GROUP SHELTERWOOD SYSTEM FOR REGENERATING OAK IN EASTERN IOWA[1]

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Abstract. -- Regenerating oaks (Quercus alba L. and Q. rubra L.) in eastern Iowa is a major problem. For identifying constraints on oak regeneration, we attempted to determine some ecological relationships between oaks, other interfering species, and sites. Fifty-one variables were examined. Variables could be categorized into energy, interference, soil, water, and successional attributes of species and sites. Multivariate statistical techniques were used to suggest oak reproductive constraints among the "noise" of many species / site interactions. Analysis suggested several factors effecting oak reproduction, some of which were unmanipulatable site factors. Interference from other tree species was the major problem identified that can be managed. The scale of most regeneration constraints involve the small patch of trees, one-quarter to one acre in size. A group shelterwood system would be suited for oak regeneration.

Keywords: Quercus alba, Quercus rubra, Eastern Iowa, oak reproduction, group shelterwood, interference, multivariate analysis

INTRODUCTION

The decline of oak (principally Quercus alba L. and Q. rubra L.) forests in eastern Iowa is partially a result of misjudging successional patterns and ecological constraints of oak species. Misconceptions concerning ecological relationships have led to silvicultural mistakes resulting in undesirable species conversions of stands, extended rotations, and inconsistent production of desirable seedlings. The current compositional change vectors within these forests favor the sugar maple regeneration group (i.e. Acer saccharum Marsh., Acer nigrum Michx, and their hybrids). Sugar maple interferes with the oak and minimizes oak reproduction (Coder, 1985)[3].

The complex mosaic of stands within these forests is the result of quick compositional changes and long periods of inhibited colonization. Resource control by the trees already present dominate reproductive patterns. The battle for available resources is intense especially in areas where resources have been recently released by cutting or other disturbance (Coder 1986). The sugar maple regeneration group is dominating an increasing number of resources at the expense of oak reproduction in many of the stands throughout eastern Iowa (Coder 1985)[3].

Early land surveyors called Eastern Iowa forests places of "scattering timbers," because of large distances between trees. The forests were open, park-like stands (Arend and Scholz 1969). The current mature oak stands developed

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3/ Coder, K.D. 1985. Regeneration ecology of oak in Eastern Iowa. PhD Dissertation. Iowa State University Department of Forestry, Ames, Iowa. 356 pp.

from heavy cutting, grazing, and burning early in the century. Elimination of these disturbance factors has modified the relationships among tree species. On productive sites without fire and grazing, successful regeneration of sugar maple is occurring. Oak reproduction is continuing to be successful only on the drier sites (Merritt 1979).

The Iowa oak forests occur at a transition of three major eco-regions and tend to be continually disturbed by natural fluctuations in environment and through interaction with man (Bailey 1981). Oak has been cited as an ecologically unstable species group in this area presenting inconsistent responses to management (Sander 1977). Oak stands have been traditionally regenerated using clearcutting and various types of shelterwooding (Roach and Gingrich 1968; Sander 1977; Barrett 1980). Oak forest regeneration by standard techniques like clearcutting or shelterwooding (i.e residual stand around 70 square inches basal area) has not been consistently successful. Market preference and traditional forest values of the landowners continue to favor the objective of regenerating oak.

This study was developed to determine some of the relationships between oak regeneration and both the forest community in which it exists and specific sites upon which it grows.

METHODS

One-hundred-thirty-three sample areas, each one acre (0.4047 ha.) in size, were examined. Samples were systematically distributed using a grid overlay on Soil Conservation Service aerial photographs in each of seven eastern Iowa counties with a minimum of 30,000 acres (12,141 ha.) of commercial forest land. Within each sample area, 30 mil-acre plots were systematically installed for determining general site characters and regeneration stocking levels. Four mil-acre (0.0004 ha.) plots within each sample area were identified for overstory data collection. Fifty-one site and species variables were examined on each sample area. Only a portion of the analysis will be presented here.

The dependent variable was the site stocking value of each regeneration group. For example, Acer saccharum, A. nigra, and their hybrids are members of the sugar maple regeneration group. If there was at least one stem of sugar maple reproduction on a mil-acre, then that mil-acre was considered fully stocked. The number of mil-acres fully stocked over the entire site, compared with the total number of mil-acres available, yielded the stocking percent for that species.

The preparation of the independent variables for multivariate analysis resulted in 36 single variables and 15 multiple or composite variables (Johnson and Wichern, 1982; Sarle, 1982a). Composite variables could be divided into two sets. The first set was composed of 12 multiple regression-produced variables (scores) from principal component analysis of soil and nutrient data with each regression containing 20 variables. The second set of composite variables was composed of 3 multiple regression-produced variables (scores) from principal components analysis of climatic data with each regression containing 23 variables. In the whole regeneration stocking model, 51 continuous variables (36 single variables, 15 composite variables from principle component analysis) could have been included. Independent variables mentioned in this paper are listed in Table 1. Table 1 is a subset of the total number of variables measured. All variables were included in the analyses. Only the ones suggested to be significant in describing regeneration magnitudes are included here. Variable preparation techniques, formulae, and further descriptions can be found in Coder (1985)3.

The philosophy of this analysis was not to search for specific variables that tightly controlled oak regeneration. Past management and the literature suggested that there was no single controlling factor but a combination of many interacting influences. This analysis was to support management rationales of site and species manipulation. The holistic story of oak regeneration in these forests was considered more important than individual variable dominace. Specifically, characteristics leading to oak regeneration were to be cataloged.

Species distribution patterns on sample areas and silvicultural treatments in stands were also recorded.

RESULTS AND DISCUSSION

Forty-two species, categorized into 25 regeneration groups, were found reproducing on the sample areas. Four general overstory types were observed: oak (18.1 percent of total), oak - hickory (31.6%), oak - ash (13.5%), and sugar maple - oak (36.8%).

Table 2 suggests those variables that might be related to the stocking values of each regeneration group. Table 2 describes the whole-model regressions for the 4 major regeneration groups (i.e. three separate regeneration groups and one combined white/red oak group). The multiple regressions found in Table 2 were created using SAS (RAY, 1982a,b,; Goodnight, 1982b) software. The information listed with the regressions are the whole model R-square value, the mean square error of the

Table 1.-- List of independent variable symbols and descriptions.

X1 = DEGREES OF SLOPE

X2 = CROWN CLOSURE DIFFERENCE (CROWN CLOSURE AT GROUND LEVEL MINUS CROWN CLOSURE AT 4.5 FEET) Horn, 1971.

X3 = CALCULATED AVERAGE EFFECTIVE LEAF DIAMETER (AVERAGE EFFECTIVE LEAF DIAMETER BETWEEN ZERO AND 4.5 FEET PLUS AVERAGE EFFECTIVE LEAF DIAMETER BETWEEN 4.5 AND CANOPY TOP, QUANTITY DIVIDED BY 2) Horn, 1971.

X4 = TOPOGRAPHIC POSITION (range between 1 for a flat top to 9 for a flat bottom position)

X5 = TOTAL RELATIVE DIRECT AND DIFFUSE RADIATION INPUT POSSIBLE FOR THE GROWING SEASON (APRIL-SEPTEMBER) (List, 1965; Shaw, 1983)1/

X6 = OAK SITE INDEX (50 year basis) (Wray and Thomson, 1980)

X7 = AVERAGE SITE AREA COVERED BY SHRUBS (determined in 10% intervals).

X8 = AVERAGE SITE AREA COVERED BY GRASS (determined in 10% intervals).

X9 = AVERAGE SITE AREA UNOCCUPIED (determined in 10% intervals).

X10 = AVERAGE SAND CONTENT OF THE A-HORIZON FROM TEXTURE ANALYSIS.

X11 = ACTUAL NUMBER OF LEAVES OVER THE SITE BETWEEN ZERO AND CANOPY TOP (-(LOG(1-CROWN CLOSURE)/EFFECTIVE LEAF AREA)) Horn, 1971.

X12 = SOIL MOISTURE INDEX BY SLOPE POSITION (Johnson, 1975; Stoeckeler and Curtis, 1960; with corrections by P. S. Johnson, USDA-Forest Service, Columbia, Missouri, 1984).

Climatic Data: (loading factors in parentheses)

X13 = PRINCIPLE COMPONENT SCORE OF CLIMATIC DATA (GENERAL CLIMATE)

X14 = PRINCIPLE COMPONENT SCORE OF CLIMATIC DATA (EVAPORATIVE ENVIRONMENT)

X15 = PRINCIPLE COMPONENT SCORE OF CLIMATIC DATA (GROWING SEASON PRECIPITATION)

Soil Chemical and Physical Data: (loading factors in parentheses)

X16 = PRINCIPLE COMPONENT SCORE OF SOIL DATA (+magnesium)

X17 = PRINCIPLE COMPONENT SCORE OF SOIL DATA (-phosphorus,-potassium)

X18 = PRINCIPLE COMPONENT SCORE OF SOIL DATA (-clay,+pH,+phosphorus)

X19 = PRINCIPLE COMPONENT SCORE OF SOIL DATA (+pH)

X20 = PRINCIPLE COMPONENT SCORE OF SOIL DATA (+clay,+phosphorus)

X21 = PRINCIPLE COMPONENT SCORE OF SOIL DATA (+clay,-magnesium)

1/ Shaw, R.H. 1983. Microclimatology note set (unpublished). Department of Agronomy, Iowa State University, Ames, Iowa. 439 pp.

Table 2.-- Multiple regressions of site and species variables on sugar maple, red oak, white oak, and combined red/white oak regeneration group stocking values.1/

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sugar maple group =

+1.32	intercept		
-0.43	(0.15)	X7	shrubs
+0.58	(0.13)	X9	unoccupied space
-2.36	(0.44)	X13	general climate
+17.66	(3.33)	X15	growing season precipitation

R-square = 0.560 MSE = 519.33 n=133

red oak group =

+16.91	intercept		
+0.76	(0.20)	X1	slope
+2.24	(0.33)	X13	general climate
+4.27	(0.94)	X14	evaporative environment
-46.64	(23.0)	X12	soil moisture index

R-square = 0.412 MSE = 294.79 n=133

white oak group =

+19.08	intercept		
+0.52	(0.01)	X8	grass
+2.02	(0.33)	X13	general climate
+5.48	(0.86)	X14	evaporative environment
-9.25	(2.64)	X21	(+clay -Mg)
+2.01	(0.93)	X17	(-P -K)
-3.24	(1.13)	X18	(-clay +pH +P)
-61.21	(31.0)	X11	actual number of leaves

R-square = 0.646 MSE = 230.98 n=133

combined oak groups =

+30.38	intercept		
+0.54	(0.18)	X8	grass
+3.65	(0.61)	X13	general climate
+8.96	(1.54)	X14	evaporative environment
+4.71	(1.68)	X17	(-P -K)
-6.94	(2.05)	X18	(-clay +pH +P)
+5.69	(2.46)	X19	(+pH)
-12.40	(4.80)	X21	(+clay -Mg)

R-square = 0.614 MSE = 763.6 n=133

1/ MSE = mean square error: n = total number of observations: Format order is the regeneration group name, the coefficient for the intercept term, the coefficients and their standard errors for the listed independent variables with descriptive titles.

model (MSE), the number of observations included (n), and the standard errors of the individual regression coefficients (in parentheses). The probability of a greater F-value occurring is less than or equal to 0.050.

Each model should ideally be viewed "in-whole" as variable groups, not as individual variables. If one variable or site factor was highly correlated to oak regeneration, the possibility is strong that management guides would have affected this given factor to control regeneration dynamics in the past. Since no one variable was suggested to be strongly correlated to stocking values over all sites, the set of variables must be appreciated for their composite, additive effect on oak regeneration.

Another method used to suggest important variables constraining oak regeneration was discriminant analysis. Software from SAS (Ray 1982a,b; Sarle 1982b; Goodnight 1982a) was used to suggest those variables that could discriminate well between two types of reproductive occurrences (i.e. heavily stocked sugar maple versus heavily stocked oak sites).

All continuous variables were inserted into the software to identify, by means of backward elimination, all variables that were good discriminators between the regeneration states selected. The variables identified as good discriminators were then used to calculate the discriminant function, based upon a pooled covariance matrix. Misclassification error rates are the simple rates and not boot-strapped. Table 3 lists the discriminant analysis results for various regeneration states.

Table 3.-- Results from the discriminant analyses for six regenerative occurrences.1/

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1) Discriminators between all sites and those sites with red oak levels greater than 60% regeneration stocking value (sign is from high red oak sites).

+X11 actual number of leaves
-X21 (+clay -magnesium)
-X16 (+magnesium)
+X1 slope
+X13 general climate
+X7 shrubs

misclassification of high red oak sites = 16%
misclassification of other sites = 8%

2) Discriminators between all sites and sites with white oak levels greater than 60% regeneration stocking value (sign is from high white oak sites).

+X11 actual number of leaves
-X21 (+clay -magnesium)
+X20 (+clay +phosphorus)
+X14 evaporative environment
+X13 general climate
+X8 grass

misclassification of high white oaks sites = 8%
misclassification of other sites = 7%

3) Discriminators between all sites and sites with sugar maple levels greater than 60% regeneration stocking value (sign is from high sugar maple sites).

+X15 growing season precipitation
-X13 general climate
+X9 unoccupied space

misclassification of high sugar maple sites= 9%
misclassification of other sites = 22%

4) Discriminators between all sites and sites with red oak and white oak levels greater than 30% regeneration stocking value (sign is from high red oak/white oak sites).

+X12 soil moisture index
+X11 actual number of leaves
-X14 evaporative environment
-X13 general climate
+X8 grass
+X1 slope

misclassification of white oak/red oak sites=15%
misclassification of other sites =12%

5) Discriminators between sites with high sugar maple levels <u>or</u> high red oak levels greater than 55% regeneration stocking value, <u>and</u> corresponding low red oak levels or low sugar maple levels less than 45% regeneration stocking value (sign is from high red oak/low sugar maple sites).

+X14 evaporative environment
+X13 general climate
+X4 topographic position
+X2 crown closure difference
+X10 sand content of the A horizon
-X6 oak site index
+X5 growing season radiation

misclassification of high maple/low red oak sites = 0
misclassification of low maple/high red oak sites = 0

6) Discriminators between sites with high sugar maple levels <u>or</u> high white oak levels greater than 55% regeneration stocking value, <u>and</u> corresponding low white oak levels or low sugar maple levels less than 45% regeneration stocking value (sign is from high white oak/low sugar maple sites).

+X13 general climate
+X14 evaporative environment
-X15 growing season precipitation
-X3 average leaf diameter
+X20 (+clay +phosphorus)

misclassification of high maple/low white oak sites = 0
misclassification of low maple/high white oak sites = 0

1/ Format order: Correlation sign of the listed variable and the descriptive title with the two associated error rates.

To understand better the significance of variables identified by multiple regression and discriminant analysis, all variables that were suggested to account for regeneration stocking value differences from both analyses were combined. These variables are listed in Table 4. Table 4 allows for the examination of the critical variables and for the potential synthesis of a hypothesis concerning regenerating a given species.

Table 4.-- Variables suggested by multiple regression and discriminant analysis as important for the reproduction of several major regeneration groups listed with correlation sign and variable name.

Good sugar maple sites:
+ growing season radiation
+ growing season precipitation
+ topographic position
+ oak site index
+ unoccupied space
+ average leaf diameter
+ crown closure difference
- general climate
- shrubs
- clay
- phosphorus

Good red oak sites:
+ general climate
+ evaporative environment
+ slope
+ shrubs
+ actual number of leaves
- soil moisture index
- clay

Good white oak sites:
+ general climate
+ evaporative environment
+ grass
+ magnesium
- pH
- potassium

Good oak sites (combined group):
+ slope
+ soil moisture index
+ grass
+ actual number of leaves
+ magnesium
- phosphorus
- potassium

Table 5 lists those variables that were suggested by analysis to be important for maximizing oak reproduction while at the same time minimizing sugar maple reproduction. Table 5 also highlights those variables that could be manipulated by a forest manager. The most critical factor for oak regeneration that arises from the variable-groups in Table 5 is the requirement for minimizing light interference close to the ground surface. The analysis also suggests the tendency for sugar maple to colonize and control the better sites with the oak relegated to poorer sites. This is a confirmation of the literature.

Table 5.-- Variables identified by multiple regression and discriminant analysis that tend to maximize oak regeneration while minimizing sugar maple regeneration (signs are correlation of maximize oak/minimize sugar maple)

+ general climate
+ evaporative environment
+ growing season radiation
+ topographic position
+ sand content of A horizon
+ slope
+ pH
+ crown closure difference 1/
+ shrubs 1/
+ grass 1/
+ magnesium 1/

- growing season precipitation
- oak site index
- soil moisture index
- potassium
- unoccupied space 1/
- average leaf diameter 1/
- actual number of leaves 1

1/ Variables that could potentially be manipulated.

The analysis suggests that interference is a critical constraint. The line between having enough light to power oak reproduction and too little light, which would favor the sugar maple regeneration group, is thin. Examining the

conditions under which oak and sugar maple regeneration are maximized leads to a basal area constraint from the existing stand. Sugar maple regeneration is maximized around 70 square feet of basal area of the residual stand. Oak regeneration was found to be maximized around 50 square feet basal area of the residual stand

Dispersal spheres in oak are also important in these forests since there seems to be a lack of significant short and long distance dispersal vectors within the forest canopy (e.g. squirrels and bluejays). Oak regeneration was found to be patchy and site specific. Areas one-quarter to one acre in size were found regenerating oaks when a seed source was present and interference was minimized

Manipulation of competing understory and overstory interference, adequate seed delivery systems, and the distribution of regenerating and mature stems suggest that a partial cutting system would minimize oak regeneration constraints while maximizing, or at least increasing, constraints on sugar maple regeneration.

Utilization of clearcutting and shelterwooding systems suggested in the literature result in too much interference on-site and/or distribute treatment over areas where oak advanced regeneration is nonexistent and/or other site constraints inhibit oak reproduction. Treatments must be made where the chances for oak regeneration are maximized and where the chances of other species competing for the same resources are minimized.

Shelterwooding with residual stands of 40-50 square feet of basal area, containing treatment areas to where advanced regeneration is already present or germination and growth potential is great, and extensive clearing of the understory of interfering species should maximize oak regeneration. Clearing techniques combining fire, periodic grazing, and mechanical/chemical treatments hold great promise. A group shelterwood system would be suited to minimizing the regenerative constraints on oak suggested by the analyses. The resulting forest would be composed of two or three age groups in patches. Group shelterwooding for oak is currently under testing.

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