PRE-EUROPEAN SETTLEMENT BARRENS AMD FOREST AMONG NINE TOWNSHIPS ON THE SHAWNEE NATIONAL FOREST

Jenny McBride & Marlin Bowles, The Morton Arboretum

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SUMMARY

To elucidate differences between barrens and forest vegetation, we analyzed the U.S. Public Land Survey notes from 10 townships on the Shawnee National Forest in southern Illinois. Timber predominated in the Shawnee Hills Natural Division, while barrens was associated with Cretaceous Hills and Lesser Shawnee Hills Natural Divisions. Barrens differed from timber by having lower tree density, as well as lower species richness and generally more open conditions. No distinct differences in woody species, elevation or integrated moisture index were apparent between barrens and timber. However, the Cretaceous Hills tend to be lower in elevation and underlain by different substrates. Nevertheless, we found that barrens occurred across a range of elevations. The lack of significant differences among environmental factors suggests that they did not play strong roles in directly affecting the presence of barrens. This suggests that fire was a critical factor in maintaining barrens.

INTRODUCTION

Understanding the composition and structure of presettlement vegetation in unglaciated southern Illinois is an important restoration and management goal. This area, as well as adjacent Indiana and Kentucky, supported areas of both timber and “barrens,” and the latter has become a focus of restoration management. However, use of the term “barrens” is often ambiguous, and the exact nature of former barrens is poorly understood (White 1999). Barrens described by the PLS in southern Illinois are often assumed to have occurred on stressful habitats (Hutchison & Johnson 1981). Modern ecological studies of thin soil habitats in this region often refer to their edaphically maintained plant communities as barrens (Taft 2003, Hiekens 1999). However, others (e.g. Keith 1983, Baskin et al. 1999) contend that barrens vegetation also occured on deeper soils, where it was a developed and maintained by fire. Modern barrens remnants on both thin and deep soils in this region respond to fire management (Taft 2003, Anderson and Schwegman 1972). Fralish, et al. (2002) suggested that fire maintained barrens in the Cretaceous Hills Natural Division of Illinois (Schwegman et al. 1973). They based this observation on the occurrence of relatively low tree density (25 trees/ha) and basal area (2.71 m-sq./ha) at relatively high elevations (> 420 ft a.s.l.) that would have been fire prone. In contrast, in more fire protected habitats on similar soil conditions <420 ft a.s.l., forest conditions prevailed, averaging 175.3 trees/ha with 22.7 m-s/ha basal area Fralish, et al. (2002).

In this report, we analyze the woody vegetation recorded by the Government Land Office Public Land Survey (PLS) in ten townships on the Shawnee National Forest in southern Illinois (Figure 1). These townships had a proportionally high cover of barrens vegetation described by the PLS. We focus on contrasting and comparing barrens and forest vegetation data to determine whether compositional, structural, and ecological differences can be identified between these vegetation types.

The Public Land Survey

The Government Land Office Public Land Survey (PLS) vegetation notes, maps, and bearing tree data were recorded in the early 1800s in Illinois (Hutchison 1988, Ebinger 1997, Schulte & Mladenoff 2001). This survey comprised a square-mile landscape grid upon which the identity, diameter, distance, and direction for one to four bearing trees were recorded at half mile intervals. These data were accompanied by measures of trees intercepted on section lines, section line vegetation summaries, other notes, and township plats distinguishing timber, prairie, and other important landscape features.

Despite evidence for bias or non-random selection of bearing trees (Bourdo 1956, Anderson 2006), the PLS data represent a large-scale vegetation sample that can be used to reconstruct landscape-scale pre-European vegetation (Brugam & Patterson 1996). These data can allow estimates of forest composition and ranking of species dominance, but the large sampling scale usually prevents accurate and detailed mapping of vegetation types (Manies & Mladenoff 2000). However, site-specific comparisons and precise mapping of vegetation boundaries described by the PLS may be possible (*e.g* Bowles & McBride 1998). These data also can be linked with ecological information when landscape features, such as soils, topography, or fire barriers, are used to interpret the distribution pattern of different vegetation types based on their composition and structure (Leitner *et al*. 1991, Anderson & Anderson 1975, Moran 1978, 1980, Rogers & Anderson 1979, Bowles *et al.* 1994 and Edgin & Ebinger 1997).

Study area

The townships selected for study occur in Hardin, Johnson, Massac, Pope, and Saline counties, and contain either Forest Service Research Natural Areas or Ecological Areas (Table 2). They also occur within two Illinois Natural Divisions (Schwegman 1973), including the Cretaceous Hills Section of the Coastal Plain Division, and the Greater Shawnee Hills and Lesser Shawnee Hills Sections of the Shawnee Hills Division. Barrens vegetation predominated in one township (T15SR6E). It was slightly less abundant than timber in T14SR8E, and occurred infrequently in three other townships.

The Greater Shawnee Hills is underlain by Pennsylvanian age sandstone, while the Lesser Shawnee Hills is underlain primarily by Mississippian age limestone and is 61 m lower in average elevation than the Greater Shawnee Hills (Anderson 2007). The Cretaceous Hills are a series of low hills underlain by Cretaceous age sand, gravels and clays (Willman & Frye 1970, Schwegman 1973). Most of the soils are derived from a cap of loess that originated from Mississippi floodplain (Fahrenbacher et al. 1968, Willman & Frey 1970). Forest vegetation is oak (*Quercus* sp) and hickory (*Carya* sp) dominated on uplands, with sugar maple (*Acer sacharrum*) in mesic habitat and American beech (*Fagus grandifolia*) in more protected conditions such as canyon bottoms (Voigt & Mohlenbrock 1964). Original barrens vegetation is poorly known, and probably comprised upland oaks, with groundlayer primarily prairie grasses and forbs, as well as more shade-adapted herbaceous plants, shrubs and vines (Hutchison & Johnson 1981). Engelmann (1863, 1866) described barrens in glaciated Jackson and Perry counties, as well as Massac and Pope counties, as hills covered with a dense growth of tall grasses, without or with only scattering large trees.

Methods

The Public Land Survey in the Shawnee National Forest area was conducted primarily in 1806-1807. Unlike much of Illinois, township plats were not prepared showing the distribution of vegetation types identified by the PLS. However, the PLS described different vegetation types as they were encountered along sections lines, including *timber, barrens, scattering timber, pond, marsh, slough, swamp, and thicket* and indicated exact distances along section lines for transitions between these vegetation types. The primary data collected by the PLS were the identity, diameter, distance, and direction for one to four bearing trees, each located in one of the four quadrants at each section corner, as well as for up to two bearing trees located in different quadrants at section quarter-corners and river crossings. Surveyors also recorded the identity and diameter of line trees intercepted by section lines and summarized tree species present along section lines. The surveyors also recorded species presence in undergrowth primarily along exterior township lines. However, they apparently did not indicate when undergrowth was absent, which is required for estimating its abundance.

Species identification

The surveyors identified about 36 different bearing and 29 line trees by common name, including most of the dominant native tree species. We assume that most witness tree species were correctly identified and placed them in modern species analogs. The term “maple” was applied to soft maple (*Acer saccharinum*), a floodplain species, while “sugar tree” was applied to sugar maple (*A. saccharum*). “B oak” was problematic, as it was the second most abundant species. This species was apparently black oak (*Q. velutina*), as black oak was identified only in a single township. Consequently, we applied black oak to b oak as well.

MODERN METHODS

Mapping and interpretation

The PLS data were taken from microfilmed copies of the original notes, which were transcribed in the 1840's. These data were used to digitize vegetation boundaries and bearing tree locations using ARC/INFO Geographical Information System (GIS) software (McBride 2004). GIS was also used to add layers for section lines, bearing trees, section and quarter-corner tree densities, line trees, tree species summaries and woody undergrowth summaries. Features of European settlement, such as fields, were not used in vegetation maps or landscape analysis. Because original township plats did not map barrens, this vegetation type could be mapped precisely only along section lines where the surveyors recorded points at which they entered or left timber and barrens.

Data processing

All recorded bearing tree distances were used to calculate tree density for each section and quarter-corner. This procedure followed the modified point-center-quarter sampling method, where trees/hectare = 10,000 $m^2 \div (\bar{x}\ d)^2$, and $\bar{x}$ d = the mean distance of up to four bearing trees at each corner adjusted for the number of trees sampled (Cottam & Curtis 1956). A 400 trees/ha ceiling for tree densities was used to avoid artificially high values that can result from the point-center-quarter method. Fifteen % of the corners in barrens did not support bearing trees, resulting in densities that would over-estimate average tree densities. For two townships in the Cretaceous Hills that were predominantly barrens, we also calculated tree density with these corners by adding zero values to the data set. According to Anderson (2007) the distribution of bearing trees among quadrants in the Shawnee Hills was non-random but probably unbiased. However, there was a bias toward selection of trees in interior quadrants along the eastern and southern township lines, as well as choice of the second bearing tree in the opposite quadrant of the first tree (Anderson 2007). The latter may have been enhanced by directions from the General Land Office, as later rules (~1850) stated that the second bearing tree should be located in the quadrant opposite the first tree (Bourdo 1956). Anderson (2007) also indicated that ½ the tree diameter should be added to the tree distance to improve precision and calculation of tree density. Our measures did not use this modification, and there fore slightly underestimate tree density.

To avoid extreme bias in calculation of tree densities in two townships with barrens in the Cretaceous Hills, bearing trees data from corners on the township lines were excluded from analysis. To further reduce effects of bias on vegetation classification, we placed density calculations into classes of *open savanna* (> 0-10 trees/ha), *savanna* (> 10-50 trees/ha), *woodland* (> 50-100 trees/ha) and *forest* (> 100 trees/ha) categories following Anderson (1975). The total and relative basal area (dominance) were calculated for each bearing tree species in all vegetation types and categories. Basal area was calculated in square meters by converting from the original measure of diameter in inches. These data are based on total occurrences within each vegetation type, thus represent an unbalanced sample. As a result, only relative data can be compared among vegetation types.

We calculated the percent frequency of woody undergrowth recorded in summaries of section lines bounding areas of timber (N = 197 line summaries) and barrens (N = 10 line summaries). As indicated, these data were recorded only from exterior township lines.

Statistical comparisons

Bearing tree data were used to make comparisons among the timber and barrens vegetation types identified by the PLS and among tree density classes. The structure of barrens and timber were compared using the relative abundance of savanna (> 0-10 trees/ha), open savanna (> 10-50 trees/ha), woodland (> 50-100 trees/ha) and forest (> 100 trees/ha) tree density classes within each of these vegetation types. We also examined differences in tree density between barrens and timber within and among townships.

To assess environmental effects, we calculated for each corner its % hillshade (22 % solar azimuth, and 45 % solar altitude), % flow accumulation, and % curvature using a USGS digital elevation model (http://data.geocomm.com/dem/) on ARCVIEW software (http://esri.com). These data were combined into an integrated moisture index on following the methods of Iverson et al. (1997), which use 40% hillshade, 30 % flow accumulation, 10 % curvature based on site preference for white oak in Ohio. We also calculated % slope, aspect, and elevation for each corner.

We used one-way analysis of variance (ANOVA) to determine whether tree density and dbh varied among townships for both timber and barrens. For the two barrens dominated townships, we used a two factor ANOVA in a general linear model to test whether tree densities differed between barrens and timber across an elevation gradient at 50-foot intervals, following Fralish et al. (2002).

RESULTS AND DISCUSSION

Among the 10 townships, seven occurring in the Greater and Lesser Shawnee Hills sections were primarily covered with timber (Figure 1). The remaining three townships occurred on both the Lesser Shawnee Hills and Cretaceous Hills sections, and were predominantly barrens. This suggests that barrens prevailed at lower elevations south of the Shawnee Hills, as was noted by Engelmann (1866). However, they were still associated with elevated conditions that probably promoted fire.

Composition

About 39 species were recorded from areas of timber, with highest richness (37 species) in forest (>100 trees/ha) timber and lowest richness (9 species) in open savanna conditions (Table 2). Surprisingly, no species showed strong trends toward gradients in dominance across tree density classes. Areas of timber were dominated by white oak, which ranged in dominance from 45-55% across all density classes. Black oak was sub-dominant, ranging from about 13-20 %. Red oak and Hickory were the only other species with substantial dominance (>5%) in more that one density class. Sweetgum exceeded 5% dominance in savanna, while walnut exceeded 5% dominance in open savanna. Twelve additional species had > 1-< 5 % dominance.

Sixteen species were recorded from areas of barrens, with highest richness (12 species) in forest conditions and lowest richness (5 species) in open savanna (Table 3). As in timber, no species showed strong trends toward gradients in dominance across tree density classes in barrens. Areas of barrens were also dominated by white oak, which ranged from 50-70 % dominance across density classes. Black oak was also sub-dominant, ranging from about 20-45% dominance. Hickory was the only other species present in all four tree density classes, but occurred with < 5% dominance. Both P oak and gum had > 5 % dominance, but occurred only in single density classes.

Eighteen species were recorded as woody undergrowth in section line summaries (Figure 2). Only five of these species occurred in barrens, which were dominated by oak, briers and grape vine. Timber was dominated by dogwood, spicebush and sassafrass. Oak and dogwood occurred in 70 % of the sections lines in timber and barrens respectively, while other species occurred in 50 % or less of the sections lines. Engelmann (1863) also noted that oak brush and grape vines were common in barrens, but that “tall barren grass” was the original growth.

Structure

More than 60 % of the corners occurring in areas identified as timber by the PLS had tree densities exceeding 100 trees/ha, indicating that forest conditions predominated in timber (Figure 3). In contrast, savanna and woodland predominated in areas identified as barrens, accounting for over 60% of the corners. The fact that > 15 % of the corners in barrens had no bearing trees also indicates the open structure of this vegetation.

Tree density and dbh varied significantly across townships, but differed between barrens and timber. Tree density in barrens did not differ among townships, but density was significantly different among townships in timber (Figure 4). In contrast, tree dbh in barrens differed significantly among townships, but dbh did not differ among townships in timber (Figure 5). In a comparison of barrens and timber within T14SR5E and T15SR7E, which contained greatest coverage of barrens, there was no significant effect of vegetation type ($F = 0.84$, $P = 0.362$) or elevation ($F = 0.97$, $P = 0.407$) on the integrated moisture index. However, tree density was significantly higher at lower elevations, and had a significant interaction with vegetation type (Figure 6). This interaction occurred because tree density was higher in barrens at lower elevations, but was higher in timber at higher elevations. Overall, when corners with no trees were added as zero values, tree density was significantly lower in barrens, averaging about 90 trees/ha vs >150 trees/ha in timber (Figure 6). Based on the percentage of corners without trees in barrens, about 15-17 % of this vegetation was open grassland or shrubland.

CONCLUSIONS

The predominant vegetation pattern among the 10 townships is dominance of timber in the Shawnee Hills and barrens in the southernmost townships, associated with Cretaceous Hills and Lesser Shawnee Hills natural divisions. Barrens differed from timber by having lower tree density and species richness and generally more open conditions. No distinct differences in woody species, elevation or integrated moisture index were apparent between barrens and timber. However, the Cretaceous Hills tend to be lower in elevation and underlain by different substrates. According to Fralish et al. (2002), barrens had low tree densities because they predominated at higher elevations in more fire-prone conditions. However, we found that barrens occurred at all elevations. The lack of significant differences among environmental factors suggests that they did not play a role in directly affecting the presence of barrens. This suggests that fire was a critical factor in maintaining barrens.

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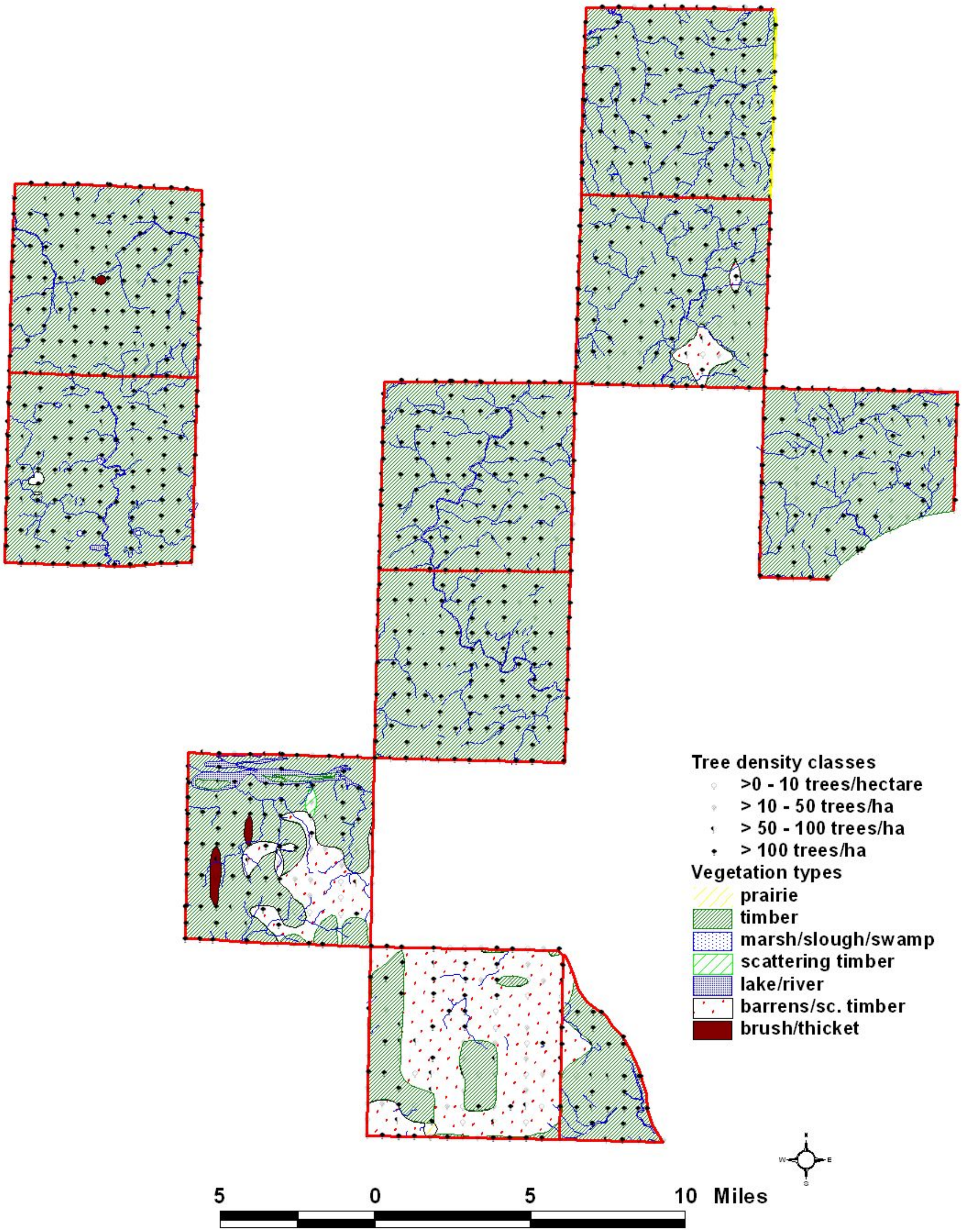

Figure 1. Distribution of timber and barrens by tree density classes in 10 townships in the Shawnee National Forest.

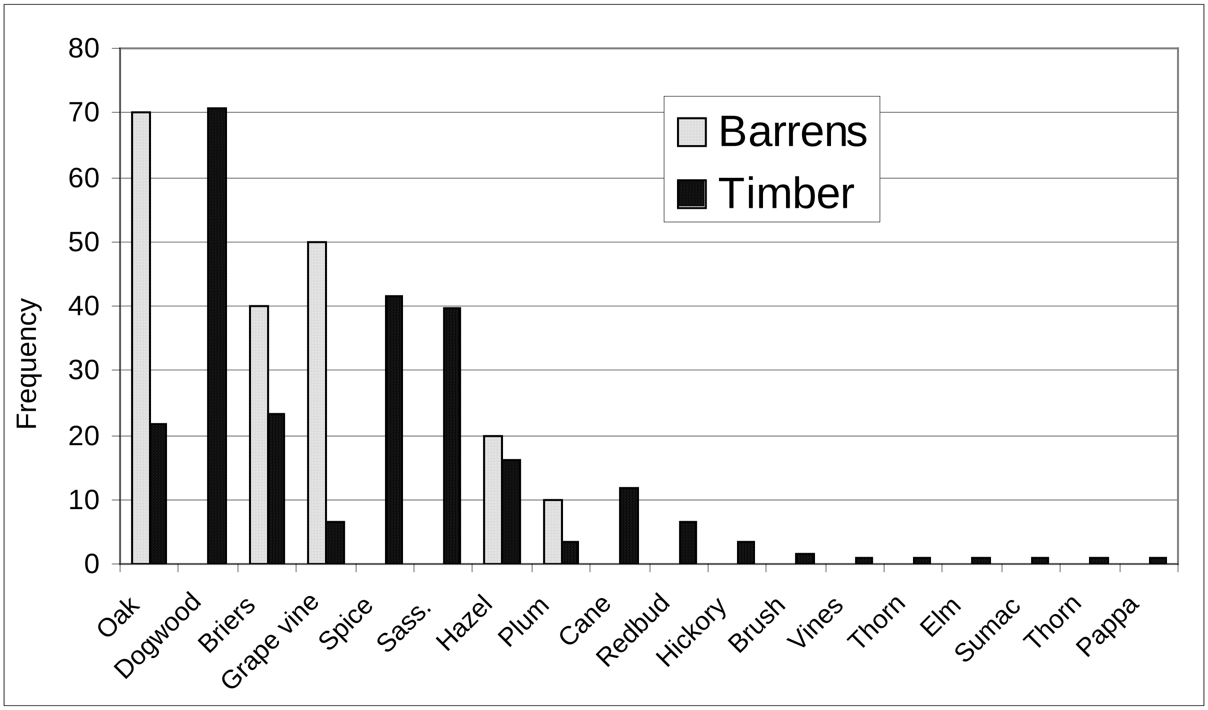

Figure 2. Frequency of woody undergrowth species recorded in section line summaries for timber and barrens.

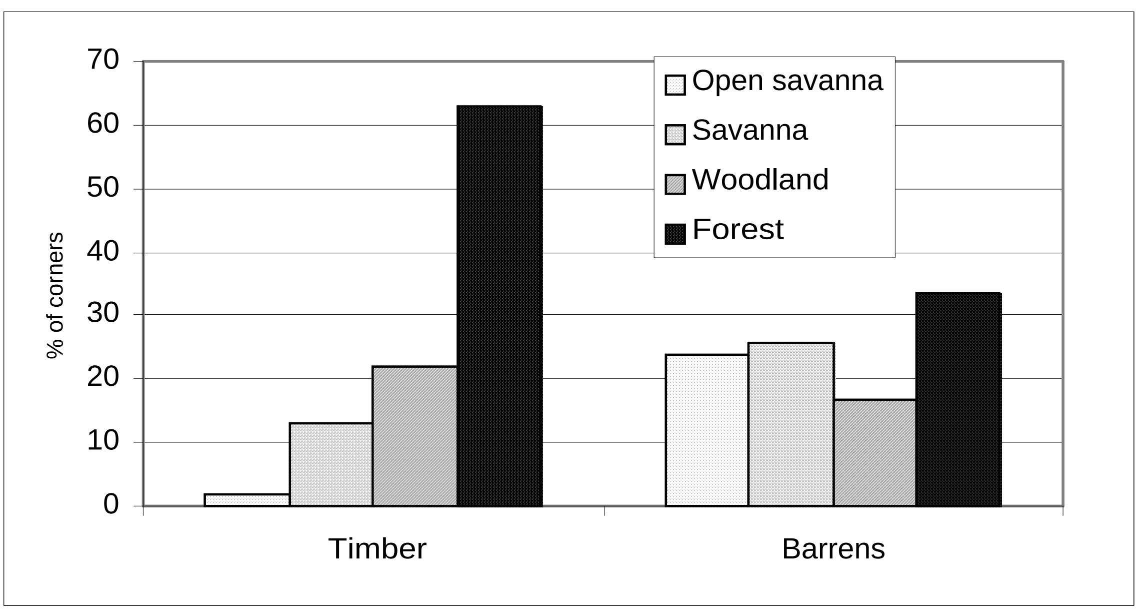

Figure 3. Percent distribution corners among tree density classes in timber and barrens. Open savanna = >0-10 trees/ha, Savanna = >10-50 trees/ha, Woodland = >50-100 trees/ha, Forest = > 100 trees/ha.

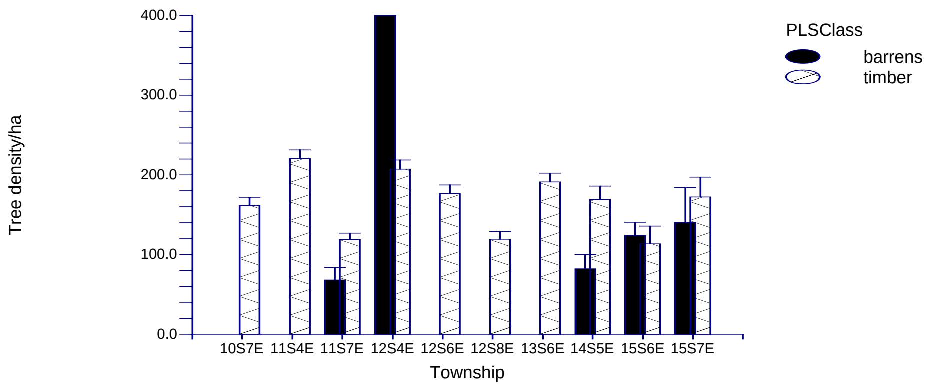

Figure 4. Variation in distribution of tree density among townships in barrens (F = 1.29, P = 0.282) and in timber (F = 10.46, P < 0.0001).

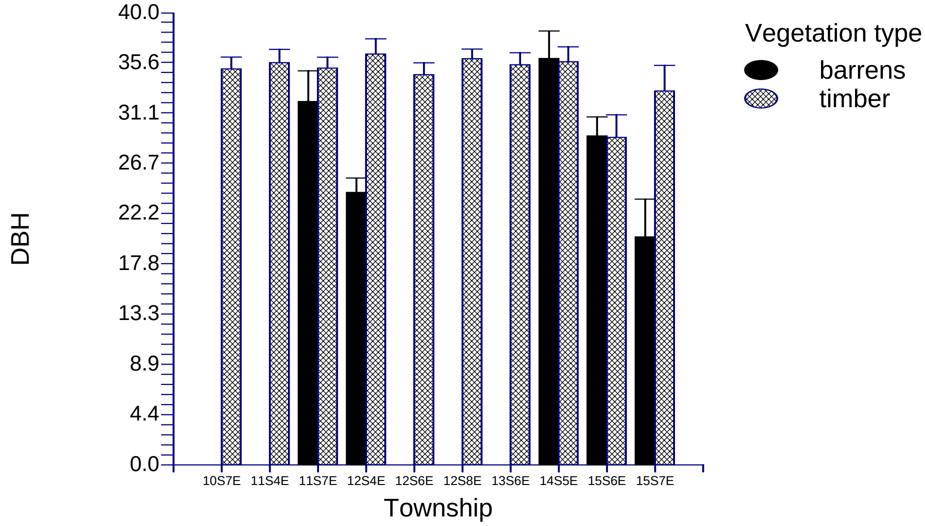

Figure 5. Variation in distribution of tree dbh among townships in barrens (F = 3.15, P = 0.015) and in timber (F = 1.31, P = 0.228).

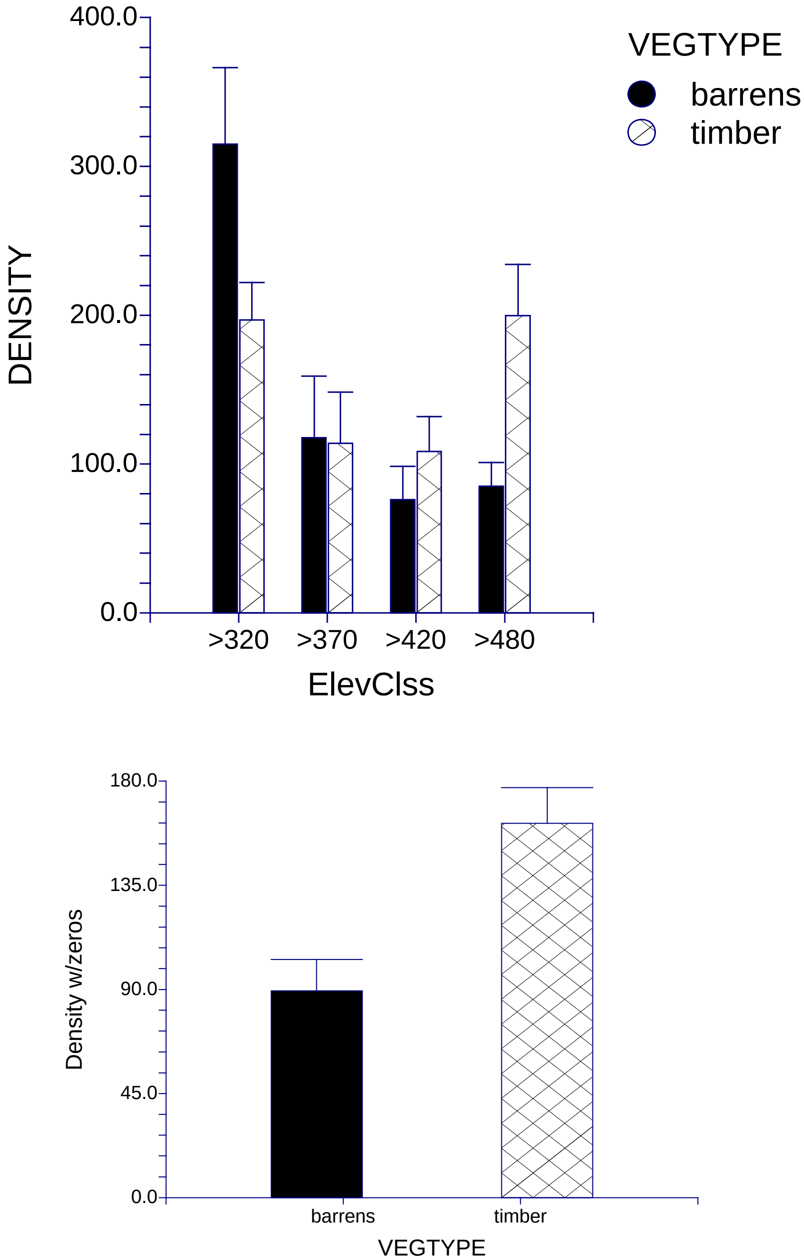

Figure 6. Upper: variation in tree density by elevation (F = 19.5, P < 0.0001), vegetation type (F = 0.08. P = 0.777), and density x vegetation type (4.88, P = 0.003). Lower: variation in tree density (with zero values added) between barrens and timber (T = -3.5367, P = 0.0005).

Table 1. Townships analyzed for composition and structure of woody vegetation. RNA = Research Natural Area, EA = Ecological Area.

1. T10S R7E (Cave Hill south, Stoneface & Dennison RNAs/EAs)

2. T11S R4E (Fink Sandstone Barrens EA north)

3. T12S R4E (Fink Sandstone Barrens EA south)

4. T11S R7E (Gibbon Creek EA) [Gyp Williams Hollow EA]

5. T12S R6E (Copperous Branch Limestone Barrens EA)

6. T12S R8E (Keeling Hill North, Keeling Hill South EAs)

7. T13S R6E (Pleasant Valley Barrens EA)

8. T14S R5E (Robnett Barrens EA)

9. T15S R6E (Burke Branch RNA/EA, Cretaceous Hills EA, Dean West EA, Dean East EA, Dog Creek Barrens EA, Kickasola EA west, Poco North EA, Poco East EA west) [Massac Tower Springs EA west]

10. T15S R7E (Kickasola EA east, Poco East EA east) [Massac Tower Springs EA east, Snow Springs EA]

Table 2. Relative basal area (dominance) of tree species in timber by tree density class.

	Density Class			
	Forest	Woodland	Savanna	Open savanna
Species	> 100 trees/ha	>50-100 trees/ha	>10-50 trees/ha	>0-10 trees/ha
white oak	44.62	54.72	54.72	48.87
black oak	21.45	13.35	21.08	15.11
red oak	3.81	6.73	4.42	6.85
hickory		5.73	4.97	10.08
sugar maple	0.90	1.06	1.98	5.51
sweet gum	1.13	1.96	5.42	
walnut	0.41	0.34	0.27	6.85
gum	3.69	3.73		
hickory	7.16			
elm	2.23	2.50	1.31	
post oak	1.65	3.06	0.88	
maple	0.84	0.26		4.39
poplar	2.73	2.10	0.33	
white ash	0.61	1.02	0.74	0.62
dogwood	1.50	1.09	0.21	
ash	1.48	0.65	0.64	
cypress	1.94			
gum			1.83	
w	0.08			1.71
mulberry	0.35	0.44	0.26	
b elder	0.41	0.09	0.29	
beech	0.01	0.70		
sycamore	0.63			
cottonwood	0.58			
hackberry	0.42			
spanish oak	0.42			
honey locust	0.11	0.28		
b jack	0.12	0.05	0.17	
sassafras	0.07		0.18	
ironwood	0.03	0.10	0.13	
cherry	0.02		0.18	
oak	0.20			
p oak	0.18			
buckeye	0.10			
shrub oak	0.03	0.03		
g? oak	0.06			
redbud	0.01			
persimmon	0.01			
Total richness	36	22	20	9

Table 3. Relative basal area (dominance) of tree species in barrens by tree density class.

	Density Class			
	Forest	Woodland	Savanna	Open savanna
Species	> 100 trees/ha	>50-100 trees/ha	>10-50 trees/ha	>0-10 trees/ha
white oak	61.74	49.16	52.74	70.81
b oak	21.83	44.93	32.08	20.24
hickory	2.11	2.95	3.58	3.39
p oak			8.35	
post oak	1.25		1.81	4.00
gum	6.70			
maple	1.69		1.45	
red oak	0.55	2.36		
spanish oak	2.21			
sycamore				1.57
shrub oak	1.05			
oak		0.59		
mulberry	0.55			
dogwood	0.31			
Total richness	11	5	6	5