Forest Ecology and Management 260 (2010) 193–206

Contents lists available at ScienceDirect

Forest Ecology and Management

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

Lessons from long-term studies of harvest methods in southwestern ponderosa pine–Gambel oak forests on the Fort Valley Experimental Forest, Arizona, U.S.A.

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ARTICLE INFO

Article history:
Received 27 October 2009
Received in revised form 15 April 2010
Accepted 15 April 2010

Keywords:
Long-term data
Permanent plots
Forest stand dynamics
Land-use legacies
Spatial patterns
Fort Valley Experimental Forest
Arizona

ABSTRACT

The Fort Valley Experiment Station (now Fort Valley Experimental Forest) has contributed many long-term studies to forest research. This paper focuses on a "Methods of Cutting" study initiated in 1913 on the Coulter Ranch Unit of Fort Valley and how that long-term study yielded important ecological and management lessons. We quantified the historical and contemporary forest patterns at this ponderosa pine–Gambel oak site, which was harvested using three different harvesting systems in 1913 (seed tree, group selection, and light selection) and was partially excluded from livestock browsing in 1919. Using nine historically stem-mapped permanent plots for the following three stand structural scenarios: 1913 pre-harvest (modeled), post-harvest (actual), and 2003–2006 (actual) conditions, we examined the short- and long-term consequences of harvest and livestock grazing land-use and stand dynamics. We assessed changes in spatial pattern under each harvesting system and in each structural scenario, and lastly, we examined spatial and temporal tree recruitment patterns as observed in the contemporary (2003–2006) conditions. The seed tree harvests effectively converted the spatial patterns from aggregated to random and left few trees, while the group selection and light selection had varying effects, but consistently exaggerated the spatial patchiness of the stand. By 2003–2006, all plots were aggregated at all scales and were one large patch of predominately small trees. Sites that were harvested, but excluded from livestock browsing had 40% more trees in 2003–2006. Contemporary recruitment patterns were significantly aggregated under all harvesting systems, but were most strongly aggregated if the site received a group selection or light selection cut. For group and light selection, pine seedlings initially established in stump patches created by harvesting and then proceeded to fill-in the remaining area, with recruitment rarely found under the residual pine or oak trees. Long-term data sets, such as these established by the Fort Valley Experimental Forest in 1913, are essential for quantifying the impact of historical land-use practices on contemporary forest composition and structure. Ignoring land-use legacies may lead to the misinterpretation of stand dynamics and development, and therefore should be explicitly quantified and incorporated into future management and restoration activities.

1. Introduction

The Fort Valley Experiment Station (now Fort Valley Experimental Forest; FVEF) has contributed many long-term studies and ecological lessons to forest research as the USFS first experimental station in the nation (Olberding, 2002). In 1908, the station was established in the ponderosa pine forests of northern Arizona with its initial focus on silvicultural research. G.A. Pearson, first director of Fort Valley, and his team of scientists conducted pioneering research on natural and artificial regeneration, stand improvement, individual tree and stand dynamics, and they initiated one of the first studies to determine the factors that controlled and limited the distribution of tree species. Many of these early studies are described in detail in "Fort Valley Experimental Forest – A Century of Research 1908–2008" (Olberding and Moore, 2008; http://www.fs.fed.us/rm/pubs/rmrs_p053.html).

For this paper, we focused on one case study from Fort Valley that exemplifies how long-term studies yield important ecological and management lessons. The case study experiment was initiated in 1913 on the Coulter Ranch section of FVEF. The original purpose of the study was to determine the effects of harvesting methods on tree regeneration and growth in a ponderosa pine–Gambel oak (*Pinus ponderosa* var. *scopulorum* Dougl. ex Laws.–*Quercus gambelii* Nutt.) forest. The experiment was part of the nation-wide 'Methods of Cutting' study that examined the feasibility of seed tree, group selection, and light selection regeneration harvests. We determined the effects of these three silvicultural harvest treatments

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0378-1127/$ – see front matter
doi:10.1016/j.foreco.2010.04.016

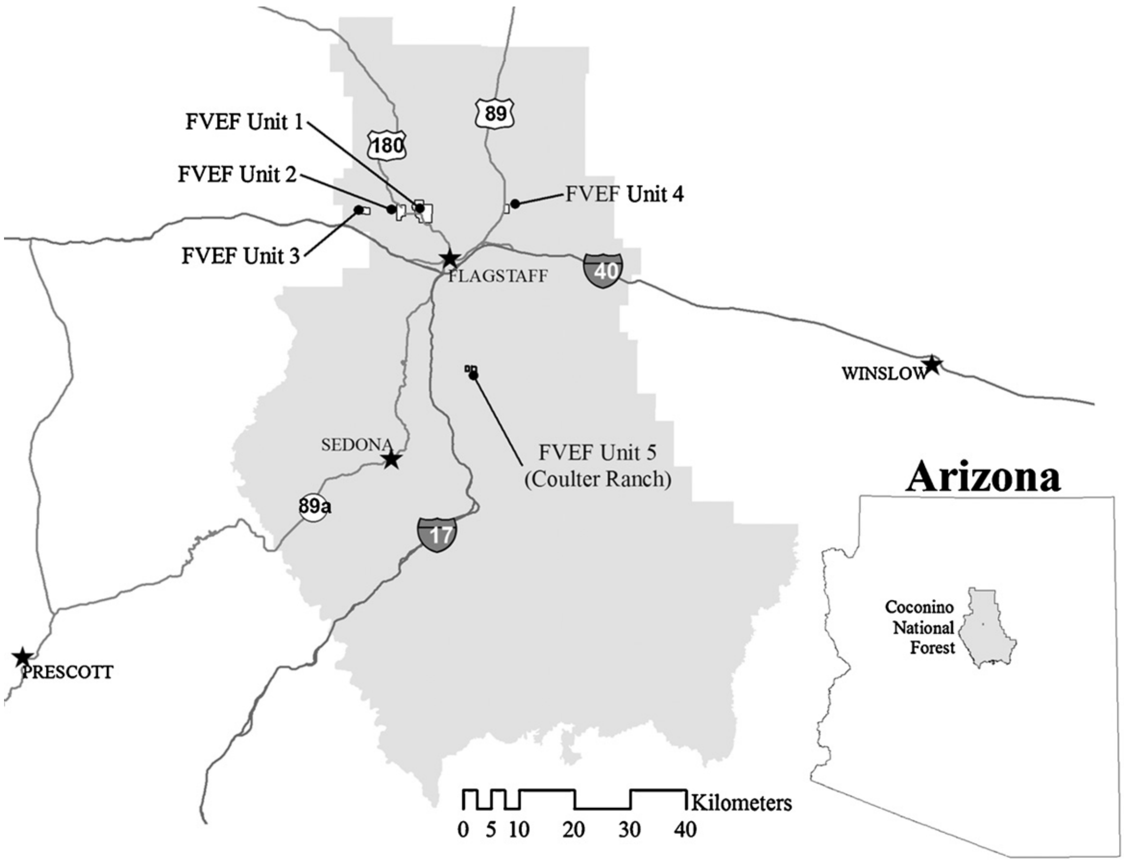

Fig. 1. Fort Valley Experimental Forest (FVEF) research unit locations (including Unit 5, the historical "Coulter Ranch" – latitude 35°0.91′N, longitude 111°36.26′W) on the Coconino National Forest, Arizona, U.S.A.

and livestock browsing on historical (1913) and contemporary (2003–2006) stand density, tree size, and spatial patterns.

The initial settlement of the Southwest by Euro-Americans (circa 1880s) markedly changed forest structure through intensive logging, livestock grazing and fire suppression, as well as indirectly through fire exclusion (Fulé et al., 1997; Allen et al., 2002; Moore et al., 2004; Cocke et al., 2005). These legacies of past land-use practices, or land-use legacies (a.k.a. site history or disturbance history), may influence forest structure and function for decades to centuries (Foster et al., 2003). Scientists and managers recognize the importance of land-use legacies, but only when we quantify the impact of these past activities can we use that information to understand contemporary or future conditions.

Land-use legacies commonly persist for many decades within ecosystems, including ponderosa pine forests, and have been shown to influence contemporary conditions (e.g., Christensen, 1989; Fulé et al., 1997; Foster et al., 2003; Youngblood et al., 2004; Moore et al., 2004). An understanding of disturbance history and vegetation change provides a context for ecological studies (Christensen, 1989; Pickett et al., 1997), a basis for natural resource management and planning (Moore et al., 1999; Swetnam et al., 1999; Egan and Howell, 2001), and is essential in restoration modeling (e.g., Covington et al., 2001). Contemporary management practices in southwestern ponderosa pine ecosystems must consider the historical context under which current forest structure developed and the subsequent influences of early silviculture and land management practices. Few studies have been able to isolate effects of harvest history on ponderosa pine stand dynamics and only a few have examined their influence on spatial pattern (Cooper, 1961; White, 1985; Biondi et al., 1994; Sánchez Meador et al., 2009, 2010).

We investigated how historical land management practices, or land-use legacies, have influenced the forest structure over a 93-year period on a long-term silviculture research site in northern Arizona. The study site is representative of ponderosa pine–Gambel oak forests found throughout northern Arizona, but is unusual in that different harvesting systems were applied when the study began in 1913. This dataset provides a unique opportunity to examine the interactions of historical (1913) harvesting methods, livestock use, and long-term (1913–2006) dynamics on forest structure and spatial pattern.

Our study addressed five questions: (1) how might forest structure have looked in the absence of seed tree, group selection and light selection harvesting in 1913 on a ponderosa pine–Gambel oak site in northern Arizona? (2) How did each harvesting system affect stand characteristics and spatial patterns over the short-term (as observed in 1913 following harvest)? (3) How did stand characteristics and spatial patterns change over the long-term (as observed in 2003–2006)? (4) How did the stand structural patterns resulting from harvesting and livestock use (specifically sheep browsing) influence the recruitment of subsequent ponderosa pine cohorts across the site and within each of the three harvesting systems? (5) Where did recruitment occur with respect to unharvested pine and oak trees, pine stumps, and natural grass openings?

2. Methods

2.1. Study site

This study was conducted on a 162-ha site, located 21 km south of Flagstaff, Arizona on the Coconino National Forest (Fig. 1); latitude 35°0.91′N, longitude 111°36.26′W. Mean annual temperature