DATE OF REPORT: July 1, 1993

LCMR Final Status Report - Summary - Research

I. TITLE: Regeneration and Management of Minnesota's Oak Forests--Forestry 15

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A. M.L. 91, Ch. 254, Art. 1, Sec. 14, Subd. 7(a) (d) Appropriation: $225,000
Balance: $ 0

Regeneration and Management of Minnesota's Oak Forests: This appropriation is to the University of Minnesota, Minnesota Extension Service, for research and education in oak regeneration and management.

B. Not applicable
C. Not applicable

II. NARRATIVE

Currently more red oak is harvested annually in southeastern Minnesota than is grown. Oaks are very valuable for wood products; acorns are a staple food for many wildlife species, and oak woodlands protect water quality, especially in hilly terrain, by serving as a buffer between agricultural land and streams. Oaks have proven difficult to regenerate and our oak woodlands are gradually converting to other tree species with less value for wood and wildlife. This species conversion is continuing whether or not timber harvesting occurs, but it may be accelerated by harvesting. Research and extension activities are planned to improve oak regeneration and management.

III. OBJECTIVES

A. TITLE: Artificial regeneration of red oak in southeastern Minnesota

1. NARRATIVE

The oak resource in southeastern Minnesota is one of the most valued of any in the state on a per acre basis. Unfortunately this resource currently is being harvested at an increasing rate without adequate oak regeneration as a replacement. Oak is difficult to regenerate and often the harvested stands convert to undesirable hardwood species with less value for timber or wildlife. Research in other states indicates that natural oak regeneration from acorns is affected by such factors as shade, competition from other understory plants, direction of slope, acorn abundance, acorn predation by animals and insects, weather conditions during the growing season--especially rainfall, natural toxic chemicals from other plants occurring on the site, and possibly deer browsing. Regeneration from stump sprouts is largely affected by tree species, diameter, and age. Field trials are needed to assess the feasibility of different artificial regeneration methods since natural regeneration generally is unreliable following current harvesting methods.

2. PROCEDURES

There is a rich collection of oak regeneration literature available. However, there are few, published results from research done in the proposed study area. There is a need for an intensive review of the existing literature based on studies done elsewhere to identify potential regeneration practices to be tested. Most oak regeneration research has taken place in states south and east of Minnesota where the soil, climate and species composition differs from southeastern Minnesota. Research will take place on good oak growing sites. Current knowledge indicates the desirability of testing shelterwood cutting as well as clearcutting. Adequate site preparation is essential for successful oak regeneration. Application of herbicides versus a control will be tested in combination with the cutting levels. Plantings of oak seedlings, oak containers, and direct seeding of acorns will be established in each treatment unit.

Known red oak seed sources will be used. Tubex shelters will be tested on a sample of each type of planting stock and seeding. Treatments will be replicated. Survival and height growth measurements will be taken at the end of the study period. Sources of damage to seedlings and acorns will be recorded. The effects of deer browsing on regeneration will not be studied directly because of the high cost for fencing to exclude deer. Individual tree shelters, however, are one form of deer protection that will be included in the study. Browsing on sheltered and unsheltered trees will be compared. A randomized block design will be utilized and multi-way analysis of variance will be used to aid in interpretation of results. Vegetative data and pertinent site information will be collected at the beginning and end of the study period. Environmental monitoring equipment, such as rain gauges and light meters, will be installed in the study area.

3. BUDGET

A. Amount budgeted: $60,815
B. Balance: $ 0

4. TIMELINE

	July91	Jan92	June92	Jan93	June93
Review literature	------				
Locate study areas & layout treatment blocks	------				
Pre-harvest vegetation inventory	--------------				
Herbicide application	----				
Harvest stands		--------			
Planting		----			
Inventory vegetation on site			---		
Survival and height growth inventory			------------		
Summarize results, prepare final report					-------------------

5. STATUS: Through July 1, 1993

METHODS

There are three research sites, all located on state forest land in southeastern Minnesota. They were chosen for their similarities in vegetation and site quality. Before any treatments occurred on the research sites, an intensive inventory was made of woody understory and overstory vegetation. In late summer of 1991 we used herbicides (chemical treatment) and a bulldozer (mechanical treatment) to kill understory vegetation. The three research sites were commercially harvested during the late fall and early winter of 1991-1992. Following the harvest, all undesirable standing trees larger than 2-inches in diameter were cut down by hand; scattered seed trees were left standing; woody debris was removed from the tree planting sites to facilitate planting. Northern red oak seedlings and acorns were planted in mid-April, 1992. Seedlings were graded as nursery run and premium seedlings. The latter were selected because of their well-developed root systems. These different grades were planted in separate locations for comparison. Plastic tubes (tree shelters) were placed over part of the seedlings and part of the acorns. All vegetation (natural and planted) on the research sites was inventoried a second time in late summer, 1992.

RESULTS

One year after the site preparation treatments there were significantly fewer stems per acre in the chemical treatment plots than were there the year before; however, the number of stems per acre in the chemical treatment plots were not significantly different from the number of stems per acre in either the mechanical or control plots at that time.

One year after the site preparation treatments, average stem height of vegetation in the control plots was significantly higher than in the chemical and mechanical treatment plots.

Survival rates after one growing season were over 99% for all categories of planted northern red oak seedlings (premium seedlings protected by tree shelters, unprotected premium seedlings, and nursery run seedlings). Survival rates for the protected acorns (42%) and unprotected acorns (27%) were significantly less than survival rates for the seedlings. Low germination and survival rates for the acorns reinforce what other researchers recommend, when planting acorns, plant two to four acorns per seed spot.

After one growing season the diameter of northern red oak seedlings in the chemical and mechanical treatment plots was significantly greater than in the control plots.

After one growing season height growth of planted northern red oak seedlings was significantly greater in the mechanical treatment plots than in the chemical plots, but not greater than height growth in the control plots.

After one growing season there were no significant differences in the height and diameter growth between the premium and nursery run northern red oak seedlings. After one growing season, planted acorns showed significantly greater height and diameter growth than the planted northern red oak seedlings. However, the premium and nursery run seedlings still had significantly greater heights and larger diameters than the acorn sprouts.

After one growing season height growth of premium northern red oak seedlings protected by tree shelters was significantly greater than the height growth of unprotected premium and nursery run seedlings. However, there were no significant diameter growth differences between protected seedlings and either the unprotected premium or nursery run seedlings.

There were no significant differences in height or diameter growth of protected and unprotected acorn sprouts.

Through statistical analysis we found that as competition increased, the planted red oak seedlings and acorns not protected by tree shelters responded by growing taller, but not larger in diameter. This height growth was greater for the premium seedlings than either the nursery run seedlings or the acorn sprouts.

Planted northern red oak seedlings grown in tree shelters showed a 200 percent increase in stem volume compared to a 70 percent increase for unprotected premium and nursery run seedlings. While this volume growth may be impressive, their growth form resembles vines and it may be several years before these seedlings will be able to stand independently from the support of tree shelters.

After one growing season we also identified and classified damage that occurred to the planted northern red oak seedlings and acorns.

Abiotic damage was defined as physical damage to plants from abiotic sources, such as the tree shelters. Sixty-three percent of the premium seedlings protected by tree shelters showed some sort of leaf deformation or lack of leaves on one or two faces of the stem. There was no such damage to unprotected premium and nursery run seedlings or to planted acorns, both protected and unprotected.

There was significantly less animal damage (mainly deer and rabbit browse) on northern red oak seedlings protected by tree shelters than on unprotected seedlings and acorn sprouts, both protected and unprotected.

The unprotected premium and nursery run northern red oak seedlings showed significantly higher rates of insect damage than the protected and unprotected acorn sprouts. But, insect damage on protected premium seedlings was not significantly different from damage on the unprotected premium and nursery run seedlings or the protected and unprotected acorn sprouts.

Biotic damage was defined as damage to leaves and stems that was of unknown origin and could not be identified as abiotic, animal, or insect damage. It appeared as top dieback, leaf wilting, and stem damage. Biotic damage was significantly higher on unprotected premium and nursery run northern red oak seedlings than on the protected and unprotected acorn sprouts. Biotic damage on the protected premium seedlings was not significantly different from damage on the unprotected seedlings and acorn sprouts, protected and unprotected.

Since these results are from the first growing season after northern red oak seedlings and acorns were planted, it would be unwise to draw conclusions about the effectiveness of the site preparation treatments, the growth rates of the different planting stock (seedling grades vs. acorns), or the utility of the tree shelters. This preliminary information does suggest that the site preparation treatments reduced the height growth of competing trees and increased the diameter growth of planted red oak seedlings. Neither the chemical nor the mechanical site preparation treatments affected planted red oak seedling survival and they did not lead to greater height growth of planted seedlings or acorns. It is possible that the effects of site preparation will be more pronounced in succeeding years. There were no important differences in the growth of premium and nursery run seedlings. It may be that the nursery run seedlings are very good quality. Tree shelters greatly increased the volume growth of oak seedlings and reduced animal damage. They show promise in improving early growth of oak seedlings. This project will continue to be monitored for at least two more years under the new LCMR project, Developing Quality Hardwood Forests.

In retrospect a few changes in our procedures would have provided more useful results. We would like to have had more control over the logging. To our surprise the DNR had marked seed trees to be left in our research plots when we wanted complete clearcuts. The logged sites also were heavily covered with slash that should have been dragged from the sites to facilitate our planting activities. We cleaned them up by hand, but this could have been accomplished more easily by a logger with a skidder. One of our proposed research sites was not harvested in time to plant because of problems in selling the timber. This caused us to create two research sites at Trout Valley that were very close together. We originally wanted a greater geographic dispersion.

We should have ordered more nursery run seedlings so that we would have had a sufficient number to destroy some and study their root structures to see if they differed significantly from the roots of premium seedlings.

We used tree shelters on the premium seedlings, but not on the nursery run seedlings. We should have used them on both to give us more complete information about the effects of tree shelters on tree diameter and height growth.

The plots used for measuring understory vegetation and natural regeneration were too small. The tremendous variability in species composition and number of trees between these plots would have been reduced with larger plots, thus allowing us to better discern any significant differences in the vegetation responses to the herbicide and bulldozing treatments.

During the next two years we will continue to monitor the growth of planted red oak seedlings and acorns as well as the growth of natural regeneration on these research sites. That will give us three years of growth data and will enable us to draw more sound conclusions about the site preparation treatments, different types of planting stock, and value of tree shelters.

We also will begin research under a new LCMR project, Developing Quality Hardwood Forests. As part of this project we will conduct a wider range of site preparation treatments and evaluate their effects on natural regeneration of oak and other species.

6. BENEFITS

This study will provide information that will lead to guidelines for forest managers in southeastern Minnesota regarding regeneration of red oak. This information is critical to sustaining red oak as a major component of our hardwood forests. Regeneration of this resource is essential to satisfy wildlife and timber demands as well as to protect water quality.

B. TITLE: Quantifying regeneration in southeastern Minnesota's oak forests

1. NARRATIVE

Anecdotal evidence suggests that oak regeneration in the hardwood forests of southeastern Minnesota frequently is unsatisfactory given an objective of continued site occupation by oak species. It is known that in general oaks reproduce best when there is abundant advance regeneration on the site before harvest. Regeneration success is highly variable, but depends on overstory and understory competition, acorn abundance, site conditions and weather. Oaks regenerate from both seed and stump sprouts though the sprouts are more reliable. No scientific surveys have been conducted to determine the nature and extent of the oak regeneration problem as it relates to the specific conditions of southeastern Minnesota. No designed studies have been implemented to determine the nature of the site to site (versus within site) variability present among successful regeneration episodes. Some foresters have observed that red oaks on good sites in southeast Minnesota often appear to be of lower quality for timber purposes than red oaks on similar sites in Wisconsin. Hybridization among oak species may be the cause.

This objective will involve collecting and analyzing field data to determine the frequency of oak regeneration successes, the site to site variability associated with successful oak regeneration, and the genetic purity of red oaks.

2. PROCEDURES

An "office" canvass will be made to identify red oak stands in southeastern Minnesota that have been harvested within the last fifteen years. Department of Natural Resources (DNR) records of harvest activity on DNR administered lands and lands owned by private individuals that have been assisted by DNR foresters will provide the basis for site identification. Local foresters also will be contacted to supplement that effort. A data base will be constructed that identifies stands with respect to a number of factors including characteristics of the parent stand, soil, and topography; logging method; and any other relevant information available. This data base will be cross-referenced with general weather information and information on years of good seed crops. From this large base, approximately 75 sites will be chosen for on-the-ground inspection. Selection will be made according to a stratified design where strata will be identified with factors described above. This will allow for valid survey results and insure representation of conditions of special interest with respect to the factors.

On the sites selected for ground study, three random locations will be permanently demarcated. At each location, three concentric, fixed-radius, circular plots will be installed. On the outermost 1/20-th acre plot, residual stand and stump information will be collected; the stump information will be utilized to supplement other knowledge concerning parent stand characteristics. On a 1/300-th acre plot regeneration will be characterized with respect to tree species, numbers, and height. On an innermost 1/3000-th acre plot, presence/absence of key indicator understory species will be noted. Photo evidence will be used to document each plot; if resources are sufficient, large-scale aerial photography will be taken of study sites. Analysis of the resulting data will involve computation of survey averages and variabilities, both among and within sites. Statistics will be tabulated by strata (site, stand, and logging factors used in initial site classification). Log-linear model analysis, including logistic regression, will be used to relate regeneration success or failure to site, stand, and logging factors. If the data appear to support it, further regression analyses will be performed to predict degree of regeneration success.

On 30 successfully regenerated sites the two larger concentric plots will be used to collect information on parent/residual stand and level of regeneration. The 75 sites referred to above will be used to provide some of these 30 sites, though it is anticipated that additional effort will be required to locate 30 stands that have been successfully regenerated. Successful regeneration will be defined according to the measures reported in the "Manager's Handbook for Oak in the North Central States."

Analysis of the resulting data will focus on characterizing site, stand, and logging conditions that led to observed successful regeneration. If fewer than 30 successfully regenerated sites are found, our analysis will continue as planned, but the resulting recommendations may be restricted to a narrower range of site conditions. Again, variability observed will be given equal or greater importance than point estimates.

Leaves will be collected from a few carefully selected red oaks. They will be analyzed by laboratory procedures to determine whether these trees are pure red oaks or hybrids.

3. BUDGET

A. Amount budgeted: $46,875
B. Balance: $ 0

4. TIMELINE

	July91	Jan92	June92	Jan93	June93
Building initial data base	--------				
Selection of ground sites	----------				
Data collection on ground sites		----------			
Data analysis for ground sites			-----------		
Data collection for successfully regenerated sites			----------	--	
Data analysis for successfully regenerated sites				---------------	

5. STATUS: Through July 1, 1993

RESULTS

The Data Base: A significant product of this study is the establishment of a data base of high quality for current and future study of the oak regeneration problem. The data base is well-documented and will be made available to other interested researchers. Where possible, all study sites and plots were permanently documented and can be returned to for future study, for example when an established stand can actually be identified. The background information collected in the present study will be invaluable in analyzing the structure of these established stands.

The response variables for subsequent analyses are regeneration amounts and percentages based on stems per acre and height per acre. Overall, regeneration has been successful on nearly all the sites examined. Most sites have 1000 to 3000 stems per acre, quite adequate given 80 percent of the sites are five to eight years from harvest. While the distribution of sites by stems per acre is quite blocked, the distribution by height per acre is smooth with good variation between sites. Target oak species for the study were northern red oak (*Quercus rubra*) and white oak (*Quercus alba*). Considering all size stems, these oak species are, on average, 12 percent of the regeneration. However, the distribution of oak representation is very skewed with many sites having 0 to 10 percent oak. This supports the existence of a real oak regeneration problem given that nearly all the sites had a significant oak component prior to harvest. When regeneration is measured in terms of height per acre the problem is further highlighted with over 60 percent of the sites having 0 to 10 percent oak. The data also point out that oak has not competed well on many of the sites; on nearly 70 percent of the sites target oaks represent a small minority of the dominant regeneration.

Analysis of Regeneration: Analysis of covariance models were fit to the six potential response variables (regeneration of all species by stems and height, percent of regeneration in target oaks by stems and height, percent of dominant regeneration in target oaks by stems and height). Literally thousands of models were fit and scores analyzed in detail for stage 1 of the effort. As expected, the variability encountered was enormous and the collinearity present between potential explanatory variables made development of a sensible model difficult. The results for stems per acre and height per acre generally paralleled one another. What follows is a presentation and discussion of the results obtained using height per acre for regeneration of all species, percent of regeneration in target oaks, and percent of dominant regeneration in target oaks.

The final model for regeneration of all species accounted for 41 percent of the overall variation (probability of a larger F < 0.01). Brush competition and soil structure contributed most to explaining initial variation in regeneration success. Low brush is the percent closure by brush species below two feet above ground level. The positive coefficient on structure suggests that blocky soils have produced greater tree regeneration. Such soils have less water penetration of the surface and probably support less ground cover competition. The results for exposed bedrock and percent stone are both readily interpretable. A negative sign on slope position here suggests that the midslope position sites tended to have less regeneration success; this may have come about for any number of reasons, the source of which is not important to the study. Depth to the E horizon is marginally statistically significant by the study criterion; its positive sign appears reasonable, suggesting a large zone where material is leeched to horizons below promotes regeneration success.

In terms of the hypothesis variables, basal area represents residual stand amount, slope percent represents site characteristics, and clearcutting represents harvest technique. The former two are marginally statistically significant but exhibit the expected relation. Aspect had no effect (alone or in combination with slope) on total regeneration. The impact of clearcutting is highly significant with a positive coefficient suggesting that clearcutting generally produces greater total regeneration than the other harvesting methods (commercial clearcut, shelterwood, other) for stands like those on the study sites.

The final model for percent of regeneration in target oaks accounted for 30 percent of the overall variation (probability of a larger F < 0.01). Only total removal enters as a new variable in stage 1 of the analysis. Though the significance of this new variable is borderline, its positive coefficient suggests that better sites (sites with higher volumes) have greater oak regeneration potential. Interestingly, the signs on the coefficients for brush and depth to the E horizon are reversed from the analysis presented for total regeneration. This suggests that factors related to these two variables may impact oak regeneration differently than overall (total species) regeneration. Whether these factors are actually brush competition or soil property related remains to be answered by designed experiments (or observational studies where variables describing additional factors are measured).

In terms of the hypothesis variables, basal area represents residual stand amount, aspect/slope represents site characteristics, and clearcutting represents harvest technique. Residual basal area would clearly seem not to have an impact on the proportion of regeneration occurring in oak. Site factors are moderately related to oak occurrence. The aspect/slope variable is equivalent to the product of slope and cosine (aspect - 49°) where 49° was determined (by the data) to be the optimum aspect for oak regeneration (in line with an accepted average standard of 45° for most tree species). Clearcutting again stands out from the other harvest techniques with oak regeneration seemingly depressed by application of the method. However, caution must be exercised in interpreting this result given the significance level on the coefficient and the signs on the coefficients of related variables in the model (total removal and basal area). There is little apparent difference between what was actually observed on the sites harvested by the various methods. Still, this result suggests further careful examination given this interesting disparity for clearcutting between total regeneration and percent that is oak.

The final model for percent of dominant regeneration in target oaks accounted for 27 percent of the overall variation (probability of a larger F < 0.01). The variables in this model are almost identical to those of the previous model for percent of total regeneration in target oak species, as might be expected. In terms of the hypothesis variables, again residual stand characteristics appear unrelated to oak regeneration amount. Site characteristics as represented by the aspect/slope variable appear significant. In this case the data-determined optimum for aspect is 44°; the consistency for this variable between the two models and with an established standard supports the reasonableness of the models overall. Again the model for percent of dominant regeneration in target oaks suggests that clearcutting negatively impacts oak establishment although the provisos listed above must be strongly considered.

Beyond the variables that appeared in the analysis of covariance models and their interpretations, it is significant to note what variables failed to appear in the final models. These include age, percent oak species in removals, and the percent of oak in the border. Range of the age variable in the data and the use of feet of height rather than stems per acre probably account for the noticeable absence of age. That composition of the parent stand and neighboring stands seemingly had no impact on the percent of target oak species in the observed regeneration is quite surprising but suggests that attributes of the site and harvesting operation methods (as well as factors not included in the study such as weather and acorn crop quantity) may be of greater importance.

The results from this study provide a starting point for developing recommendations on manipulating harvest practices to encourage oak regeneration or indicate the nature of sites on which we can expect better oak regeneration. The models developed in the study can be useful as regeneration components of larger growth and yield systems that are used in stand management planning. It can not be overemphasized that the observational nature of the study puts great restrictions on our ability to draw explicit inferences. The results might best be interpreted as hypothesis generation rather than hypothesis confirmation mechanisms. The need for followup designed studies is great. Over the next two years scientists involved in other parts of this project will begin to install some of these studies using LCMR funding.

Two important pieces of information were missing from the present work that could have proved helpful in further untangling the variation associated with oak regeneration success rate. The first was reliable information on quantity and quality of the acorn crop over the past decade. Only fragmented information was available, insufficient to be effective in our analyses. An effort is now underway to establish a network of recording stations so that such information will be available in the future. The second type of information that was lacking was site specific weather data. Given the sites were put in "after the fact" this is not surprising. The paucity of weather stations also makes this whole question problematic. However, in an unrelated study being conducted by the investigator, generated weather data, based on newly developed statistical techniques for extending the usefulness of sparse weather station data, is being tested for its ability to predict tree growth variation. If that work is successful the method will be applied to the data base collected in this study to see if the models presented above can be refined.

A final difficulty encountered in the study was with stump data collected on the central 1/20-acre plot at each sample location. "Dead" (non-sprouting) stumps appeared to be under-counted by roughly 25 percent. Heavy brush closure on such a large plot makes reliable location of such stumps nearly impossible. In the future, smaller, more numerous plots, like the satellite plots used for tallying regeneration, should be used to observe stump sprouting. The research assistant charged with this aspect of the study plans on revisiting the sites to attempt to correct this problem as initial analyses of stump sprouting success demonstrated encouraging results. Such information would be as, or possibly more, useful than that obtained from the analysis of the oak regeneration data.

Species/Hybrid Identification: Lab isozyme analysis of the data indicated results similar to a study of oaks in northeastern Wisconsin. Three isozymes were found to be useful in distinguishing between the three red oak species and their various hybrids while only one isozyme was needed to differentiate northern red and black oak. Preliminary application of the RAPD molecular marker technique confirmed these results with three markers required to differentiate between species.

The lab results confirm that we were successful in obtaining pure and hybrid samples in our field work. Field identification by the U.S. Forest Service expert were highly correlated with lab results. Quantitative morphometric indices are being constructed by a scientist at Indiana University using our sample materials. These two sources will be used to develop more detailed field keys that will enable foresters to better identify pure northern red oak and various hybrids in the field.

This part of the project was quite small and funded at a minimum level. An attempt was made to capture existing expertise and apply it to Minnesota's oak forest regeneration problems. The results were very encouraging and have led us to plan for a more intensive field data collection effort. That effort is being funded by LCMR and will concentrate on studying the relationship between regeneration species composition and that of the parent and residual stand after harvests of various types. This will both extend and build on the positive results obtained to date for study of this problem.

6. BENEFITS

Reliable information obtained in a defensible manner is a prerequisite for identifying the true nature and extent of the oak regeneration problem. The proposed research will provide a start toward answering that need in southeastern Minnesota. Study of site and other factors as they relate to observed regeneration will aid managers in their prescription of appropriate harvest treatments. Since permanent plots will be established as part of this study, important future monitoring efforts will be possible; future monitoring of study sites as they develop into timber stands will allow economic aspects of the regeneration problem to be more fully addressed.

C. TITLE: Educating woodland owners, loggers, and youth about oak management

1. NARRATIVE

Most oak woodlands are owned by nonindustrial private woodland owners. They commonly own woodlands as part of a farm or for recreation, wildlife, or fuelwood harvesting. Only a small percentage use the services of a forester at the time of harvest and owners generally are not knowledgeable about management practices that will encourage oak regeneration. Timber is harvested by loggers who generally are not informed about the impact of timber harvesting on oak regeneration. Our youth will in the future own woodlands and need to begin learning principles of forest management. Educational programs are planned to inform private woodland owners, loggers, and youth about how to manage hardwood stands and maintain oaks as an important component of these stands.

2. PROCEDURES

An extension forester will be hired to work in a seven-county area in southeastern Minnesota. This forester will develop educational materials and will conduct meetings, workshops, conferences, and other educational programs on hardwood forest management. Educational programs will focus on private woodland owners, loggers, and youth. The educational content of these programs will cover hardwood management for multiple-uses. There will be an emphasis on managing hardwood stands to perpetuate oaks as a significant component. Educational programs will be coordinated with the Minnesota Department of Natural Resources which is scheduled to receive an LCMR grant to increase technical assistance to private forest landowners in southern Minnesota for oak regeneration. This extension forester also will assist with data collection described under Objective A.

3. BUDGET

A. Amount budgeted: $117,310
B. Balance: $ 0

4. TIMELINE

TIMELINE	July91	Jan92	June92	Jan93	June93
Form advisory committee	--				
Conduct search to fill position	---				
Workshops and field tours for loggers and landowners		------------		-------------	
Recruit and train 4-H forestry project leaders		-------		-----------	
Assist with collecting plot data from field trials planned under Objective A			----------		

5. STATUS: Through July 1, 1993

One of our primary goals was to provide forest management information to private woodland owners in a 7-county area in southeast Minnesota to enable them to make informed judgments about regenerating and managing hardwood forests. We conducted approximately 48 educational events aimed at private woodland owners and reached approximately 600 landowners. Our goal was to reach 1,200 landowners, but attendance at events was lower than anticipated despite intensive publicity. We tried to reach new landowners that had not previously obtained forestry assistance and therefore did not use landowner mailing lists consisting of Department of Natural Resources cooperators. We advertised by directly mailing brochures about upcoming events to rural landowners; placing posters on bulletin boards at numerous public places; placing announcements in newsletters produced by the MN Extension Service, Soil and Water Conservation Districts, and the Agricultural Stabilization and Conservation Service; and sending written news releases to area newspapers.

We wanted to reach at least 500 youth with forest management information so that they would understand basic forestry concepts and issues, and learn about careers in natural resource management. We held approximately 27 events for youth and youth educators, eventually reaching approximately 2,370 youth and 210 educators with information about forestry.

Although we wanted to reach a high percentage of loggers in southeast Minnesota with information about hardwood management and regeneration, our contacts with several logging firms indicated that this audience was not interested in spending time learning about forestry. This was disappointing since their long-term livelihood depends on sustainable forest management.

A meeting was held with sawmill owners to find out how they thought we could reach loggers. They were not encouraging, but they did agree to forward to us the names of landowners for whom their loggers had harvested timber so that a forester could contact the landowners and offer forest management and regeneration assistance. Only about fifteen percent of the landowners in southeastern Minnesota use the services of a forester to help them manage and market timber. This is a continuing problem, since loggers are not well-informed about how to harvest timber to insure adequate natural regeneration of desirable tree species. High-grading of timber is commonplace.

We took advantage of every opportunity to reach community leaders and conservation-minded people with information about forestry issues and management concerns in southeast Minnesota. Some of these people own forest land, but otherwise many are in a position to influence public attitudes about forestry. We believe it is important that community leaders and the public understand basic principles of natural resource management. Approximately 58 educational events were held that reached over 1,670 people with forestry information. These ranged from members of civic clubs and sportsmans organizations to elected officials and natural resource management professionals. In the future we will spend much more effort speaking to sportsmans associations that are interested in wildlife management.

This educational program will continue for two more years under a new LCMR project, Developing Quality Hardwood Forests. Our primary target audience will continue to be private woodland owners. We will use land ownership records in selected county courthouses to develop a list of woodland owners. This will enable us to target our publicity for educational events more directly. We will continue to hold workshops for landowners. We also will initiate a pilot educational project that involves direct mailing forestry publications to a random selection of private woodland owners with follow-up mailings made to landowners who request additional information. Not all landowners want to attend meetings, but some may be willing to learn on their own by reading publications or viewing videos. We also will survey landowners who participated in previous forestry education events to learn what impact those events had on their management decisions.

Our youth education events will continue, but we will focus more on providing in-depth forestry information to fewer youth. We especially will try to recruit more adult leaders for the 4-H Forest Resources Project because they will then continue our educational work into the future.

We will continue to look for ways to reach loggers, but this is a difficult audience to reach. The Timber Producers Association is considering development of a logger certification program. Such a program may lead to better opportunities for educating loggers about the impacts of timber harvesting on forest regeneration.

Educational events we conducted during the last two years for various audiences are described below.

6. BENEFITS

We estimate that a high percentage of the loggers in southeastern Minnesota and 1,200 woodland owners will be informed about the latest recommendations for managing hardwood stands to maintain oaks. Approximately 25 woodland owners will receive 40 hours of forestry training in return for providing 50 hours of volunteer service in educating other landowners and youth about up-to-date forestry practices. An estimated 500 youth will be better informed about how to manage woodlands for multiple-uses. The long-term consequences are that hardwood stands will be better managed to perpetuate oaks. These hardwood stands will continue to produce oak wood products, acorns for wildlife, and forest cover for watershed protection.

IV. EVALUATION

In the short term this project can be evaluated by our ability to (1) identify artificial regeneration practices that increase oak regeneration; (2) identify stand conditions, site conditions, and harvest practices that are likely to lead to better natural regeneration of oak; (3) provide educational programs onhardwood management that reach approximately 1,200 woodland owners, a high percentage of loggers in southeast Minnesota, and 500 youth.

In the long term this project can be evaluated by the increase in hardwood stands successfully regenerated to oak as a result of actions by the persons who participate in or make use of materials produced by this project.

V. CONTEXT: RELATED CURRENT AND PREVIOUS WORK

A. In regard to Objective A, very limited research has been conducted on regenerating Minnesota's oak resource. Field research on different oak regeneration methods currently is being conducted in northern Wisconsin and southern Iowa. These are new studies for which data have not been collected and analyzed. They are in regions which have different soils, site characteristics, and climate from southeastern Minnesota.

In regard to Objective B, a similar study was carried out in southwestern Wisconsin, southeastern Minnesota, and northeastern Iowa in the early 70s. However, this study focused solely on clearcut sites, whereas much logging in southeastern Minnesota is better characterized as diameter limit (single-tree selection) harvesting. The associated species examined also were ones that may be less common in southeastern Minnesota than in Wisconsin and Iowa.

Regarding Objective C, there have been a few conferences and field tours in southeastern Minnesota over the past few years which provided information to private woodland owners about oak management, but relatively few owners have been reached by these events. There has been no training of loggers on hardwood management and youth forestry activities are currently very minimal. The Minnesota Extension Service currently is producing a slide program, video, and several publications on oak management with funds from the U.S. Forest Service. An extension agent is needed to organize and conduct educational programs that will reach out to landowners and loggers with these new materials. 4-H Forest Resources project materials are under development, but there is no staff person to recruit and train volunteer leaders to use the materials.

B. Oak regeneration research proposed under Objective A will test regeneration methods that have been successful in a few cases in nearby states, but which have not been tested in southeastern Minnesota where growing conditions and species compositions differ. The survey of oak regeneration under different harvesting practices proposed under Objective B will examine oak regeneration under a wider range of harvest practices than were examined by previous studies and it will focus on species mixes common to southeastern Minnesota. The extension agent to be hired under Objective C will disseminate educational materials on oak management that are being developed for landowners and loggers under another federal grant. This agent also will conduct conferences, workshops, field tours, and other events that could not be offered with the existing extension staff level. The agent also will recruit and train volunteer leaders to increase enrollment in the 4-H Forest Resources project.

C. LCMR has not previously funded research or education programs concerning oak regeneration and management. The Minnesota Department of Natural Resources and University of Minnesota, Department of Forest Resources currently are cooperating on a small-scale research study on the effects of site scarification on red oak regeneration. This is a short-term study on just one site. It focuses on how to encourage more natural oak regeneration, while the proposed new research focuses on artificial regeneration. The Minnesota extension service has conducted one conference and several field tours on oak management over the previous five years for landowners in southeast Minnesota. These events have reached relatively few landowners.

Potential future LCMR proposals may request funds for more oak regeneration research, depending on the results of this current LCMR project. The current project does not permit us to test as wide a range of sites or as many different management practices as we believe should be tested in order to learn how to regenerate oaks on different sites and under different stand conditions. This project's two-year duration also is too short a time period to satisfactorily evaluate the full impact of some cultural practices.

D. Not applicable

VI. QUALIFICATIONS

1. <u>Program Manager and Principal Investigators</u>

Dr. Steven B. Laursen, Natural Resources Program Leader and Associate Professor, Minnesota Extension Service, University of Minnesota.
    Ph.D. Forest Science, University of Idaho, 1984; M.S. Forest Resources, University of Idaho, 1979.

Dr. Laursen worked for 5 years as a researcher and instructor in forestry and computer science at the University of Idaho before as an Extension Specialist and Assistant Professor at Montana State University, and served as programmatic and administrative leader for Minnesota Extension Service natural resources programs from 1988-1993. He currently serves as Assistant Dean for Outreach in the College of Natural Resources. He has published articles in forest pest management, ecological modeling, urban forestry, and leadership. His primary role will be in coordination of the entire project and as a cooperator in the implementation of Objective C.

Dr. Melvin J. Baughman, Extension Specialist--Forest Resources and Associate Professor, Department of Forest Resources, University of Minnesota.
    Ph.D. Forest Policy & Economics, University of Minnesota 1982; M.S. Forest Recreation, Michigan State University, 1971.

Dr. Baughman has 16 years experience in extension forestry including over 6 years field experience advising individual private woodland owners about hardwood forest management. He has published articles on forest economics in refereed journals. His current research includes a study of the effects of site scarification on red oak regeneration. Currently he also is producing a slide-tape program, video tape, and several publications on oak management for private woodland owners and loggers. He will participate in carrying out Objectives A and C.

Dr. Alvin A. Alm, Professor, Department of Forest Resources, University of Minnesota.
Ph.D. Forestry, University of Minnesota, 1971; M.S. Forestry, University of Minnesota, 1965.

Dr. Alm has 25 years of experience in field regeneration research primarily with northern conifers. He is the author of over 100 scientific and technical publications on that and other subjects of silvicultural interest. He is a University of Minnesota research project leader and has advised a number of graduate students in silvicultural research. His primary role will be to participate in the accomplishment of Objective A.

Dr. Thomas E. Burk, Associate Professor, Department of Forest Resources, University of Minnesota.
Ph.D. Forest Biometrics, University of Minnesota, 1981; M.S. Statistics, University of Minnesota, 1980.

Dr. Burk's expertise is in resource assessment and modeling. He has previous research experience with the hardwood resource of the southern Appalachians. He has extensive experience in the design of field studies and is Research Chair of the Great Lakes Forest Growth and Yield Cooperative. Dr. Burk's primary role will be to lead the accomplishment of Objective B.

Publications Related to Hardwood Research:

Harrison, W.C., T.E. Burk and D.E. Beck. 1986. Individual tree basal area increment and total height equations for Appalachian mixed hardwoods after thinning. So. J. Applied For. 10:99-104.

Bowling, E.H., H.E. Burkhart, T.E. Burk and D.E. Beck. 1989. A stand-level, multi-species growth model for Appalachian hardwoods. Can. J. For. Res. 19:405-412.

2. Cooperators/Other Investigators

Bob Pajala, Silviculturist, Minnesota Department of Natural Resources

Rodney Jacobs, Hardwood Forest Management Consultant (retired from USDA, Forest Service)

Jud Isebrands, Tree Physiologist and Red Oak Regeneration Project Leader, USDA Forest Service, North Central Forest Experiment Station

VII. REPORTING REQUIREMENTS

Semiannual status reports will be submitted not later than January 1, 1992, July 1, 1992, January 1, 1993 and a final status report by June 30, 1993.

1991 RESEARCH PROJECT ABSTRACT
FOR THE PERIOD ENDING JUNE 30, 1993
This project was supported by MN Future Resources Fund Subd. 7(d)

TITLE: Regeneration and Management of Minnesota's Oak Forests--Forestry 15
PROGRAM MANAGER: Steven B. Laursen
ORGANIZATION: University of Minnesota
LEGAL CITATION: M.L. 91, Ch. 254, Art. 1, Sec. 14, Subd. 7(d)
APPROP. AMOUNT: $225,000

STATEMENT OF OBJECTIVES

We planned to learn (1) whether pre-harvest site preparation by herbicides or bulldozing would increase survival and growth of planted red oak seedlings; (2) whether planted red oak seedlings with well-developed root systems survived and grew faster than nursery run seedlings; (3) whether sprouts from planted acorns would survive and grow as well as planted red oak seedlings; (4) whether tree shelters would increase survival and growth of planted red oak seedlings and acorns; (5) how different timber harvest types, residual canopy levels, and site characteristics affected natural red oak regeneration; and (6) whether it was possible to reliably distinguish northern red oaks from closely related species and hybrids of those species and northern red oaks. (7) We wanted to educate at least 1,200 woodland owners and 500 youth about multiple use management of hardwood forests with an emphasis on oak regeneration.

OVERALL PROJECT RESULTS

(1) Site preparation by herbicides and bulldozing did not affect survival of planted red oak seedlings and acorns. They did reduce height growth of natural competition and increased diameter growth of planted red oak seedlings.
(2) There was no significant difference in survival, height, or diameter growth of premium and nursery run planted red oak seedlings.
(3) Survival rates for acorns were significantly lower than survival rates for seedlings.
(4) Tree shelters did not affect seedling survival or diameter growth, but they did increase height growth of red oak seedlings. Tree shelters did not affect survival, height, or diameter growth of acorn sprouts. Tree shelters caused some minor leaf deformity, but reduced animal damage.
(5) A data base containing information from intensive examination of 91 recently harvested oak sites in southeastern Minnesota was compiled and summarized. General inspection of the data suggest that oak regeneration is indeed problematic in the region: oak constituted over 75 percent of the removal on most sites but averaged only 12 percent of the regeneration. Analysis of regeneration in total, as well as the oak component, suggested that harvest technique may impact regeneration results; clearcutting (as practiced over the last decade) tended to give better overall regeneration than other methods but resulted in a smaller component of oak expected to reach the established canopy. Site characteristics, particularly slope and aspect, substantiatively impacted oak regeneration. Residual stand amount and composition had little impact on either total or oak regeneration.
(6) Three isozymes were found useful in distinguishing among northern red oak, related species, and hybrid combinations. Both winter and summer morphological characteristics (particularly bark, bud, and leaf forms) were successfully applied in distinguishing these genetically different individuals.
(7) We conducted approximately 133 educational events on forest management in southeast MN and reached approximately 600 woodland owners, 2,371 youth, 210 youth educators, and 1,670 other adults.

PROJECT RESULTS USE AND DISSEMINATION

Accomplishments under objectives 1 through 4 will be incorporated into a masters degree thesis after the sites have been remeasured again later in 1993. Plots will be measured at least two more years and then a report will be submitted to a forestry journal for publication. A forestry field trip will be held in 1994 or 95 to show these research sites to forestry professionals and discuss results. The results from objectives 5 and 6 are being used to plan new LCMR-funded studies and the project report will be rewritten for presentation at a scientific meeting or in a journal. Educational programs under objective 7 will continue through 1995 and their impact will be evaluated by surveying program participants.

DATE OF REPORT: July 1, 1993

LCMR Final Status Report - Detailed for Peer Review - Research

I. TITLE: Regeneration and Management of Minnesota's Oak Forests--Forestry 15

Program Manager: Steven B. Laursen
Minnesota Extension Service
University of Minnesota
240 Coffey Hall
St. Paul, MN 55108
(612) 624-9298

A. M.L. 91, Ch. 254, Art. 1, Sec. 14, Subd. 7(d) Appropriation: $225,000
Balance: $ 0

Regeneration and Management of Minnesota's Oak Forests: This appropriation is to the University of Minnesota, Minnesota Extension Service, for research and education in oak regeneration and management.

B. Not applicable
C. Not applicable

II. NARRATIVE

Currently more red oak is harvested annually in southeastern Minnesota than is grown. Oaks are very valuable for wood products; acorns are a staple food for many wildlife species, and oak woodlands protect water quality, especially in hilly terrain, by serving as a buffer between agricultural land and streams. Oaks have proven difficult to regenerate and our oak woodlands are gradually converting to other tree species with less value for wood and wildlife. This species conversion is continuing whether or not timber harvesting occurs, but it may be accelerated by harvesting. Research and extension activities are planned to improve oak regeneration and management.

III. OBJECTIVES

A. TITLE: Artificial regeneration of red oak in southeastern Minnesota

1. NARRATIVE

The oak resource in southeastern Minnesota is one of the most valued of any in the state on a per acre basis. Unfortunately this resource currently is being harvested at an increasing rate without adequate oak regeneration as a replacement. Oak is difficult to regenerate and often the harvested stands convert to undesirable hardwood species with less value for timber or wildlife. Research in other states indicates that natural oak regeneration from acorns is affected by such factors as shade, competition from other understory plants, direction of slope, acorn abundance, acorn predation by animals and insects, weather conditions during the growing season--especially rainfall, natural toxic chemicals from other plants occurring on the site, and possibly deer browsing. Regeneration from stump sprouts is largely affected by tree species, diameter, and age. Field trials are needed to assess the feasibility of different artificial regeneration methods since natural regeneration generally is unreliable following current harvesting methods.

2. PROCEDURES

There is a rich collection of oak regeneration literature available. However, there are few, published results from research done in the proposed study area. There is a need for an intensive review of the existing literature based on studies done elsewhere to identify potential regeneration practices to be tested. Most oak regeneration research has taken place in states south and east of Minnesota where the soil, climate and species composition differs from southeastern Minnesota. Research will take place on good oak growing sites. Current knowledge indicates the desirability of testing shelterwood cutting as well as clearcutting. Adequate site preparation is essential for successful oak regeneration. Application of herbicides versus a control will be tested in combination with the cutting levels. Plantings of oak seedlings, oak containers, and direct seeding of acorns will be established in each treatment unit.

Known red oak seed sources will be used. Tubex shelters will be tested on a sample of each type of planting stock and seeding. Treatments will be replicated. Survival and height growth measurements will be taken at the end of the study period. Sources of damage to seedlings and acorns will be recorded. The effects of deer browsing on regeneration will not be studied directly because of the high cost for fencing to exclude deer. Individual tree shelters, however, are one form of deer protection that will be included in the study. Browsing on sheltered and unsheltered trees will be compared. A randomized block design will be utilized and multi-way analysis of variance will be used to aid in interpretation of results. Vegetative data and pertinent site information will be collected at the beginning and end of the study period. Environmental monitoring equipment, such as rain gauges and light meters, will be installed in the study area.

3. BUDGET

A. Amount budgeted: $60,815
B. Balance: $ 0

4. TIMELINE

TIMELINE	July91	Jan92	June92	Jan93	June93
Review literature	------				
Locate study areas & layout treatment blocks	------				
Pre-harvest vegetation inventory	--------------				
Herbicide application	---------				
Harvest stands		--------			
Planting		----			
Inventory vegetation on site			---		
Survival and height growth inventory			------------		
Summarize results, prepare final report					-------------------

5. STATUS: Through July 1, 1993

METHODS

Research sites were chosen for their similarities in vegetation: (1) white oak-black oak-northern red oak forest cover type and understory indicator plants associated with mesic site conditions, (2) site index for northern red oak was 60 or higher, and (3) soil classification was Seaton-Blackhammer-Southridge association which includes well drained, silty soils formed mostly in loess, sloping to moderately steep, and found on the tops of ridges.

There are three research sites, one in Houston County (Money Creek site) and two in Winona County (Trout Valley East and Trout Valley West sites). All are located on Department of Natural Resources state forest land.

Before any site preparation treatments or harvesting occurred, an intensive inventory was made of woody understory and overstory vegetation on the research sites.

Site preparation treatments (chemical and mechanical) were performed in late summer of 1991. The chemical treatment consisted of 2 quarts of Accord, 2 ounces of Oust, and Valent X-77 (a surfactant) in 10 gallons of water per acre. Herbicides were applied by a backpack mistblower. The mechanical treatment consisted of a D-6 bulldozer (93 to 169 flywheel horsepower) running over shrubs and small trees and uprooting non-merchantable trees. The third area was a control that received no treatment, and was used for comparison. Prior to harvesting at the two Trout Valley sites, a "hack and squirt" operation was performed on all site preparation treatment plots using Tordon RTU to kill most of the boxelders.

The three research sites were commercially harvested during the late fall and early winter of 1991-1992. According to our pre-harvest inventory, white oak, black oak and northern red oak were the main overstory species in these areas prior to logging. Other common overstory species included basswood, black cherry, hackberry, and hickory. The logging operations removed 60 to 90 percent of the overstory trees larger than 4-inches diameter (dbh). The remaining overstory was composed primarily of "seed trees" which the DNR left for natural regeneration purposes and some undesirable species, including boxelder and hackberry, which were not removed in either the harvesting or site preparation treatments.

Following the harvest at all research sites and on all site preparation treatment plots, all undesirable standing trees larger than 2-inches in diameter were cut down by hand. Scattered seed trees were left standing. Slash was limbed and knocked down to less than two feet in height. Much of the slash was removed from the tree planting sites to facilitate planting.

Two types of northern red oak seedlings as well as northern red oak acorns were tested in this project. The 2+0 bareroot seedlings were grown by the Minnesota DNR's General Andrews Nursery at Willow River, from acorns collected in the Lewiston area. The two grades of seedlings used were: (1) seedlings with at least six first-order (greater than 1 mm) lateral roots (referred to hereafter as premium) and (2) nursery run seedlings.

Acorns used in this project were purchased from a private nursery. According to the manager, these acorns had been collected early in the season (prior to September 5, 1991) from a limited number of open-grown trees and/or dominant and co-dominant trees from forest stands. It is not known whether these acorns were collected from trees that meet the Minnesota DNR's definition of a "plus" tree.

Acorns were sorted by water floatation and all unsound acorns were discarded. The remaining acorns were placed in plastic bags in cold storage (34° degrees fahrenheit) over the winter.

Seedlings were planted in mid-April, 1992 using a hand-held, power auger to dig the holes.

Acorns were planted at the same time by hand with one acorn being planted per seed spot. While normally it is advisable to plant two to four acorns per seed spot, we were unable to do that in this project since tree shelters (Tubex quills) were used in some of our trials. The tree shelters placed over the acorns were only one inch in diameter so it was physically impossible to plant more than one acorn in them. In order to keep the tree shelter and non-tree shelter trials the same, only one acorn was planted at each seed spot.

Two seedling trials of premium seedlings per understory treatment plot were protected by 4-foot tall brown Tubex tree shelters which vary in diameter from 3 1/4 inches to 4 inches. Acorns in one acorn trial per understory treatment plot were protected by 30-inch tall Tubex quills which were 1 inch in diameter. Tree shelters and quills were installed the same day that the seedlings and acorns were planted.

The experimental design for this research project was a split-plot design in which each block is divided into whole plots, which are further subdivided into subplots (split plots).

This project has three blocks, each a little larger than three acres. These blocks are the research areas located at Trout Valley East, Trout Valley West, and Money Creek. Each block was divided into three whole plots [the understory treatments: (1) mechanical, (2) chemical, and (3) control], each about one acre in size.

The whole plots were further divided into subplots for the seedling and acorn trials: (1) two replications of seedlings with six or more first-order lateral roots, unprotected by tree shelters (2) two replications of seedlings with six or more first-order lateral roots protected by tree shelters, (3) one replication of unprotected nursery run seedlings, (4) one replication of planted acorns, unprotected by tree shelters, and (5) one replication of planted acorns, protected by tree shelters.

All vegetation (natural and planted) on the research sites was inventoried a second time in late summer, 1992. This was at the end of the growing season.

Analysis of variance was used to identify significant differences in treatment effects on survival and growth of natural regeneration and on oak seedlings and acorns.

RESULTS

Prior to the site preparation and harvest treatments, there were no significant differences in the mean number of stems per acre among the chemical (12,624 stems per acre), mechanical (9,314), and control (10,115) plots. One year after the site preparation treatments there were significantly fewer stems per acre in the chemical (5,714) treatment plots than were there the year before; however, the number of stems per acre in the chemical treatment plots were not significantly different from the number of stems per acre in either the mechanical (12,516) or control (14,688) plots at that time.

Prior to site preparation and harvest treatments, there were no significant differences in the mean stem height of naturally occurring tree seedlings and shrubs among the chemical (87 cm), mechanical (70 cm), and control (78 cm) plots. One year after the site preparation treatments, mean stem height of vegetation in the control plots (86 cm) was significantly higher than in the chemical (64 cm) and mechanical (59 cm) treatment plots.

Survival rates after one growing season were over 99% for all categories of planted northern red oak seedlings (premium seedlings protected by tree shelters, unprotected premium seedlings, and nursery run seedlings). Survival rates for the protected acorns (42%) and unprotected acorns (27%) were significantly less than survival rates for the seedlings. Low survival rates for the acorns is puzzling. In two separate greenhouse trials almost 90% of the acorns germinated and survived for over a month. Low germination and survival rates for the acorns reinforce what other researchers recommend, when planting acorns, plant two to four acorns per seed spot.

After one growing season the diameter of northern red oak seedlings in the chemical (1.2 mm) and mechanical (1.2 mm) treatment plots was significantly greater than in the control plots (0.7 mm).

After one growing season height growth of planted northern red oak seedlings was significantly greater in the mechanical treatment plots (14.3 cm) than in the chemical plots (8.6 cm), but not greater than height growth in the control plots (12.7 cm).

After one growing season there were no significant differences in the height and diameter growth between the premium (4.1 cm and .5 mm) and nursery run (2.1 cm and 0.5 mm) northern red oak seedlings. After one growing season, planted acorns showed significantly greater height growth (12 cm) and diameter growth (1.9 mm) than the planted northern red oak seedlings. However, the premium and nursery run seedlings still had significantly greater heights and larger diameters than the acorn sprouts.

After one growing season height growth of premium northern red oak seedlings protected by tree shelters (21.2 cm) was significantly greater than the height growth of unprotected premium (4.1 cm) and nursery run seedlings (2.1 cm). However, there were no significant diameter growth differences between protected seedlings (0.5 mm) and either the unprotected premium (0.5 mm) or nursery run (0.5 mm) seedlings.

There were no significant differences in height or diameter growth of protected and unprotected acorn sprouts (12 cm and 1.9 mm compared to 20 cm and 1.8 mm).

To determine if there was a relationship between competition and planted northern red oak seedling growth, seedling growth allocation (height growth divided by diameter growth) was plotted against competition (stems per ft^2 x mean stem height). This graph showed that as competition increased, the seedlings and acorns not protected by tree shelters allocated more photosynthetic material to height growth. Regression analysis showed that competition accounted for 50 to 80 percent of the variation in growth allocation and that the premium seedlings were better able to respond to competition (with increased allocation to height growth) than either the nursery run seedlings or the acorn sprouts.

Planted northern red oak seedlings grown in tree shelters showed a 200 percent increase in stem volume (diameter^2 x height) compared to a 70 percent increase for unprotected premium and nursery run seedlings. While this volume growth may be impressive, their growth form resembles vines and it may be several years before these seedlings will be able to stand independently from the support of tree shelters.

It was surprising that both the unprotected premium seedlings and nursery run seedlings increased their volume growth by about 70%. We expected the premium seedlings to grow faster and nursery run seedlings. Two possible explanations come to mind. First, while there was a statistically significant difference in initial height and diameter between the premium and nursery run seedlings, there may be no real difference in their root structure (we have data only on first-order lateral roots for the premium seedlings). Therefore, if there is no difference in the root structure between the two types of planting stock, there may be no "real" difference between them at all and consequently their percent change in stem volume should be the same. Second, the stem volume equation (diameter^2 x height) is more sensitive to changes in diameter growth than in height growth. At the time of planting, the premium seedlings were larger in height and diameter than the nursery run seedlings, however, after one year of growth the premium and nursery run seedlings had the same diameter growth. This may be responsible for giving the appearance of a proportional relationship where none really exists. Whether this relationship will remain constant or change with time as competition increases remains to be seen.

After one growing season we also identified and classified damage that occurred to the planted northern red oak seedlings and acorns.

Abiotic damage was defined as physiological damage to plant tissue from abiotic sources, such as the tree shelters. Sixty-three percent of the premium seedlings protected by tree shelters showed some sort of leaf deformation or lack of leaves on one or two faces of the stem. There was no such damage to unprotected premium and nursery run seedlings or to planted acorns, both protected and unprotected.

There was significantly less animal damage (mainly deer and rabbit browse) on northern red oak seedlings protected by tree shelters than on unprotected seedlings and acorn sprouts, both protected and unprotected. Fifteen percent of the unprotected premium northern red oak seedlings and 13 percent of the unprotected nursery run seedlings had animal damage. In contrast there was animal damage on only two percent or fewer of the premium and nursery run seedlings that were not protected by tree shelters and on acorn sprouts, both protected and unprotected.

Insect damage was caused mainly by whole-leaf feeders, window feeders, and leaf miners. The unprotected premium and nursery run northern red oak seedlings showed significantly higher rates of insect damage than the protected and unprotected acorn sprouts. But, insect damage on protected premium seedlings was not significantly different from damage on the unprotected premium and nursery run seedlings or the protected and unprotected acorn sprouts.

Biotic damage was defined as damage to leaves and stems that was of unknown origin and could not be identified as abiotic, animal, or insect damage. It appeared as top dieback, leaf wilting, and stem damage. Biotic damage was significantly higher on unprotected premium (65%) and nursery run (68%) northern red oak seedlings than on the protected (0.5%) and unprotected (18%) acorn sprouts. Biotic damage on the protected premium seedlings (43%) was not significantly different from damage on the unprotected seedlings and acorn sprouts, protected and unprotected.

Since these results are from the first growing season after northern red oak seedlings and acorns were planted, it would be unwise to draw conclusions about the effectiveness of the site preparation treatments, the growth rates of the different planting stock (seedling grades vs. acorns), or the utility of the tree shelters. This project will continue to be monitored for at least two more years under the new LCMR project, Developing Quality Hardwood Forests.

In retrospect a few changes in our procedures would have provided more useful results. We would like to have had more control over the logging. To our surprise the DNR had marked seed trees to be left in our research plots when we wanted complete clearcuts. The logged sites also were heavily covered with slash that should have been dragged from the sites to facilitate our planting activities. We cleaned them up by hand, but this could have been accomplished more easily by a logger with a skidder. One of our proposed research sites was not harvested in time to plant because of problems in selling the timber. This caused us to create two research sites at Trout Valley that were very close together. We originally wanted a greater geographic dispersion.

We should have ordered more nursery run seedlings so that we would have had a sufficient number to do destructive sampling of some to determine the number of first-order lateral roots. Then we could have made a more complete comparison between the physical dimensions of the premium and nursery run seedlings.

We used tree shelters on the premium seedlings, but not on the nursery run seedlings. We should have used them on both to give us more complete information about the effects of tree shelters on tree diameter and height growth.

The plots used for measuring understory vegetation and natural regeneration were too small. The tremendous variability in species composition and number of trees between these plots would have been reduced with larger plots. Larger plots might have enabled us to discern more significant differences in the vegetation responses to understory treatments.

During the next two years we will continue to monitor the growth of planted red oak seedlings and acorns as well as the growth of natural regeneration on these research sites. That will give us three years of growth data and will enable us to draw more sound conclusions about the site preparation treatments, different types of planting stock, and value of tree shelters.

We also will begin research under a new LCMR project, Developing Quality Hardwood Forests. As part of this project we will conduct a wider range of site preparation treatments and evaluate their effects on natural regeneration of oak and other species.

6. BENEFITS

This study will provide information that will lead to guidelines for forest managers in southeastern Minnesota regarding regeneration of red oak. This information is critical to sustaining red oak as a major component of our hardwood forests. Regeneration of this resource is essential to satisfy wildlife and timber demands as well as to protect water quality.

B. TITLE: Quantifying regeneration in southeastern Minnesota's oak forests

1. NARRATIVE

Anecdotal evidence suggests that oak regeneration in the hardwood forests of southeastern Minnesota frequently is unsatisfactory given an objective of continued site occupation by oak species. It is known that in general oaks reproduce best when there is abundant advance regeneration on the site before harvest. Regeneration success is highly variable, but depends on overstory and understory competition, acorn abundance, site conditions and weather. Oaks regenerate from both seed and stump sprouts though the sprouts are more reliable. No scientific surveys have been conducted to determine the nature and extent of the oak regeneration problem as it relates to the specific conditions of southeastern Minnesota. No designed studies have been implemented to determine the nature of the site to site (versus within site) variability present among successful regeneration episodes. Some foresters have observed that red oaks on good sites in southeast Minnesota often appear to be of lower quality for timber purposes than red oaks on similar sites in Wisconsin. Hybridization among oak species may be the cause.

This objective will involve collecting and analyzing field data to determine the frequency of oak regeneration successes, the site to site variability associated with successful oak regeneration, and the genetic purity of red oaks.

2. PROCEDURES

An "office" canvass will be made to identify red oak stands in southeastern Minnesota that have been harvested within the last fifteen years. Department of Natural Resources (DNR) records of harvest activity on DNR administered lands and lands owned by private individuals that have been assisted by DNR foresters will provide the basis for site identification. Local foresters also will be contacted to supplement that effort. A data base will be constructed that identifies stands with respect to a number of factors including characteristics of the parent stand, soil, and topography; logging method; and any other relevant information available. This data base will be cross-referenced with general weather information and information on years of good seed crops. From this large base, approximately 75 sites will be chosen for on-the-ground inspection. Selection will be made according to a stratified design where strata will be identified with factors described above. This will allow for valid survey results and insure representation of conditions of special interest with respect to the factors.

On the sites selected for ground study, three random locations will be permanently demarcated. At each location, three concentric, fixed-radius, circular plots will be installed. On the outermost 1/20-th acre plot, residual stand and stump information will be collected; the stump information will be utilized to supplement other knowledge concerning parent stand characteristics. On a 1/300-th acre plot regeneration will be characterized with respect to tree species, numbers, and height. On an innermost 1/3000-th acre plot, presence/absence of key indicator understory species will be noted. Photo evidence will be used to document each plot; if resources are sufficient, large-scale aerial photography will be taken of study sites. Analysis of the resulting data will involve computation of survey averages and variabilities, both among and within sites. Statistics will be tabulated by strata (site, stand, and logging factors used in initial site classification. Log-linear model analysis, including logistic regression, will be used to relate regeneration success or failure to site, stand, and logging factors. If the data appear to support it, further regression analyses will be performed to predict degree of regeneration success.

On 30 successfully regenerated sites the two larger concentric plots will be used to collect information on parent/residual stand and level of regeneration. The 75 sites referred to above will be used to provide some of these 30 sites, though it is anticipated that additional effort will be required to locate 30 stands that have been successfully regenerated. Successful regeneration will be defined according to the measures reported in the "Manager's Handbook for Oak in the North Central States."

Analysis of the resulting data will focus on characterizing site, stand, and logging conditions that led to observed successful regeneration. If fewer than 30 successfully regenerated sites are found, our analysis will continue as planned, but the resulting recommendations may be restricted to a narrower range of site conditions. Again, variability observed will be given equal or greater importance than point estimates.

Leaves will be collected from a few carefully selected red oaks. They will be analyzed by laboratory procedures to determine whether these trees are pure red oaks or hybrids.

3. BUDGET

A. Amount budgeted: <u>$46,875</u>
B. Balance: $ 0

4. TIMELINE

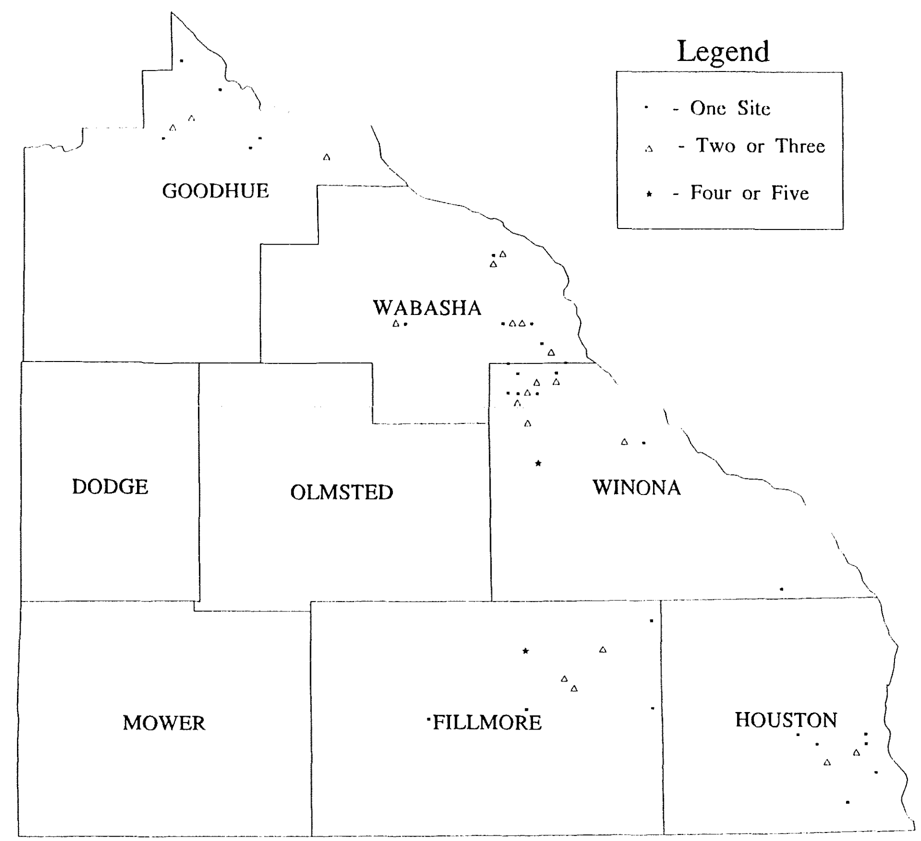
	July91	Jan92	June92	Jan93	June93
Building initial data base	--------				
Selection of ground sites	----------				
Data collection on ground sites		-----------			
Data analysis for ground sites			-----------		
Data collection for successfully regenerated sites			----------	--	
Data analysis for successfully regenerated sites				---------------	

5. STATUS: Through July 1, 1993

METHODS BACKGROUND

Field: The focus of the field work was on what we termed a "site." A site was an area homogeneous with respect to physical and biological conditions present. Any particular harvest area potentially could be sub-divided into sites. A total of 91 sites in southeastern Minnesota finally constituted the study (see map for geographic distribution). Random selection of sites was not possible; instead we sampled every site we could find where a harvest had taken place in the last 5 to 10 years in the study region. Nearly all the sites ultimately visited (84) were on land where a DNR-assisted timber sale had taken place; records from the sale were obtained to provide basic harvest background information. A cursory reconnaissance of the site was used to purposively sample up to five trees in the border area of the site that were representative of surrounding woody vegetation; these trees were characterized as to DBH, total height, species, and percent of the border area (ocular) they represented. Finally, the physical condition of the site was characterized.

Location of Oak Regeneration Study Sites



Each site was sampled using two to four "plots" (more properly, sample locations), the number depending on the size and variability present on the site. Plots within a site were located systematically with a random start. At a sample location, a 1/20-acre plot was established where residual trees and stumps of cut trees were identified and characterized as to size (DBH, total height, and crown dimensions where applicable). A soil core (to six feet where possible) was extracted from the center of this plot and a standard Soil Conservation Service analysis performed. An ocular estimate of the degree of brush closure was made at plot center at heights of one, two, three, and four feet above ground level. On a 1/300-acre plot concentric to the 1/20-acre plot, and on six additional such plots arranged systematically about the center plot at a distance of 40 feet, regeneration was characterized. For each individual, species was determined and height and DBH (if applicable) measured. Each individual was identified as being a stump sprout or not. For a sprouted stump, the one or two individuals judged to have the greatest chance of survival were tallied.

Three sites (in Wabasha and Winona counties) were selected for collection of material for study of hybridization of northern red (*Quercus rubra*), black (*Quercus velutina*), and northern pin (*Quercus ellipsoidalis*) oaks. In each case the site supported (or had supported) stands dominated by red oak species. All stands were (or had been) composed of sawtimber size trees. One stand had been recently cut with seed trees left in place. Another was a fairly uniform stand about 50 years old, on a poor quality site. The final stand was quite old, to the point that some age related mortality was beginning to occur. In winter 1992, approximately 20 tree were purposively sampled on each site with an attempt being made to obtain "pure" and hybrids of each red oak species present on the site. Twig and bud samples were collected from the top of the crown using a shotgun. Photographs of bark characteristics were also taken. An expert from the U.S. Forest Service made a determination of species (or hybrid) based on winter characteristics. During the growing season of 1992, the sample trees were revisited and leaf and acorn samples taken (again from the top of the canopy). The same U.S. Forest Service expert made a summer characteristics determination of species (or hybrid).

Traditional electrophoresis and RAPD analyses were conducted on the twig and leaf tissue samples.

Office: All data collected in the study were transferred from field sheets into an RBase™ data base. Several tables were created that are linked by site and, where applicable, plot. Data were thoroughly checked and initial analyses performed to identify suspect data items.

Upon verification of the data, two basic types of analyses were performed. The first was to summarize the basic data concentrating on variables of potential usefulness in a second analysis. The second analysis consisted of a stage-wise analysis of covariance to identify important factors determining oak regeneration success. For all analyses the basic record was the site. Plot and sub-plot values were generally averaged to obtain site values except for some categorical variables where a mode was determined to be a more appropriate summary statistic.

The first analysis focused on five basic classes of variables: amount of regeneration, amount of competition, soils, harvest detail, and physical site attributes.

Regeneration: Regeneration was characterized both for all species in total and for targeted oak species. Both stems per acre and feet of height per acre were computed. While regeneration is commonly summarized in terms of number of stems, total height of regeneration (essentially stems per acre weighted by size) can be more meaningful in terms of characterizing stems that will survive beyond seedling/sapling size. In addition to considering all stems, statistics were computed for stems whose height exceeded that of the individual of mean height on the sample unit. Such stems were termed "dominant regeneration." Due to the inherently positively skewed height distributions, on average, dominant regeneration corresponds to trees above the 65th percentile of height. Again number and height for all species and target oak species were computed for this dominant regeneration component.

Competition: Regeneration must compete with any residual stems left after harvest as well as brush situated closer to the ground. Residual basal area of all stems and target oak species stems were computed. Since competition for light can be very important, a variable denoted "effective crown volume" was also computed for residual stems. Effective crown volume was computed using crown width and crown length by assuming the crown shape approximated a paraboloid and reducing that volume by (1.0 - crown fullness). Initial analysis of brush closure variables indicated a high degree of association between one and two foot and three and four foot measurements. Each pair was thus averaged using as values the midpoint of the classes: 5%, 20%, 50%, and 85%, respectively.

Soils: Initial analyses of soils data indicated that the study sites differed substantively with respect to: depth of "A" horizon, depth of "E" horizon, depth to rock, stoniness, texture, structure, and presence/absence of a pan.

Harvest: Quite detailed information was available for all sites in which DNR personnel had been involved in the timber sale (84 sites). Of relevance to the present study were: acreage, harvest date, removal volumes by species, and harvest technique. To characterize removal amount, a total cordwood value was computed assuming 3.5 cords per thousand board feet of sawtimber or veneer. This value was added to cords of firewood or pulpwood removed. Percent removal in target oak species was also computed. Harvest technique was classified into clearcut, commercial clearcut, shelterwood, and indeterminate. The information on species composition of the site border was also considered in this class of variables. For those data, percent of oak, weighted by total tree height, was computed.

Physical: Initial analyses of physical site attributes indicated high variation with respect to slope, slope position, aspect, and exposed bedrock. Aspect requires special attention due to its being measured on a "circular" scale. Most past vegetation research has used the transformation cosine (aspect - θ) where θ is the "best" aspect often taken to be 45° for forested sites. Here we used the approach involving both sine and cosine transformation of aspect which allows for data-based estimation of θ.

The study we conducted is usually termed an observational study (versus designed experiment). The primary advantage of an observational study is the ability to collect broadly applicable information efficiently; we basically observe what nature has produced. The disadvantage of an observational study is the difficulty in applying strict inference procedures as part of subsequent analysis. Since no control was exercised in the assigning of experimental units, it is much more difficult to ascertain the basis for observed differences (for example between harvest techniques). Observational studies such as ours are often used to suggest specific experiments that should be conducted under more controlled conditions (this is actually the case at present where the results from the work will be used to suggest experimental factors in a new LCMR-funded study). A common method of analyzing data from observational studies is by analysis of covariance where observations on variables not of direct interest from an inference perspective are used to adjust for differences between experimental units prior to any statistical testing; one obtains control through analysis rather than design.

Analysis of covariance was used to develop models relating regeneration response to site characteristics and factors deemed of interest in oak regeneration problems. Three vague hypotheses had been identified during the definition of this study: 1) oak regeneration success is related to harvest technique, 2) oak regeneration success is related to characteristics of the residual stand, 3) oak regeneration success is related to physical characteristics of the site. The variables used to investigate these hypotheses ("hypothesis variables") were 1) harvest technique, 2) residual basal area or effective crown volume of residuals, and 3) slope or aspect. The analysis of covariance method was thus applied in two stages. First a model was developed, excluding the hypothesis variables, that explained as much of the variability between study sites as possible. Then, hypothesis variables were added singly and in combination to assess differences or whether unexplained variability was related to these hypothesis variables. All other variables in the amount of competition, soils, harvest detail, and physical site attributes categories of variables, and transformations thereof, could potentially enter into the model of the first stage.

An all-possible regressions approach was taken for the first stage. First, the best five variable sets for six through 12 variable models were identified based on amount of variation explained. Second, several of these models were then analyzed in detail to determine if transformations were needed and to check for adherence to assumptions of the analysis of covariance approach. Standard residual plots were used for this purpose. In addition to overall variation explained, the signs and statistical significance of individual model coefficients were examined. A model was dropped if collinearity inappropriately reversed the sign of a coefficient or if it contained more than one variable whose coefficient was insignificant at the 0.20 level; this very conservative significance level was chosen due to the extreme variability associated with observations of regeneration. These two steps (all possible regressions followed by detailed analysis) were repeated until a model satisfying all criteria was obtained. It must be remembered that the objective of this stage was not so much to obtain a perfectly explainable model but rather to explain as much of the variation as possible to add control to the study of the hypothesis variables.

Upon obtaining a model in stage one, hypothesis variables were added and evaluated for significance. For harvest technique, a dummy variable approach was used. The possibility of non-parallelism was examined with all variables previously in the model. For the "residual stand" and "physical site characteristics" variables, partial regression residual plots were used to identify the metric in which the variable might potentially enter the model. The variable was then added to the model and evaluated via a standard t-statistic (testing at the 0.20 level as above). Residual plots were used to evaluate potential interactions.

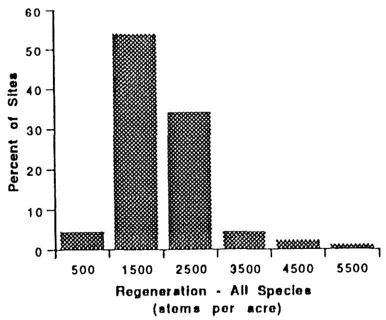
Discussions with DNR foresters and other oak regeneration experts during the conduct of the study pointed out the difficulty in specifying the occurrence of a successful oak regeneration episode. To avoid this, a series of regeneration responses were studied: total amount of regeneration, percent of the total that is in the target oak species, and percent of the dominant regeneration that is in the target oak species. Analyses of the first of these will indicate what about the harvest or site leads to the establishment of any sort of future timber stand. Analysis of the second and third responses will indicate what conditions tend to favor target oak species appearing in regenerated stands, the third providing a better indication of a stand that may actually mature into one dominated by target oak species. The above analysis methodology was applied independently to all three of these responses, both as indicated by stems per acre and feet of height per acre. Of particular interest was the consistency (or lack thereof) in the variable sets that appeared in the final models. Consistency would support the contention that a variable is indeed indicating a relationship (not just random happenstance). Further, differences in signs between variables for response type one versus types two and three would suggest factors favoring or disfavoring the establishment of a stand with target oak species.

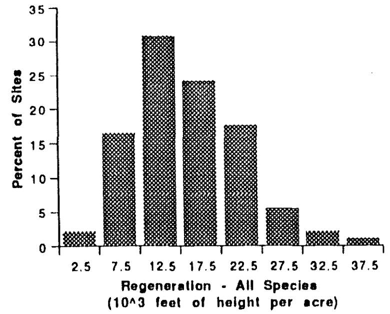
RESULTS

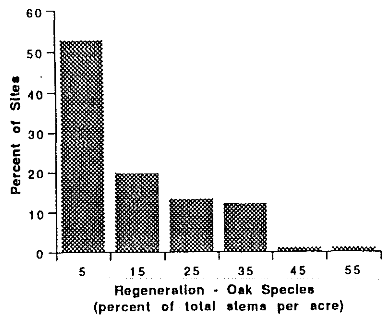
The Data Base: A significant product of this study is the establishment of a data base of high quality for current and future study of the oak regeneration problem. The data base is well-documented and will be made available to other interested researchers. Where possible, all study sites and plots were permanently documented and can be returned to for future study, for example when an established stand can actually be identified. The background information collected in the present study will be invaluable in analyzing the structure of these established stands. A basic summary of important variables in that data base follows.

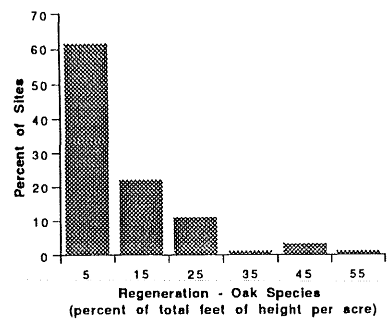
Graphical summaries of the primary variables included in the analyses of this study appear on accompanying pages.

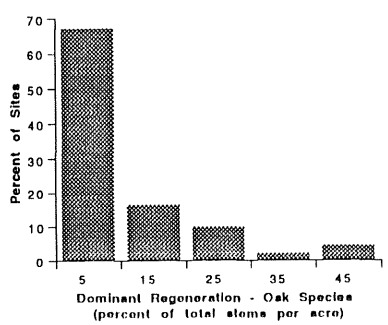
The response variables for subsequent analyses are regeneration amounts and percentages based on stems per acre and height per acre. Overall, regeneration has been successful on nearly all the sites examined. Most sites have 1000 to 3000 stems per acre, quite adequate given 80 percent of the sites are five to eight years from harvest. While the distribution of sites by stems per acre is quite blocked, the distribution by height per acre is smooth with good variation between sites. Target oak species for the study were northern red oak and white oak (*Quercus alba*).

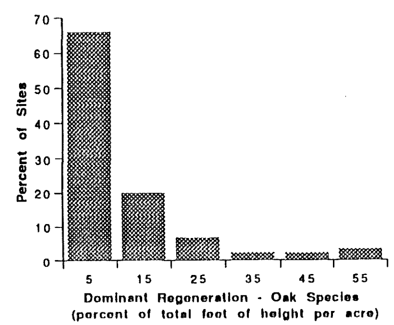










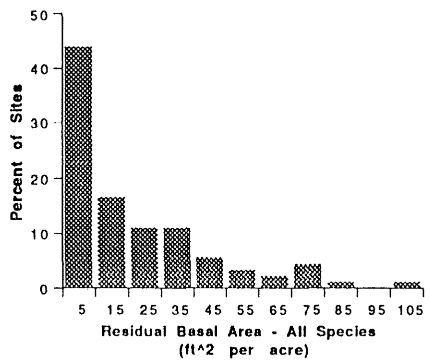


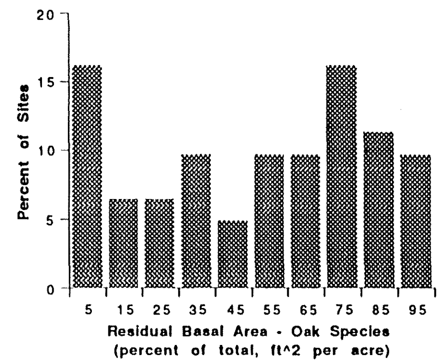
Considering all size stems, these oak species are, on average, 12 percent of the regeneration. However, the distribution of oak representation is very skewed with many sites having 0 to 10 percent oak. This supports the existence of a real oak regeneration problem given that nearly all the sites had a significant oak component prior to harvest. When regeneration is measured in terms of height per acre the problem is further highlighted with over 60 percent of the sites having 0 to 10 percent oak. The data also point out that oak has not competed well on many of the sites; on nearly 70 percent of the sites target oaks represent a small minority of the dominant regeneration. The problem addressed later will be to identify site characteristics, if any, where this is not the case.

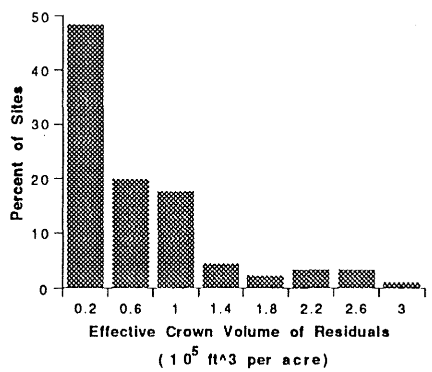
In total, over 15000 individual stems were measured during this study. A total of 75 percent of the stems were elm, cherry, maple/basswood, target oaks, aspen/birch, or other oaks (22, 19, 15, 12, 5, and 2 percent, respectively).

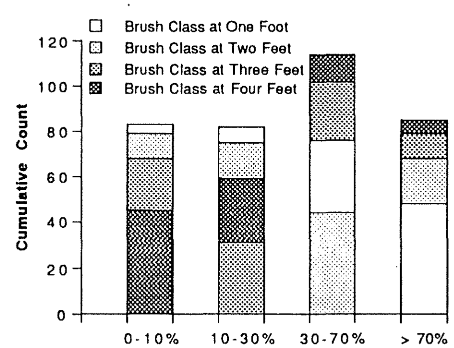
Competition from the residual stand was assessed by basal area of residual stems as well as effective crown volume of residual stems. The distributions for both variables is highly positively skewed with few sites having appreciable residual stands. While the distributions of these two variables are similar, they are not as related as one might expect ($r = 0.68$). Oak composition of the residual stand as measured by percent of total basal area is fairly uniformly distributed between 0 and 100 percent. Competition from brush is assessed by the brush class data. Class distributions at one and two feet are exactly inverted from those at three and four feet; most sites have greater closure closer to the ground.

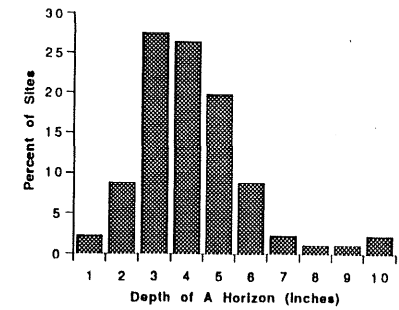
Important soil variables present in the data include depth of A horizon, depth of E horizon, depth to rock, structure, percent stone, and presence of a pan. The depth of the A horizon averages five inches on the study sites with a fairly symmetric distribution about that value. The E horizon averages 8 inches depth with most sites in the 5 to 10 inch range. Over 20 percent of the sites had a depth to stone greater than six feet (the length of the core). Still, 70 percent of the sites had a rock layer less than 40 inches from the surface. A high proportion of the sites had soils

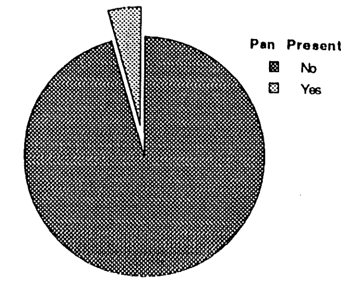

Percent of Sites
Residual Basal Area - All Species
(ft^2 per acre)

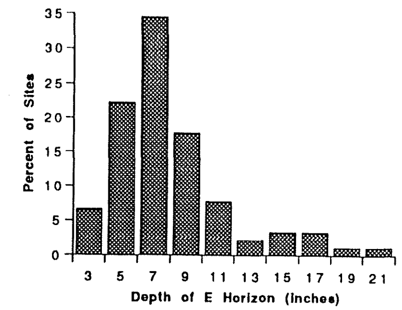

Percent of Sites
Residual Basal Area - Oak Species
(percent of total, ft^2 per acre)

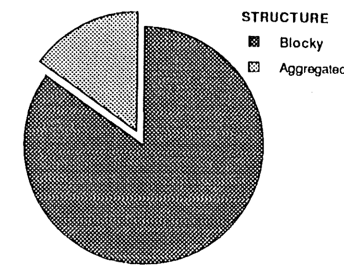

Percent of Sites
Effective Crown Volume of Residuals
(1 0^5 ft^3 per acre)

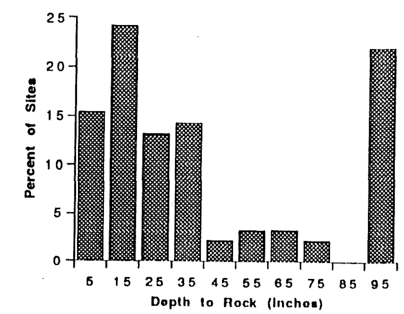

Brush Class at One Foot
Brush Class at Two Feet
Brush Class at Three Feet
Brush Class at Four Feet
Cumulative Count
0-10%
10-30%
30-70%
> 70%

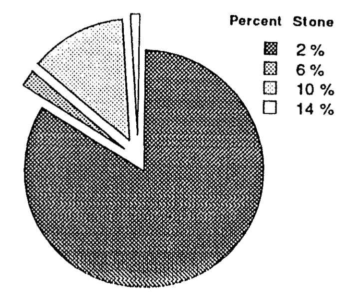

Percent of Sites
Depth of A Horizon (Inches)


Pan Present
No
Yes


Percent of Sites
Depth of E Horizon (Inches)


STRUCTURE
Blocky
Aggregated

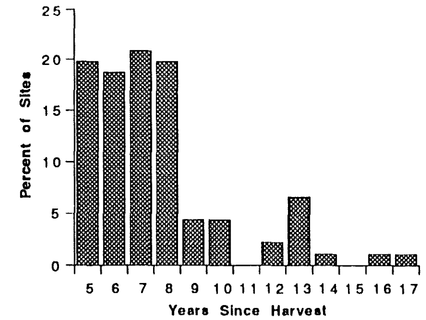

Percent of Sites
Depth to Rock (Inches)

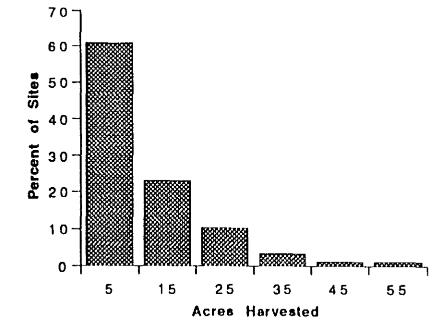

Percent Stone
2 %
6 %
10 %
14 %

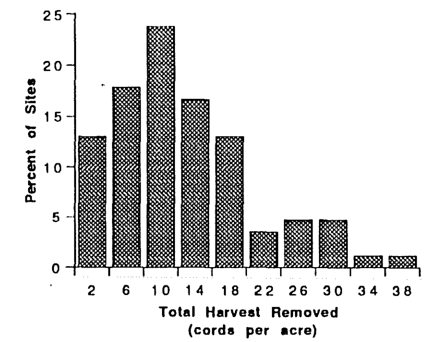
with less than two percent stone content, of blocky structure, with no pan present.

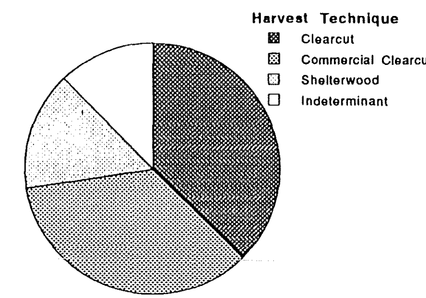
The target "years since harvest" range for this study was 5 to 10 years. It was thought that five years was sufficient for species composition to begin being sorted out and for target oak species to "grow above the brush." It can be seen that approximately 80 percent of the sites turned out to be in the 5 to 8 year range. That we were able to find sufficient sites in such a narrow range increased the control for the study. Although "size of harvest area" was not expected to impact oak regeneration success, it was significant that 75 percent of the study sites were less than 10 acres in size. This is typical of harvest opportunities in southeastern Minnesota. Average removal for the sites was approximately 12 cords per acre, near the State average. There is a fairly uniform distribution of removal amounts over a broad range, indicating that we were successful in balancing this potentially important factor. Target oak species represented over 75 percent of removal on the vast majority of sites so that parent stand characteristics were nominally good in terms of oak regeneration potential. Roughly 35 percent of the sites were harvested by clearcut or commercial clearcut and 15 percent by shelterwood methods. Since commercial clearcut has no strict definition, it would seem that most of the power for evaluating harvest techniques lies in comparing clearcutting to other methods ("on average"). Oak is less well represented in the current border areas of the study sites although 10 to 15 percent of the sites fall into each ten-foot-percent class between 10 and 60 percent oak. Oaks do tend to be the dominant trees, in terms of height, in the border areas of most sites.

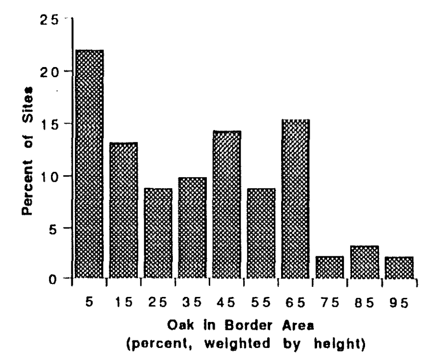
The primary site variables in the data base are slope, aspect, exposed bedrock, and slope position. Ninty percent of the study sites are on land with slopes of 10 to 50 percent (5 to 25 degrees). The sites are generally located on the upper part of the slope, though 20 percent of the sites are on midslope. Over 60 percent of the sites have no exposed bedrock. Most sites have a northeast or northwest exposure with a minimum number of sites existing on southwest exposures, consistent with what one would expect for sites originally dominated by oak.

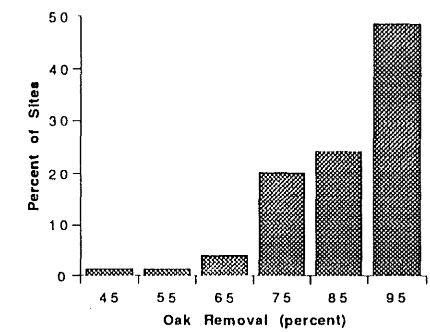


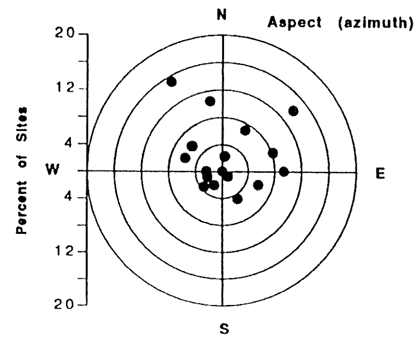


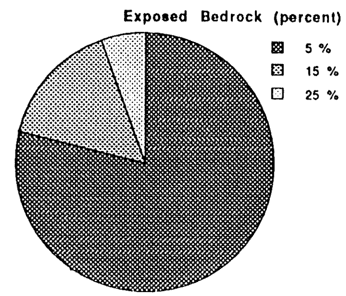


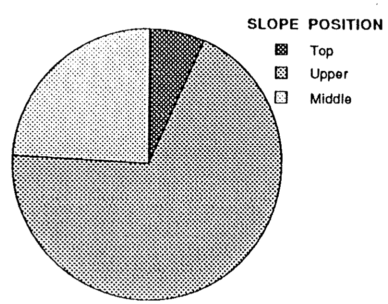


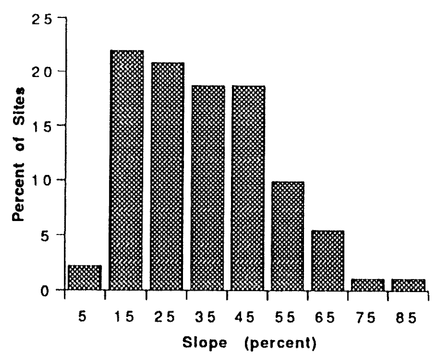












Analysis of Regeneration: Analysis of covariance models were fit to the six potential response variables (regeneration of all species by stems and height, percent of regeneration in target oaks by stems and height, percent of dominant regeneration in target oaks by stems and height) using the methods described above. Literally thousands of models were fit and scores analyzed in detail for stage 1 of the effort. As expected, the variability encountered was enormous and the collinearity present between potential explanatory variables made development of a sensible model difficult. As would be expected given the data summaries above, the results for stems per acre and height per acre generally paralleled one another. What follows is a presentation and discussion of the results obtained using height per acre for regeneration of all species, percent of regeneration in target oaks, and percent of dominant regeneration in target oaks.

The final model for regeneration of all species can be summarized as:

Variable	Coefficient Sign	Significance level
Low Brush	negative	<0.01
Depth E	positive	0.24
Percent Stone	negative	0.13
Structure	positive	<0.01
Slope Position	negative	0.12
Exposed Bedrock	negative	0.07

Basal Area	negative	0.19
Slope Percent	negative	0.18
Clearcutting	positive	0.02

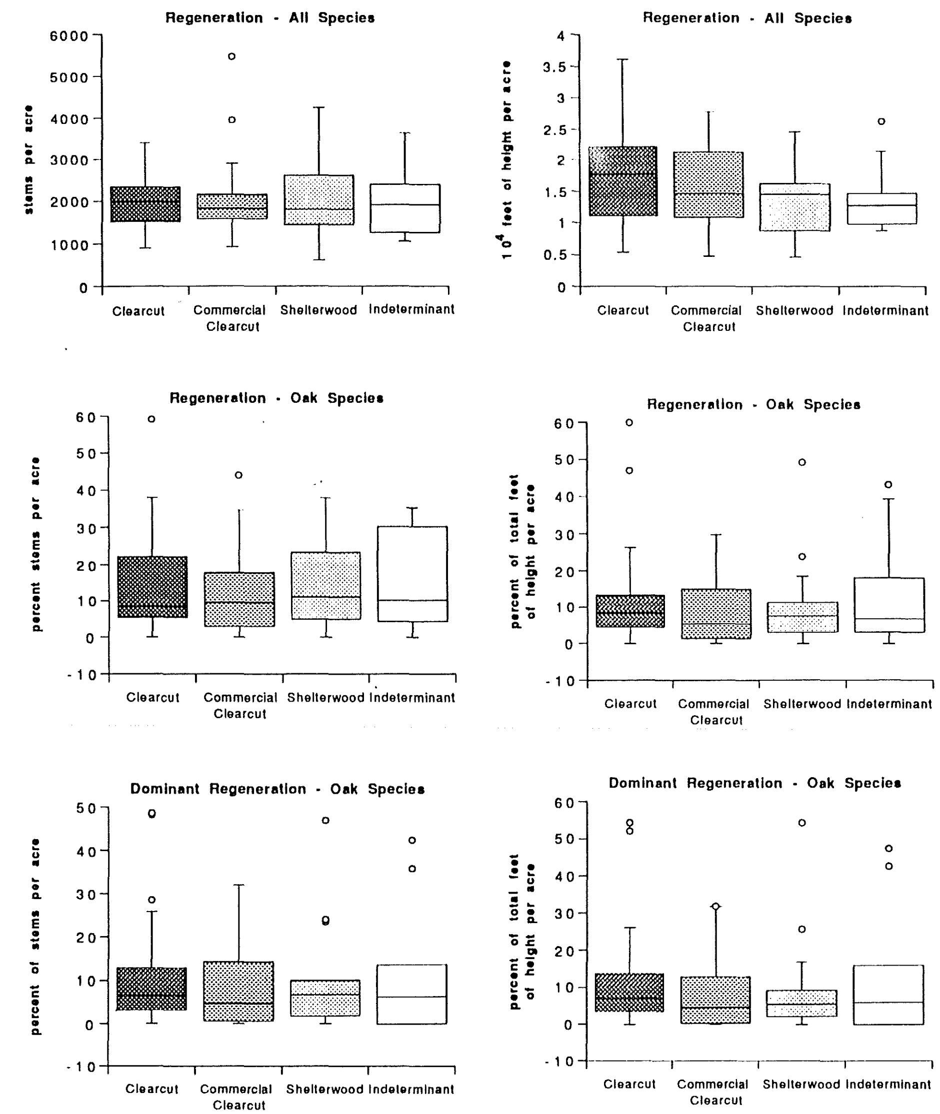
The model accounted for 41 percent of the overall variation (probability of a larger $F < 0.01$). Brush competition and soil structure contributed most to explaining initial variation in regeneration success. Low brush is the percent closure by brush species below two feet above ground level. The positive coefficient on structure suggests that blocky soils have produced greater tree regeneration. Such soils have less water penetration of the surface and probably support less ground cover competition. The results for exposed bedrock and percent stone are both readily interpretable. A negative sign on slope position here suggests that the midslope position sites tended to have less regeneration success; this may have come about for any number of reasons, the source of which is not important to the study. Depth to the E horizon is marginally statistically significant by the study criterion; its positive sign appears reasonable, suggesting a large zone where material is leeched to horizons below promotes regeneration success.

In terms of the hypothesis variables, basal area represents residual stand amount, slope percent represents site characteristics, and clearcutting represents harvest technique. The former two are marginally statistically significant but exhibit the expected relation. Aspect had no effect (alone or in combination with slope) on total regeneration. The impact of clearcutting is highly significant with a positive coefficient suggesting that clearcutting generally produces greater total regeneration than the other harvesting methods (commercial clearcut, shelterwood, other) for stands like those on the study sites. This trend is the most obvious one in the accompanying figure illustrating unadjusted (by covariance analysis) means by harvest technique.

The final model for percent of regeneration in target oaks can be summarized as:

Variable	Coefficient Sign	Significance level
Low Brush	positive	<0.01
Depth E	negative	0.05
Structure	positive	0.19
Total Removal	positive	0.21
Exposed Bedrock	negative	0.18

Basal Area	positive	0.30
Aspect/Slope	--	0.13
Clearcutting	negative	0.13



The model accounted for 30 percent of the overall variation (probability of a larger F < 0.01). Only total removal enters as a new variable in stage 1 of the analysis. Though the significance of this new variable is borderline, its positive coefficient suggests that better sites (sites with higher volumes) have greater oak regeneration potential. Interestingly, the signs on the coefficients for brush and depth to the E horizon are reversed from the analysis presented for total regeneration. This suggests that factors related to these two variables may impact oak regeneration differently than overall (total species) regeneration. Whether these factors are actually brush competition or soil property related remains to be answered by designed experiments (or observational studies where variables describing additional factors are measured).

In terms of the hypothesis variables, basal area represents residual stand amount, aspect/slope represents site characteristics, and clearcutting represents harvest technique. Residual basal area would clearly seem not to have an impact on the proportion of regeneration occurring in oak. Site factors are moderately related to oak occurrence. The aspect/slope variable is equivalent to the product of slope and cosine (aspect - 49°) where 49° was determined (by the data) to be the optimum aspect for oak regeneration (in line with an accepted average standard of 45° for most tree species). Clearcutting again stands out from the other harvest techniques with oak regeneration seemingly depressed by application of the method. However, caution must be exercised in interpreting this result given the significance level on the coefficient and the signs on the coefficients of related variables in the model (total removal and basal area). Also, it is clear from the accompanying figure presenting unadjusted means that, overall, there is little apparent difference between what was actually observed on the sites harvested by the various methods. Still, this result suggests further careful examination given this interesting disparity for clearcutting between total regeneration and percent that is oak.

The final model for percent of dominant regeneration in target oaks can be summarized as:

Variable	Coefficient Sign	Significance level
Low Brush	positive	<0.01
Depth E	negative	0.14
Structure	positive	0.23
Exposed Bedrock	negative	0.12

Eff. Crown Vol.	negative	0.29
Aspect/Slope	--	0.06
Clearcutting	negative	0.02

The model accounted for 27 percent of the overall variation (probability of a larger F < 0.01). The variables in this model are almost identical to those of the previous model for percent of total regeneration in target oak species, as might be expected. In terms of the hypothesis variables, again residual stand characteristics appear unrelated to oak regeneration amount. Site characteristics as represented by the aspect/slope variable appear significant. In this case the data-determined optimum for aspect is 44°; the consistency for this variable between the two models and with an established standard supports the reasonableness of the models overall. Again the model for percent of dominant regeneration in target oaks suggests that clearcutting negatively impacts oak establishment although the provisos listed above must be strongly considered.

Beyond the variables that appeared in the analysis of covariance models and their interpretations, it is significant to note what variables failed to appear in the final models. These include age, percent oak species in removals, and the percent of oak in the border. Range of the age variable in the data and the use of feet of height rather than stems per acre probably account for the noticeable absence of age. That composition of the parent stand and neighboring stands seemingly had no impact on the percent of target oak species in the observed regeneration is quite surprising but suggests that attributes of the site and harvesting operation methods (as well as factors not included in the study such as weather and acorn crop quantity) may be of greater importance.

The results from this study provide a starting point for developing recommendations on manipulating harvest practices to encourage oak regeneration or indicate the nature of sites on which we can expect better oak regeneration. The models developed in the study can be useful as regeneration components of larger growth and yield systems that are used in stand management planning. It cannot be over-emphasized that the observational nature of the study puts great restrictions on our ability to draw explicit inferences. The results might best be interpreted as hypothesis generation rather than hypothesis confirmation mechanisms. The need for followup designed studies is great. Over the next two years scientists involved in other parts of this project will begin to install some of these studies using LCMR funding.

Two important pieces of information were missing from the present work that could have proved helpful in further untangling the variation associated with oak regeneration success rate. The first was reliable information on quantity and quality of the acorn crop over the past decade. Only fragmented information was available, insufficient to be effective in our analyses. An effort is now underway to establish a network of recording stations so that such information will be available in the future. The second type of information that was lacking was site specific weather data. Given the sites were put in "after the fact" this is not surprising. The paucity of weather stations also makes this whole question problematic. However, in an unrelated study being conducted by the investigator, generated weather data, based on newly developed statistical techniques for extending the usefulness of sparse weather station data, is being tested for its ability to predict tree growth variation. If that work is successful the method will be applied to the data base collected in this study to see if the models presented above can be refined.

A final difficulty encountered in the study was with stump data collected on the central 1/20-acre plot at each sample location. "Dead" (non-sprouting) stumps appeared to be under-counted by roughly 25 percent. Heavy brush closure on such a large plot makes reliable location of such stumps nearly impossible. In the future, smaller, more numerous plots, like the satellite plots used for tallying regeneration, should be used to observe stump sprouting. The research assistant charged with this aspect of the study plans on revisiting the sites to attempt to correct this problem as initial analyses of stump sprouting success demonstrated encouraging results. Such information would be as, or possibly more, useful than that obtained from the analysis of the oak regeneration data.

Species/Hybrid Identification: Lab isozyme analysis of the data indicated results similar to a study of oaks in northeastern Wisconsin. Three isozymes were found to be useful in distinguishing between the three red oak species and their various hybrids while only one isozyme was needed to differentiate northern red and black oak. Preliminary application of the RAPD molecular marker technique confirmed these results with three markers required to differentiate between species.

The lab results confirm that we were successful in obtaining pure and hybrid samples in our field work. Field identification by the U.S. Forest Service expert were highly correlated with lab results. Quantitative morphometric indices are being constructed by a scientist at Indiana University using our sample materials. These two sources will be used to develop more detailed field keys that will enable foresters to better identify pure northern red oak and various hybrids in the field.

This part of the project was quite small and funded at a minimum level. An attempt was made to capture existing expertise and apply it to Minnesota's oak forest regeneration problems. The results were very encouraging and have led us to plan for a more intensive field data collection effort. That effort is being funded by LCMR and will concentrate on studying the relationship between regeneration species composition and that of the parent and residual stand after harvests of various types. This will both extend and build on the positive results obtained to date for study of this problem.

6. BENEFITS

Reliable information obtained in a defensible manner is a prerequisite for identifying the true nature and extent of the oak regeneration problem. The proposed research will provide a start toward answering that need in southeastern Minnesota. Study of site and other factors as they relate to observed regeneration will aid managers in their prescription of appropriate harvest treatments. Since permanent plots will be established as part of this study, important future monitoring efforts will be possible; future monitoring of study sites as they develop into timber stands will allow economic aspects of the regeneration problem to be more fully addressed.

C. TITLE: Educating woodland owners, loggers, and youth about oak management

1. NARRATIVE

Most oak woodlands are owned by nonindustrial private woodland owners. They commonly own woodlands as part of a farm or for recreation, wildlife, or fuelwood harvesting. Only a small percentage use the services of a forester at the time of harvest and owners generally are not knowledgeable about management practices that will encourage oak regeneration. Timber is harvested by loggers who generally are not informed about the impact of timber harvesting on oak regeneration. Our youth will in the future own woodlands and need to begin learning principles of forest management. Educational programs are planned to inform private woodland owners, loggers, and youth about how to manage hardwood stands and maintain oaks as an important component of these stands.

2. PROCEDURES

An extension forester will be hired to work in a seven-county area in southeastern Minnesota. This forester will develop educational materials and will conduct meetings, workshops, conferences, and other educational programs on hardwood forest management. Educational programs will focus on private woodland owners, loggers, and youth. The educational content of these programs will cover hardwood management for multiple-uses. There will be an emphasis on managing hardwood stands to perpetuate oaks as a significant component. Educational programs will be coordinated with the Minnesota Department of Natural Resources which is scheduled to receive an LCMR grant to increase technical assistance to private forest landowners in southern Minnesota for oak regeneration. This extension forester also will assist with data collection described under Objective A.

3. BUDGET

A. Amount budgeted: $117,310
B. Balance: $ 0

4. TIMELINE

TIMELINE	July91	Jan92	June92	Jan93	June93
Form advisory committee	--				
Conduct search to fill position	---				
Workshops and field tours for loggers and landowners		------------		-------------	
Recruit and train 4-H forestry project leaders		-------		-----------	
Assist with collecting plot data from field trials planned under Objective A			----------		

5. STATUS: Through July 1, 1993

One of our primary goals was to provide forest management information to private woodland owners in a 7-county area in southeast Minnesota to enable them to make informed judgments about regenerating and managing hardwood forests. We conducted approximately 48 educational events aimed at private woodland owners and reached approximately 600 landowners. Our goal was to reach 1,200 landowners, but attendance at events was lower than anticipated despite intensive publicity. We tried to reach new landowners that had not previously obtained forestry assistance and therefore did not use landowner mailing lists consisting of Department of Natural Resources cooperators. We advertised by directly mailing brochures about upcoming events to rural landowners; placing posters on bulletin boards at numerous public places; placing announcements in newsletters produced by the MN Extension Service, Soil and Water Conservation Districts, and the Agricultural Stabilization and Conservation Service; and sending written news releases to area newspapers.

We wanted to reach at least 500 youth with forest management information so that they would understand basic forestry concepts and issues, and learn about careers in natural resource management. We held approximately 27 events for youth and youth educators, eventually reaching approximately 2,370 youth and 210 educators with information about forestry.

Although we wanted to reach a high percentage of loggers in southeast Minnesota with information about hardwood management and regeneration, our contacts with several logging firms indicated that this audience was not interested in spending time learning about forestry. This was disappointing since their long-term livelihood depends on sustainable forest management.

A meeting was held with sawmill owners to find out how they thought we could reach loggers. They were not encouraging, but they did agree to forward to us the names of landowners for whom their loggers had harvested timber so that a forester could contact the landowners and offer forest management and regeneration assistance. Only about fifteen percent of the landowners in southeastern Minnesota use the services of a forester to help them manage and market timber. This is a continuing problem, since loggers are not well-informed about how to harvest timber to ensure adequate natural regeneration of desirable tree species. High-grading of timber is commonplace.

We took advantage of every opportunity to reach community leaders and conservation-minded people with information about forestry issues and management concerns in southeast Minnesota. Some of these people own forest land, but otherwise many are in a position to influence public attitudes about forestry. We believe it is important that community leaders and the public understand basic principles of natural resource management. Approximately 58 educational events were reached over 1,670 people with forestry information. These ranged from members of civic clubs and sportsman's organizations to elected officials and natural resource management professionals. In the future we will spend much more effort speaking to sportsman's associations that are interested in wildlife management.

This educational program will continue for two more years under a new LCMR project, Developing Quality Hardwood Forests. Our primary target audience will continue to be private woodland owners. We will use land ownership records in selected county courthouses to develop a list of woodland owners. This will enable us to target our publicity for educational events more directly. We will continue to hold workshops for landowners. We also will initiate a pilot educational project that involves direct mailing forestry publications to a random selection of private woodland owners with follow-up mailings made to landowners who request additional information. Not all landowners want to attend meetings, but some may be willing to learn on their own by reading publications or viewing videos. We also will survey landowners who participated in previous forestry education events to learn what impact those events had on their management decisions.

Our youth education events will continue, but we will focus more on providing in-depth forestry information to fewer youth. We especially will try to recruit more adult leaders for the 4-H Forest Resources Project because they will then continue our educational work into the future.

We will continue to look for ways to reach loggers, but this is a difficult audience to reach. The Timber Producers Association is considering development of a logger certification program. Such a program may lead to better opportunities for educating loggers about the impacts of timber harvesting on forest regeneration.

Educational events we conducted during the last two years for various audiences are described below.

EDUCATIONAL EVENTS FOR WOODLAND OWNERS

October 24, 1991. Helped conduct open forum on the need for a regional forestry association. Co-sponsored with Minnesota Forestry Association. Rochester. 45 attended.

November 22, 1991. Gave 20-minute presentation on oak regeneration during tour held on Houston County Forestry Day. Caledonia. 65 woodland owners and foresters attended.

May 21, 1992. Helped conduct 2-hour forestry tour as part of Goodhue County Forestry Day. Event sponsored by DNR and MN Extension Service. 75 woodland owners and foresters attended.

May 30, 1992. Conducted a day-long oak conference including lectures and a field tour. 60 woodland owners attended.

September 12, 1992. Helped conduct forestry tour as part of Winona County Forestry Day. Event sponsored by DNR, ASCS, and MN Extension Service. 15 woodland owners and foresters attended.

September 14, 15, 16, 17, 22, 23, 24 and 26, 1992. Three-hour educational program on developing a forest stewardship plan was held in 8 locations in 7 counties in southeast Minnesota. 50 woodland owners and other adults attended.

October 12, 13, 14 15, 20, 21, 22 and 24. Three-hour educational program on forest recreation opportunities and management was held at 8 locations in 7 counties in southeast Minnesota. 60 woodland owners and other adults attended.

October 16, 1992. Forty-minute presentation on oak regeneration given at Fillmore County Soil and Water Conservation District banquet. 50 attended.

January 11, 12, 13, 14, 19, 20 and 21, 1993. Three-hour educational class on wildlife management offered at 7 locations in 7 counties in southeast MN. 70 woodland others and other adults attended.

February 17, 1993. Gave 20-minute presentation on forestry best management practices to protect water quality as part of an evening water quality class. 8 landowners attended.

March 8, 9, 11, 15, 16, 17, 18, and 20, 1993. Three-hour educational seminar on oak management conducted at 8 locations in 7 county area. 60 woodland owners and other adults attended.

April 3, 1993. Gave 2-hour presentation on property taxes to Metro Area Tree Farmers. Arden Hills. 30 woodland owners and foresters attended.

May 10, 11, 12, 13, 18, 19 and 20, 1993. Conducted 7 forestry tours in each of 7 southeastern MN counties to show oak regeneration and management practices. 90 woodland owners attended.

June 9, 1993. Set up University of MN forestry exhibit at Houston County Forestry Day--Fairgrounds and distributed information and brochures on forest management.

EDUCATIONAL EVENTS FOR YOUTH AND EDUCATORS

January 15, 1992. Twenty-minute talk about forestry education to Principals Around Rochester. Rochester Holiday Inn South. 20 school principals attended.

September 3 and 4, 1991. Spent two days at Wolf Ridge Environmental Learning Center reviewing curriculum including tree keys and forest management activities. Finland, MN.

September 23, 1991. Helped organize and conduct Conservation Day activities sponsored by Fillmore County Soil and Water Conservation District. All Fillmore County sixth graders came to the Forest Resource Center where they stopped at six different stations to learn about forestry, wildlife management, soils, and hazardous waste. 360 youth.

September 24, 1991. Met with Southeast District 4-H agents to discuss LCMR funded oak regeneration and management project and the new 4-H Forest Resources Project materials. Owatonna. 10 agents attended.

October 18, 1991. Conducted workshop for teachers on using 4-H Forest Resources Project manuals. Forest Resource Center, Lanesboro. 6 teachers.

November 13, 1991. Met for 30 minutes with Principals Around Rochester to explain LCMR funded oak regeneration and management project and how we could work together. Rochester. 25 school principals attended.

May 8, 1992. Completed 30-minute presentation on hardwood management to southeast Minnesota Science Teachers. Forest Resource Center, Lanesboro. 28 attended.

May 16, 1992. Conducted one-hour training session on new 4-H forestry manuals at 4-H District Project Day sponsored by Southeast District 4-H program. 4-H Building, Olmsted County Fairgrounds, Rochester. 12 attended.

June 6, 1992. Two-hour presentation on forestry related materials to Southern MN Environmental Education Council. Forest Resource Center, Lanesboro. 9 attended.

June 21-27, 1992. Helped conduct week-long Forkhorn Camp co-sponsored with MN Deer Hunters Association. Taught 6 hours of classes on forest management and water quality. 15 attended.

August 7, 1992. Conducted day-long workshop, Natural Resources in the Classroom, co-sponsored with DNR. Forest Resource Center, Lanesboro. 12 attended.

August 19, 1992. Conducted a day-long Forest Heritage Program in which youth and adults from Fillmore, Houston, and Winona Counties received training in forest management for multiple uses; trees were harvested and taken to a sawmill where they were sawn into lumber; participants then used the lumber to make products. Spring Grove. 30 youth and adults attended.

September 7, 1992. Conducted day-long workshop, Natural Resources in the Classroom, co-sponsored with DNR. 8 attended.

September 30, 1992. Helped design and conduct Regional Future Farmers of America Forestry and Soils Contest. Forest Resource Center, Lanesboro. 180 youth attended.

October 23, 1992. Conducted workshop on Project Learning Tree/Project Wild. Forest Resource Center, Lanesboro. Forest Resource Center, Lanesboro. 12 teachers attended.

November 11, 1992. Gave tour of forestry demonstrations at the Forest Resource Center to River Bend Nature Center staff. Forest Resource Center, Lanesboro. 18 attended.

November 13 and 14, 1992. One-hour presentation on forest management and the Forest Resource Center at MN Naturalist Association Meeting. Forest Resource Center, Lanesboro. 60 attended.

December 8, 1992. Three-hour review of forestry demonstrations for Hormel Nature Center staff. Forest Resource Center, Lanesboro. 15 attended.

April 27, 1993. Gave 20-minute forestry presentation at Fillmore County Ag Extravaganza. Forest Resource Center, Lanesboro. 350 youth attended.

April 28, 1993. Gave 20-minute forestry presentation at Houston County Ag Extravaganza. Eitzen. 180 youth attended.

May 3-4, 1993. Gave six thirty-minute talks about tree identification, reforestation, and forestry issues at Winona County Ag Extravaganza. Lewiston. 400 youth.

May 6, 1993. Gave six thirty-minute talks about tree identification, reforestation, and forestry issues at LeSeuer County Ag Extravaganza. Sacatah State Park. 120 youth.

February 9, 1993. Eight kids interested in career opportunities in forestry assisted for 6 hours in completing forestry demonstration work during Chatfield Rotary Shadow Days.

May 15, 1993. Gave 20-minute talk and demonstration on tree identification at southeast MN Boy Scout Camporee. 650 youth.

June 20-26, 1993. Taught 3-hour forest management class at Fork Horn Camp co-sponsored by MN Deer Hunters Association. Forest Resource Center, Lanesboro. 13 youth.

June 27-July 2, 1993. Conducted 6-day Forests for the Future Summer Camp to teach youth about multiple-use management of forests. 40 youth.

Worked with Olmsted County Extension Office, two teachers, and the school principal to design a five-acre "school forest" for educational use at the Elgin/Millville Elementary School. Five thousand dollars were raised for planting from local sources and the Minnesota Releaf Program.

EDUCATIONAL EVENTS FOR LOGGERS

September 19, 1991. Met with sawmill owners in southeast MN to discuss how we can work together. They agreed to provide names of landowners for whom they recently had harvested timber so that a DNR forester could contact landowners and offer regeneration and management assistance. Forest Resource Center, Lanesboro.

A logger safety and communication workshop was planned in cooperation with the Timber Producers Association and Duluth AVTI. Duluth AVTI had the leadership role, but it did not publicize the event in a timely manner. Workshop was cancelled for lack of logger participation.

EDUCATIONAL EVENTS FOR OTHERS

September 5, 1991. Joined U of MN President Hasselmo on his tour of Winona County. Had ten minutes to explain Extension's role in LCMR funded project on oak regeneration and management. Winona.

September 10 and 11, 1991. Participated on interagency team organized by the Department of Natural Resources to inspect use of best management practices for water quality on timber harvest sites in southeast MN. Caledonia and LaCrescent.

September 16, 1991. Participated in meeting of county extension educators in Clusters 17 and 18. Discussed plans for educational programs under the LCMR funded oak regeneration and management project. Rochester.

September 25, 1991. Helped produce video tape that briefly described LCMR funded oak regeneration and management project. Tape used to update county extension committees on extension programs. Nerstrand Woods, Faribault.

September 26, 1991. Conducted two-hour forestry tour and talk to Rochester Izaak Walton League. Forest Resource Center, Lanesboro. 25 attended.

September 28, 1991. Talked about forest management for 30 minutes as part of Minnesota Mycological Association's fall mushroom hunt. Forest Resource Center, Lanesboro. 25 attended.

October 2, 1991. Met with Cluster 17 Extension Advisory Committee and gave 15-minute review of LCMR funded oak regeneration and management project. Rushford. 40 attended.

October 9, 1991. Met with Forestry Advisory Committee for LCMR oak regeneration and management project to outline education workplan for the upcoming year. Rochester. 12 attended.

October 28, 1991. Participated in southeast MN tourism meeting to review what is happening and to identify the players. Bluff Country, Trail Town, Office of Tourism, and MN Extension Service staff attended. Forest Resource Center, Lanesboro. 6 attended.

November 1, 1991. Legislator update. Met with Virgil Johnson, Elton Redalen, Steve Morse, Duane Benson, Greg Davids, and Jim Brooks--DNR to review forestry situation and work plan for educational activities to be conducted under LCMR funded oak regeneration and management project. Rochester.

During 1992 we served on an interagency MN ReLeaf Committee to evaluate funding proposals and allocate $110,000 in state funds to cities and organizations in southeast Minnesota to encourage energy savings through the use of trees.

January 22, 1992. Gave twenty-minute presentation on oak regeneration to Spring Valley Kiwanis. Spring Valley Community Center. 32 attended.

February 4, 1992. Gave thirty-minute talk to Winona County Professionals on oak regeneration and what we expected to do in this LCMR funded oak regeneration and management project. Recreation Cafe, Lewiston. 18 attended.

February 5, 1992. Gave thirty-minute talk to Wykoff Lions and their spouses about forest management and oak regeneration. Forest Inn, Wykoff. 48 attended.

February 7, 1992. Gave guided tour of Forest Resource Center's wood waste system as part of the Wood Waste Tour sponsored by the MN Department of Energy. Also talked about oak regeneration. Forest Resource Center, Lanesboro. 96 attended.

February 13, 1992. Talked to South Metro Chapter of Minnesota Deer Hunters Association on oak regeneration and its importance to the deer herd. Richfield. 78 attended.

March 6, 1992. Guest speaker for World Women Concerned for the Environment. Similar meetings were going on world wide to improve awareness of environmental issues. Approximately 40 people met in rural Lanesboro.

March 31, 1992. One-hour presentation to forestry vendors on timber stand improvement as part of day-long Vendor Training Workshop sponsored by the MN DNR, Division of Forestry. Elk's Club, Rochester. 40 attended.

April 1, 1992. Talked to DNR Regional Fisheries managers about forest management issues for 30 minutes. Forest Resource Center, Lanesboro. 12 attended.

April 7, 1992. Day-long Farm Business Managers Workshop on forest management was conducted. Gave talks on oak regeneration, timber marketing, harvesting systems, and timber tax laws. A two-hour tour of forestry demonstrations followed. Forest Resource Center, Lanesboro. 9 farm management consultants attended.

April 20, 1992. Talked for 15 minutes on oak regeneration issues at a Town Meeting on regional concerns hosted by U.S. Representative Tim Penny. St. Charles. 45 attended.

April 23, 1992. Gave 30-minute presentation on forest management issues to southeast Minnesota Farm Bureau Agents. Forest Resource Center, Lanesboro. 18 attended.

June 5, 1992. One-hour forestry presentation during corporate retreat for AFC at Chatfield. Forest Resource Center, Lanesboro. 20 attended.

June 12, 1992. Participated in 4-hour discussion and tour on hardwood forest management with MN Soil and Water Conservation District Forestry Committee. Forest Resource Center, Lanesboro. 40 SWCD staff attended.

June 23, 1992. Led one-hour forestry hike for Wykoff and Peterson Garden Clubs. Forest Resource Center, Lanesboro. 27 attended.

June 25, 1992. Three-hour program on forest management and wood utilization for the Rockler Companies--The Woodworker Store to help their sales people understand that we can harvest and regenerate trees. Forest Resource Center, Lanesboro. 52 attended.

July, 1992. Conducted forestry tour for southeastern MN county commissioners and state legislators. 9 attended.

July 8, 1992. Thirty-minute presentation to DNR Regional Forestry staff on the LCMR funded extension forestry program in southeast Minnesota and what we have accomplished. Forest Resource Center, Lanesboro. 8 attended.

July 14, 1992. General forestry presentation to Rochester Exchange Club. 62 attended.

July 20, 1992. Led one-hour forestry hike as part of Science Museum-information tour on southeastern MN. 48 attended.

July 23, 1992. One-hour presentation on oak regeneration to Southern Conservation Society. 42 attended.

August 6, 1992. Thirty-minute talk on forestry to Chatfield Rotary. 28 attended.

August 8, 1992. Talk on forestry to Lanesboro Lions. Forest Resource Center, Lanesboro. 36 attended.

August 10, 1992. One-hour presentation on status of forestry in southeastern MN given to MN Department of Agriculture-Strategic Planning Session. Forest Resource Center, Lanesboro. 22 persons.

August 17, 1992. Day-long seminar and tour on forest management and timber taxes for Farm Business Managers. Forest Resource Center, Lanesboro. 11 attended.

September 2, 1992. Talked on oak regeneration to Soil and Water Conservation District staff from southeast MN. Forest Resource Center, Lanesboro. 21 attended.

September 21, 1992. Conducted forestry tour as part of day-long Ag Perspectives Short Course for personnel in Department of Natural Resources, Department of Agriculture, Pollution Control Agency. Goodhue County. 34 attended.

September 21, 1992. Forty-minute presentation on forestry issues in southeast Minnesota at Lions District Meeting. Forest Resource Center. 27 attended.

October 6, 1992. Twenty-minute presentation explaining LCMR project on oak management and regeneration given to county extension educators at Cluster 17 Extension Committee Meeting. Forest Resource Center, Lanesboro. 35 attended.

November 10, 1992. Thirty-minute presentation on forest management and the Forest Resource Center given to American Cancer Society. 14 attended.

November 10, 1992. Forty-five minute presentation on forest management, oak regeneration, and deer management given to Hayfied Chapter of MN Deer Hunters Association. Hayfield. 20 attended.

December 10, 1992. Helped design curriculum for single parent camp scheduled for July 3-5, 1993. Aimed at single parents in southeast MN. Curriculum includes environmental education and parenting skills. Winona County.

December 15, 1992. 10-minute interview about oak regeneration on KRCH Radio--Rochester.

January 25, 1993. Thirty-minute presentation on value of windbreaks and shelterbelts at Hiawatha RC&D meeting. 40 attended.

February 4, 1993. 40-minute presentation on forest management to Chatfield Lions Club. 30 attended.

February 17, 1993. Participated in Forest Stewardship Education Committee meeting to review funding proposals for educational projects aimed at private woodland owners. U of MN St. Paul Campus.

February 24, 1993. Presented an update on accomplishments of LCMR forestry project at meeting of county extension educators in Cluster 17 meeting in Preston.

March 2, 1993. One-hour presentation on oak regeneration and forest management given during MN Soil and Water Conservation District Tour. Forest Resource Center, Lanesboro. 40 SWCD staff, county commissioners, legislators attended.

March 26 and 27, 1993. Set up forestry exhibit at MN Deer Hunters Association convention and distributed brochures on oak regeneration and upcoming forestry camp for youth. Alexandria. 200 attended.

March 29, 1993. Participated in Forest Stewardship Committee meeting to judge funding proposals for technical assistance and education projects aimed at private woodland owners. St. Cloud.

March 29, 1993. Participated in Cluster 18 county extension meeting. Used forest products display, explained LCMR forestry project, talked with two county committees (Goodhue and Wabasha). Rochester.

April 5, 1993. Gave 40-minute presentation on forestry in southeast MN at Historic Bluff Country monthly meeting. Forest Resource Center, Lanesboro. 50 attended.

May 13, 1993. Gave 40-minute presentation on forest management to Golden Kiwanis. Red Wing. 64 attended.

May 21 and 22, 1993. Conducted four-hour tour about forestry and oak regeneration for Tuohy Furniture sales representatives. 62 attended.

May 28, 1993. Met with Houston City Planning Committee and other officials to review park restoration and development plans for land acquired by the City of Houston in the late 70's.

June 7, 1993. Gave 30-minute presentation on status of forests in southeast MN to Wykoff Progress Club. Forest Resource Center, Lanesboro. 19 attended.

June 8, 1993. Gave 50-minute presentation on status of forests in southeast MN to Rushford Historical Society. 16 attended.

June 15 and 16, 1993. Participated in two-day meeting on feasibility of alternative woody agriculture crops. Co-sponsored with University of Minnesota Center for Alternative Plant and Animal Products. May result in grant proposal to study alternative crops. Forest Resource Center, Lanesboro. 52 attended.

6. BENEFITS

We estimate that a high percentage of the loggers in southeastern Minnesota and 1,200 woodland owners will be informed about the latest recommendations for managing hardwood stands to maintain oaks. Approximately 25 woodland owners will receive 40 hours of forestry training in return for providing 50 hours of volunteer service in educating other landowners and youth about up-to-date forestry practices. An estimated 500 youth will be better informed about how to manage woodlands for multiple-uses. The long-term consequences are that hardwood stands will be better managed to perpetuate oaks. These hardwood stands will continue to produce oak wood products, acorns for wildlife, and forest cover for watershed protection.

IV. EVALUATION

In the short term this project can be evaluated by our ability to (1) identify artificial regeneration practices that increase oak regeneration; (2) identify stand conditions, site conditions, and harvest practices that are likely to lead to better natural regeneration of oak; (3) provide educational programs onhardwood management that reach approximately 1,200 woodland owners, a high percentage of loggers in southeast Minnesota, and 500 youth.

In the long term this project can be evaluated by the increase in hardwood stands successfully regenerated to oak as a result of actions by the persons who participate in or make use of materials produced by this project.

V. CONTEXT: RELATED CURRENT AND PREVIOUS WORK

A. In regard to Objective A, very limited research has been conducted on regenerating Minnesota's oak resource. Field research on different oak regeneration methods currently is being conducted in northern Wisconsin and southern Iowa. These are new studies for which data have not been collected and analyzed. They are in regions which have different soils, site characteristics, and climate from southeastern Minnesota.

In regard to Objective B, a similar study was carried out in southwestern Wisconsin, southeastern Minnesota, and northeastern Iowa in the early 70s. However, this study focused solely on clearcut sites, whereas much logging in southeastern Minnesota is better characterized as diameter limit (single-tree selection) harvesting. The associated species examined also were ones that may be less common in southeastern Minnesota than in Wisconsin and Iowa.

Regarding Objective C, there have been a few conferences and field tours in southeastern Minnesota over the past few years which provided information to private woodland owners about oak management, but relatively few owners have been reached by these events. There has been no training of loggers on hardwood management and youth forestry activities are currently very minimal. The Minnesota Extension Service currently is producing a slide program, video, and several publications on oak management with funds from the U.S. Forest Service. An extension agent is needed to organize and conduct educational programs that will reach out to landowners and loggers with these new materials. 4-H Forest Resources project materials are under development, but there is no staff person to recruit and train volunteer leaders to use the materials.

B. Oak regeneration research proposed under Objective A will test regeneration methods that have been successful in a few cases in nearby states, but which have not been tested in southeastern Minnesota where growing conditions and species compositions differ. The survey of oak regeneration under different harvesting practices proposed under Objective B will examine oak regeneration under a wider range of harvest practices than were examined by previous studies and it will focus on species mixes common to southeastern Minnesota. The extension agent to be hired under Objective C will disseminate educational materials on oak management that are being developed for landowners and loggers under another federal grant. This agent also will conduct conferences, workshops, field tours, and other events that could not be offered with the existing extension staff level. The agent also will recruit and train volunteer leaders to increase enrollment in the 4-H Forest Resources project.

C. LCMR has not previously funded research or education programs concerning oak regeneration and management. The Minnesota Department of Natural Resources and University of Minnesota, Department of Forest Resources currently are cooperating on a small-scale research study on the effects of site scarification on red oak regeneration. This is a short-term study on just one site. It focuses on how to encourage more natural oak regeneration, while the proposed new research focuses on artificial regeneration. The Minnesota extension service has conducted one conference and several field tours on oak management over the previous five years for landowners in southeast Minnesota. These events have reached relatively few landowners.

Potential future LCMR proposals may request funds for more oak regeneration research, depending on the results of this current LCMR project. The current project does not permit us to test as wide a range of sites or as many different management practices as we believe should be tested in order to learn how to regenerate oaks on different sites and under different stand conditions. This project's two-year duration also is too short a time period to satisfactorily evaluate the full impact of some cultural practices.

D. Not applicable

VI. QUALIFICATIONS

1. <u>Program Manager and Principal Investigators</u>

Dr. Steven B. Laursen, Natural Resources Program Leader and Associate Professor, Minnesota Extension Service, University of Minnesota.
Ph.D. Forest Science, University of Idaho, 1984; M.S. Forest Resources, University of Idaho, 1979.

Dr. Laursen worked for 5 years as a researcher and instructor in forestry and computer science at the University of Idaho as an Extension Specialist and Assistant Professor at Montana State University. and served as programmatic and administrative leader for Minnesota Extension Service natural resources programs from 1988-1993. He currently serves as Assistant Dean for Outreach in the College of Natural Resources. He has published articles in forest pest management, ecological modeling, urban forestry, and leadership. His primary role will be in coordination of the entire project and as a cooperator in the implementation of Objective C.

Dr. Melvin J. Baughman, Extension Specialist--Forest Resources and Associate Professor, Department of Forest Resources, University of Minnesota.
Ph.D. Forest Policy & Economics, University of Minnesota 1982; M.S. Forest Recreation, Michigan State University, 1971.

Dr. Baughman has 16 years experience in extension forestry including over 6 years field experience advising individual private woodland owners about hardwood forest management. He has published articles on forest economics in refereed journals. His current research includes a study of the effects of site scarification on red oak regeneration. Currently he also is producing a slide-tape program, video tape, and several publications on oak management for private woodland owners and loggers. He will participate in carrying out Objectives A and C.

Dr. Alvin A. Alm, Professor, Department of Forest Resources, University of Minnesota.
Ph.D. Forestry, University of Minnesota, 1971; M.S. Forestry, University of Minnesota, 1965.

Dr. Alm has 25 years of experience in field regeneration research primarily with northern conifers. He is the author of over 100 scientific and technical publications on that and other subjects of silvicultural interest. He is a University of Minnesota research project leader and has advised a number of graduate students in silvicultural research. His primary role will be to participate in the accomplishment of Objective A.

Dr. Thomas E. Burk, Associate Professor, Department of Forest Resources, University of Minnesota.
Ph.D. Forest Biometrics, University of Minnesota, 1981; M.S. Statistics, University of Minnesota, 1980.

Dr. Burk's expertise is in resource assessment and modeling. He has previous research experience with the hardwood resource of the southern Appalachians. He has extensive experience in the design of field studies and is Research Chair of the Great Lakes Forest Growth and Yield Cooperative. Dr. Burk's primary role will be to lead the accomplishment of Objective B.

<u>Publications Related to Hardwood Research:</u>

Harrison, W.C., T.E. Burk and D.E. Beck. 1986. Individual tree basal area increment and total height equations for Appalachian mixed hardwoods after thinning. So. J. Applied For. 10:99-104.

Bowling, E.H., H.E. Burkhart, T.E. Burk and D.E. Beck. 1989. A stand-level, multi-species growth model for Appalachian hardwoods. Can. J. For. Res. 19:405-412.

2. <u>Cooperators/Other Investigators</u>
Bob Pajala, Silviculturist, Minnesota Department of Natural Resources

Rodney Jacobs, Hardwood Forest Management Consultant (retired from USDA, Forest Service)

Jud Isebrands, Tree Physiologist and Red Oak Regeneration Project Leader, USDA Forest Service, North Central Forest Experiment Station

VII. REPORTING REQUIREMENTS

Semiannual status reports will be submitted not later than January 1, 1992, July 1, 1992, January 1, 1993 and a final status report by June 30, 1993.