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Short communication

# Effects of human disturbances on Korean pine coverage and age structure at a landscape scale in Northeast China

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ABSTRACT

Korean pine (*Pinus koraiensis*) is an important species of forests in Northeast China and the Russian Far East. In recent years, human disturbances have increasingly threatened the long-term population sustainability of Korean pine in Northeast China. Though the Chinese government has implemented various programs to restore and protect Korean pine, results have not been satisfactory. Economic income often conflicts with ecosystem function, so figuring out ways to balance ecologic and economic values is important for Korean pine sustainability and management. The effects of humans on Korean pine forest are complex and interact in ways that are difficult to predict at the landscape scale. In this paper, we used a simulation approach to examine multiple intensities of timber harvest and seed harvest on landscape-scale Korean pine coverage and age structure. We found that the influences of seed harvest became increasingly important over the simulation period. Seed harvest noticeably influenced the percent coverage of young (<60 yr) Korean pine. Young age classes of Korean pine disappeared when seed harvest intensity was high, even with a low timber harvest intensity. Except during high timber harvest intensities, Korean pine maintained its coverage and age structure to a certain extent under a medium seed harvest level. When seed harvest was prohibited, Korean pine coverage remained steady compared to initial conditions, regardless of the timber harvest intensity. Percent coverage of young and middle age (60–120 yr) Korean pine increased late in the simulation period. Our study showed that some level of seed harvest intensity combined with medium and low timber harvest intensities may be optimal for managers to maintain a viable economy together with ecosystem sustainability.



## 1. Introduction

Humans are an important component of both managed and unmanaged forests. With continued population growth, human disturbance has intensified and is likely altering ecosystem structure and function (DeFries et al., 2004; Yu et al., 2011). Activities such as the over-harvesting of trees and cones can dramatically alter interspecific interactions and feedback processes, which may lead to a decline in ecological communities (Finnegan et al., 2014; Summerville and Crist, 2002; Piao et al., 2011). Individual and combined effects of human disturbances on forest dynamics are complex and interact in ways that are difficult to predict at the landscape scale (Gustafson et al., 2010). In designing a scientifically sound management plan, evaluating some of the more disruptive effects of humans on forest ecosystems from a landscape perspective is worthwhile.

Korean pine broadleaf mixed forest is an important system for maintaining biodiversity and ecosystem function in Northeast China and the Russian Far East. Major human disturbances of this ecosystem include seed harvesting and timber harvesting. In this region forests are harvested primarily by clear-cutting or high intensity selective cutting (Dai et al., 2009). Due to excessive logging, about 85% of the mature and old-growth forests have been converted into different types of secondary forests and planted forests (Meng et al., 2008). The age structure of the forests has become younger and simpler (Shao et al., 2001; Zhao and Shao, 2002). This poses an immediate need for ecological restoration to protect and improve forest health.

Since 2000, the Chinese government has pursued a new forest management policy, where various harvest intensities have

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replaced a monoculture-oriented high intensity harvest regime. In order to compensate for a decreasing economic value of timber harvest, Korean pine seed was intensively harvested due to its high economic value. Korean pine (*Pinus koraiensis*) is an ecologically and economically important tree species for this system. Because seed source is one of the most important factors that can potentially affect successional dynamics (He and Mladenoff, 1999), the harvesting of Korean pine cones is the most significant obstacle for restoration of this species (Liu et al., 2004, 2005). To restore and protect Korean pine, evaluating the tradeoffs between different levels of seed harvest intensity and timber harvest intensity are needed to help determine the most sustainable management plan for this ecosystem.

In this study we examined the effects of timber and seed harvesting on Korean pine coverage and age structure from a landscape perspective. Specifically, we examined: (1) effects of these disturbances on maintaining Korean pine coverage; (2) relative influences of varying levels of timber and seed harvest, and their interaction, on Korean pine coverage; and (3) effects of these disturbances on Korean pine age structure. We conducted our study using a simulation approach which considered two experimental factors, timber harvest intensity (3 levels) and seed harvest intensity (3 levels). Percent cover of Korean pine, and area occupied by different age cohorts of Korean pine, served as response variables for evaluating structural changes in the Korean pine forest.

## 2. Materials and methods

### 2.1. Study area

Our study site was located on the northwest-facing slope of the Changbai Mountains in Lushui River Forestry Bureau (42°20′–42°40′N, 127°29′–128°02′E) and covered about 130,000 ha. The forest is characterized by a continental climate, with long cold winters and short hot summers. Mean annual precipitation and temperature are approximately 894 mm and 2.9 °C, respectively. Major coniferous tree species in this area include Korean pine (*P. koraiensis*) and Korean spruce (*Picea koraiensis*). Broadleaf species include basswood (*Tilia amurensis*), maple (*Acer mono*), Manchurian ash (*Fraxinus mandshurica*), Manchurian walnut (*Juglans mandshurica*), Mongolian oak (*Quercus mongolica*), white birch (*Betula platyphylla*), elm (*Ulmus pumila*), and aspen (*Populus davidiana*). Korean pine is the climax species in this ecosystem. The forest land in our study area was divided into two major management areas: a commercial harvest area (80%) and a conservation area (20%). In the commercial harvest area, timber and seed harvesting were allowed. In the conservation area, only seed harvesting was allowed.

### 2.2. Experimental design

We designed a factorial experiment that included three harvest intensities and three seed harvest levels. Tree seed harvest levels were based on a local government rule, issued in 2003, defining three conditions under which Korean pine seed can legally be harvested: (a) high seed harvest intensity—unlimited seed collection up to 100%; (b) low seed harvest intensity—about 30% seed collection; and (c) no seed harvest—no seed collection permitted. Timber harvest levels were based on the current management plan of the Lushui River Bureau. The three intensities used in our study included: (a) low harvest intensity—cutting limit set at 3% per decade; (b) medium harvest intensity—set at 5% per decade; and (c) high harvest intensity—set at 10% per decade. This work was conducted based on Forestry Standards "Observation Methodology for Long-term Forest Ecosystem Research" of the People's Republic of China.

We used LANDIS, a spatially explicit forest landscape model, as the simulation tool for our study. Detailed information on model design, testing and model parameters of our study area may be obtained from other sources (He and Mladenoff, 1999; Zhao et al., 2011). Based on our experimental design, nine scenarios were created using LANDIS to simulate forest succession under varying disturbance regimes. We determined 100 years to be an adequate timeline for forest management because policy can change with the changing of forest structure. Thus, the model ran for 100 years, beginning in 2003. Each scenario was replicated five times to account for stochasticity in the LANDIS model.

While recognizing that ecological effects of seed harvest, timber harvest, and their interaction are complex and interrelated, we limited the focus of our analysis to species coverage and age structure, which are key parameters of the forest landscape. Species coverage was expressed as the proportion of pixels indicating the presence of a species relative to that of the entire landscape. Age structure was expressed as the proportion of landscape dominated by different age classes of Korean pine (young: ≤60; middle age: 61–120; mature: >120).

### 2.3. Data analysis

Simulation results were analyzed using univariate analyses in the General Linear Model (SPSS 16.0) for early, middle and late simulation periods. Type III sums of squares derived from univariate analyses were used to quantify the unique contributions of timber harvest, seed harvest, and their interaction on coverage of young age Korean pine at a landscape scale. The actual type III sums of square values were comparable within one statistical model, but not necessarily between two or more statistical models. Therefore, we used proportions of actual type III values to compare differences among the relative contribution of timber harvest, seed harvest and their interaction for early (0–30 yr), middle (40–70 yr) and late (80–100 yr) periods of a given simulation.

## 3. Results

### 3.1. Effects of multiple intensities of timber and seed harvest on Korean pine coverage

Our results showed that timber harvest was more important than seed harvest for coverage of Korean pine in the early simulation period (Fig. 1). As the simulation periods progressed, the influences of seed harvest increased. By the middle simulation period, the relative importance of seed harvest and timber harvest on Korean pine coverage was similar. By the late simulation period, effects of seed harvest were far greater than those of timber harvest. These results indicate that seed harvest has a long-term influence on Korean pine coverage that requires multiple decades to become evident, but can exceed the influence of timber harvest within one century.

Our results also revealed differences in percent coverage of Korean pine under the varying levels of seed harvest and timber harvest intensity. Coverage was highest with low and medium timber harvest and no seed harvest (Fig. 2). Coverage was lowest when seed harvest intensity was high, especially when combined with high timber harvest intensity (Fig. 2a). Under low seed harvest intensity, Korean pine maintained its coverage to a certain extent, when timber harvest was low and medium (Fig. 2b). With no seed harvest, Korean pine coverage remained steady compared to initial conditions, regardless of timber harvest intensity, and even