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Disturbance history of an old-growth subalpine larch forest in the Qinling Mountains, north-central China

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ABSTRACT

Knowledge on how historical disturbances shaped the long-term development of forests is essential for understanding the present forest structure and for predicting the future forest ecosystem dynamics. In this study, dendroecological methods were used to reconstruct the disturbance history of an old-growth subalpine larch (*Larix chinensis*) forest in the Qinling Mountains of north-central China. Growth patterns of 690 and 582 increment cores extracted respectively from two climatically and topographically different larch stands in the northern and southern slope of the Qinling Mountains were examined for abrupt increases in radial growth indicating formation of past canopy gaps and for rapid early growth rates indicating recruitment in former canopy gaps. The findings demonstrated that there were no large-scale, stand-replacing disturbances during the past more than two centuries. Low- and medium-severity disturbance events predominated, which were probably caused by windthrows due to strong winds. The stand was unevenly aged, and the recruitment pulses associated with disturbance peaks could be distinguished. There were considerable spatio-temporal differences in disturbance dynamics of the subalpine larch stand between the topographically and climatically different sites, manifesting that the larch stand in the northern slope experienced frequent moderate but rare major disturbance events, contrasting with frequent major and moderate disturbance events in the southern slope. This study provided strong evidences that there were substantial variations in the intensity and frequency of disturbance dynamics, leading to considerable differences in the size and age structures of the subalpine larch forest.

1. Introduction

Natural disturbances such as windstorms, forest fires, and insect outbreaks play a critical role in forest dynamics at scales ranging from small patches to large landscape. They can greatly influence community structure and composition as well as species coexistence by changing resource availability and by resulting in stem mortality and thus creating canopy openings for tree regeneration (Bergeron et al., 2004; Song et al., 2011; Hart et al., 2012). Knowledge on forest disturbance history is essential for understanding the present forest composition and for predicting the future forest ecosystem dynamics (Dejan et al., 2009; Omelko et al., 2016). As a result, many researches have been conducted on disturbance history of various forest types (including the boreal, temperate and tropical forests) during the past several decades (Mccarthy and Bailey, 1996; Fraver and White, 2005; Margolis et al., 2007; Svoboda et al., 2012; Nagel et al., 2014).

The occurrence of disturbance events in mixed forest can facilitate the coexistence of tree species and eventually influences species diversity (Mori et al., 2007). Disturbance severity in closed-canopy temperate forests usually changes from frequent small-scale canopy gaps caused by tree-fall or branch breakage to infrequent stand-replacing events resulting from severe forest fires, insect outbreaks or windstorms (Margolis et al., 2007; D'Amato and Orwig, 2008). Response of trees with different strategies to disturbance varies widely, depending on the frequency, size, type, intensity of disturbance as well as on tree species' ecological characteristics (Zhang et al., 2014). For example, small canopy openings are usually sufficient for shade-tolerant tree species to trigger regeneration and increase of growth, while shade-intolerant trees have a faster growth rate and require relatively larger canopy gaps for establishment. Recent researches have indicated that intermediate-severity disturbance events in many old-growth forests may be necessary for canopy recruitment of more light-demanding tree species (Dejan et al., 2009; Svoboda et al., 2012; Nagel et al., 2014; Petritan et al., 2017).

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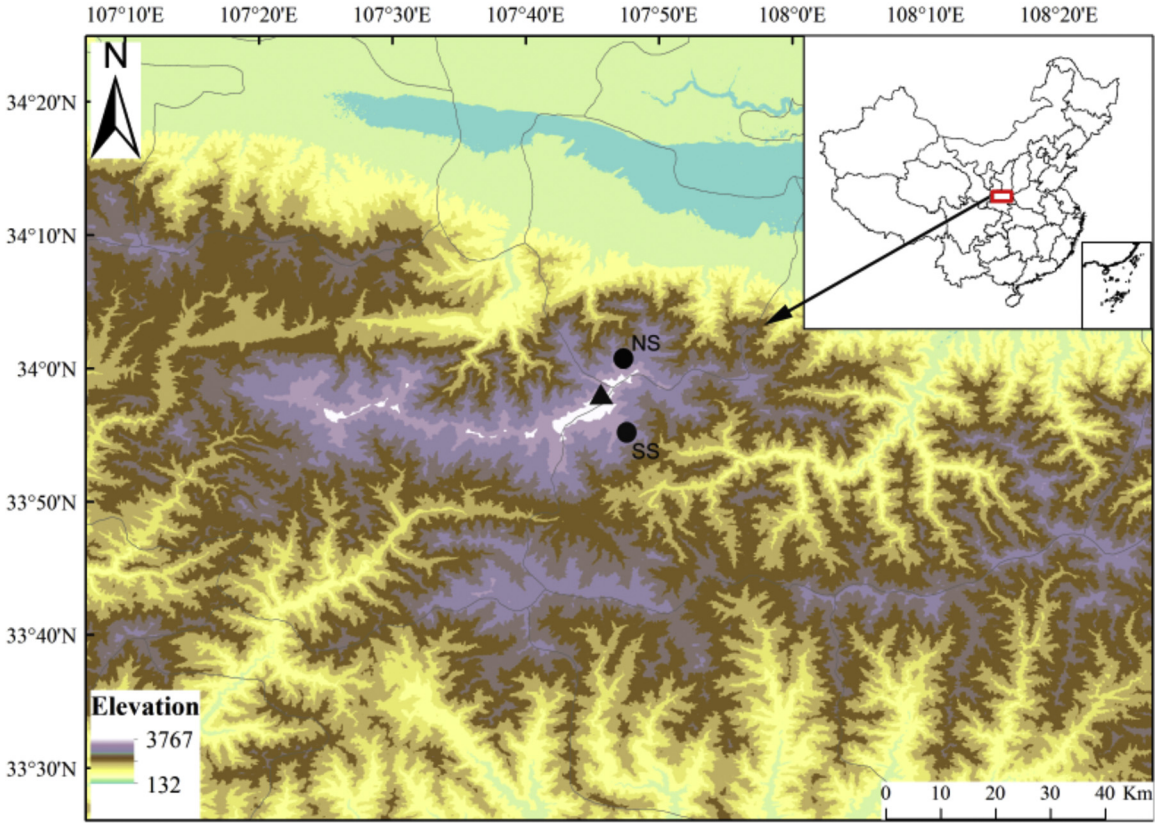

Fig. 1. Location of study sites on the northern slope of the temperate region (NS) and on the southern slope of the subtropical region (SS) in the Qinling Mountains, north-central China. Filled triangle, the highest peak of the Qinling Mountains (Mt Taibai, 3767 m).

Variability in the size, spatial pattern and severity, as well as frequency of disturbance events often produce spatio-temporal effects on tree growth, recruitment and survival (Omelko et al., 2016). Conditions for tree growth and recruitment can be typically improved when canopy gaps are created by the occurrence of disturbance event, initiating tree regeneration (i.e., gap origin) and leading to abrupt and sustained increases in tree radial growth followed by a gradual decrease in the following years due to canopy closure (i.e., growth release) (Black and Abrams, 2003; Fraver and White, 2005). Such growth release and gap origin can be identified in tree-ring records within a few years of the disturbance events. Dendroecological approaches are a very useful tool and are widely employed to reconstruct past disturbance dynamics (such as frequency and severity of disturbance events) and tree recruitment patterns based on the dating of growth release and the analyzing of tree establishment in sampled individuals (Nowacki and Abrams, 1997; Black and Abrams, 2003). Many reconstructions of disturbance history have been achieved from old-growth forests by using dendroecological techniques, which are of great implication for understanding ecosystem process such as population dynamics, community structure and stand development (Frelich and Lorimer, 1991; Mccarthy and Bailey, 1996; Binkley, 1999; Svoboda et al., 2012; Nagel et al., 2014).

The subalpine larch, *Larix chinensis*, is an endemic subalpine tree species in China, which is widely distributed in the elevations between 2700 and 3500 m in the Qinling Mountains, north-central China. The Qinling Mountains run east-west and form the basin divider between China's two longest rivers, the Yangtze river and the Yellow river. The Qinling Mountains are situated in the transitional zone from the subtropics in the southern slope to the temperate region in the norther slope in terms of climate (Yu, 1958; Tang and Fang, 2006). The northern slope is characterized by a steep topography with a narrow width of less than 40 km from the ridgeline to the Weihe plain, while the southern slope has a relatively gently rolling topography with a large width of 100–120 km from the ridgeline to the Hanzhong basin (Yu, 1958). In the absence of forest fire and insect outbreak, wind is the primary disturbance factor in this territory (Ren, 1998), which often kills larges trees disproportionately to small trees (Binkley et al., 2015). Especially, at the high elevations of the Qinling Mountains, wind usually is the dominant coarse-scale disturbance agent to cause a wide range of disturbance events ranging from single and multiple treefall to large blowdown, resulting in fine-scale gap-phase dynamics of forests (Duan et al., 2013; Huang et al., 2016). Several dendroecological studies had been conducted before to reconstruct mean air temperature and examine the radial growth response of *L. chinensis* to climatic factors along elevational gradients in the Qinling mountains (Kang et al., 2010; Qin et al., 2016; Huang et al., 2017; Qin et al., 2017). However, few studies have characterized the disturbance dynamics of the *L. chinensis* forest, which remains intact due to the remoteness and difficult accessibility. Very little is known about the disturbance history and development dynamics of the subalpine old-growth larch forest as well as whether there are differences in disturbance patterns between the topographically and climatically different sites in the northern and southern slopes of the Qinling Mountains, a biodiversity hotspot in China.

In this study, we characterized the old-growth subalpine larch forest (*L. chinensis*) at topographically and climatically different sites in the northern and southern slopes of the Qinling Mountains of north-central China. We reconstructed the development dynamics of the subalpine old-growth larch forest by combining tree recruitment pattern with dendroecological evidences of past canopy disturbance. The goal of this study was to reconstruct the disturbance history of the subalpine larch forest in the Qinling Mountains of north-central China. The specific objectives were to (1) determine whether large-scale, high intensity disturbance events occurred historically; (2) identify the influences of