Stand structure and regeneration of a beech-dominated forest in the Kawakami Forest, Mountain Science Center, University of Tsukuba, central Japan

SEINO Tatsuyuki (Ikawa Forest Station, Mountain Science Center, University of Tsukuba)

Beech (*Fagus crenata*)-dominated stands in the inner area of central Japan were scarce. A beech-dominated forest of the Kawakami Forest Station, University of Tsukuba, in Nagano Prefecture was found in the inner area of central Japan. Stand structure and dynamics were examined to analyze the mechanism of stand development in this forest. A research plot (0.25 ha) was set on the gentle ridge of the Kawakami Forest, and DBH and height were measured. Tree age was measured using core samples from near the plot. A tree census was carried out every two years from 2008 to 2016. Beech was dominant, with 57.9% of the total basal area. DBH and height also showed the dominance of beech and intermittent regeneration. These results suggested that beeches of this stand were regenerated all at once after some disturbances, and the stand developed stably throughout after those past events.

Key words: *Fagus crenata*, *Quercus crispula*, regeneration, stand dynamics, stand structure

I Introduction

The Japanese Beech (*Fagus crenata* Blume) is recognized as a climax and dominant species in a temperate forest in Japan (*5*). The structure and species composition of the beech forest in Japan are distinguished by climatic condition according to snow depth in winter: the Pacific side type (little snow) and the Japan Sea side type (deep snow) (*5, 6*). The Pacific type of beech forest is characterized by dryness in the winter and is co-dominated with other broad-leaved species and/or coniferous species with intermittent regeneration (*5*). On the other hand, the Japan Sea type of beech forest has much greater snow depth and is mono-dominated by *F. crenata* at all regeneration stages (*6*). From the pattern of stand structure and regeneration points of view, this beech forest in the inner area of central Japan was rare and unique. In some inner areas of central Japan, *F. crenata* cannot dominate for ecophysiological reasons, such as dry winter conditions, and instead of *F. crenata*, *Quercus crispula* Blume dominates (*2*). However, beech-dominated stands are found in some inner areas of central Japan (*8, 4*). These stands are found on the gentle ridge and are distinguished by their floristic composition as compared with an adjusted forest. A beech-dominated forest found in the Kawakami Forest Station, Mountain Science Center, University of Tsukuba, in Nagano Prefecture is found in the inner area of central Japan. In this study, the stand structure and dynamics were examined to analyze the mechanism of stand development in this forest with a history of regeneration throughout its stand development.

II The study site and methods

The study site is located in a cool-temperate area of the Kawakami Forest, Mountain Science Center, University of Tsukuba, Japan. The mean annual air temperature was 7.0˚C, and the mean annual precipitation was 1462 mm at the weather station of the Kawakami Forest for a decade (2001–2011). A research plot of 0.25 ha (50 m × 50 m) was established on a ridge slope of the Kawakami Forest in 2008. The plot was divided into 25 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, with their locations in the plot mapped. The height (H) of the trees was measured except for lean or broken stems in 2012. Re-censuses of DBH and survival status were carried out every two years from 2010 to 2016. Tree age was investigated using a core-bowler from outside of the plot. The cores were sampled from a height of 1 m from the ground.

III Results and discussion

Seventeen species with 291 stems and a basal area (BA) of 34.7 m^2ha^{-1} were recorded in 2008. Table 1 shows the tree composition of the plot. *Fagus crenata* was dominant, with 57.9% of the total BA in the initial census (2008). The other dominant species was *Quercus crispula*, with 25.7% of the total BA. These two dominant species accounted for 83.6% of the total BA. The DBH–H relationship of the two dominant species is shown in Figure 1. The maximum DBH (D_{max}) and H (H_{max}) of *F. crenata* (63.2 cm and 21.8 m,

清野達之*
長野県中部に位置する筑波大学山岳科学センター川上演習林におけるブナ優占林の組成と構造
seino.tatsuyuki.gw@u.tsukuba.ac.jp

respectively) were greater than those of *Q. crispula* (39.6 cm and 18.3 m, respectively; Table 1). DBH distribution was different between *F. crenata* and *Q. crispula* (Kolmogorov-Smirnov test, $P < 0.001$; Figure 2). The median DBH of *F. crenata* was 25.8 cm, and that of *Q. crispula* was 17.1 cm.

The stand dynamics during eight years (from 2008 to 2016) are shown in Figure 3. The number of stems and the BA did not change. The ages of *F. crenata* and *Q. crispula* were similar when the DBHs were larger than 20 cm (Figure 4). The average age of trees with a DBH larger than 20 cm was 72 years in both dominant species.

A beech-dominated area of the Kawakami Forest Station, University of Tsukuba, in Nagano Prefecture was found in the inner area of central Japan. The structure of this stand differed from that of an adjacent forest by the mono-dominance of beech. On the Pacific side, beech coexists with other members in the beech forest and does not mono-dominate (*5*). The inner area of central Japan, between the Pacific side and Japan Sea side, is characterized by high altitude, and some areas are affected by climatic limitations such as cold and dry conditions in winter and frost in spring (*3*). In such areas, *Q. crispula* is dominant instead of *F. crenata* (*3*). Takaoka (2010) and Koyama et al. (2014) reported that the beech-dominated forest in the inner area of central Japan was established on a ridge. The location of the studied stand was also on a gentle ridge. It is considered that the topographical conditions seemed to function as a refuge from harsh climatic conditions for beeches in the inner area of central Japan.

A previous study (*4*) indicated that beeches regenerated all at once. The average age of *F. crenata* and *Q. crispula* canopy trees was 72 years in the studied stand. By subtracting 72 from the investigated year (2012), it is considered that canopy trees were regenerated before the 1940s. The Kawakami Forest and adjacent forests were strongly affected by human disturbance, such as logging and fuel utilities (*1*). However, there were no management records of the Kawakami Forest area before 1959, and the site around the research plot was recognized as a natural forest (*7*). Thus, beeches were regenerated after some past disturbances since early 1900s all at once, and dominated with stable status with sub-dominance of *Q. crispula* in the Kawakami Forest of this study.

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Table 1. Number of stems (N, 0.25 ha^{-1}), maximum DBH (Dmax, cm), basal area (BA, m^2 ha^{-1}), and relative basal area against the total (RBA, %) o of each species identified in the initial census in 2008.

Species	N	Dmax	BA	RBA
Fagus crenata Blume	125	63.2	20.1	57.9
Quercus crispula Blume	103	39.6	8.9	25.7
Tilia japonica (Miq.) Simonk.	24	27.9	1.6	4.6
Acer sieboldianum Miq.	30	19.1	0.8	2.2
Acer rufinerve Siebold et Zucc.	6	34.0	0.7	1.9
Acer japonicum Thunb.	8	23.2	0.5	1.5
Larix kaempferi (Lamb.) Carrière	1	37.4	0.4	1.3
Enkianthus campanulatus (Miq.) G.Nicholson	52	9.8	0.4	1.3
Cerasus maximowiczii (Rupr.) Kom.	8	13.4	0.3	0.8
Acer diabolicum Blume ex K. Koch	1	26.9	0.2	0.7
Betula ermanii Cham.	2	22.2	0.2	0.7
Aria alnifolia (Siebold et Zucc.) Decne.	4	16.9	0.2	0.5
Acer shirasawanum Koidz.	5	16.4	0.1	0.3
Fraxinus lanuginosa Koidz. f. *serrata* (Nakai) Murata	18	10.2	0.1	0.2
Carpinus cordata Blume	5	9.0	0.1	0.2
Acer pictum Thunb.	1	16.0	0.1	0.2
Hydrangea paniculata Siebold	4	7.3	0.0	0.0
Euonymus oxyphyllus Miq.	4	5.8	0.0	0.0

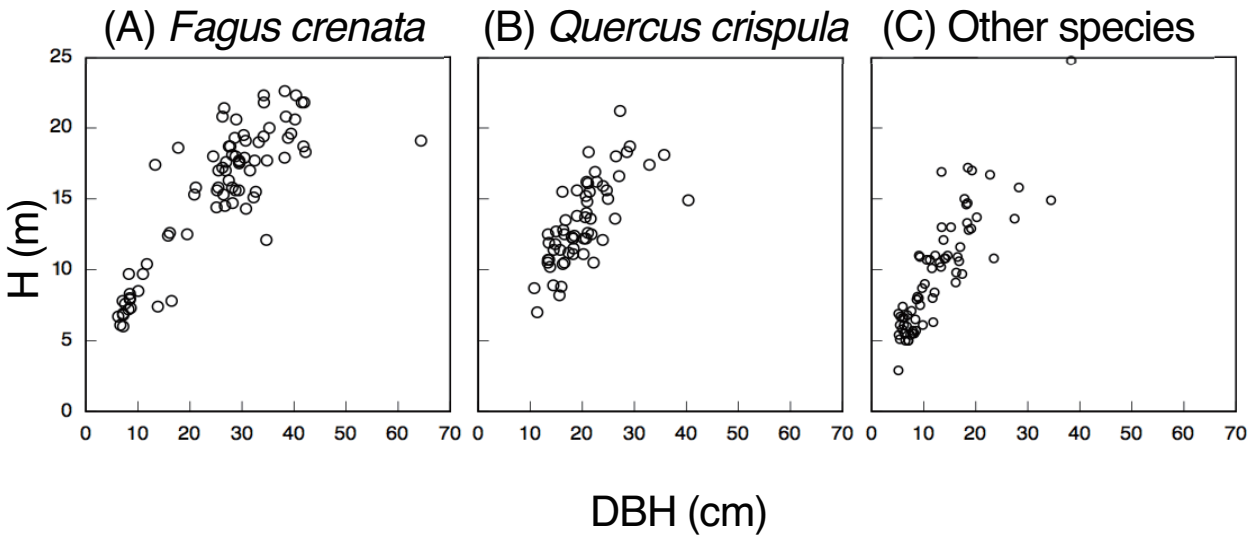

Figure 1. Relationships between DBH and tree height in *Fagus crenata* (A), *Quercus crispula* (B), and the other species (C).

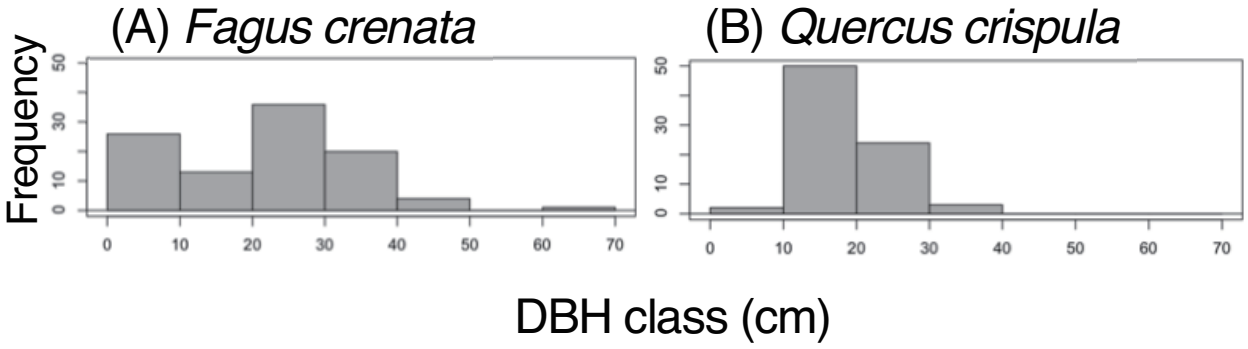

Figure 2. DBH histograms in *Fagus crenata* (A) and *Quercus crispula* (B).

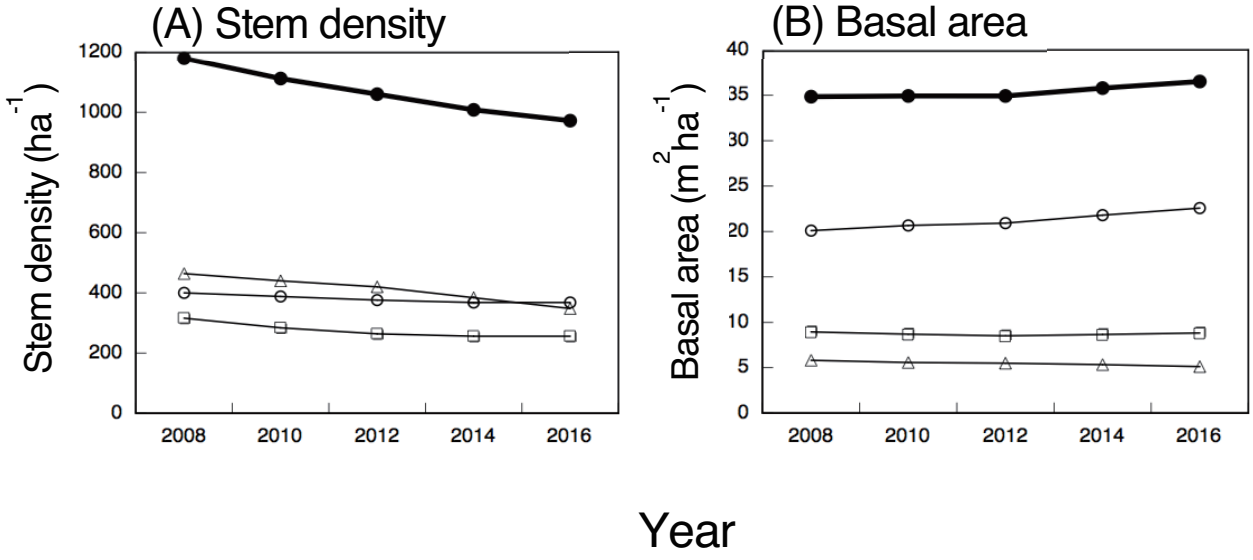

Figure 3. Changes in stem density (A) and basal area (B) during 2008–2016. Black circle, white circle, white square, and white triangle are overall trees, *F. crenata*, *Q. crispula*, and the other trees, respectively.

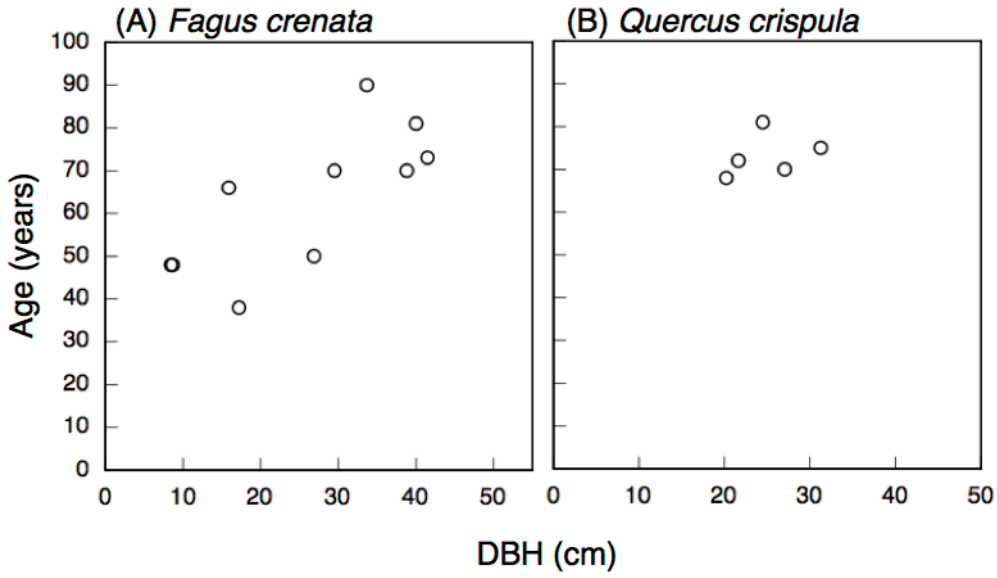

Figure 4. Relationships between DBH and age in *Fagus crenata* (A) and *Quercus crispula* (B).