



Disturbed regeneration of saplings of Korean fir (*Abies koreana* Wilson), an endemic tree species, in Hallasan National Park, a UNESCO Biosphere Reserve, Jeju Island, Korea

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pygargus* Pallas);
Stand dynamics;
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Abstract Limited knowledge is available on the regeneration of Korean fir (*Abies koreana* Wilson), an endemic plant species, growing on the upper part of Mt. Hallasan, a volcanic mountain, located in the central part of Jeju Island, Korea. A forest stand with the size of 1 ha dominated by Korean fir trees was established and all the trees with DBH 2 cm or larger were mapped and surveyed. Initial analysis indicated that the numbers of saplings with their DBHs between 2 cm and 10 cm were very small and that there was a big gap in the frequency of the number of saplings regenerated from the forest stand. It seems clear that the regeneration of the Korean fir trees was disturbed for longer than the last two decades, potentially by the browsing of the seedlings by ungulate including Siberian roe deer and by the physical hindrance of the dwarf bamboo to the development of the saplings of the Korean fir. Urgent measures and extensive studies are needed to promote the natural regeneration of the tree species on the dynamics of the forest regeneration and the mechanism of forest development of the forests on the Mt. Hallasan, Jeju Island, Korea.

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Introduction

Jeju Island is the southern-most and the largest island in Korea. It is a volcanic island and is designated from UNESCO as a UNESCO World Biosphere Reserve in 2002, World Natural Heritage in 2007 and UNESCO Global Geopark in 2010 (Woo et al., 2013). Mt. Hallasan, located in the central part of the island, has the highest peak in Korea with its altitude of 1950 m above the mean sea level.

On the upper part of the mountain, Korean fir (*Abies koreana* Wilson), a subalpine coniferous tree species, is growing forming forest stands. Korean fir is an endemic tree species classified by Wilson (1920) and categorized as an endangered species by IUCN (<http://www.iucnredlist.org/details/31244/0>). In addition, Korean fir was designated as Climate-sensitive Biological Indicator Species (CBIS) in Korea (Lee et al., 2010; Park et al., 2015). The forests of Korean fir trees suffered from a severe decline in 1960s, whose causes were not known until now (Kim, 1994; 1996). Recently, the Korean fir forests on Mt. Hallasan suffer from decline, which has diverse symptoms including: the big Korean fir trees fallen due to higher susceptibility for windfall, especially situated on a lava floor, where soil is not deep enough to fully support the root systems of the tall trees in height; patches of dead trees of Korean fir of different sizes, whose causes of the death not well studied. To cope with the societal needs to address the problems of the decline of the Korean fir tree species, in late October 2015, the Warm Temperate and Subtropical Forest Research Center of the Korea Forest Research Institute organized an International Symposium to conserve the Korean fir trees on Mt. Hallasan in Seogwipo City, Jeju Island, Korea. Presentations on managerial issues to prevent the decline of the tree species as well as botanical characteristics of the species were made and discussion was extended to the measures to prevent the decline of the tree species on Mt. Hallasan (Korea Forest Research Institute, 2015).

In Jeju Island, there is a saying from the local people that Korean fir can live only one hundred years, which is a quite interesting saying possibly based upon long-term observation of nature in Jeju Island. This saying gives an insight to the decline of the big and old trees of Korean fir, which indicates that it is an unavoidable natural phenomenon related to increased vulnerability of the trees with shallow root systems standing on thin soil layers formed on lava floor of basalt. Vulnerability of the aged trees to the ever powerful winds, consequently lowered vigors of the trees and increased susceptibility to harsh and changing environment disturbed by omnipotent typhoons and frequent droughts might be the causes for the decline of the old trees. In other part of the world, the phenomena of declining fir trees at high altitudes were reported as the series of waves of dying fir trees, so called, 'fir waves' or 'Shimagare' (Sprugel, 1976; Kohyama, 1988).

A worrisome phenomenon that we can observe from the forests on Mt. Hallasan is the fact that it is quite difficult to observe small trees of Korean fir trees at forest stands on Mt. Hallasan, which is a real concern for us, ecologists, to observe at the forest indicating the eventual decline of the tree species in the long run. From stand dynamics' view points of the natural forests, trees are regenerated from seeds or sprouts from stumps and roots, which develop into seedling, saplings, and eventually into maturing trees (Meyer, 1952; Helms, 1998;

Halpern, 2001). Saplings are differentiated from seedlings in size, especially in height. Although there are different measures to differentiate sapling from seedling, saplings are generally regarded as the small trees whose heights are taller than certain heights (e.g., 1.3–1.5 m, 2.0 m, or breast height), whereas seedlings are smaller trees whose heights are smaller than certain heights. As the saplings are the small trees that can be developed into the bigger and mature trees at the forests, they are the indicators of the future condition of the forest, in composition, health, development, etc. If there are few saplings in the forests where bigger trees are simultaneously under decline, we can evaluate that the forests are under the condition of real decline.

In conserving the Korean fir forests, managing the forests sustainably, and, ultimately, preventing the decline of the Korean fir forests on Mt. Hallasan, it is crucial to establish and promote the natural regeneration of saplings of the Korean fir trees on the forests. Currently, there are two major factors that potentially disturb the regeneration of the forests, which are the browsing of the seed germinates, young seedlings, and growing saplings by the Siberian roe deer (*Capreolus pygargus* Pallas); and the physical hindrances and competition of the dwarf bamboo (*Sasa quelpaertensis* Nakai) inhibiting the establishment of the seedlings of Korean fir on Mt. Hallasan. There are many cases supporting the effects of the factors around the world. In October 2015, IUFRO International Conference was held to discuss the effects of ungulate browsing on forest regeneration and silviculture, which was organized by IUFRO and Swiss Federal Institute for Forest. Halpern (2001) reviewed the literature on the constraints on the conifer regeneration. In order to establish the successful seedlings and saplings, there are series of stages where the constraints to be overcome from seed production, seed dispersal, seed germination, seedling establishment, sapling establishment, and eventually mature trees. On affecting the regeneration, he suggested that there are groups of factors including abiotic and biotic variables, where biotic variables include herbivore browsing, competition with other plants, mycorrhizal limitation, fungal pathogens and phytotoxic effects.

There are few studies carried out to investigate the factors related to the regeneration of the saplings of Korean fir on Mt. Hallasan, Jeju Island. Currently, we rarely know about what has been happening at the forests on the animal-plant interactions, interspecific competing among plant species, adaptation mechanism of plant species surviving the harsh environmental conditions of the forest stands. On this issue of the decline of the Korean fir forests, it is important to address such questions as:

- what are the general patterns of frequency distribution over tree sizes (DBH Class) of Korean fir trees?
- how much has the pattern of frequency distribution disturbed and what does it imply in interpreting the situation of the decline of Korean fir forest?
- what would it imply in the management of the decline of Korean fir forests?

Here, emphasis is placed upon finding out the gaps in frequency distribution of the Korean fir trees on Mt. Hallasan, Jeju Island, Korea. The objectives of this study are (1) to investigate the current status of frequency distribution of the saplings of the Korean fir trees, (2) to characterize the gap

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