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Early tree regeneration is consistent with sustained yield in low-input boreal forest management in Alaska

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ABSTRACT

The boreal forest of Alaska has experienced a small area of forest cuttings, amounting to 7137 ha out of a total of 256,284 ha of timberland in the Fairbanks and Kantishna area of state forest land. Low product values and high costs for management have resulted in a low-input type management with heavy reliance on natural regeneration. Because of increasing demand for wood biomass energy which may reduce rotation ages, understanding post-harvest regeneration is crucial. Harvested areas must meet stocking standards within seven years under the state Forest Resources & Practices Act (FRPA). We evaluated whether state forest harvest units are adequately regenerated up to 40 years following harvest based on FRPA standards in terms of stem density and biomass accumulation. We measured density of all tree size classes, and DBH and height of tree species in 726 plots from 30 representative harvest units, distributed according to harvest and treatment types, harvest year, unit size, and the geographical location of harvests. The majority of regenerated tree stems came from natural regeneration, even on planted units (77%). White spruce (*Picea glauca*) natural regeneration appears to continue for a few decades (seed crops) following harvest. Stem density was below the standard in most units surveyed during the FRPA 7-year period, but far exceeded the standard when resampled in this study (average 16 years later), suggesting either seven years is too early to evaluate tree regeneration, or that a different standard is needed for early surveys. We found a major peak in white spruce stem density (45,000 ha^{-1}) in units harvested in 1987 (an historically large spruce seed crop year), suggesting that where possible, foresters need to adjust management plans according to spruce mast years. Post-harvest and post-fire successional patterns are similar, involving rapid establishment and growth of hardwoods and slow growth of white spruce, but post-harvest white spruce recruitment appears to continue longer than post-fire. By 2014 all measured harvest units met FRPA standard under low-input management, but some issues of uniformity of regeneration may remain. Although regeneration density varied among species and by management practices, biomass accumulated steadily over time (60 t ha^{-1} after 40 years), largely composed of hardwoods, indicating that short-rotation forest management must utilize hardwoods. Our results are based on relatively small harvest units within a matrix of natural forest, and similar results might not occur in landscapes dominated by stands originated from more extensive and intensive management.

1. Introduction

Tree regeneration is an essential stage that can determine forest structure and composition for the remainder of a successional sequence, particularly for the boreal forest that is a stand replacement disturbance-driven system (Foote, 1983; Chapin et al., 2006; Gauthier et al., 2015). Fire is the dominant disturbance in North American boreal forest (Burton et al., 2008), and numerous studies examining post-fire forest regeneration are available for Alaska and adjacent Canada (Viereck and Schandelmeier, 1980; Purdy et al., 2002; Johnstone et al., 2004; Johnstone and Chapin, 2006; Johnstone et al., 2011; Shenoy et al., 2011). However, studies of post-harvest regeneration are limited (Youngblood and Zasada, 1991; Wurtz and Zasada, 2001; Boateng et al., 2009). Forest fire and forest harvest do not produce identical effects, differing in removal of coarse woody debris and the consumption of the forest organic layer (McRae et al., 2001; Brassard and Chen, 2008; Ilisson and Chen, 2009), for example. Differences in successional

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trajectory and plant species diversity also have been detected between fire and logging disturbance (Rees and Juday, 2002; Taylor et al., 2013).

The boreal forest of Alaska has experienced the smallest area or proportion of forest cuttings and regeneration management of the major forest regions of North America. Although intensive forest cutting took place locally at the time of the gold rush in the early 20th century in Interior Alaska, demand for wood declined quickly by the 1920s (Naske, 1987; Roessler, 1997). The total area harvested in the Tanana Valley State Forest and forest classified lands since record collection began in the mid-20th century is about 14,000 ha (Alaska Division of Forestry (AKDOF) Forest Management Database; Tanana Chiefs Conference Timbersale Database). This harvested area compares to a total of state timberland (USDA FIA definition) of 871,000 ha in the Tanana Valley State Forest and forest classified lands (Hanson, 2013). Since Alaska statehood in 1959, local demand for wood harvest has been relatively low in Interior Alaska, and export markets have only been profitable for limited periods of high prices (Wurtz et al., 2006). In the early 21st century, annual harvested volume for spruce and birch have been about 1622 and 200 mcf (1000 cubic feet), respectively from state forest lands in the Tanana Valley (AKDOF Forest Management Database), which combined is about 20% of the estimated annual allowable cut for sustained yield (Hanson, 2013). In this situation, a form of forest management involving low-cost input with heavy reliance on natural regeneration has developed.

In Alaska, a mandate for sustainable yield was adapted within Article VIII of the State's Constitution. Elaboration of the sustainable yield mandate in the context of forestry was developed in the Alaska Forest Resources & Practices Act (FRPA).[1] This was followed by the establishment of FRPA regulations.[2] According to these regulations, reforestation is required for all forest harvests in the State with stocking levels dependent on the exact location of the harvest. Additional regeneration efforts are required in Interior and South-central Alaska, when more than 10% of the harvest area fails to meet State regeneration standards within seven years following harvest (Table 1). The Alaska Division of Forestry (AKDOF) is required by the FRPA[3] to conduct regeneration surveys within seven years after harvest to ensure the stand is adequately regenerated. However, because forest regeneration in Interior Alaska may take place over an extended period of time following disturbance (Viereck and Schandelmeier, 1980), it is impractical to determine if natural regeneration has been successful based on these short term surveys. Therefore, a comprehensive, long-term investigation of tree establishment and post-harvest growth is necessary to determine whether low-cost forest management with heavy reliance on natural regeneration has met at least the first requirement for sustained yield, which is successful tree regeneration.

More recently, the demand for wood products from state land is evolving from sawlogs to woody biomass (AKDOF, 2013). As of 2015, nine wood biomass energy facilities have been built, 10 are under construction, and more than 11 are in design or feasibility status in Interior Alaska (AEA, 2015). As the new wood energy facilities begin to operate, demand for wood will increase in this region (Fresco and Chapin, 2009). The increased wood biomass energy demand will require expanded forest harvest and a change in product emphasis from large-dimension white spruce to additional species at smaller diameters. Increased birch harvest for use as firewood has already occurred (AKDOF Forest Management Database). In addition, the harvest cycle may become shorter for biomass harvest than for large-dimension wood products, requiring more frequent regeneration (Janowiak and Webster, 2010). In order to meet the needs of this evolving forest management situation on the sustained yield basis, it is crucial to understand post-harvest regeneration of all the woody species that could meet the new biomass demand.

Table 1
Post-harvest stocking standard established by the State of Alaska.

DBH (cm)	Minimum stocking standard (trees ha^{-1})
Seedlings	1112
2.5–15.2	495
15.2–22.9	420
>22.9	297

Note: Example of calculation of percent stocking for seedlings.
% stocking = $(d/1112) \times 100$.
where d is the stem density ha^{-1} measured in each plot. Percent stocking standard was calculated similarly for the other three size classes for their minimum density values.

Although the total area harvested is small, Interior Alaska boreal forest has experienced 40 years of varying harvest and regeneration practices. Forty years is too short a period to address all the issues associated with sustainable harvest through an entire rotation, but may be sufficient to address critical questions of forest regeneration. The objective of this study was to evaluate success of post-harvest regeneration up to 40 years in terms of stem density and biomass accumulation. To achieve this objective, we evaluated whether harvest units are adequately regenerated up to 40 years following timber harvest based on current yield standards set forth in FRPA. Ours is the first broad scale study in Interior Alaska to examine, across time and space, the effects of mature forest harvest on regeneration in an operational context in which low-input management is characteristic of the region.

2. Methods

2.1. Study area

The study was conducted within the Fairbanks and Kantishna Management Areas of the Tanana Valley State Forest and forest classified lands ("state forest lands"; Fig. 1) which covers 348,178 ha. The study area is within the Alaska boreal forest which is primarily composed of white spruce (*Picea glauca* (Moench) Voss), black spruce (*Picea mariana* (Mill.)), Alaska birch (*Betula neoalaskana* Sarg.), quaking aspen (*Populus tremuloides* (Michx)), with minor amount of balsam poplar (*Populus balsamifera*), and tamarack (*Larix laricina*) (Labau and van Hees, 1990). Tree cover of the state forest lands is composed of black and white spruce/hardwood forest, white spruce/hardwood forest, birch forest, white spruce forest, and white spruce/birch (Hanson, 2013). Total net cubic volume is greatest for the white spruce/hardwood and lowest for the black and white spruce/hardwood cover types (Table 2). Soils are mostly silt loams formed from loess parent material (Ping et al., 2006) and elevations range from 100 m to 600 m. The climate of the study area is strongly continental, but long-term climate data are primarily available for low elevation sites. Data from Fairbanks International Airport indicate a mean annual temperature of −2 °C and annual precipitation of 270 mm, with extreme winter temperatures as low as −50 °C. The growing season is approximately 123 frost-free days in Fairbanks since the late 20th century (Wendler and Shulski, 2009).

2.2. Silvicultural systems

The two primary commercial harvest methods used during the period of this study on the Fairbanks and Kantishna areas of state

[1] AS 41.17.
[2] Alaska Forest Resources and Practices Regulations (11 AAC 95) implement and interpret FRPA (AS 41.17). The requirement of regeneration survey is mentioned in section 385 of the regulations. Booklets of FRPA and the regulations are available at http://forestry.alaska.gov/forestpractices.
[3] FRPA 11 AAC 95.385.