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Growth of Oaks in Southeastern Iowa in Relation to Stand Density and Grazing

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High yields of wood depend upon maintaining forest stands of "optimum" density and providing levels of water, nutrients, light and heat sufficient for the full development of different species as determined by their genetic potentials.

European studies of growth in relation to stand density have yielded somewhat contradictory results. Møller (1954) indicates that growth increases with increasing stand density up to about 50 or 60 percent of the maximum attainable density; beyond this there is either no change or a slight decrease in growth depending upon the criterion for growth used. Assmann (1955) and Mitscherlich (1954) have found maximum growth at 80 to 95 percent of maximum stand density with growth decreases at higher and lower densities. Most authors agree, however, that there is at least a narrow range of stand densities over which the differences in growth are small.

Heavy grazing in hardwoods often lowers the density of stands and changes the soil, climatic and biotic environment of the trees. The soil is compacted with simultaneous changes in pore-space relationships. Infiltration of water is reduced and aeration affected. Some root injury generally occurs. The original understory vegetation is destroyed and a gradual reduction in the density of the main stand may occur, the results of which are increasing solar radiation within the stand, increasing temperatures and wind movement, higher vapor pressure deficits at the ground line and the transpiring surfaces of leaves, and increasing dryness.

The purpose of the present study was to determine the effects of continued heavy grazing and reduction in stand density on the height, diameter and volume growth of trees in the oak-hickory forests of southeastern Iowa.

Area and Methods

The study was limited to farm woodlots in southern Wapello and northern Davis Counties, Iowa. The forests in this area occur on gray-brown podzolic soils of the Weller-Lindley soil-association area. Soils on the upper slopes and flat ridges are derived from fine-textured loess and belong to the Weller and Marion series. On the middle and

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lower slopes the soils are chiefly Lindley loams with clay loam B horizons and are derived from glacial till. The principal upland forest type is white oak and the stands are even-aged second-growth that followed cuttings starting about the time of the Civil War. Almost all stands have been grazed. The site index for oak (Schnur, 1937) ranges mostly between 40 and 60.

In this area growth was studied on 15 one-fourth acre plots. All study areas were in the white oak type, on Lindley loam soil and in the middle-third or lower, upper-third slope positions. Aspects, with two exceptions, were in the northern hemisphere, slope percentages ranged from 10 to 35 and stand ages, with two exceptions, were in the 70-90 year age group. With the exception of grazing history and stand density the areas chosen for study were as comparable as could be obtained. On two of the better stocked woodlots there was no current grazing and past grazing had been light. On the other areas the stand density had been altered by grazing and limited cutting. An attempt was made to select a series of plots varying only with respect to stand density and in apparent severity of past grazing (Fig. 1). Two of the plots represented open-grown stands of low initial density. The remainder were stands whose original dense stocking had been modified by treatment.

On each plot all trees were tallied by species, diameter at breast height and crown class. Every third tree above the 4-inch class was taken as a sample tree and total height, diameter to the nearest 0.1 inch and radial width of the last 10 annual rings, measured. Ages were determined at breast height on 3 or 4 of the sample trees and then corrected to total age by adding two years, on the assumption all trees were of sprout origin. Only one of four sample trees was permitted to fall in the intermediate crown class.

Volume growth for the period 1933-1943 was computed by finding the volume of the average tree in each diameter class of the present stand and subtracting the volume the same tree had 10 years ago. This was accomplished by plotting radial growth at breast height over diameter-breast-height, doubling and correcting for bark and subtracting to obtain the diameter of the present trees ten years ago. Heights for trees at the beginning of the 10-year period were read from a height-over-diameter curve using the diameters as found above. Volumes were interpolated from the standard oak volume tables of Schnur (1937). The volume growth of each plot was obtained by multiplying the periodic growth of the average tree in each diameter class by the number of trees in that class in the present stand and summing. Since no estimates were made of mortality during the period, the resulting growth figures are conservative.

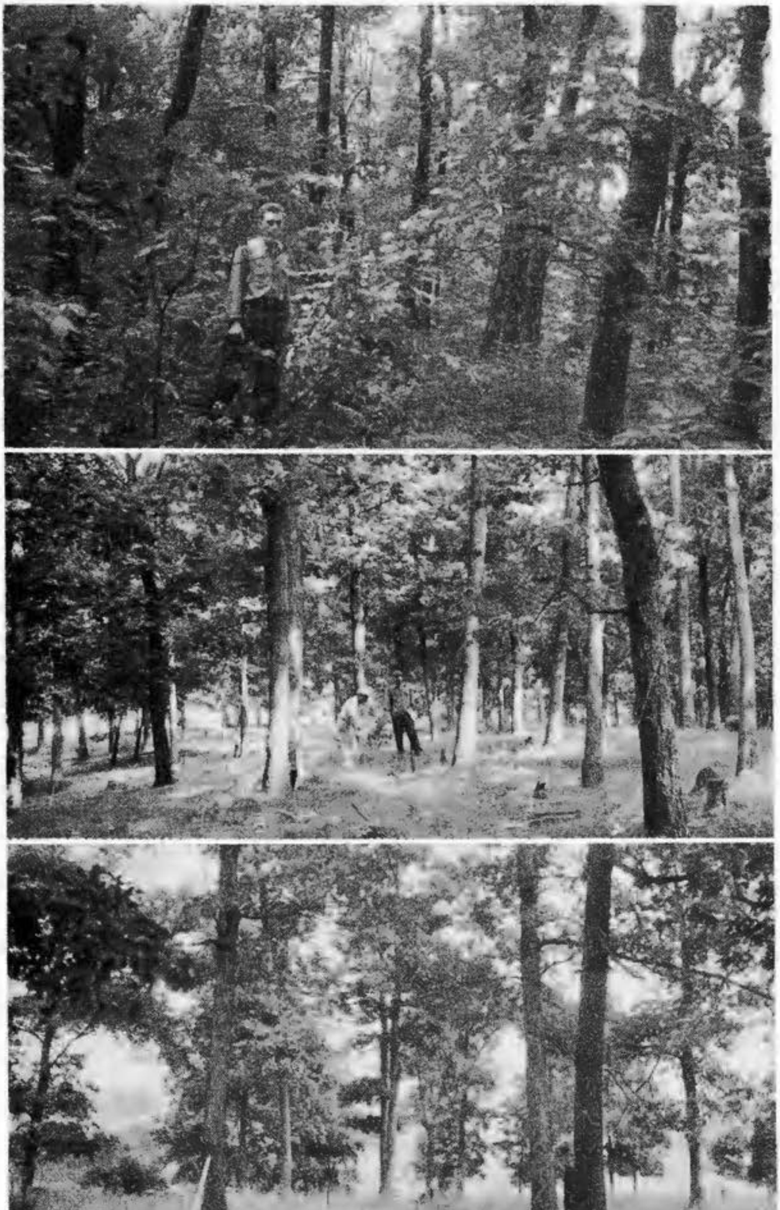

Figure 1. Stands of different density resulting from grazing in the white oak type in southeastern Iowa. Upper, dense and ungrazed; center, medium-high density and grazed; lower, low density and grazed.

Separate periodic volume growth tables were made for white oak and associates and for red oak and associates.

To aid in computing more accurate periodic increment estimates the data for white oak and its associates, bur oak and hickory, were segregated into two classes based on stand density and a third class which included the two plots with open-grown trees. This procedure was indicated after preliminary inspection of the data showed that trees in the less dense plots were shorter and growing more rapidly in diameter. The data for red oak and its associates, white ash, walnut and elm, were not segregated by density classes because they were not numerous enough to give strong averages.

The stand composition, based on all plots, was white oak (*Quercus alba L.*) 78 per cent, red oak (*Q. rubra L.*) and black oak (*Q. velutina Lam.*) 8 percent, hickory (*Carya ovata* (Mill) K. Koch and *C. cordiformis* (Wangenh.) (K. Koch) 8 percent and miscellaneous 6 percent.

Results

Basic data relating to the 15 individual plot sites and the trees on them are contained in Table 1.

The relationship of total height to diameter for white oak and associates, segregated into three stand-density classes, is shown in Figure 2. Curve C represents trees on two plots where there never had been competition for crown space. Curves A and B represent stands, once closed, which had been gradually opened as a result of grazing. The lower density plots (curve B) presumably had been

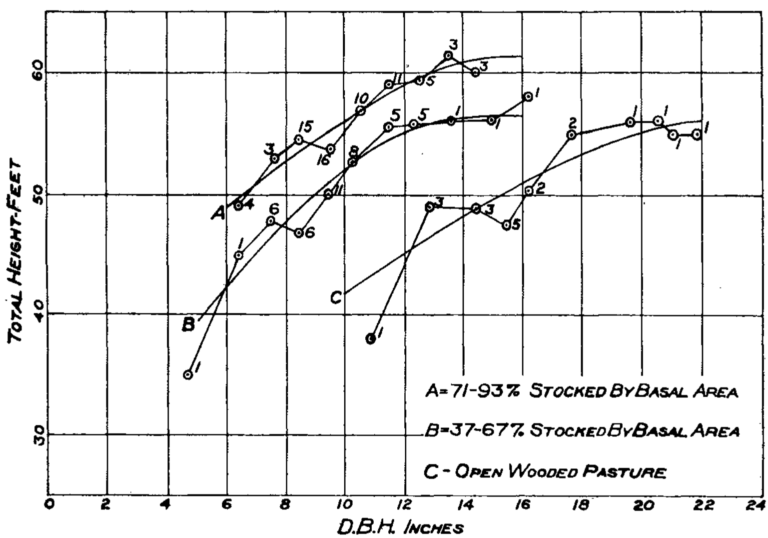

Figure 2. Heights of white oak and associates in relation to diameter at breast height for three different stand density classes.

grazed more intensively and for a longer period of time. Curve A represents more nearly full-stocking. The data suggest a real reduction in height growth apparently associated with stand density and grazing. These results are in agreement with those obtained by Gevorkiantz and Scholz (1948) and Gaiser and Merz (1951) for oaks. They are contrary to the findings of Craib (1947) and others with reference to conifers.

Inspection of plot descriptions (Table 1) indicates no consistent site differences other than those associated with grazing and limited cutting. The differences in height growth probably can best be explained in terms of moisture relationships. Soil compaction usually interferes with the infiltration of water and affects the growth and the functioning of roots in moisture absorption. Crowns in open stands tend to be larger with more growing points and leaf area that must be supplied with water. The microclimate of open stands is different than that of closed stands. More solar radiation and usually more precipitation reach the interior of the stand and the soil surface; temperature, wind movement and vapor pressure deficits are larger; evaporation and transpiration stress tend to increase. Where grasses or sedges replace the forest shrub and herb layer there is a greater concentration of roots in the surface soil horizons, greater moisture use from these layers and less moisture penetrating to the subsoil where, during periods of moisture stress later in the growing season, it may be absorbed by the deeper penetrating tree roots. Most of these factors operate to reduce the water available for tree growth.

The diameter growth at breast height for white oak and associated species in stand-density groups A and B is shown in Figure 3. Data for trees in group C, the open, wooded-pasture stands, are not shown because of inability to plot them to a suitable scale on the graph. The diameter growth of group C trees ranged from 0.74 inches for an 11-inch tree to 2.96 inches for a 22-inch tree. The data for all groups follow the expected trend with trees of the smaller diameter classes in the better-stocked stands growing more slowly than trees of like diameter in more open stands. The more rapid diameter growth in less dense stands reflects the additional growing space and the greater crown volume, leaf area and radiation available to these trees (Dale, 1955) (Burger, 1947).

Graphs similar to those for white oak in Figures 2 and 3 were constructed for red oak and associated species, with the exception that the red oak data were not segregated by stand-density classes. Data from these graphs were used to compute periodic growth in terms of both cubic feet and board feet based on present diameters and average heights. The appropriate growth values were applied to the individual stands to obtain the growth for the individual one-

Table 1
Summary of Plot Data

Density Class	Plot No.	Aspect	Position on Slope	Age	Heights—Feet Dominants and Codominants	Trees/Acre 4″ and over	Trees/Acre 1″ and over	Basal Area Sq. Ft./Acre Trees 1″ and Over	Volume Cu. Ft./Acre Trees 4″ and Over
A									
71-93% Stocked									
by Basal Area	1	NE	Upper ⅓	82	57	188	216	105.1	2,186
	2	E-NE	Upper ⅓	92	57	132	132	91.7	1,986
	3	N	Upper ⅓	82	58	124	128	82.5	1,661
	10	NW	Middle ⅓	85	57	176	188	83.9	1,711
	11	N	Upper ⅓	77	57	144	144	82.0	1,728
	12	E-NE	Middle ⅓	85	59	228	232	90.0	1,782
	13	S-SW	Upper ⅓	67	50	228	248	90.6	1,779
B									
37-67% Stocked									
by Basal Area	6	NW Cove	Middle ⅓	75	53	136	136	63.7	1,284
	8	N-W-S	Upper ⅓	90	57	124	256	72.6	1,486
	9	N	Middle ⅓	77	52	112	112	47.6	952
	14	E	Upper ⅓	85	53	124	124	61.9	1,572
	15	N-NE	Middle ⅓	53	54	88	88	55.8	1,212
	17	E-S	Middle ⅓	72	44	96	96	40.2	838
C									
Open, Wooded									
Pasture	4	NE	Upper ⅓	82	48	52	52	59.7	1,217
	16	E	Upper ⅓	85	53	28	32	53.9	1,268

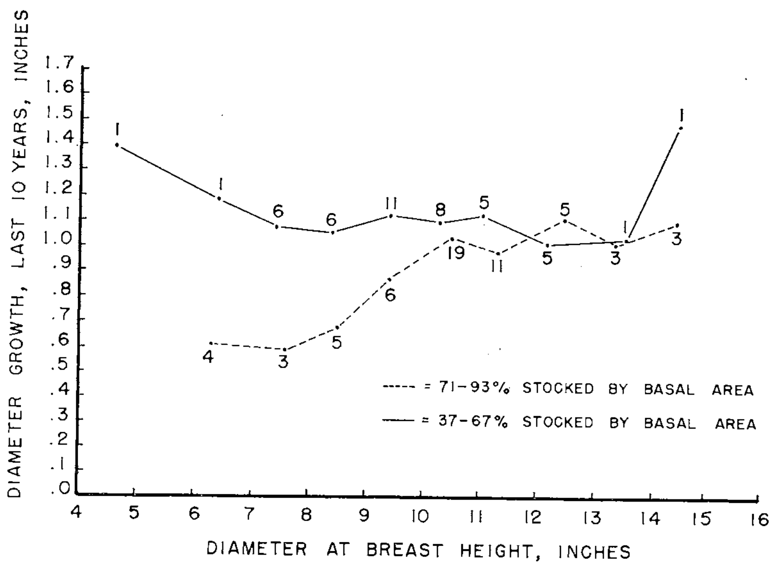

Figure 3. Diameter growth of white oak and associates in relation to diameter at breast height for two stand density classes.

four acre plots. These plot growth values, plotted over basal area as a measure of stand density, are shown in Figures 4 and 5. A fully-stocked oak stand for these sites (Site Index 45±), according to Schnur (1937) and Gevorkiantz and Scholz (1948), has about 113 square feet of basal area at age 80.

The average annual growth in cubic feet (Fig. 4) for the 10-year period, for all trees 4 inches and larger in diameter, decreased from about 40 for stands nearly fully-stocked to about 25 for stands half-stocked. The relationship is almost linear although a quadratic equation accounted for slightly more of the total sum of squares than was accounted for by linear regression. The correlation coefficient of 0.936 indicates that 88 percent of the variation is associated with basal area differences. When only the sawtimber stand is considered, growth measured in cubic feet decreased from about 29 for a fully-stocked stand to about 17 in stands half-stocked.

The board-foot volume growth in terms of the International ¼-inch log rule is shown in Figure 5. When all trees eight inches and over are considered, growth decreased from about 200 board feet per acre for a fully-stocked stand to about 125 board feet for a stand 50 percent stocked. When all trees 10 inches and over are considered the corresponding growth figures are 140 and 90 board feet. These graphs show that on the average about 45 board feet, or some 28 percent of the larger growth figure, occurs in trees in the 8- and 9-inch diameter classes. The quadratic equations gave slightly better fits to the basic board data than did linear regression, but again the differences were not statistically significant. The correlation coefficients are lower than for the cubic foot data because of differences in the diameter distribution of the trees in the stands. Periodic volume growth plotted over stand volumes showed the same general relationship as shown for basal area.

These data are thought to represent a reasonably accurate estimate of the relationship between gross periodic volume growth in 70- to 90-year-old white oak stands on Lindley soils, and stand density and site conditions as altered by long continued grazing. They do not reflect the lower quality of the open-grown timber. Relating these data to the time required to make the transition by grazing from fully-stocked forest to open pasture will give some estimates of the forest growth potential lost due to heavy pasturing.

The decrease in volume growth with decrease in basal area, in the range from 100 to 50 percent of maximum stand density, does not agree with the findings of Møller (1954) and Baker (1953) and this decrease is equal to or in excess of the decreases reported by Assman (1956), Mitscherlich (1954) and Gaines (1951). It is

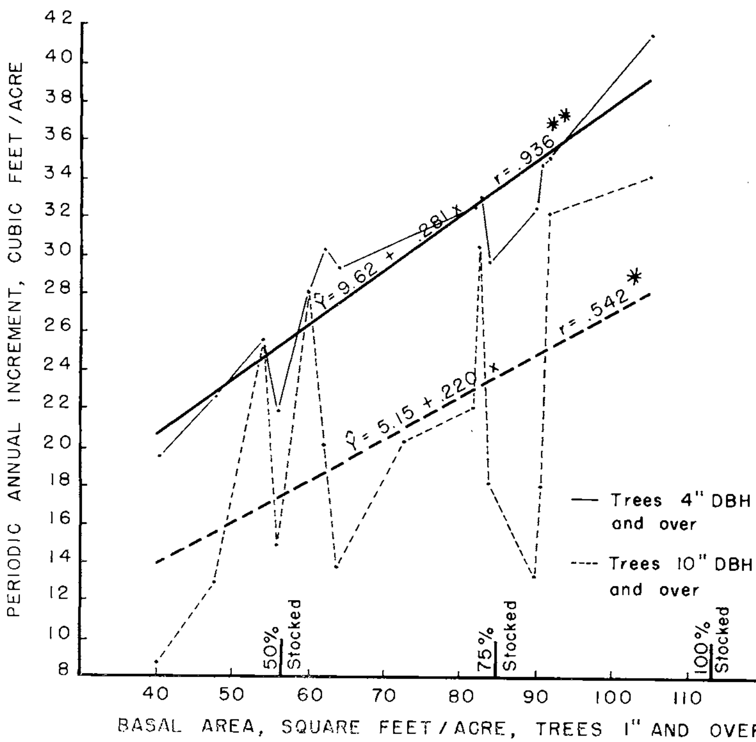

Figure 4. Periodic annual increment in cubic feet per acre in relation to stand density as measured by basal area.

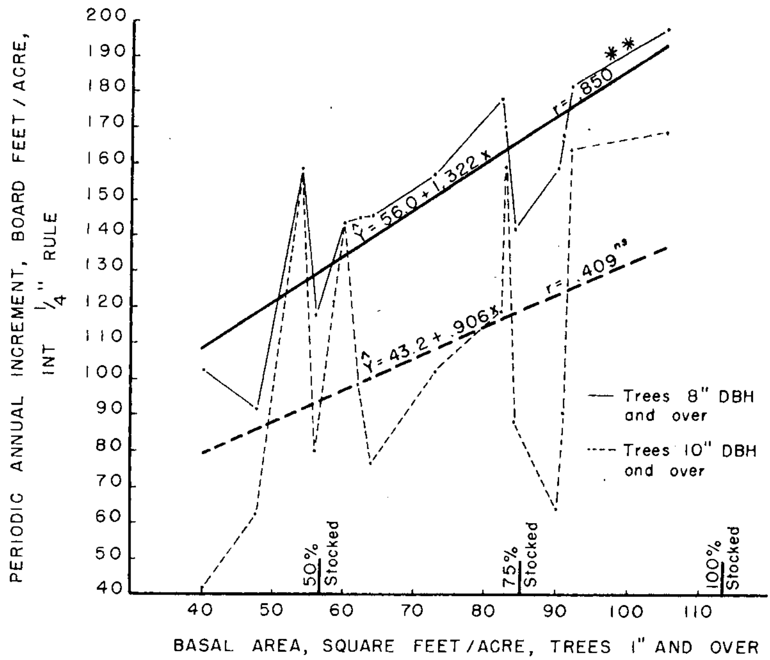

Figure 5. Periodic annual increment in board feet per acre in relation to stand density as measured by basal area.

suggested that the differences observed are due to both (1) a real decrease in growth associated with decreasing stand density and (2) a real decrease in growth due to the modifying action of grazing on the site. The shorter trees on the more heavily grazed plots are evidence for the real nature of the site changes, but because the average site index, as related to grazing varies only from 47 to 45 the site differences are probably not great enough to account completely for the rather large differences in volume growth. Therefore, it is assumed that stand density above the level of 50 to 60 percent of maximum stocking exerts an important effect on total growth. From our data there is no evidence that the unit of measure and the portion of the total stand used in growth computations have any effect on the form of the growth-density relationship in the range from 35 to 95 percent of maximum density as measured by the basal area of the entire stand. It should be noted, however, that the rates of growth computed for the stands 4 inches or 8 inches and over in diameter are greater than the rates for stands 10 inches and over (Figs. 4 and 5). These differences in rates are not statistically significant and since they are contrary to expectation are considered part of the error involved in the study.

Advanced reproduction of oaks was almost lacking in the more open stands. In nearly fully-stocked stands some reproduction had become established, apparently during intervals of light grazing, and had persisted as seedling sprouts. Where present in the more open stands reproduction consisted chiefly of American elm and black cherry.

Discussion and Summary

The upland forests of southeastern Iowa are composed chiefly of different species of oaks and hickory with white oak by far the most important. These forests are mostly second-growth established after cutting, much of which was done about the time of the Civil War and shortly thereafter. A high percentage of the stems is of sprout origin.

Almost all of the wooded areas have been pastured in varying degrees. Grazing tends to destroy the original herbaceous and shrubby layer of the forest, grasses invade and sedges may increase. The smaller trees are gradually killed and this, with some cutting, reduces stand density. Opening the stands brings about changes in microclimate and soil.

This study shows that tree heights in dense stands are 4 to 5 feet greater than in more open stands, that diameter growth is greater in open stands, and that periodic volume growth measured as cubic feet or board feet decreases with stand density. The reduction in height growth in more open stands is thought due to real site changes associated with pasturing and affecting the water economy of the trees. The differences in diameter growth of the smaller trees can be explained in terms of larger crowns, more leaf area and greater light saturation in the more open stands.

The steady decrease in volume growth in relation to stand density indicates that the greater diameter growth in smaller trees has not compensated for the lesser heights and fewer trees in the more open stands. It is suggested that decreased volume growth is due to both adverse site changes associated with grazing and to decreasing stand density itself as the latter is related to the efficiency in utilizing the growth factors in producing wood.

For stand density measured as the basal area of all trees, and for stem growth in either cubic feet or board feet, the limited data presented do not support the theory that stand growth remains more or less constant between stand densities of 50 and 100 percent of the maximum. Diameter growth at stem heights above four and one-half feet was not measured but it is thought unlikely that the general conclusion would have been materially modified by measurement of changes in stem form. The data give no clue as to how much site changes, as contrasted to changes in stand density, have contributed to the overall reduction in volume growth.

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