Adequacy of Advance Tree-Seedling Regeneration in Pennsylvania's Forests

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ABSTRACT. *Measurement of tree seedlings and herbaceous vegetation from 499 sample locations across Pennsylvania revealed that advance tree-seedling regeneration is inadequate for new stand establishment across most of the State. The samples were located in stands from 40% to 75% stocked to focus on stands with ample light and growing space for establishment of abundant advance regeneration. A range of regeneration adequacy criteria was applied to the measurements. Using the least stringent criterion, a low density of stems of any tree species, resulted in 40% of the sample locations being adequately stocked. Applying the most stringent criterion, a high density of stems of desirable species, resulted in only 4% of the sample locations being adequately stocked. With the exception of forest-type group, no significant relationship was found between the adequacy of regeneration and other variables tested at the broad level of geographic scale of this study. Levels of fern and grass sufficient to hamper tree-seedling development were found at 54% of the sample locations. Fern species that propagate primarily by spreading rhizomes accounted for 70% of the total fern sample. North. J. Appl. For. 12(4):187–191.*

Information on the adequacy of advance tree-seedling regeneration over large geographic areas has not been available in the past for the northeastern United States. Such information is important because native deciduous species in this region rely almost exclusively on advance regeneration for development of new stands following harvest (Marquis et al. 1992, Smith 1988). Also, regeneration adequacy has emerged as an important issue of concern in the region (Loftis and McGee 1993). Practicing foresters need information on regeneration adequacy to aid decisions about silvicultural investments and future markets for timber products.

This study used large-scale inventory data to quantify the character and abundance of advance tree-seedling regeneration in Pennsylvania and to determine if existing stands contain adequate stocking of tree seedlings for establishing the next generation of forests. Adequacy of tree-seedling regeneration was based on a range of regeneration stocking criteria. We sought to make as many statistically significant conclusions as possible while staying within the limits of the data and recognizing that forecasts of future compositional shifts was beyond the scope of the study.

Note The authors wish to recognize and express heartfelt appreciation to Dave Marquis, Sandy Cochran, and others involved with initiating this study and providing training for the NE-FIA field personnel. Also, we are sincerely indebted to the NE-FIA field foresters who collected the information on which the study is based.

Methods

A statewide inventory of Pennsylvania's forests was completed for the year 1989 by the Forest Inventory and Analysis unit of the Northeastern Forest Experiment Station (NE-FIA). Measurements of tree-seedling regeneration and herbaceous cover were added to the standard NE-FIA design due to concern about possible regeneration problems in the State. These supplemental measurements were necessary because NE-FIA's standard seedling counts were not designed to evaluate regeneration adequacy. To aid species identification, measurements of tree seedlings and herbaceous cover were taken on all NE-FIA sample locations visited during the leaf-on season, from May to September.

Measurements of regeneration and herbaceous cover were adapted from the understory sampling procedure developed by Marquis et al. (1992). The design consisted of two nested circular plots at each of five satellite points dispersed within the sampled area of each NE-FIA sample location. On a 6 ft plot, tree seedlings (more than 2 in. in height and less than 1 in. diameter) were tallied by species and height class. On a 16

ft plot, percentage cover was estimated for four classes of herbaceous vegetation: bracken, hayscented, and New York fern; other fern; grass; and *Rubus* sp.

The supplemental measurements were collected across a range of stand conditions, but for this study, the sample was limited to stands within the range of stand-level stocking (or relative density) where advance tree-seedling regeneration should be abundant—in stands from 40% to 75% stocked. Stands in this stocking range have a significant overstory, but available light should not limit the establishment and growth of tree seedlings. The screening resulted in 499 sample locations that were well distributed among the two dominant forest-type groups of Pennsylvania: oak–hickory and northern hardwoods (Figure 1). The sample underrepresented the southwestern part of the State because the inventory of that region was conducted during the dormant season.

Natural variability in conditions that affect seedling growth and survival precludes the use of a single measure to test the adequacy of advance tree-seedling regeneration in a broad regional study such as this. Also, there is some variance within the literature about what constitutes adequate advance regeneration. To overcome these difficulties, six criteria were adapted from the work of Marquis et al. (1992) The criteria assess the adequacy of advance tree-seedling regeneration for three species groups and two levels of satellite-plot stocking:

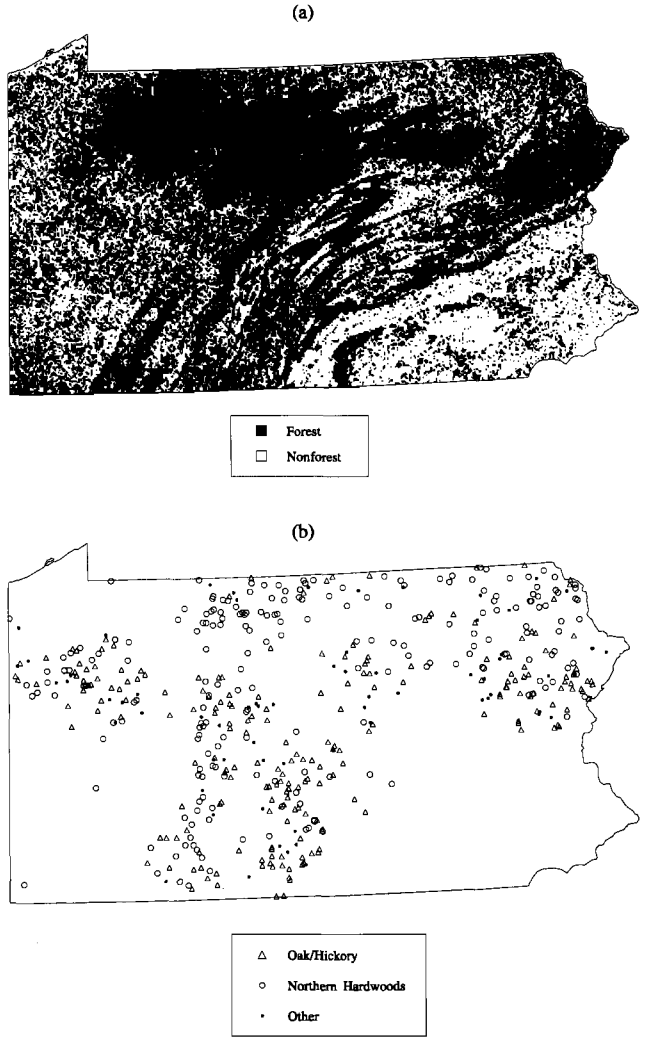

Figure 1. (a) Location of forestland in Pennsylvania; (b) distribution of sample locations by forest-type group.

Species Group

Desirable: Black cherry, oak, sugar maple, red maple, conifer, hickory, yellow-poplar, ash, basswood, cucumbertree, walnut, and butternut.

Commercial: All desirable species and birch, beech, gum, elm, black locust, willow, hackberry, aspen, and buckeye.

Woody: All desirable species, commercial species, and honeylocust, sassafras, ironwood, ailanthus, mountain-ash, blue-beech, hawthorn, dogwood, redbud, pin cherry, striped maple, hercules club, scrub oak, chokecherry, and shadbush

Stocking

Seedling density	Minimum number of seedlings per plot
High	100
Low	25

To account for different seedling survival rates by height class, each seedling was weighted as follows:

Height	Weight
2 in. to 1 ft	1
1 to 3 ft	2
3 to 5 ft	20
5 ft and larger	50

Any combination of weighted stems that met or exceeded the minimum number required was considered adequately stocked. For example, a plot was considered to meet the high-density requirement for desirable species if it contained at least two stems at least 5 ft tall. Similarly, a plot was stocked with a low density of woody tree species if it contained 20 stems 6 in. tall and 3 stems 2 ft tall. A sample location was considered stocked if at least four of the satellite plots (or at least 80%) contained the minimum number of seedlings The low-density measures are similar to the guidelines of Sander et al. (1976) for oak and Leak (1988) for northern hardwoods. The high-density measures parallel the recommendations of Marquis and Bjorkbom (1982) for Allegheny hardwoods and reflect regeneration needs under conditions unfavorable for seedling development (i.e., high deer impact).

A search was made for statistically significant relationships between stocking adequacy and other variables collected by NE-FIA. Those 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).

Results

The data suggest that advance tree-seedling regeneration is inadequate for new stand establishment across most of Pennsylvania's forested landscape (Figure 2). Applying the least stringent criterion (a low density of woody tree seedlings) only 40% of the sample locations were adequately stocked. Using the high density of woody tree seedlings criterion, the estimate of adequacy is only 11%. These measures assess the outlook for establishing tree cover following complete removal of the overstory (clearcutting) without regard to the commercial value of the species that regenerate. Most likely, many new stands would include a significant component of species such as striped maple and pin cherry.

The success rates using the commercial-species measures of stocking adequacy were 28% for the low-density measure, and 6% for the high-density measure. In these cases, the commercial species group included beech, a common understory species in Pennsylvania.

Estimates of stocking adequacy for more desirable species were the lowest. The percentage of sample locations that were adequately stocked with desirable stems was 21 based on the low-density measure and 4 for the high-density measure.

Figure 3 shows the distribution of sample locations by stocking adequacy for the most stringent and least stringent criteria used in this study. Discounting southwestern Pennsylvania that was underrepresented in the sample, both maps suggest a somewhat higher concentration of inadequately stocked sample locations in the north-central region of the State. Stocking adequacy is somewhat higher along the northern tier counties with the low-density criterion, possibly because beech is common in the understory there. Secondly, outside the north-central region, inadequately stocked sample locations are distributed randomly.

Of all categories tested, the only significant differences were between the oak–hickory and northern hardwoods forest-type groups (Figure 4). For all density measures, oak–hickory forests were associated with a higher abundance of advance tree-seedling regeneration than northern hardwood forests. Values for all density measures were higher for the Ridge and Valley section than for either the Allegheny

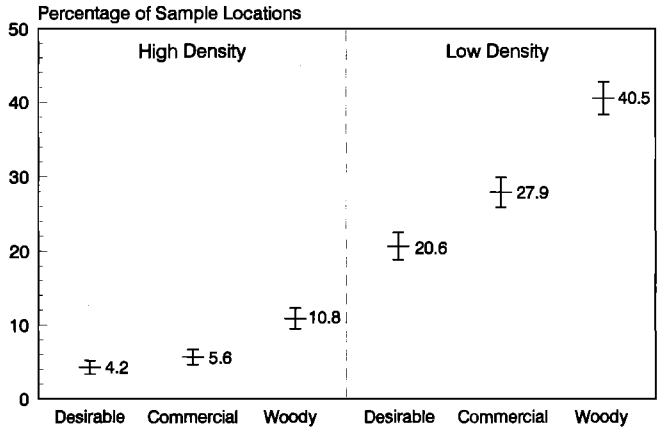

Figure 2. Mean percentage of sample locations adequately stocked with tree seedlings (with 95% confidence intervals) by species group and density measure, Pennsylvania, 1989.

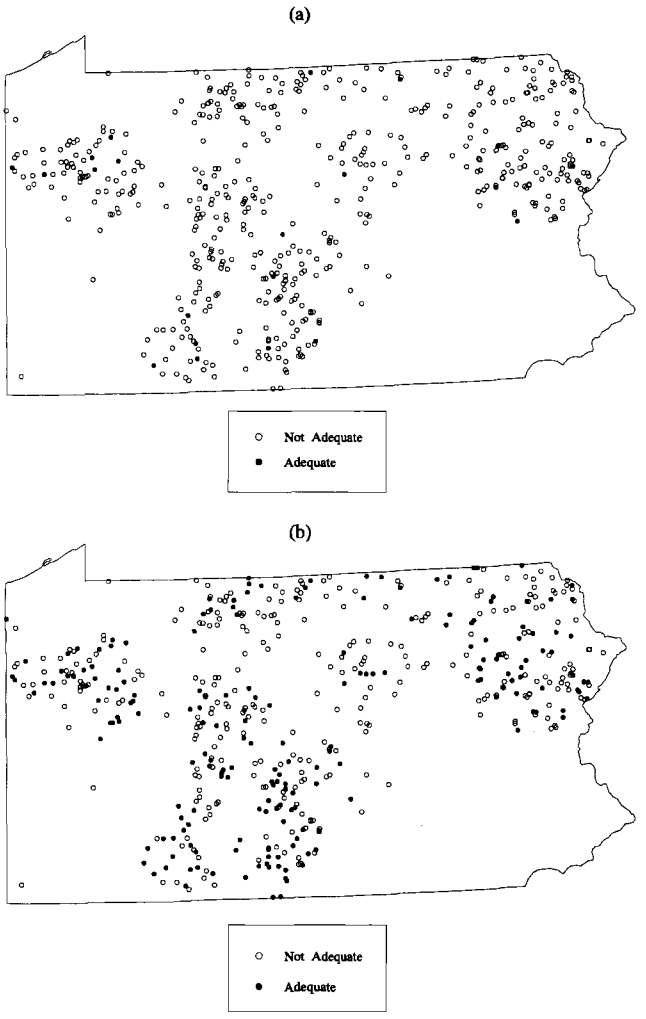

Figure 3. Distribution of sample locations by adequacy of tree-seedling stocking using measures of (a) high density of desirable stems and (b) low density of woody stems, Pennsylvania, 1989.

Mountain or Allegheny Plateau section, yet the differences were not significant. This implies that poor advance regeneration is widespread.

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 advance regeneration for a final removal cut, the silvicultural guidelines recommend considering treatment to control herbaceous vegetation if at least 70% of the plots are stocked. (An herbaceous cover plot is considered stocked if 30% or more of the plot is covered.) If sufficient regeneration is lacking, a shelterwood seed cut is recommended. For the shelterwood treatment, herbaceous control is considered if 30% of the plots are stocked. These thresholds are based on the relative growth rates of seedlings and herbaceous vegetation under different light conditions. Under the high light conditions that follow a final removal cut, seedling growth can outpace the growth of herbaceous vegetation. Under the lower light conditions of a shelterwood seed cut, seedling growth is reduced and herbaceous vegetation is able to outcompete tree

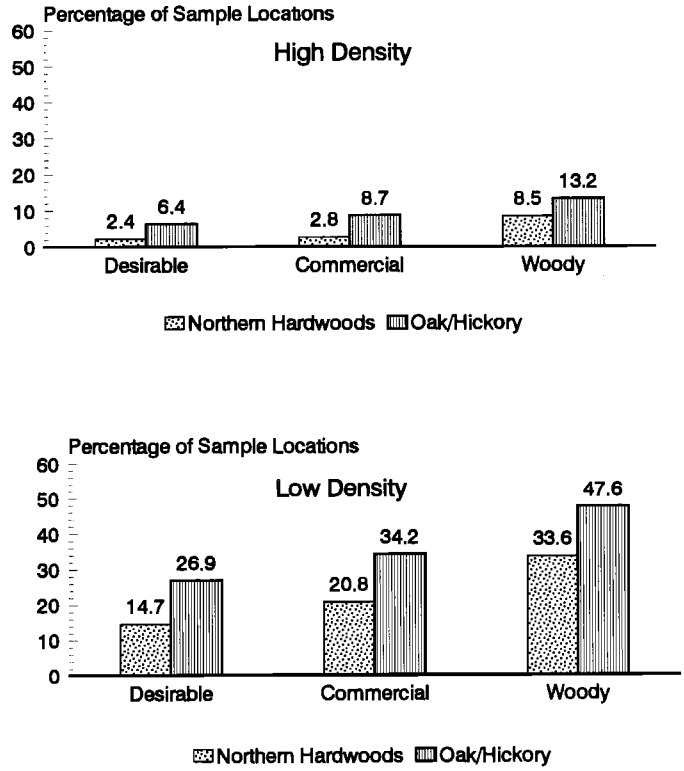

Figure 4. Mean percentage of sample locations adequately stocked with tree seedlings by species group, density measure, and forest-type group, Pennsylvania, 1989. Differences between paired bars are statistically significant at 95% confidence level.

seedlings. Using the 30% threshold, over half of the sample locations would be potential candidates for herbaceous control due to the presence of fern, grass, or both in combination (Figure 5). In the presence of fern alone, nearly one-third of the sample locations would qualify for treatment.

The sample provided a general measure of the abundance of fern in Pennsylvania. Data show that 40% of the sample locations had at least one herbaceous cover plot stocked with 30% or more fern cover. The fern sample was collected for two species groups: species that spread primarily 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.

Discussion

The findings clearly document the impoverished condition of advance tree-seedling regeneration in Pennsylvania's forests. The sample was drawn with the specific intent of focusing on stands in the range of stocking where advance regeneration should be abundant. A range of adequacy measures was used to account for differences in published guidelines and an array of possible forest management objectives It is not possible to correlate this study's findings with causal factors, although it is important to recognize that high deer populations, gypsy moth, and drought were ubiquitous dur-

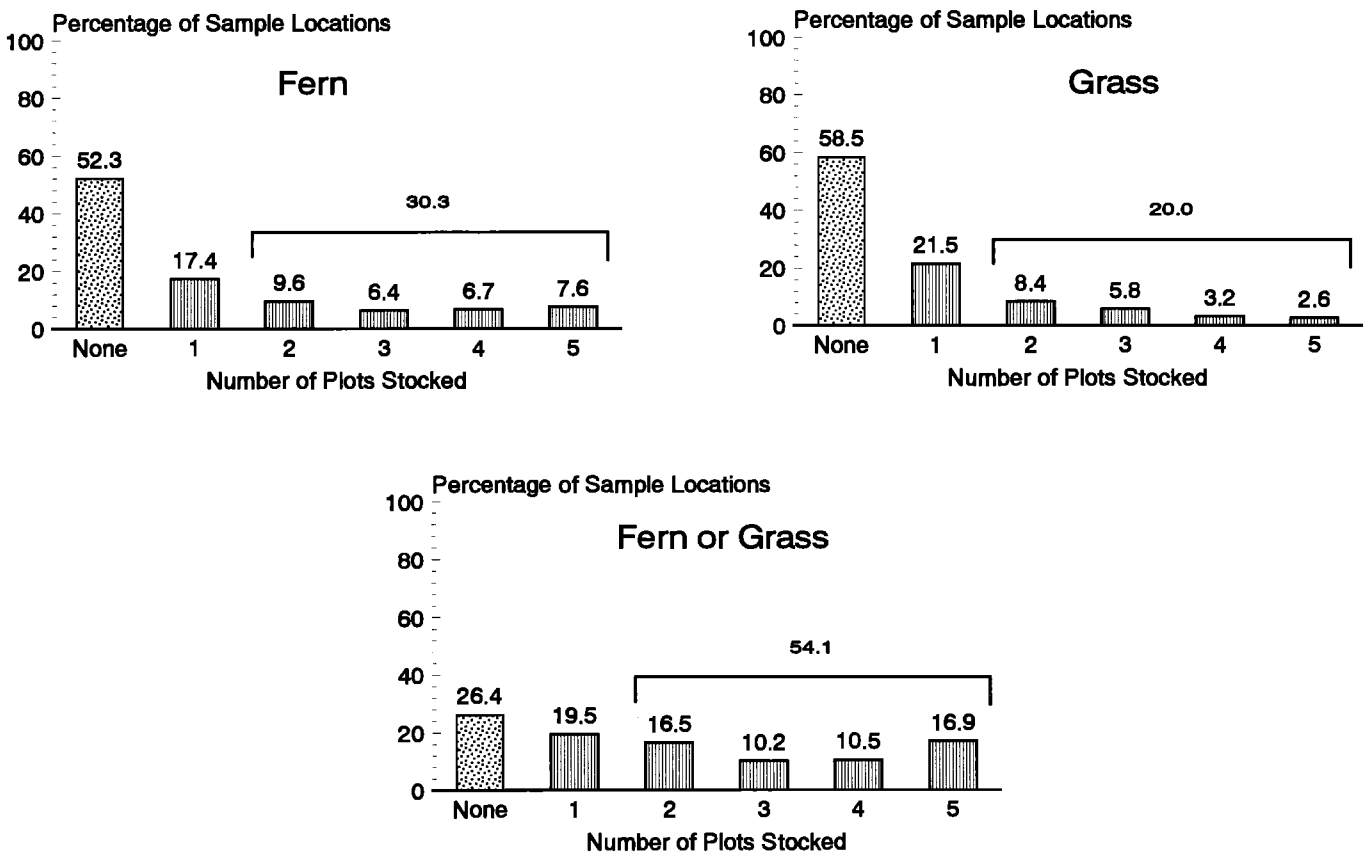

Figure 5. Mean percentage of sample locations and number of herbaceous cover plots stocked with at least 30% herbaceous plant cover, by type of vegetation, Pennsylvania, 1989.

ing the period covered by the NE-FIA inventory. These factors will continue to bear consideration when prescribing silvicultural treatments.

The impact of deer browsing is perhaps the most pervasive obstacle to regeneration (Marquis 1981). Research has shown that deer density in excess of 18 deer per square mile of forest has devastating consequences on regeneration (Tilghman 1989). Population data show that deer density exceeded this threshold throughout the study region (Penn. Game Comm. 1991). The silvicultural guides of Marquis et al. (1992) propose treatments to overwhelm deer with so much food within the home range of local populations that some seedlings persist in harvest areas to establish new stands. This can be accomplished by:

- selecting areas with abundant advance regeneration,
- using shelterwood cuttings to stimulate regeneration,
- using herbicides to eliminate plants that prevent regeneration establishment and growth,
- fencing areas with few interfering plants until regeneration grows beyond the reach of deer, and
- maximizing the area in high deer food producing conditions.

In the stands selected for this study, with overstory stocking between 40% and 75%, lighting conditions at the time of measurement were like those found after a shelterwood cutting. Further cutting is unlikely to increase advance regeneration in the many stands where it is lacking. Herbicide and/or fencing investments may be required in many of these stands. For other stands, landscape management strategies to increase the proportion of surrounding areas in high deer food producing conditions may be a viable option.

Guidelines for silvicultural treatments to contend with gypsy moth are provided by Gottschalk (1992). One implication of treatments in stands influenced by gypsy moth is that long-term trends in composition will be away from oaks and other preferred species. Advance planning for unpredictable events such as drought is difficult and generally outside the scope of traditional silvicultural guides.

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