Dendrochronologia 32 (2014) 21–31

Contents lists available at ScienceDirect

Dendrochronologia

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

Original Article

Disturbance and regeneration dynamics of a mixed Korean pine dominated forest on Changbai Mountain, North-Eastern China

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ARTICLE INFO

Article history:
Received 25 January 2013
Accepted 6 June 2013

Keywords:
Canopy gaps
Dendroecology
Disturbance regime
Growth release
Old-growth forest

ABSTRACT

We used dendrochronological methods to study disturbance history of a mixed Korean pine (*Pinus koraiensis* Siebold et Zuccarini) dominated forest on the northern slope of Changbai Mountain, North Eastern China, over 1770–2000. Frequent small-scale canopy gaps and infrequent medium-scale canopy disturbances dominated natural disturbance regime in the forest, which did not experience stand-replacing disturbances over the studied period. Percentages of growth releases in subcanopy trees were below 6% in most decades, suggesting that disturbances initiating these releases were of low intensity. Strong winds were likely cause of moderate disturbance events. Two episodes with increased disturbance rates (19% and 13%) were dated to the 1920s and 1980s, timing of the 1980s event was consistent with a hurricane occurred in 1986 on the western slope of the Changbai Mountain. Age structure and growth release analyses revealed species-specific regeneration strategies of canopy dominants. Shade-intolerant Olga bay larch (*Larix olgensis* Henry) recruited mainly before the 1860s. Recruitment of moderately shade-tolerant *P. koraiensis* occurred as several regeneration waves (1820s, 1850s, 1870–1880s, 1930s, and 1990–2000s) of moderate intensity. Shade-tolerant Jezo spruce (*Picea jezoensis* Carr. var. *komarovii* (V. Vassil.) Cheng et L.K.Fu) and Manchurian fir (*Abies nephrolepis* (Trautv.) Maxim.) regenerated continuously over the last 220 and 130 years, respectively. Enhanced recruitment of *P. koraiensis*, *P. jezoensis*, and *A. nephrolepis* was observed during the 1930s and 1990s, coinciding with increased growth release frequency in the 1920s and 1980s, and suggesting disturbance events of moderate intensity. Our results indicate that the current disturbance regime of the mixed Korean pine dominated forest maintains coexistence of light-demanding and shade-tolerant species and that change in wind climate may be particularly important for future forest composition.

Introduction

Natural disturbances have profound effects on forest dynamics, influencing growth, regeneration, diversity, and coexistence of tree species (Frelich and Lorimer, 1991; Abrams et al., 1999; Kubota, 2000; Bergeron et al., 2004). Studies in forest disturbance history are critical for understanding the present forest composition and predicting the future forest structure under different climate and management scenarios (Girardin et al., 2001; Kuuluvainen, 2002; Dang et al., 2009). Dendroecological techniques are widely applied to reconstruct forest history, disturbance regimes, and past forest dynamics (Brisson et al., 1992; Tardif et al., 2001; Fraver and White, 2005). Tree ring analyses allow reconstruction of forest disturbance history through dating of growth release and analyzing the establishing dates in sampled individuals (Lorimer and Frelich, 1989; Frelich and Lorimer, 1991; Black and Abrams, 2003).

Disturbance regimes in the mixed forest are important in promoting coexistence of tree species (Runkle, 1985; Liu, 1997; Bergeron, 2000). In closed-canopy temperate forests, the gradient in forest disturbance severity ranges from small canopy gaps created by single or multiple treefalls to large-scale stand-replacing events (Runkle, 1985; Runkle and Yetter, 1987; Foster et al., 1998; Romme et al., 1998; Turner et al., 1998; Ilisson et al., 2005; Margolis et al., 2007). Variation in the size and frequency of disturbances causes spatial and temporal heterogeneity in environment affecting establishment, growth, and survival of trees

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http://dx.doi.org/10.1016/j.dendro.2013.06.003

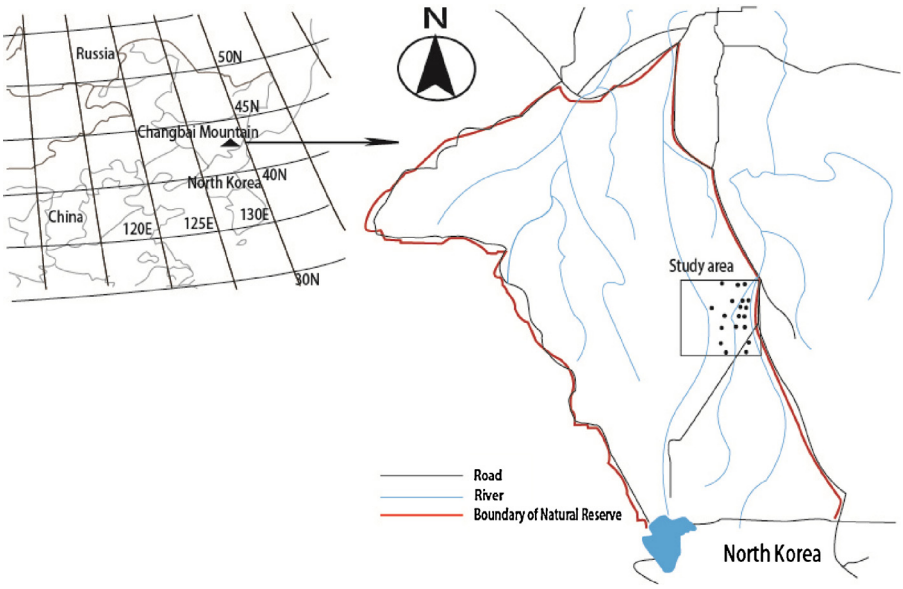

Fig. 1. The location of study sites on the northern slope of Changbai Mountain, North Eastern China.

(Liu, 1997; Mori and Takeda, 2004). Species may respond differently to the range of disturbance sizes and severities, depending on their own ecological characteristics such as shade tolerance and regeneration requirements (Runkle and Yetter, 1987; Bergeron et al., 1998; Drobyshev, 1999). Typically, shade-tolerant trees benefit from advanced regeneration and often colonize small canopy gaps, whereas shade-intolerant trees reveal faster growth rates but require large disturbance patches for establishment (Runkle and Yetter, 1987; Kobe et al., 1995; Liu, 1997). Diversity in disturbance events may therefore allow coexistence of both groups of trees within a community.

Mixed Korean pine (*Pinus koraiensis* Siebold et Zuccarini) dominated forest is a major forest type in the Northeastern China with Changbai Mountain as its core distribution area. Volcanism and wind are two main natural disturbance factors affecting forest dynamics in Changbai Mountain (Manchida et al., 1987; Liu, 1997; Dai et al., 2011). Volcanism results in large-scale and stand-replacing disturbances in the area. The most severe volcanic eruption in the Changbai Mountain occurred around 1100 AD and destroyed vegetation over the area of 100 km^2, the current vegetation cover originating largely after that event (Zhao, 1981). The most recent eruptions occurred in 1597, 1668, and 1702 and had spatially limited effects on local forests (Zhao, 1981; Manchida et al., 1987). Instead, wind mainly causes a wide range of disturbance events ranging from large blowdowns to single and multiple tree falls (Dai et al., 2011), all of which are considered important for forest dynamics in the Changbai Mountain. Large scale wind disturbances (>1000 m^2) are important for persistence of shade intolerant species in the forest canopy, such as Olga bay larch (*Larix olgensis* Henry) (Yang et al., 1994; Okitsu et al., 1995; Liu, 1997). Wind-induced small canopy gaps maintain mid-tolerant *P. koraiensis* in broadleaf-Korean pine forest (Dai et al., 2011). Jezo spruce (*Picea jezoensis* Carr. var. *komarovii* (V. Vassil.) Cheng et L.K. Fu) and Manchurian fir (*Abies nephrolepis* (Trautv.) Maxim.) appear to be less dependent on canopy disturbances due to their shade tolerance (Yang et al., 1994; Okitsu et al., 1995; Liu, 1997). Historical records on the frequency and intensity of disturbance events themselves are largely missing, which precludes a deeper understanding of community dynamics in this part of the Eastern Asian temperate zone.

In an attempt to quantify the multi-century pattern of natural disturbances in Asian mixed temperate forests, we studied forest disturbance history and regeneration dynamics in a primary mixed Korean pine forest, the most typical forest type in the Changbai Mountain. Our specific objectives were (1) to investigate temporal patterns of tree species regeneration, (2) to reconstruct local disturbance history of this mixed forest, and (3) to understand the relationship between disturbance history and species coexistence. Based on our field observations and published studies (Yang et al., 1994; Okitsu et al., 1995; Liu, 1997; Dai et al., 2011), we hypothesized that (1) the forest disturbance regime is dominated by frequent small-scale disturbances, whereas medium or large-scale disturbances (>1 ha) are infrequent, and (2) both regeneration and growth patterns of three dominant species (*P. koraiensis*, *P. jezoensis*, and *A. nephrolepis*) are synchronized by the canopy disturbances. Understanding the level of control exercised by the disturbance regime upon trees' regeneration is crucial for modeling future species population dynamics. We therefore discuss our results in the context of potential effects of climatic variability on natural disturbance regime and dynamics of the mixed Korean pine forests.

Materials and methods

Study area and climate

The study was conducted on the northern slope of Changbai Mountain in North Eastern China (1900 km^2, 41°31′–42°28′N, 127°9′–128°55′E, Fig. 1), within the territory of Changbaishan Natural Reserve. The area has a temperate continental climate, with long, cold, and windy winters and short, warm, and rainy summers. Annual mean temperatures vary from 7.3 °C at the low elevations (700 m a.s.l.) to 2.8 °C at the top of the mountain (2691 m a.s.l.). The mean annual precipitation along this gradient varies from 750 to 1340 mm (Zhao, 1981). The frequency of storms (episodes with wind speeds above 17 m s^{-1}) varies from 30 days $year^{-1}$ at 770 m a.s.l. to 267 days $year^{-1}$ at 2600 m a.s.l. (Liu, 1997). The topography of the area below 1700 m is gentle with slope inclinations being below 5°. Above 1700 m, the slope is relatively steep with an