Ecological positions of conifers on the stand structure of the temperate forest in central Japan

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The mixed conifer-hardwood forest was found in cool temperate forests of central Japan that co-dominated with conifers and deciduous broad-leaved trees. To examine the ecological roles of conifers in a cool temperate forest of central Japan, the florisitic composition and stand structure were analyzed along an altitudinal gradient of the temperate zone in Shizuoka Prefecture, Japan. Research plots of 20 m square (0.04 ha) were set up between altitudes of 900 m and 1800 m. Species were identified, and measured their diameters and heights. As a result, species replacement of conifers was not observed conspicuously by altitude gradient, and *Abies firma* and *Tsuga sieboldii* were widely dominant. Conifers affected the forest structure, such as canopy height and maximum DBH. Conifers showed a high contrition on the stand structure in cold temperate forests of central Japan.
Key words: altitudinal gradient, conifer, mixed conifer-broad-leaved forest

I Introduction

The forest structure of central Japan changes along a gradient of altitudinal zonation (*6*). In central Japan, cool temperate forest is observed between the intermediate-temperate forest (below 800 m asl) and subalpine forest (from 1800 m to 2600 m asl), and it dominates the deciduous broad-leaved forest with conifers. A mixed conifer-hardwood forest is also found co-dominated with conifers and deciduous broad-leaved trees. Species replacement of conifers in temperate forest occurred due to altitudinal conditions (*2, 6, 11*) and soil substrates (*12*). Thus, conifers are expected to play an ecological role of forest structure for species richness, canopy structure, and total basal area (*1*). The species composition of the temperate forest on the Pacific side of central Japan is different than that on the Sea of Japan side due to precipitation conditions, especially in the winter climate (*3*). The temperate forest on the Pacific side is characterized by high in species diversity due to large amounts of rainfall and steep mountain slopes (*11, 7*). The contribution of conifers to the stand structure in temperate forests is key to evaluating the functional role in the ecosystem and the formation process of mixed conifer-broad-leaved forests. In this paper, we examine the ecological position of the conifers in a cool temperate forest of central Japan and how conifers act on the florisitic composition and stand structure along an altitudinal gradient of the species-rich temperate zone in Shizuoka Prefecture, Japan.

II Study site and methods

The study site is located in a cool-temperate area of the Ikawa Forest, Mountain Science Center, University of Tsukuba, Japan, and its adjacent area (Table 1). The mean annual air temperature was 9.0℃, and the mean annual rainfall was 2800 mm at the Ikawa Forest weather station for a decade (2001–2011). Five research plots of 0.04 ha (20 m × 20 m) were established on the research area in 2016 (0990LB1, 1250LB2, 1300LB1, and 1800LB1) and 2018 (1040MJ1). The plots were divided into 4 contiguous subplots (10 m × 10 m). All living trees larger than 5.0 cm in diameter at breast height (DBH) 1.3 m from the ground were identified and then measured. The height (H) of the trees was measured. The maximum DBH (D_{max}) was defined as the largest size observed, and the maximum tree height (H_{max}) was used as the 95th percentile of the size distribution, as established by (*4*).

III Results and discussion

Figure 1 shows the dominant tendency of five coniferous species and other trees among the sites by basal area. *Abies firma* and *Tsuga sieboldii* were dominant in the temperate zone, and *Abies homolepis* and *Tsuga diversifolia* were dominant in a high-altitude site (1800LB1) close to the subalpine coniferous forest. Site 1040MJ1 was characterized as having a high dominance of *Tsuga sieboldii*. Figure 2 shows relationships between altitude and basal area, D_{max}, and H_{max}. There were no special relationships among them. Figure 3 shows the relationships of broad-leaved trees *versus* conifers of the basal area, D_{max}, and H_{max}. If there is a high contribution of conifers, then it is plotted above the line; whereas, if broad-leaved trees contribute more than that of conifers, then it is plotted below the line. As a result, two sites were dominated by conifers over broad-leaved trees by total basal area. Figure 4

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shows the DBH-H relationship between the mixed forest sites (0990LB1, 1250LB2, and 1300LB1) and the conifer-dominant sites (1040MJ1 and 1800LB1) based on the results in Figure 3. In mixed forest sites, conifers and broad-leaved trees were coexistent in the same size structure. On the other hand, it was found that broad-leaved trees only contributed to the subcanopy and shrub layer in conifer-dominated sites.

We found equivalent contributions of conifers on forest structure in the temperate zone of central Japan in mixed-forest sites (0990LB1, 1250LB2, and 1300LB1). These sites were dominated by *Abies firma* and *Tsuga sieboldii.* Similar observations were reported by (*10, 11*) in the temperate forest of Shikoku, southwestern Japan. On the other hand, *Tsuga sieboldii* mono-dominated forests were also found in this study. *Tsuga sieboldii* sometimes dominated in temperate forests (*10, 5*) this was caused by past disturbance regimes, slope aspect, and soil conditions (*8*). The forest of the Ikawa area of Shizuoka Prefecture, including the study sites, was affected by past logging (*9*). This background seems to influence the present forest structure and species composition of both mixed and conifer-dominated forests. The species composition of the high altitude site (1800LB1) was characterized by the dominance of subalpine conifers such as *Tsuga diversifolia*. Franklin et al. (1979) reported similar observations. However, site 1800LB1 was found to be dominated by *Abies homolepis,* which dominates on the temperate zone on the Pacific side of Japan (*10*). Site 1800LB1 could be regarded as the boundary between the temperate and subalpine zones in terms of species composition.

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Table 1. Outline of the research plots

Plot code	Latitude	Longitude	Altitude (m)	Slope inclination (°)	Slope aspect
0990LB1	35.3239	138.2231	990	42	N90W
1040MJ1	35.2993	138.2061	1038	23	N30E
1250LB1	35.3375	138.2280	1248	46	N0E
1300LB1	35.3414	138.2287	1278	32	N275W
1800LB1	35.3348	138.2372	1811	28	N290W

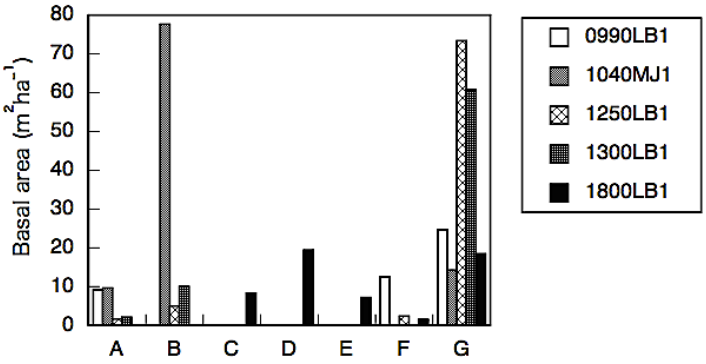

Figure 1. Dominance by basal area of (A) *Abies firma*, (B) *Tsuga sieboldii*, (C) *Abies homolepis*, (D) *Tsuga diversifolia*, (E) *Larix kaempferi,* (F) other conifers, and (G) broad-leaved trees

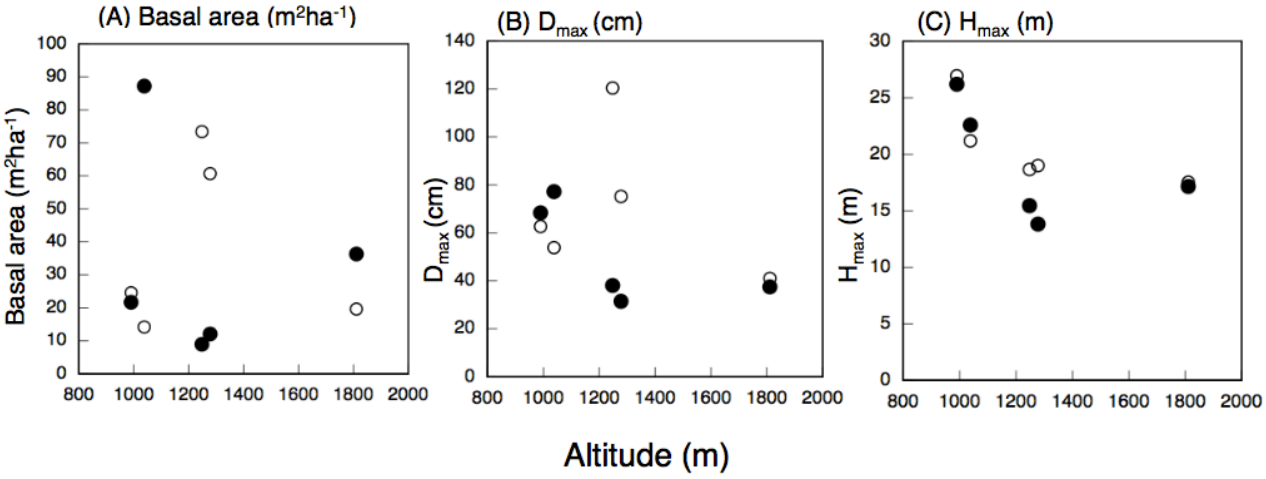

Figure 2. Relationships between altitude and basal area (A), maximum DBH (D_{max}) (B), and maximum tree height (H_{max}) (C); closed and open circles are conifer and broad-leaved trees, respectively.

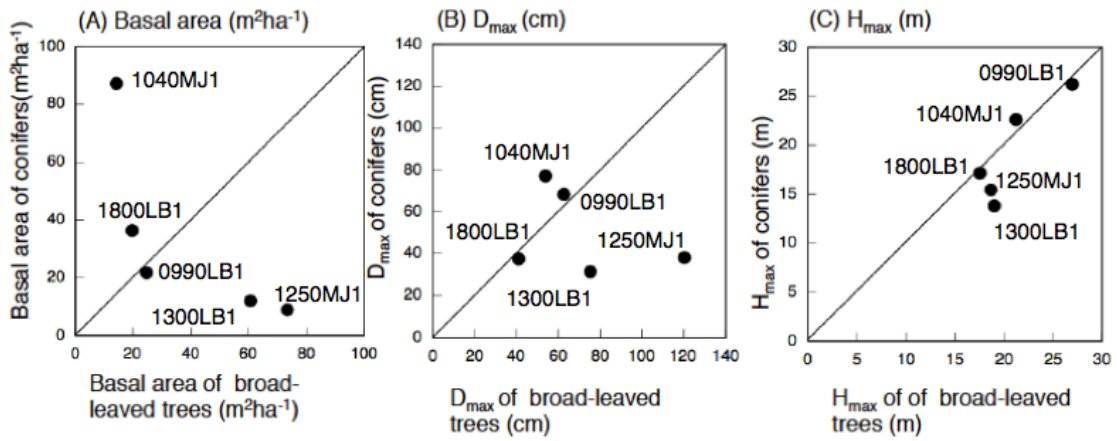

Figure 3. Relationships of broad-leaved trees versus conifers by basal areas (A), maximum DBH (D_{max}) (B), and maximum tree height (H_{max}) (C). See Table 1 for code of the plots.

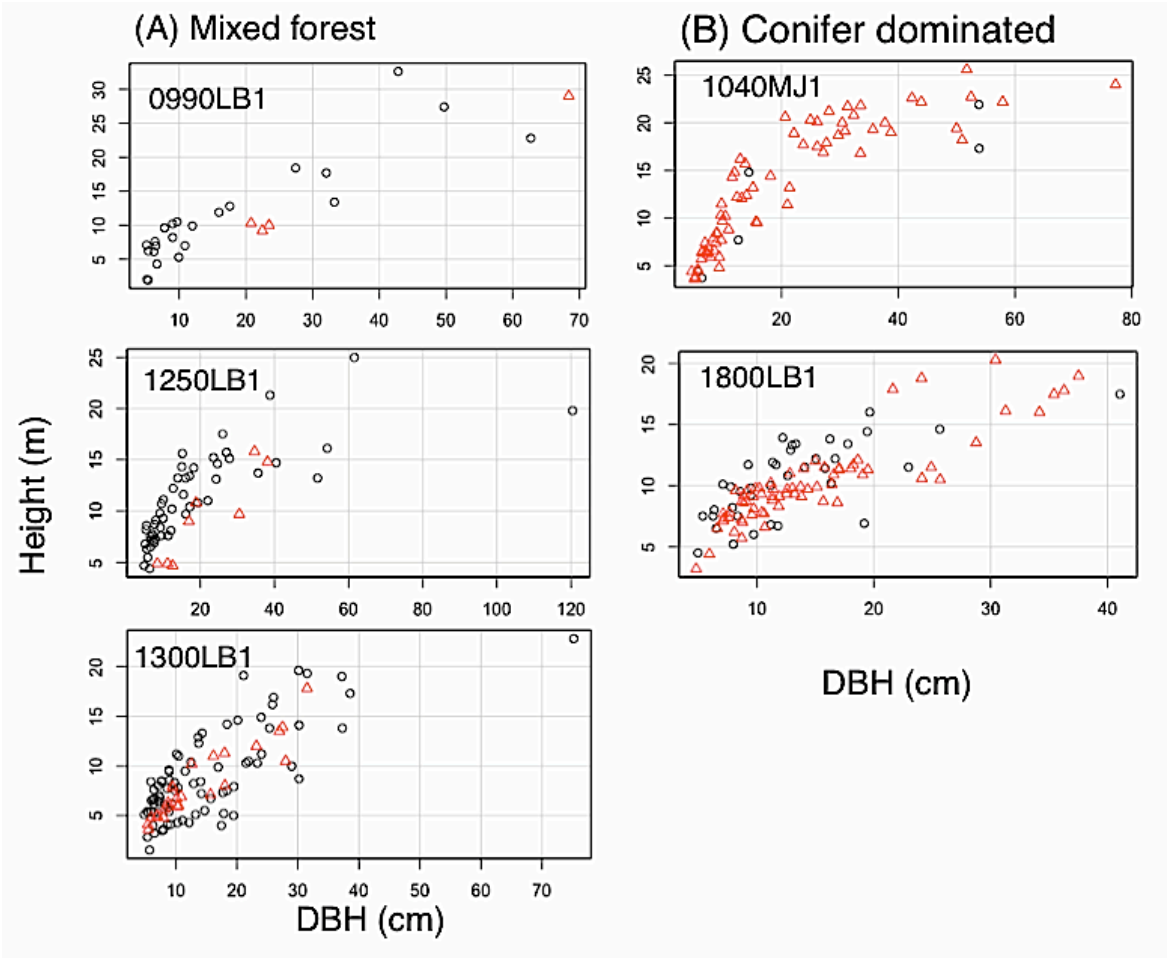

Figure 4. DBH-tree height relationship in each plot by (A) mixed forest and (B) conifer-dominated sites. Triangles and circles are conifer and broad-leaved trees, respectively.