lines (38 percent) within the Springfield Plateau; none occurred in the Boston Mountains. She concluded that these were the actual “barrens” referred to in narratives. The lines of the Class III areas were often described as “open woods”. The average distance to trees on the lines with “barrens” are not provided, nor are the locations of the Class III areas.

Red oaks and white oaks were the most frequently recorded tree species groups within the study area at 374 and 365 trees respectively, and post oak was third with 145 trees. The Class III savanna areas that contained 18 percent of the total trees contained 29 percent of the total post oaks, 0.6 percent of the white oaks and 24 percent of the red oaks. Thus post oak and the red oaks were more important than average in these areas and white oak much less important.

The vegetation of Benton and Washington counties, in the Springfield Plateau and both Upper and Lower Boston Mountains subsections, was mapped from the GLO notes interpreted with the assistance of topographic maps by Miller (1972). Five generalized communities were interpreted and mapped: (1) oak barrens (also called open woodlands and prairie woodlands), (2) lowland forest, associated with streams, (3) lowland or bottomland prairie, in the floodplain of major streams, (4) upland forest, and (5) upland prairie. The oak barrens were “basically grass covered with interspersed trees and brush”. They “were most often located on relatively flat lands at moderate elevations (1100-1400 feet), or steep rough slopes.” Predominant trees were post oak and blackjack, with a few occurrences of black oak and black hickory. Lowland forest was diverse, with red oak, bur oak, black walnut, ash, slippery elm, shagbark hickory and others. Species of the prairies were not listed. Upland forest generally occurred at elevations from 1400-1700 feet. It was dominated by white oak, black oak, red oak, post oak, walnut, chinkapin oak, and others. At some places it was more open, with more xerophytic species, and difficult to distinguish from barrens without clues from topography. He concluded, “…it seems that this area was largely Oak Barrens and Prairie with the forest restricted to the highlands and stream bottoms.” This agreed with the historic description of Owen (1858).

NEW ANALYSIS OF GLO SURVEY NOTES

The purpose of the current study is to characterize the original plant community mosaic of the Arkansas Ozarks. Using field notes of General Land Office surveyors, I analyze the distributions of dominant species, along with density of trees along survey lines. Because of the limitations of available data, the study concentrates on structure of vegetation rather than processes that maintained it, such as fire.

METHODS

In order to provide broad characterization of the vegetation of the Arkansas Ozarks, I analyzed GLO data along north-to-south transects. These transects crossed each of the ecological sections and subsections of the Ozark Ecoregion (fig. 1). This provided a sample of the entire region. I recorded the following data at each section and quarter section point: (1) species of bearing trees and (2) average distance in links to the bearing trees. I summarized mile notes if they provided insight into community structure (e.g., “barrens”, “thinly timbered”, “oak-hickory” etc.). I grouped species recorded in the notes based on reliability of identification and ecological insight provided. The groups pine, white oaks and red oaks characterize the overall vegetation of broad areas. I recorded post oak and blackjack oak separately since they might indicate more xeric areas and/or more frequently burned areas, beech as an indicator of more mesic areas, and cedar since it is easily killed by fire and its presence in large numbers could indicate lack of fire. All other species were recorded as “other”.

The density of trees in the non-prairie areas can be estimated from the surveyor’s data on distance to the bearing trees. The square of the average distance to bearing trees in links (1 link=2/3 foot) provides an estimate of the average area in square feet occupied by each tree (Anderson and Anderson 1975). From this figure the density of trees per acre can be calculated. This approach is equivalent to the correction factor provided by Cottam and Curtis (1956) for utilizing the point-centered quarter method with two, rather than four sampled trees. In a few instances the GLO surveyors recorded the distances to 4 bearing trees, generally at the corners of each township. In calculating density at these corners, the point centered-quarter method should use the square of the average distance in feet to determine area occupied by each tree (Cottam and Curtis 1956). In this study, basal area was calculated as the average basal area of the bearing trees multiplied by the calculated density.

Tree density categories used in Illinois (Anderson and Anderson 1975, Rodgers and Anderson 1979) were used in this study as well, and have already been stated. The terms savanna and barrens are used in this analysis to maintain consistency with the earlier studies cited here. However, an additional distance criterion was chosen to approximate a cover of 25 percent using a density half that of the maximum “savanna” criterion of Anderson and Anderson (1975). This distance of 67 links or 45 feet gives a density of 9.5 trees per acre and a canopy cover of 25 percent. A corner with lower density of trees than this is termed here “open savanna”. The term “savanna” is favored here over “barrens” since the former term may be given a simple and objective definition, whereas no such definition for “barrens” exists; it may have meant different things to different observers.

In addition to defining classes using density only, a second method of calculation is used that includes both density and diameter. Since the class definitions are actually based on tree canopy coverage, a given density of small trees will have less canopy coverage than the same density of large trees. The older techniques were empirically derived, based on typical densities and sizes of trees in woodlands of Illinois. The newer method allows measured diameters and basal area to be used along with density to provide an estimate of canopy coverage, which is the actual criterion on which definitions of savanna or forest are based. It is derived from formulas and tables widely accepted by foresters to distinguish “fully stocked” timber stands, that is, those whose crowns are just touching and therefore are fully utilizing the available sunlight, from those that are too open or too dense (Gingrich 1967). Law and others (1994) used the same equations to provide a graphical technique for estimating the percentage of total area covered by oak crowns based on knowledge of basal area, tree diameter and density. Strictly speaking, these equations and the resulting charts only apply to oak forests, but both the authors and most users apply them to mixed forests where oaks make up the largest component. This applies to the forests encountered in the GLO surveys of the Arkansas Ozarks. This method estimates percent canopy coverage for any combination of tree density, diameter and basal area, which can then be grouped into classes based on any desired definition.

Definitions of open wooded communities other than those cited already have been used. Current efforts to create a U.S. National Vegetation Classification System by The Nature Conservancy, NatureServe, The Ecological Society of America, the Federal Geographic Data Standards Committee and others do not use the terms savanna or barrens. The nearest equivalent term is woodland, and is defined to be a community with a canopy cover of trees of from 25 to 60 percent (Grossman and others 1998). Nuzzio (1986) provided an alternative definition of “oak savanna” as having a tree canopy cover of 10 to 80 percent. Since the method proposed by Law (1994) produces an estimate of actual canopy cover, corner points can be grouped and analyzed using any definition. Therefore, this method was used in conjunction with these two definitions as well as with the Anderson definitions.

These techniques for recording and analyzing data minimize surveyor bias in at least two ways: (1) species identification is simplified since the species groups could be easily identified by the surveyor, (2) exact locations of corner points are not a concern since they are grouped by broad but ecologically meaningful ecological regions. Bias in selection of species would under-represent the species selected against and over-represent the species selected for. Bias in selection would also overestimate the distance to bearing trees, since other trees had been ignored. The use of broad density classes minimizes this effect. The use of several openness categories simply shifts the corner to the next lower openness class, rather than a much lower openness class.

Results are reported by subsection and include frequency of each species group, average density, and openness class of woody cover (prairie, open savanna, savanna, woodland, open forest and closed forest). Nomenclature throughout follows Smith (1988).

RESULTS

The surveyors of the lines used in this study identified 27 taxa among the 792 trees at 379 corners (table 1). White oak and black oak were the most common trees named, making up 29 and 24 percent of the total sample, respectively. Post oak, pine and hickory followed in abundance, each with over 6 percent of the total trees. The white oak species group, consisting of white oak and post oak, was the most abundant, with 41 percent of the total number. The red oak group, consisting of black oak, blackjack oak, Spanish oak (southern red oak), red oak, pin oak and chinquapin oak, followed with 31 percent of the total.

The red oak group (without blackjack oak) was consistently abundant across all subsections, varying from 38 percent of the total bearing trees in the Upper Boston Mountains and 35 percent in the Springfield Plateau to 24 to 26 percent in the other subsections (table 2). Blackjack oak occurred only in the subsections of the Ozark Highlands, comprising a maximum of 16 percent of the bearing trees of the Central

Table 1—Tree names recorded by the surveyors, with presumed species, analysis group, and number of individuals recorded

Surveyor name	Presumed species	Group	Total	Percent
Ash	*Fraxinus* sp.	Other	10	1.3
Beech	*Fagus grandifolia* Ehrh.	Other	7	0.9
Black jack (oak)	*Quercus marilandica* Muench.	Red oak	26	3.3
Blackgum	*Nyssa sylvatica* Marsh.	Other	32	4.0
Black oak	*Quercus velutina* Lam.	Red oak	191	24.1
Cedar	*Juniperus virginiana* L.	Cedar	8	1.0
Cherry	*Prunus serotina* Ehrh.	Other	1	0.1
Chinquapin	*Castanea pumila* (L.) Mill.	Other	7	0.9
Chinquapin oak	*Quercus muehlenbergii* Engelm.	Red oak	1	0.1
Dogwood	*Cornus florida* L.	Other	8	1.0
Elm	*Ulmus* sp.	Other	14	1.8
Gum elastic	*Bumelia lanuginosa* (Michx.) Pers.	Other	1	0.1
Gum	uncertain species	Other	3	0.4
Hickory	*Carya* sp.	Hickory	48	6.1
Maple	*Acer* sp.	Other	7	0.9
Mulberry	*Morus rubra* L.	Other	1	0.1
Pin oak	*Quercus palustris* Muench.?	Red oak	1	0.1
Pine	*Pinus echinata* Mill.	Pine	55	6.9
Post oak	*Quercus stellata* Wang.	Post oak	95	12.0
Red, slippery elm	*Ulmus rubra* Muhl.	Other	2	0.3
Red oak	uncertain species	Red oak	21	2.7
Sassafras	*Sassafras albidum* (Nutt.) Nees	Other	4	0.5
Spanish oak	*Quercus falcata* Michx.	Red oak	10	1.3
Sugar tree	*Acer saccharum* Marsh.	Other	3	0.4
Sweetgum	*Liquidambar styraciflua* L.	Other	3	0.4
Walnut	*Juglans nigra* L.	Other	2	0.3
White oak	*Quercus alba* L.	White oak	231	29.2
Total			792	100.0

Plateau Subsection. The greatest abundance of white oak was in the Central Plateau where it made up 57 percent of the total trees. Its abundance was intermediate in the Boston Mountains (32 to 38 percent) and lowest in the Springfield Plateau and White River Hills (13 to 15 percent). The abundance of post oak was almost the inverse of white oak in that it was the most named-bearing tree in the White River Hills (28 percent). It was of intermediate abundance in the Upper Boston Mountains and Springfield Plateau (11 and 16 percent) and it comprised only 2 percent of the trees in the Lower Boston Mountains and 1 percent of the trees in the Central Plateau (table 2).

Pine was most commonly selected in the Springfield Plateau (14 percent) and was of intermediate abundance in the Lower Boston Mountains and White River Hills (8 percent of each). It made up only 1 percent of the Central Plateau total and was not recorded in the Upper Boston Mountains. Hickory was recorded in all subsections except the Central Plateau and reached its highest levels in the Boston Mountains at 9 percent. Eight cedars were used as bearing trees only in the White River Hills, making up 4 percent of the total. Seven beech trees occurred only in the Lower Boston Mountains, comprising 3 percent of the total. "Other" trees consistently made up 11 to 15 percent of the total in each subsection, but comprised only 1 percent of the total in the Central Plateau (table 2).

The Boston Mountains subsection corners were dominantly white oak and red oak, but with pine, hickory and other at the next level in the Lower Boston Mountains and post oak, hickory and other in the Upper Boston Mountains. The Central Plateau Subsection was dominated by white oak with red oak as a distant second and blackjack oak as a distant third. The White River Hills Subsection was dominated by post oak and red oak, with white oak and other at the next level, and the Springfield Plateau was dominated by red oak, with post oak, white oak, pine and other sharing the next level (table 2).

Average density over the entire study area was 52 trees per acre (table 3). Density varied from 38 trees per acre in the Central Plateau to 76 trees per acre in the Upper Boston Mountains. Density in the Boston Mountains and Ozark Highlands sections were comparable at 52-54.

As expected, the Anderson method, which used density alone, generally placed corners into more closed classes than the Law method, which used both density and diameter of bearing trees (tables 3 and 4). While Anderson's method classed 38 percent of all corners as closed forest, the Law method classed only 21 percent as closed forest. The open forest and savanna classes were not greatly different between the two methods, but the Anderson method classed only 13 percent of the corners as open savanna,

Table 2—Number and percentages of tree species groups in each subsection

Section/subsection	White oak		Red oak		Post oak		Pine		Hickory		Black-jack		Cedar		Beech		Other		Total	
	no.	*%*	*no.*	*%*	*no.*	*%*	*no.*	*%*	*no.*	*%*	*no.*	*%*	*no.*	*%*	*no.*	*%*	*no.*	*%*	*no.*	*%*
Lower Boston Mountains	101	38	68	26	6	2	20	8	23	9					7	3	40	15	265	100
Upper Boston Mountains	33	32	39	38	11	11			9	9							12	12	104	100
Boston Mountains total	134	36	107	29	17	5	20	5	32	9					7	2	52	14	369	100
Springfield Plateau	21	15	47	35	22	16	19	14	6	4	3	2					18	13	136	100
White River Hills	25	13	48	24	55	28	15	8	10	5	9	5	8	4			27	14	197	100
Central Plateau	51	57	22	24	1	1	1	1			14	16					1	1	90	100
Ozark Highlands total	97	23	117	28	78	18	35	8	16	4	26	6	8	2			46	11	423	100
Total	231	29	224	28	95	12	55	7	48	6	26	3	8	1	7	1	98	12	792	100

Table 3—Average density, and number and percentages of corners in structural classes using method of Anderson and classes selected to maintain consistency with previous studies

Section/subsection	Density	Closed For.		Open For.		Savanna		Open Sav.		Prairie		Forest		Open		Total
	no./ac	*no.*	*%*	*no.*	*%*	*no.*	*%*	*no.*	*%*	*no.*	*%*	*no.*	*%*	*no.*	*%*	*no.*
Lower Boston Mountains	44.8	49	40	42	34	25	20	6	5	0	0	91	75	31	25	122
Upper Boston Mountains	75.7	26	53	17	35	4	8	2	4	0	0	43	88	6	12	49
Boston Mountains total	53.7	75	44	59	35	29	17	8	5	0	0	134	78	37	22	171
Springfield Plateau	61.8	27	41	11	17	17	26	10	15	1	2	38	58	28	42	66
White River Hills	47.4	30	32	20	21	22	23	17	18	5	5	50	53	44	47	94
Central Plateau	38.5	12	25	3	6	15	31	13	27	5	10	15	31	33	69	48
Ozark Highlands total	49.9	69	33	34	16	54	26	40	19	11	5	103	50	105	50	208
Arkansas Ozarks total	51.6	144	38	93	25	83	22	48	13	11	3	237	63	142	37	379

Table 4—Number and percentages of corners in structural classes using method of Law and classes selected to maintain consistency with previous studies

Section/subsection	Closed For.		Open For.		Savanna		Open Sav.		Forest		Open		Total
	no.	*%*	*no.*	*%*	*no.*	*%*	*no.*	*%*	*no.*	*%*	*no.*	*%*	*no.*
Lower Boston Mountains	28	23	34	28	42	34	18	15	62	51	60	49	122
Upper Boston Mountains	11	22	11	22	16	33	11	22	22	45	27	55	49
Boston Mountains total	39	23	45	26	58	34	29	17	84	49	87	51	171
Springfield Plateau	17	26	9	14	14	21	26	39	26	39	40	61	66
White River Hills	17	18	18	19	20	21	39	41	35	37	59	63	94
Central Plateau	5	10	2	4	7	15	34	71	7	15	41	85	48
Ozark Highlands total	39	19	29	14	41	20	99	48	68	33	140	67	208
Arkansas Ozarks total	78	21	74	20	99	26	128	34	152	40	227	60	379

while the Law method placed 34 percent in this class. There is no criterion in the Law method for defining prairie, but the Anderson method placed over 3 percent of the corners in this structure class. Overall, the Anderson method classed 63 percent of the corners as closed or open forest (table 3), while the Law method placed about 60 percent of the corners into the open classes (table 4).

Although the Law method predicted much less closed forest in each subsection than Anderson, the relative amounts are similar (tables 3 and 4). Based on the Anderson method, the Upper Boston Mountains had the greatest percentage of corners classed as closed forest at 53 percent, with the Springfield Plateau and Lower Boston Mountains ranked next. Using the Law method, the Springfield Plateau has the highest percentage of corners classified as closed forest at 26 percent, with the Lower Boston Mountains and Upper Boston Mountains ranked next. Interestingly, the Upper Boston Mountains, with the highest density, dropped from first to third in the two rankings. Since the Anderson method only considers density and Law adds diameter, this is an indication that the diameters of trees in the Upper Boston Mountains were smaller than those of the other two subsections.

The Law method predicted a similar or lower percentage of open forest in each subsection than the Anderson method, with Upper and Lower Boston Mountains showing the greatest declines, and with savanna becoming predominant in those subsections. Open savanna increased greatly using the Law method, and is the predominant class in the subsections of the Ozark Highlands with the highest proportion in the Central Plateau Subsection at 71 percent. The Anderson method defined prairie only in the Ozark Highlands subsections.

Combining closed forest and open forest into “forest”, and savanna, open savanna and prairie into “open”, using the Anderson method, the Boston Mountains subsections are dominantly Forest, the Central Plateau is dominantly Open, and the Springfield Plateau and White River Hills are approximately evenly divided (table 3). Using the Law method, the Boston Mountains subsections are approximately evenly divided between forest and open, the Central Plateau is dominantly open, and the Springfield Plateau and White River Hills subsections are somewhat more open than forest (table 4).

Using the cover estimates from Law and the class definitions of Grossman, the percentage of forest (>60 percent cover) varied from 40 percent in the Lower Boston Mountains to 15 percent in the Central Plateau, with the other subsections clustering around 34 percent (table 5). The herbaceous class of Grossman is equivalent to the open savanna class

Table 5—Number and percentages of corners in structural classes using method of Law and classes of Grossman

Section/subsection	Forest		Woodland		Herbaceous		Total
	no.	*percent*	*no.*	*percent*	*no.*	*percent*	*no.*
Lower Boston Mountains	49	40	56	46	17	14	122
Upper Boston Mountains	16	33	25	51	8	16	49
Boston Mountains total	65	38	81	47	25	15	171
Springfield Plateau	23	35	18	27	25	38	66
White River Hills	32	34	27	29	35	37	94
Central Plateau	7	15	8	17	33	69	48
Ozark Highlands total	62	30	53	25	93	45	208
Arkansas Ozarks total	127	34	134	35	118	31	379

Table 6—Number and percentages of corners in structural classes using method of Law and classes of Nuzzio

Section/subsection	Forest		Savanna		Herbaceous		Total
	no.	*percent*	*no.*	*percent*	*no.*	*percent*	*no.*
Lower Boston Mountains	33	27	83	68	6	5	122
Upper Boston Mountains	14	29	31	63	4	8	49
Boston Mountains total	47	27	114	67	10	6	171
Springfield Plateau	18	27	36	55	12	18	66
White River Hills	22	23	46	49	26	28	94
Central Plateau	5	10	22	46	21	44	48
Ozark Highlands total	45	22	104	50	59	28	208
Arkansas Ozarks total	92	24	218	58	69	18	379

used before, except that a canopy cover of exactly 25 percent is classed as woodland under the Grossman definition and herbaceous under the open savanna definition used here.

Using cover estimates from Law and class definitions of Nuzzio, the highest percentage of forest (>80 percent cover) was 29 percent in the Upper Boston Mountains, with Lower Boston Mountains and Springfield Plateau closely following (table 6). The Nuzzio herbaceous class (<10 percent cover) varied from 44 percent in the Central Plateau to 5 and 8 percent in the Lower and Upper Boston Mountains, respectively.

The average cover of corners described as “barrens” or “thinly timbered” by the surveyors was 28 percent and the average density was 39 trees per acre. These indicate open conditions but not greatly so.

DISCUSSION

The criteria proposed by Law and others are based on those widely accepted in forest management and therefore should be preferred, particularly for distinguishing closed forest from open forest. These criteria become more difficult to implement as the structure becomes more open, however, partly because the structure of the charts allows less precise definition of lower canopy coverage. Also, there is no criterion under this method for distinguishing prairie. This method generally defines more open communities for a specified density than the criteria proposed by Anderson and Anderson, but where tree diameters are large it can predict more closed communities.

Guldin and others (1999) analyzed Ozark and Ouachita timber by ecological Section based on USDA Forest Inventory and Analysis data. They showed a density of trees greater than 6 inches d.b.h. of 153 per acre in the Boston Mountains Section and 116 per acre for the Ozark Highlands Section. Density of trees in the early 19th Century in these Sections was 54 and 50 per acre, respectively. Although the modern and GLO numbers are not strictly comparable, this indicates a substantial increase in density of trees in the Ozarks over this period. This agrees with others such as Ladd (1991), who attributed this increase to fire suppression.

The various methods and class definitions generally agree that the Upper and Lower Boston Mountains subsections and the Springfield Plateau Subsection had more closed forest than the other subsections but that the amount, particularly based on the Law method, was much less than today. The subsections of the Ozark Highlands all had high coverage of the most open communities (open savanna and herbaceous).

Based on findings of earlier studies (Joyce 1981, Miller 1972), it is likely that the location of transects used in this study causes an overestimate of the amount of forest in relation to open structure in the Springfield Plateau, in that both of those studies demonstrated more open conditions than data from transects in this study. Both of their study areas were located west of the westernmost transect in this study, where the Springfield Plateau is broader and more level than the places where these transects crossed. The broader and flatter sites, combined with the level-bedded strata of the Ozark Mountains, would have been more exposed to wind, more droughty and more susceptible to frequent fire. The high amounts of pine along the transects studied here are indicative of steep, cherty slopes in contrast to the often level plains underlain by limestone further west.

Although geologic substrate and topography exert control directly over plant communities of the Ozarks, they probably also exert indirect control through precipitation since the Upper Boston Mountains are higher and moister than the other subsections and have up to 10” per year greater precipitation than subsections to the north within the Arkansas study area.

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