Posters

SOIL SAMPLING ON SURFACE MINED SPOILS: SYSTEMATIC VS. SYSTEMATIC-COMPOSITE VS. RANDOM

William R. Thomas, Matthew Pelkki and James Ringe[1]

Abstract—When sampling soils, there is a balance between complete and adequate description of the resource and the sampling effort. Any technique that can reduce the cost of sampling without reducing its descriptive value is worthwhile. This problem is especially relevant when dealing with surface mine spoil. Mining procedures result in spoils with greater heterogeneity than agricultural soil or naturally developed forest soils. Most soil sampling techniques have been developed with intensively managed annual crops in mind, and the ones that deal with surface mine lands allow a composite sample to represent from 5 to 20 acres (Evangelou and Barnhisel 1981). However, research plots are much smaller and verification of soil attributes requires greater precision. Three different sampling techniques (systematic, systematic-composite, and random) were used on translocated surface mine spoil in eastern Kentucky and evaluated for similarities in their ability to describe soil characteristics.

METHODS

The spoil was moved from above the coal seam and placed into overburden piles which were then moved again and deposited into research plots. This translocation caused a mixing of the original topsoil and parent rock material. Based on this expected heterogeneity, we felt that systematic sampling would provide the best description of the soil attributes. From this baseline we compared systematic-composite and random sampling, which reduced the costs of sampling.

The systematic sampling consisted of five samples taken from each of nine research plots. A composite sample was taken from the five systematic samples and a separate random sample was taken from each plot. All samples were submitted for analysis of eleven parameters: organic matter, phosphorus, potassium, calcium, magnesium, pH, nitrate nitrogen, soluble salts, total nitrogen, sodium, and water holding capacity. A 95 percent confidence interval was established for the eleven parameters based on the systematic sample. If systematic-composite or random sampling can provide means for the eleven parameters that are within the 95 percent confidence interval for the systematic sample, these lower cost methods are preferable.

RESULTS AND DISCUSSION

While the outcome can be influenced by the soil parameters chosen, these parameters are typical in surface mine reclamation. Of the eleven parameters measured on the nine plots, three of the systematic-composite samples and eight of the random samples fell out of the systematic sample confidence interval (Table 1). The results indicate that a significant time and cost savings (Table 2) can be realized if systematic-composite sampling is used. Random samples offer a lower degree of statistical precision while only providing marginal cost savings over systematic-composite samples.

REFERENCES

Evangelou, V.P.; Barnhisel, R.I. 1981. Sampling surface mine lands before and after mining. Ext. Publ. AGR-41. University of Kentucky.

Table 1—Soil sampling parameters falling outside the 95 percent confidence interval established by the systematic sampling

Research plot	Systematic composite	Random
1	None	Organic matter
		Calcium
		Total nitrogen
2	None	None
3	None	None
4	None	None
5	None	Organic matter
6	Sodium	Sodium
	Water holding capacity	Water holding capacity
7	None	None
8	None	Phosphorus
9	Water holding capacity	Water holding capacity

[1] Research Assistant and Associate Professors, respectively, Dept. of Forestry, University of Kentucky, Lexington, KY 40546.

Citation for proceedings: Stringer, Jeffrey W.; Loftis, David L., eds. 1999. Proceedings, 12th central hardwood forest conference; 1999 February 28-March 1-2; Lexington, KY. Gen. Tech. Rep. SRS-24. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southern Research Station. 293 p. [Poster abstract].

Table 2—Soil sampling costs associated with the various soil sampling approaches on a per sample and per plot (20 m^2) basis

Sample method	Field[a]	lab	total	Number of samples	Total cost
	----- *Cost per sample* ----				
Systematic	$1.67	$4	$5.67	5	$28.35
Systematic composite	$2.50	$4	$6.50	1	6.50
Random	$1.67	$4	$5.67	1	5.67

[a] Field costs are based on a wage of $10/hr.

QUAKING ASPEN EMERGENCE AND INITIAL SURVIVAL UNDER DIFFERENT RELATIVE HUMIDITY, MOISTURE, AND SEED PLACEMENT TREATMENTS

L.A. Ahlswede and T.W. Bowersox[1]

Abstract—Quaking aspen (*Populus tremuloides* Michx.) is the most widely distributed tree species in North America. When present in a stand, quaking aspen can be a prolific root sprouter, especially after a disturbance. This seems to be the primary mode of reproduction for the species. A better understanding of the sexual reproduction of quaking aspen is needed to ensure genetic diversity and colonization of new areas.

A study was designed to examine the effects of different relative humidity, moisture and seed placement treatments on the emergence and initial survival of quaking aspen in an environmental chamber. There were a total of six trials in the environmental chamber, each lasting for fourteen days. Either a low (60 percent) or high (90 percent) relative humidity was selected for each trial. A constant temperature of 65° F was maintained for all trials. Three moisture treatments were no additional water, 5 ml every other day, and 10 ml every other day. Seed placement in potting material was at the surface, at 5 mm depth, and at 10 mm depth. Emergent counts were taken after 72, 144, 240 and 336 hours.

Analysis of variance of the environmental chamber study showed that there were significant differences between relative humidity, water, and seed placement treatments. On average, the treatments that had the greatest number of quaking aspen emergents develop and the highest survival were high humidity, 10 ml of water, and seed placement at the surface. This appears to demonstrate the importance of moisture for the establishment of quaking aspen seed.

The moisture and seed placement treatments were applied to a clearcut that was irrigated weekly with 5 cm of treated wastewater. Quaking aspen seeds were planted one day after an irrigation cycle. Moisture treatments of no additional water, 5 ml every other day, and 10 ml every other day were administered. All quaking aspen seed plantings received a second irrigation cycle after six days. Seed placement treatments were the same as in the environmental chamber. Emergents were counted after seven and fourteen days.

Under these conditions, there were no differences in the number of emergents that developed or fourteen-day survival among moisture treatments. However, there was a significant difference among seed placement treatments. Seeds placed at the surface had an average of 83 emergents develop and survive after fourteen days. Seeds placed at the 5 mm and 10 mm depth had an average of 32 and 4 emergents develop and survive, respectively. These studies indicate the opportunity to establish quaking aspen seedlings is greatest when seeds at the soil surface have sufficient moisture. Additional studies are needed to determine precise moisture requirements for the field germination and initial survival of quaking aspen.

---

[1] Graduate Student and Professor of Silviculture, respectively, The Pennsylvania State University, 204A Ferguson Building, University Park, PA 16802.

Citation for proceedings: Stringer, Jeffrey W.; Loftis, David L., eds. 1999. Proceedings, 12th central hardwood forest conference; 1999 February 28-March 1-2; Lexington, KY. Gen. Tech. Rep. SRS-24. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southern Research Station. 293 p. [Poster abstract].

STRATEGIES FOR IMPROVING ESTABLISHMENT AND PRODUCTIVITY OF HARDWOODS PLANTED ON MARGINAL AGRICULTURAL LANDS IN SOUTHERN ILLINOIS

John W. Groninger and James J. Zaczek[1]

Abstract—Low inherent productivity, frequent flooding and changing landowner objectives are rendering much acreage in southern Illinois marginal for row crop production. Owners of these lands are attracted to reforestation by tree planting incentive programs such as the Conservation Reserve Program (CRP) which covers costs associated with site preparation, planting and stand establishment. Continued participation of these lands in set aside programs is often limited by poor survival and slow growth, forcing landowners to return these lands to agricultural production. Further, well-established and productive stands will more likely encourage landowners to retain the stand for the duration of a commercial rotation upon expiration of CRP leases.

Some factors that may be hindering the success of reforestation in southern Illinois include aggressive weed communities, poor matching of species and site, high populations of deer and rodents, and sub-optimal planting stock. A further challenge to foresters in southern Illinois is the transitional nature of its forests making uncertain the applicability of research results from elsewhere in the Central Hardwoods and Southern Bottomland Hardwoods regions. To reduce these uncertainties, we are initiating a series of studies to enhance the survival and productivity of plantings with the goal of producing fully-stocked stands in a minimum amount of time following establishment. All treatments are designed to fall within the budgetary constraints in place on reforestation incentive programs. The following research strategies will be implemented during the coming years as funding and other resources become available.

DEVELOPING LOW COST PRODUCTIVITY PREDICTIONS AND SPECIES SELECTION GUIDELINES FOR FORMER AGRICULTURAL LANDS

Many tree species are sensitive to subtle changes in topography and soil properties in bottomland settings. Failure to recognize these differences may lead to slow growth or regeneration failures. Further, site changes brought about by long-term row crop cultivation may limit the utility of site-species recommendations based on pre-agricultural conditions. Using readily available soil information, existing plantings and the experience of foresters in the region, we are developing recommendations to minimize species-site incompatibilities.

ASSESSING THE NEED FOR HERBICIDAL WEED CONTROL IN FALLOW BOTTOMLAND SITES FORMERLY IN SOYBEAN PRODUCTION

Observations by southern Illinois foresters indicate a divergence of opinions regarding the need for competition control on recently abandoned soybean lands. Some maintain that competing vegetation slows the growth of seedlings while others believe that vegetation control is unnecessary and increases seedling vulnerability to deer damage. We plan to establish vegetation control treatments throughout the region to determine the magnitude of a growth response due to vegetation management. Effects of the timing and duration of vegetation control treatments will also be evaluated. Further analyses will be conducted to determine the cost-effectiveness of these treatments.

OPTIMIZING PLANTING STOCK SELECTION FOR SITE CONDITIONS

Critical for maximizing hardwood planting success is utilizing nursery stock that is properly cultured and conditioned to begin rapid growth soon after planting. Planting stock must be able to not only tolerate but thrive when faced with competition for limited resources such as water, nutrients, or light. Stock must also be resistant to damage from herbivores. Our intent is to investigate the economic and ecological feasibility of using highly cultured and conditioned non-traditional bareroot planting stock for use in the rapid reforestation of marginal agricultural lands. We believe that the extra costs associated with utilizing higher quality planting stock will be offset by savings in post-planting care and maintenance.

STRATEGIES FOR IMPROVING ESTABLISHMENT SUCCESS ON TALL FESCUE-DOMINATED FIELDS

While the antagonistic relationship of tall fescue to hardwood tree species is well recognized, practical control measures are not fully developed. Herbicides newly labeled for forestry applications show potential to aid hardwood establishment but prescriptions to ensure establishment are still lacking. An alternative strategy involves the use of loblolly pine (*Pinus taeda* L.) as a nurse crop to suppress tall fescue and accelerate the growth of interplanted hardwoods. This strategy is especially attractive because profits from the removal of pine may be realized during the lifetime of the landowner.

---

[1] Assistant Professor of Silviculture and Assistant Professor of Forest Ecology, respectively, Department of Forestry, Southern Illinois University, Carbondale, IL. 62901-4411.

Citation for proceedings: Stringer, Jeffrey W.; Loftis, David L., eds. 1999. Proceedings, 12th central hardwood forest conference; 1999 February 28-March 1-2; Lexington, KY. Gen. Tech. Rep. SRS-24. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southern Research Station. 293 p. [Poster abstract].

MODELING LANDSCAPE CHANGE IN THE MISSOURI OZARKS IN RESPONSE TO ALTERNATIVE MANAGEMENT PRACTICES

Stephen R. Shifley, Frank R. Thompson III, William D. Dijak and David R. Larsen[1]

Abstract—Management of Central Hardwood forest ecosystems requires an understanding of how forest landscapes will change under alternative management practices. We calibrated a landscape simulation model, LANDIS, for the Missouri Ozarks and used it to predict changes in forest size structure and species composition that will result from even-aged harvesting, uneven-aged harvesting, and no-harvest management. We simulated forest vegetation response to harvest, fire, and wind disturbance for mapped landscapes ranging from 800 to 25,000 ha in extent in the heavily forested Missouri Ozarks. The most extensive simulations were for a 842-ha mature forest landscape that was inventoried as part of the Missouri Ozark Forest Ecosystem Project.

We simulated three disturbance regimes that differed in the type and intensity of harvest. The first regime simulated even-aged management by clearcutting. Ten percent of the area was harvested each decade with oldest stands harvested first. The second disturbance regime simulated uneven-aged management by group selection. Group openings were created on 5 percent of the area of each stand in each decade. Opening size ranged from 0.1 to 0.3 ha. The third disturbance regime had no harvesting. All three regimes included simulated fire disturbance with a 300-year mean return interval (similar to fire disturbance under current levels of active wildfire suppression) and simulated wind disturbance with an 800-year mean return interval.

Required input maps for the simulation included the initial species and age class of the forest vegetation (derived from an current inventory information), ecological land types, and stand boundaries. Output maps by decade included forest age structure, species composition, type and location of harvest, intensity and location of fire, and intensity and location of wind disturbance. These maps graphically illustrate anticipated changes in forest age structure and species composition through time across the landscape. This information can be used to derive additional maps of forest type and size class (seedling, sapling, pole, and sawlog). Maps of simulated landscape change under alternative management scenarios provide opportunities to view and discuss the spatial implications of management decisions. The digital landscape maps can be further analyzed with a geographical information system to summarize landscape features such as change in forest size distribution through time, patch size, amount and type of forest edge, or other features associated with wildlife habitat quality (figures 1 and 2).

More complicated harvest patterns can be simulated by subdividing any landscape into management areas that each receive a different harvest regime. Although this simulation system will not predict the exact location of future harvest, wind, and fire disturbance events, it predicts expected large-scale vegetation patterns that result from alternative management and disturbance regimes.

[1] Shifley, Thompson, and Dijak are with USDA Forest Service, 202 Anheuser-Busch Natural Resources Building, University of Missouri, Columbia, MO 65211-7260; and Larsen is with the School of Natural Resources, 203 Anheuser-Busch Natural Resources Building, University of Missouri, Columbia, MO 65211-7270, respectively.

Citation for proceedings: Stringer, Jeffrey W.; Loftis, David L., eds. 1999. Proceedings, 12th central hardwood forest conference; 1999 February 28-March 1-2; Lexington, KY. Gen. Tech. Rep. SRS-24. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southern Research Station. 293 p. [Poster abstract].

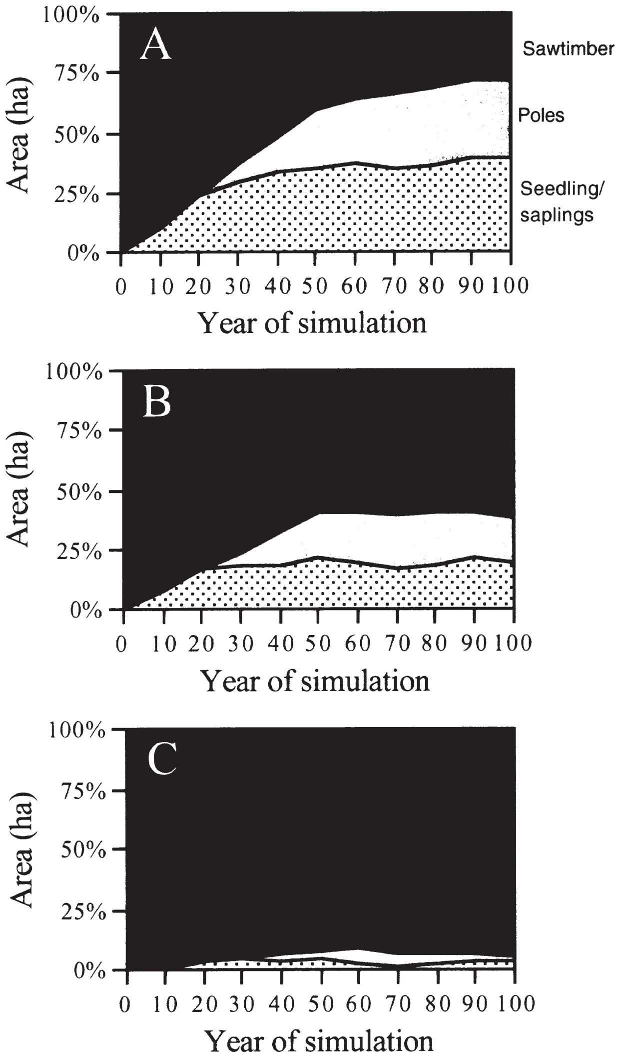

Figure 1—Area by size class over time on an 842-ha upland oak-hickory forest in the Missouri Ozarks under three simulated disturbance regimes: (A) even-aged management; (B) uneven-aged management; (C) no harvest.

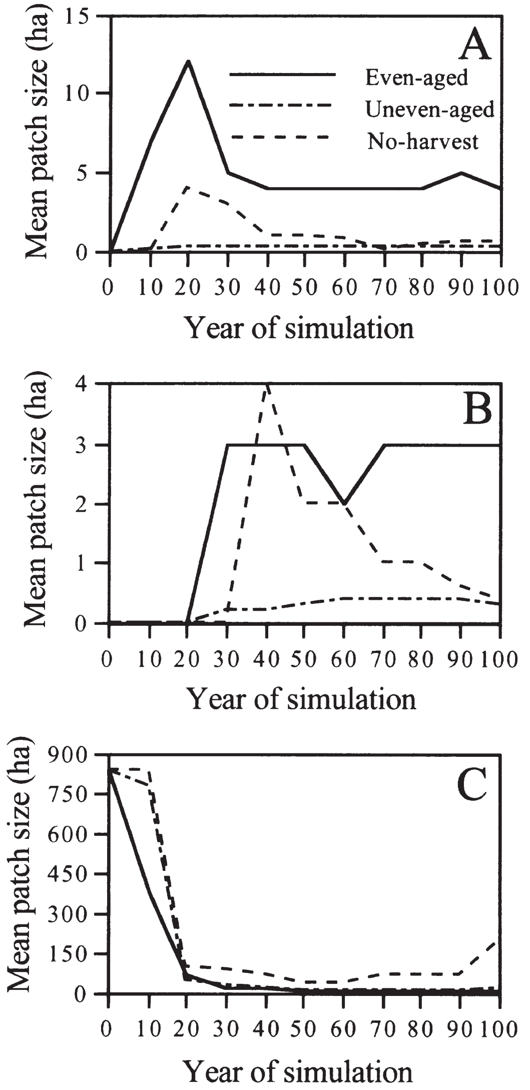

Figure 2—Mean patch size over time for three simulated disturbance regimes applied to an 842-ha upland oak-hickory forest in the Missouri Ozarks: (A) seedling/saplings; (B); pole timber; (C) sawtimber.

A FORESTLAND ALLOCATION MODEL FOR URBANIZING LANDSCAPES

Andrew D. Carver[1]

Abstract—With rapid increases in rural population and continuing expectations of economic growth, pressures on land resources within the central hardwoods region have increasingly become a topic of public debate. Controversy over the allocation of rural and urban fringe forestland often results from the competition between forest management and low-density residential development. Land allocated to forest management provides a flow of both market and non-market benefits to society. These same forests, on the other hand, are sought by developers for profitable building sites.

Though forests provide many economic and environmental benefits to communities, local land use plans and zoning ordinances rarely consider forest management as the highest and best use of rural land. This study employs a multi-criteria/multi-objective decision making model to allocate land within a 32,000 acre study area in north central Indiana to competing uses. Results form an appraisal of each 30x30 meter cell in a raster GIS database of the study area in terms of suitability for forestry and residential use. Results of the land allocation model also identify lands with increased potential for urban/forest conflict.

[1] Assistant Professor, Department of Forestry, University of Southern Illinois Carbondale, Mailcode 4411, Carbondale, IL 62901.

Citation for proceedings: Stringer, Jeffrey W.; Loftis, David L., eds. 1999. Proceedings, 12th central hardwood forest conference; 1999 February 28-March 1-2; Lexington, KY. Gen. Tech. Rep. SRS-24. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southern Research Station. 293 p. [Poster abstract].

MANAGING FORESTS FOR GYPSY MOTH (*LYMANTRIA DISPAR* L.) USING SILVICULTURE: TESTING THE EFFECTIVENESS OF SILVICULTURAL TREATMENTS IN REDUCING DEFOLIATION AND MORTALITY

Kurt W. Gottschalk, Rose-Marie Muzika and Mark J. Twery[1]

Abstract—Invasion of eastern forests by the exotic insect, gypsy moth (*Lymantria dispar* L.), has resulted in widespread defoliation and subsequent tree mortality. Disturbance from these factors varies widely across the landscape; some stands have little or no mortality while other stands have almost complete mortality. With average mortality rates of 25 to 35 percent, silvicultural treatments have been proposed as an alternative to insect suppression treatments to minimize gypsy moth effects. Study objectives were: 1) to evaluate the effectiveness of two silvicultural treatments (presalvage and sanitation thinnings) in minimizing gypsy moth effects on forests; and 2) to determine the mechanisms involved in silviculture-gypsy moth interactions. Only the first objective will be addressed in this presentation.

METHODS

Sanitation thinnings have as their primary objective to reduce the susceptibility of the stand to gypsy moth defoliation. The thinning treatment achieves this objective through manipulation of the species composition; reducing the preferred host composition of mixed stands to 20 percent or less of the basal area. Presalvage thinnings have as their primary objective to reduce the vulnerability of the stand to gypsy moth-related mortality. The thinning treatment achieves this objective by removing trees with higher probabilities of mortality if defoliated (low crown vigor trees) and retaining trees with lower probabilities of mortality if defoliated (high crown vigor trees).

Four replicates of each thinning and adjacent unthinned treatment stands were installed prior to gypsy moth defoliation. Each stand was 20 to 30 acres in size and contained 20 0.1-acre permanent plots arranged in a grid. All trees larger than 2.5 inches were numbered and marked at dbh. The thinning treatments were completed in April 1990. Gypsy moth defoliation occurred in May and June of 1990 and 1991 in six of 16 stands. Three years after defoliation ended, mortality was evaluated using basal area.

RESULTS AND CONCLUSIONS

Host preference class had a significant effect on defoliation patterns but thinning did not. Susceptible species (oaks, *Quercus* spp.) had higher defoliation levels than resistant and immune species but thinned and unthinned stands of the same oak composition had similar defoliation levels.

Mortality was strongly influenced by defoliation patterns and by thinning. Stands with little or no defoliation had mortality levels similar to pretreatment conditions. Stands that were defoliated had increased mortality. Thinning and defoliation had a significant interaction: in undefoliated stands, thinning had no effect on mortality, but in defoliated stands, it reduced mortality. Defoliated sanitation thinnings did not have a significant effect on either defoliation or mortality, but thinned stands did have lower mortality rates. Defoliated presalvage thinnings had significantly lower mortality rates than unthinned stands.

This study was a worst case scenario for evaluating treatments due to the short time lapse between completion of the thinning treatments and defoliation. Had there been several years for the residual trees to adjust to the thinning treatment and increase in vigor, we might have seen even larger differences. Despite this worst case situation, the significant results for presalvage thinning support the use of silvicultural treatments prior to gypsy moth defoliation to minimize gypsy moth effects on tree mortality.

[1] Project Leader and Research Forester, USDA Forest Service, Northeastern Research Station, 180 Canfield St., Morgantown, WV 26505-3101; former Research Ecologist now Assistant Professor, School of Natural Resources, University of Missouri, Columbia, MO 65211; and Project Leader and Research Forester, USDA Forest Service, Northeastern Research Station, P.O. Box 968, Burlington, VT 05402-0968, respectively.

Citation for proceedings: Stringer, Jeffrey W.; Loftis, David L., eds. 1999. Proceedings, 12th central hardwood forest conference; 1999 February 28-March 1-2; Lexington, KY. Gen. Tech. Rep. SRS-24. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southern Research Station. 293 p. [Poster abstract].

A STAND DENSITY MANAGEMENT DIAGRAM FOR NORWAY SPRUCE PLANTATIONS IN CENTRAL NEW YORK

Lianjun Zhang, Fasheng Li, Ralph D. Nyland and James P. Halligan[1]

Abstract—Norway spruce (*Picea abies* (L.) Karst.) is an economically important species in the State of New York. It has been widely planted, especially in the 1930's, and currently occupies about 100,000 acres of forest land in New York (46 percent sawtimber, 36 percent poletimber, and 18 percent sapling). Many of these plantations have already received thinning treatments over years. However, there is little information or few management tools available to guide forest managers in deciding when to start thinning and in selecting appropriate thinning intensities. The objective of this study was to construct a stand density management diagram for the Norway spruce stands in central New York.

A total of sixty-five plots (size 0.01 - 0.25 acre) were sampled from the Norway spruce plantations in six counties in central New York. Tree diameters at breast height were recorded and summarized to stand attributes such as the number of trees per acre (TPA), stand total basal area (BA) in square feet per acre and quadratic mean tree diameter (QMD) in inches. Only fully-stocked or most crowded stands undergoing self-thinning were selected and utilized to formulate the self-thinning line. Major axis regression was applied to estimate the slope and intercept coefficients of the self-thinning equation, resulting in:

$$\text{Ln(QMD)} = 6.18 - 0.63 * \text{Ln(TPA)}$$

A stand density management diagram was then constructed. To illustrate the applications of the diagram, a forest growth and yield model, NE-TWIGS, was used to simulate long-term stand developments of Norway spruce for a range of initial stand densities and different thinning regimes. Figure 1 shows the time trajectories of three hypothesized Norway spruce plantation stands: (1) a stand with a density of 2722 TPA (4x4 ft spacing) at age 10 and no thinning; (2) a stand with a density of 1210 TPA (6x6 ft spacing) at age 10 and three commercial thinnings to 700 TPA at age 40, to 400 TPA at age 70 and to 200 TPA at age 100; and (3) a stand with a density of 1210 TPA at age 10 and one pre-commercial thinning to 200 TPA at age 10.

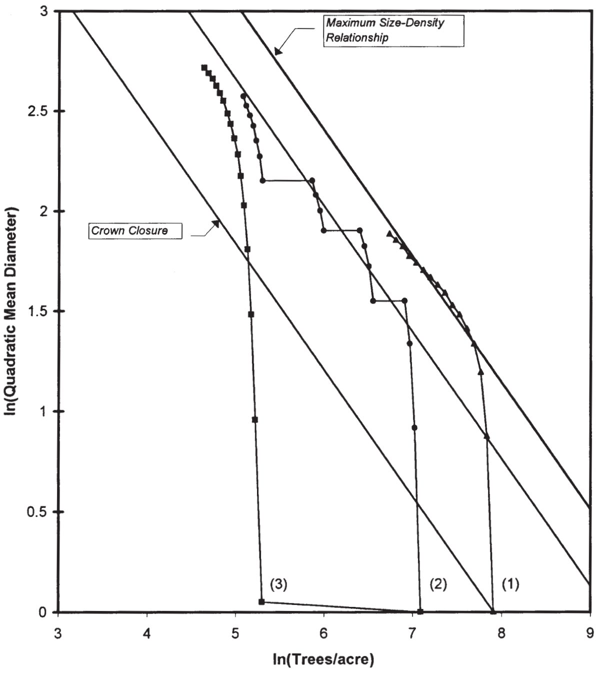

Figure 1—A stand density management diagram for the Norway spruce plantations in central New York. Simulations using NE-TWIGS for three hypothesized stands (from the right to the left): (1) a stand with a density of 2722 trees/acre (4x4 ft spacing) at age 10 and no thinning; (2) a stand with a density of 1210 trees/acre (6x6 ft spacing) at age 10 and three commercial thinnings; and (3) a stand with a density of 1210 trees/acre at age 10 and one pre-commercial thinning.

[1] Faculty of Forestry, SUNY ESF, Syracuse, NY 13210.

Citation for proceedings: Stringer, Jeffrey W.; Loftis, David L., eds. 1999. Proceedings, 12th central hardwood forest conference; 1999 February 28-March 1-2; Lexington, KY. Gen. Tech. Rep. SRS-24. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southern Research Station. 293 p. [Poster abstract].

FORCING ENVIRONMENT AFFECTS EPICORMIC SPROUT PRODUCTION FROM BRANCH SEGMENTS FOR VEGETATIVE PROPAGATION OF ADULT HARDWOODS

J.W. Van Sambeek and John E. Preece[1]

Abstract—Successful rooting of cuttings of adult hardwoods often requires that propagules be removed from the more juvenile parts of trees. Latent or dormant axillary buds found in the bark of a tree usually possess some juvenile characteristics because these buds developed when the stem or branches were first formed. In this study we evaluated the effect of different forcing environments on production of epicormic sprouts from latent buds on branch segments taken from adult trees of four hard-to-root hardwoods. In addition, we evaluated whether these sprouts were suitable as softwood or semi-woody cuttings for vegetative propagation.

In the spring of 1997 and 1998, one to four lower branches were removed from each of three phenotypically superior trees of black walnut (*Juglans nigra* L), white ash (*Fraxinus americana* L.), white oak (*Quercus alba* L), and northern red oak (*Q. rubra* L.). Branches were cut into 24 cm long segments ranging from 2.0 to 8.0 cm in diameter. Branch segments were placed horizontally in plastic 1040 trays filled with moist perlite and set in one of seven greenhouse forcing environments. Forcing environments include 1) water daily with 5 cm of water and allow to drain, 2) water daily with 5 cm of water and keep flooded 1 cm deep, 3) mist daily with 10 cm of water in 45 minutes and allow to drain, 4) mist daily with 10 cm of water in 45 minutes and keep flooded 1 cm deep, 5) place inside a humidity tent and water every other day with 5 cm of water, 6) cover trays with humidity domes and water every other day with 5 cm of water, and 7) place on shaded mist bench and mist for 6 seconds every 8 minutes during daylight hours. Due to limited greenhouse space, the forcing experiment had to be replicated over time.

Large differences were found in the number of epicormic sprouts produced per segment among trees within each species even when branch segments were taken from trees of the same age. Overall, white ash, black walnut, white oak, and northern red oak produced 5, 7, 12, and 15 sprouts per m of branch segment, respectively. The most frequently discussed forcing environment in the scientific literature, the water daily treatment, was one of the better treatments for forcing epicormic sprouts on all four hardwood species. Previous studies showed that if the epicormic sprouts were kept dry while watering the perlite, these sprouts could be surface disinfested and used as explants for in vitro culture. Branch segments under the intermittent mist treatment started producing epicormic sprouts later and produced more sprouts over a longer period of time than branch segments within any of the other six forcing environments. Shoots from the intermittent mist treatment made excellent leafy softwood and semi-woody cuttings; however, they may be unsuitable for use as explants for in vitro culture.

Branch segments in the humidity dome treatment also produced more sprouts than the branch segments in the water daily treatment. Because epicormic sprouts of white and northern red oak showed episodic growth, the sprouts inside the humidity dome had to be harvested as softwood cuttings during rapid stem elongation with immature leaves. Branch segments in the humidity tent treatment produced only half as many epicormic sprouts as branch segments in the humidity dome treatment. Presumably, the condensation inside the humidity domes reduced light penetration and kept air temperatures lower than in the humidity tent. Branch segments in the water daily with flooding and mist daily with flooding treatments produced the lowest number of epicormic sprouts. The perlite layer in these two flooded treatments retained high levels of bacteria which may have depleted the amount of oxygen, nitrogen, and carbohydrates available for epicormic sprout growth. An exploratory study with walnut and white oak showed that segments cut from the basal portion of the lower branches produced as many sprouts as segments from along the central stem.

Softwood cuttings from epicormic sprouts 4.0 cm or longer of black walnut and white oak treated with 0.1 to 4.5 percent IBA in talc and placed under intermittent mist failed to root. Subsequently softwood cuttings of all four species were dipped for 10 to 60 minutes in various dilutions of Dip'n Grow (1 percent indole-3-butyric acid and 0.5 percent napthaleneacetic acid). Over 80 percent of semi-woody epicormic sprouts from white ash dipped in a 1:24 or 1:99 dilution of Dip'n Grow rooted and could be transplanted to rootrainers for subsequent field planting. None of the softwood cuttings of black walnut or white oak rooted. Of the few northern red oak cuttings that rooted, all rooting occurred on semi-woody sprouts with full leaf expansion that had not been killed by fungi growing in the vermiculite-perlite rooting medium.

---

[1] Research Plant Physiologist, North Central Forest Experiment Station, 202A.-B. Natural Resources Bldg., University of Missouri, Columbia, MO 65211-7260; and Professor, Department of Plant, Soil, and General Agriculture, Mailcode 4415, Southern Illinois University, Carbondale, IL 62901-4415, respectively.

Citation for proceedings: Stringer, Jeffrey W.; Loftis, David L., eds. 1999. Proceedings, 12th central hardwood forest conference; 1999 February 28-March 1-2; Lexington, KY. Gen. Tech. Rep. SRS-24. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southern Research Station. 293 p. [Poster abstract].

In conclusion, epicormic sprouts can be successfully forced on branch segments cut from adult trees either by periodically watering the perlite medium or by using intermittent mist to maintain a high humidity micro-environment. Epicormic sprouts tended to root best if taken as semi-woody leafy cuttings.

LONG-TERM CHANGES IN TREE COMPOSITION IN A MESIC OLD-GROWTH UPLAND FOREST IN SOUTHERN ILLINOIS

James J. Zaczek, John W. Groninger and J.W. Van Sambeek[1]

Abstract—The Kaskaskia Woods (Lat. 37.5 N, Long. 88.3 W), an old-growth hardwood forest in southern Illinois, has one of the oldest and best documented set of permanent plots with individual tree measurements in the Central Hardwood Region. In 1935, eight 0.101-ha plots were installed in a 7.4 ha upland area consisting of xeric oak-hickory and mesic mixed hardwoods communities. The soils are cherty silt loams of the Alford and Baxter soil series in which productivity depends largely on moisture availability. The Kaskaskia Woods has never been cleared; however, increment coring in 1965 revealed a majority of the trees were either more than 160 years old or 80 to 100 years old. The area was apparently heavily cut for railroad ties in the 1880s which left most of the yellow-poplar (*Liriodendron tulipifera* L.), hickory, and oaks less than 30 cm in DBH. An abrupt change in diameter growth rates suggests a partial cut took place in the 1910's when it was likely that white oak and hickory were cut for stave wood and handle stock. The area has not been subjected to fire, grazing, cutting, or silvicultural treatments since 1933 following purchase by the USDA Forest Service.

In 1935, all trees 4 cm DBH (1.3 m above ground) or larger were tagged and identified as to species, DBH, and total height. Subsequently, tagged trees in the plots have been remeasured for survival, and DBH in 1940, 1958, 1965, 1973, 1978, 1983, and 1997 as well as height in 1958 and 1978. Ingrowth, new trees 4 cm or larger DBH, were also tagged. Six camera points were established in 1935 and rephotographed in 1958 and 1998. Individual tree locations were mapped in 1973. In the late 1990's the plots were remonumented and all live trees retagged. We report on changes in density (trees per ha) and basal area (m^2 ha^{-1}) by species composition from 1935 to the present. Importance values (IV-200), were computed by summing the percentage number of trees and percentage basal area for each species or species group.

Over the last 65 years there has been a relatively consistent and gradual increase in basal area from an initial 22.7 m^2 ha^{-1} to 34.3 m^2 ha^{-1} in 1997. During this period there have been relatively dramatic changes in species composition, and to a lesser degree, changes in density. By 1965, 479 of the 892 trees present in 1935 had died with ingrowth adding 448 new trees per ha. By 1997, 675 trees per ha had died leaving less than 25 percent of the original trees still alive. Tree density gradually declined to 788 trees per ha over the first 43 years and dropped more rapidly to 588 trees per ha during the last 20 years. The remaining trees tend to be large overstory trees with few saplings and poles in the understory.

The once dominant oaks (black, *Quercus velutina* Lam.; northern red, *Q. rubra* L.; and scarlet, *Q. coccinea* Muenchh.) and hickories (shagbark, *Carya ovata* (Mill.) K. Koch; mockernut, *C. tomentosa* (Poir.) Nutt.; pignut, *C. glabra* (Mill.) Sweet) have declined from 337 trees per ha in 1935 to less than 82 trees per ha at the present. Percentage basal area (of the total stand) for these species has dropped only slightly from 56.2 to 50.2 during the same period. The importance value (IV 200) for oak and hickory was 94.0 initially and showed a steady decline to 55.5 by 1997. The percentage of yellow-poplar basal area increased from 16.1 to 23.9 concurrently with a reduction in the number of trees (from 23.5 to 19.8 trees per ha) also reflecting the presence of massive but declining trees in the overstory.

Initially, the understory was dominated by shade-tolerant flowering dogwood (*Cornus florida* L.) and shade-intolerant sassafras (*Sassafras albidum* {Nutt.} Nees.) (247 trees per ha). By 1997, sassafras was extirpated and only 7 dogwood trees per ha remain. Black walnut, eastern redcedar, black cherry, red mulberry, and persimmon (*Juglans nigra* L., *Juniperus virginiana* L., *Prunus serotina* Ehrh., *Morus rubra* L., *Diospyros virginiana* L., respectively), present in 1935, were no longer found in the plots. In contrast, sugar maple (*Acer saccharum* Marsh.) has increased from 156 trees per ha and 1.1 m^2 ha^{-1} of basal area in 1935 to 346 trees per ha and 6.9 m^2 ha^{-1} in 1997. Over the same time period the IV 200 for sugar maple increased from 21.9 to 78.9 far exceeding any other species.

Over the course of the study, ingrowth has been primarily from shade tolerant species. Of the 637 ingrowth stems, 58.2 percent were sugar maple and 20.7 percent white ash (*Fraxinus americana* L.). Most (68.0 percent) of the sugar maple ingrowth remains alive whereas only 29.0 percent of white ash ingrowth survives. There are no surviving ingrowth trees of oak or hickory.

---

[1] Assistant Professor of Forest Ecology and Assistant Professor of Silviculture, Department of Forestry, Southern Illinois University, Carbondale, IL 62901-4411; and Research Plant Physiologist, North Central Forest Experiment Station, University of Missouri-Columbia, Columbia, MO 65211-7260, respectively.

Citation for proceedings: Stringer, Jeffrey W.; Loftis, David L., eds. 1999. Proceedings, 12th central hardwood forest conference; 1999 February 28-March 1-2; Lexington, KY. Gen. Tech. Rep. SRS-24. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southern Research Station. 293 p. [Poster abstract].

Without a major disturbance for nearly 100 years, sugar maple has become the dominant species in the Kaskaskia Woods. It is likely that the coming decades will bring a continuing decline or perhaps total loss of oak and hickory as well as other associated species in this southern Illinois forest.

ASSESSMENT OF RESIDUAL STAND DAMAGE AND TREE DECAY IN PARTIAL HARVESTS

Matthew D. Seese and Mary Ann Fajvan[1]

Abstract—Partial harvesting subjects residual trees to potential stem and crown damage from felling and machinery. Stem wounds increase the potential for decay and future value loss. This study will examine the correlation between different types of logging wounds and their effects upon tree decay. Both conventional and cable logging systems will be sampled on National Forest partial harvests. Harvest types will be stratified by season of harvest, time since harvest and pre- and post-harvest stocking. Data such as tree species, dbh, merchantable height, dimensions/type of logging wounds, and individual wood samples will be gathered using 0.04 ha circular plots. All residual plot trees > 11.4 cm dbh will be assessed for damage. The dimensions of all logging wounds in the root collar and butt log (4.8m) will be measured. Each wound will be classified into three categories of increasing severity: scuff, scrape, and gouge, caused by either felling or machinery. Individual wood samples from damaged and healthy trees will be collected and specific gravity determined by the water immersion method. Volume loss due to decay will then be estimated. Relationships will be examined between 1) damage severity and harvest intensity and 2) between size and type of logging wound and potential volume loss due to decay.

Another objective of this study is to test the accuracy of three electronic decay detection devices on damaged trees. The Shigometer, Pilodyn, and an ultrasound device will be used on each logging wound to monitor the presence of decay and/or discoloration. Undamaged trees of similar size and species, will be paired with each damaged tree as a control. For the Shigometer, five 3/32 inch diameter holes will be drilled for testing. One hole will be drilled in the center of the wound, and four other holes will be drilled at right angles, 7.6 cm away from the wound's edge. The Pilodyn will be tested 2.5 cm above or below each drilled hole to evaluate its effectiveness. The ultrasound device will be tested as close to the center of the wound as possible. For the control trees, one hole will be drilled at the same height as the center hole on the damaged tree. Each device will then be tested in a similar manner as on the damaged tree. Increment cores will also be taken from each test tree to verify the presence of decay, discoloration, or sound wood.

[1] Graduate Research Assistant and Assistant Professor of Silviculture, respectively, Division of Forestry, West Virginia University, P.O. Box 6125, Morgantown, WV 26506.

Citation for proceedings: Stringer, Jeffrey W.; Loftis, David L., eds. 1999. Proceedings, 12th central hardwood forest conference; 1999 February 28-March 1-2; Lexington, KY. Gen. Tech. Rep. SRS-24. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southern Research Station. 293 p. [Poster abstract].

THE EFFECTS OF THINNING INTENSITY ON SNAG AND CAVITY TREE ABUNDANCE IN AN APPALACHIAN HARDWOOD STAND

Aaron Graves and Mary Ann Fajvan[1]

Abstract—Historically, silvicultural practices have focused on manipulating forest vegetation structure for commodity production. Impacts of silvicultural treatments on characteristics important to nongame species, such as feeding substrate, potential nesting sites, or the rate at which these habitat features form are often not considered. In this study, features such as snags, cavity trees, and defective/decayed trees, which are important to five local woodpecker species, will be compared among even-aged stands. In 1983, a 50-year-old Appalachian mixed hardwood stand was divided into twenty, 1.2 ha blocks, each of which contained a central 0.2 ha plot. All live trees ≥2.54 cm dbh in the central 0.2 ha plot were permanently tagged. Five plots each were thinned to either 75 percent, 60 percent, or 45 percent relative density, and five plots were uncut controls. Plots have been remeasured for fifteen years at five year intervals and data from these remeasurements will be used to quantify tree mortality and snag dynamics over time. Trees were classified as snags if they were ≥10 cm dbh and 1.5 m tall, and were self supporting. A total of 319 snags were sampled in plots encompassing 4 ha.

Mean snag densities show an inverse relationship to thinning intensity (Figure 1), with individual plots ranging from 9.9 snags/ha (45 percent) to 192.7 snags/ha (Control). Large diameter snags (≥30 cm) were uncommon in all treatments. Sassafras (*Sassafras albidum*) and black cherry (*Prunus serotina*) were the most common snag species, comprising 59 percent of snag density.

Similar to other studies, the percentage of snags standing decreased dramatically as time since death increased. After 0-5 years, 85 percent of mortality trees remained standing, which decreased to 59 percent at 5-10 yrs and 25 percent at 10-15 yrs. The longevity of snags in this study is greater than reported for other eastern hardwood species, which is likely due to the large component of decay resistant sassafras and black cherry.

Future efforts will focus on quantifying defects and decay in live overstory trees, and quantifying characteristics of trees containing bird excavated cavities.

[1] Graduate Research Assistant and Assistant Professor, respectively, Division of Forestry, West Virginia University, P.O. Box 6125, Morgantown, WV 26506-6125.

Citation for proceedings: Stringer, Jeffrey W.; Loftis, David L., eds. 1999. Proceedings, 12th central hardwood forest conference; 1999 February 28-March 1-2; Lexington, KY. Gen. Tech. Rep. SRS-24. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southern Research Station. 293 p. [Poster abstract].

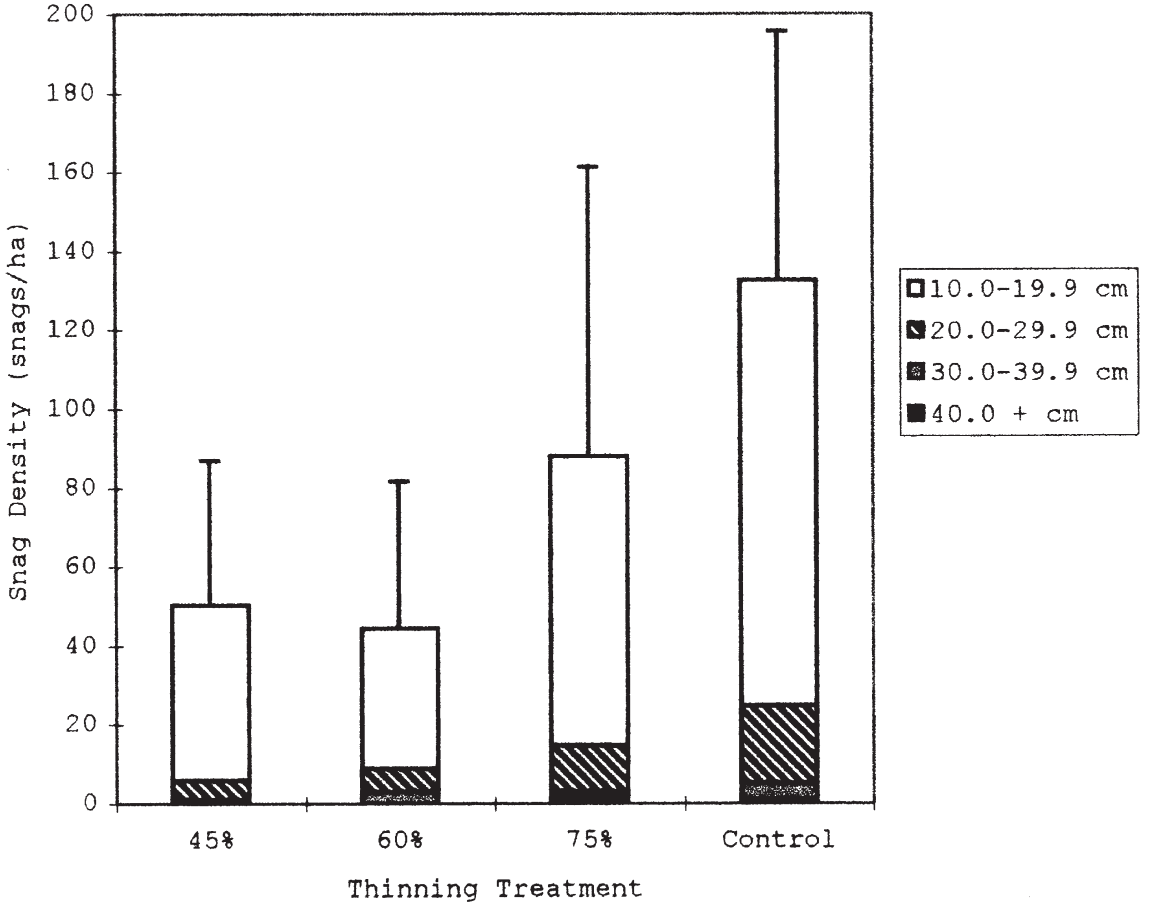

Figure 1—Snag density (snags/ha) by thinning treatment and size class. Bars = 1 SD.

A COMPARISON OF FVS/SUPPOSE COMPUTED VOLUME WITH USDA FOREST SERVICE CRUISE VOLUME ON THE MONONGAHELA NATIONAL FOREST

Melissa Thomas-Van Gundy[1]

Abstract—Summarized plot data from Forest Service stand inventory for four separate stands was entered in FVS/Suppose. The tree data, collected in 1984 and 1989, was grown to the common year 1997 in FVS using NE-Twigs. Either a clearcut or two-age harvest was applied to each stand depending on the prescription given in the environmental assessment. The resulting removal volume in board feet by species was compared to volumes calculated by the National Cruise program from a standard timber sale cruise conducted by district personnel.

Tables 1a and 1b show the total volume by species for each stand and the absolute differences between the two. Differences in removal volumes by species ranged from 1 to 76 MBF. Comparisons of volumes by species within each stand were not made because the range of differences was so great and variable. Only raw data is reported here.

The FVS/Suppose program used here has not been calibrated with either local data or Forest Inventory and Analysis plot data. This is needed before volumes created from the growth model in FVS/Suppose can be applied to individual stands. Schuler and others (1993) found NE-Twigs to be suitable for predicting basal area per acre, medial stand diameter, number of trees, and percentage of basal area in the primary species group for transition hardwood and oak-hickory forest types for West Virginia. However, the authors caution that these reasonable estimates were based on an average of numerous stands.

REFERENCES

Schuler, T.M.; Marquis, D.A.; Ernst, R.L.; Simpson, B.T. 1993. Test of four stand growth simulators for the Northeastern United States. Res. Pap. NE-676. Radnor, PA: U.S. Department of Agriculture, Forest Service, Northeastern Forest Experiment Station.

[1] Timber Management Assistant, Greenbrier Ranger District, Monongahela National Forest, P.O. Box 67, Bartow, WV 24920.

Citation for proceedings: Stringer, Jeffrey W.; Loftis, David L., eds. 1999. Proceedings, 12th central hardwood forest conference; 1999 February 28-March 1-2; Lexington, KY. Gen. Tech. Rep. SRS-24. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southern Research Station. 293 p. [Poster abstract].

Table 1a—Total volumes from cruise data and FVS

Payment unit (*acres*)	Comp Stand	Chestnut oak MBF cruise MBF FVS	Hickory MBF cruise MBF FVS	Pine MBF cruise MBF FVS	Red Maple MBF cruise MBF FVS
2	58	20	0	2	2
(14)	5	19	0	18	0
Diff.		1	0	16	2
3	58	23	2	4	1
(17)	30	94	6	0	0
Diff.		71	4	4	1
4	58	5	1	0	1
(9)	30	50	3	0	0
Diff.		45	2	0	1
5	58	18	3	2	5
(17)	30	94	6	0	0
Diff.		76	3	2	5
6	58	13	2	8	1
(18)	46	33	3	35	0
Diff.		20	1	27	1
8	60	15	1	0	3
(12)	21	56	21	0	1
Diff.		41	20	0	2

Table 1b—Total volumes from cruise data and FVS

Payment unit (*acres*)	Comp Stand	N. red oak MBF cruise MBF FVS	White oak MBF cruise MBF FVS	Yellow-poplar MBF cruise MBF FVS	Other hdwds. MBF cruise MBF FVS
2	58	29	2	1	0
(14)	5	3	0	0	20
Diff.		26	2	1	20
3	58	17	2	0	0
(17)	30	56	7	0	17
Diff.		39	5	0	17
4	58	26	9	0	0
(9)	30	30	4	0	9
Diff.		4	5	0	9
5	58	60	0	3	0
(17)	30	56	7	0	17
Diff.		4	7	3	17
6	58	20	10	1	0
(18)	46	21	13	0	19
Diff.		1	3	1	19
8	60	54	3	1	0
(12)	21	11	15	2	2
Diff.		43	12	1	2

THE EFFECT OF USING CONTROL BAGS ON LITTERBAG MEASUREMENTS OF LEAF LITTER DECOMPOSITION AND NUTRIENT DYNAMICS

K.A. Holzbaur, P.E. Pope, T.W. Idol and F. Ponder, Jr.[1]

Abstract—In most litterbag decomposition studies, mass loss is calculated as simply the change in litter mass between successive time periods. However, studies have found that the influx of soil, foreign litter, and microbial biomass can add weight to litter in litterbags. This can lead to underestimates of true litter mass loss and incorrect calculations of nutrient mineralization and immobilization patterns. The purpose of this study was to assess the effect of using control bags on the mass loss and nutrient dynamics calculated from a traditional litterbag study of decomposing leaf litter. Litter and fermentation layers from four oak-hickory stands ranging in age from 5 to approximately 100 years since harvest were collected, dried, and placed in nylon mesh litterbags. Control bags consisted of inert, undecomposable material approximately the shape and size of the litter. All bags were placed in the forest floor of the 90, or 120 days. Mass loss and nutrient content of the litter was determined and calculations of the decomposition and nutrient mineralization and immobilization patterns were assessed both with and without correcting for the control bags. Results suggest that control bag corrections had a dramatic effect on calculations of mass loss and nutrient dynamics. Thus, short-term decomposition and nutrient dynamics cannot adequately be assessed in these traditional studies without the use of control bags.

[1] Graduate Student, Professor, and Graduate Student, Purdue University, 1159 Forestry Building, West Lafayette, IN 47907-1189; and Research Soil Scientist, USDA Forest Service, North Central Forest Experiment Station, Jefferson City, MO 65102, respectively.

Citation for proceedings: Stringer, Jeffrey W.; Loftis, David L., eds. 1999. Proceedings, 12th central hardwood forest conference; 1999 February 28-March 1-2; Lexington, KY. Gen. Tech. Rep. SRS-24. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southern Research Station. 293 p. [Poster abstract].

UNDERSTORY FIRE EFFECTS ON PIN CHERRY (*PRUNUS PENSYLVANICA* L. F.) SEED GERMINATION

David W. McGill, Edmund T. Bridge, and Jason B. Hudson[1]

Abstract—Pin cherry (*Prunus pensylvanica* L. f.) is an undesirable species in silvicultural systems that aim to produce high quality sawtimber and pulpwood. During stand initiation, pin cherry can rapidly capture canopy growing space and relegate other species to subcanopy positions as it is among the most rapid growers in height. It is estimated that pin cherry seed can remain viable for 50-150 years (Wendel 1990) and its germination is stimulated by regeneration cutting or other intense canopy disturbance. The intense competitive positioning of pin cherry during stand initiation can result in reduced growth or mortality of more desirable species. Although relatively short-lived, pin cherry can comprise a significant amount of stocking up to age 20. This prolonged dominance decreases efficiency and flexibility of early precommerical thinnings: thinning crews will likely focus on eliminating pin cherry rather than selecting crop trees from among competing desirable species. The intent of this poster is to document the effects of an understory fire on dormant pin cherry seed germination and to discuss implications for potential control of this species.

On April 3, 1997, a 3.8-acre wildfire was started by a downed powerline near Anjean, Greenbrier Co., WV. Merchantable stand basal area was 116 sq. ft. per acre in the 46-year-old northern hardwood stand, comprised of yellow-poplar, black cherry, red oak, sugar maple, and birch. The fire moved up the 30- to 40-percent south-facing slope burning only the uppermost portion of the leaf litter and charring the lower trunk bark of overstory trees.

On April 11, 1997, ten 0.001-acre regeneration plots were established to assess fire effects on germination of the pin cherry seedbank. Numbers of seedlings (less than 4.5 feet) were recorded. Five plots were located in the burned area and five plots in the adjacent unburned area, all were beneath pin cherry stems that ranged from 6 to 12 inches dbh. In the burned area, three of the pin cherry stems were living and two were dead; in the unburned area two were living and three were dead. In July 1997, seedlings were again counted on all plots.

Three months following the fire, pin cherry was the most abundant species on the burned regeneration plots, averaging 26,400 seedlings per acre. Root suckers of living pin cherry trees were observed but not counted in the regeneration assessment. No pin cherry seedlings were observed on the unburned plots. Species richness was higher in the unburned area (14 species) than in the burned area (7 species).

The germination of pin cherry seed observed following this understory burn was surprising because of the intact and complete canopy cover present at the time of and following this relatively low intensity burn. Most references describing the germination of pin cherry seed suggest that some degree of canopy disturbance is required to stimulate the dormant seed bank (e.g., Marks 1974); germination of dormant seed has been shown to result from high fluctuations of soil temperature (Laidlaw 1987) and from increased soil nitrate levels (Auchmoody 1979), both characteristics found in forest soils following intense canopy disturbances.

Fire also stimulates pin cherry seed germination, although no mention has been made in the literature that low intensity understory burning leads to this result. Pin cherry establishment is usually linked with some type of intense canopy disturbance. Low intensity understory burning may provide a means to reduce potential competition by pin cherry. If dormant seeds in the seedbank of untreated stands can be stimulated to germinate, then these shade intolerant seedlings will likely die out in the low light environment of the forest understory before the stands are regenerated.

REFERENCES

Auchmoody, L.R. 1979. Nitrogen fertilization stimulates germination of dormant pin cherry seed. Canadian Journal of Forest Research. 9: 514-516.

Laidlaw, T.F. 1987. Drastic temperature fluctuation—the key to efficient germination of pin cherry. Tree Planter's Notes. 38(3): 30-32.

Marks, P.L. 1974. The role of pin cherry (*Prunus pensylvanica* L. f.) in the maintenance of stability in northern hardwood ecosystems. Ecological Monographs. 44: 73-88.

Wendel, G.W. 1990. *Prunus pensylvanica* L. f.—Pin Cherry. In: Burns, R.M.; Honkala, B.H., tech. coords. Silvics of North America: hardwoods. Agric. Handb. 654. Washington, DC: U.S. Department of Agriculture, Forest Service. Vol. 2

[1] Research Scientist, Forest Ranger, and 1997 Summer Intern, respectively, Westvaco Corporation, Appalachian Forest Research Center, Rupert, WV 25984.

Citation for proceedings: Stringer, Jeffrey W.; Loftis, David L., eds. 1999. Proceedings, 12th central hardwood forest conference; 1999 February 28-March 1-2; Lexington, KY. Gen. Tech. Rep. SRS-24. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southern Research Station. 293 p. [Poster abstract].

USING PRESCRIBED BURNING TO RELEASE OAK SEEDLINGS FROM SHRUB COMPETITION IN SOUTHERN CONNECTICUT

Jeffrey S. Ward and Emery Gluck[1]

Abstract—In a managed forest, control of species composition is important for both the economic value and biological health of the forest. Regenerating oaks on better quality sites is often hampered by an extensive shrub layer that suppresses the shorter oak seedlings, especially following shelterwood harvests. The abundance of mature oaks in the present forest is due, in part, to a history of periodic burning and clearcutting prior to 1920 in Connecticut. Fire is a possible method of killing (or stunting) shrubs and allowing oak sprouts to grow above the shrub layer.

A shelterwood cut in 1987 in a mature oak stand had broken up a layer of mountain laurel that dominated the understory and increased the number of oak seedlings to nearly 4000/acre by 1989. However, most oak seedlings were less than 1 foot tall and were stagnating under a dense shrub layer. A prescribed burning study was established to determine whether fire can be used to release oak seedlings from shrub competition. Thirty-six plots were located on a nominal 150 foot by 150 foot grid. Seedlings and saplings were sampled by species and height class within 1/300 acre circular plots. Trees (> 4.5 inches dbh) were sampled with a 10-factor prism. Residual basal area was 60 ft^2/ac with oak species accounting for 51 percent of the total.

Half of the 29 acre stand was burned by a surface fire on April 5, 1991, in cooperation with the Division of Forestry, Connecticut Department of Environmental Protection. The fire was implemented under mild burning conditions: dead fuel moisture 10-12 percent, winds 2-7 mph, and relative humidity 38-56 percent. The flame length of the head fire rarely exceeded 1 ft while burning in the hardwood litter. The fire extinguished itself in the wetter sections. The fire killed to the ground most stems less 1 inch in diameter. In June, it appeared that the oaks were competitive with the resprouting shrubs. Regeneration was sampled immediately before the burn and in the fall following the burn. Regeneration was again sampled three and six years after the burn. Overstory removal was completed by the fall of 1994 (4 growing seasons post-burn).

Burning has increased relative and absolute oak seedling density. Two years after final harvest, oak density was 17,475/acre on the burned section compared with 5,125/acre on the unburned sections. More significantly, oak species accounted for fully 25 percent of tree stems ≥ 3 feet tall on the burned section and only 8 percent on the unburned section (fig. 1). Prescribed burning also reduced the density of red maple, sassafras, and shrubs. Prescribed burning may be a useful for controlling vegetation that competes with oak following shelterwood cuts.

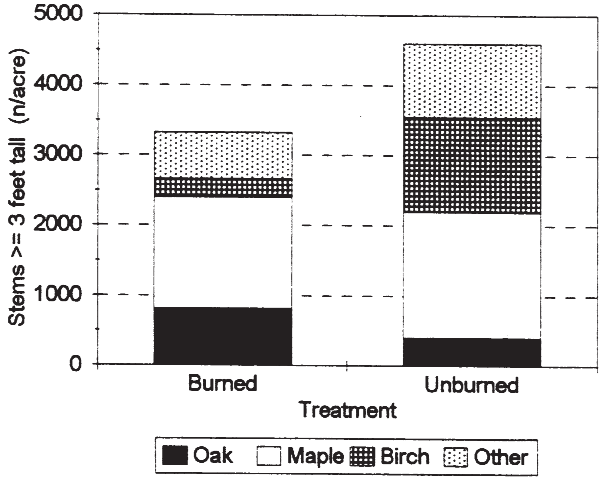

Figure 1—Distribution of stems ≥ 3 feet tall by species group 2 years after final harvest and 6 years after prescribed spring burn.

[1] Associate Scientist, Department of Forestry and Horticulture, Connecticut Agricultural Experiment Station, P.O. Box 1106, 123 Huntington Street, New Haven, CT 06504; and Forester I, Division of Forestry, Connecticut Department of Environmental Protection, 209 Hebron Road, Marlborough, CT 06447, respectively.

Citation for proceedings: Stringer, Jeffrey W.; Loftis, David L., eds. 1999. Proceedings, 12th central hardwood forest conference; 1999 February 28-March 1-2; Lexington, KY. Gen. Tech. Rep. SRS-24. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southern Research Station. 293 p. [Poster abstract].

CONSTRUCTION METHODS FOR A COUNTY-WIDE LAND USE/COVER MAP

C.J. Liu[1]

Abstract—Laboratory of Geometronics, through a cooperative agreement with the Big Sandy Area Development District, has constructed a GIS-based, county-wide digital land use/cover map to facilitate county-level economic development and resources management planning efforts. The construction procedures described can readily be used for projects of similar scope and objective.

The procedures of map construction are: (1) photointerpretation, (2) photogrammetric transformation, (3) scanning, (4) georeferencing, (5) vectorization, (6) data editing, and (7) cartographic manipulations. Detailed processing is presented below.

Sixty seven vertical aerial photos taken in March of 1997 by the National High-altitude Photography Program were acquired for photointerpration. Phototerpretation was peformed by viewing stereo pairs under a stereoscope while land cover types identified and marked. Land use polygons marked on the photos were than transferred to fourteen USGS 7.5' quadrangle topographic maps using a sketchmaster. These topographic maps were treated as the project's base maps in a GIS. In 1-bit monochrome mode, based maps with land covers identified were scanned at 100 dpi. This process converted polygonal features on base maps to their corresponding raster images. Using a set of ground control points collected on additional reference materials, raster images were georeferenced in Arc/Info. Georeferenced raster files were subsequently vectorized which converted raster images to grid files in Arc/Info. Next, boundary lines for all land use polygons were traced to produce vectors, using grid files in Arctools. These vectorized polygons were ten saved as a GIS coverage. Fourteen GIS coverages of land uses were merged, in Arcedit, to form a single coverage. The resulting coverage were attributed in Arcview by assigning land use types to polygons. The next step was to dissolve, in Arc, boundaries of polygons having the same attribute values (i.e., land-use types). After a georeferenced land-use coverage was built, several cartographic treatments were applied to the coverage in Arcview. These treatments included: (a) a 1000-meter UTM grid coverage and markers, (b) a 5-foot longitude/latitude grid coverage and markers, (c) other legends common to all paper maps.

Following the above outlined procedures, a color-coded county-wide land use maps was successfully constructed. The Magoffin County Land-Use Map is in U.S. State Plane Coordinate (Kentucky South) and North American Datum of 1983. The table below summarizes Magoffin County Land Uses.

Table 1—Magoffin County land uses

	Area	Percentage
	Acres	
Agriculture land	19,986.88	10.09
Barren land	2,277.99	1.15
Deciduous forest	163,262.51	82.42
Mixed forest	415.98	0.21
Stripped mine	9,389.28	4.74
Urban land	2,674.16	1.35
Water body		
(exclude streams)	99.04	0.05
Total	198,086.04	100.00

[1] Laboratory of Geometronics, Department of Forestry, University of Kentucky, Lexington, Kentucky, 40546.

Citation for proceedings: Stringer, Jeffrey W.; Loftis, David L., eds. 1999. Proceedings, 12th central hardwood forest conference; 1999 February 28-March 1-2; Lexington, KY. Gen. Tech. Rep. SRS-24. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southern Research Station. 293 p. [Poster abstract].

COMPARISON OF NE-TWIGS AND ZELIG ON ACTUAL GROWTH OF TWO SITES IN KENTUCKY

Daniel A. Yaussy[1]

Abstract—Two individual-tree growth simulators are used to predict the growth and mortality on a 30-year-old forest site and an 80-year-old forest site in eastern Kentucky. An empirical growth and yield model (NE-TWIGS, Hilt and Teck 1989) was developed to simulate short-term (< 50 year) forest growth from an industrial perspective. The gap model (ZELIG, Urban 1990) is based on the theory of growth processes and was designed to simulate long-term (100 years and greater) forest succession. Based on comparisons of species specific diameter distributions, biomass, and board-foot and cubic-foot volumes, NE-TWIGS performed better for the 80-year-old site than did ZELIG. Neither simulator provided acceptable predictions for the 30-year-old site.

The ZELIG model over predicted the number of stems for the 30-year-old site, but under predicted the biomass and volumes. This implies that the model does not grow the white oaks fast enough. The red maples, on the other hand, grew too fast and the white oaks incurred too much mortality on the ZELIG simulations of the 80-year-old site.

The NE-TWIGS model cannot be easily altered to obtain better predictions for specific areas. One could annually adjust the site-index value based on seasonal temperatures and precipitation rates being above or below local averages. NE-TWIGS was designed to work in the time frame and region used in this comparison; however, it is a generalized model, not developed, specifically for an even-aged, upland oak stand.

The species parameters in the gap models can be modified, which might produce comparable growth predictions. An adjustment of site specific and species parameters was investigated for white oak on these data sets. White oak made up more than 75 percent of the stems at each site, and any improvement in prediction of the growth for this species would improve the overall predictions immensely. Soil fertility was the site parameter in which I had the least confidence. Whittaker (1975) reports net primary productivity for temperate deciduous forests ranges from 6 to 25 Mg/ha/yr averaging 12 Mg/ha/yr, much higher than was calculated for these sites. Another parameter which might be altered is the species growth constant which changes the age at which a tree of that species puts on most of its diameter growth. A larger constant implies that trees of this species grow quickly early in their life and growth tapers as the tree ages. A lower constant allows trees of the species to grow in diameter evenly as they age. The maximum age and diameter that a tree species can attain are parameters which determine many aspects of growth and mortality within the ZELIG model.

Systematic combinations of values within the ranges of the soil fertility parameter (2-24 Mg/ha/yr) and the white oak growth constant parameter (50-300) were tested within the ZELIG framework seeking a combination that would improve the simulations of both stands. Graphs of the relationships between these parameters and average dbh, number of trees per hectare, and the volume measures showed that the volume measures and average dbh were not sensitive to soil fertility values above 10 Mg/ha/yr. Number of stems on each site was quite sensitive to both parameters. Parameters were found for the 30-year-old site which satisfactorily predicted number of stems, average dbh, biomass, and cubic foot volumes; however the diameter distribution was such that the board foot estimates were still quite low (not enough large trees). These parameters simulated reasonable volume measures for the 80-year-old site, but the estimated average dbh and number of trees were not close to those of the actual site. No combination of parameters tested could produce enough trees for the eighty-year-old stand. Reasonable average dbh estimates for the 80-year-old site could be attained, but never with the proper number of trees to produce the right combination of biomass, cubic-foot volume or board-foot volume.

REFERENCES

Hilt, D.E.; Teck, R.M. 1989. NE-TWIGS: An individual-tree growth and yield projection system for the Northeastern United States. The Compiler. 7(2): 10-16.

Urban, D.L. 1990. A versatile model to simulate forest pattern: a user's guide to ZELIG. Version 1.0. Charlottesville, VA: The University of Virginia, Environmental Sciences Department. 108 p.

Whittaker, R.H. 1975. Communities and ecosystems. 2d ed. New York: MacMillan. 385 p.

[1] Research Forester, USDA Forest Service, Northeastern Research Station, 359 Main Road, Delaware, OH 43015-8640.

Citation for proceedings: Stringer, Jeffrey W.; Loftis, David L., eds. 1999. Proceedings, 12th central hardwood forest conference; 1999 February 28-March 1-2; Lexington, KY. Gen. Tech. Rep. SRS-24. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southern Research Station. 293 p. [Poster abstract].

THE IMPACT OF PRESCRIBED FIRE ON HERBIVORY LEVELS OF UNDERSTORY WHITE OAK

Aaron S. Adams and Lynne K. Rieske-Kinney[1]

Abstract—Historical data and the presence of fire-resistant characteristics support the role of fire in the establishment and maintenance of the mixed-oak (*Quercus* spp.) forests of eastern North America. Following the clear cutting of eastern forests in the 1800's, fire suppression became a dominant forest management technique. Age and species mosaics declined and forest stand composition shifted, allowing more vigorous and shade tolerant species to dominate. As a result, seedlings in oak-dominated forests became suppressed by vegetative competition, and today oaks are virtually non-existent in the midstory. This shift in species composition has resulted in the economic loss of an extremely valuable hardwood group, and may also impact forest succession rate, wildlife composition and distribution, and watershed characteristics.

The use of prescribed fire as a management tool to enhance oak regeneration has recently been met with renewed interest. Fire enhances oak growth by reducing vegetative competition, increasing sunlight penetration, and increasing nutrient composition in the soil.

Traditionally research has focused on environmental factors and vegetative competition influencing oak regeneration. However, acorns, seedlings, and mature oaks are constantly exposed to insect herbivory. Prescribed fire may serve to manipulate insect composition and abundance, which could effect seedling establishment and sprout success. Fire may impact herbivore populations directly by habitat alteration and disruption of the life cycle, or it may have indirect impacts caused by alterations in food quality and availability.

OBJECTIVES
This study is identifying biotic factors attributing to the lack of oak regeneration in eastern Kentucky forests, and will assess the effects of prescribed fire on the herbivore complex associated with oak regeneration. The specific objectives of this research are to characterize the effects of single year and multiple year burns on: 1) oak seedling growth, 2) phytochemistry, and 3) herbivory levels.

MATERIALS AND METHODS
Study sites were established in the Daniel Boone National Forest (DBNF) on oak-dominated ridgetops under the following burn regimes: 1) single year burn - areas burned in late winter of 1998, 2) multiple year burn - areas burned in late winter of 1998 and 1996, following the prescribed fire management program established by the DBNF, and 3) unburned controls - areas with no recent history of fire activity.

Within each site, subplots consisting of a series of herbivore exclusion treatments were established to assess herbivory levels in each burn regime. Each subplot consists of seedling fencing/insecticide treatments designed to:
1) exclude arthropod herbivory(- fence/ + insecticide),
2) exclude mammalian herbivory(+ fence/ - insecticide),
3) exclude both mammalian and arthropod herbivory (+ fence/ + insecticide), and 4) no herbivore exclusion (- fence/ - insecticide). The split plot design involves seedling treatments (+/- fence, +/- insecticide) replicated 3 times within site treatments (1x-burn, 2x-burn, non-burned), which are also replicated three times.

To assess the effects of prescribed fire on oak growth, measurements of seedling performance (shoot elongation, height, diameter) were taken at 4 equal intervals throughout the growing season. Twenty five adjacent seedlings were flagged for periodical destructive sampling for phytochemical analysis. Foliar samples were collected to analyze for total non-structural carbohydrates, nutrients, protein, and phenolics.

Herbivory was visually assessed by measuring the area affected by mammalian and arthropod feeding on each tree at 14 d intervals throughout the season. Levels of herbivory in each of the 4 seedling (subplot) treatments were compared under the different burn regimes. Herbivory levels will be correlated with seedling growth (Objective 1) and phytochemistry (Objective 2).

To augment the relatively low (0-30 percent) natural herbivory levels, fall webworm (FWW) larvae were caged on additional seedlings. Paired seedlings were caged with and without larvae in each burn regime and allowed to feed for 6 days. After caging, leaf tissue was flash frozen for future phytochemical analysis.

RESULTS
Results of the augmented herbivory experiment are presented here. Final herbivory levels across burn treatments averaged 50 percent. Since there was no significant difference between the once and twice burned sites pre- or post-FWW challenge, results for the burn treatments were pooled. Prior to the FWW caging

[1] Department of Entomology, University of Kentucky, Lexington, KY 40546-0091.

Citation for proceedings: Stringer, Jeffrey W.; Loftis, David L., eds. 1999. Proceedings, 12th central hardwood forest conference; 1999 February 28-March 1-2; Lexington, KY. Gen. Tech. Rep. SRS-24. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southern Research Station. 293 p. [Poster abstract].

experiment, mean defoliation levels of seedlings on non-burned sites exceeded that of burned sites (Table 1). This trend was reversed for the post-challenge sample date, when defoliation on seedlings from burned sites exceeded that of non-burned sites. FWW defoliation increased by greater than 90 percent on burned sites, but only 75 percent on non-burned sites.

The overall herbivory rate of FWW challenged oak seedlings on burned sites significantly exceeded that of non-burned control sites (Fig. 1, $P = 0.0442$).

DISCUSSION

By FWW Herbivory

The lower herbivory levels in pre-challenged, burned plots may reflect enhanced production of inducible defenses such as phenolics due to site (burn) treatment. The increase in herbivory on burned sites for the post-FWW challenge may be attributable to an induced defensive response which has been compromised by the stresses of site treatment combined with herbivory levels. Future research will concentrate on analysis of phytochemical compounds within each treatment.

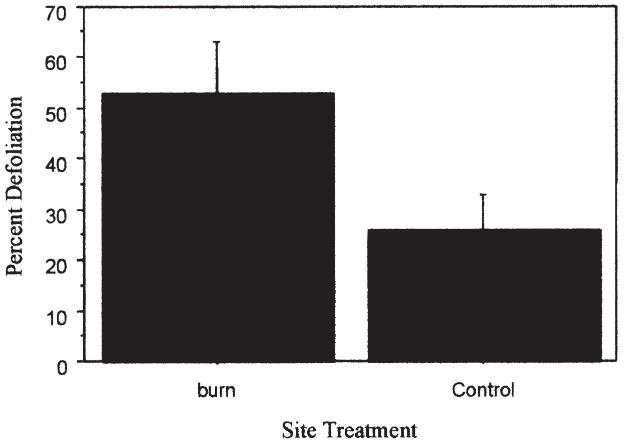

Fig. 1—Defoliation of white oak seedlings challenged.

Table 1—Mean percent defoliation (s.e.) of white oak seedlings challenged by fall webworm herbivory on burned and non-burned sites

White oak seedlings	Burned	Non-burned control
	------- *Percent defoliation* ------	
Pre-FWW challenged	6.46 (1.89)	9.66 (2.10)
Post-FWW challenged	59.29 (10.27)	35.68 (5.27)

This study will elucidate some of the complex interactions between fire, oak seedling growth, phytochemistry and herbivory. Knowledge of these interactions may alleviate some of the difficulties associated with the oak regeneration issue. As natural oak regeneration and human management techniques fail to produce the desired results, prescribed burning offers some hope.

NURSERY TREATMENTS ALTER ROOT MORPHOLOGY OF 1+0 NORTHERN RED OAK SEEDLINGS

Patricia T. Tomlinson[1]

Abstract—Poor root growth is frequently associated with poor planted northern red oak seedling establishment and performance. Therefore, we determined if several nursery treatments resulted in differences in northern red oak seedling characteristics, particularly in root systems, which might increase rapidity of growth after outplanting and thus improve regeneration success. The treatments we chose were undercutting after two flushes of growth and dipping germinated seed in either low concentration (2,000 ppm) or high concentration (8,000 ppm) K-IBA prior to planting. Each of these has been reported to alter number of first-order lateral roots and/or their distribution along the taproot. However, reports of these treatments compared were not found. Half-sib seed from each of two mother trees were planted either in the fall 1992 (control and undercut treatments) or in the spring 1993 (auxin dipped seed treatments) at Wilson State Forest Tree Seedling Nursery in Boscobel Wisconsin (43N lat., 90W long.). The mother trees were located in Nicolet National Forest (SS1) and in Chequamegon National Forest (SS2) in northern Wisconsin. Seedlings in the undercut treatment were undercut at 15 cm depth when seedlings were approaching the end of the second flush of growth. Seedlings were lifted at 20 cm depth after one season of growth in April 1994. They were characterized by height; numbers of permanent first-order lateral roots on the upper and lower 10 cm of the taproot; diameters at-, 10 cm below-, and 2 cm above- root collar.

Taproot length and distribution of lateral roots along the taproot were significantly impacted by treatment. Auxin, especially high concentration, shortened taproot length and increased the proportion of lateral roots in the upper 10 cm of the taproot. However, total number of first-order lateral roots was not significantly different among cultural practices for either seed source. Root collar diameter as well as stem diameter (2 cm above root collar) was impacted by both seed source and treatment. For SS1, high concentration auxin treatment resulted in smaller diameters than control or undercut treatments. In contrast, control seedlings displayed smaller diameters compared to other treatments for SS2, although the difference was only significant for undercut versus control comparison. Taproot diameters (10 cm below the root collar) were decreased by auxin treatment and increased by undercutting. Shoot height was not significantly affected by any treatment for either seed source. We also quantified the number of growth flushes; however, this was uniform among seed sources and treatments as observed in the past over a broader range of conditions.

Thus, root morphology can be manipulated by undercutting and auxin treatments. These treatments appear to alter the root system with less impact on the shoot system of the seedling. Seedling height was not impacted although both root collar diameter and stem diameter were altered by the treatments for at least one seed source. Further, such influences on the shoot were modified by seed source whereas root diameter was dependent only on treatment. Undercutting and auxin treatments alter the distribution of first-order lateral roots along the taproot without impacting the total number of lateral roots. The impacts of these differences in root morphologies on outplanting performance and seedling establishment is being tested.

[1] North Central Forest Experiment Station, Forestry Sciences Laboratory, 5985 Highway K, Rhinelander, WI 54501.

Citation for proceedings: Stringer, Jeffrey W.; Loftis, David L., eds. 1999. Proceedings, 12th central hardwood forest conference; 1999 February 28-March 1-2; Lexington, KY. Gen. Tech. Rep. SRS-24. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southern Research Station. 293 p. [Poster abstract].

EFFECTS OF LEAF LITTER DEPTH ON ACORN GERMINATION

Jeffrey W. Stringer and Laurie Taylor[1]

INTRODUCTION

Lack of advanced regeneration is generally considered to be the primary factor associated with the failure to regenerate oak particularly on medium to high quality sites. This is generally considered to be a function of the limited light environment often associated with undisturbed canopies on mesic sites. However, other factors such as a relatively thick litter associated with these types of sites has been shown to increase the desiccation of acorns during the initial stages of radical immersion and thus potentially reduce the number of seedlings established. This study was designed to test a litter reduction treatment (prescribed fire) on the successful germination and establishment of selected upland oak species.

METHODS

The study was located at Robinson Forest, the University of Kentucky research and demonstration forest located in the Cumberland Plateau Physiographic Province in southeastern Kentucky. Two upland oak stands, approximately 3 acres in size, on slopes of opposing aspects were used in this study. One stand was located on a predominately southwest facing slope (black oak site index=65ft) and the other stand was located on a northeast facing slope (black oak site index=90ft). Ten study plots (9 m^2) were randomly located in each stand. The study incorporated a split plot design where each plot was split into a untreated subplot and a treated (prescribed burned) subplot. Each subplot was divided into 4 species plots. One of four oak species (*Quercus rubra*, *Q. alba*, *Q. prinus*, and *Q. coccinea*) were randomly assigned to each of the 4 species plots and 20 acorns of that species were planted in October of 1997. In the untreated subplots acorns were placed on the existing litter directly prior to leaf fall. Acorns were protected from vertebrate predation and the current years leaf deposition covered the acorns. To avoid altering the environment around the acorns predation protection was removed after leaf deposition. Treated subplots were established by burning directly prior to planting in October. The burn was sufficient to remove the majority of the litter. Acorns were then dropped on the exposed soil, or in some instances charred organic matter. They were protected from predation and leaf deposition allowed to cover the acorns at which time protection was removed. A 565 cm^2 sampling frame was used to collect litter samples were collected from five areas at the edge of each subplot. Samples were dried and pre-treatment litter mass determined. Within the burned subplots litter samples were also collected after leaf fall to determine litter cover over the acorns. The litter samples were used to determine pre-treatment litter mass (kg/ha) and post-treatment average litter mass for each subplot. Plots were evaluated in June. The percentage of acorns which developed seedlings in each species block was determined and subjected to normalization using an arc sin transformation for analysis using the Wilcoxon two sample t-test to determine treatment effects for the data pooled over sites and species as well as species within a site.

RESULTS

Burning resulted in significantly higher seedling establishment percent for some species. Overall seedling establishment averaged 1.32 percent on burned plots and 1.04 percent on unburned plots. These values are similar to other reported establishment percent for years where acorn production is average or below average. Establishment rates have been shown to be as high as 10 percent for years when bumper crops occur. A more pronounced and significant difference ($p=0.0297$) was found on the northeast site compared to the southwest site. Mean seedling establishment percent pooled over all species on the northeast site was 1.38 on burned plots and 0.62 on unburned plots. Mean seedling establishment percent pooled over all species was not significantly different ($p>0.05$) between treatments on the southwest site (unburned = 1.41 percent and burned = 1.25 percent).

Northern red oak exhibited significantly higher ($p=0.0006$) establishment percent in burned plots (mean=2.0) on the northeast site compared to unburned plots (mean=0.30) (Table 1). Chestnut oak also exhibited significantly higher ($p=0.02$) establishment percent on burned plots (mean=2.0) compared with unburned plots (mean=0.50). No treatment differences were exhibited by white oak (which totally failed on the northeast site) or scarlet oak on either site.

This study indicates that prescribed burning may represent a viable treatment for increasing the development of advanced regeneration of chestnut oak and northern red oak on intermediate and high quality upland sites. While the primary effect of the burning was believed to be on litter thickness it may have also changed other factors which could have effected germination and establishment. The

[1] Department of Forestry, University of Kentucky, Lexington, KY 40546-0073.

Citation for proceedings: Stringer, Jeffrey W.; Loftis, David L., eds. 1999. Proceedings, 12th central hardwood forest conference; 1999 February 28-March 1-2; Lexington, KY. Gen. Tech. Rep. SRS-24. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southern Research Station. 293 p. [Poster abstract].

burning may have influenced population densities of predatory insects which might feed on acorns and emerging radicles or altered the potential of infection by pathogens. Regardless, this study indicates that the use of properly timed prescribed burning should be investigated as an aid in establishing oak advanced regeneration on mesic sites.

Table 1—*Quercus* seedling establishment as influenced by prescribed fire

	Q. coccinea	*Q. prinus*	*Q. alba*	*Q. rubra*
	---	*Percent*	---	
Southwest slope				
Burned	1.25 (0.55)[1]	1.88 (0.63)	0.63 (0.06)	1.26 (0.56)
Unburned	1.88 (0.63)	2.50 (0.65)	0.61 (0.06)	1.89 (0.90)
Northeast slope				
Burned	1.50 (0.53)	2.00[a] (0.56)	0	2.00[a] (0.76)
Unburned	1.50 (0.53)	0.50[b] (0.34)	0	0.30[b] (0.03)

[1] Values represent mean seedling establishment percent (standard errors). Values with different letters represent a significant different ($p<0.01$) between treatments using Wilcoxon two sample t-test.

DEVELOPMENT OF ADVANCED OAK REGENERATION FROM TWO-AGE RESERVE TREES

Jeffrey W. Stringer[1]

INTRODUCTION

The two age system uses methods or treatments which retain a limited number of older canopy trees (reserve trees) along with a cohort of younger regenerating stems. Methods such as “irregular shelterwood” or “shelterwood with reserves” developed from treatments such as deferment cuts can be used successfully in many hardwood stands. This method has been used as an aesthetic alternative to clearcutting and as a means of potentially developing a limited number of large diameter high value sawtimber trees in a stand. A shelterwood with reserves differs from a traditional shelterwood in that reserve trees will be maintained for a second rotation length rather than removed after regeneration goals have been met. To allow for continued rapid development of the younger age class the reserve trees must be scattered and few in number (10-30 ft^2 of basal area a^{-1}). In this case, the term shelterwood with reserves is misleading as the goal is not to shelter or modify regeneration but to allow it to develop relatively unhindered. The reserve trees must be of proper vigor, landscape position, species, age, and potential tree grade so that they will survive and provide a viable product after two rotations. Not all stands and species can be managed using the two age system. Species which are relatively long lived and are commercially important make good candidates for reserve trees.

The two age system also can be used to “life boat” species which do not have viable reproductive life forms at the time of cutting. A traditional clearcut essentially stops sexual reproduction in the stand for a substantial portion of the rotation and can limit the potential for the development of viable advanced regeneration. The reserve trees in the two age system provides for the potential for continued sexual reproduction in the stand and the ability to develop advanced regeneration which can be manipulated prior to the second regeneration cut. The maintenance of sexual reproduction throughout a rotation or a significant portion of it may be important for sporadic producers such as oak species. This study was designed to determine if small sawtimber reserve white oak (*Quercus alba*) trees left after a two-age treatment could effectively initiate the development of advanced regeneration.

METHODS

The study was located at Robinson Forest, the University of Kentucky research and demonstration forest located in the Cumberland Plateau Physiographic Province in southeastern Kentucky. Twelve 2 acre 60- to 90-year-old white oak dominated stands were used in this study. Each stand was randomly assigned one of 3 treatments including an uncut treatment, a treatment leaving only 20 canopy trees per acre, and one leaving only 34 canopy trees per acre. The treatments were imposed by full crown touching release of selected canopy trees (reserve trees). These trees were of average dbh for co-dominant and dominant trees in these stands. No site preparation treatments were used. One-half acre growth and yield plots were established in the middle of each treated stand. Trees > 2.54 cm dbh were tagged and survival and growth monitored and ten 1/100th acre regeneration plots were also randomly established in each growth and yield plot.

This study reports the development of new seedlings and advanced regeneration from white oak reserve trees 15 years after treatment. Regeneration measurements were taken during July and included the number and height of each white oak stem established after treatment. To provide a relative gauge of canopy light interception and the light environment at each regeneration plot a concave spherical crown densitometer™ (Forestry Suppliers, Inc. 24 quarter inch cross hairs) reading was taken at plot center. Data was recorded and is expressed in this paper as the number of cross-hairs where open sky was observed. At the same time a series of five photosynthetic photon flux density (PPFD) measures ($\mu mol\ m^{-2}s^{-1}$ PAR) were taken at a height above ground equal to the average height of the advanced regeneration (30 cm) at every other plot center using a quantum sensor (LI-COR, Inc.) and the values averaged by plot. All PPFD and densitometer readings were taken under clear sky conditions. Advanced regeneration data were pooled by treatment and subjected to statistical analysis using ANOVA and LSD(t) to determine treatment effects. Simple linear regression was used to establish the relationship between PPFD (dependent variable) and densitometer reading (independent variable) and advanced regeneration height (dependent variable) and densitometer reading (independent variable) pooled over all treatments. The Levenberg-Marquardt algorithm was used to establish best-fit coefficients of nonlinear functions for regeneration density (dependent) and densitometer reading (independent) pooled over all treatments.

---

[1] Department of Forestry, University of Kentucky, Lexington, KY 40546-0073.

Citation for proceedings: Stringer, Jeffrey W.; Loftis, David L., eds. 1999. Proceedings, 12th central hardwood forest conference; 1999 February 28-March 1-2; Lexington, KY. Gen. Tech. Rep. SRS-24. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southern Research Station. 293 p. [Poster abstract].

RESULTS

Highly significant differences ($p<0.001$) were found among treatments for white oak advanced regeneration density, advanced regeneration height and densitometer readings (Table 1). The 20 reserve tree per acre treatment developed twice the number of regenerating white oak trees as the other treatments. The height of the white oak regeneration established after the treatment was greater for both cut treatments compared to the uncut treatment. The average height of the regeneration is relatively small at this point in time and would not be expected to be competitive if the stands were regenerated at this time. It is probable that some form of manipulation will be necessary to develop high vigor advanced regeneration prior to a future regeneration harvest. However, the advanced regeneration that developed after treatment indicates that the reserve trees are providing viable propagules which are developing advanced regeneration for future manipulation and stand regeneration. Densitometer readings were also higher for the cut stands compared to the uncut stands.

A positive linear relationship (y = 0.016 + 0.00724 (densitometer reading), R^2=0.733) was found between densitometer reading and PPFD indicating a relationship between measurable canopy density and light levels at advanced regeneration height (Figure 1). A positive relationship was also found between densitometer reading and advanced regeneration height (Figure 2) and densitometer reading and advanced regeneration density (Figure 3). An exponential relationship was found between densitometer reading and regeneration density (y = 43.615 + 22.373*exp(-densitometer reading/-2.489), R^2=0.974) while a linear relationship existed between densitometer reading and regeneration height (y=0.549+0.0705 (densitometer reading), R^2=0.743).

The results of this study indicate that small sawtimber sized co-dominant reserve white oak trees are capable of successfully producing advanced regeneration which will potentially aid in the long-term maintenance of this species after future regenerative treatments. A positive correlation between canopy density and regeneration height along with the positive correlation between canopy density and light level indicates that light levels developed from the treatments encouraged regeneration development. This data indicates dramatic increases in advanced regeneration density can be obtained when the combined understory, midstory, and overstory exhibit a densitometer reading greater than 6.

Table 1—Density and height of *Quercus alba* advanced regeneration developed from reserve trees in two age stands

	Density	Height	Densitometer reading
	No./ha	*Cm*	
Uncut	227[b1]	19.8[b]	5.72[c]
20 per acre	930[a]	35.0[a]	7.16[a]
35 per acre	450[b]	29.9[a]	6.47[b]

[1]Values with different letters are significantly different ($p<0.01$) using ANOVA and LSD(t).

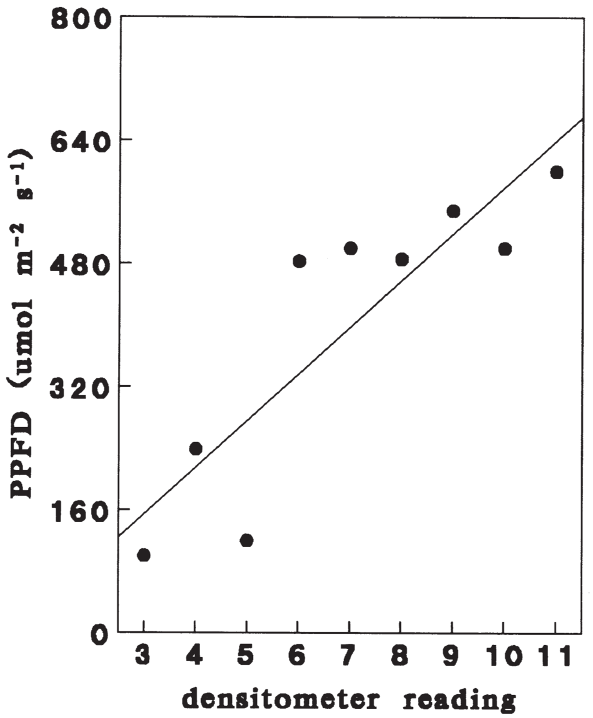

Figure 1—Data points represent average PPFD for each densitometer reading. The line represents a positive linear relationship (y = 0.016 + 0.00724(x), R^2=0.733) between densitometer reading and PPFD.

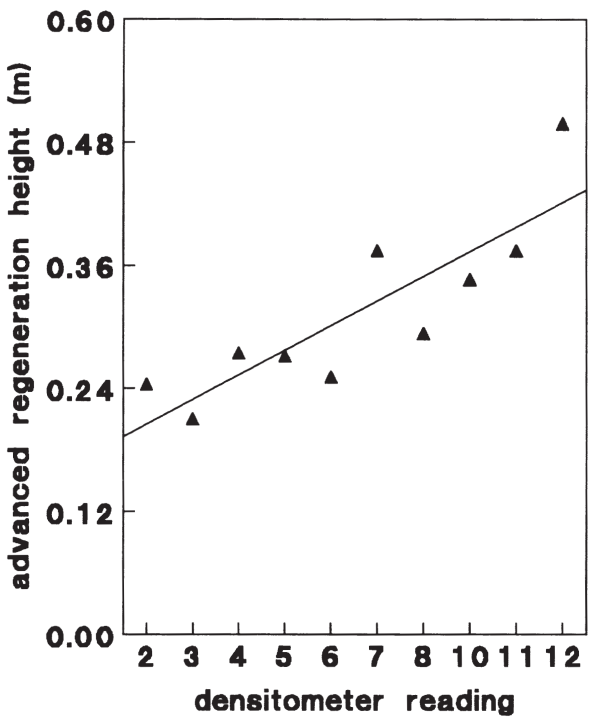

Figure 2—Data points represent average *Quercus alba* advanced regeneration stem density for each densitometer reading. The line represents an exponential relationship between densitometer reading and regeneration density (y = 43.615 + 22.373*exp(-x/-2.489), R^2=0.974).

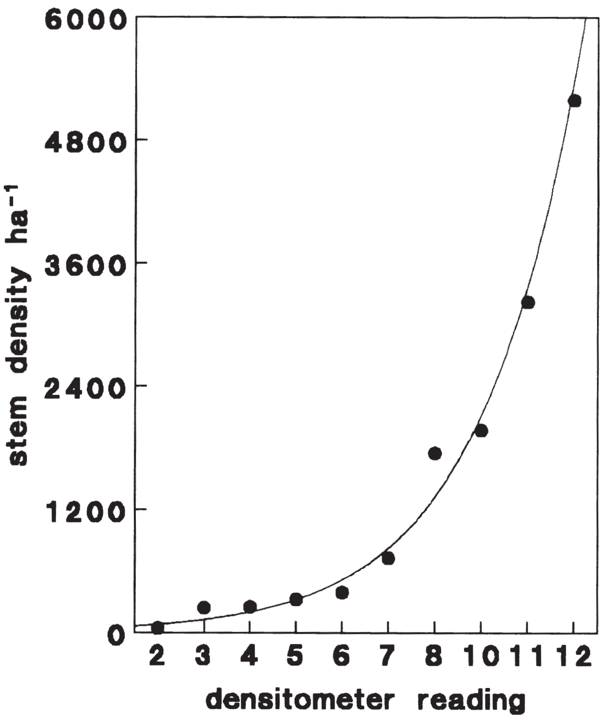

Figure 3—Data points represent average *Quercus alba* advanced regeneration height for each densitometer reading. The line represents a linear relationship between densitometer reading and regeneration height (y=0.549+0.0705(x), R^2=0.743).

Stringer, Jeffrey W.; Loftis, David L., eds. 1999. Proceedings, 12th Central Hardwood Forest Conference; 1999 February 28, March 1-2; Lexington, KY. Gen. Tech. Rep. SRS-24. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southern Research Station. 293 p.

There were 32 oral presentations, 11 abstracts, and 22 poster presentations presented at the 12th Central Hardwood Forest Conference. Presentation topics included wildlife management, nutrient dynamics, stand structure, reforestation/reclamation, timber harvesting, modeling and inventory, silviculture, disturbance effects, and genetics/tree improvement.

Keywords: Air pollution, forest ecology, forest economics, forest health, forest management, harvesting, oak-hickory, reclamation, reforestation, silviculture, stand dynamics, timber harvesting, tree physiology.