CHANGES IN A MISSOURI OZARK OAK-HICKORY FOREST DURING 40 YEARS OF UNEVEN-AGED MANAGEMENT

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Abstract: Changes in basal area, density and average diameter were examined on a 156,000-acre privately owned oak-hickory forest in the Missouri Ozarks. The forest has been managed since 1954 using the single-tree selection method. Trees greater than five inches dbh were monitored on 486 one-fifth-acre permanent plots at five year intervals from 1962 through 1992. Seven species/species groups accounted for approximately 90% of both basal area and density throughout this 30-year period. Average basal area increased by 48% and average density by 69% during the study period. Quadratic mean diameter declined by 8.5% over the first 15 years and has since remained relatively stable.

INTRODUCTION

Silviculture is defined as the art and science of manipulating a forest to meet the landowners' objectives (Smith, 1986). Since traditional even-aged management has fallen into disfavor with a large segment of the general population in recent years, there is increased pressure to apply uneven-aged management in systems such as the oak-hickory type (Sander and Graney, 1993). However, little long-term information is available on the growth and compositional changes occurring in oak-hickory forests under uneven-aged management. By applying selection techniques to these systems at this time, the practice of silviculture becomes less of a science and more of an art.

The single-tree selection method has been successfully used to manage shade-tolerant species. Such species are able to develop beneath the continually present canopy of uneven-aged forests. In contrast, shade-intolerant species require a light intensity for their survival and recruitment into the overstory that is often lacking in uneven-aged forests (Oliver and Larson, 1990). It has even been suggested that single-tree selection will not regenerate the oak component of a forest (Sander and Clark, 1971; Sander and Graney, 1983). A major concern in using uneven-aged methods of management then centers on a compositional shift toward more shade-tolerant species, which may be of lesser commercial value (Johnson, 1977; Niese and Strong, 1992). However, most studies that have demonstrated a shift in tolerance were conducted in mesic systems where oak reproduction does not tend to survive and accumulate in the understory. In xeric, oak-dominated systems such as are present in the Missouri Ozarks, oak reproduction does tend to accumulate, so the possibility exists for sustained oak recruitment into the overstory (Johnson, 1992).

To improve our understanding of the long-term effects of uneven-aged management, this paper presents 30 years of data on changes in the composition and basal area of a predominantly oak-hickory forest managed by the single-tree selection method for 40 years. The information represents an initial assessment of uneven-aged management as applied in a xeric to dry-mesic oak-hickory forest in the Missouri Ozarks.

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Management Strategy

The management plan for this forest was developed to meet three objectives: (1) to obtain income from timber sales; (2) to maintain a continuous forest cover; and (3) to refrain from the use of clearcutting in managing the forest. Although maximization of income has not been a primary goal, the forest is required to be self-supporting.

To meet these requirements, the forest plan calls for an approximate 20-year cutting cycle. However, the timing of reentry coincides with the stand reaching 95 - 100 ft^2 of basal area per acre. Upon reentry, the stand is cut to about 65 ft^2 per acre. The operational unit on the forest is the equivalent of one section (640 acres) but topography rather than section lines are used to delimit section units. This reduces adverse site impacts when adjacent sections are harvested.

Only merchantable trees (hardwoods greater than 10 inches dbh and pine greater than 9 inches) are marked for harvest. Culls that suppress potential crop trees are marked and felled as a condition of a timber sale. Lack of markets and the length of time required to grow small diameter stems to merchantable size makes the cost of precommercial thinning prohibitive. Only where a market exists are smaller stems removed.

When a stand is marked for harvesting, the goal is to create or maintain a three-tiered condition comprised of an overstory, a midstory and a sapling/reproduction layer. If the time between entries is too great, small diameter trees are lost and a two-tiered stand results. During marking, each merchantable tree is examined for possible removal. Those deemed likely to die before the next entry are marked for removal. Healthy trees are also considered for harvest. Whenever crop trees are competing, one is removed. Vigor, potential value (e.g. branching patterns limiting merchantable height gain), slope position, aspect and species are used to determine trees to be removed.

Salvage harvests are also made. Marking is accomplished in a manner similar to that of a normal harvest with one exception. If after marking all dead and damaged stems it is determined that the stand will be understocked to the point where the next harvest will be significantly longer than 20 years, all stems of merchantable size are reevaluated as to their ability to survive to the next entry. Any trees deemed likely to survive are left.

METHODS

For forty years this forest has been monitored through the use of well-distributed permanent 0.2 acre continuous forest inventory (CFI) plots. The first inventory was conducted in 1952 with remeasurements made every five-years. In 1957, the current monitoring procedure was established. The number of CFI plots was doubled; one plot was installed for every 320 acres of land on the forest. On each 0.2 acre plot, all stems 5.0 inches dbh and greater, were permanently numbered. Species, dbh, merchantable height to the nearest two-foot class and percent soundness were recorded along with forest-specific product and mortality codes. During subsequent inventories, trees were remeasured, mortality since the last inventory noted and any ingrowth stems were assigned new identification numbers and tallied.

Description of the Forest

The forest covers over 156,000 acres in the Ozark Highlands of southern Missouri. Approximately 90,000 acres were purchased by the current owner in 1954. Additional land was purchased to bring the size of the forest to 134,000 acres by 1962 and to 150,000 acres by 1972. Additional CFI plots were installed as the size of the forest increased. As a provision of the original purchase, the previous owners retained the right to harvest white oak (*Quercus alba* L.) greater than 16 inches dbh. Harvesting of those trees occurred on selected areas of the forest into the early 1960's which left some stands with very low residual stockings. In 1962, 31.6% of the CFI plots supported less than 31 ft^2 of basal area per acre, 86% of the plots had less than 61 ft^2 (Figure 1).

Because of the size of the forest, site quality and vegetation vary widely. However, topography is generally steep with broad flat ridges. The soils are generally rocky and droughty, but range from deep gravel and rock outcrops to areas where the soil is over four feet deep. The soil is derived mainly from dolomitic limestone. Site index (base age 50-years) ranges from 50 to 90 for black oak (*Quercus velutina* Lam.). Although the forest is predominantly oak-hickory, shortleaf pine occurs throughout as scattered trees and as pure stands on upper south-facing slopes. Lower north-facing slopes and deep valleys typically support mixed mesophytic hardwoods.

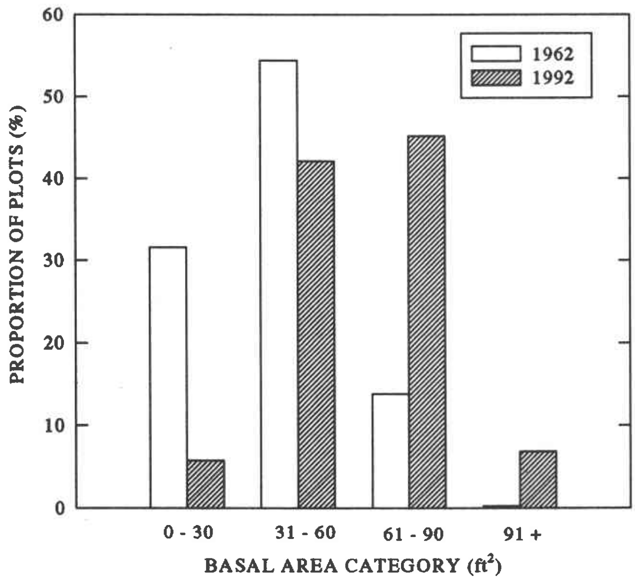

Figure 1. Breakdown of CFI plots, by basal area, at beginning and end of study period.

Analysis

Only the CFI data from 1962 to 1992 are presented in this paper. Basal area (ft^2 per acre), density (trees per acre), and quadratic mean diameter (QMD), were calculated by species for each measurement year. This information reflects a preliminary analysis of the dataset. Data from all available CFI plots have been included in the averages presented. Therefore, because additional property was added to the forest through time, of the landbase included in the 1992 data, 78% had been managed with single-tree selection for 40-years, 8% for 30-years, 10% for 20-years, 3% for 15-years and 1% for 10-years.

RESULTS

Seven principal species/species groups accounted for approximately 90% of both basal area and density throughout the 30-year study period from 1962 to 1992. These species include white oak, scarlet oak, black oak, northern red oak (*Quercus rubra* L.), post oak (*Quercus stellata* Wangenh.), shortleaf pine and hickories (*Carya* spp.). During that time, total basal area on the forest increased by 48% and density by 69% (Table 1). However, of the primary species studied, only scarlet oak maintained the same proportion of basal area and density relative to the entire forest. White oak relative density increased by 12.8% while a similar percentage decline was observed in the remaining species. White oak and shortleaf pine have shown the strongest increase in relative basal area, 8.3 and 5.4% respectively.

Table 1. Average basal area, density and quadratic mean diameter, by year, averaged across species and CFI plots on the forest.

Year	Basal Area (ft^2 / acre)	Density (stems / acre)	QMD (inches)
1962	40.94	86.31	9.33
1967	44.57	97.77	9.14
1972	47.21	107.87	8.96
1977	49.58	124.72	8.54
1982	52.14	131.34	8.53
1987	54.03	134.32	8.59
1992	60.51	145.90	8.72

In absolute terms, five of the seven principal species have increased in density during the study period (Figure 2). Post oak (data not shown) and northern red oak, the two least common of the seven species, maintained relatively stable densities. The hickories, scarlet oak and black oak exhibited similar trends in density change, increasing from 1962 through 1977 and remaining stable thereafter. Density of shortleaf pine has been constant since 1972. Only white oak has continued to show substantial increases throughout the study period and accounts for 87% of the total gain in density occurring on the forest between 1977 and 1992.

The three red oaks (black, scarlet and northern red), exhibited similar trends for both basal area and quadratic mean diameter (QMD) through time (Figure 2). A steady decline was observed in QMD for the first 20 years followed by a recovery. Changes in QMD appear to be closely tied to changes in density. The decline in QMD was accompanied by an increase in density, northern red oak excepted, from 1962 - 1977. Stabilization and recovery of QMD for the red oak group has occurred since the density of black and scarlet oak leveled off. Basal area changes have shown an upward trend with scarlet oak exhibiting the greatest gain followed by black oak and finally northern red oak (Figure 2).

The pattern of change in QMD differed between the white and red oak groups. White and red oaks demonstrated the same initial decline in QMD; however, white oak QMD did not recover while red oak QMD did. Since 1977, white oak QMD has continued to decline, but at a greatly reduced rate. At the same time, white oak density and basal area have increased sharply.

For shortleaf pine, both basal area and QMD have steadily increased through time. The rate of change for these variables appears to have been effected when density peaked in 1977 with QMD increasing and basal area decreasing.

DISCUSSION

Indications are that the composition of this forest is not shifting toward shade tolerant species. The seven species found to be most prominent when single-tree selection was implemented in 1954, still comprise the same relative proportions of the forest today. Density for all species except white oak has been relatively constant since 1977 (Figure 2). White oak, which has high value both for timber and mast production, is increasing in prominence on the forest. Its density has increased over three-fold and its basal area has more than doubled during the 40-year monitoring period. As a proportion of the forest total, in 1962 white oak comprised less than 18% of the total basal area. In 1992, 26% of the basal area was in this valuable species.

Ingrowth and the harvesting of timber both have a suppressing effect on QMD. Since ingrowth is measured and averaged into the plot total when a tree reaches five-inches dbh, if QMD is larger than 5.0 inches any new ingrowth will bring about a reduction in QMD value. Likewise, if QMD is smaller than the ten-inch minimum harvest diameter, cutting any tree will lower the QMD. Only diameter increases of trees greater than five-inches dbh will increase the QMD.

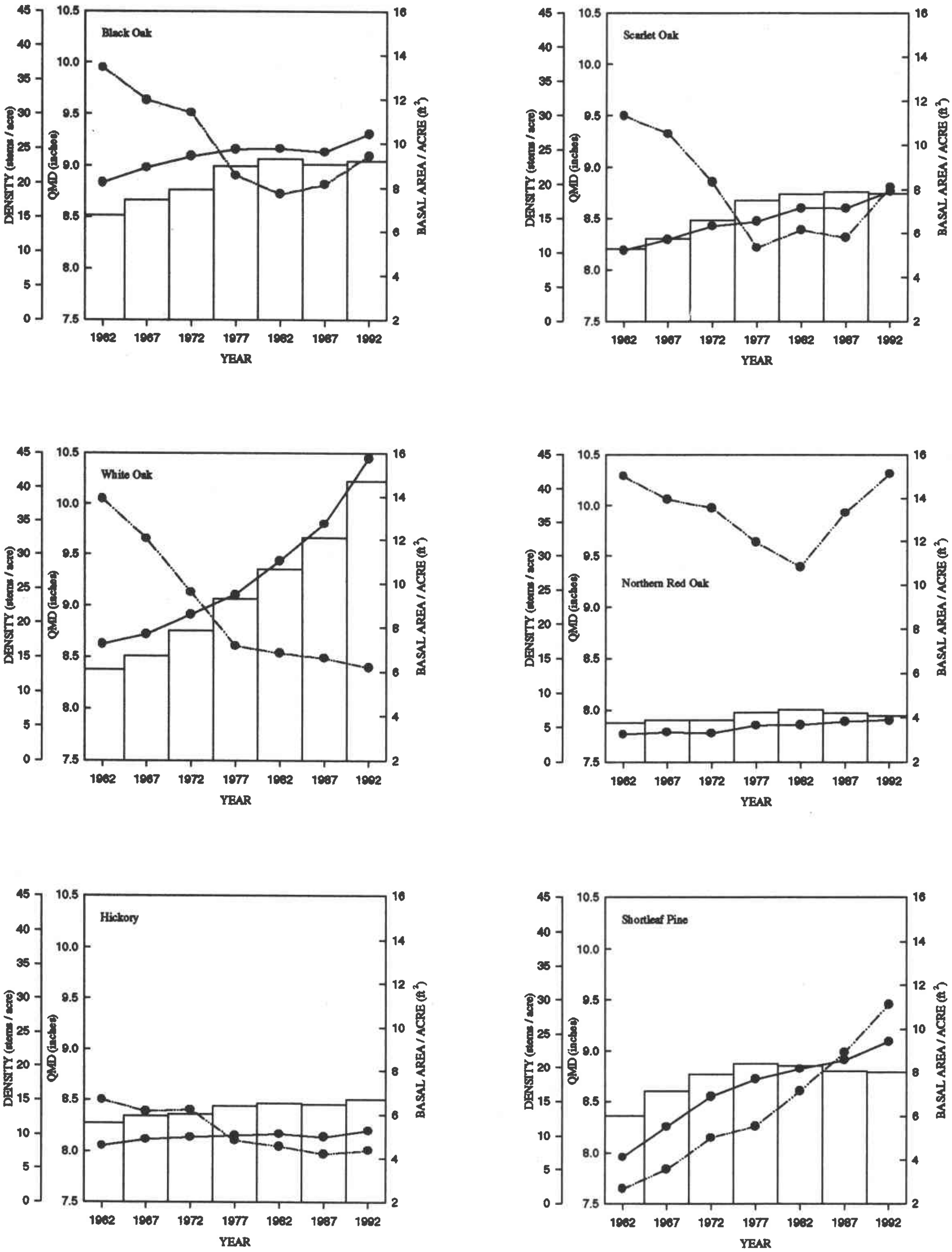

Figure 2. Changes in quadratic mean diameter (broken line), basal area per acre (solid line) and density per acre (hollow bars), for six species/species groups under uneven-aged management practices.

Average basal area has remained relatively stable for northern red oak and hickory, slowly increased for black oak and scarlet oak, markedly increased for shortleaf pine and increased exponentially for white oak (Figure 2). With black oak, scarlet oak and shortleaf pine, this increase in basal area mirrors the increase observed in QMD. Since the density of these species is stable (ingrowth equals the sum of harvest and mortality), both basal area and QMD will also likely stabilize when the growing capacity of the forest is reached.

The large increase observed in white oak basal area paralleled a similar increase observed in density. The fact that the QMD has declined only slightly since 1977 (0.2 inches) while density has continued to increase, indicates that considerable diameter development is occurring. Numbers and size of mortality and trees harvested were not available at the time of manuscript preparation; therefore, changes in density that are reported represent an extremely conservative estimate of ingrowth and its consequent effect on QMD suppression. The sharp early drop observed in white oak QMD is believed to be due to the ten stem per acre increase which occurred between 1962 and 1977, almost doubling the species' density (Figure 2). In this same 15-year period, basal area increased by 2.2 ft^2 per acre. Since ten, five-inch stems account for only 1.4 ft^2, the remaining 0.8 ft^2 (plus any basal area removed by mortality or harvesting) had to result from the growth of the remaining stems. Since 1977 the evidence for diameter development is even more dramatic. Again, almost a doubling of density was observed (23.5 to 41 stems per acre). However, during this time period the sharp decline in QMD observed earlier, did not occur. The 17 additional white oak stems tallied account for 2.4 ft^2 of the 6.2 ft^2 of basal area added since 1977.

As of the last remeasurement period (1992), the single-tree selection management approach appears to be maintaining a healthy, sustainable forest. Ingrowth into the five-inch diameter class is occurring at a rate sufficient to maintain or increase density for all of the principal forest species even after accounting for harvested stems. Diameter development is occurring as evidenced by the stabilization of QMD for the forest as a whole while average basal area and density are steadily increasing (Table 1). However, even though single-tree selection has been applied for 40 years, the forest can not yet be considered regulated. This is evidenced by the continuing increase in basal area and density which can only occur while there is available growing space. The forest is obviously still recovering from the low stocking levels which were present at the time ownership was transferred; as of 1992, approximately 45% of the forest still supported less than 60 ft^2 of basal area per acre (Figure 1). Despite the lack of full regulation, initial indications support Johnson's (1992) suggestion that under the conditions present in this xeric to dry-mesic, oak dominated ecosystem, selection silviculture may result in sufficient recruitment to perpetuate the oak-hickory type.

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