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Simulating the effects of reforestation on a large catastrophic fire burned landscape in Northeastern China

Xugao Wang [a,c,*], Hong S. He [b], Xiuzhen Li [a], Yu Chang [a], Yuanman Hu [a], Chonggang Xu [a,c], Rencang Bu [a], Fuju Xie [a,c]

[a] *Institute of Applied Ecology, Chinese Academy of Science, P.O. Box 417, Shenyang 110016, China*
[b] *School of Natural Resources, University of Missouri, Columbia*
[c] *Graduate School of Chinese Academy of Science, Beijing 100039, China*

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Abstract

We use the LANDIS model to study the effects of planting intensity and spatial pattern of plantation on the abundance of three main species (larch (*Larix gmelini*), Mongolian Scotch pine (*Pinus sylvestris* var. *Mongolica*), and white birch (*Betula platyphylla*)) in the Tuqiang Forest Bureau on the northern slopes of Great Hing'an Mountains after a catastrophic fire in 1987. Four levels of planting intensity (covering 10%, 30%, 50%, and 70% of the severely burned area) and two spatial patterns of plantation (dispersed planting and aggregated planting) were compared in a 4×2 factorial design over a 300-year period. The results showed that increasing planting intensity positively influenced larch and Mongolian Scotch pine abundance, but negatively influenced white birch abundance. However, the increased degree of larch abundance with increasing planting intensity was significantly different between intensities. The difference in larch abundance between the 10% planting intensity scenario and the 30% planting intensity scenario was greater than that between the 50% planting intensity scenario and the 70% planting intensity scenario. However, the difference between 30% and 50% planting intensity scenarios was significantly low. Hence, given considerable labor input and economic costs, 30% planting intensity would be effective for forest recovery. In addition, dispersed planting showed more promising results on forest recovery than aggregated planting. However, the difference of larch abundance between dispersed planting and aggregated planting under intermediate planting intensity scenarios (30% and 50% planting intensity) was greater than that under a low planting intensity scenario and a high planting intensity scenario. Therefore, it is necessary to incorporate spatial pattern of plantation into planting practice, especially under an intermediate planting intensity scenario. These results have important implications for forest managers to design sound forest restoration projects for landscapes affected by large infrequent disturbances. In particular, the results suggest that the current planting strategy (50% planting intensity with aggregated planting) employed after the catastrophic fire in 1987 could not be optimum, and the dispersed planting strategy covering about 30% of the severely burned area would better stimulate forest recovery.

Keywords: Great Hing'an Mountains; LANDIS; Planting intensity; Spatial pattern of plantation; Forest recovery

1. Introduction

The deciduous and coniferous forests of the Great Hing'an Mountains in northeastern China provide the most timber of any forested area in the country; simultaneously, this area encompasses rather unique ecological and environmental systems in the region (Zhou, 1991; Xu, 1998). Human activities, particularly timber harvesting, have substantially altered the spatial pattern and ecological functions of these systems. Decades of fire suppression have reduced fire size, prolonged the fire return interval (i.e., the number of years between two successive fire events for a specific area), and indirectly influenced forest composition and dynamics (Shu et al., 1996). The success of fire suppression, coupled with a warmer, drier climate due to global warming (Xu, 1998), have led to a fuel buildup and resulted in fires of greater intensity and extent than those that occurred previously in the region.

Catastrophic fires can have disastrous effects on forest composition and structure, ecosystem processes, and landscape pattern (Romme, 1982; Turner et al., 1997, 1999). On May 6, 1987, a catastrophic fire occurred on the northern slopes of Great Hing'an Mountains, burning a total area of 1.3×10^6 ha.

* Corresponding author. Tel.: +86 24 83970350; fax: +86 24 83970351.
E-mail addresses: wxg_7980@163.com, wangxugao@hotmail.com (X. Wang).

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This immense, high-intensity fire consumed vegetation cover and precipitated the exposition of mineral soils – as well as the subsequent erosion and runoff – during post-fire rain events (Xiao et al., 1988; Shu et al., 1996). Forest recovery in such vastly burned areas is challenging because the long-term landscape-level vegetation dynamic in a forest landscape is complicated by spatial and temporal interactions among multiple ecological and anthropogenic processes.

In many cases, natural succession can eventually lead to post-fire recovery. This is especially true for cases in which there are sufficient residual forests remaining nearby to act as seed sources (Turner et al., 1999; Borchert et al., 2003). In cases such as the 1987 fire in the Great Hing'an Mountains, natural recovery is difficult because the severely burned area is extensive, the burn severities are high, and the seed sources are far removed (Xiao et al., 1988). In these situations, the process of vegetation recovery is slow, increasing the risk of soil erosion and environmental degradation. Thus, ecological restoration through human mediation is necessary. After the 1987 fire, forest management in this region shifted from timber harvesting to reforestation – particularly in the severely burned area – in order to accelerate forest restoration.

Various approaches have been developed to restore forest vegetations for degraded systems where natural recovery is unlikely. Grass seeding provides quick, temporary vegetation ground cover; these are typically annuals or short-lived perennials that can hold soil (Beyers, 2004). However, such a treatment does not facilitate long-term ecosystem restoration. Long-term ecosystem restorations are accomplished either through the planting of a small number of early successional nursery trees or shrubs to create habitats for seed-dispersing birds (e.g., Lamb, 1998), or through high-density plantation of tree species once present in the disturbed areas (e.g., Smale et al., 2001; Nagashima et al., 2002).

Although these approaches have shown promising results for development of forest structure, increase of species richness, and recovery of natural successional processes, they are often limited to relatively small areas (Lamb, 1998). In the Great Hing'an Mountains, it is not sufficient to restore only a few burned areas, and it is highly impractical to plant trees in the vast severely burned area due to the considerable labor and economic resources required. It is therefore necessary to assess the planting intensity (the proportion of the burned area for reforestation) and spatial patterns of plantation (the spatial allocation of reforestation in the field) for forest recovery. In the Great Hing'an Mountains, the planting strategy after the catastrophic fire in 1987 was to plant coniferous seedlings in an aggregated fashion over about 50% of the severely burned area where coniferous forests used to grow. Others such as dispersed planting, an alternative to the aggregated planting, have not been evaluated and compared. A dispersed planting would entail planting trees in a random fashion across the entire severely burned area.

Descriptive studies and field experiments are often inadequate sources of input for managers developing and implementing reforestation plans. Comparing ecological restoration strategies on a large-scale landscape is often beyond the limits of traditional or experimental studies. Models have therefore become an important tool for predicting the effects of alternative management options. Landscape models are particularly important in this study because other types of models, such as gap models and ecosystem process models, are often limited in spatial extents (He et al., 2002b; Mladenoff, 2004). While other anthropogenic disturbances – such as fire suppression and forest harvesting – have been studied using landscape models (Gustafson et al., 2000; Franklin et al., 2001; Sturatevant et al., 2004; Wimberly, 2004), the effects of reforestation on long-term forest dynamics has not been explicitly simulated.

The purpose of this research is to study the effects of different reforestation scenarios on vegetation dynamics in the severely burned area of the Great Hing'an Mountains. We will examine the effects of planting intensities and spatial patterns of plantation (dispersed vs. aggregated) on forest landscape recovery. We will apply a factorial design of planting intensity and spatial pattern of plantation on the realistically parameterized forest composition maps of 1987 to identify the combinations of planting intensity and method that could best accelerate forest restoration. Understanding the probable post-fire dynamics of the region under different reforestation scenarios will not only provide insights into landscape scale processes, but also will provide baseline information on forest landscape restoration in northeast China after catastrophic fire disturbances.

2. Study area

The Tuqiang Forest Bureau (Fig. 1), encompassing approximately 4×10^5 ha on the northern slopes of Great Hing'an Mountains, is in the Mohe County of Heilongjiang province in northeast China (from 52°15′55″ to 53°33′40″N, and 122°18′05″ to 123°29′00″E). It borders Russia to the north (separated by Heilongjiang River), the Xilinji Forest Bureau to the west, the Amur Forest Bureau to the east, and the Inner Mongolia Autonomous Region to the south. The area has a cold, continental climate, with an average annual temperature

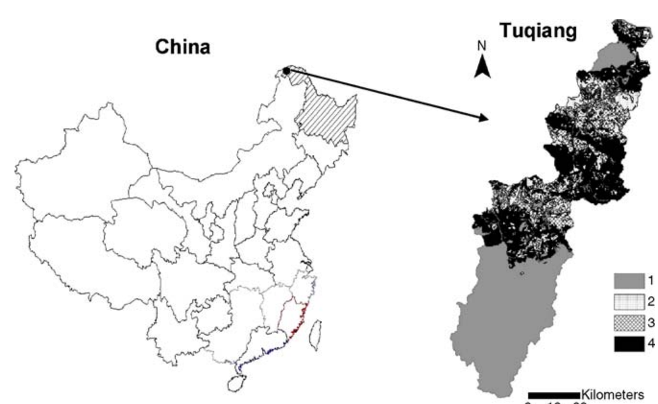

Fig. 1. The location of Tuqiang Forest Bureau and burn severities after the catastrophic fire in 1987 (1, unburned area (MA 1); 2, severely burned area where conifers were dominant before the fire (MA 2); 3, severely burned area where conifers were not dominant before the fire (MA 3); 4, other burned area (MA 4)).