Geobotany Studies
Basics, Methods and Case Studies

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Phytosociology of the Beech (Fagus) Forests in East Asia

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Preface

The beeches (genus *Fagus*, with a dozen of species) are widespread elements in the woody flora of the northern hemisphere. In the mountain vegetation, beech woodlands occupy the upper belt of compact deciduous forests, so that, at more elevated altitudes only the evergreen needle-lived forests of boreal conifers occur. At the boundary between deciduous and evergreen forest, the beech forests can be observed on Mt. Fuji, in the mountains of China, in Caucasus, and in the Alps. The only exception are the north American species of beech (*F. grandifolia*) growing in the plains, under cold climate, together with other deciduous trees, mainly maple. These mountain forests of the northern hemisphere have a counterpart in the *Nothofagus* forests of Patagonia and New Zealand, which look very similar (as to aspect and ecology) although recent results demonstrate that *Fagus* and *Nothofagus* evolved independently from one another.

The beech forest was clearly perceived from botanists and foresters as a distinct vegetation form, because of the compact structure of the canopy. This vegetation was clearly described still in the nineteen century, from the most relevant phytogeographers, in Germany, Switzerland and Austria. The first concept of the beech forest, as an essential biological and ecological unit of plant life in the mountains, is expressed in several publications of B. Pawlowski (prof. in Krakow, Poland), who in 1928 described the alliance Fagion sylvaticae and order Fagetalia based on the beech forests of the Tatra mountains (Carpathians): the presence of these coenological units was successively confirmed on all mountain systems of Central and Southern Europe, from the Pyrenées to the Alps, Balkans and Apennines, until the Mediterranean islands Corsica and Sicily. Independently from these developments, in the years 1949–1954, Tokio Suzuki described in Japan the beech forests with *Fagus crenata*. The successive travels and field investigations by R. Tüxen in Japan (in the 1960s) allowed the possibility to compare the parallel adaptations (and the differences) between these important forest systems in Europe and Japan.

During the following years, several Japanese scientists visited Europe (in particular A. Miyawaki) and scientists from Europe had the possibility to be introduced to the study of the vegetation of Japan (for the writer of these lines, the first experience was during the memorable International Excursion of 1974). The following discussions and exchange of experiences (in many papers, meetings and in the

field) led to the persuasion that the beech forests on both extremities of Eurasia had similar composition and ecology. From this background, develops the personal experience of prof. T. Hukusima, the first Author of this book, who in the period 1980–1990 elaborated a synthesis of beech forests in Japan and successively carried out many research periods investigating directly in the field the beech forests of Europe, SW-Asia and N-America, and in particular with excursions in different countries of E-Asia (Korea, continental China, Taiwan). These field investigations had a focal point when both Hukusima and myself had the possibility, at the beginning of November 2003, to investigate the habitat of the rare *Fagus mexicana*, growing in a remote chain of the Sierra Madre Oriental.

It has been necessary as shown above to briefly summarize the long historical development, which lead to the origin of this book. It was realized with the collaboration of leading scientists from different East-Asiatic countries, the following elaboration of data and discussion of the results were carried out successively, during repeated stages of prof. T. Hukusima in the Botanical Garden of the Rome University. This study gives, for the first time, the possibility to have a general outlook on the different aspects of the beech forests in East Asia, from Hokkaido to Taiwan and from the coasts of the Pacific Ocean to the easternmost chains of the Himalayan system. This large synthesis gives a general information on over 50 different types of beech forests, distributed in two vegetation classes with 22 types of forest communities. Over 1,500 species of the forest flora of East Asia (trees, shrubs, herbs, mosses) are reported. In this way, it is shown clearly the extraordinary biodiversity concentrated in the deciduous forests of the East-Asiatic mountains. From this synthesis, it is also possibly to propose a hypothesis on the evolution of the beech forests, based on the central role played by the mountain systems of SW China (Yunnan) as an ancient centre of origin for botanical groups: many of them in the following eras spread over most of the boreal hemisphere and presently are an essential component of the flora in the temperate and cold zone of Eurasia.

Sandro Pignatti

Acknowledgements

This study was possible because it is based on the previous studies performed by many senior researchers and associate researchers. Especially, it would not have been possible for us to understand Chinese beech forests, without the previous pioneer work performed by Wang, Z.X. of College of Resources and Environmental Science, Hubei University, former Prof. Dr. Kazue Fujiwara of Yokohama National University and her colleagues. We here express our respect and gratitude for their precise research results. We are also grateful to our colleagues, Hiroyuki Takasuna, Yutaka Tsunetomi and Yutaka Kyan. This study was partly funded by the Global Environmental Research of Japan (S-8) program, the Ministry of the Environment. Lastly we wish to dedicate this work to our mutual masters, the late Prof. Dr. Tokio Suzuki and the late Prof. Dr. Hyoji Suzuki, both of them contributed greatly to the development of vegetation science in Japan. This research was partly supported by the Environment Research and Technology Development Fund (S-8) of the Ministry of the Environment, Japan.

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Phytosociology of the Beech (*Fagus*) Forests in East Asia

1

1.1 Introduction

The beech (genus *Fagus*) is often the dominant species in forests in many locations and is an extremely important species to local ecosystems. In East Asia, forests including species of *Fagus* form, in a phytogeografical vision, an extended forest belt in the zone with temperate climate, that lies between the evergreen broad-leaved forests spreading out across the lower latitudes of the tropics and the evergreen coniferous trees (boreal forests) of the northern latitudes. This can be also considered, in an altitudinal vision, as a horizontal forest belt that also lies between those two forest types in a vertical sense. In general, beech forests occur in areas with oceanic climate (at least moderately) and avoid conditions of elevate continentality. Because of their location, East Asian forests containing species of the genus *Fagus* can help clarify, through a comparative study of East Asian vegetation, the characteristics of beech forests in the Northern Hemisphere (Eurasia and North America) as well as play a crucial role in providing an understanding of East Asian vegetation, thus making the beech a key vegetation type.

In addition, although the distribution of the species is wide, beech forests share their temperate zone habitat with man and in many locations suffer a good deal of disturbance from human activity. At present, they continue to represent a valuable resource, providing both material for human habitations and pasturage for stock. However, severe over-usage has caused a rapid reduction in beech forests in many areas. East Asia is no exception.

In such an environment, it is extremely important to precisely record the characteristics of beech forests. Since the 1950s, vegetation studies using phytosociological procedures have been carried out in each country in East Asia, and the floristic compositional characteristics of the beech forests distributed over each country have been clarified. However, in terms of study range, these studies were focused mainly within each individual country, and until now only limited comparative research has been undertaken. Therefore, there has been little overall study of the homogeneity or heterogeneity of Asian beech forests as a whole. The present

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advance in the accumulation of data for the study of *Fagus* dominated forests in each country provides a more comprehensive range from which the compositional characteristics of the beech forests in East Asia, as a whole, can now be determined.

In this study, we compared the known data on East Asian forests that include species of the genus *Fagus* with new data that we obtained from the areas where little previous research had been conducted. Through this comparison, we aimed to define the phytosociological characteristics of the beech forests in E-Asia, assess the forests phytosociologically, and systematically classify the plant communities therein.

1.2 *Fagus* Species and Associated Forests in East Asia

East Asia forms the core area of the worldwide distribution of species of the genus *Fagus*, Many species of *Fagus* are distributed across this region (Fig. 1.1). Two species of *Fagus*, (*Fagus crenata* Blume and *F. japonica* Max.) are distributed over Japan, although, generally, when the ranges of these species overlap, *F. japonica* tends to be found at lower elevations than *F. crenata*. Differences can be seen in both their range and ecological adaptations. *F. crenata* is single-trunked, and seldom coppice; however, the *F. japonica* is sparse-leaved, multi-trunked and coppice vigorously, but is short-lived. *F. crenata* ranges from about 31° 30′N to 42° 45′N, covering an area that stretches from Mt. Takakuma in Kagoshima Prefecture in southern Kyushu, across Kyushu, Shikoku and Honshu, to the southern area of Hokkaido. *F. japonica* ranges from approximately 32°N in Miyazaki Prefecture in Kyushu, over Kyushu and Shikoku, to 40°N of Honshu (Ishizuka et al. 1992), but with the exception of the Chugoku region, it is not found along the Japan Sea side of the country. This species is seldom dominant and it tends to be distributed along the Pacific Ocean side of Japan, where it often forms forests with *Abies firma*, *Tsuga sieboldii*, *F. crenata* and *Quercus mongolica* var. *grosseserrata*.

Fagus multinervis Nakai is found in Korea. However, this species is not distributed over the Korean Peninsula, but is restricted to Ulleungdo, an island 140 km to the east of the Korean Pensinsula in the Japan Sea (130° 50′E, 37° 30′N). This is a small volcanic island, with a land area of 73 km^2, known to have erupted around 9,300 years ago. The highest point on the island is Seonginbong Peak (983 m), which occupies one corner of the outer rim of the volcano. The beech trees coppice, and resemble *F. japonica* in shape. The form of the leaf is also similar to that of *F. japonica*, but the cupules and form of the seeds are different from those of *F. multinervis*, being generally larger. The trees are distributed above an elevation of 350 m, and are dominant across large areas. Because steep slopes dominate the island's topography, many valleys are formed, and beech forests range almost to the bottom of the gorges, although no ravine forests, such as found in Japan, are present. The island is located at the meeting point of warm and cold ocean currents, and there are foggy conditions throughout the year. The yearly average humidity is

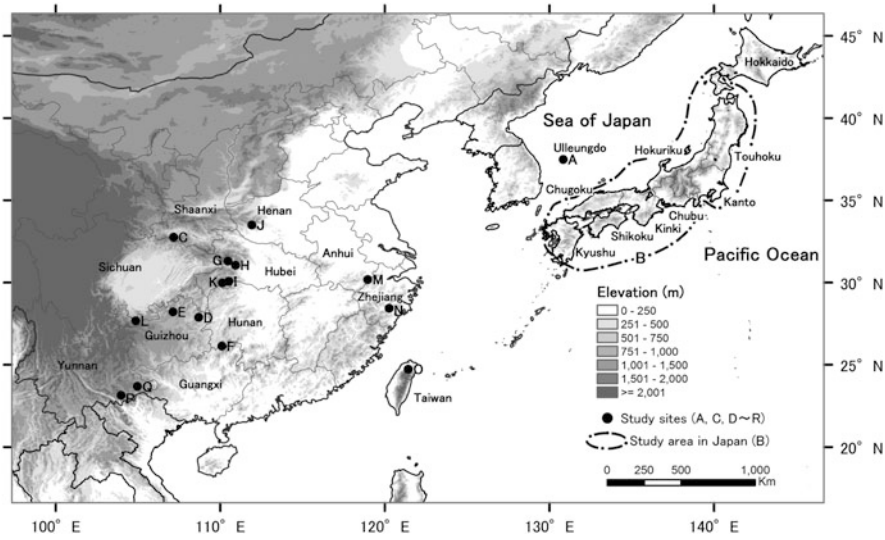

Fig. 1.1 Study site locations (A to Q) and geographical features of the study area. Note that the site B is in the areas enclosed by the *dashed-dotted line* in Japan

high at 74 %. Reflecting this environment, hygrophilous pteridophytes are dominant on the beech forest floor.

Fagus hayatae Palib. ex Hayata has been reported in Taiwan, which is located between approximately 22°N and 26°N and lies only approximately 200 km southeast of mainland China. This species is small-leaved and bears small seeds and cupules. The trees are limited to the summits of the individual peaks in the mountainous region in the north of Taiwan. The area is in the subtropical zone and many evergreens grow among the beech forests. Since most of the island has a subtropical Pacific monsoon climate, evergreen broadleaved forests dominate the greater part of the island. Reflecting the high yearly average humidity, many ferns, bryophytes and epiphytes are found on the trunks of the beech forests; however, the forest floor is predominantly covered with schulab scrub bamboo, which is particular to the island, and there is much growth of hygrophilous pteridophytes.

In China, species of the genus *Fagus* are found in the South and South Central regions, south of the Yellow River and east of the Henduang mountain range, from approximately 23°to 34°N, particularly in Sichuan, Yunnan, Guizhou, Hunan, Hubei, Henan, Jiangxi and Zhejiang provinces. However, as the forests are limited to the higher areas of the mountain peaks, their distribution is eminently discontinuous.

Nine species of beech have been reported in China. Of the nine, the geographical distribution of the following four species (the last of them occurring in one subspecies and one variety) is clear: (a) *Fagus longipetiolata* Seem., (b) *F. engleriana* Seem., (c) *F. lucida* Rehd. et Wils. and (d) *Fagus hayatae* Palib. ex

Hayata (including *Fagus hayatae* ssp. *pashanica* C.C.Yang as well as *Fagus hayatae* var. *zhejiangensis* M.C.Liu *et* M.H.Wu).

(a) *F. longipetiolata* has the largest distribution range among the representative species, ranging from south of the Yangtze River (30°N) to Fujian Province, and from the southwest Qinling mountains to Yunnan Province and the mountain ranges surrounding Sichuan Province.
(b) *F. lucida* is distributed between 30°N and 24°N, south of the main Yangtze River valley, and across Hubei, Guizhou, Yunnan and Sichuan provinces.
(c) *F. engleriana* is distributed from 33.5°N to 27.5°N over the southeast Qinling mountains, the mountain ranges bordering Sichuan, Hubei, and Guizhou provinces, and the mountainous districts of western Sichuan.
(d) *F. hayatae ssp. pashanica* C.C.Yang is distributed broadly over Sichuan Province and the mountains bordering Shaanxi Province.

There are large overlaps among these three widely distributed species, although, south to north, they are found in the following sequence: *F. longipetiolata*, *F. lucida*, *F. engleriana*, with *F. hayatae* ssp. *pashanica* C.C.Yang also found in the northernmost areas. One feature of the Chinese beech forests is the vigorous growth of evergreen flora, with most forests consisting of a mixture of a wide variety of evergreen species. The presence of evergreen arboreal, shrubby and herbaceous species increases from the north to the south with evergreen pteridophytes becoming abundant on the inferior vegetation layers of the forest. This phenomenon is remarkably similar to that seen in *F. hayatae* forests in Taiwan. In addition, other species are described: *F. clavata* Y.T.Chang, *F. brevipetiolata* Hu, *F. bijiensis* C.F. Wei *et* Y.T. Chang, *F. tientaiensis* Liou and *F. cheinii* Cheng but their ranges are not clear. The taxonomical analysis of the genus *Fagus* in China at the species level is presently still incomplete and in need of further investigations.

The beech forests of East Asia share the same strong connection between the dominant species of the genus *Fagus* and several species of *Acer* . This is a common condition also in the beech forests in Europe, the Near and Middle East, and North America (Suzuki 1966). A characteristic feature of the *Fagus* forest floors in East Asia is the strong growth of scrub bamboos such as species belonging to genera *Sasa*, *Sasamorpha*, *Sinarundinaria*, *Indosasa*, *Qiongzhea*, *Sinocalamus*, *Indocalamus* together with *Yushania nitakayamensis*. Scrub bamboos are not present in the *Fagus* forests of Europe and of North America, indeed other genera of bamboos (e.g. *Chusquea*) are widespread in the *Nothofagus* forests of South America (in the mountain ranges of Chile and Argentina).

In terms of species composition and vegetation structure, the beech forests of Japan and Ulleungdo Island (belonging to South Korea) are predominantly deciduous (Suzuki 1949a, b, 1952, 1966; Miyawaki et al. 1964, 1968; Sasaki 1964, 1970). In contrast, species of the genus *Fagus* in China and Taiwan grow alongside evergreens, with the evergreens representing a large proportion of the forest composition (Suzuki 1954; Wang and Fujiwara 2003; Hukusima et al. 2005; Wang et al. 2005). In their compositional structures, therefore, the East Asia beech forests clearly differ from those of Europe, the Near and Middle East, and North America. Further on, differences in species composition and structure are

likely to exist also between the various types of forest communities, each of them with the dominance of one among the four *Fagus* species (a – b – c – d), because of the high diversity in the phytogeographical elements distributed over the different regions of East Asia.

1.3 Methods for Structuring the Vegetation Analysis

As a general rule in structuring these association tables, we used the phytosociological method. Data analysis was carried out on vegetation relevés from the different forests in East Asia (China, Japan, Korea, Taiwan) in which species of the genus *Fagus* were dominant.

A large number of relevés is available for Japan. In this area, two species of the genus *Fagus* occur: *F. crenata* and *F. japonica*. With regard to the *F. crenata* forests, those of each individual region have been investigated from the mid-twentieth century, and many associations, based on differing concepts were described. Different criteria for the classification of the *F. crenata* forest plant communities have been proposed (Suzuki 1949a, b, 1952, 1966; Miyawaki et al. 1964, 1968; Sasaki 1964, 1970). With the aim of consolidating these many associations, Hukusima et al. (1995) put together existing data with that obtained by the authors to create a synoptic table using 2,717 relevès, with the synthesis of all existing data for the forest plant communities with dominance of *F. crenata* in Japan. As a result, this conspicuous amount of data was arranged into one order, with two alliances and five associations. This structure gave consideration to and consolidated all the previous plant community concepts and syntaxonomical tentatives. In the present comparative study, we used the data of Hukusima et al. (1995) for the forests of Japan, in which *F. crenata* is dominant. However, there are considerably more data available from Japan than from other countries; therefore, for the Japanese data used in this analysis, the relevès that best demonstrated the compositional, ecological and distributional characteristics of that particular association were selected and extracted from the relevès for each association, leaving 425 relevès. On the other hand, the other *Fagus* species found across Japan is *F. japonica,* which occurs in several forests areas. We took the data for the *F. japonica* forests in Japan, as a whole, from Suzuki and Miyawaki (2001), together with data collected by the authors, and created an association table, which was then compared against the data for *F. crenata* forest plant communities from Hukusima et al. (1995). As a result, we found that *F. japonica* is rarely dominant in forests, together with species such as *Meliosma myriantha, Rhododendron semibarbatum, Fraxinus sieboldiana* and *Ainsliaea apiculata* often growing in the same community. There are some common species that appear in *F. japonica* forests with high constancy, but there are a few species which can be really be considered as character species for these plant communities. In addition, although *F. japonica* is sometimes the dominant species in the canopy layer, in the forests where *F. japonica* occurs, in general the presence of character species is limited and this vegetation appears scarcely autonomous because of the presence of many species belonging to other

forests classes such as the coniferous *Abies firma* forests or to the deciduous broad-leaved *Quercus* forests. Therefore, we extracted relevés with strong relations to *F. crenata* forests for comparison of species composition with the other beech forests. The results showed that in mixed stands, where *F. crenata* and *F. japonica* grow together, many lower units can be distinguished, with species differing quantitatively; however, these do not represent compositionally autonomous plant communities. In consequence, these mixed communities were considered as lower units and placed at the subassociation level of the *F. crenata* forest association.

In the Korean Peninsula or Jeju Island, both of which are in close proximity to Japan, no species belonging to the genus *Fagus* are present, although in mountain areas favourable ecological conditions would exist, at least in terms of elevation. In Korea, *F. multinervis* Nakiai is distributed only over the isolated Ulleungdo Island, located in the Sea of Japan, but under the Korean souverainity. Kim et al. (1986) and Kim (1988) previously undertook studies of the island and reported on its plant community with *Fagus* dominance. For the present analysis, we added the data collected by the authors to that of Kim et al. (1986) and Kim (1988) to obtain a total of 54 relevès for the association table.

As to the *Fagus* woodlands in China, Wang and Fujiwara (2003) published a synoptic table based on data collected in the beech forests such as *Fagus longipetiolata* Seem., *F. engleriana* Seem., *F. lucida* Rehd. et Wils. and *Fagus hayatae* ssp. *pashanica* C.C. Yang. The relevés were obtained from forest communities in southwest Hunan Province and the border of Hunan and Guangxi Province (Nanzan), Fanjingshan Nature Reserve and Kuankuoshui Nature Reserve in Guizhou Province, northwest Hunan Province, the Badagongshan Nature Reserve on the border of Hunan and Hubei Province; the Dalaoling forest station, Longmenhe forest station, and Houhe Nature Reserve in Hubei Province; the Baotianman Nature Reserve in Hunan Province, and the Sihaishan Nature Reserve and Qingliangfeng Nature Reserve in Zhejiang Province. Thereafter, Wang et al. (2005) reported on the plant communities and classification of forests with *F. lucida* and *F. engleriana* as dominant tree. An original vegetation survey table with a list of all species appearing, except for data from the Sihaishan Nature Reserve and Qingliangfeng Nature Reserve in Zhejiang Province, was included. In the present analysis, data for the two nature reserves in Zhejiang Province were taken directly from synoptic tables, while we prefer to use the original data from Wang et al. (2005) for all other areas. Where the study area of Wang et al. (2005) overlapped with that of the authors for the Fanjingshan Nature Reserve in Guizhou Province, however, we consolidated the data to create a larger association table. Relevés from the Sanjiangkou Nature reserve in the north of Yunnan Province, Wenshan and Xichou counties in the south of Yunnan Province, and Nanjiang country in the north of Sichuan Province, were all collected by the authors. Raw data from Yunnan Province are included in Wu et al. (1987), and although these data do not represent a complete species list, it does provide representative members of the species in each forest level. Consequently, we decided to include it in this analysis, because these data were very valuable for these areas, in which no other vegetation survey data

sets were available. We then reached a gross total of 108 Chinese relevès in the association table.

Because there were no data available for comparison, some of the authors visited Taiwan to undertake a study in cooperation with researchers from the Taiwan Forestry Research Institute. In this study we were able to obtain 23 relevès, distributed on all stands of the Taiwanese beech forests at Mt. Chulu, Mt. Peichatien, Mt. Lala and Mt. Tonshan. The results were published in Hukusima et al. (2005).

The present study, is based on the total of 657 relevés, partly collected in the field by the authors and partly from the literature. These relevés were then used to produce the general synoptic table, association tables and to select the character species at all syntaxonomical levels, from the vegetation classes to orders, alliances and associations.

1.4 Classification of the Plant Communities

All published data, as well as our original data have been assembled in association tables, and successively organized into synoptic tables. In the first elaboration, we closely examined the data contained in published or unpublished association tables, and corrected the data for plant communities presented therein to create synoptic tables for comparison. After this resorting, we created a general synoptic table with the synthesis for the entire plant communities including all types of the beech forests until now described for East Asia (Table 3.1a, 3.1b, 3.1c [Online]). Synoptic tables are the ideal vehicle to obtain the complete overview of all species connected with a given vegetation unit. However, it has a sense to give a complete list of all species only in the case that data derive from a small number of study units. When there are a large number of study units to consider, as in this case, the large number of species appearing only a few times (sporadic species) can become a problem. In this case, we listed only species with an incidence of 2 % or greater, whereas the merely occasional species were not more taken into consideration.

With regard to the identification of associations, we examined the units previously reported at the level of associations, and, respecting these previous results as far as possible, we created a new ordered list of the associations described in the literature. However, with regard to plant communities with different compositions, we closely examined the character species and consequently, we arrived to an improved definition for a number of associations. This method was successively used for the superior hierarchical levels of alliance, order and class. With regard to orders and above, we basically used the same method as that used to study associations and alliances; however, we also undertook a comparison with adjacent orders and classes reported from each study area.

From the analysis of the climatic conditions (Table 3.5), it results that, in the beech forests the differences in temperature conditions are quite significant between the different classes of vegetation, whereas differences in precipitation are more

important in the definition of the growth activity of the forests, at the order and alliance level.

The analysis of the species composition, genus composition, life form composition and the examination of the relationships between the classified vegetation units and climatic conditions overall elucidate the clear differences in characters of the proposed vegetation classes of beech forests in East Asia. Moreover, the classified orders and alliances show, for the most of the case, clear differences and unique characters in terms of species, genus and life form compositions. On the other hand, associations and subassociations show characters which are distinctive only within a much smaller context. The two last associations (No. 21–22) are differing in many characters and belong to a still incompletely defined vegetation class. These results are all suggesting that, when vegetation units are compared, the evaluation of species composition (raw data) is the most important procedure at the association and subassociation level, whereas the analysis of genus and life form composition, such as similarity and dissimilarity (meta-data), are important for the classification at the order or class level.

The comparisons at genus-level show that the combinations of genera are most informative feature for a distinction among the classes. The differences are most accentuated between Ulleungdo Island in Korea and Japan, which have a prevailing proportion of deciduous genera; the same can be observed in a comparison between the beech forests of China and Taiwan, which have higher proportions of evergreen genera. The same tendency was also found at the level of the five orders. However, at alliance level, distinct genera became less obvious, and furthermore, at association and subassociation level, no important differences at the genus level were found.

For the comparison of the floristic composition of the different phytosociological units, Table 3.1 is fundamental. Indeed, the consultation of this table is very difficult, because of his unusually large dimensions (over 1,500 rows by more than 50 columns). For this reason, Table 3.1 was divided into Table 3.1a (Korea and Japan) and 3.1b (China and Taiwan); a general outlook is possible in Table 3.1c (On line) where the presences III, IV and V (40–100 %) are indicated with a black square and presences 1–39 % with a point. Alphabetical lists of the species as well as a taxonomical outlook of the flora of the East Asiatic beech forests are given in the Appendix 1 and Appendix 2.

Syntaxonomy of the East Asiatic *Fagus* Forests

2

2.1 Introductory Notes

Table 3.1 is a synoptic table of the forests dominated by the genus *Fagus* in East Asia. According to Table 3.1, the phytosociological system of beech forests in East Asia was classified as in Table 3.9 and the distribution map of the classified classes, orders, alliances and associations was depicted as Fig. 2.1. In Table 3.1, 68 species categorized as the species group 49 are the common species occurring in the beech forests in East Asia, although there is a regional bias. Many of the 68 species are character species of beech forests in each region.

Species constantly found in the beech forests in Ulleungdo Island are: *Dryopteris crassirhizoma*, *D. fortunei* var. *radicans*, *Disporum sessile*, and *Viola selkirkii*.

Commonly found in the beech forests both in Taiwan and Japan are: *Viburnum furcataum*, *Rhus ambigua*, *Ardisia japonica*, *Parathelypteris japonica*.

Species distributed in China, Taiwan and Japan, but not in Ulleungdo Island are: *Hydrangea paniculata*, *Sorbus alnifolia*, *Oxalis griffithii*, *Acer mono*, *Athyrium wardii*, *Clethra barbinervis*, *Ilex macropoda*, *Lindera umbellata*, *Cornus kousa*, *Vaccicinium japonicum*. Moreover, these species are highly frequent in the *F. crenata* forests in Japan.

Common species in the beech forests in China and Taiwan are: *Daphniphyllum macropodum*, *Ardisia crenata*, *Cleyera japonica*, *Maesea japonica*, *Plagiogyria euphlebia*, *Skimmia reevesiana*, *Peracarpa carnosa*, *Symplocos sumuntia*, *Smilax lanceofolia* var. *opaca*. There are many evergreen, broad-leaved species. Moreover, *Daphniphyllum macropodum* and *Ardisia crenata* in Japan are growing in the evergreen, broad-leaved forests rather than in the beech forests.

In the synoptic table (Table 3.1c), it is possible to have an outlook on the classification of the beech forests in East Asia into 51 vegetation units. Each of the units was compared with each of the vegetation unit that have been proposed in the published literature, with regards to the similarities of the species composition. As a result of this comparison, we were able to organize the phytosociological

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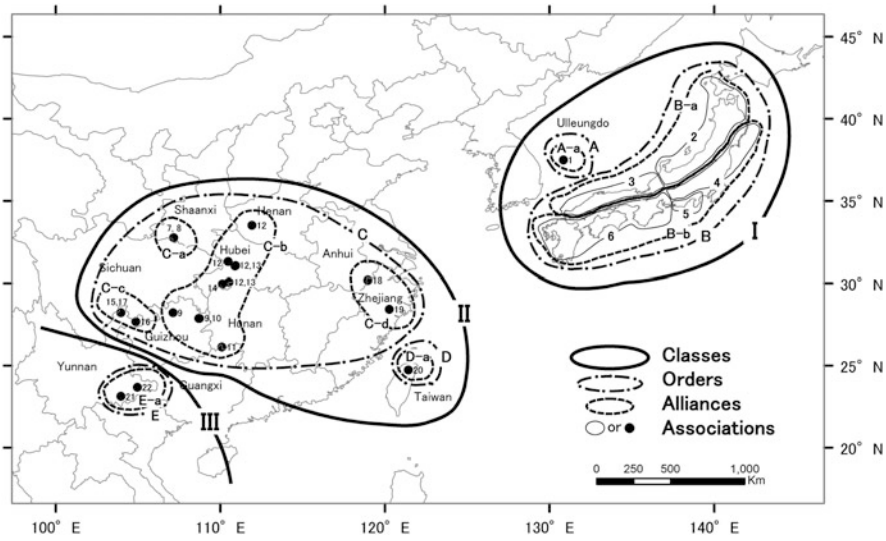

Fig. 2.1 Distributions of classes, orders, alliances and associations for the beech forests in East Asia

classification, including new vegetation units (Table 3.9, Fig. 2.1). For the East Asian forests with dominance in the tree layer of species of the genus *Fagus*, it was possible to organize the classification of the plant communities in the following syntaxonomical treatment.

The first vegetation class (Fagetea crenatae) includes all beech forests recognized in Japan and on the Korean Ulleungdo Island, associations no. 1–6, distributed among 2 orders and 3 alliances.

The second vegetation class (Litseo elongatae-Fagetea) includes the beech forests with prevalence of deciduous species, recognized in China: associations 7–20, distributed among 2 orders and 4 alliances.

The third vegetation class is still incompletely known (and consequently still unnamed); it includes the beech forests with prevalence of evergreen species, recognized in South China: associations 21–22, belonging to 1 order and 1 alliance. In the following chapters, all these vegetation units are described and discussed.

2.2 I. Fagetea crenatae (Miyawaki et al. 1964) (Run. No. 1–27)

Character species: *Hydrangea petiolaris*, *Schizophragma hydrangeoides*, *Sorbus commixta*, *Disporum smilacinum*, *Kalopanax pictus*, *Viburnum wrightii*, *Trillium smallii*, *Tripterospermum japonicum*, *Smilax nipponica*, *Styrax obassia*, *Mitchella undulata*, *Maianthemum dilatatum*.

This class was described for the beech forests of Japan by Miyawaki et al. in 1964. As a result of our revision, it becomes clear to be confirmed that all Japanese

F. crenata forests and *F. multinervis* forests on Ulleungdo Island, Korea, fit into this class. In addition, the composition of the forests distributed over Jeju Island, the Korean Peninsula and northeastern China, where species of *Fagus* are not present, was reported instead to be with *Quercus mongolica* as dominant tree. A comparison of the forest composition of the *Q. mongolica* forests of Jeju Island (Yun et al. 2008), reveals the presence of many common species, suggesting those forests could be included in this class. Song (1988) defined this class as *Quercetea mongolicae* (Song 1988) from a study of the Korean conifer-broad-leaved mixed forests, and this was supported by Takeda et al. (1994). On the other hand, in the similar *Quercus mongolica* forests in North Korea, Kolbek et al. (2003) revised the concept of the Querco-Fagetea crenatae (Miyawaki et al. 1968) proposed by Miyawaki et al. (1968). In northeast China, Wang et al. (2006) recognizes Quercetea mongolicae (Song 1988). Wang et al. (2006) also defined Querco mongolicae-Betuletea davuricae (Wang et al. 2006) as a new independent class. A comparison of the reports by Kolbek et al. (2003) and Wang et al. (2006) with the association tables for beech forests presented in this study shows that many species not found in *Fagus* classes, such as *Quercus mongolica*, *Vitis amurensis*, *Carex nanella*, *Lespedeza bicolor*, *Pinus koraiensis*, *Philadelphus schrenkii*, *Tilia amurensis*, *Maackia amurensis*, *Athyrium crenatum*, *Artemisia keiskeana*, *Deutzia glabrata*, *Rhododendron mucronulatum*, and *Polygonatum involucratum*, are common and are present at characteristically high constancies. Furthermore, there are many species that are not distributed in beech forests, indicating that the compositional differences are large. Hence, this class can be judged to be a distinct class. However, an interesting point to note is that where *Quercus mongolica* var. *grosseserrata* forests (Hoshino 1998; Suzuki 2002) come into contact with beech forests at lower elevations in Japan, many species common to the *Quercus mongolica* forests are found. To explain these relations, it is necessary to examine not only current climatic factors but also historical factors dating from the Quaternary period.

As to the floristic composition, it has to be pointed out that the proportion of deciduous flora is high, and that of evergreen broad-leaved flora is extremely low in this class. This represents a major difference between the characteristics of this class and the Litseo elongatae-Fagetea sp. div.cl. nov. class seen in beech forests in China and Taiwan.

This class includes two orders: Fagetalia multinervis (Kim et al. 1986) (*F. multinervis* order) defined by Kim et al. (1986) on Ulleungdo Island (Korea) and Saso Fagetalia crenatae (Suzuki 1966) (*Fagus-Sasa* order) in Japan defined by Suzuki (1966). Many of the character species of this order are common to the two abovementioned orders; however, *Tripterospermum japonicum*, *Euonymus alatus* fo. *ciliato-dentatus*, *Smilax nipponica*, *Styrax obassia*, *Mitchella undulata*, *Maianthemum dilatatum*, *Asperula odorata*, *Polystichum retroso-paleaceum* and *Viola kusanoana* are limited to the beech forests distributed on Ulleungdo Island and in Japan on the Japan Sea side of Honshu Island, and are extremely rare on the Pacific Ocean side of Japan, suggesting that Ulleungdo Island and the Japan Sea side of Japan were historically closely connected.

Fig. 2.2 Landscape of *Fagus multinervis* forests on Ulleungdo Island, Korea. The beech forests grow at an elevation of 300 m or above

2.2.1 A. Fagetalia multinervis (Kim et al. 1986) (Run. No. 1–5)

Character species: *Acer okamotoana*, *Acer takesimense*, *Prunus takesimensis*, *Asperula odorata* (=*Galium odoratum*), *Arisaema amurense*, *Polystichum retroso-paleaceum*, *Viola kusanoana*, *Solidago virga-aurea* var. *gigantea*, *Ligustrum foliosum*, *Dystaenia takesimana*, *Aster glehnii*, *Athyrium brevifrons*.

Ulleungdo Island is located in the Sea of Japan, ca. 100 miles off the coast of the Korean peninsula and at a larger distance from the western coast of Hondo. On Ulleungdo, the coastal areas below an elevation of approximately 50 m is covered of evergreen broad-leaved forest with dominant *Persea thunbergii*, whereas the habitats at higher elevation are covered with a deciduous broad-leaved forest (Fig. 2.2). The order Fagetalia multinervis includes all the units in the deciduous broad-leaved forests distributed on Ulleungdo and it was already named as the upper units of the *F. multinervis* forest association by Kim et al. (1986). Further on, there is no beech forest plant community on the Korean Peninsula that can be included in this order. Hepatico-Fagion multinervis (Kim et al. 1986) is the only alliance belonging to this order.

A-a. Hepatico-Fagion multinervis (Kim et al. 1986) (Run. no. 1–5)

Character species: The character species are the same as those of the order.

This alliance was defined by Kim et al. (1986). According to the authors' data, the Dystaenio takeshimanae-Aceretum okamotoanae prov. association, where *Hovenia dulcis*, *Cornus brachypoda*, *Acer takesimense*, *Zelkova serrata*, *Aralia cordata*, *Osmorhiza aristata* and *Cyrtomium fortunei* are indicated as character species, is distributed at the lower elevation areas of Ulleungdo Island from 50 to 350 m above sea level. This alliance includes this association (which has not the character of a beech forest) and the Hepatico-Fagetum multinervis (Kim et al. 1986), widespread on higher altitude (350–820 m).

1. Hepatico-Fagetum multinervis (Kim et al. 1986) (Run. no. 1–5)

Character species: *Fagus multinervis*, *Hepatica maxima*, *Allium victorialis* var. *platyphyllum*, *Tilia insularis*, *Botrychium multifidum* var. *robustum*, *Lilium hansonii*, *Viola hondoensis*, *Taxus cuspidata*, *Ulmus laciniata*.

Fig. 2.3 Inner view of *Fagus multinervis* forest on the middle slope (Ulleungdo Island, Korea). The beech forms multiple trunks. The understory is dominated by herbs and ferns such as *Rumohra standishii* with *Hepatica maxima*, *Allium victorialis* var. *platyphyllum* and *Maianthemum dilatatum*

Type relevé: Kim et al. (1986), Tab. 1, Relevé reference number 17 (Elevation 820 m, Ulleungdo).

This association was recorded and named by Kim et al. (1986) on Ulleungdo Island (Figs. 2.3, 2.4 and 2.5). Even the relevés published in Kim (1988) were carried out on this island. The climate of Ulleungdo is warm and humid. The annual mean temperature of 11.5 °C at 357 m elevation (corresponding to 8 °C at 1,000 m, but the island has not such elevate mountains) is relatively high in comparison with temperatures of the beech forests in Japan (Table 3.4); rainfall is relatively low (1,371 mm), indeed the elevate atmospheric humidity is maintained by the isolated location in the middle of the sea. The beech forests distributed on the highlands above an elevation of 350 m have been little impacted by humans, and remain in a predominantly natural state.

The Hepatico-Fagetum multinervis is characterized by the abovementioned character species with *Fagus multinervis*, *Hepatica maxima* and *Tilia insularis*, all endemic to the island. In addition, although they are not character species, *Dystaenia takesimana*, *Acer okamotoana*, *Ligustrum foliosum* and *Prunus takesimensis* are also endemic to Ulleungdo, indicating the high endemicity of the flora in this island.

Pteridophytes, such as *Rumohra standishii*, *Polystichum tripteron* and *Polystichum retroso-paleaceum*, which are character species in Japanese ravine forests, are predominant on the forest floors in this association. This confirms that this island experiences a warm, wet, typical oceanic climate. Kim et al. (1986) sorted this association into the *Rumohra standishii* subass. (Running number. 1), *Sasa kurilensis* subass. (Run. no. 2), typical subass. (Run. no. 3) and *Rhododendron brachycarpum* subass. (Run. no. 4), with Kim (1988) later recognizing the same subassociations. Our addition of new data obtained by the authors to the previous data published by Kim et al. (1986) and Kim (1988) resulted in the recognition of an additional subassociation: *Celtis jessoensis* subass. (Run. no. 5).

The structural characteristics of this association include the dominance of deciduous species such as *Fagus multinervis*, *Acer okamotoana* and *A. takesimense*

Fig. 2.4 *Fagus multinervis* forest growing on the gentle upper slope and the ridge (Ulleungdo Island, Korea). *S. kurilensis* often dominates the shrub layer of *F. crenata* forests in Japan, on the Sea of Japan side. Both of the forest physiognomy look similar

Fig. 2.5 Leaves of *Fagus multinervis* Nakai of Ulleungdo Island. Its leaves are similar to the leaves of the Japanese beech *Fagus japonica* Maxim.; however, *Fagus multinervis* has larger cupules and no hairs on the inferior side of leaves

in the canopy layer, with herbaceous species such as *Allium victorialis* var. *platyphyllum*, *Hepatica maxima* and *Maianthemum dilatatum* and pteridophytes such as *Rumohra standishii*, *Polystichum tripteron* and *Polystichum retrosopaleaceum* forming the forest floor. Evergreen trees and shrubs have a reduced presence (1–3 %). Very significant is the high presence of geophytes with rhizomes (30 %) or with bulbs (4 %), the highest values in the beech forests of East Asia. Very diffused are also the perennial herbs (hemicryptophytes) with a total of over 33 % and climbers (12.5 %).

2.2.2 B. Saso-Fagetalia (Suzuki 1966) (Run. No. 6–27)

Character species: *Fagus crenata*, *Acanthopanax sciadophylloides*, *Magnolia obovata*, *Fraxinus lanuginosa*, *Quercus mongolica*. var. *grosseserrata*, *Skimmia japonica* var. *intermedia f. repens*, *Acer rufinerve*, *Tilia japonica*, *Acer sieboldianum*, *Acer micranthum*, *Paris tetraphylla*, *Smilacina japonica*, *Acer*

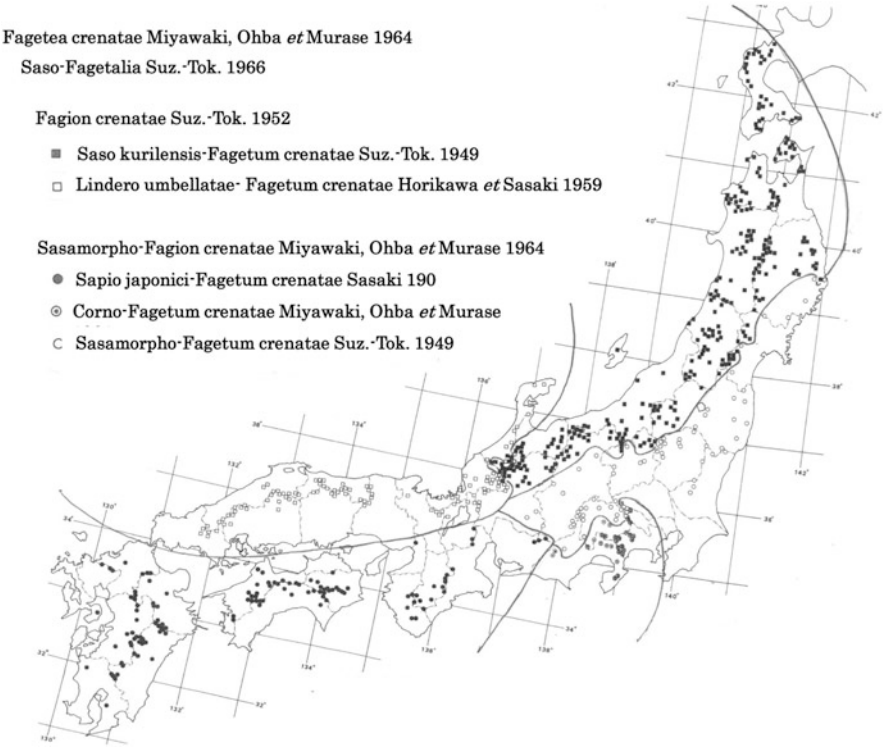

Fig. 2.6 Distribution map of the five beech forest associations in Japan

japonicum, *Dryopteris sabaei*, *Carex dolichostachya* var. *glaberrima*, *Prunus grayana*, *Corylus sieboldiana*, *Sasa senanensis*, *Betula grossa*, *Symplocos coreana*, *Acer shirasawanum*, *Carpinus japonica*, *Stewartia pseudo-camellia*.

This order was named by Suzuki (1966). It is characterized by the above species; however, *Symplocos coreana*, *Lindera umbellata*, *Acer shirasawanum*, *Carpinus japonica* and *Stewartia pseudo-camellia* are not distributed in the association Saso kurilensis-Fagetum crenatae (Suzuki 1949). This order includes the *F. crenata* forests and parts of the *F. japonica* forests distributed over the mountain zone in Japan (Fig. 2.6), and it comes into contact at higher elevations with communities belonging to the order Abieti-Piceetalia (Miyawaki et al. 1968), a part of class, Vaccinio-Piceetea (Braun-Blanquet et al. 1939), which is distributed over the highlands (Braun-Blanquet et al. 1939). However, the species composition of Saso-Fagetalia has not much in common with the character species of the order, Abieti-Piceetalia.

On the other hand, at lower elevations it comes into contact with Quercetalia serratae-grosseserratae (Miyawaki et al. 1971), and to the north with forests of the order Carpino cordatae-Quercetum grosseserratae (Takeda et al. 1983), where species of the genus *Quercus* are dominant. These forests are sometimes impacted