ALTERNATIVE SILVICULTURAL PRACTICES IN APPALACHIAN FOREST ECOSYSTEMS: IMPLICATIONS FOR SPECIES DIVERSITY, ECOSYSTEM RESILIENCE, AND COMMERCIAL TIMBER PRODUCTION

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Abstract—Increasing demands for timber and non-timber forest products often conflict with demands to maintain biodiversity and ecosystem processes. To examine tradeoffs between these goals, we implemented six alternative management systems using a stand-level, replicated experiment. The treatments included four silvicultural regeneration methods designed to sustain timber production, one commercial harvest without regard for future stand values, and a no harvest control. Our goal was to determine effects of management alternatives on multiple system components, including biodiversity, medicinal plants, timber production, terrestrial amphibians, soil disturbance, invasive exotic plants, soil and leaf litter invertebrates, leaf litter decomposition rates and nutrient flux. Plant species richness increased with increasing canopy disturbance, through colonization both by shade-intolerant native species and by exotic species. We detected several species of medicinal plants. Oak regeneration depended more on site quality than treatment. Terrestrial salamander populations declined precipitously on all treatments subjected to canopy disturbance. Although initial soil loss was reduced by using treatments that retained higher levels of basal area in the stand, over a complete rotation, the effects of repeated entries are likely to cause greater soil loss than a clearcut and greater impacts on salamanders.

INTRODUCTION

The Silviculture and Biodiversity in Southern Appalachian Forests study was designed to address the conflict between increasing pressures to harvest commodities and pressures to restrict harvests in order to achieve recreation and conservation goals. This conflict may be seen in local efforts to prevent clearcutting on National Forests. We hoped to be able to provide reliable information about the costs and benefits of different management strategies for both commodity and non-commodity components of the forest.

We approached this study with three points in mind: (1) Managers need to know the costs and benefits of each management practice in relation to alternatives. (2) Randomly assigned experimental manipulations are needed to differentiate between real effects and artifacts of site peculiarities. Although chronosequence studies can contribute valuable information, the confounding relationships that exist between site conditions and management techniques severely limit the inferences that can be drawn. (3) Although short-term trends can be informative, these initial responses may or may not reflect longer-term trends. We designed this study to extend over a complete rotation (80-100 years). In this paper, of course, we are limited to reporting only preliminary results.

Our major objective was to compare the short- and long-term effects of alternate forest management techniques. A key benchmark of success was long-term maintenance of oak dominance. Oak stands have high timber value, high value for many game and non-game species of wildlife, and were common in

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much of the immediate pre-European settlement forests in the central and southern Appalachians. For this reason, the alternatives we chose to study include only those that have been used successfully or are currently being promoted as techniques for oak regeneration.

METHODS

We established 5 replications in the George Washington and Jefferson National Forest, in Virginia, and 2 on MeadWestvaco Corporation's Wildlife and Ecosystem Research Forest in West Virginia. Harvests occurred between 1994 and 1998 with all harvesting treatments implemented at approximately the same time at each location. Six treatments 2 ha in size were included in each installation: (See Wender 2000, Hood 2001, and Knapp and others 2003 for details of prescriptions.)

1. Control: no silvicultural activity within the stand

2. Group selection system: two or three groups, each from 0.1-0.25 ha, were made in each area. All stems in the group cut were felled. Additionally, a timber stand improvement cut that removed poor quality trees from the lower crown classes was implemented in the areas between harvest groups.

3. Shelterwood system: 11-14 m^2/ha of main canopy basal area was retained following the initial cut.

4. Commercial clearcut: 5-10 m^2/ha of basal area was retained during the harvest. The residual stand was typically unmerchantable poletimber or sawtimber cull trees.

5. Leave-tree system: 25-50 trees/ha (approximately 5 m^2 of BA/ha) were left to remain throughout the rotation, thus creating a two-aged structure. Residual trees were selected based on good form, dominant or codominant crown position, and species desirability (oaks and other commercial species).

6. Silvicultural clearcut: removal of all stems >5 cm DBH, creating an even-aged structure. Non-merchantable stems were felled and left on the ground.

Quantitative data on overstory, midstory, and understory vegetations were collected from permanently marked plots arrayed in a nested design of 24 x 24 m tree, 6 x 6 m shrub, and 1 x 1 m herbaceous plots. In each treatment, 3 sets of nested plots were established. A 24 m x 24 m "tree plot" was established where height and diameter of all trees was measured. The tree plot was divided into sixteen 6 m x 6 m "shrub plots". Three of the shrub plots were randomly selected and height of all woody vegetation less than 1.3 m tall was measured. The shrub plots were then divided into 1 m x 1 m "herbaceous plots". Nine of the herbaceous plots were randomly selected and inventoried for all vascular plants. Vascular plant species were also inventoried in each 2 ha treatment plot using complete walk-throughs twice per growing season. Pretreatment data was collected for one year prior to treatment at each site. Post treatment data was collected at 1 year and five years following harvest.

We sampled actively foraging salamanders using night-time area-constrained searches (Harpole and Haas 1999) only during or after rain events (Feder and Londos 1984). We established a grid of nine 2 x 15 m transects per treatment plot and sampled a subset of these per plot per year.

RESULTS

Species richness of woody and herbaceous plants 1-year post-treatment was higher in plots with canopy disturbance (Wender 2000). Considering individual species, there was almost no loss of herbaceous plant species in response to harvest (Wender 2000, Hood 2001). Increases in exotic species richness were dramatic on harvested sites, averaging more than 10 new species per treatment plot. (Preharvest levels averaged less than 1 per plot.) Some of these were introduced through the seed mixes used to revegetate skid trails. The increase in exotics varied significantly among our sites, suggesting that landscape context may play a large role in the probability of a site being invaded.

To test the effects of harvesting on understory plant community structure, we analyzed plant community dissimilarity using Jaccard's distance. We expected the naturally patchy plant community to become more homogenous or uniform after harvest, leading to a post-harvest decline in Jaccard's distance. We found both positive and negative slopes, depending on the harvest treatment applied, suggesting that the different treatments may have very different effects on community structure, some increasing and some decreasing homogeneity.

Although our sites are relatively dry, unsuitable to some medicinal plants such as ginseng (*Panax quinquefolius* L.), we identified 30 species of plants known to be used for medicinal purposes. Several of the medicinal plants appeared to respond positively to harvest in the short-term, but at least one species showed a more than 40 percent decline in cover 1-year post-treatment (unpublished data).

The effects of harvesting on oak regeneration were compared among sites and among treatments. Oak regeneration dominance (relative density of dominant and codominant oak regeneration) varied by site, but did not vary by silvicultural treatment; all treatments resulted in relatively low numbers (Lorber 2003). Advanced oak regeneration was not abundant at any of the sites prior to harvest. Oak regeneration dominance four years after harvest varied by site, with successful regeneration of oak only on the lowest quality site (SI 60). In contrast, on the intermediate and higher quality sites (SI 70-80), oak has not regenerated successfully and is being replaced by other species such as black cherry (*Prunus serotina* Ehrhart.), yellow-poplar (*Liriodendron tulipifera* L.), and cucumber magnolia (*Magnolia acuminata* L.). Oaks will likely make up a smaller proportion of the trees in the future stands compared to the parent stands. The biggest losses in oak importance occurred on the intermediate and high quality sites. Therefore, the silvicultural treatments used here were not enough to overcome the site specific limitations to successful oak regeneration. Multiple linear regression analysis was used to identify the factors controlling oak regeneration at a smaller scale. The most important variables were those that described the oak stump sprouting potential, the understory and overstory oak component in the pre-harvest stand, post-harvest light and soil nitrogen levels.

In the period 1-4 years post-treatment, none of the harvest treatments differed significantly from the silvicultural clearcut in the relative abundance of salamanders (Harpole and Haas 1999, Knapp and others 2003). Even though only approximately 20 percent of the canopy in the group selection harvest was disturbed, salamander abundance on these plots declined to less than 50 percent of the preharvest population (Knapp and others 2003).

Although 1-year post-treatment clearcuts showed the highest level of estimated soil loss, projected over a 100-year rotation the group selection harvest showed the highest level. Over the rotation, group selection was projected to increase erosion 108 percent over the control while a clearcut would increase erosion only 38 percent (Hood and others 2002).

DISCUSSION

When land managers consider eliminating clearcutting, they should evaluate the costs and benefits of alternative management practices. Although there has been concern that clearcutting harms understory plant and animal communities (e.g., Ash 1988, Duffy and Meier 1992; Petranka and others 1993, 1994), our short-term evidence does not show an advantage of other regeneration techniques. We found almost no loss of herbaceous plant diversity in any of the treatments. However, if local plant extinctions were to occur, we might expect these during the period of low light penetration that occurs 4-20 years after harvest, rather than in the first year post-harvest. Our data support previous studies showing that salamander populations decline drastically following clearcuts. However, the same response was found on all treatments subjected to canopy removal, so there is no advantage to switching to alternate techniques.

We also found little evidence that regeneration techniques that retain some canopy reduce soil loss over the long run compared to clearcuts, because most of the erosion originates from roads and skid trails.

USLE estimates of soil erosion in each treatment indicate that erosion rates decline rapidly vegetation grows following disturbance. However, because of the multiple entries and increased number of skid trails required in the group selection system, projections over a 100-year rotation indicate that the group selection treatment showed the highest soil loss, and the shelterwood was no different from the clearcut.

Our preliminary results suggest that there may be some effects of harvest treatment on herbaceous plant community structure and resilience and we hope to be able to study this further. We will also need to collect more intensive data in order to compare the effects of harvest treatments on plants used in the medicinal plant trade.

Because oak dominance often declines following clearcutting, alternative regeneration systems are frequently recommended to regenerate these intermediate shade tolerant species. However, we found that the different regeneration treatments had little effect on oak regeneration. Site quality determined whether oaks would persist or be replaced by other species. Without substantial amounts of oak advanced regeneration prior to harvest, oak dominance will likely decrease following harvest on all but the lowest quality sites.

Considerations of uneven- and some even-aged regeneration methods often fail to account for the multiple stand entries required by these methods (e.g. group selection and shelterwood). The disturbance created by harvesting does cause declines in populations of salamanders and some medicinal plants and results in soil loss. Repeating these disturbances frequently, or spreading them across a larger portion of the landscape, may actually result in detrimental effects much greater than those of a clearcut. In conclusion, we hope our work will illustrate how the choice of management techniques results in different tradeoffs in the short and long terms and how the effects will vary based on initial site characteristics.

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