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学 位 論 文 内 容 の 要 旨

博士（環境科学）

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学 位 論 文 題 名

Dynamic properties of subalpine coniferous forests in Nepal Himalaya and

Hokkaido

（ネパール・ヒマラヤと北海道の亜高山帯針葉樹林の動態特性）

主論文要旨

Subalpine coniferous forests in Northern Hemisphere are forested ecosystems located in the highest elevation, which provide a range of ecosystem services to not only local human communities but also those in the downstream regions. Subalpine forests in Himalayas in low latitude at 27-29°N are located in the world-highest locations, experiencing low atmospheric pressure and high UV-B radiation. In contrast, subalpine forests in Hokkaido around 43°N in low altitude experience high intra-annual temperature variation, where severe winter brings about tree damage by snow deposition and stem freezing. Himalayan subalpine forests usually suffer from land use pressure, while Hokkaido forests do not. This thesis examined determinants of population and biomass dynamics in two

contrastive subalpine forests: *Abies spectabilis* dominated forest in Langtang National Park, eastern Himalaya, and primeval *Picea glehnii*-*Abies sachalinensis* dominated forest on Mt. Oakan, eastern Hokkaido, to specify major factors that determine the biomass storage and turnover of these forest ecosystems.

I investigated the subalpine forest dominated by *Abies spectabilis* in Langtang National Park, Nepal Himalaya, by setting 80 plots of 10-by-10 m scattered over the range of subalpine forest from 3100 to 3900 m a.s.l. on a north-facing slope, and examined the relationship between topographic factors (e.g. altitude and slope inclination), anthropogenic factors (e.g. number of cut stumps and trampling intensity), and forest stand variables (e.g. woody species richness and composition, tree and juvenile density, basal area, and topsoil C/N content). Species richness was decreased with altitude, number of fallen logs, and trampling intensity while at the same time, it was increased with slope inclination and cut stump density. Stands in higher altitude showed lower tree density and basal area, while higher juvenile density of *A. spectabilis*. Juvenile density was decreased with high basal area. Stands on steeper slopes had higher tree density with smaller maximum size on poorer soil. With increasing cut stumps, basal area and soil carbon content were decreased while woody species richness and tree density were increased, suggesting enhanced stand recovery in response to canopy removal. This results shows that *Abies* population is vulnerable to topsoil removal by

trampling and cutting, and that altitude-dependent management is needed.

In the same Langtang forest, I quantified altitudinal change in aboveground biomass and its turnover rate by examining tree stem allometry and stem wood increment of canopy trees. I established 36 plots (3251 m² in total) for closed-canopy stands, and additional sapling plots in open-canopy sites (772 m²) in October 2015. I recorded stem diameter at breast height D and top height H for all trees ($H \geq 2.0$ m) and saplings ($2.0 > H \geq 0.2$ m). Five-year radial increment of D was measured using a core borer from all canopy trees in the plots, and recorded height increment of all saplings in recent three years by annual bud scars on leader shoot. I quantified altitude-dependent change in stem shape in D - H relationship, by extended allometric equation with asymptotic H . I estimated aboveground biomass (AGB) using an allometric equation between D^2H and aboveground tree mass W employing the data of Yoda (1968) in eastern Nepal. For canopy trees with past D estimates in 2010, I estimated past H using the D - H allometry, and past W as well. Based on the change in W for canopy trees per plot, I estimated aboveground coarse wood production rate (CWP) for each plot, as the annualized increment of AGB for survived trees. Tree height H of *Abies spectabilis* at any given D was decreased with altitude. Relative growth rate (RGR) in W was decreased with tree biomass (W) and with altitude. RGR of sapling height was increased with altitude for taller saplings (> 50 cm), whereas, it was decreased with altitude for shorter saplings. Aboveground biomass of *Abies* trees in 36 plots was 48.9 kg m⁻² and coarse

wood production rate was $0.488 \text{ kg m}^{-2} \text{ year}^{-1}$. AGB and CWP tended to be decreased with altitude. CWP relative to AGB was also decreased with altitude, suggesting slower turnover in high altitude. The present study shows that there is huge biomass storage in subalpine *Abies spectabilis* forest in eastern Himalaya, and that biomass is maintained by slow turnover rate (ca. 1% per annum in CWP/AGB) relative to usual forest ecosystems (1.5–2%). Altitude-dependent decline in canopy height, AGB and CWP/AGB suggests adaptation to ambient conditions for the maintenance of forest structure.

In the Oakan forest in eastern Hokkaido, I examined architectural and demographic properties of two dominant canopy tree species of *Picea glehnii* and *Abies sachalinensis*, based on repeated censuses in 1-ha permanent plot at 540 m above the sea level, over eleven years. Tree-size dependent growth rate and mortality rate varied between two species. *P. glehnii* showed better growth and survival at canopy with the maximum height of about 35 m, whereas *A. sachalinensis* did so in understory with higher recruitment rate, which contributed to coexistence through species stratification along canopy profile. Aboveground biomass of 14 kg m^{-2} in average was maintained by fairly high turnover rate of 0.04 year^{-1} , which suggests that the forest experienced high disturbance, resulting in high proportion of young stands in the plot. Increasing abundance of *A. sachalinensis* was therefore associated with young regeneration.

Comparison of results from two contrastive forests suggest that

Himalayan subalpine forests in mild winter would experience lower natural disturbances compared to subalpine forests in higher latitude, regardless of the presence of anthropogenic disturbances. High biomass storage with tall canopy stature can be attributed to mild climatic conditions. In contrast, low biomass storage and high biomass turnover rate of the Oakan forest reflected a high proportion of young stands after natural disturbances. Co-dominance of two coniferous species can be associated with high disturbances in severe climate, which enhance inter-specific differentiation along canopy profile and regeneration stages.