

LANDSCAPE-LEVEL REGENERATION ADEQUACY FOR NATIVE HARDWOOD FORESTS OF PENNSYLVANIA

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Abstract: Studies of advance regeneration and post-disturbance regeneration adequacy were conducted during the recent USDA Forest Service inventory of forest resources in Pennsylvania. The first study examined advance tree-seedling regeneration in stands where stocking levels would suggest that advance regeneration should be abundant. A range of metrics was used to describe regeneration adequacy. Findings indicate that advance regeneration is generally lacking in the State. The results ranged from only 4% to 40% of the sample locations being adequately stocked (based on the most and least stringent metric, respectively). Levels of fern and grass cover were sufficient to make treatment to control herbaceous vegetation an option at 54% of the sample locations. The second study focused on mixed-oak (*Quercus* spp.) stands that had undergone significant disturbance since the time of the previous inventory. Results indicate that 92% of the mixed-oak stands were adequately stocked with woody species. Stocking of oak species was far below what it was before disturbance. The least stringent metric of oak regeneration showed that only 16% of the sample locations were adequately stocked with oak species.

INTRODUCTION

At a time when many within the environmental community are concerned about regeneration of native hardwood forests, there is little information that describes regeneration adequacy at large geographic scales. Practicing foresters need information on regeneration adequacy to aid decisions about silvicultural investments and future markets for timber products. Studies of advance tree-seedling regeneration and post-disturbance regeneration were carried out as part of a recent inventory of forest conditions in Pennsylvania (Alerich 1993). The inventory was conducted by the USDA Forest Service, Forest Inventory and Analysis Unit of the Northeastern Forest Experiment Station (NE-FIA). The advance regeneration study evaluated tree-seedling abundance in a variety of forest types. The post-disturbance study focused on heavily disturbed mixed-oak stands.

METHODS

Advance Tree-Seedling and Herbaceous Cover Sample

Measurements of tree seedlings and herbaceous cover were adapted from the understory sampling procedure of Marquis et al. (1992) and added to the standard NE-FIA inventory procedures. The design for each sample location consisted of two nested circular plots--a 6-foot-radius plot and a 16-foot-radius plot located at each of five satellite points. On the 6-foot plot, tree seedlings (more than 2 in. in height and less than 1 in. in diameter) were tallied by species and height. On the 16-foot plot, percent cover was estimated for four classes of herbaceous vegetation: bracken fern (*Pteridium aquilinum* L.), hayscented fern (*Dennstaedtia punctilobula* Michx.), and New York fern

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(*Thelypteris noveboracensis* L.); other fern; grass; and blackberry (*Rubus* spp.). Sample locations were screened for the range of stand-level stocking (or relative density) where advance tree-seedling regeneration should be abundant, that is, in stands with overstory stocking of 40- to 75-percent. Stands in this stocking range have a significant overstory, but available light is not likely to limit the establishment and growth of tree seedlings. The screening resulted in 499 sample locations. Six metrics were developed to represent a range of expectations about future conditions for seedling development. The metrics assess the adequacy of advance tree-seedling regeneration for three species groups: woody, commercial, and desirable; and two levels of stocking: high and low. The specifics of deriving the metrics are described in the Appendix. The low-density measures follow the guidelines of Sander et al. (1976) and Leak (1988). The more conservative high-density measures parallel the recommendations of Marquis and Bjorkbom (1982) and reflect regeneration needs under conditions that are unfavorable for seedling development, i.e., high deer (*Odocoileus virginianus* L.) impact.

Post-Disturbance Sample

When the statewide inventory was completed, information on disturbance, species composition, and relative density (Ernst, R.L. and W. Knapp 1985) were used to identify heavily disturbed mixed-oak sample locations. The decision to focus on mixed-oak stands was in response to concern over oak regeneration (Loftis and McGee 1993). Three criteria were used to select sample stands. First, candidate stands must have had at least 50% of total density in oak species at the time of previous measurement. Second, the stand must have been at least 60% stocked at the time of previous measurement (or above B-level stocking). Third, the stand must have been reduced to below 40% stocking at the most recent measurement (or below C-level stocking). Stands in this range are considered to be in need of regeneration (Ginrich 1967). These selection criteria yielded a total of 49 sample locations which were then revisited, and a grid of twenty 6-foot-radius circular plots was installed. At each plot, stem counts were conducted by species and height class. To reduce collection cost, stem counts were limited to the number of stems needed to satisfy the most conservative of two guidelines for determining if the plot was adequately stocked with regeneration. Various stand disturbances were encountered, but most involved heavy cutting and (or) overstory mortality resulting from gypsy moth (*Lymantria dispar* L.) defoliation, drought, or other factors. For most of the sampled stands, 10 to 15 years had elapsed since disturbance. Sample locations were located across the State with highest concentrations in southcentral counties where gypsy moth defoliation had a strong impact.

Measurements were taken to gauge whether these mixed-oak stands were adequately stocked with woody, commercial, or oak species following disturbance. A high-density metric was adapted from the work of Marquis and Bjorkbom (1982). A low-density metric of roughly half the high-density guideline was used to provide a range for analyzing the results. The number of stems required for adequate stocking are:

<u>Tree-Size</u>	<u>Stocking Level</u>	
	<u>Low</u>	<u>High</u>
# of stems/plot		
5 inches dbh and larger	1	1
>= 5 feet tall and < 5 inches dbh	1	2
>= 3 feet tall and < 5 feet tall	3	5
>= 2 inches tall and < 3 feet tall	15	25

Sample locations were considered adequately stocked if at least 50% of the satellite plots satisfied a given metric. The 50% rule was used because most of the sampled stands had established forest cover of sufficient age to assume that stocking of satellite plots provides a good representation of stocking once the stand reaches merchantable size--the typical objective of post-disturbance regeneration inventories.

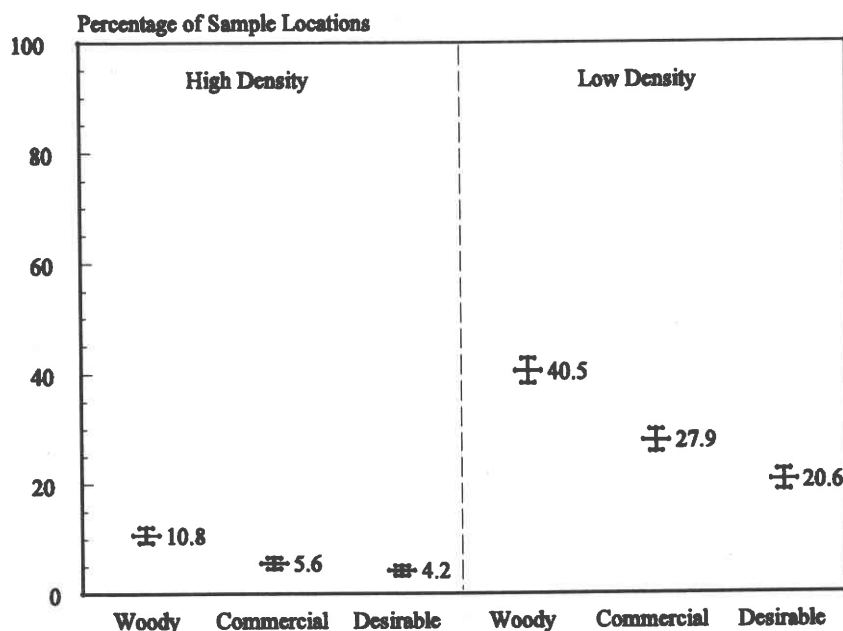


Figure 1. Mean percentage of sample locations adequately stocked with tree seedlings, by species group and density measure. (Brackets indicate the 95% confidence interval.)

RESULTS

Advance Tree-Seedling Regeneration and Herbaceous Cover

The data suggest that existing advance tree-seedling regeneration is an inadequate source for new stand establishment across most of Pennsylvania's forested landscape. Using the least stringent metric (a low density of woody stems) results in only 40% of the sample locations being adequately stocked (Fig. 1). When a high density of woody species is used, the estimate of adequacy is reduced to 11%. The woody-species measures assess the outlook for establishing woody cover following removal of the overstory without regard to how desirable the species may be for timber management. The success rates using the commercial-species measures of stocking adequacy are 28% for the low-density measure and 6% for the high-density measure. The commercial species group excludes species that contribute little to the stand's commodity value. The desirable group contains species most favored for timber production and, in general, offers more vigorous growth and a higher probability of developing a canopy of large well-formed stems that satisfy aesthetic objectives. The percentage of sample locations that were adequately stocked with desirable stems was 21 with the low-density measure and 4 with the high-density measure.

A search for statistically significant relationships between stocking adequacy and other variables collected by NE-FIA was conducted to find factors that might explain why advance tree-seedling regeneration so often is lacking in the forest understory. The variables of interest were: physiographic section (after Fenneman 1938), forest-type group, terrain position, aspect, stocking level, county-level deer density, and percentage of county-level land area occupied by forest. Continuous variables were grouped into discrete classes. Significance tests were conducted for all classes of variables and combinations of classes with at least 25 sample locations using SAS's categorical data modeling procedure (SAS Institute 1989). Of all categories tested, the only significant differences were between the oak-hickory and northern hardwoods forest-type groups. For all density measures, oak-hickory forests were associated with a higher abundance of advance tree-seedling regeneration than northern hardwood forests. This and the

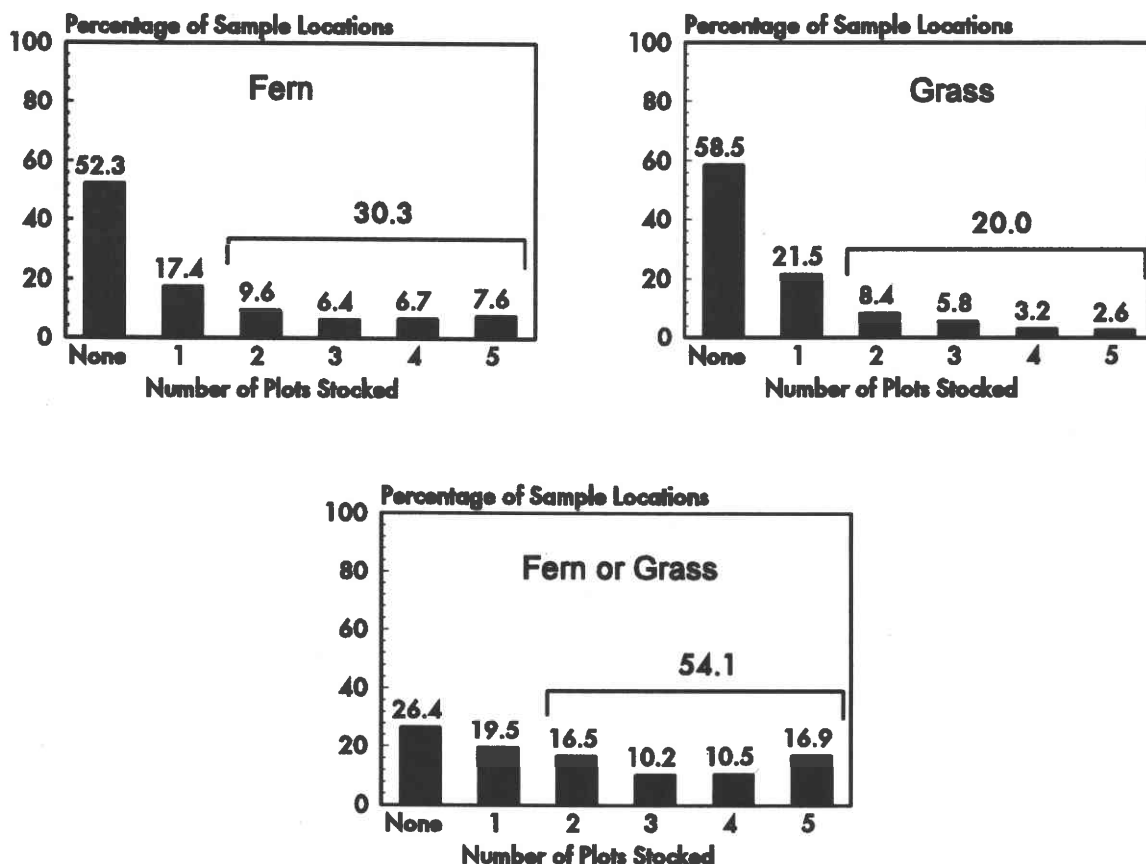


Figure 2. Mean percentage of sample locations and number of herbaceous cover plots stocked with at least 30% herbaceous plant cover, by type of vegetation.

finding that other variables and combinations were not significant suggest that poor advance regeneration is perhaps more wide ranging than was suspected.

The impact of herbaceous vegetation on regeneration ultimately depends on the abundance of advance regeneration because this determines the harvest options available (Marquis et al. 1992). In stands with sufficient regeneration for a final removal cut, the silvicultural guidelines recommend controlling herbaceous vegetation if at least 70% of the inventory plots are stocked with interfering herbaceous plants. (A herbaceous plot is considered stocked if 30% or more of the plot is covered.) If sufficient regeneration is lacking and a shelterwood seed cut is recommended, herbaceous control is considered if 30% of the plots are stocked. If the more conservative 30% threshold is used, over half of the sample locations would be potential candidates for herbaceous control due to the presence of fern, grass, or both in combination (Fig. 2). In the presence of fern alone, nearly one-third of the sample locations would qualify for treatment.

The sample also provides a general measure of the abundance of fern in Pennsylvania. Forty-eight percent of the sample locations had at least one herbaceous-cover plot stocked with 30% or more fern. The fern sample was collected for two species groups: species that have potential to spread through elongation of a perennial rhizome (bracken, hayscented, and New York fern) and other fern species. The former group is an aggressive invader of forest sites (Horsley 1988). Bracken, hayscented, and New York fern accounted for 70% of the total abundance of fern found in the sample.

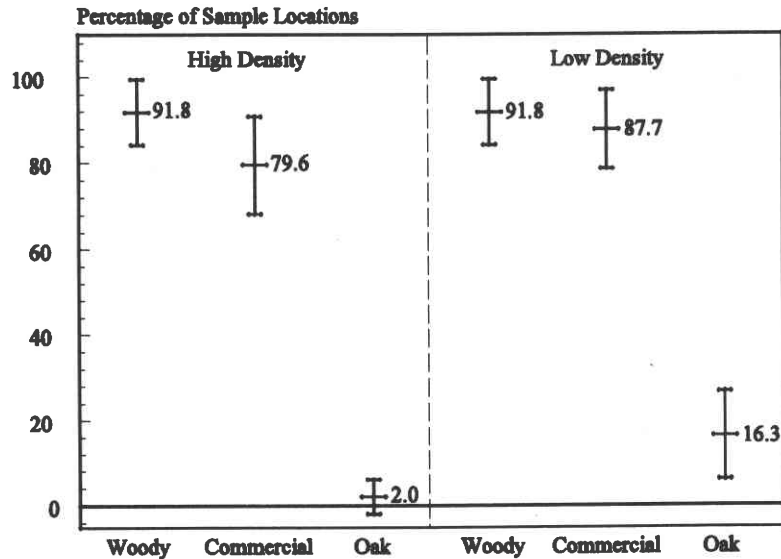


Figure 3. Mean percentage of sample locations adequately stocked with tree species following disturbance in oak-dominated stands by species group and density measure. (Brackets indicate the 95% confidence interval.)

Post-Disturbance Regeneration

The post-disturbance sample of mixed-oak stands was designed to answer two questions: 1) are stands regenerating with an adequate stocking of tree species and, 2) what is the status of oak species in the new stand? The results indicate that mixed-oak stands are regenerating adequately with tree species following heavy disturbance. Ninety-two percent of the sample locations were stocked with woody species using both the high- and low-density metrics (Fig. 3). For commercial species, 80% of the sample locations satisfied the high-density metric and 88% satisfied the low-density metric.

The findings show that the oak component is generally lacking following heavy disturbance in mixed-oak stands. When the high-density metric was used, oak regeneration was virtually non-existent. Only 2% of the sample locations were adequately stocked and this estimate was not significantly different from zero. When the low density metric was used, 16% of the sample locations were adequately stocked with oak. The low-density metric is probably a good indicator of adequacy for the oak component because of general stand conditions encountered on sample locations. Although evidence of deer was abundant on nearly all of the sample locations, most of the stands had developed to a point where sample trees were above 5 feet in height. Also, most of the oak regeneration encountered was found to be superior in terms of height, dominance, and vigor. In stands where oak regeneration was lacking, the most common species of the regeneration component were sweet birch (*Betula lenta* L.), red maple (*Acer rubrum* L.), and black cherry (*Prunus serotina* Ehrh.). As all of the stands in the study were at least 50% oak prior to disturbance, the results suggest a shift to forest types other than oak for most of the sample locations in the study. Further investigation of the data are planned to compare species composition before and after disturbance and the impact of disturbance on species diversity.

DISCUSSION

The results of these two studies have documented some significant regeneration challenges that exist across Pennsylvania's forested landscape. The advance regeneration study focused on stands where stocking levels would suggest that advance regeneration should be abundant. The most optimistic measure of advance regeneration adequacy was satisfied at only 40% of the sample locations. Fern and grass competition was significant at 54% of the sample locations. The impact of deer was not measured directly in the study, but Pennsylvania's deer herd has been a significant factor affecting understory conditions (Tilghman 1989). Other factors include soil and site characteristics, drought, stresses from diseases and insects, and other herbivores. The study of regeneration following heavy disturbance of mixed-oak stands found that regeneration was abundant, but species composition had changed due to poor regeneration of oak. The oak regeneration component was found to be inadequate in all but 16% of the sample locations. These findings are similar to those of Allen and Bowersox (1990).

It is interesting to compare the results of these two studies of regeneration adequacy even though they were conducted independently. The basic message of the advance tree-seedling study was that very few stands in Pennsylvania contained enough advance regeneration to adequately regenerate following harvest. The study of mixed-oak stands found that most stands had regenerated, but the composition tended to contain a new suite of species. The new stands typically contained light-seeded intolerant species such as black cherry and sweet birch. Black cherry and sweet birch are not preferred food sources for deer. The other prevalent species was red maple, which is very common throughout Pennsylvania and is a prolific producer of wind disseminated seed. Although not observed as part of this study, these invader species were likely not part of the advance seedling component of the sampled stands. This suggests that we need to know more about how well advance regeneration stocking guides predict future stand-level stocking and how forest composition changes as stands evolve over time.

LITERATURE CITED

- Allen, David and Todd Bowersox. 1990. Regeneration in oak stands following gypsy moth defoliations. In Proceedings of the seventh central hardwoods forest conference, 1989 March 5-8, Carbondale, IL.
- Alerich, Carol L. 1993. Forest Statistics for Pennsylvania-1978 and 1989. Res. Bull. NE-126. Radnor, PA: U.S. Department of Agriculture, Forest Service, Northeastern Forest Experiment Station. 244 p.
- Ernst, R.L. and W. Knapp. 1985. Forest stand density and stocking: concepts, terms, and the use of stocking guides. Gen. Tech. Rep. WO-44. Washington, DC: U.S. Department of Agriculture, Forest Service. 8 p.
- Fenneman, Nevin M. 1938. Physiography of the eastern United States (1st edition). New York: McGraw-Hill. 714 p.
- Ginrich [Gingrich], S.F. 1967. Measuring and evaluating stand density in upland hardwood forests in the Central States. For. Sci. 13:38-53.
- Horsley, Stephen B. 1988. How vegetation can influence regeneration. P. 38-55 in Proceedings of guidelines for regenerating Appalachian hardwood stands, SAF Publ. 88-03. Bethesda, MD: Soc. Am. For.
- Leak, William B. 1988. Effects of weed species on northern hardwood regeneration in New Hampshire. North. J. Appl. For. 5:237-240.
- Loftis, David and Charles E. McGee. 1993. Oak regeneration: serious problems, practical recommendations. Symposium Proceedings. Gen. Tech. Rep. SE-84. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southeastern Forest Experiment Station 319 p.

- Marquis, David A., Richard L Ernst, and Susan L. Stout. 1992. Prescribing silvicultural treatments in hardwood stands of the Alleghenies (revised). Gen. Tech. Rep. NE-96. Radnor, PA: U.S. Department of Agriculture, Forest Service, Northeastern Forest Experiment Station. 101 p.
- Marquis, David A. and John C. Bjorkbom. 1982. Guidelines for evaluating regeneration before and after clearcutting Allegheny hardwoods. Res. Note NE-307. Radnor, PA: U.S. Department of Agriculture, Forest Service, Northeastern Forest Experiment Station. 4 p.
- Sander, Ivan L., Paul S. Johnson, and Richard F. Watt. 1976. A guide for evaluating the adequacy of oak advance reproduction. Gen. Tech. Rep. NC-23. St. Paul, MN: U.S. Department of Agriculture, Forest Service, North Central Forest Experiment Station. 7 p.
- SAS Institute, Inc. 1989. SAS/STAT user's guide, version 6, 4th ed., volume 1. Cary, NC: SAS Institute. 943 p.
- Tilghman, Nancy G. 1989. Impacts of white-tailed deer on forest regeneration in northwestern Pennsylvania. J. Wildl. Manage. 53(3):524-532.

APPENDIX

Guidelines for determining the adequacy of advance tree-seedling regeneration.

Species Group

Desirable: Black cherry, oak, sugar maple (*Acer saccharum* Marsh.), red maple, conifer (*Juniperus virginiana* L., *Larix* spp., *Pinus* spp., *Tsuga canadensis* L.), hickory (*Carya* spp.), yellow-poplar (*Liriodendron tulipifera* L.), ash (*Fraxinus* spp.), basswood (*Tilia americana* L.), cucumbertree (*Liriodendron acuminata* L.), walnut (*Juglans nigra* L.), and butternut (*Juglans cinerea* L.).

Commercial: All desirable species and birch (*Betula* spp.), beech (*Fagus grandifolia* Ehrh.), blackgum (*Nyssa sylvatica* Marsh.), elm (*Ulmus* spp.), black locust (*Robinia pseudoacacia* L.), willow (*Salix* spp.), hackberry (*Celtis occidentalis* L.), and aspen (*Populus* spp.).

Woody: All desirable species, commercial species, and honey locust (*Gleditsia triacanthos* L.), sassafras (*Sassafras albidum* (Nutt.) Nees), ironwood (*Ostrya virginiana* (Mill.) K. Koch.), ailanthus (*Ailanthus altissima* (Mill.) Swingle), mountain ash (*Sorbus americana* Marsh.), blue beech (*Carpinus caroliniana* Walt.), hawthorn (*Crataegus* spp.), dogwood (*Cornus* spp.), redbud (*Cercis canadensis* L.), pin cherry (*Prunus pensylvanica* L.), striped maple (*Acer pensylvanicum* L.), hercules club (*Zanthoxylum clava-herculis* L.), scrub oak (*Q. ilicifolia* Wangenh.), chokecherry (*Prunus virginiana* L.), and shadbush (*Amelanchier arborea* (Michx f.) Fern.).

Satellite Plot Stocking

<u>Seedling density</u>	<u>Minimum number of seedlings per plot</u>
High	100
Low	25

To account for different seedling survival by height class, seedlings were weighted as follows:

<u>Height</u>	<u>Weight</u>
2 inches to 1 foot	1
1 to 3 feet	2
3 to 5 feet	20
5 feet and larger	50

Any combination of weighted stems that meets or exceeds the minimum number required is considered stocked. For example, a plot is considered to meet the high-density requirement for desirable species if it contains at least two stems at least 5 feet tall. Similarly, a plot is stocked with a low density of woody species if it contains 20 stems 6 inches tall and 3 stems 2 feet tall.

Sample Location Stocking

A sample location is considered stocked if at least four of the satellite plots (or at least 70%) contain the minimum number of seedlings.