Forest Ecology and Management 432 (2019) 140–149

Contents lists available at ScienceDirect

Forest Ecology and Management

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

Effects of conversion harvests on light regimes in a southern pine ecosystem in transition from intensively managed plantations to uneven-aged stands

Ajay Sharma[a,*], Kimberly K. Bohn[a,1], Justin McKeithen[a], Aditya Singh[b]

[a] West Florida Research and Education Center, University of Florida, 5988 U.S. 90, Building 4900, Milton, FL 32583, USA
[b] Department of Agricultural and Biological Engineering, University of Florida, 261 Rogers Hall, 1741 Museum Rd., Gainesville, FL 32611, USA

ARTICLE INFO

Keywords:
Stand conversion
Slash pine
Group selection
Shelterwood
Natural regeneration
Leaf area index
Uneven-aged silviculture
Gap dynamics

ABSTRACT

Uneven-aged silviculture is increasingly viewed as ecologically and economically appropriate strategy to manage forest ecosystems. Consequently, there is interest in converting intensively managed pine plantations to uneven-aged stands in the southeastern United States. Understanding biophysical factors that determine performance and growth of desirable species is critical to success of such conversions. We initiated a replicated, long-term, operational-scale stand conversion experiment in mature slash pine (*Pinus elliottii* Engelm.) plantations in mesic-wet flatwoods sites in northwest Florida, and examined how five conversion harvests (shelterwood, group selection, staggered third row thin, third row thin, cut 2 leave 3 thin harvests), in addition to an uncut control, affected understory light availability in these forests. Light availability was measured in terms of leaf area index, sky, and fractions of Absorbed Photosynthetically Active Radiation (both direct and diffuse). The values of these variables were derived by analyzing a total of 880 (450 in the harvest treatment plots and additional 430 in the gaps of group selection) Digital Hemispherical Photographs using image analyzing software CAN-EYE. We found that shelterwood harvest resulted in highest light availability, whereas greatest variability in light conditions was observed following group selection harvests. Among the four circular gap sizes (0.1, 0.2, 0.4 and 0.8 ha) we studied, gaps of larger sizes had greater light availability. Light availability increased as the distance from the gap edge increased and was highest either in the center of the gap or slightly towards northern and western sides of the gap center. Variability in light availability increased as gap size increased from 0.1 to 0.4 ha but was reduced in the 0.8 ha gap. In shade-intolerant species like slash pine in wet flatwoods– where soil moisture and nutrients are generally not limiting– light availability could be the most critical factor determining the success of regeneration and stand conversion. Overall, the results indicated that shelterwood harvest resulted in highest average light availability which would be conducive to slash pine regeneration while group selection harvest created the most diverse light environment during the stand conversion which may promote a broader diversity of groundcover species. Long-term monitoring of regeneration growth and recruitment following prescribed burning and over multiple cutting cycles will determine if slash pine can be sustainably managed using uneven-aged silviculture.

1. Introduction

There has been increasing interest in restoring and managing forest stands using uneven-aged silviculture for multiple objectives, particularly in context of ecological forestry (Nyland, 2003; Mizunaga et al., 2010; Diaci et al., 2011; O'Hara, 2014; Sharma et al., 2014; Kirkman and Jack, 2017). Uneven-aged silviculture is suggested to mimic natural disturbances that historically sustained forest ecosystems and is increasingly promoted as ecologically appropriate strategy for sustainable, multifunctional forest management (Brockway et al., 2005a, 2005b; Brockway and Outcalt, 2015; Tahvonen and Ramo, 2016; Sharma et al., 2016). Structurally diverse stand conditions resulting from uneven-aged silviculture inherently have higher resilience and potential to adapt to changing climate (Drever et al., 2006; Guldin, 2011) and, thus, could be an appropriate form of future risk management. In addition to ecosystem services (Axelsson and Angelstam, 2011; Boncina, 2011; Nolet et al., 2018), several studies (e.g., Haight, 1987; Tahvonen et al., 2010; Pukkala et al., 2011; Kuuluvainen et al., 2012; Juutinen et al., 2018) have shown that uneven-aged silviculture can be economically competitive to even-aged management, especially when

* Corresponding author at: 5988 U.S. 90, Building 4900, Milton, FL 32583, USA.
E-mail address: ajay.sharma@ufl.edu (A. Sharma).
[1] Present address: Penn State Extension, The Pennsylvania State University, 17129 Rt. 6, Smethport, PA 16749, USA.

https://doi.org/10.1016/j.foreco.2018.09.019
Received 20 July 2018; Received in revised form 7 September 2018; Accepted 12 September 2018
0378-1127/

interest rates and artificial regeneration costs are high. Additionally, the public perceives uneven-aged forest structures as environmentally and esthetically favorable over clearcuts (Silvennoinen et al., 2001; Bradley and Kearney, 2007). Considering these benefits of uneven-aged forest stands, many public agencies and some private landowners have embarked on projects to convert intensively managed plantations on their lands to uneven-aged stands (Guldin and Farrar, 2002; Loewenstein and Guldin, 2004; Florida Division of Forestry, 2007; Brockway and Outcalt, 2010). However, our knowledge base to practice stand conversions and apply such multifunctional silvicultural systems is inadequate. In the southern United States Coastal Plain, much of the research over the past 50 years focused on even-aged methods associated with high intensity plantation management with very little attention given to uneven-aged silviculture, so land managers have little information to guide their long-term stand conversion projects.

Several strategies have been suggested to convert even-aged stands to structurally diverse, uneven-aged stand conditions (O'Hara, 2001; Guldin and Farrar, 2002; Nyland, 2003; Loewenstein and Guldin, 2004; Loewenstein, 2005; Kerr et al., 2010; Sharma et al., 2014; Kerr et al., 2017). Typically, these stand conversion strategies involve partial cutting of the stand– either uniformly over the stand (e.g., shelterwood harvest) or in patches of different sizes (e.g, group selection harvest) – to allow establishment of multiage cohorts and eventual application of uneven-aged silvicultural systems such as single tree selection or group selection system. Shelterwood harvest at initiation of the conversion process has been proposed as a rapid way to convert a stand to two-aged stand and eventually to multi-aged stand (Brockway et al., 2005a, 2005b). In such an approach, the even-aged stand in the beginning is heavily harvested by removing suppressed and inferior trees from lower crown classes to create a vigorous low-density residual stand to which a new age class is added following natural regeneration. Sometimes a preparatory harvest may be included as a preliminary step to lightly open up a stand. In the conversion of an unthinned plantation, such a preparatory cut could be implemented in the form of row thinnings as an alternative to a traditional shelterwood prep cut because it is easier and more efficient for mechanized equipment. Preparatory cuts help the residual trees to develop crown and vigor before implementing seed harvest. All these harvests, varying in amount and distribution of residual basal area across a stand, create spatially differentiated microclimatic conditions across the stands, particularly in terms of understory light availability (McGuire et al., 2001; Palik et al., 2003; Battaglia et al., 2003; Beaudet et al., 2011; Lochhead and Comeau, 2012; Sharma et al., 2012; Ligot et al., 2014).

Understory light availability is a prominent driver of forest dynamics. It influences several aspects of forest regeneration and growth processes, including seed germination, seedling establishment, young tree survival and recruitment (Muscolo et al., 2014; Jack and Pecot, 2017). In flatwoods ecosystems, light is one of the primary factors that limit growth of pine seedlings both in artificial as well as naturally created gaps (Gagnon et al., 2003, 2004). Greater understory light availability has also been associated with increased growth in basal area and crown width (Harrington and Edwards, 1999; Brockway and Outcalt, 2017) and greater abundance of understory vegetation in southern pines (Wolters, 1973, 1981; Platt et al., 2006; Brockway and Outcalt, 2015). Additionally, light directly or indirectly may affect other environmental parameters such as temperature, humidity, wind speed, soil moisture, soil nitrogen, and can be even an effective indicator of the differences in stand structure across forests (Palik et al., 1997, Brockway, 1998, Galhidy et al., 2006). Understanding these changes in light conditions created by conversion harvests, thus, can provide critical guidance to desirable stand development and application of uneven-aged silviculture.

We conducted this study in mature slash pine (*Pinus elliottii* Engelm.) plantation stands under active conversion to uneven-aged stands in northwest Florida and employed high resolution Digital Hemispherical Photography (DHP) for assessment of light conditions. Slash pine is one of the most important commercial species in southeastern United States, with total acreage, including mixed stands with longleaf pine (*Pinus palustris* Mill.), of 5.3 million hectares (Smith et al., 2009). While uneven-aged management of other southern pines, including longleaf and loblolly/shortleaf pines, has received considerable attention (Brockway et al., 2005a, 2005b; Guldin, 2006, 2011; Brockway and Outcalt, 2015, 2017), slash pine has largely been ignored. In Florida, slash pine is the dominant species constituting 27% of total forest area, much higher than the extent of longleaf pine (5.7%) or loblolly pine (6.5%) (USDA Forest Service, 2015). As a shade- intolerant species, slash pine occurs primarily in natural wet and hydric flatwoods sites with species-rich understory (Florida Natural Areas Inventory, 1990; Lohrey and Kossuth, 1990; Brewer, 1998; Sharma et al., 2018). Soil moisture and nutrients are generally not limiting factors in mesic-hydric flatwood sites, making light availability a critical factor determining species performance in these sites (Palik et al., 1997; McGuire et al., 2001; Gagnon et al., 2003, 2004). Therefore, the objectives of this study were to (1) characterize understory light availability following different conversion harvest treatments, and (2) examine how light availability is affected by gap size and location within a gap. We used this information to discuss gap dynamics and its implications for uneven-aged management of slash pine.

2. Materials and methods

2.1. Site description

The mature 35-year-old stand pine plantation stands under active conversion to uneven-aged stands were located at the Tate's Hell State Forest (29.93 N, 84.77 W) between the Apalachicola and Ochlockonee rivers in north-west Florida (Fig. 1). Tate's Hell State Forest, with humid subtropical climate and annual precipitation totaling about 1200 mm, consists of about 820 km^2 of poorly drained lowland mesic-hydric flatwoods with the elevation ranging from 0 to 10 m above mean sea level and nearly level topography. Soil in the study area consisted of Scranton sand, Scranton fine sand, Leon sand, Plummer fine sand, Rutledge fine sand, and Sapelo fine sand (NRCS, 2018). Historically, the study site was a swampy mosaic of many unique and diverse community types including wet prairies, floodplain forests, basin swamp, cypress (*Taxodium* spp.) sloughs, Atlantic white cedar (*Chamaecyparis thyoides* L.) forests and other wetland and pine flatwoods communities. Pine flatwoods communities consisted of mix of longleaf and slash pine, with slash pine dominating at wetter sites. During the 1960s through 1980s, extensive areas of these native communities were converted to intensive pine plantations following large-scale silvicultural operations

Fig. 1. Location of study site (Tate's Hell State Forest) in north-west Florida, USA.