Forest Ecology and Management xxx (2016) xxx–xxx

Contents lists available at ScienceDirect

Forest Ecology and Management

journal homepage: www.elsevier.com/locate/foreco

Managing Appalachian hardwood stands using four management practices: 60-year results

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ARTICLE INFO

Article history:
Received 29 February 2016
Received in revised form 5 August 2016
Accepted 11 August 2016
Available online xxxx

Keywords:
Fernow
Cutting practice level
Uneven-age management
Productivity
Tree quality
NPV

ABSTRACT

A long-term forest management case study on the Fernow Experimental Forest in West Virginia referred to as the Cutting Practice Level study is evaluated after 60 years. Treatments include a commercial clearcut (one time application), a 39 cm diameter-limit (applied 4 times), uneven-aged management using two variations of single-tree selection (applied 7 and 8 times, respectively), and an unmanaged reference area. We examine productivity, species composition and diversity, structure, tree quality, and revenues generated related to each treatment since establishment. The diameter-limit treatment resulted in greatest average periodic annual increment (PAI) of sawtimber volume of 3.1 m^3 ha^{-1} yr^{-1} while the unmanaged reference area resulted in the least of 2.2 m^3 ha^{-1} yr^{-1} (based on the difference in standing volume from 1956 to 2008). All types of partial harvesting resulted in greater sawtimber productivity than either the commercial clearcut or the reference area. Post-harvest tree quality, as measured by proportion of grade 1 butt logs, has improved from 1988 to 2008 for all but the diameter-limit treatment, which is similar to conditions in 1968. In 2008, the proportion of grade 1 trees in the residual stand ranged from a high of 0.22 for single-tree selection to 0.15 for diameter-limit harvesting. Species composition is becoming less diverse and more dominated by shade-tolerant species in all treatment groups but the change has been the greatest in the two single-tree selection treatments. Initially, size-class distributions were somewhat unimodal and reflective of even-aged stands with shade tolerant species persisting in the understory. In 2008, the single-tree selection treatments were both characterized by a reverse-J size class distribution and it appears this structure can be maintained due to recruitment of shade-tolerant species in the smaller size classes with concomitant reductions in species diversity. The net present value for each treatment in 2008, the time of the last management intervention, ranged from \$20,000 ha^{-1} for reference area to almost \$34,000 ha^{-1} for the single-tree selection treatment that included management of pole-sized trees based on all revenue and the value of standing timber using an internal rate of return of 4%.

Published by Elsevier B.V.

1. Introduction

In the middle of the 20th century, forest science was still in its early developmental phase in North America. Following a period of forest exploitation from about 1880–1920 in the eastern United States and the end of World War II, scientists and managers were poised to test and apply concepts about forest management that were not yet fully understood. Long-term forest research and demonstrations were set up on the network of Experimental Forests administered by the U.S. Forest Service to learn more about silviculture, economics, utilization and other issues (Shapiro, 2014). Some of these studies and demonstrations continue to the present time and the insights gained are often contrary to the original hypotheses or expectations. Moreover, as time passes, what society wants or needs from forests also changes and likewise the questions asked about these long-term studies also change. Habitat for protected species, carbon sequestration and climate change resilience are all relevant issues today, but were not envisioned when these older silvicultural experiments were initiated. Thus, some of the most valuable insights gained from long-term silvicultural research may be unrelated to the original goals of the study.

Here we report on a silvicultural demonstration that spans more than six decades and highlights both the challenges and opportunities gained through long-term studies on experimental forests (Lugo et al., 2006; Hayes et al., 2014). In 1948 an area

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http://dx.doi.org/10.1016/j.foreco.2016.08.019
0378-1127/Published by Elsevier B.V.

was established on the Fernow Experimental Forest in West Virginia to demonstrate different forest management practices that could be applied to hardwood forest types in the Central Appalachians. This descriptive case study, referred to as the Cutting Practice Level (CPL) demonstration, consisted of four compartments each assigned a different long-term management practice, including a commercial clearcut, a diameter-limit harvest, and two variations of single-tree selection. In 1956, an adjacent unmanaged area with the same site conditions and pretreatment disturbance history was added to serve as a reference condition through time. For the past 60 years, harvests have continued without interruption, approximately every 10 years for the single-tree selection compartments and every 20 years for the diameter-limit compartment.

The term "cutting practice levels" was first used in a 1945 survey of forest conditions and forest management being conducted throughout the United States (Harper and Rettie, 1946). At that time, the "levels" of high-order, good, fair and poor were intended to reflect the quality of forest management practices in use at that time. The same terminology was incorporated into the Fernow CPL demonstration as high-order (single-tree selection that included management of pole-sized trees and other additional treatments), good (single-tree selection for sawlog-size trees only), fair (diameter-limit harvesting), and poor (commercial clearcut) cutting practices. Other experimental forests in the northeast and north-central United States have similar case studies that were established at about the same time for the same purpose but treatments vary according to each region (Kenefic and Schuler, 2008).

The CPL case study on the Fernow began with a set of descriptive theories about how forests respond to different cutting practices. High-order cutting was considered the best method of harvesting that would rapidly build up and maintain the quantity and quality of yields consistent with the full productive capacity of the land. Good cutting was characterized as a practice that would produce acceptable yields and retain desirable species, although with longer cutting cycles than high-order cutting. Fair cutting was envisioned as a practice that would result in some species that were marketable with sufficient growing stock to yield a commercial harvest but require a longer cutting cycle than with high-order or good cutting practices, about every 20–30 years. And poor cutting was envisioned as a practice that would provide limited means for natural regeneration of desirable species following liquidation-style cutting resulting in forest decline; represented by short-lived and unmerchantable species and reduction in both quantity and quality of yield.

As a case study, the Fernow CPL was not designed to rigorously test these theories but to demonstrate this range of forest management practices. However, after 60 years of forest management research in the northeastern and north-central United States, most initial assumptions have been modified or rejected by the cumulative efforts of researchers region-wide and the results presented here, illustrating the importance of on-the-ground trials of accepted but untested forestry principles. The trends we report illustrate long-term forest stand dynamics and economic returns that were not anticipated decades ago and provide the opportunity for developing new ideas about forest stand dynamics and related concerns in the 21st century.

2. Methods

2.1. Study area

This case study was conducted on the Fernow Experimental Forest in north-central West Virginia (39.03°N, 79.67°W). The Fernow is part of the Allegheny Mountains of the Central Appalachian Broadleaf Forest (McNab and Avers, 1994). The average growing season is about 145 days and annual precipitation averages 142 cm (Pan et al., 1997). The CPL encompasses 5 equally-sized compartments totaling just over 10 ha with a predominantly western aspect. The relatively small area facilitated the training and demonstration component of this work. Larger areas on the Fernow that are replicated and with site index added as an explanatory variable have been reported on before and partially corroborate the findings we report on here (Schuler, 2004). The site has an average elevation of 760 m ASL with slopes ranging from 10 to 30% and an average northern red oak site index of about 24 m. The Belmont soils of the CPL study area have moderately high fertility and soil moisture capacity. Historically, the site has supported northern red oak (*Quercus rubra*), yellow-poplar (*Liriodendron tulipifera*), and sugar maple (*Acer saccharum*) and the forest type is classified as mixed-mesophytic. Collectively these features represent one of the most productive sites in the Central Appalachians.

2.2. Silvicultural treatments

The commercial clearcut (CC) in the CPL removed all merchantable stems greater than 12.7 cm dbh (diameter at breast height) after the 1949 growing season with no cull tree removal or planned silvicultural treatments to improve the next stand. This was presumed to be an exploitive type of harvest believed to be the "prevalent liquidation method of cutting characterized by forest deterioration" at the inception of this case study (Weitzmann, 1949). It was assigned the "poor" forest management practice moniker, but it was noted that at times it might be more appropriately classified as a destructive cutting practice. Although no intermediate treatments were planned, in 1988, 40 years after the regeneration harvest, grapevines (*Vitus* spp.) were cut so that the ongoing even-age stand development could progress. Approximately 825 vines were cut using hand tools and required 4.5 h of labor. This cultural treatment deviated somewhat from the original intent to represent only poor or exploitive practices for this part of the case study.

A diameter-limit harvest (DL) on a 20-year cutting cycle was implemented as a "fair cutting" practice. Since the first harvest in 1949, there have been three additional harvests in 1968, 1988, and 2008. In each harvest, all trees more than 39 cm dbh were cut while smaller trees were allowed to remain in the stand, reflecting the original "fair" level of management intensity. Also, most grapevines are cut near the ground line after each cutting cycle. Some small grape arbors, where grapevines developed into matted entanglements in tree crowns and cause periodic crown damage due to snow loading, have existed in this compartment for many years but were not allowed to expand by cutting vines around the perimeter of the arbor.

Single-tree harvesting of sawlog-size trees (ST) on a 10-year cutting cycle was used for the "good" cutting practice level. To date, there have been seven harvests (1949, 1958, 1968, 1978, 1988, 1998, and 2008) and in each one some trees more than 28 cm dbh and all grapevines were cut or girdled. Residual stand goals were defined by the BDq method (Nyland, 1996) which consists of the residual basal area (B), the dbh of the largest tree to retain after each harvest (D), and the ratio of trees in successively smaller size classes (q). The q-value results in a negative exponential size-class distribution, sometimes referred to as a reverse-J distribution. In this instance, the prescription included a residual basal area for sawlog-size trees of 16 $m^2\ ha^{-1}$, a maximum dbh of 81 cm, and a q of 1.3 (based on 5 cm dbh classes). The maximum dbh is appropriate for the excellent growing conditions found at the site.