



Title	Assessing insect herbivory on broadleaf canopy trees at 19 natural forest sites across Japan
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1 **Title**

2 Assessing insect herbivory on broadleaf canopy trees at 19 natural forest sites across  
3 Japan

4

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61

62 **Abstract**

63 We present the largest freely available herbivory dataset for Japan representing data  
64 collected from a network of 19 natural forest sites across the country. Sampled network  
65 sites were part of the Monitoring Sites 1000 Project organized by the Ministry of the  
66 Environment. Sites were located across a range of climate zones, from subarctic to  
67 subtropical, and broadleaf trees (both evergreen and deciduous) were targeted at each  
68 site. Litterfall traps were used to assess leaf damage caused by leaf-chewing insects in  
69 2014 and 2015. Using a standardized protocol, we assessed herbivory on 117,918 leaves  
70 of 39 dominant tree species. Preliminary analyses suggest that insect herbivory  
71 increases with increasing latitude for deciduous broadleaf species. In particular, oak  
72 (*Quercus crispula*) and beech (*Fagus crenata*) were subject to increased insect  
73 herbivory with increasing latitude. In contrast, insect herbivory decreased with  
74 increasing latitude in evergreen broadleaf species. The latitudinal gradient of herbivory  
75 differed according to leaf type (i.e., evergreen or deciduous). This dataset offers  
76 excellent opportunities for meta-analysis and comparative studies of herbivory among  
77 various forest types.

78

79 **Keywords**

80 evergreen species, deciduous species, insect-plant interactions, the Monitoring sites  
81 1000 Project, latitudinal gradient

82

83 **Metadata**84 **1. Introduction**

85 Herbivory, the act of eating plants, plays a fundamental role in carbon and nutrient  
86 cycling (Metcalf et al., 2013) and may affect diversity and structure in forest  
87 communities by altering biomass (Cyr & Pace, 1993) and tree fitness (Coley & Barone,  
88 1996). Exploring changes in herbivory that may reflect global climate change has  
89 become increasingly popular in recent decades (Kozlov & Zvereva, 2015). However,  
90 debate remains as to the mechanisms by which biotic and abiotic factors regulate  
91 herbivory (e.g., Coley, Bryant, & Chapin, 1985; Endara & Coley, 2011; Moles, Bonser,  
92 Poore, Wallis, & Foley, 2011).

93         It is believed that biotic interactions become stronger as latitude decreases  
94 (Dobzhansky, 1950; Janzen 1970; Schemske et al. 2009). For insect–plant interactions,  
95 ecologists have long examined how insect herbivory intensity varies with latitude (e.g.,  
96 MacArthur, 1972; Pennings & Siliman, 2005; Schemske, Mittelbach, Cornell, Sobel, &  
97 Roy, 2009; Hiura & Nakamura, 2013). In two seminal review papers published in the  
98 1990s, Coley and colleagues found that tropical forests experienced significantly higher  
99 herbivory than did temperate forests (Coley & Aide, 1991; Coley & Barone, 1996). These  
100 studies served as the foundation for the latitudinal herbivory–defense hypothesis  
101 (LHDH), which predicts that herbivory will be higher in warmer and more stable  
102 climates (i.e., at low latitude or low elevation), which then leads to selective pressure  
103 for the evolution of more effective plant defenses (Dobzhansky, 1950; MacArthur,  
104 1972; Coley & Aide, 1991). Latitudinal gradients in insect herbivore abundance and  
105 species richness are likely responsible for stronger herbivore pressure on plants at low  
106 latitudes (Salazar & Marquis, 2012). It is widely accepted that forests in warmer  
107 climates suffer greater herbivory than those in cooler climates (Kozlov, 2008; Kozlov,  
108 van Nieukerken, Zverev, & Zvereva, 2013; Lim, Fine, & Mittelbach, 2015; Wang et al.,  
109 2016; Zhang, Zhang, & Ma, 2016; Moreira et al., 2018). [Additionally, variation in the  
110 production cost of defense compounds as predicted by optimal defense theory is an  
111 important determinant of geographic patterns in plant defense \(Kooyers et al. 2017\).](#)  
112 However, some studies have shown that no latitudinal gradient in herbivory exists (e.g.,

113 Andrew & Hughes, 2005), that the trend is counter to what would generally be expected  
114 by the LHDH (e.g., Moles et al., 2011), or that the trend is nonlinear (e.g., Kozlov,  
115 Lanta, Zverev, & Zvereva, 2015). Therefore, despite widespread interest in this pattern,  
116 the empirical evidence comprises controversial results regarding latitudinal gradients in  
117 herbivory. [The wide range of latitudes \(20–46 degrees\) and mountainous terrain in Japan,](#)  
118 [which include a wide range of subarctic and subtropical forest types themselves, gives](#)  
119 [rise to suitable conditions for addressing this question.](#)

120 This study reports insect herbivory data collected across a network of 19  
121 natural forest sites; this is the largest published herbivory dataset available for Japan  
122 with sites spanning a wide latitudinal gradient (26.74–44.37°N). This study focuses on  
123 the latitudinal gradient in insect herbivory in temperate regions of East Asia. The forest  
124 site network is part of the Forest and Grassland Survey of the Monitoring Sites 1000  
125 Project established by the Ministry of the Environment (Ishihara, Toyota, & Nakamura,  
126 2007; Ishihara et al., 2010). Some Monitoring Sites 1000 locations are also part of the  
127 Japan Long-Term Ecological Research Network (JaLTER), which further contributes to  
128 the International Long-Term Ecological Research Network (ILTER). These herbivory  
129 data, which were collected in 2014 and 2015, offer an opportunity for meta-analysis and  
130 comparative studies among forest types and for testing community ecology and  
131 ecosystem function hypotheses at broad spatial scales (e.g., testing for a latitudinal  
132 gradient in insect–plant interactions and elucidating the relative importance of insect  
133 herbivory in forest ecosystem function).

134

## 135 2. IDENTIFIER

136 xxxx(Ecological Research Data Paper Archives ID, describe after accepted)

137

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142

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148

#### 149 4. GEOGRAPHIC COVERAGE

150 A. Geographic Description

151 Japan

152 B. Geographical Position

153 Longitude: 128° 23' E - 142° 28' E

154 latitude: 26° 74' N - 44° 37' N

155

#### 156 5. TEMPORAL COVERAGE

157 A. Begin:

158 2014

159 B. End:

160 2015

161

#### 162 6. TAXONOMIC COVERAGE

163 The data include 20 families, 27 genus and 39 species of broadleaf trees (see SpList.csv

164 for details). *Castanopsis* spp. in Tano site includes *Castanopsis sieboldii* and

165 *Castanopsis cuspidate*.

166

#### 167 7. METHODS

168 A. Study sites and data acquisition

169 Herbivory data were obtained at 19 natural forest sites as part of the Monitoring Sites

170 1000 Project, with one to five permanent plots located within each site. These sites

171 covered the major climate zones and biogeographic regions in Japan (Ministry of the

172 Environment 2001, <http://www.env.go.jp/press/press.php?serial=2908>, last accessed on



173 [October 6, 2020](#)) (Fig. 1, Table 1; see also Ishihara et al., 2011) as well as the four  
174 major forest types. Plots were classified to four forest types based on the dominant tree  
175 species; evergreen conifer forest (EC), broadleaf and conifer mixed forest (BC),  
176 deciduous broadleaf forest (DB), and evergreen broadleaf forest (EB) (Ishihara et al.,  
177 2011). The majority of the surveyed forest were old-growth or older secondary forests,  
178 but some were secondary forests aged <100 years. We classified forests stands to three  
179 age categories: old growth (OG), old secondary (OS), and secondary (S) (Ishihara et al.,  
180 2011; see Appendix 1 for details).

181           The mean annual temperature and precipitation and mean maximum snow  
182 depth during 1981–2010 were extracted from the Mesh Climate Data 2010 database  
183 distributed by the Japan Meteorological Agency (2012). The database provides climate  
184 variables estimated at 1-km spatial resolution. Mean annual temperature was corrected  
185 to account for altitudinal difference between a given plot and the 1-km cell mean using  
186 a lapse rate of 0.55°C per 100 m. Database estimates for snow depth may contain  
187 inaccuracies (i.e., over- or underestimation) given that snow depth is highly spatially  
188 heterogeneous. Therefore, we provide snow depths reported in other publications and  
189 personal observations in Appendix 1 and Table S1.

190           Additional ecological data collected at the 19 study sites were available from  
191 publications, including seasonal patterns and inter-annual dynamics of litterfall (Suzuki  
192 et al., 2012), forest stand structure, composition, and dynamics (Ishihara et al., 2010), as  
193 well as ground-dwelling beetle community and understory variables (Niwa et al., 2016).  
194 At the Shiiba site (SI), only tree census data (Ishihara et al., 2010) were available.  
195 Additional ecological information including understory vegetation, disturbance history,  
196 and soil parameters collected from study sites are provided in Appendix 1 and partially  
197 summarized in Table S1.

198

## 199 B. Sampling design, field methodology, and preliminary analyses

### 200 B-1. Sampling design

201 One permanent plot at each of the 19 sites was selected for litter collection. Plots ranged  
202 in size from 0.64 to 1.2 ha and were usually approximately 1 ha in size (see Appendix 1,

203 SiteList.csv). Plots were placed or their shapes were adjusted to avoid forest roads and  
204 urban edges. Plots were typically divided into 10 x 10-m grid cells. Typically, 25  
205 conical litter traps, each with a circular collection area of 0.5 m<sup>2</sup>, were installed within  
206 each plot (see Suzuki *et al.*, 2012 for details of the litter traps). Traps were placed  
207 approximately 1 m above the ground at grid cell corners and were spaced 20 m apart.  
208 Litterfall that collected within the traps was collected monthly. Traps were either  
209 removed or placed on the ground during winter at sites that received snow.

210

### 211 B-2. Field methodology

212 Litterfall from these traps was then used for a visual assessment of leaf damage by  
213 leaf-chewing insects. Herbivory has been assessed visually in other publications (e.g.,  
214 review by Kozlov *et al.*, 2015). Although few studies have used litter traps for the visual  
215 assessment of herbivory (but see Hiura & Nakamura, 2013), litter traps are useful for  
216 collecting litterfall, especially for the assessment of multiple tree species over long  
217 periods. One technician visually assessed leaf damage blindly with respect to site. The  
218 protocol was standardized across all sites, enabling comparisons among forest types. At  
219 broadleaf forest sites, the 5 traps with the largest amount of litter were selected from all  
220 25 traps. At BC sites, 5 traps located near broadleaf trees were selected. During the  
221 4-month period when litterfall was highest (Table 2), we visually categorized the extent  
222 of herbivory on fallen leaves to six classes: no damage; 1–10% of leaf area lost; 11–  
223 25% loss; 26–50% loss; 51–75% loss; and >76% loss (Nakamura, Asanuma, & Hiura,  
224 2010; Nakamura, Nakaji, Muller, & Hiura, 2014). This herbivory assessment was  
225 applied to all broadleaf tree species that were considered dominant at each site (up to  
226 50% dominance, Table 3). In addition, oak (*Quercus crispula*, 8 sites in 2014, 8 sites in  
227 2015) and beech (*Fagus crenata*, 8 sites in 2014, 9 sites in 2015) leaves were also  
228 assessed regardless of their dominance at sites.

229

### 230 B-3. Preliminary analyses

231 We preliminarily analyzed the latitudinal gradient in insect herbivory as observed in  
232 deciduous species, evergreen species, *Q. crispula*, and *F. crenata* in 2014 and 2015

233 using linear mixed models (LMM) in the R library lme4 package. In the models, the  
234 median herbivory rate of each leaf (i.e., 0%, 5.5%, 18%, 38%, 63%, and 88%,  
235 respectively) was treated as a response variable; latitude, year sampled, and their  
236 interaction were treated as fixed effect variables. The year sampled was treated as a  
237 factor. Plot ID was treated as a random effect variable. The likelihood-ratio chi-square  
238 test was used to determine whether the herbivory rate was significantly related to  
239 latitude. The preliminary analyses indicated that insect herbivory on deciduous species  
240 significantly increased toward higher latitudes ( $\chi^2 = 35.03$ ,  $P < 0.001$ ; Fig. 2a, Table 4),  
241 whereas that on evergreen species significantly decreased ( $\chi^2 = 4.82$ ,  $P < 0.05$ ; Fig. 2b,  
242 Table 4). [These results were congruent with the latitudinal pattern in defense strategy in](#)  
243 [deciduous and evergreen species reported by Saihanna et al. \(2018\), who showed that](#)  
244 [deciduous species used physical defenses at lower latitudes, whereas evergreen species](#)  
245 [exhibited the opposite latitudinal defense patterns.](#) In particular, insect herbivory on *Q.*  
246 *crispula* significantly increased with increasing latitude ( $\chi^2 = 8.99$ ,  $P < 0.05$ ; Fig. 3a,  
247 Table 4), and herbivory on *F. crenata* tended to increase with latitude, although the  
248 trend was not significant (Fig. 3b, Table 4). These results were congruent with the  
249 latitudinal pattern in beech herbivory reported by Hiura & Nakamura (2013).

250 Our findings suggested that the latitudinal gradient of insect herbivory  
251 differed depending on leaf type (i.e., evergreen or deciduous). Leaf type is an important  
252 predictor of resource use; evergreen species typically show a more conservative  
253 resource-use strategy and slower growth rates (Givinish, 2002), whereas deciduous  
254 species show an exploitative resource-use strategy and higher growth rates (Reich,  
255 Ellsworth, & Walters, 1998). Our preliminary results suggest that the resource-use  
256 strategy may be an important determinant of the directionality of latitudinal gradients in  
257 insect herbivory.

258

### 259 C. Data verification procedures

260 We note that our data collection at two sites, Kamigamo (2014) and Wakayama (2015),  
261 was limited to a single year. The selected litter traps at some sites did not capture fallen  
262 leaves of some target tree species. Specifically, we did not capture leaves from *Acer*

263 *ukurunduense* at Otanomosutaira in 2015, *Castanea crenata* at Ogawa in 2015, *Illicium*  
 264 *anisatum* at Shiiba in 2014, *Quercus acuta* at Aya in 2014, and *Ilex macropoda* at  
 265 Kamigamo in 2015. Thus, herbivory was not assessed for those species in those years.

266

## 267 8. DATA STATUS

### 268 A. Latest update

269 January 15 2020

270

### 271 B. Metadata status

272 Metadata are complete for this period and stored with the data.

273

## 274 9. ACCESSIBILITY

### 275 A. License and usage right

276 This dataset is provided under a Creative Commons Attribution 4.0 International license  
 277 (CC-BY 4.0) (<https://creativecommons.org/licenses/by/4.0/>).

278

### 279 B. Contact

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285

## 286 10. DATA STRUCTURE

### 287 A. Data tables

Data file name	Description
SiteList.csv	Site-wise information table. Sites are listed by latitude from north to south.
SpList.csv	Species-wise information table.

Herbivory.csv	Herbivory data of each species in each site in 2014 and 2015. The herbivory of each leaf was classified into the six herbivory class, and a total number of the leaves of each the class is calculated (see method 7. B).
---------------	---

288

289 B. Format type

290 The data files are comma delimited (csv) in UTF-8 encoding.

291

292 C. Header information

293 Headers corresponding to variables names (see 10. D.) are included as the first row in  
294 the data files.

295

296 D. Variable definitions

297 The variables are listed in the order they appear in each data file. Variable names are  
298 headers included as the first row in the data files. All variables of SiteList.csv are  
299 compliant with the data papers (Ishihara et al., 2010; Suzuki et al., 2012; Niwa et al.,  
300 2016), although variables of Temp30yr, Rain30yr, and Snow30yr (1971-2000) are  
301 updated to 1981-2010 due to updating the database Mesh Climate Data by the Japan  
302 Meteorological Agency.

303

Data file name	Variable name	Variable definition
SiteList.csv	Code	Plot code. The third and fourth digits are unique to each site, and the fifth and sixth digits are plot numbers.
	PlotID	Alphanumeric plot code.
		An alphanumeric code as [abbreviated site name]-[forest type code][plot number]. For example, TM-DB1 represents the first plot of deciduous broadleaf forest (DB) in the

		site, Tomakomai (TM).
SiteName		Site name.
Type		Alphabetical code for forest type:
		BC = Broadleaf conifer mixed forest.
		DB = Deciduous broadleaf forest.
		EB = Evergreen broadleaf forest.
		EC = Evergreen coniferous forest.
Status		Forest age classifications (See 7. A and Appendix 1.pdf).
		S: Secondary.
		OS: Old secondary.
		OG: Old growth.
Latitude		WGS84 latitudinal coordinates in decimal degrees (°) to 2 decimal places.
Longitude		WGS84 longitudinal coordinates in decimal degrees (°) to 2 decimal places.
Altitude		Elevation above mean sea level (m).
		The precision is 5 m.
Area		Plot area (ha).
		The precision is 0.01 ha.
Shape		Shape of plot.
Temp30yr		Mean of mean annual temperature during the period from 1981 to 2010 (° C).
		The precision is 0.1 ° C.
Rain30yr		Mean of annual precipitation during the period from 1981 to 2010 (mm).
		The precision is 0.1 mm.
Snow30yr		Mean of annual maximum snow depth during the period from 1981 to 2010 (cm).

		The precision is 1 cm.	
SpList.csv	SpJapan	Japanese common name of species, which was romanized following the Kunrei-siki romanization system (ISO3602).	
	Family	Botanical family to which the species.	
	Genus	Genus name.	
	SpecificName	Specific name.	
	Subspecies	“subsp.” represents subspecies.	
	SubspeciesName	Subspecies name.	
	NameAuth	The scientific name of species with authority name. Under-bars are used in place of spaces.	
	Synonym		Numeric code for a synonym in Japanese common name.
			1 = accepted name.
			0 = synonym.
Deciduous_Evergreen		Functional type of the species.	
		Deciduous_broadleaf or Evergreen_broadleaf.	
Herbivory.csv	SiteName	Site name.	
	Year	Leaves sampled year. The leaf collection period at Aichi-akazu, Kamigamo, and Shiiba were two calendar years because the peak month of litter fall occurred during these calendar years (See Table 2).	
	Genus	Genus name.	
	SpecificName	Specific name.	
	Subspecies	“subsp.” represents subspecies.	
	SubspeciesName	Subspecies name.	

	herbivory_0	A total number of leaves as classified herbivory class 0 (no damage).
	herbivory_1	A total number of leaves as classified herbivory class 1 (1-10% loss).
	herbivory_2	A total number of leaves as classified herbivory class 2 (11-25% loss).
	herbivory_3	A total number of leaves as classified herbivory class 3 (26-50% loss).
	herbivory_4	A total number of leaves as classified herbivory class 4 (51-75% loss).
	herbivory_5	A total number of leaves as classified herbivory class 5 (> 76% loss).
	Latitude	WGS84 latitudinal and longitudinal coordinates in decimal degrees (° ) to 2 decimal places.
	Longitude	Elevation above mean sea level (m).

304

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314 the Environment, Japan.

315



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446

## 447 13. FIGURE LEGEND

448 Figure 1 Location of the 19 natural forest sites across Japan.

449 Figure 2 Latitudinal gradient of insect herbivory in (a) deciduous and (b) evergreen  
450 broadleaf tree species in 2014 and 2015. Symbols represent the mean herbivory rate  
451 of each site. Lines indicate fitted lines from the prediction from the linear mixed  
452 models.

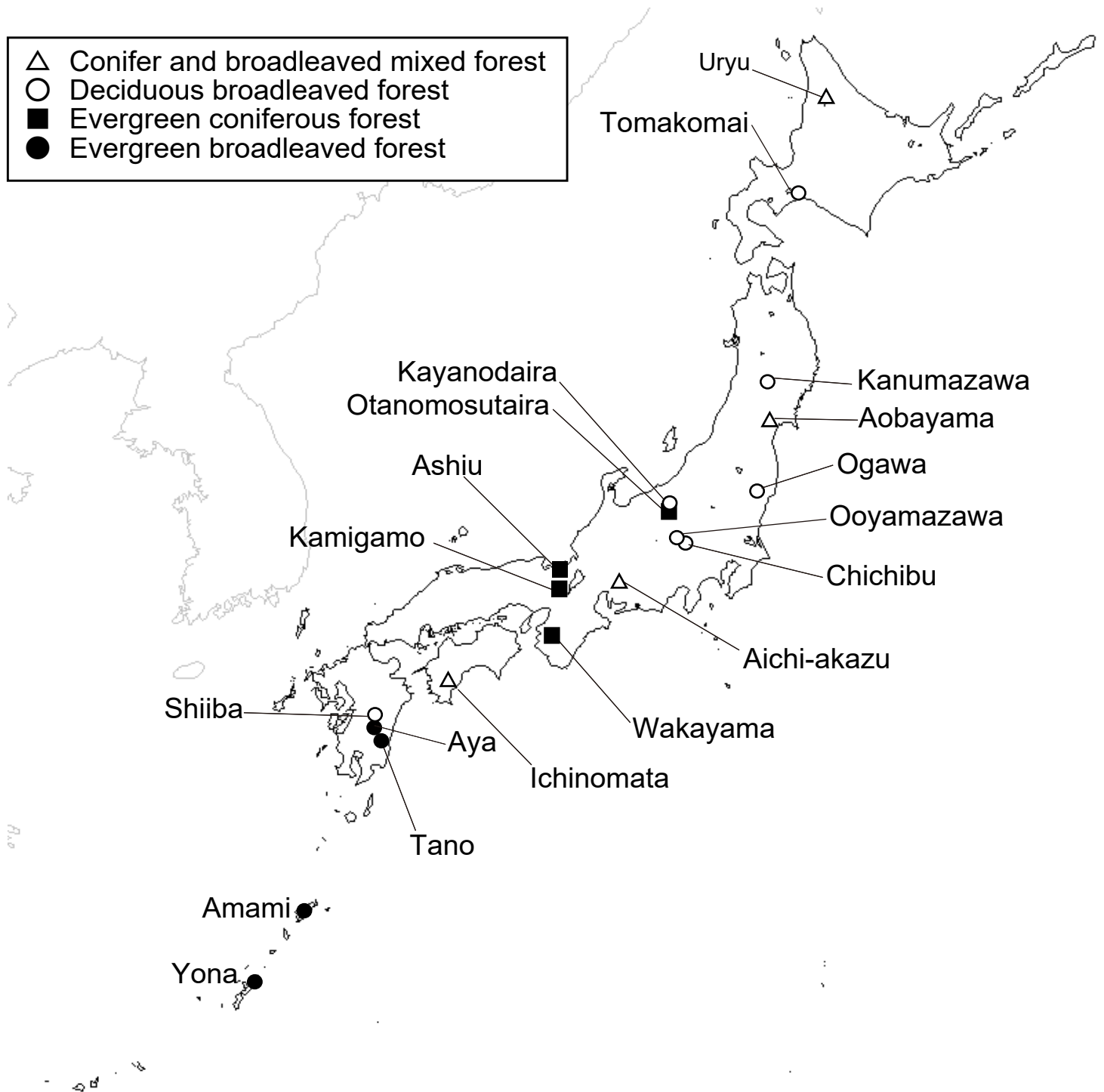
453 Figure 3 Latitudinal gradient of insect herbivory in (a) *Quercus crispula* and (b) *Fagus*  
454 *crenata* in 2014 and 2015. Symbols represent the mean herbivory rate of each site.  
455 Lines indicate fitted lines from the prediction from linear mixed models.

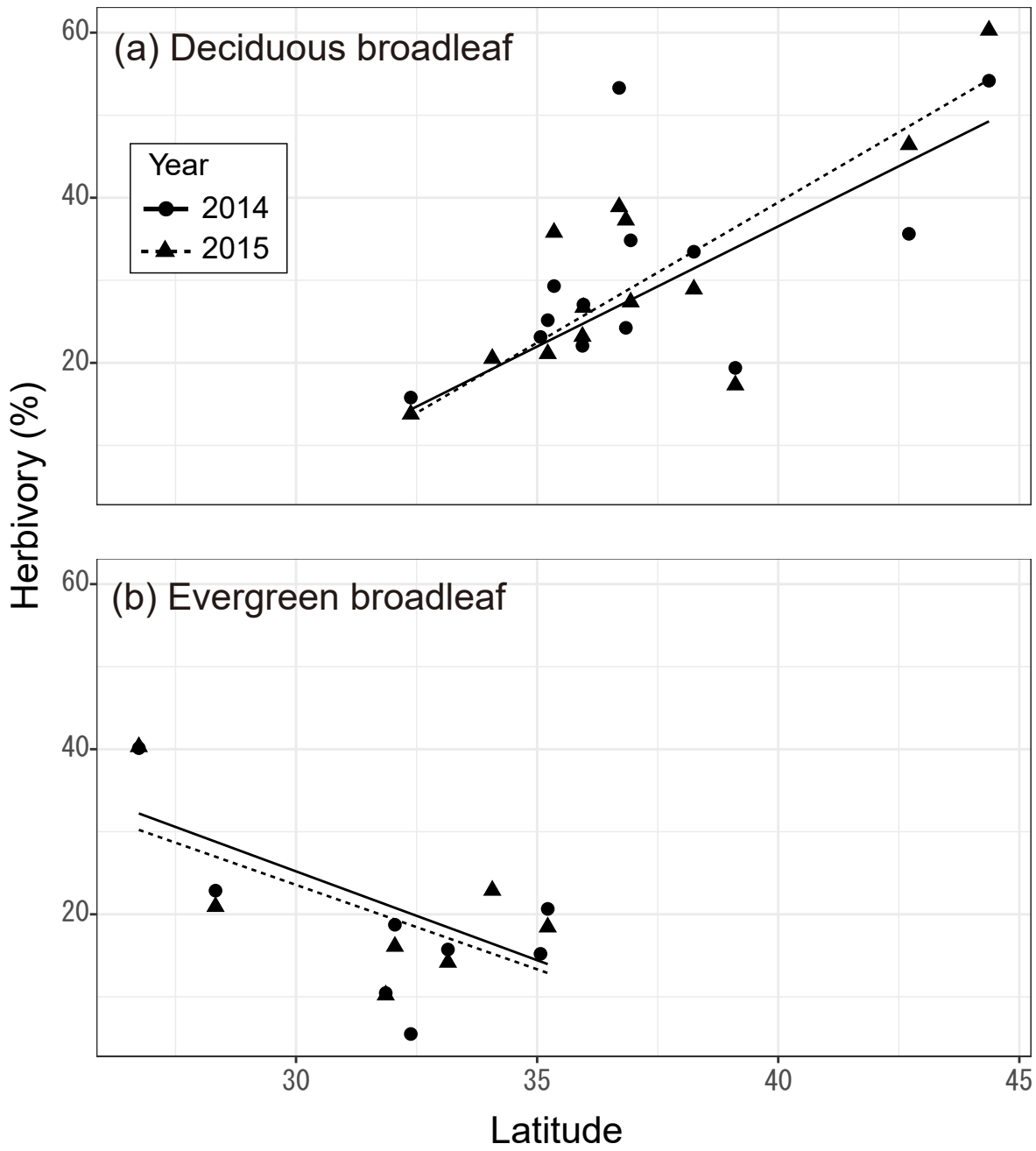
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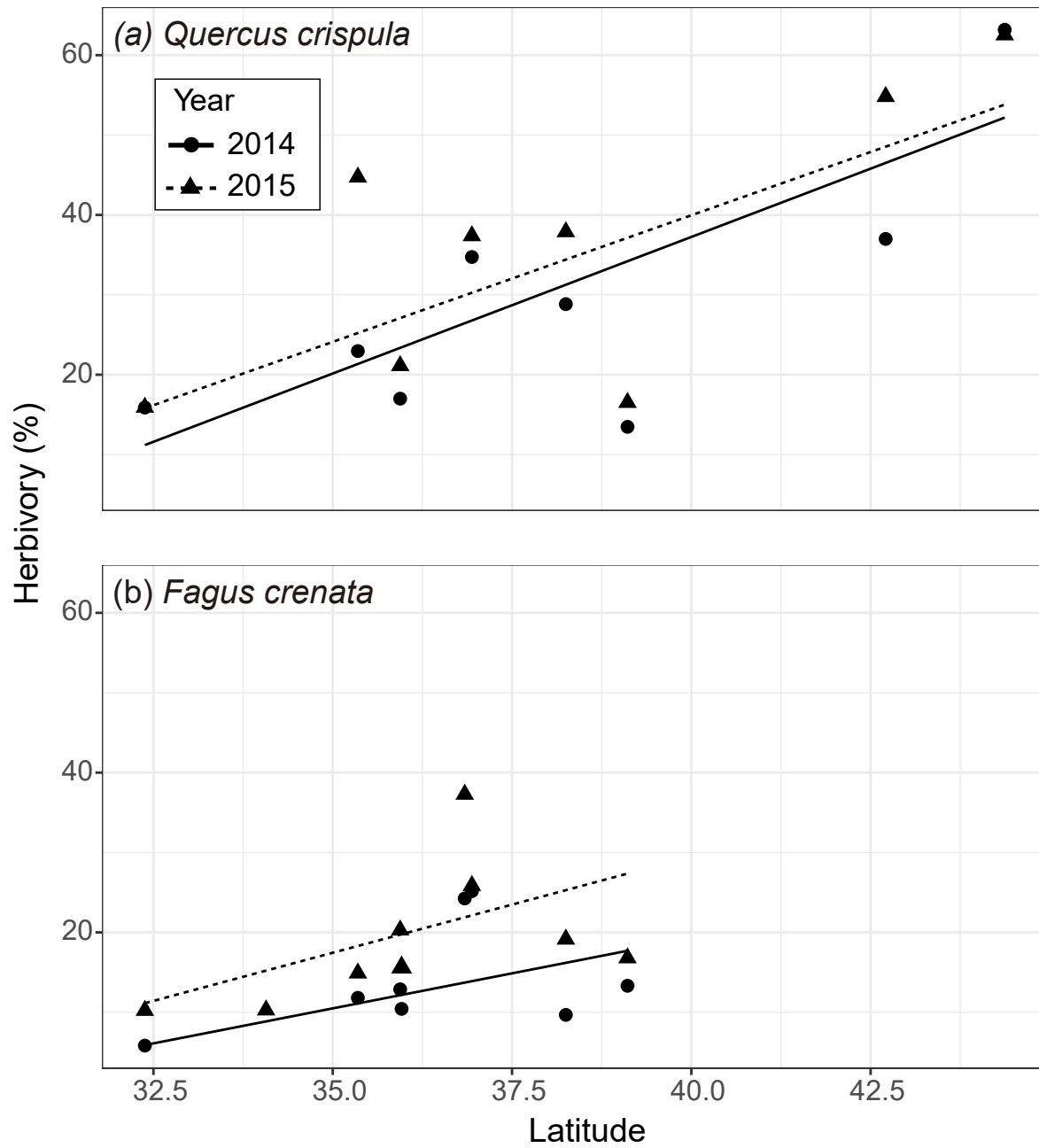


Table 1. Major climatic zones and biogeographic regions of the 19 sites. The blank cells indicate our study sites is not located on these climatic zones and biogeographic regions, although these distribute in Japan. "Rare" and "Not distributed" in the cell means that the combination of climatic zones and biogeographic regions is rarely or not distributed in Japan.

Biogeographic region	Climatic zone			
	Subalpine or subarctic	Cool temperate	Warm temperate	Subtropical
Eastern Hokkaido Island		Uryu (UR)	<i>Not distributed</i>	<i>Not distributed</i>
Western Hokkaido Island		Tomakomai (TM)	<i>Not distributed</i>	<i>Not distributed</i>
The Pacific Ocean side of the Northern Honshu Island		Aobayama (AO) <sup>1</sup> Ogawa (OG) Chichibu (CC) Ooyamazawa (OY)		<i>Not distributed</i>
The Sea of Japan side of the Northern Honshu Island	Otanomosutaira (OT)	Kanumazawa (KM) Kayanodaira (KY)	<i>Rare</i>	<i>Not distributed</i>
Hokuriku and Sanin region		Ashiu (AU)	Kamigamo (KG)	<i>Not distributed</i>
The Pacific Ocean side of the Chubu region			Aichi-akazu (AI)	<i>Not distributed</i>
The Inland Sea	<i>Not distributed</i>	<i>Rare</i>		<i>Not distributed</i>
The Kii Peninsula, Shikoku and Kyushu Islands	<i>Rare</i>	Shiiba (SI)	Wakayama (WK) Ichinomata (IC) Aya (AY) Tano (TN)	<i>Not distributed</i>
The Amami and Ryukyu Islands	<i>Not distributed</i>	<i>Not distributed</i>	<i>Rare</i>	Amami (AM) Yona (YN)
The Bonin Islands	<i>Not distributed</i>	<i>Not distributed</i>	<i>Not distributed</i>	

<sup>1</sup> Sites located between the cool and warm temperate zones.

Table 2. The four months when these traps caught the largest amount of fallen leaves in each site. The visual measurement of leaf damage by leaf-chewing insects was applied to these leaves.

Site name	Abbreviated site name	Leaf collection period
Uryu	UR	August–November
Tomakomai	TM	August–November
Kanumazawa	KM	August–November
Aobayama	AO	September–December
Ogawa	OG	September–December
Kayanodaira	KY	August–November
Otanomousutaira	OT	July–November
Ooyamazawa	OY	August–November
Chichibu	CC	September–December
Ashiu	AU	August–November
Aichi-akazu	AI	October–January
Kamigamo	KG	October–January
Wakayama	WK	September–December
Ichinomata	IC	April–July
Shiiba	SI	September–January in 2014 (sampled year), September–December in 2015 (sampled year)
Aya	AY	April–July
Tano	TN	April–July
Amami	AM	March–June
Yona	YN	February–May

Table 3. The measured species in this study. Broadleaf tree species with a dominant ranking of five or species with a total of up to 50% of dominance and broad distributed species *Quercus crispula* and *Fagus crenata* were measured.

SiteName	Broadleaf tree species									
Uryu	<i>Betula ermanii</i>	<i>Quercus crispula</i>	<i>Acer mono</i>							
Tomakomai	<i>Cercidiphyllum japonicum</i>	<i>Ostrya japonica</i>	<i>Quercus crispula</i>	<i>Tilia japonica</i>	<i>Acer mono</i>					
Kanumazawa	<i>Cercidiphyllum japonicum</i>	<i>Fagus crenata</i>	<i>Quercus crispula</i>	<i>Pterocarya rhoifolia</i>	<i>Aesculus turbinata</i>					
Aobayama	<i>Fagus crenata</i>	<i>Quercus crispula</i>	<i>Quercus serrata</i>	<i>Idesia polycarpa</i>	<i>Prunus verecunda</i>					
Ogawa	<i>Castanea crenata</i>	<i>Fagus crenata</i>	<i>Fagus japonica</i>	<i>Quercus crispula</i>	<i>Quercus serrata</i>	<i>Acer mono</i>				
Kayanodaira	<i>Fagus crenata</i>									
Otanomosutaira	<i>Betula ermanii</i>	<i>Acer ukurunduense</i>								
Ooyamazawa	<i>Cercidiphyllum japonicum</i>	<i>Fagus crenata</i>	<i>Fraxinus platypoda</i>							
Chichibu	<i>Carpinus cordata</i>	<i>Fagus crenata</i>	<i>Fagus japonica</i>	<i>Quercus crispula</i>						
Ashiu	<i>Magnolia obvata</i>	<i>Betula grossa</i>	<i>Fagus crenata</i>	<i>Quercus crispula</i>	<i>Acer sieboldianum</i>					
Aichi-akazu	<i>Quercus serrata</i>	<i>Acer sieboldianum</i>	<i>Cleyera japonica</i>							
Kamigamo	<i>Castanopsis cuspidata</i>	<i>Clethra barbinervis</i>	<i>Ilex macropoda</i>	<i>Ilex pedunculosa</i>						
Wakayama	<i>Fagus crenata</i>	<i>Quercus acuta</i>	<i>Stewartia monadelphica</i>							
Ichinomata	<i>Quercus salicina</i>	<i>Cleyera japonica</i>								
Shiiba	<i>Illicium anisatum</i>	<i>Betula grossa</i>	<i>Carpinus laxiflora</i>	<i>Carpinus tschonoskii</i>	<i>Fagus crenata</i>	<i>Quercus crispula</i>	<i>Acer sieboldianum</i>	<i>Swida controversa</i>	<i>Kalopanax pictus</i>	<i>Acer rufinerve</i>
Aya	<i>Machilus thunbergii</i>	<i>Distylium racemosum</i>	<i>Quercus acuta</i>	<i>Quercus salicina</i>						
Tano	<i>Machilus thunbergii</i>	<i>Distylium racemosum</i>	<i>Castanopsis</i> spp. <sup>1</sup>	<i>Quercus salicina</i>						
Amami	<i>Castanopsis sieboldii</i> <i>subsp. lutchuensis</i>									
Yona	<i>Castanopsis sieboldii</i> <i>subsp. lutchuensis</i>	<i>Schima wallichii</i>								

<sup>1</sup> *Castanopsis sieboldii* and *Castanopsis cuspidata* were included.

Table 4. Results of generalized linear mixed-effect models for estimating the latitudinal gradient of insect herbivory of deciduous broadleaf species, evergreen broadleaf species, *Q. crispula*, and *F. crenata* in 2014 and 2015. Estimates of parameters, Chi-square value, and statistical significance (*P*-value) are given. The likelihood ratio test was used for the statistical significance.

Functional type/Species	Parameter	Estimate	Chi-square	<i>P</i> -value
Deciduous broadleaf	Latitude	2.91	35.03	<i>P</i> < 0.001
	Year	-16.66	76.29	<i>P</i> < 0.001
	Latitude*Year	0.49	69.22	<i>P</i> < 0.001
Evergreen broadleaf	Latitude	-2.15	4.82	<i>P</i> < 0.05
	Year	-4.84	25.98	<i>P</i> < 0.001
	Latitude*Year	0.11	0.58	0.45
<i>Quercus crispula</i>	Latitude	3.42	8.99	<i>P</i> < 0.01
	Year	12.69	5.92	<i>P</i> < 0.05
	Latitude*Year	-0.25	1.01	0.32
<i>Fagus crenata</i>	Latitude	1.75	2.91	0.09
	Year	-16.01	641.48	<i>P</i> < 0.001
	Latitude*Year	0.66	18.11	<i>P</i> < 0.001

Table S1. Detailed ecological information of each plot collected from study sites. Soil parameters, snow depth, and maximum canopy height collected from study sites. This information was described in Appendix of Ishihara et al. (2011), Suzuki et al. (2012), and Niwa et al. (2016). Plot ID indicates an alphanumeric code of each plot (see SiteList.csv and Ishihara et al. (2011)). Soil types based on the soil classification system of the Food and Agriculture Organization of the United Nations (FAO) (Dudal 1968), were extracted from the 1:200,000 scale soil map of the Land Classification Survey conducted by the Ministry of Land, Infrastructure, Transport and Tourism, Japan (<http://mrb-www.mlit.go.jp/kokjo/inspect/landclassification/download/index.html>, last accessed on March 13, 2020). In addition, soil types based on the Classification of Forest Soil in Japan (Forest Soil Division 1976) were also shown, which are according to related literatures and personal observations of researchers. 'NA' means data not available. See appendix 1 for details and references, and other ecological information.

Site name	PlotID	Soil type		Soil pH		Bedrock	Snow depth		Maximum canopy height	
		FAO	Forest Soil Division	Value	Reference		Value (m)	Reference	Value (m)	Reference
Uryu	UR-BC1	Humic Cambisols	Brown forest soil	3.9–4.5	Shibata <i>et al.</i> 2002	Andesite tuff-breccia	2	Shibata <i>et al.</i> 2002	28	Yoshida T. unpublished data
Tomakomai	TM-DB1	(Andic) Rhodosols	Shallow top soil	5.3–6.2	Shibata <i>et al.</i> 1998	Volcanic ejecta of 1–2 m depth	0.5	Shibata <i>et al.</i> 1998	26.5	Ishihara M. personal observation
Kanamazawa	KM-DB1	Residual Regosols	Gravel (large and sandy), brown forest soil <sup>1</sup>	5.2	-	Igneous rock (green tuff and others)	1.8	Suzuki <i>et al.</i> 2002	30	Suzuki <i>et al.</i> 2002
Aobayama	AO-BC1	Humic Cambisols	Brown forest soil <sup>2</sup>	NA	-	Aobayama formation on tuff <sup>3</sup>	0.1	-	20	Kobayashi K. personal observation
Ogawa	OG-DB1	Ochric Cambisols	Brown forest soil partly black or gley soil	4.7–6.2	Yoshinaga <i>et al.</i> 2002	Metamorphic rock, volcanic ejecta	0.5	Yoshinaga <i>et al.</i> 2002	About 35	Nakashizuka 2002
Kayanodaira	KY-DB1	Humic Cambisols	Brown forest soil	NA	Ida H. personal observation	Plateau originated from lava flow	3–4	Ida 2013	25	Watanabe 1994
Otanomousutaira	OT-EC1	Humo-Ferric (Gleyic) Podzols	Wet humus podzolic partly dry podzolic or moderately moist brown forest soil	3.8–4.5	Takai <i>et al.</i> 1976	Deposition of andesite and volcanic mudflow	2	Ida H. personal observation	22	Kuroiwa and Watanabe 1997
Ooyamazawa	OY-DB1	Humo-Ferric Podzols	Sand, gravel, rock	NA	Sakio 1997	Greywacke, sandstone	0.3	Sakio 1997	35	Sakio H. unpublished data
Chichibu	CC-DB1	Humic Cambisols	Moderately moist brown forest soil	NA	University Forest in Chichibu 2000	Sedimentary rock	0.2–0.3	Sawada <i>et al.</i> 2005	29	University Forest in Chichibu unpublished data
Ashiu	AU-EC1	Humic Cambisols	Brown forest soil	4.5	Ueda <i>et al.</i> 1993	Sandstone, slate, mudstone, shale, chert	2–3	Yamanaka <i>et al.</i> 1993	25	Kawanabe <i>et al.</i> 1994; Sakimoto M. personal observation
Aichi-akazu	AI-BC1	Humic Cambisols	Moderately moist brown forest soil	4.5–5.1	Moroto <i>et al.</i> 1987	Deeply weathered granite	0.101 <sup>4</sup>	University Forest in Aichi, the University of Tokyo unpublished data	20	Ariyakanon <i>et al.</i> 2000
Kamigamo	KG-EC1	Gleysols	Dry brown forest soil	NA	Tokuchi <i>et al.</i> 2002	Bedded chert with siliceous shale	Few <sup>5</sup>	-	20	Sakimoto M. personal observation
Wakayama	WK-EC1	Humic Cambisols	Moderately moist brown forest soil	4.8–4.9	Ueda <i>et al.</i> 1994	Sandstone, shale	0.3 <sup>6</sup>	-	25–30	Sakimoto M. personal observation
Ichinomata	IC-BC1	Humic Cambisols	Moderately moist to weakly dried brown forest soil, dry podzolic soil	3.6–5.1	Hirai <i>et al.</i> 2007	Sandstone, mudstone	0.15	Sakai T. personal observation	41	Sakai <i>et al.</i> 2006
Shiiba	SI-DB1	NA	Brown forest soil	4.97–5.29	Enoki T. personal observation	Granite	0.2	Hatsushima 1970	27	Enoki T. unpublished data
Aya	AY-EB1	Humic Cambisols	Dry, moderately moist, or moderately moist drier subtype brown forest soil	NA	Sato <i>et al.</i> 1999	Shale, sandstone, partly covered by pumice stone from volcanic eruption	0	Ohnuki <i>et al.</i> 1998; Sato <i>et al.</i> 1999	30	Saito and Sato 2007
Tano	TN-EB1	Andosols	Moderately moist brown soil	5.7	Takagi M. unpublished data	Shale	0	Endo 1958	25	Takagi M. unpublished data
Amami	AM-EB1	Humic Cambisols	Weakly dried to moderately moist yellow soil at the valley	NA	Ishida K. personal observation	Shale partly sandstone	0	Ishida K. personal observation	25	Kumamoto Forest Office and Japan Forest Technology Association 1997
Yona	YN-EB1	Helvic Acrisols	Weakly dried to moderately moist yellow soil	4.1–4.3	Yamamori <i>et al.</i> 1986	Sandstone and slate	0	Enoki 2003	20	Shinzato <i>et al.</i> 1986

<sup>1</sup> Cambic Red-Yellow soils (based on Japan Soil Inventory <https://soil-inventory.de.affrc.go.jp>), with boulders and gravels.

<sup>2</sup> Scale 1:50,000 Fundamental Land Classification Survey in Miyagi, Sendai, 1976.

<sup>3</sup> <http://www.biology.tohoku.ac.jp/garden/geology.htm>

<sup>4</sup> Average between 1966 and 1999.

<sup>5</sup> Few cm (Kamigamo Experimental Station, Kyoto University <http://fserc.kyoto-u.ac.jp/kami/>).

<sup>6</sup> Wakayama Forest Research Station, Kyoto University (<http://fserc.kyoto-u.ac.jp/waka/>).

<sup>7</sup> 27 m for *Abies firma* and 24 m for *Fagus crenata*.

## Appendix 1 Detailed information of each plot.

This material gives detailed information of each plot: forest age, disturbance history, soil type, soil pH, bedrock, snow depth, dwarf bamboo as understory vegetation, maximum canopy height, layout of the plot and subplots, remarks (optional), and acknowledgements (optional). This material includes information which was described in Appendix of Ishihara et al., (2011), Suzuki et al., (2012), and Niwa et al., (2016). Plot ID indicates an alphanumeric code of each plot (see SiteList.csv and Ishihara et al., (2011)). For definition of forest age classifications, see 7. A and Ishihara et al., (2011). Forest age or maximum tree age is the age in 2010 unless specified. Soil types based on the soil classification system of the Food and Agriculture Organization of the United Nations (FAO) (Dudal, 1968), were extracted from the 1:200,000 scale soil map of the Land Classification Survey conducted by the Ministry of Land, Infrastructure, Transport and Tourism, Japan (<http://nrb-www.mlit.go.jp/kokjo/inspect/landclassification/download/index.html>, last accessed on March 13, 2020). In addition, soil types based on the Classification of Forest Soil in Japan (Forest Soil Division, 1976) were also shown, which are according to related literatures and personal observations of researchers. 'NA' means data not available. References with \* are those conducted in the plot.

*Site name:* Uryu

*Plot ID:* UR-BC1

*Forest age:* OG.

*Disturbance:* No record of human disturbance (Yoshida T. personal communication).

*Soil type FAO:* Humic Cambisols.

*Soil type Forest Soil Division:* Brown forest soil (Shibata et al., 2002).

*Soil pH:* 3.9–4.5 (Ozawa, Shibata, Satoh, & Sasa 2001).

*Bedrock:* Andesite tuff-breccia (Shibata et al., 2002).

*Snow depth:* 2 m (Shibata et al., 2002).

*Dwarf bamboo as understory vegetation:* Understory is covered by dwarf bamboo (Yoshida T. personal observation).

*Maximum canopy height:* 28 m (Yoshida T. unpublished data).

*Plot & Subplots:* The shape of plot is 70×150 m. The direction of Y-axis is 71° west from true north.

*Remarks:* Croplands are 600 m northwest and 300 m southwest of the plot.

*Acknowledgements:* We thank the staff of Uryu Experimental Forests of Hokkaido University for the field work.

*Site name:* Tomakomai

*Plot ID:* TM-DB1

*Forest age:* OG. About 270–340 years old (Igarashi, 1987).

*Disturbance:* The forest regenerated after the volcanic eruption of Mt. Tarumae in 1669 and 1739 (Igarashi, 1987). The forest was disturbed by strong typhoons in 1954 (Mishima, Taniguchi, Taniguchi, & Hishinuma, 1958) and 2004.

*Soil type FAO:* (Andic) Rhogosols.

*Soil type Forest Soil Division:* Shallow top soil (Hiura et al., 1998\*).

*Soil pH:* 5.3–6.2 (Shibata, Kirikae, Tanaka, Sakuma, & Hatano, 1998).

*Bedrock:* Volcanic ejecta of 1–2 m depth (Igarashi, 1987).

*Snow depth:* 0.5 m (Hiura et al., 1998\*).

*Dwarf bamboo as understory vegetation:* Understory vegetation is partly dominated by *Sasamorpha borealis* (Hiura et al., 1998\*).

*Maximum canopy height:* 26.5 m (Ishihara M. personal observation).

*Plot & Subplots:* The 1-ha plot is a part of a 9-ha permanent plot. The direction of Y-axis is 31° west from true north.

*Acknowledgements:* We thank the staff of Tomakomai Experimental Forests of Hokkaido University for the field work.

*Site name:* Kanumazawa

*Plot ID:* KM-DB1

*Forest age:* OG. Maximum tree age is about 1000 years old according to Suzuki, Osumi, Masaki, Takahashi, Daimaru, & Hoshizaki (2002\*).

*Disturbance:* Canopy gaps and more infrequent, debris flows. No sign of human disturbance although selective cuttings were conducted at surrounding forests until 20–30 years ago (Masaki, Tanaka, Tanouchi, Sakai, & Nakashizuka, 1999\*; Suzuki et al., 2002\*).

*Soil type FAO:* Residual Regosols.

*Soil type Forest Soil Division:* Cambic Red-Yellow soils (based on Japan Soil Inventory <https://soil-inventory.dc.affrc.go.jp>), with boulders and gravels; brown forest soil (Masaki et al., 1999\*).

*Soil pH:* 5.2.

*Bedrock:* Igneous rock (green tuff and others).

*Snow depth:* 1.8 m (Suzuki et al., 2002\*).

*Dwarf bamboo as understory vegetation:* *S. kurilensis* and *S. palmata* are distributed widely but dominant only patchily. Instead, evergreen shrub (*Camellia japonica* var. *decumbens*), tall herbs (e.g. genera *Laportea*, *Elatostema* and *Petasites*) and ferns (genera *Polystichum*, *Dyopteris* and *Arachniodes*) dominate the understory layer (Hoshizaki, Suzuki, & Sasaki, 1997\*).



*Maximum canopy height:* 30 m (Suzuki et al., 2002\*).

*Plot & Subplots:* The 1-ha plot is a part of a 4.71-ha permanent plot. The direction of Y-axis is 11° east from true north.

*Remarks:* A stream flows in the plot. A road is 50 m east and 100 m northwest of the plot. Rivers are 250 m southeast and 400 m southwest of the plot.

*Acknowledgements:* We thank Wajirou Suzuki, Katsuhiro Osumi and Kazunori Takahashi for early setup of the plot; Ohta Kazuhide for soil descriptions.

*Site name:* Aobayama

*Plot ID:* AO-BC1

*Forest age:* OG.

*Disturbance:* Human usage of the forest has been restricted for the past 400 years (Suzuki Mitsuo personal communication).

*Soil type FAO:* Humic Cambisols.

*Soil type Forest Soil Division:* Brown forest soil (Scale 1:50,000 Fundamental Land Classification Survey in Miyagi, Sendai, 1976).

*Soil pH:* NA.

*Bedrock:* Aobayama formation on tuff (<http://www.biology.tohoku.ac.jp/garden/geology.htm>).

*Snow depth:* 0.1 m.

*Dwarf bamboo as understory vegetation:* Patchy distribution of *Sasa borealis* (Kobayashi K. personal observation).

*Maximum canopy height:* 20 m (Kobayashi K. personal observation).

*Plot & Subplots:* The direction of Y-axis is 18° west from true north.

*Remarks:* Grasslands and urban areas are 150 m north and southeast of the plot.

*Acknowledgements:* We thank Kadzutaka Kobayashi, Motonari Oyama for the field work.

*Site name:* Ogawa

*Plot ID:* OG-DB1

*Forest age:* OG.

*Disturbance:* Although the forest is an old-growth forest, human disturbances such as fire, grazing, and selective cutting took place until 1930s at surrounding forests. Remains of charcoal making were found around the plot (Masaki et al., 1999\*; Suzuki, 2002\*).

*Soil type FAO:* Ochric Cambisols.

*Soil type Forest Soil Division:* Brown forest soil partly black or gley soil (Masaki et al., 1999\*).

*Soil pH:* 4.7–6.2 (Yoshinaga, Takahashi, & Aizawa, 2002\*).

*Bedrock:* Metamorphic rock, volcanic ejecta (Yoshinaga et al., 2002\*).

*Snow depth:* 0.5 m (Masaki et al., 1999\*).

*Dwarf bamboo as understory vegetation:* Patchy distribution of *Sasamorpha borealis* and *Sasa nipponica* (Suzuki, 2002\*).

*Maximum canopy height:* About 35 m (Nakashizuka, 2002\*).

*Plot & Subplots:* The 1.2-ha (100×120 m) plot is a part of a 6-ha permanent plot (see Nakashizuka & Matsumoto, 2002). The direction of Y-axis is 100° west from true north.

*Remarks:* Grasslands and croplands are 400 m north and 500 m southwest of the plot.

*Acknowledgements:* Grants in support came from the Ministry of Agriculture, Forestry and Fishery, and the Ministry of Education, Science, Sports and Culture.

*Site name:* Kayanodaira

*Plot ID:* KY-DB1

*Forest age:* OG.

*Disturbance:* A light selective cutting probably occurred because remains of charcoal making were found around the plot (Watanabe, 1993; Ida, 2013).

*Soil type FAO:* Humic Cambisols.

*Soil type Forest Soil Division:* Brown forest soil (Ida H. personal observation).

*Soil pH:* NA.

*Bedrock:* Plateau originated from lava flow (Ida, 2013).

*Snow depth:* 3–4 m (Ida, 2013).

*Dwarf bamboo as understory vegetation:* Understory is dominated by 1.5 m high *Sasa kurilensis* and *Sasa senanensis* (Peters, Nakashizuka, & Ohkubo, 1992; Ida, 2013).

*Maximum canopy height:* 25 m (Watanabe, 1994).

*Plot & Subplots:* The direction of Y-axis is 97° west from true north. Subplots were slightly moved after the census in 2006.

*Remarks:* Grasslands and pastures are 100 m west and 350 m south of the plot.

*Site name:* Otanomosutaira

*Plot ID:* OT-EC1

*Forest age:* OG.

*Disturbance:* No record of human disturbance (Ida H. personal observation).

*Soil type FAO:* Humo-Ferric (Gleyic) Podzols.

*Soil type Forest Soil Division:* Wet humus podzolic partly dry podzolic or moderately moist brown forest soil (Takai, Kanazawa, Asami, Takeshima, & Kawashima, 1976).

*Soil pH:* 3.8–4.5 (Takai et al., 1976).

*Bedrock:* Deposition of andesite and volcanic mudflow (Takai et al., 1976).

*Snow depth*: 2 m (Ida H. personal observation).

*Dwarf bamboo as understory vegetation*: Understory is dominated by 1 m high *Sasa kurilensis* (Kuroiwa & Watanabe, 1997\*).

*Maximum canopy height*: 22 m (Kuroiwa & Watanabe, 1997\*).

*Plot & Subplots*: The direction of Y-axis is 3° west from true north.

*Remarks*: Grasslands, wetlands, ski slopes and a road are 600 m west to southwest of the plot.

*Site name*: Ooyamazawa

*Plot ID*: OY-DB1

*Forest age*: OG. 254-year-old tree was recorded in 1988 (Sakio, 1997\*).

*Disturbance*: *Fraxinus platypoda* established after a land slide caused by an earthquake in 1770 to 1790 (Sakio, 1997\*). No record of logging (Kubo, Sakio, Shimano, & Ohno, 2005\*).

*Soil type FAO*: Humo-Ferric Podzols.

*Soil type Forest Soil Division*: Sand, gravel, rock (Sakio, 1997\*).

*Soil pH*: NA.

*Bedrock*: Greywacke, sandstone (Sakio, 1997\*).

*Snow depth*: 0.3 m (Sakio, 1997\*).

*Dwarf bamboo as understory vegetation*: 2 m height *Sasamorpha borealis* dominates at slope (Sakio H. personal observation).

*Maximum canopy height*: 35 m (Sakio H. unpublished data).

*Plot & Subplots*: The direction of Y-axis is 116° west from true north.

*Remarks*: The plot includes a stream and was established in a riparian forest dominated by *Fraxinus platypoda*, *Pterocarya rhoifolia*, and *Cercidiphyllum japonicum* (Sakio, Kubo, Shimano, & Ohno 2002\*).

*Acknowledgements*: We thank Drs. Motohiro Kawanishi, Motoki Higa, and Masako Kubo for the field works of the research site. Thanks are also due to the members of Mori to Mizu no Genryu Bunkajuku for their various assistances.

*Site name*: Chichibu

*Plot ID*: CC-DB1

*Forest age*: OG.

*Disturbance*: No record of logging since the University forest was established in 1916.

*Soil type FAO*: Humic Cambisols.

*Soil type Forest Soil Division*: Moderately moist brown forest soil (University Forest in Chichibu, 2000).

*Soil pH*: NA.

*Bedrock*: Sedimentary rock (University Forest in Chichibu, 2000).

*Snow depth*: 0.2–0.3 m (Sawada, Ohkubo, Kaji, & Oomura, 2005\*).

*Dwarf bamboo as understory vegetation*: None.

*Maximum canopy height*: 29 m (University Forest in Chichibu unpublished data).

*Plot & Subplots*: The direction of Y-axis is true north.

*Remarks*: A river flows 350 m southwest of the plot.

*Acknowledgements*: We thank the staff of the University of Tokyo Chichibu Forest for the field work.

*Site name*: Ashiu

*Plot ID*: AU-EC1

*Forest age*: OG. 230-year-old tree was recorded in 1980 (Tamai & Tempo, 1990).

*Disturbance*: Since the establishment of Ashiu Experimental Forest in 1924, no human disturbance occurred (Yamanaka, Matumoto, Oshima, & Kawanabe, 1993). Mass mortality of Fagaceae trees by Japanese oak wilt has occurred since 2002.

*Soil type FAO*: Humic Cambisols.

*Soil type Forest Soil Division*: Brown forest soil (Ueda, Ando, & Kanzaki, 1993).

*Soil pH*: 4.5 (Ueda et al., 1993).

*Bedrock*: Sandstone, slate, mudstone, shale, chert (Ueda et al., 1993; Yamanaka, Matumoto, Oshima, & Kawanabe, 1993).

*Snow depth*: 2–3 m (Yamanaka et al., 1993).

*Dwarf bamboo as understory vegetation*: None since before severe herbivory by Sika deer occurred (Sakimoto M. personal observation).

*Maximum canopy height*: 25 m (Kawanabe, Ando, Sakai, & Wada, 1994; Sakimoto M. personal observation).

*Plot & Subplots*: The direction of Y-axis is 69° west from true north.

*Acknowledgements*: We thank the technical staff of Aisu Forest Station, Kyoto University for their work.

*Site name*: Aichi-akazu

*Plot ID*: AI-BC1

*Forest age*: S. Less than 100 years old (Shibano, 2000\*).

*Disturbance*: The forest established on the previously bare land due to fuel wood consumption (Shibano, 2000\*). *Chamaecyparis obtusa* trees were planted in 1917–1918 to prevent soil erosion. At present, the forest is composed of pine tree and broadleaf tree species that have naturally established. Mass mortality of pine trees by Pine wilt disease occurred in 1980s and late 2000s. In

2010 and 2011, many oak trees were attacked by ambrosia beetle *Platypus quercivorus*, which transport the pathogenic fungi *Raffaelea quercivora* causing Japanese oak wilt.

*Soil type FAO*: Humic Cambisols.

*Soil type Forest Soil Division*: Moderately moist brown forest soil (Moroto, Mashimo, & Haruta, 1987).

*Soil pH*: 4.5–5.1 (Moroto et al., 1987).

*Bedrock*: Deeply weathered granite (Moroto et al., 1987).

*Snow depth*: 0.101 m on average between 1966 and 1999 (University Forest in Aichi, the University of Tokyo unpublished data).

*Dwarf bamboo as understory vegetation*: None.

*Maximum canopy height*: 20 m (Ariyakanon, Numamoto, & Suzuki, 2000).

*Plot & Subplots*: The direction of Y-axis is true north. All subplots were relocated from outside to inside the plot after the census in 2004. Subplot 1, 3, 4 and 5 were moved several meters after the census in 2009.

*Remarks*: Roads are 100 m south and 200 m north of the plot. Open lands and some buildings are 200 m west of the plot.

*Acknowledgements*: We thank Haruo Sawada, Yukiko Kamata, Masaki Matsui, Takehiko Tsukamoto, Yoshihide Hara, Kenji Yanase, Nobuyo Mizuno, Dr. Hirofumi Shibano, Dr. Noriko Iwai, and Dr. Koichiro Kuraji for the field work.

*Site name*: Kamigamo

*Plot ID*: KG-EC1

*Forest age*: S. About 90 years old (Sakimoto, Morishita, & Sakanoue, 2009b\*).

*Disturbance*: After mass mortality of dominant pine trees by Pine wilt disease in 1970s, *Chamaecyparis obtusa* that formed the middle and lower layers have become dominant (Sakimoto M. unpublished data).

*Soil type FAO*: Gleysols.

*Soil type Forest Soil Division*: Dry brown forest soil (Tokuchi, Fujimaki, & Terai, 2002\*).

*Soil pH*: NA.

*Bedrock*: Bedded chert with siliceous shale (Kimura et al., 1998).

*Snow depth*: Few cm (Kamigamo Experimental Station, Kyoto University <http://fserc.kyoto-u.ac.jp/kami/>).

*Dwarf bamboo as understory vegetation*: None (Sakimoto M. personal observation).

*Maximum canopy height*: 20 m (Sakimoto M. personal observation).

*Plot & Subplots*: The shape of plot is 80×80 m. The direction of Y-axis is 180° east from true north.

*Remarks*: A grassland and a golf course are 50 m south and 500 m southwest of the plot, respectively.

Urban areas are 150 m north, east and south of the plot.

*Site name:* Wakayama

*Plot ID:* WK-EC1

*Forest age:* OS. About 100 years old (Sakimoto et al., 2009a\*).

*Disturbance:* Cut stumps created in 1920–1922 were found and the forest was used until the establishment of the University Forest in 1926 (Furuno, Uenishi, & Uenishi, 1986).

*Soil type FAO:* Humic Cambisols.

*Soil type Forest Soil Division:* Moderately moist brown forest soil (Ueda., Ando, & Takeuchi, 1994).

*Soil pH:* 4.8–4.9 (Ueda et al., 1994).

*Bedrock:* Sandstone, shale (Toda et al., 2000).

*Snow depth:* 0.3 m (Wakayama Forest Research Station, Kyoto University  
<http://fserc.kyoto-u.ac.jp/waka/>).

*Dwarf bamboo as understory vegetation:* None (Sakimoto M. personal observation).

*Maximum canopy height:* 25–30 m (Sakimoto M. personal observation).

*Plot & Subplots:* The direction of Y-axis is 30° east from true north.

*Site name:* Ichinomata

*Plot ID:* IC-BC1

*Forest age:* OG. Maximum tree age is about 300 years old (Sakai T. unpublished data).

*Disturbance:* *Chamaecyparis obtusa* trees were cut selectively in 1985–1986 at the ridge (Sakai, Sakai, Kuramoto, & Sato, 2006\*; Sakai T. personal communication).

*Soil type FAO:* Humic Cambisols.

*Soil type Forest Soil Division:* Moderately moist to weakly dried brown forest soil, dry podzolic soil (Hirai, Kaneko, & Takahashi, 2007\*).

*Soil pH:* 3.6–5.1 (Hirai et al., 2007\*).

*Bedrock:* Sandstone, mudstone (Sakai et al., 2006\*).

*Snow depth:* 0.15 m (Sakai T. personal observation).

*Dwarf bamboo as understory vegetation:* None (Sakai T. personal observation).

*Maximum canopy height:* 41 m (Sakai et al., 2006\*).

*Plot & Subplots:* The direction of Y-axis is 142° west from true north.

*Remarks:* A road is 450 m east of the plot.

*Acknowledgements:* We thank Tatsuro Kawasaki, Ryuichi Tabuchi and Atsushi Sakai for setup and maintenance of the research site. Thanks are also due to the members of Shikoku Research Center, Forestry and Forest Products Research Institute for their various assistances.

*Site name:* Shiiba

*Plot ID:* SI-DB1

*Forest age:* OS.

*Disturbance:* No record of logging since the establishment of University Forest at about 70 years ago.

No cut stump can be found although large trees are scarce (Enoki T. personal observation).

*Soil type:* Brown forest soil (Enoki T. personal observation).

*Soil pH:* 4.97–5.29 (Shibata H. unpublished data).

*Bedrock:* Granite (Hatsushima, 1970).

*Snow depth:* 0.2 m (Enoki T. unpublished data).

*Dwarf bamboo as understory vegetation:* *Sasamorpha borealis* dominates (Murata et al., 2009; Saruki, Inoue, Shiba, Nagasawa, Osaki, & Kubota, 2004).

*Maximum canopy height:* 27 m for *Abies firma* and 24 m for *Fagus crenata* (Enoki T. unpublished data).

*Plot & Subplots:* The shape of plot is 100×100 m.

*Acknowledgements:* We thank technical staff of the Shiiba Research Forest for the field work.

*Site name:* Aya

*Plot ID:* AY-EB1

*Forest age:* OG.

*Disturbance:* No record of human disturbance (Tanouchi and Yamamoto, 1995\*). The forest experienced typhoon disturbance in 1993, 2004 and 2005 (Saito and Sato, 2007\*).

*Soil type FAO:* Humic Cambisols.

*Soil type Forest Soil Division:* Dry, moderately moist, or moderately moist drier subtype brown forest soil (Sato et al., 1999\*).

*Soil pH:* NA.

*Bedrock:* Shale, sandstone, partly covered by pumice stone from volcanic eruption (Ohnuki, Sato, Fujimoto, & Inagaki 1998\*; Sato et al., 1999\*).

*Snow depth:* 0 m (Masaki et al., 1999\*).

*Dwarf bamboo as understory vegetation:* None (Saito S. personal observation).

*Maximum canopy height:* 30 m (Saito and Sato, 2007\*).

*Plot & Subplots:* The 1-ha plot is a part of a 4-ha permanent plot. The direction of Y-axis is 166° west from true north.

*Remarks:* A road and a river are 450 m northeast of the plot.

*Acknowledgements:* We thank Masahiro Kiyofuji, Dai Sugimoto, Mikiyo Hatomura, Yoshimi Narimatsu and the member of Kyushu Research Center, Forestry and Forest Products Research Institute for their various assistances.

*Site name:* Tano

*Plot ID:* TN-EB1

*Forest age:* S. 87 years old (Kubota and Takagi, 2007\*).

*Disturbance:* The forest regenerated in 1924 (Kubota and Takagi, 2007\*).

*Soil type FAO:* Andosols.

*Soil type Forest Soil Division:* Moderately moist brown soil (Takagi M. unpublished data).

*Soil pH:* 5.7 (Takagi M. unpublished data).

*Bedrock:* Shale (Endo, 1958).

*Snow depth:* 0 m (Takagi M. personal observation).

*Dwarf bamboo as understory vegetation:* None (Takagi M. personal observation).

*Maximum canopy height:* 25 m (Takagi M. unpublished data).

*Plot & Subplots:* The direction of Y-axis is 6° east from true north.

*Acknowledgements:* We thank the staff of University of Miyazaki Tano Forest Science Station for the field work. We also thank Machiko Kuroki for processing litter trap samples.

*Site name:* Amami

*Plot ID:* AM-EB1

*Forest age:* OS. About 140 years old.

*Disturbance:* Remains of charcoal making were found in the plot. Protected from human disturbance for 100 years as a reserve (Ishida, Kawaguchi, Torikai, Takashi, & Kawaguchi, 2008).

*Soil type FAO:* Humic Cambisols.

*Soil type Forest Soil Division:* Weakly dried to moderately moist yellow soil at the valley (Ishida K. personal observation).

*Soil pH:* NA.

*Bedrock:* Shale partly sandstone (Ishida K. personal observation).

*Snow depth:* None (Ishida K. personal observation).

*Dwarf bamboo as understory vegetation:* None (Ishida K. personal observation).

*Maximum canopy height:* 20 m (Kumamoto Forest Office and Japan Forest Technology Association, 1997).

*Plot & Subplots:* The direction of Y-axis is 175° east from true north. Subplots were slightly moved after the first pitfall trapping in 2005.

*Acknowledgements:* We thank Hidemi Kawaguchi and the member of Amami Ecosystem Study Group.

*Site name:* Yona



*Plot ID:* YN-EB1

*Forest age:* OS.

*Disturbance:* Human disturbance such as selective cutting occurred until 1950s (Enoki, 2003\*; Saito, 2011).

*Soil type FAO:* Helvic Acrisols.

*Soil type Forest Soil Division:* Weakly dried to moderately moist yellow soil (Yamamori, Hirata, Aramoto, Sunakawa, & Asato 1986).

*Soil pH:* 4.1–4.3 (Yamamori et al., 1986).

*Bedrock:* Sandstone and slate (Enoki, 2003\*).

*Snow depth:* 0 m.

*Dwarf bamboo as understory vegetation:* *Pleioblastus linearis* distributed at ridges (Takashima A. personal observation).

*Maximum canopy height:* 20 m (Shinzato, Taba, Hirata, & Yamamori, 1986).

*Plot & Subplots:* The direction of Y-axis is 40° west from true north.

*Acknowledgements:* We thank Takanori Kinjo and the staff of Yona field Subtropical Field Science Center, Faculty of Agriculture, University of the Ryukyus.

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