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Article

# Richness, Climatic Position, and Biogeographic Potential of East Asian Laurophyll Forests, with Particular Reference to Examples from Taiwan[1)]

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# 東アジアの照葉樹林の豊富性，気候的位置づけおよび生物地理学的潜在性—とくに台湾を例として[1)]

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**Synopsis**

Laurophyll forests are extra-tropical evergreen broad-leaved forests such as those which are especially well developed in humid warm-temperate to subtropical areas of East Asia and some equivalent but smaller areas on other continents. There are two main types: true laurel forests dominated by Lauraceae and forests dominated by evergreen Fagaceae, which in East Asia also have a mesomorphic, laurophyll character. Laurophyll forests are also known for their taxonomic richness, which is seen well in some mature laurophyll forests of more protected areas in the steep mountains of central Taiwan. Taxonomic richness and biogeographic affinities are described at species, genus and family levels. The laurophyll forests of Taiwan are marginally subtropical, as distinguished from warm-temperate types lacking tropical taxa and tolerating more frost. Under global warming (without drying), weedy and other highly mobile species can be expected to migrate more rapidly than mature-forest species. This provides special problems for vegetation stability, but especially on islands and other dissected land areas. The regeneration potential of laurophyll forests appears good, however, suggesting that their potential areas could expand under global warming.

**Keywords**: East Asian biogeography, evergreen Fagaceae forest, humid subtropical zone, laurel forest, laurophyll forest, regeneration potential, southern China, Taiwan, taxonomic richness, vegetation response to global warming, warm-temperate zone

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## Introduction

East Asia contains the world's largest region of extra-tropical evergreen broad-leaved forests, often known as "laurel forests" because of the importance and often the dominance of trees from the laurel family, Lauraceae. Such trees generally have intermediate-sized, dark green (shade-tolerant), thin-coriaceous but mesomorphic leaves which are especially characteristic of evergreen Lauraceae and were thus called 'Lorbeerblätter' (e. g. Rübel 1930) or laurophylls (e. g. Klötzli 1988; Box 1996, 1997). Since these leaves are somewhat glossy, they have also been called lucidophylls (Kira 1969, 1977, 1991). Forests dominated by laurophyll trees are rather dark and somber, with low light levels below the canopy, and are typically evergreen from top to bottom.

The term laurophyll forest is used in this paper because laurophyll forests are generally of two main types, those dominated by Lauraceae (i. e. true "laurel forests") and those dominated by laurophyll Fagaceae, mainly the genus *Castanopsis* but also *Lithocarpus* (*Pasania*) and evergreen *Quercus* (*Cyclobalanopsis*). Both types occur throughout the warm-temperate and humid subtropical zones of East Asia, from coastal areas of northern Japan, through southern Japan and the south tip of Korea, to Taiwan and large areas of southeastern and southwestern China (e. g. Suzuki 1952, 1953; Liu and Yang 1961; Wang 1961; Wu 1980; Fujiwara 1981-86). Similar laurophyll forests also occur in montane belts in subtropical and tropical mountains as far south as Indonesia and Malaysia (e. g. Whitmore 1975, Klötzli 1984, Chen et al. 1986, Fujiwara 1986). Comparable laurophyll forests also occur in equivalent climatic situations on other continents, including southern Brazil, scattered areas of eastern Australia and southeastern Africa (mainly montane belts), topogenically moist patches in the southeastern USA, and in cool-maritime New Zealand, Tasmania, and Southern Chile (e. g. Ovington 1983, Hübl 1988, Klötzli 1988, Box 1997, Tagawa 1997).

At the time our relevés were made in Taiwan and China (1985-88), laurophyll forests were not widely recognized outside East Asia as a basic biome type, nor had symposia on laurophyll forests been held or detailed studies been published. Basic description was an important objective. Although some descriptions were published (Box et al. 1989, 1991a, 1991b), other commitments conspired to prevent earlier publication of the material from Taiwan (as well as from the Yunnan Plateau and from Korea). The Taiwan relevés are thus used now to examine some remaining questions and to compare with results and hypotheses from some recent, more detailed research programs on laurophyll forests /(Hara and Yonebayashi 1997, Tagawa and Hotta 1997). Laurophyll forests, especially in East Asia, are known for their taxonomic richness. Since our material is insufficient for phytosociological analysis, the focus of this paper is on the structure, richness and biogeographic relations of some especially well developed laurophyll forest examples in Taiwan and adjacent southern China, as well as the climatic position and regeneration potential of East Asian laurophyll forests in general.

## Field Data

The data used herein include two good examples of mature, natural laurophyll forest from less accessible, rugged mountain areas of central Taiwan, as illustrated in Photos 1 and 2. Slopes can be quite steep, 20° or more, and may also harbor stands of the endemic conifer *Taiwania cryptomerioides* (Photo 3). The Taiwanese and Chinese laurophyll forests were described by standard Braun-Blanquet relevés, as documented by Fujiwara (1987). Each relevé represents an area of about 400-600 square meters. The particular stands studied include the following:

**Photo 1.** General appearance of natural Laurophyll forest (Central Taiwan).

**Photo 2.** Extensive Laurophyll forest on steep slopes in Central Taiwan
(Yu-Shan 玉山 Mountains, near Yi-Nu Pu-Bu 乙女瀑布, Yu-Shan National Park 玉山国立公園).

**Photo 3.** *Taiwania cryptomerioides* stand in Central Taiwan (Yu-Shan National Park 玉山国立公園).

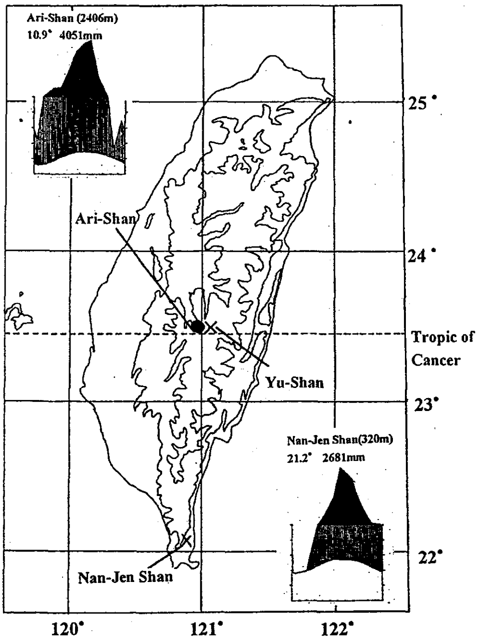
1) a very tall (34m) laurel forest co-dominated by four Lauraceae species, at 1690m elevation, just below the Guan-Gao hut in the Yu-Shan Mountains of central Taiwan;
2) a tall (30m) evergreen Fagaceae forest dominated by Castanopsis carlesii (albeit with a somewhat disturbed understorey), at 1810m elevation just above Yi-Nu Pu-Bu, in the same part of the Yu-Shan Mountains; and
3) a much shorter (16m) *Castanopsis-Elaeocarpus* forest, frequently disturbed by cattle and man as well as by typhoons, at 380m elevation in the Nan-Jen Shan (Mandarin: Nan-Ren Shan), in the Kenting National Park of southern Taiwan.

The locations are shown in Figure 1. Relevés and photographs are shown below.

Except where local experts provided other taxonomic names, nomenclature in the relevés and tables generally follows that of the "Flora of Taiwan" (Flora of Taiwan Editorial Committee 1975-79), which will be subsequently referred to without author citation. The Taiwanese and Chinese usages of *Machilus* (=*Persea*) and *Cyclobalanopsis* (=evergreen *Quercus*) are preserved in the releves and tables, and generally in the text, except when referring to Japanese contexts for the same species. The "Flora of Taiwan" (1975-79) still uses *Cyclobalanopsis* but has adopted *Persea* in place of *Machilus*.

Data collection resulted in the following numbers of taxa recognized:

1) 26 species of pteridophytes (18 fully identified, 8 as genus only), in 14 genera and seven families (*sensu* Mabberley 1987, in which the Aspleniaceae are treated as including the Athyriaceae, Aspidiaceae and Dryopteridaceae);
2) two conifers, *Podocarpus formosensis* (Podocarpaceae) and *Cephalotaxus wilsoniana* (Cephalotaxaceae), the latter endemic to Taiwan;
3) 24 species of monocotyledons (11 fully identified, 13 as genus only), in 14 genera and eight



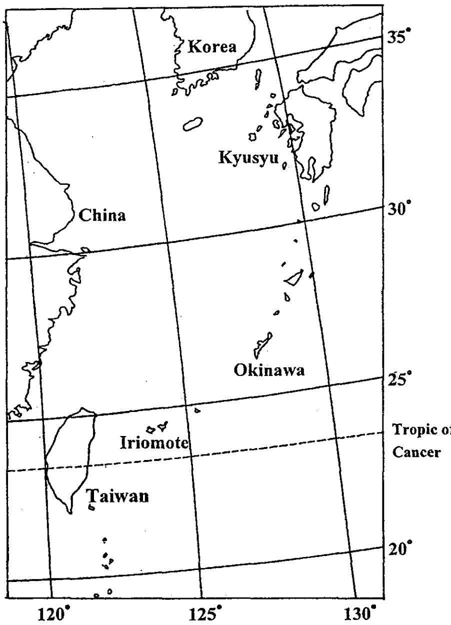




**Fig. 1.** Locations of the relevê sites in Taiwan (left) and of Taiwan relative to the Ryukyu Islands, China, and southern Japan (right).

families (including Smilacaceae as separate from Liliaceae);

4) 128 species of dicotyledons (117 fully identified, 9 as genus only, and two totally unidentified), in 88 genera (as in the "Flora of Taiwan" and the Appendix, some classified differently in Japan and elsewhere) and 48 families; and

5) one variety, *Schima superba* var. *kankoensis,* as separate from its main species which also is represented (if main species not present, varieties were counted as species).

The full list of species found in the relevês is given in the Appendix, classified by genus and family and with indications of relevê occurrence and general biogeographic distribution.

## Composition and Structure of a Mature Laurel Forest

The composition and three-dimensional structure of mature laurophyll forests in Taiwan is illustrated by two samples from the Yu-Shan Mountains in Central Taiwan, both of which are clearly analogous to laurophyll forests in Japan. The first stand represents a true "laurel forest" in which Lauraceae are quite dominant and is illustrated by a relevê at 1690m elevation on a 25° slope to the northeast just above the mountain hut at Guan-Gao (Relevê 1). The general sub-canopy structure of this stand, in the fog, is shown in Photo 4.

In the laurel forest stand at Guan-Gao, the canopy layer ($T_1$ layer) is composed entirely of laurophyll species. The four species with the greatest cover are all from the family Lauraceae: *Beilschmidia erythrophloia, Litsea acuminata, Machilus* (=*Persea*) *thunbergii* and *M. kusanoi. Persea thunbergii* is a major laurel forest dominant in Japan, while *P. kusanoi* was separated from *P. thunbergii* by Hayata (1911) and is now considered by the "Flora of Taiwan" to be the same as *P. japonica. Litsea* species, in Taiwan as well as Japan, occur more commonly as understorey trees, but some, including *L. acuminata,* can reach over 20m in height. Two other canopy species are the laurophyll Fagaceae *Lithocarpus lepidocarpus,* a fairly common and

**Relevé 1.** Tall Mature Laurel Forest at Guan-Gao, Yu-Shan Mountains, Central Taiwan.

| | | | |
|---|---|---|---|
| $T_1$ | 34 m | 80 % | 1690 m, 25° slope to NE |
| $T_2$ | 20 m | 50 % | |
| S | 6 m | 30 % | 30 x 25 m |
| H | 1.5 m | 90 % | Personnel: KF, CCH, EB |

$T_1$: 3.3 *Beilschmidia erythrophloia*
2.2 *Machilus thunbergii*
1.2 *Lithocarpus lepidocarpus*
1.1 *Schima superba*
2.3 *Litsea acuminata*
2.1 *Machilus kusanoi*
1.1 *Pasania kawakamii*

Liana: 2.2 *Mucuna macrocarpa*

$T_2$: 3.3 *Eurya strigilosa*
2.2 *Turpinia formosana*
1.2 *Machilus japonica*
1.1 *Cinnamomum randaiense*
\+ *Michelia compressa*
1.2 *Litsea acuminata*
1.1 *Lithocarpus lepidocarpus*
1.2 *Eurya glaberrima*
1.1 *Tricalysia dubia*

Vines: +.2 *Ficus sarmentosa* var. *henryi*
\+ *Schisandra arisanensis*

Epiphyte: +.2 *Asplenium antiquum*

S: 3.3 *Eurya glaberrima*
1.2 *Beilschmidia erythrophloia*
1.1 *Ardisia crenata*
+.2 *Machilus japonica*
\+ *Cinnamomum randaiense*
2.2 *Turpinia formosana*
1.2 *Litsea acuminata*
1.1 *Ilex formosana*
+.2 *Eurya leptophylla*
\+ *Ficus erecta*

Vines: 1.1 *Piper kadsura*
\+ *Schisandra arisanensis*
\+ *Itea parviflora*
\+ *Bauhinia championii*
\+ *Trachelospermum asiaticum*
\+ *Tetrastigma formosana*
\+ *Ficus sarmentosa* var. *henryi*
\+ *Mucuna macrocarpa*
\+ *Parthenocissus himalayana*
\+ *Smilax bracteata* ssp. *verruculosa*
\+ *Stauntonia hexaphylla*

Epiphyte: 1.1 *Trichomanes auriculatum*
\+ *Procris laevigata*
+.2 *Alpinia* sp.
\+ *Microsorium buergerianum*

H: 4.4 *Pellionia radicans*
+.2 *Goodyera* sp.
\+ *Alpinia* sp.
2.2 *Beilschmidia erythrophloia*
\+ *Peperomia reflexa*

Vines: + *Piper kadsura*
\+ *Bauhinia championii*
\+ *Ficus tannoensis*
\+ *Parthenocissus himalayana*
\+ *Smilax bracteata* ssp. *verruculosa*

Ferns: 2.3 *Diplazium dilatatum*
1.2 *Pteris tokioi*
\+ *Arachniodes aristata*
\+ *Polystichum hancockii*
\+ *Microsorium buergerianum*
\+ *Dryopteris* sp.
2.2 *Diplazium donianum*
+.2 *Arachniodes pseudaristata*
\+ *Arachniodes amabilis*
\+ *Microlepia marginata*
\+ *Microlepia* sp.

**Photo 4.** Interior of tall mature laurel forest at Guan-Gao, documented in Relevé 1. The forest stand is at 1690m, in an often foggy area just below the Guan-Gao hut, Yu-Shan National Park. The canopy is composed entirely of laurophyll species: four Lauraceae with higher cover (*Beilschmidia, Machilus* and *Litsea*), plus two species of evergreen Fagaceae (*Lithocarpus* and *Pasania*) and *Schima superba* (Theaceae). All three understorey layers are also composed overwhelmingly of laurophyll species.

abundant but endemic canopy tree, and *Pasania kawakamii,* usually a medium-sized tree but very common and also endemic to Taiwan. The other canopy component is *Schima superba,* a widespread canopy component of East Asian evergreen broad-leaved forests, from another important laurophyll family, Theaceae, often more widely represented by trees and arborescents of laurel forest understoreys.

The tree understorey ($T_2$ layer) and shrub layer of this laurel forest are also largely composed of species from these three families, including *Eurya* (Theaceae, three species) and *Cinnamomum randaiense* (Lauraceae). Also included, however, are woody species from other largely laurophyll families: *Michelia compressa* (Magnoliaceae), which also occurs fairly commonly in southern Japan and the Ryukyu Islands; *Tricalysia dubia* (Rubiaceae), which occurs throughout Taiwan and also in China; and in the shrub layer the widespread *Ardisia crenata* (Myrsinaceae, also in Japan) and *Ilex formosana* (Aquifoliaceae, Taiwan and southern China, not to be confused with the Taiwan endemic *I. formosae*). The only remaining arborescent understorey component is *Turpinia formosana* (Staphyleaceae), a small, endemic, but very common essentially laurophyll tree. This genus has some tropical members (Indomalaysia and tropical America), although other genera in the small family (*Euscaphis, Staphylea, Tapiscia*) are temperate except for *Huertia* (tropical America). One frutescent individual of deciduous *Ficus erecta* (Moraceae) also occurred in the shrub layer.

An elegant theory of canopy and tree-understorey composition of East Asian evergreen broad-leaved forests and their relations with tropical montane forests has recently been proposed by Ohsawa (1991, 1995), who divides the laurophyll component of these forests into two "guilds" (actually synusiae):

1) lauro-fagaceous notophyll trees, characteristic of the forest canopy and of lower-montane tropical evergreen forests, and delimited by growing-season warmth and by low temperatures; and
2) symploco-myrsinaceous microphyll trees, characteristic of the tree and shrub understoreys and of higher-montane tropical cloud forests, with lower warmth requirements but still delimited also by low temperatures.

These two synusiae form separate forests on tropical mountains but gradually merge into a single forest type, but with vertical separation, as the temperature ranges for the two types merge in the warm-temperate zone. The sample in Relevé 1 supports this idea, showing canopy dominance by the lauro-fagaceous element and occurrence of such smaller-leaved laurophylls as *Ardisia crenata* (Myrsinaceae), *Eurya leptophylla* (Theaceae), and *Ilex formosana* (Aquifoliaceae) only in the shrub layer. Of the three *Eurya* species in the relevé, *E. strigilosa* ($T_2$) is described by the "Flora of Taiwan" as a small tree, *E. glaberrima* ($T_2$ and S) as a small tree or shrub, and *E. leptophylla* (S) as a shrub. Leaf size of the three species is also given as descending in that order. Of course saplings of some canopy and sub-canopy species also occur in the shrub layer, but the other shrub-layer species generally have leaves shorter than 8cm and are not Lauraceae or Fagaceae.

The herb layer, vine/liana synusia, and epiphyte synusia represent quite different families. The subcoriaceous but not really laurophyll tropical liana *Mucuna macrocarpa* (Leguminosae, Malaysia and Polynesia), which is common throughout Taiwan at lower and middle elevations, reached the canopy with significant cover. *Piper kadsura* (Piperaceae), a scandent common also in southern Japan and Korea, was significant and was one of very few species to occur in all three relevés. The relatively rich vine synusia also included *Ficus sarmentosa* var. *henryi*, *F. tannoensis*, *Bauhinia championii* (Leguminosae), and the laurophyll *Trachelospermum asiaticum* (Apocynaceae) with tropical affinities, as well as more temperate elements such as evergreen *Smilax bracteata* ssp. *verruculosa* (Smilacaceae) and *Stauntonia hexaphylla* (Lardizabalaceae), and deciduous *Schisandra arisanensis* (Schisandraceae) and a *Parthenocissus* species identified as *P. himalayana* (Vitaceae, but incompletely known in Taiwan). The herb layer had a cover of 90% and was dominated by *Pellionia radicans* (Urticaceae), along with seedlings of canopy co-dominant *Beilschmidia erythrophloia* and several ferns, especially *Diplazium dilatatum*, *D. donianum*, *Pteris tokioi*, and three species of *Arachniodes*. The only herbs were unidentified species of *Goodyera* (Orchiaceae) and *Alpinia* (Zingiberaceae), plus *Peperomia reflexa* (Piperaceae). *Trichomanes auriculatum* (Hymenophyllaceae, Japan to Thailand and Indonesia, now called *Vandenboschia auriculata* in the "Flora of Taiwan") was the most common epiphyte, along with *Asplenium antiquum* and *Microsorium buergerianum* (both also widespread outside Taiwan).

## Composition and Structure of a Mature Laurophyll Fagaceae Forest

The second relevé represents the evergreen Fagaceae type of laurophyll forest (*Castanopsis* dominant) which occurs over perhaps even wider areas of East Asia, including much of more inland southern Japan. The relevé was made at 1810m, on a 20-30° slope to the southwest, near the observation point at Yi-Nu Pu-Bu (Relevé 2). The interior of this stand is shown in Photo 5.

This forest is dominated more completely by a single species, *Castanopsis carlesii* (Fagaceae,

**Relevé 2.** Tall Mature *Castanopsis* forest at Yi-Nu Pu-Bu, Yu-Shan Mountains, Central Taiwan.

| | | |
|---|---|---|
| $T_1$ | 30 m | 90 % |
| $T_2$ | 15 m | 25 % |
| S | 6 m | 45 % |
| H | 0.6 m | 70 % |

1810 m, 20-30° slope to SW

30 x 25 m
Personnel: KF, CCH, EB

$T_1$:
5.4 *Castanopsis carlesii*
1.1 *Beilschmidia erythrophloia*
1.1 *Machilus japonica*
\+ *Cyclobalanopsis longinux*
\+ *Lithocarpus lepidocarpus*
(+.2) *Idesia polycarpa*
2.3 *Schima superba*
1.1 *Eriobotrya deflexa*
1.1 *Elaeocarpus sylvestris*
\+ *Pasania kawakamii*
\+ unknown tree (not *Itea*)

$T_2$:
1.2 *Beilschmidia erythrophloia*
1.2 *Pasania kawakamii*
\+ *Lithocarpus lepidocarpus*
\+ *Cinnamomum insularimontanum*
\+ *Actinodaphne nantoensis*
1.1 *Machilus japonica*
+.2 *Turpinia formosana*
\+ *Castanopsis carlesii*
\+ *Machilus thunbergii*
\+ *Evodia roxburghiana*

S:
2.2 *Turpinia formosana*
2.2 *Hydrangea chinensis*
1.2 *Beilschmidia erythrophloia*
+.2 *Michelia compressa*
+.2 *Elaeagnus* sp.
\+ *Castanopsis carlesii*
\+ *Machilus japonica*
\+ *Pasania kawakamii*
\+ *Quercus stenophylloides*
\+ *Ternstroemia gymnanthera*
\+ *Daphniphyllum himalaense*
\+ *Damnacanthus indicus*
\+ *Morus australis*
\+ *Salix* sp.
\+ *Callicarpa formosana*
\+ *Mussaenda parviflora*
\+ *Desmodium* sp.
\+ unknown shrub (not *Itea* or *Paederia*)
2.2 *Litsea acuminata*
1.2 *Eurya leptophylla*
1.2 *Ardisia crenata*
+.2 *Osmanthus matsumuranus*
+.2 *Boehmeria* sp.
\+ *Eriobotrya deflexa*
\+ *Elaeocarpus sylvestris*
\+ *Lithocarpus lepidocarpus*
\+ *Symplocos cochinchinensis*
\+ *Ilex formosana*
\+ *Gordonia axillaris*
\+ *Viburnum parvifolium*
\+ *Zanthoxylon scandens*
\+ *Maesa formosana*
\+ *Cephalotaxus wilsoniana*
\+ *Embelia lenticellata*
\+ *Itea parviflora*

Vines:
+.2 *Smilax* $sp_1$
\+ *Parthenocissus himalayana*
\+ *Ficus nipponica*
\+ *Clematis* sp.
\+ *Schisandra arisanensis*
\+ *Stauntonia* sp.
\+ *Smilax* $sp_2$
\+ *Jasminum hemsleyi*
\+ *Clematis alsomitrifolia*
\+ *Lonicera acuminata*
\+ *Trachelospermum gracilipes*

Epiphyte:
+.2 *Microsorium buergerianum*

H: 1.2 *Damnacanthus indicus*
+ *Machilus japonica*
+ *Idesia polycarpa*
+ *Embelia lenticellata*
+.2 *Rubus swinhoei*
+ *Pasania kawakamii*
+ *Ardisia crenata*
+ *Acanthopanax trifoliatus*

Vines: 2.2 *Tetrastigma formosana*
+.2 *Hedera rhombea*
+.2 *Ficus nipponica*
+ *Smilax* sp.
1.2 *Piper kadsura*
+.2 *Parthenocissus himalayana*
+.2 *Trachelospermum gracile*

Forbs: +.2 *Alpinia* sp.
+ *Cymbidium* sp.
+ *Ophiopogon* sp.
+ *Calanthe arisanensis*
+ *Polygonum* sp.

Ferns: 2.3 *Arachniodes pseudaristata*
1.2 *Dryopteris* $sp_1$
+ *Dryopteris* $sp_3$
+.2 *Pteris cretica*
+ *Acrophorus stipellatus*
+ *Coniogramme* sp.
2.2 *Arachniodes amabilis*
+.2 *Dryopteris* $sp_2$
+.2 *Microlepia* sp.
+ *Polystichum* sp.
+ *Pteris fauriei*

Graminoids: +.2 *Oplismenus compositus*
+ *Carex* sp.
+ *Carex lenta*

**Photo 5.** Tall mature *castanopsis* forest at Yi-Nu Pu-Bu, documented in Relevê 2. The canopy is dominated by *Castanopsis carlesii*, with some *Schima superba* and individuals of *Beilschmidia, Machilus, Elaeocarpus*, and *Eriobotrya*. This stand is at 1810m, above Yi-Nu Pu-Bu 乙女瀑布, in Yu-Shan National Park 玉山国立公園.

Taiwan and adjacent southeastern China), as is common in the evergreen Fagaceae forests of East Asia. The other canopy components are also mainly laurophylls: *Schima superba* (Theaceae), plus Lauraceae and evergreen Fagaceae, as well as laurophyll *Elaeocarpus sylvestris* (Elaeocarpaceae, = *E. ellipticus* in Japan). In addition, however, there was also a large individual of evergreen but not really laurophyll *Eriobotrya deflexa* (Rosaceae), a Taiwan endemic; a tall evergreen tree which could not be identified at all; and, on the edge of the plot, individuals of the deciduous invasive *Idesia polycarpa* (Flacourtiaceae, monospecific genus), which occurs in China and Japan but comes from a family with mainly tropical affinities. The tree understorey involved mainly the canopy and other species of Lauraceae and evergreen Fagaceae (very little *C. carlesii*), as well as laurophyll *Turpinia formosana* (as in the laurel forest relevê) and quasi-laurophyll *Evodia roxburghiana* (Rutaceae, evergreen), considered the same as *E. merrillii* by the "Flora of Taiwan."

The shrub understorey showed definite signs of disturbance, including a larger number of species (47 versus 25) and higher total cover (45% versus 30%) than in the laurel-forest relevê, despite a canopy cover of 90%. Nevertheless, the shrub layer included 10 species from the main laurophyll families (Lauraceae, evergreen Fagaceae, Theaceae) and 14 other laurophyll species (including fairly abundant *Hydrangea chinensis*), and the same number (11) of vine species as in the laurel-forest shrub layer. The remaining 12 species include single or few individuals of such non-laurophyll components as evergreen *Eriobotrya deflexa;* shrubs *Elaeagnus* sp., *Viburnum parvifolium, Callicarpa formosana, and Zanthoxylon scandens;* coniferous *Cephalotaxus wilsoniana;* unidentified species of *Salix, Boehmeria,* and *Desmodium;* and one completely unidentified shrub.

The vine synusia was similar to that of the laurel forest, but there was only one epiphyte, *Microsorium buergerianum*. The herb layer was a bit less dense at 70% (versus 90% for the laurel forest) and was composed of a more even mix of ferns (especially two *Arachniodes* species), small vines, and some seedlings and herbs.

## A Disturbed "Typhoon Forest"

In contrast to the mature forests of Relevês 1 and 2, the third stand studied represents a much shorter forest, at 380m elevation on a 15° slope to the south, in the Nan-Jen Mountains of the Kenting National Park, Hengchun Peninsula, southern Taiwan. This forest seemed to have been disturbed frequently, both by animals and by typhoons. Being further south, it also contains more species with tropical affinities. The structure and composition of this typical "typhoon forest" is illustrated by Relevê 3. (See also vegetation descriptions by Chen 1984, 1985, and data from a study in the same area by Hara et al. 1997.) The shorter stature of this stand is shown in Photo 6.

The short (16m) but moderately dense (80%) canopy was dominated by *Castanopsis indica,* along with *Elaeocarpus sylvestris,* and with significant cover also by *Schima superba* var. *kankoensis,* plus evergreen but not really laurophyll *Schefflera octophylla* (Araliaceae, southeast Asia and southern China to the Ryukyu Islands) and deciduous *Engelhardtia roxburghiana* (Juglandaceae, India to Malaysia and southern China). There were also a very few or single individuals of laurophyll *Beilschmidia, Machilus, Castanopsis, Cyclobalanopsis, Gordonia, Michelia, Eurya* and *Ilex* species, plus more typically understorey laurophyll *Symplocos, Syzygium,* and *Daphniphyllum* species. In addition, though, there were also a few canopy individuals of the usually shrubby, non-laurophyll *Glochidion rubrum* (common in thickets) and *Sapium discolor* (both Euphorbiaceae, with ranges extending to Malaysia); usually shrubby *Pithecellobium lucidum* (Leguminosae, moderately large compound leaves; from Hainan to the Ryukyu Islands);

**Relevé 3.** Frequently Disturbed *Castanopsis-Elaeocarpus* Typhoon Forest in the Nen-Jen Shan 南仁山, Kenting National Park 墾丁国立公園, southern Taiwan.

| | | | |
|---|---|---|---|
| $T_1$ | 16 m | 80 % | 380 m, 15° slope to S |
| $T_2$ | 8 m | 30 % | |
| S | 4 m | 50 % | 25 x 25 m |
| H | 0.6 m | 30 % | Personnel: KF, CCH, Chiou W.-L., EB |

$T_1$:

4.4 *Castanopsis indica*
2.3 *Schefflera octophylla*
2.2 *Engelhardtia roxburghiana*
+.2 *Glochidion rubrum*
+.2 *Daphniphyllum glaucescens*
\+ *Ilex formosae*
\+ *Eurya hayatai*
\+ *Pithecellobium lucidum*
\+ *Beilschmidia tsangii*
\+ *Ilex cochinchinensis*
\+ *Symplocos wikstroemifolia*
3.3 *Elaeocarpus sylvestris*
2.2 *Schima superba* var. *kankoensis*
+.2 *Cyclobalanopsis longinux*
+.2 *Michelia compressa*
+.2 *Gordonia axillaris*
\+ *Astronia ferruginea*
\+ *Machilus zuihoensis*
\+ *Castanopsis stellato-spina*
\+ *Prunus phaeostica*
\+ *Syzygium euphlebium*
\+ *Sapium discolor*

$T_2$:

3.3 *Illicium arborescens*
1.1 *Ilex matsudai*
+.2 *Ilex formosae*
\+ *Schima superba* var. *kankoensis*
\+ *Cyclobalanopsis longinux*
\+ *Daphniphyllum glaucescens*
\+ *Neolitsea buisanensis*
\+ *Ardisia sieboldii*
\+ *Helicia formosana*
1.2 *Ilex cochinchinensis*
+.2 *Litsea nakai*
\+ *Beilschmidia erythrophloia*
\+ *Engelhardtia roxburghiana*
\+ *Michelia compressa*
\+ *Pasania brevicaudata*
\+ *Adinandra formosana* v.*hypochl.*
\+ *Glochidion lanceolatum*
\+ *Gardenia jasminoides*

S:

1.2 *Engelhardtia roxburghiana*
1.2 *Eurya hayatai*
1.2 *Helicia formosana*
1.1 *Diospyros eriantha*
1.1 *Symplocos glomerata*
+.2 *Illicium arborescens*
+.2 *Pasania brevicaudata*
+.2 *Castanopsis carlesii*
+.2 *Castanopsis indica*
+.2 *Psychotria rubra*
+.2 *Ilex cochinchinensis*
\+ *Gardenia jasminoides*
\+ *Michelia compressa*
\+ *Astronia ferruginea*
\+ *Beilschmidia tsangii*
\+ *Elaeocarpus sylvestris*
\+ *Schima superba* var. *kankoensis*
\+ *Cryptocarya chinensis*
\+ *Lithocarpus amygdalifolius*
\+ *Ficus formosana*
\+ *Zanthoxylon nitidum*
\+ *Ficus erecta*
1.2 *Ilex formosae*
1.2 *Microtropis japonica*
1.1 *Cyclobalanopsis longinux*
1.1 *Ardisia quinquegona*
1.1 *Ardisia cornudentata*
+.2 *Litsea nakai*
+.2 *Neolitsea buisanensis*
+.2 *Ehretia longiflora*
+.2 *Daphniphyllum glaucescens*
+.2 *Sarcandra glabra*
+.2 *Pithecellobium lucidum*
\+ *Glochidion rubrum*
\+ *Gordonia axillaris*
\+ *Machilus zuihoensis*
\+ *Symplocos wikstroemifolia*
\+ *Schefflera octophylla*
\+ *Garcinia multiflora*
\+ *Machilus thunbergii*
\+ *Podocarpus formosensis*
\+ *Meliosma rigida*
\+ *Osmanthus marginatus*
\+ *Lasianthus plagiophyllus*

+ *Lasianthus* sp.
+ *Wikstroemia taiwanensis*
+ *Litosanthes biflora*
+ *Strychnos henryi*
+ *Viburnum odoratissimum*
+ *Callicarpa remotiflora*
+ *Tarenna gracilipes*
+ *Ilex asprella*

Palm: 1.1 *Daemonorops margaritae*

Bamboo: 1.1 *Schizostachyum diffusum*

Vines: 1.1 *Smilax* sp.
+ *Stauntonia hexaphylla*
+ *Psychotria serpens*
+ *Epipremnum pinnatum*
+ *Piper kadsura*
+ *Smilax lanceifolia*
+ *Fissistigma glaucescens*

H: +.2 *Castanopsis indica*
+ *Pithecellobium lucidum*
+ *Daphniphyllum glaucescens*
+ *Ficus* sp. (apocynoid)

Vines: +.2 *Trachelospermum gracilipes*
+ *Psychotria serpens*
+ *Stauntonia hexaphylla*

Herbs: 2.2 *Ophiopogon* $sp_1$
+.2 *Aspidistra daibuensis*
+ *Semnostachya longespicatus*
+ *Ophiopogon* $sp_2$
+.2 *Zingiber kawagoii*
+.2 *Codonacanthus pauciflorus*
+ *Calanthe* sp.
+ *Lophatherum gracile*

Ferns: 3.3 *Pronephrium triphyllum*
1.2 *Diplazium donianum*
+.2 *Diplazium mettenianum*
1.2 *Pleocnemia rufinervis*
+.2 *Diplazium dilatatum*
+ *Blechnum orientale*

**Photo 6.** Frequently disturbed "Typhoon Forest" in the Nan-Jen Shan 南仁山 (Kenting National Park 墾丁国立公園, southern Taiwan), documented in Relevé 3. The shorter stature of the forest and somewhat broken canopy are apparent in the photograph. The canopy is composed (in descending order of cover) by *Castanopsis indica*, followed by *Elaeocarpus sylvestris* and then *Schefflera octophylla*, *Schima superba* var. *kankoensis*, and *Engelhardtia roxburghiana*.

mid-size coriaceous-leaved tree *Astronia ferruginea* (Melastomataceae, northern Philippines to southernmost Taiwan); and subcoriaceous *Prunus phaeostica* (Rosaceae, Assam to southern China; also common in thickets).

The 8 m arborescent ($T_2$) layer and 4 m shrub layer showed similar diversity, with laurophylls most numerous but not predominant, as they were in the mature forests in the central mountains. The herb layer and the vine synusia were generally similar to those of other stands but also had some species with more tropical affinities. Other than overall stature, the typhoon forest differed most from the mature stands through its greater number of species, especially in the shrub layer but also in the two tree layers.

## Taxonomic Richness of Taiwanese Laurophyll Forests

As mentioned already, the three laurophyll relevés in Taiwan involved 128 species, in 88 genera and 48 families. The most species-rich families were the Lauraceae (13 spp.), Rubiaceae (10 spp.), Fagaceae and Theaceae (9 species each), Moraceae (7 species, but 6 from *Ficus*), Myrsinaceae (6 spp.), and Aquifoliaceae (5 species, all *Ilex*). The most species-rich genera were thus *Ficus* and *Ilex,* but were followed by *Ardisia, Eurya, Lithocarpus* (including *Pasania*), and *Persea* (4 species each), and then *Castanopsis* and *Symplocos* (3 species each). Finally, the most genus-rich families were Rubiaceae (8 genera), Lauraceae (7 genera, counting an *Actinodaphne* species often called *Litsea*), and Fagaceae and Theaceae (5 genera each). These results generally agree with those of Oono et al. (1997) from their detailed floristic study of laurophyll forests from southern Kyushu to Taiwan. The richness of the laurophyll families Lauraceae and Fagaceae which provide the main canopy trees, is especially striking, along with that of the Theaceae and Rubiaceae, which compose much of the understorey.

The distribution of taxonomic richness (three levels) over the different strata in the three laurophyll relevés is summarized in Table 1. The typhoon forest had the most species, but the evergreen Fagaceae forest (Relevé 2) had almost as many, due to the large number of species in the somewhat disturbed shrub layer. The lower total diversity of the mature laurel forest (Guan-Gao) can be attributed to competitive elimination of species during succession but may also be enhanced by the overwhelming dominance by dark-green, shade-tolerant laurophyll trees, which effectively eliminates species not tolerant of unusually low light levels.

The number of species in the canopy is significantly higher only for the typhoon forest. The greater number of species in the typhoon forest, both in the canopy and in the understoreys, does not seem to be due to a more open canopy, however, which had the same cover of 80% as in the mature laurel forest. Rather, the shorter canopy, at 16m, can be reached by both canopy species and normal understorey species. Some of these understorey species, as well as more light-demanding canopy species, may be eliminated if the canopy can become significantly taller before being struck by the next typhoon.

Although the species richness in these forests is relatively high for temperate, even warm-temperate to subtropical forests, the richness at higher taxonomic levels is more remarkable. Table 1 also shows values for relative richness at higher levels, defined as the number of unique taxa at one taxonomic level divided by the number of unique taxa in the next lower level. The rate at which the species represent unique genera exceeds 77% in all levels of all relevés, as well as for total numbers in all three relevés. This is extraordinary taxonomic diversity, occurring in situations of unusually low diversity in plant physiognomy. At the next level, the number of unique families represented by genus-level richness is also high, although the pattern is

**Table 1.** Taxonomic richness of the three Laurophyll forest relevés in Taiwan.

| Forest Type | | Species | Genera | Families |
|---|---|---|---|---|
| **Guan-Gao Lauraceae** | | **48** | **38** (79%) | **25** (66%) |
| $T_1$ layer | 80% | 8 | 7 (87%) | 4 (57%) |
| $T_2$ layer | 50% | 12 | 11 (92%) | 9 (82%) |
| S layer | 30% | 25 | 23 (92%) | 18 (78%) |
| H layer | 90% | 22 | 17 (77%) | 13 (76%) |
| **Yi-Nu** ***Castanopsis*** | | **80** | **71** (89%) | **44** (62%) |
| $T_1$ layer | 90% | 11 | 11 (100%) | 5[1] (45%) |
| $T_2$ layer | 25% | 10 | 9 (90%) | 4 (44%) |
| S layer | 45% | 47 | 44 (94%) | 31[2] (70%) |
| H layer | 70% | 34 | 29 (85%) | 20[2] (69%) |
| **Kenting disturbed** | | **86** | **67** (78%) | **47** (70%) |
| $T_1$ layer | 80% | 22 | 20 (91%) | 15 (75%) |
| $T_2$ layer | 30% | 18 | 16 (89%) | 13 (81%) |
| S layer | 50% | 61 | 51 (84%) | 38 (75%) |
| H layer | 30% | 21 | 18 (86%) | 15 (83%) |

The numbers indicate taxon richness, i.e. numbers of unique species, genera and families in the respective relevé layers, as well as the totals (bold). Numbers in parentheses indicate richness relative to that of the next lower taxonomic level: ratio of genus to species richness (genus column) and ratio of family to genus richness (family column). All species are used in this tabulation, even if not completely identified, except as noted:

[1] excluding 1 unknown tree species and *Idesia polycarpa* (just outside relevé)

[2] excluding 1 unknown shrub species

[3] excluding *Idesia polycarpa* (just outside relevé)

See main text for stand descriptions; see Tables 1-3 for actual relevés.

somewhat different and less uniform across stand layers. The typhoon forest shows the highest relative family richness (75%, or more in each layer, relative to genus richness). This may be due to the frequent disturbance but may be enhanced also by the transitional location in which more tropical taxa appear.

For comparison, the total numbers of species, genera and families represented in a much larger sampling of 779 essentially laurophyll forest plots in Taiwan (Hsieh et al. 1997a, 1997b) are shown in Table 2. Relevés 1 and 2 from the central mountains of Taiwan probably represent the *Machilus-Castanopsis* category of Hsieh et al., while the typhoon forest in southern Taiwan probably represents at least the potential for the *Ficus-Machilus* forest type. The values for higher-level relative richness must be lower in compilations over many plots, but these values are also

**Table 2.** Woody taxon richness of Taiwan by forest type.

| | Plots | Species | Genera | Families |
|---|---|---|---|---|
| I. *Ficus-Machilus* forest | 148 | 324 | 195 (60%) | 77 (39%) |
| II. *Machilus-Castanopsis* forest | 238 | 496 | 246 (50%) | 92 (37%) |
| III. Lower *Quercus* forest | 277 | 457 | 202 (44%) | 86 (43%) |
| IV. Upper *Quercus* forest | 116 | 263 | 131 (50%) | 59 (45%) |

The values are for woody species only, as compiled by Hsieh et al. (1997a, b) based on 779 sampling plots with a total of 569 species. The forest types, from I through IV, were considered by Hsieh et al. to correspond to tropical, subtropical, warm-temperate and temperate climatic conditions respectively, but with somewhat different Warmth Index ranges than equivalent types in Japan. The numbers in parentheses represent higher-level taxon richness: number of genera per number of species, in the genus column, and number of families per number of genera in the last column.

high.

Only four species occurred in all three Taiwanese relevés, *Piper kadsura* plus three laurophyll canopy trees: *Beilschmidia erythrophloia* and *Machilus thunbergii* (both Lauraceae) and *Michelia compressa* (Magnoliaceae). In addition to these four, 15 more species occurred in both relevés in the central mountains: three vines, three ferns, *Itea parviflora,* and eight laurophyll trees or arborescents (see Appendix for names.)

## Biogeographic Relations of Taiwanese Laurophyll Taxa

The general geographic ranges of the relevé species are shown, as far as could be reasonably determined, in the Appendix. The main canopy and sub-canopy tree species in the two mature-forest relevés, plus selected understorey trees, are listed in Table 3, along with the total numbers of congeneric species occurring in Taiwan, Japan, and China. As one can see from the table, the Taiwanese laurophyll forests represent only a small fraction of the species richness within the main families of laurophyll canopy trees. The main genera of laurophyll trees are very species-rich, especially in China, but most of the genera also reach Japan (cf. Fujiwara 1981-86). The other canopy tree genera in the two mature-forest relevés, from typically non-laurophyll families, show much less species richness, at least in China and Taiwan (with the exception of *Schefflera*).

Those species from the Taiwan relevés which occur also in Japan include:

1) all but one (*Pleocnemia rufinervis,* cf. *Tectaria*) of the 18 identified pteridophytes, and all 14 genera;
2) neither of the two conifers, although both genera do occur in Japan (*Podocarpus* and *Cephalotaxus*);
3) only five of the 11 identified monocotyledon ous species but 12 of the 14 genera; and
4) only 50 of the 117 identified dicotyledon ous species but all families except Annonaceae and

**Table 3.** Geographic range and congeneric richness of major canopy tree species in Taiwan.

| Families | Relevé species | Taiwan total | Species in Japan | Species in China |
|---|---|---|---|---|
| **Lauro-Fagaceous Canopy Trees** | | | | |
| Lauraceae | | | | |
| *Actinodaphne* | *A. nantoensis* | 11 | 2 others | 19 |
| *Beilschmidia* | *B. erythrophloia* | 2 | *B. erythrophloia* | 35 |
| | *B. tsangii* | | | |
| *Cinnamomum* | *C. insularimontanum* | 10 | *C. camphora* | 46 |
| | *C. randaiense* | | + 5 others | |
| *Cryptocarya* | *C. chinensis* | 2 | *C. chinensis* | 19 |
| *Litsea* | *L. acuminata* | 14 | 1 other | 66 |
| | *L. nakai* | | | |
| *Machilus* (= *Persea*) | *M. japonica* | 5 | *P. japonica*, | 67 |
| | *M. kusanoi* | | *P. thunbergii*, | |
| | *M. thunbergii* | | + 3 others | |
| | *M. zuihoensis* | | | |
| *Neolitsea* | *N. buisanensis* | 10 | 5 others | 42 |
| Fagaceae | | | | |
| *Castanopsis* | *C. carlesii* | 8 | 1 other | 53 |
| | *C. indica* | | | |
| | *C. stellato-spina* | | | |
| *Cyclobalanopsis* | *C. longinux* | 12 | (14, as *Quercus*) | (=*Quercus*) |
| *Lithocarpus* | *L. amygdalifolius* | 2 | (5, as *Quercus*) | 119 |
| | *L. lepidocarpus* | | | (incl. *Pasania*) |
| *Pasania* | *P. brevicaudata* | 12 | 2 others | (=*Lithocarpus*) |
| | *P. kawakamii* | | | |
| *Quercus* | *Q. stenophylloides* | 6 | 20+ others | 114 |
| | | | | (incl. *Cyclobalan.*) |
| **Other Laurophyll Canopy Trees** | | | | |
| *Elaeocarpus* (Elaeocarp.) | *E. sylvestris* | 5 | = *E. ellipticus*, + 4 | 37 |
| *Helicia* (Proteaceae) | *H. formosana* | 2 | *H. cochinchinensis* | 13 |
| *Michelia* (Magnoliaceae) | *M. compressa* | 1 | *M. compressa*, + 1 | 25 |
| *Schima* (Theaceae) | *S. superba* | 1+ | = *S. liukiuensis*, + 1 | 14 |
| | *S. superba* var. *kankoensis* | | | |
| **Other Canopy Trees** | | | | |
| *Engelhardtia* (Juglandac.) | *E. roxburghiana* | 1 | - - - | 4 |
| *Eriobotrya* (Rosaceae) | *E. deflexa* | 1+ | *E. deflexa, E. japonica* | 4 |
| *Idesia* (Flacourtiaceae) | *I. polycarpa* | 1 | *I. polycarpa* | 1 |
| *Podocarpus* (conifer) | *P. formosensis* | 5 | *P. nagi, P. macrophyllus* | 6 |
| *Schefflera* (Araliaceae) | *S. octophylla* | 4 | *S. octophylla* | 37 |
| *Turpinia* (Staphyleaceae) | *T. formosana* | 3 | *T. ternata* | 3 |

All canopy species of the mature-forest relevés in Taiwan are included, as well as most understorey trees. Numbers of species are from: "Flora of Taiwan" (1975-79), "Handbook of Japanese Vegetation" (Miyawaki et al. 1994), and "Iconographia Cormophytorum Sinicorum" (Institute of Botany 1972-76).

80 of the 88 genera.

The eight genera which do not reach Japan are *Fissistigma* (Annonaceae, 60 spp.), *Strychnos* (Loganiaceae, 190 spp., especially in Africa), *Semnostachya* (Acanthaceae, 9 spp., western Malesia), and *Litosanthes* (Rubiaceae, 5 spp.) with mainly tropical distributions; *Engelhardtia* (Juglandaceae, 5 spp. from the Himalaya to Malesia), *Embelia* (Myrsinaceae, 130 spp.), and *Astronia* (Melastomataceae, 70 spp.) which also have subtropical members; and *Gordonia* (Theaceae, 70 spp.). *Gordonia* apparently occurred in Japan before the Pleistocene glaciations and still has about 15 species in China and one in the southeastern USA.

The number of endemics in the relevé samples was rather high. This included 34 of the 117 dicotyledonous species and the one variety identified (plus one conifer and three monocotyledons). There were five endemics each in the main laurophyll families Lauraceae, Fagaceae, and Theaceae, as well as two each in the Myrsinaceae, Rubiaceae, and the genus *Ilex* (Aquifoliaceae). Given the high taxon richness among laurophylls already noted, this should be no surprise. The highest rate of endemism is in the Fagaceae and Theaceae, each with five endemics out of nine species recorded.

Analysis of taxon occurrence in China is not done in detail, but some impressions can be gained from relevés by two of the authors (KF, EB) at several well studied sites in southern China: Tiantong National Park, near Ningbo south of Shanghai (Box et al. 1991b; cf. Song 1995); Ding-Hu Shan Biosphere Reserve west of Guangzhou, the lowland part of which Kong et al. (1997) described as "transitional to tropical"; unpublished; cf. Pignatti et al. 1990a, 1990b Wang et al. 1982; Jianfeng-Ling 尖峰岺 montane forest in southwestern Hainan (Box et al. 1989); and Man-Ka mountain in the Menglun area of lowland, tropical Xishuangbanna, in southern Yunnan, near the Lao border (Box et al. 1991a). The compositions of the canopy and understorey tree strata of the most comparable of these stands are juxtaposed in Table 4. Ding-Hu Shan and Tiantong span the subtropical zone in eastern China, while the short montane forest at 1070m on Man-Ka mountain in southern Yunnan is also a *Castanopsis*-dominated stand (each by a different species). Jianfeng-Ling 尖峰岺, at 890 m on Hainan, is tropical lower montane, with a much larger tropical component including the dominant *Dacrydium pierrei* (Podocarpaceae) and families such as Xanthophyllaceae and Pentaphylacaceae (monospecific). Its canopy and tree understorey still, however, contain four evergreen Fagaceae and four Lauraceae species.

The canopy and sub-canopy compositions of relevés at these four locations in China are juxtaposed in Table 4. Even in different areas with different species, it appears that the basic overstorey structure of East Asian laurophyll forests can remain similar, with dominance shared by laurophyll species of Lauraceae and evergreen Fagaceae as well as other laurophyll families such as Theaceae. Total richness in these four relevés varies from 108 species, 82 genera, and 47 families at Jianfeng to 52 species, 42 genera, and 28 families in the Tiantong *Castanopsis* forest. The ratio of laurophyll to total species in the relevés ranges from 17% at Ding-Hu to 52% at Tiantong 天童 (31% and 33% for the two mature Taiwan relevés). Absolute numbers of laurophyll taxa also vary widely, from 13 species, 10 genera and 7 families at Ding-Hu to 42 species, 24 genera and 11 families at Jianfeng. As Table 4 suggests, however, the number of laurophyll taxa in the canopy and sub-canopy appears to remain somewhat more consistent. For example, tropical montane Jianfeng had the largest number of laurophyll taxa at all levels, but a greater fraction of them appeared only in understorey layers and may be restricted to successional status.

In addition to Ohsawa's idea of separate noto-laurophyll and micro-laurophyll synusiae, Ohsawa and Nitta (1997) have posed two hypotheses concerning the structure of taxon richness

**Table 4.** Tree-stratum composition of selected Chinese evergreen broad-Leaved forest stands.

| | Ding-Hu Shan | | Jianfeng-Ling | | Man-Ka | | Tiantong | |
|---|---|---|---|---|---|---|---|---|
| $T_1$ | 27 m 80 % | | 35 m 85 % | | 15 m 85% | | 25 m 80 % | |
| $T_2$ | 15 m 40 % | | 18 m 60 % | | 8 m 30% | | 13 m 40 % | |
| S | 3 m 40 % | | 5 m 70 % | | 3.5 m 40 % | | 4 m 30 % | |
| H | 0.6 m 90 % | | 0.4 m 20 % | | 0.5 m 20 % | | 0.8 m 40 % | |
| $T_1$: | 4.3 | *Castanopsis chinensis* | 3.3 | *Dacrydium pierrei* | 3.4 | *Castanopsis hystrix* | 4.3 | *Castanopsis fargesii* |
| | 3.3 | *Cryptocarya concinna* | 2.3 | *Xanthophyllum hainanensis* | 3.3 | *Lithocarpus fordianus* | 2.1 | *Liquidambar formosana* (decid.) |
| | 1.1 | *Cryptocarya chinensis* | 2.2 | *Lithocarpus fenzelianus* | 2.2 | *Pasania* sp. (smaller lvs.) | 1.1 | *Castanopsis carlesii* |
| | 1.2 | *Schima superba* | 2.1 | *Gordonia balanse* | 1.2 | *Pasania* sp. (larger lvs.) | 1.1 | *Schima superba* |
| | 1.2 | *Syzygium acuminata* | 1.2 | *Alseodaphne hainanensis* | | | 1.1 | *Diospyros lotus* (decid.) |
| | 1.1 | *Engelhardtia roxburgh.* | 1.2 | *Madhuca hainanensis* | | | | |
| | | | 1.1 | *Cinnamomum ovatum* | | | | |
| | | | 1.1 | *Cyclobal. fleuryi* | | | | |
| | | | 1.1 | *Lithocarpus amygd.* v. *praec.* | | | | |
| | | | 1.1 | *Alstonia scholaris* | | | | |
| | | | + | *Beilschmidia tungfangensis* | | | | |
| $T_2$: | 2.2 | *Cryptocarya concinna* | 2.2 | *Turpinia gleberrima* | 2.2 | *Castanopsis hystrix* | 2.3 | *Castanopsis fargesii* |
| | 2.2 | *Gironniera subaequalis* | 2.2 | *Decaspermum cambodianum* | 1.2 | *Lithocarpus fordianus* | 2.2 | *Lithocarpus henryi* |
| | 1.2 | *Syzygium rehderianum* | 1.1 | *Cyclobalanopsis blakei* | 1.2 | *Pasania* sp. (smaller lvs.) | + | *Styrax fabri* (*S. confusa*) (decid.) |
| | 1.2 | *Casearia villilimba* | 1.1 | *Schima superba* | 1.2 | *Elaeocarpus sylvestris* | | |
| | 1.1 | *Lindera chunii* | 1.2 | *Symplocos lancilimba* | 1.1 | *Actinodaphne henryi* | | |
| | +.2 | *Psychotria rubra* | 1.1 | *Ilex kobuskiana* | + | *Wendlandia parviflora* (Rubiac.) | | |
| | +.2 | *Sarcosperma laurinum* | + | *Adinandra millettii* | | | | |
| | | | + | *Pentaphylax euroides* | | | | |
| | | | + | *Persea balanse* | | | | |
| | | | + | *Diospyros eriantha* | | | | |
| | | | + | *Altingia obovata* | | | | |
| | | | + | *Rhus succedanea* (decid.) | | | | |

within laurophyll forests:

1) that genus richness remains similar as species richness decreases, both toward the north and upward in mountains; and
2) that the ratio of the notophyll and microphyll synusiae remains relatively consistent in different laurophyll forests and locations.

The four Chinese relevés tend to support the first hypotheses somewhat, especially within the canopy and sub-canopy layers. The ratio of notophyll to microphyll laurophyll species seems more variable, however, ranging from 6:10 at Ding-Hu 鼎湖 to 10:6 at Man-Ka 曼卡 (9:7 and 14:11 in the two mature Taiwan relevés; based simply on the numbers of species occurring in families designated as mainly notophyll or microphyll.) These are interesting hypotheses and deserve more detailed further study.

Only one species occurred in more than three of the total of seven relevés (i. e. three from Taiwan and four from China). That species was *Schima superba,* which along with its variety *kankoensis* in southern Taiwan occurred in all relevés except Man-Ka in southern Yunnan, where it was replaced by *Schima wallichii.*

## Climatic Position of East Asian and other Laurophyll Forests

Terms such as 'warm-temperate' and 'subtropical' — even 'tropical' (cf southern Taiwan) — are used commonly but quite inconsistently. In East Asia the situation is complicated by the conflict between the official system of climatic zones in China, based mainly on the growing season and agricultural potentials, and the more global, or at least Northern Hemispheric, perspective of the system used in Japan and Korea, based on the main factor which limits vegetation zones, i. e. winter temperatures. Equivalences between the two systems have been given by Song (1995) and by Box (1991b, 1995a).

Essentially, the Chinese usage of warm-temperate is for the temperate deciduous forest zone, and zones are called subtropical as soon as the zonal vegetation becomes (broad-leaved) evergreen. This terminology seems to have come from the work of Alisov (1954) and is seen also in various European and other high-latitude perspectives. From a more global perspective (e. g. Walter 1985), as well as from a wider East Asian perspective (e. g. Kira 1945, 1977, 1995; Suzuki 1952, 1953), the temperate deciduous forest zone is called temperate (or cool-temperate) and the adjacent first equatorward zone of evergreen broad-leaved forests is called warm-temperate, with recognition that this forest type may extend into the subtropics with little change in physiognomy.

The transition into the subtropics is accompanied, however, by the largest turnover in taxonomic composition along the entire polar-tropical gradient. This taxonomic discontinuity is familiar in Japan, falling between the northern Ryukyu Islands, with flora much like that of Kyushu, and the southern Ryukyu Islands, with many tropical taxa similar or identical to those of Taiwan (cf. Hosokawa 1958). A similarly abrupt, major turnover in taxa is found in southern Florida, where most essentially temperate woody taxa from the north are replaced, over a north-south distance of less than 100km, by an essentially Caribbean flora in south Florida (e. g. Little 1971).

An attempt to provide global criteria for a comprehensive system of zonal terminology is given in Table 5 (cf. Box 1995a). The fundamental question in reconciling the two climatic perspectives involves the meaning of the term subtropical. The root 'sub' means almost. It seems semantically more reasonable to name the bioclimatic zones such that the boundary between tropical and temperate falls at the botanical discontinuity between tropical and temperate floras. This is

**Table 5.** Criteria for global climatic zonation in lowlands.

| | Temperature extremes | Significance | Examples |
|---|---|---|---|
| TROPICAL | No frost or other "cold" temperatures ever | Extreme cold sensitivity of many truly tropical plants | Amazon Basin, East Indies |
| SUBTROPICAL | Occasional frost or near-frost, not every year and not below about -1°C | Frost sensitivity of tropical evergreen and most other tropical plants | South and Southeast Asia, southern Africa, southern Brazil/northern Argentina |
| WARM-TEMPERATE | Light to moderate frost, every/nearly every year; absolute minima not < -15°C | Leaf-changing seasonal broad-leaved evergreens tolerate, subtropical evergreens may not | Southern mainland Japan, east-central China, SE USA |
| TEMPERATE | Significant frost every year, occasional temperatures significantly below -15°C | Below coldness tolerance limit for extra-tropical evergreen broad-leaved plants | Deciduous forest regions of eastern North America, N Japan and NE China, most of middle Europe |
| COOL-TEMPERATE | Moderate to significant frost every winter, plus cool summer | Growing-season warmth marginal for many typical temperate-zone plants, including deciduous | Northern Europe (not boreal), Hokkaido, NE USA/E Canada |
| BOREAL | Cool, short summer and long severe winter; absolute minima << -15°C and perhaps < -40°C | Growing season insufficient for most deciduous trees (exceptions: larch, birch, etc.) | Most of Russia, Canada-Alaska, and Fenno-Scandia except south (nowhere in Southern Hemisphere) |
| AUSTRAL | Like cool-temperate but extremes moderated by essentially oceanic climate | Growing season marginal but snow-free/frost-free periods longer: more evergreenness | Southern New Zealand, subantarctic and some subarctic islands, |
| POLAR | Short summers below 10°C and long severe winters below 0°C, extremes < -40°C unless oceanic | Growing-season too cool for wood-producing enzymes: no trees or significant shrubs | Polar regions and alpine belts of mountains |

done in Table 5, unifying the basic terminology from a global perspective while focusing also on the main limiting factors of the main vegetation zones. This also coincides with the usage of Kira, Walter, and others, resulting in relatively well balanced tropical, temperate, and polar regions.

In East Asia and to a lesser extent in southeastern North America, this results in evergreen broad-leaved forest spanning the warm-temperate and adjacent (humid) subtropical zone — and spanning the major taxonomic discontinuity, without striking difference in physiognomy. The two parts of the evergreen broad-leaved forest zone, at least in the Northern Hemisphere, can be distinguished as follows (cf. Fujiwara 1981-86):

1) warm-temperate evergreen broad-leaved forests are mainly lauro-fagaceous, with a few tolerant subtropical taxa and a temperate deciduous element; the secondary forest is mainly temperate deciduous;
2) subtropical evergreen broad-leaved forests are also mainly lauro-fagaceous, but with many taxa which are exclusively tropical/subtropical and very few truly temperate elements; the secondary forest is mainly evergreen, often formed by coppice of canopy species.

The boundary between subtropical and warm-temperate is the taxonomic discontinuity, since the appearance of significant frost limits the tropical taxa. Subtropical (evergreen) plants can tolerate only infrequent, very short periods of very light frost, if they tolerate any frost at all; warm-temperate (evergreen) plants tolerate at least light frost every year and may tolerate temperatures as low as about -15℃ overnight (cf. Larcher 1976; Woodward 1987; Box 1995a, 1995b).

In this sense, the laurophyll forests in the central Taiwanese mountains appear to be at most only transitional to the subtropics, since there are few exclusively (sub)tropical taxa. The typhoon forest in southern Taiwan is marginally subtropical, as seen from its larger component of non-laurophyll, (sub)tropical elements such as *Glochidion, Engelhardtia, and Pithecellobium.* Lowland regions (and plants) should not be called tropical until truly tropical taxa appear inland, not just along a coastal strand (cf. southern Taiwan), and dominants of the warm-temperate lauro-fagaceous forest largely disappear or are at least reduced to successional status.

## Regeneration Potential of East-Asian Laurophyll Forests

Not only proximal forest disturbance but also effects of global warming suggest that it may be important to examine the regeneration potential of laurophyll forests, both *in situ* and relative to dispersal and migration. Occurrence of canopy and tree-understorey species in the lower stand layers provides initial suggestions of regeneration potentials and is summarized in Table 6 for the three relevēs. This table also shows more graphically the differences in canopy structure between the mature laurophyll forest relevēs, which are composed almost totally of laurophyll species, and the typhoon forest of southern Taiwan, with more non-laurophyll species.

The first impression one gets from these data is that regeneration is occurring for most tree species but is rather idiosyncratic in any particular stand, with some canopy species showing seedlings and others not. There was also regeneration by woody laurophyll species not in the canopy (see Relevē 2), but in the other two samples the relatively few seedlings in the herb layers were of canopy species. In the laurel forest sample the only woody seedlings in the herb layer were of *Beilschmidia erythrophloia,* which also had saplings in the shrub layer. *Schima superba* (including var. *kankoensis*) was the only species common to the canopy of all three relevēs but did not occur in a lower relevē layer except in the typhoon forest. Every other true canopy species occurred in a lower relevē layer except *Machilus kusanoi* from the laurel forest (Relevē 1) and *Castanopsis*

**Table 6.** Regeneration by main canopy tree species in Taiwanese Laurophyll forest stands studied.

| | Guan-Gao | | | | Yi-Nu Pu-Bu | | | | Kenting | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | $T_1$ | $T_2$ | S | H | $T_1$ | $T_2$ | S | H | $T_1$ | $T_2$ | S | H |
| Lauraceae | | | | | | | | | | | | |
| *Actinodaphne nantoensis* | | | | | . | + | . | . | | | | |
| *Beilschmidia erythrophloia* | 3 | . | 1 | 2 | 1 | 1 | 1 | . | | | | |
| *Beilschmidia tsangii* | | | | | | | | | + | . | + | . |
| *Cinnamomum insularimontanum* | | | | | . | + | . | . | | | | |
| *Cinnamomum randaiense* | . | 1 | . | . | | | | | | | | |
| *Cryptocarya chinensis* | | | | | | | | | . | . | + | . |
| *Machilus japonica* | . | 1 | + | . | 1 | 1 | + | + | | | | |
| *Machilus kusanoi* | 2 | . | . | . | | | | | | | | |
| *Machilus thunbergii* | 2 | . | . | . | . | + | . | . | . | . | + | . |
| *Machilus zuihoensis* | | | | | | | | | + | . | + | . |
| Fagaceae | | | | | | | | | | | | |
| *Castanopsis carlesii* | | | | | 5 | + | + | . | . | . | + | . |
| *Castanopsis indica* | | | | | | | | | 4 | + | + | . |
| *Castanopsis stellato-spina* | | | | | | | | | + | . | . | . |
| *Cyclobalanopsis longinux* | | | | | + | . | . | . | + | + | 1 | . |
| *Lithocarpus amygdalifolius* | | | | | | | | | . | . | + | . |
| *Lithocarpus lepidocarpus* | 1 | 1 | . | . | + | + | + | . | | | | |
| *Pasania brevicaudata* | | | | | | | | | . | + | + | . |
| *Pasania kawakamii* | 1 | . | . | . | + | 1 | + | + | | | | |
| *Quercus stenophylloides* | | | | | . | . | + | . | | | | |
| Other laurophyll trees | | | | | | | | | | | | |
| *Elaeocarpus sylvestris* | | | | | 1 | . | + | . | 3 | . | + | . |
| *Evodia roxburghiana* | | | | | . | + | . | . | | | | |
| *Gordonia axillaris* | | | | | . | . | + | . | + | + | . | . |
| *Michelia compressa* | . | + | . | . | . | . | + | . | + | + | + | . |
| *Schima superba* (+ var *kanko.*) | 1 | . | . | . | 2 | . | . | . | 2 | + | + | . |
| *Turpinia formosana* | . | 2 | 2 | . | . | + | 2 | . | | | | |
| *Daphniphyllum glaucescens* | | | | | | | | | + | + | + | + |
| *Eurya hayatai* | | | | | | | | | + | . | 1 | . |
| *Helicia formosana* | | | | | | | | | . | + | 1 | . |
| *Ilex cochinchinensis* | | | | | | | | | + | 1 | + | . |
| *Ilex formosae* | | | | | | | | | + | + | 1 | . |
| *Symplocos wikstroemifolia* | | | | | | | | | + | . | + | . |
| *Syzygium euphlebium* | | | | | | | | | + | . | . | . |
| Other trees | | | | | | | | | | | | |
| *Astronia ferruginea* | | | | | | | | | + | . | + | . |
| *Engelhardtia roxburghiana* | | | | | | | | | 2 | + | 1 | . |
| *Eriobotrya deflexa* | | | | | 1 | . | + | . | | | | |
| *Ficus formosana* | | | | | | | | | . | . | + | . |
| *Glochidion lanceolatum* | | | | | | | | | . | + | . | . |
| *Glochidion rubrum* | | | | | | | | | + | . | + | . |
| *Pithecellobium lucidum* | | | | | | | | | + | . | + | + |
| *Prunus phaeostica* (Rosaceae) | | | | | | | | | + | . | . | . |
| *Sapium discolor* (Euphorbiaceae) | | | | | | | | | + | . | . | . |
| *Schefflera octophylla* (Araliaceae) | | | | | | | | | 2 | . | + | . |

*stellato-spina* from the typhoon forest (Relevé 3). There seems to be less regeneration by shrubs than by tree species, perhaps due to the greater resources (light) available to the taller trees. The pattern of lower-level regeneration in the Chinese relevés (not shown) was similar.

Under global warming, dispersal potential becomes important along with the ability to germinate and grow in a forest understorey or opening. The kinds of species which might regenerate successfully under these conditions are suggested, for central Japan, by data on those species which invade planted forests of potential canopy species in urban and peri-urban areas (Fujiwara and Box, in press). In the 35 plots studied, woody species which entered the most plots the fastest included weedy shrubs such as *Ligustrum japonicum,* less undesirable species such as *Euonymus japonicus* and *Pittosporum tobira,* but also deciduous trees such as *Celtis sinensis* var. *japonica* and *Aphananthe aspera* (both Ulmaceae), and a few laurophylls such as *Cinnamomum japonicum* and *Neolitsea sericea* (Lauraceae), *Eurya japonica* (Theaceae), and shrubs *Fatsia japonica* and *Aucuba japonica.*

## Conclusion

The richness of East Asian laurophyll forests, as represented by the two mature stands documented from the mountains of central Taiwan, is extraordinary, but especially so in Lauraceae, in laurophyll taxa in general, and in higher-level relative richness (number of genera and families relative to richness in the next lower levels). In this respect these forests approach the tropical pattern, in which almost every individual in tropical rainforest plots may represent a different species, usually a different genus, and often a different family.

This fact alone, however, does not make the laurophyll forests, tropical or even subtropical, since taxa which are limited to the tropics and subtropics may not be well represented. Most laurophyll species are not limited to the tropics and/or subtropics but rather come up through the subtropical zone and well into the warm-temperate zone as their coldness sensitivities permit. Most East Asian laurophyll species tolerate significant frost, to temperatures as low as about -15℃ as a general limiting value (even for short-term exposure). The major taxonomic discontinuity as one enters the subtropics from the temperate zone occurs in the middle of the evergreen broad-leaved forest zone of the Northern Hemisphere, both in East Asia and in eastern North America. This is less clear in the Southern Hemisphere, but there is no compelling general biogeographic evidence to the contrary. As a result, one has the interesting situation in which evergreen broad-leaved forests, including laurophyll forests, span the warm-temperate and (humid) subtropical zones on continental east sides, with little change in physiognomy or in representation of laurophyll genera and families — but with a major genus-level discontinuity outside these main laurophyll families.

Evergreen broad-leaved forests, including laurophyll forests, can be classified as warm-temperate or subtropical based on climatic criteria, the biogeographic ranges of the taxa involved (mainly above the species level), and on the typical composition of their secondary forest vegetation after disturbance. These three classes of specific criteria usually agree; if not, the location in question may best be described as transitional.

Natural regeneration of East Asian laurophyll forests, both *in situ* after disturbance and involving dispersal and migration, appears to be relatively good. Many taxa characteristic of mature forests produce fleshy fruits which can be dispersed readily by birds, especially the Lauraceae, Elaeocarpaceae, Magnoliaceae, and Theaceae. In the subtropical zone these laurophyll taxa may have less competition from the bird-dispersed fleshy fruits of Rosaceae and other more typically temperate taxa and so may be able to disperse faster, including migration as necessary under conditions of global warming.

The situation for laurophyll forests under global warming may be suggested somewhat by the composition of the typhoon forest shown in Relevé 3. Warmer conditions will cause canopy and subcanopy trees to die off (probably gradually), opening the canopy for colonization by other species. These other species may involve a greater number of tropical and subtropical taxa, as in the typhoon-forest sample. Canopy laurophyll species will not necessarily be eliminated from these areas, though, just because canopy individuals have died. Their seedlings may tolerate the warmer conditions and be able to remain in these locations quite well as long as they adapt their metabolism, biomass accumulation, and consequent respiration loads to the new conditions.

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**Appendix** : Species identified from three laurophyll forest stands studied in Taiwan.

Identifications were made mainly by the Taiwanese co-author and colleagues, following the nomenclature of the "Flora of Taiwan" (Flora of Taiwan Editing Committee 1975-79). Species are listed by family, based on Mabberley (1987). Species occurrences in the three stands (see main text) are indicated as follows: G = Guan-Gao (Yu-Shan Mountains, central Taiwan); Y = Yi-Nu Pu-Bu (Yu-Shan Mountains, central Taiwan); K = Kenting National Park (Nan-Jen Shan, southern Taiwan). Information on distribution outside Taiwan is from the "Flora of Taiwan" supplemented as needed by Miyawaki et al. (1994). Species not listed in the "Flora of Taiwan" are indicated by a following asterisk.

| **Pteridophyta** | Stands | Distribution outside Taiwan |
|---|---|---|
| Adiantaceae (incl. Pteridaceae) | | |
| *Coniogramme* sp. | . Y . | (genus: Africa to Polynesia) |
| *Pteris cretica* (< Pteridaceae) | . Y . | tropical & temperate regions |
| *Pteris fauriei* | . Y . | China to SE Asia and Japan |
| *Pteris tokioi* | G . . | S Japan |
| Aspleniaceae (incl. Athyriaceae) | | |
| *Acrophorus stipellatus* (< Dryopterid.) | . Y . | N India to Pacific islands |
| *Arachniodes amabilis** (< Dryopteridac.) | G Y . | India, Malaysia, China to Japan |
| *Arachniodes aristata* | G . . | Pakistan to Malaysia, Japan, Polynesia |
| *Arachniodes pseudaristata* | G Y . | Japan, Ryukyus |
| *Asplenium antiquum* | G . . | Japan, Ryukyus |
| *Diplazium dilatatum* (Athyrioidae) | G . K | Indonesia, China, Ryukyus |
| *Diplazium donianum* (Athyrioidae) | G . K | India, SE Asia, China, Ryukyus |
| *Diplazium mettenianum* (Athyrioidae) | . . K | China, Japan |
| *Dryopteris* sp. (< Dryopteridac.) | G . . | (genus: cosmopolitan) |
| *Dryopteris* $sp_1$ | . Y . | |
| *Dryopteris* $sp_2$ | . Y . | |
| *Dryopteris* $sp_3$ | . Y . | |
| *Pleocnemia rufinervis* (< Aspidiac.) | . . K | India to Philippines (cf. *Tectaria*) |
| *Polystichum hancockii* (< Dryopteridac.) | G . . | S China to Japan |
| *Polystichum* sp. | . Y . | |
| Blechnaceae | | |
| *Blechnum orientale* | . . K | tropical Asia, Pacific, Australia |
| Dennstaedtiaceae | | |
| *Microlepia marginata* | G . . | India, Himalaya to SE Asia, Japan |
| *Microlepia* $sp_2$ | G . . | |
| *Microlepia* sp. | . Y . | |
| Hymenophyllaceae | | |
| *Trichomanes auriculatum* (Vandenboschia) | G . . | Japan to Indonesia, Philippines |
| Polypodiaceae | | |
| *Microsorium buergerianum* | G Y . | Vietnam, China to Japan |
| Thelypteridaceae | | |
| *Pronephrium triphyllum* | . . K | Sri Lanka to Japan, Australia |

| Gymnospermae | Stands | Distribution outside Taiwan |
|---|---|---|
| Cephalotaxaceae | | |
| *Cephalotaxus wilsoniana* | . Y . | **endemic** to Taiwan |
| Podocarpaceae | | |
| *Podocarpus formosensis* | . . K | SE China |

| Angiospermae: Monocotyledonae | | |
|---|---|---|
| Araceae | | |
| *Epipremnum pinnatum* | . . K | Australia to China, Polynesia |
| Cyperaceae | | |
| *Carex lenta** | . Y . | India, China to Japan |
| *Carex* sp. | . Y . | (genus: cosmopolitan) |
| Gramineae | | |
| *Lophatherum gracile* | . . K | India, Malaysia, China to Japan |
| *Oplismenus compositus* | . Y . | cosmopolitan |
| *Schizostachyum diffusum* (bamboo) | . . K | Philippines |
| Liliaceae | | |
| *Aspidistra daibuensis* | . . K | **endemic** to Taiwan |
| *Ophiopogon* sp. | . Y . | (genus: eastern India to East Asia) |
| *Ophiopogon* $sp_1$ | . . K | |
| *Ophiopogon* $sp_2$ | . . K | |
| Orchidaceae | | |
| *Calanthe arisanensis* | . Y . | **endemic** to Taiwan |
| *Calanthe* sp. | . . K | |
| *Cymbidium* sp. | . Y . | (genus: tropical and E Asia, Australia) |
| *Goodyera* sp. | G . . | (genus: world except Africa, polar) |
| Palmae | | |
| *Daemonorops margaritae* | . . K | southern China |
| Smilacaceae | | |
| *Smilax bracteata* ssp. *verruculosa* | G . . | SE Asia, Philippines |
| *Smilax lanceifolia* | . . K | Himalaya to SE China, Malesia |
| *Smilax* $sp_1$ | . Y . | (genus: tropical and subtropical) |
| *Smilax* $sp_2$ | . Y . | |
| *Smilax* sp. (seedling) | . Y . | |
| *Smilax* sp. | . . K | |
| Zingiberaceae | | |
| *Alpinia* sp. | . Y . | (genus: Old World tropics) |
| *Alpinia* sp. (tall) | G . . | |
| *Zingiber kawagoii* | . . K | **endemic** to Taiwan |

| Angiospermae: Dicotyledonae | Stands | Distribution outside Taiwan |
|---|---|---|
| Acanthaceae | | |
| *Codonacanthus pauciflorus* | . . K | India, S China, Ryukyus, Japan |
| *Semnostachya longespicatus* (now *-cata*) | . . K | **endemic** to Taiwan |
| Annonaceae | | |
| *Fissistigma glaucescens** | . . K | (cultivated) |
| Apocynaceae | | |
| *Trachelospermum asiaticum* | G . . | (included in *T. gracilipes*) |
| *Trachelospermum gracilipes* | . Y K | NE India through China to SE Asia |
| Aquifoliaceae | | |
| *Ilex asprella* | . . K | Luzon, SE China |
| *Ilex cochinchinensis* | . . K | N Indo-China, Hainan |
| *Ilex formosae* | . . K | **endemic** to S tip of Taiwan |
| *Ilex formosana* | G Y . | southern China |
| *Ilex matsudai* | . . K | **endemic** to S Taiwan (Hengchun Pen.) |
| Araliaceae | | |
| *Acanthopanax trifoliatus* | . Y . | *s.l.*: India to Philippines, China |
| *Hedera rhombea* | . Y . | Japan, Korea |
| *Schefflera octophylla* | . . K | S China to SE Asia, Ryukyus |
| Boraginaceae | | |
| *Ehretia longiflora* | . . K | SE Asia, Hainan, Hong Kong |
| Caprifoliaceae | | |
| *Lonicera acuminata* | . Y . | E India to China |
| *Viburnum odoratissimum* | . . K | India, S China, Philippines, Japan |
| *Viburnum parvifolium* | . Y . | **endemic** to Taiwan central mountains |
| Celastraceae | | |
| *Microtropis japonica* | . . K | Japan, Ryukyus |
| Chloranthaceae | | |
| *Sarcandra glabra* | . . K | Sri Lanka to Java, Philippines, Japan |
| Daphniphyllaceae | | |
| *Daphniphyllum glaucescens* (= *oldhamii*) | . . K | Cambodia, Vietnam, S China to Japan |
| *Daphniphyllum himalaense* | . Y . | China, Korea, Japan |
| Ebenaceae | | |
| *Diospyros eriantha* | . . K | Malaysia to S China, Japan |
| Elaeagnaceae | | |
| *Elaeagnus* sp. | . Y . | (genus: S Europe, Asia, N America) |
| Elaeocarpaceae | | |
| *Elaeocarpus sylvestris* | . Y K | S China, Ryukyus, Japan |

| (Angiospermae: Dicotyledonae) | Stands | Distribution outside Taiwan |
|---|---|---|
| Euphorbiaceae | | |
| *Glochidion lanceolatum* | . . K | Ryukyus |
| *Glochidion rubrum* | . . K | Malaysia, Ryukyus |
| *Sapium discolor* | . . K | Malaysia, S China |
| | | |
| Fagaceae | | |
| *Castanopsis carlesii* | . Y K | *s.l.*: SE China |
| *Castanopsis indica* | . . K | Hainan |
| *Castanopsis stellato-spina* | . . K | **endemic** to Taiwan |
| *Cyclobalanopsis longinux* | . Y K | **endemic** to Taiwan |
| *Lithocarpus amygdalifolius* | . . K | SE China |
| *Lithocarpus lepidocarpus* | G Y . | **endemic** to Taiwan |
| *Pasania brevicaudata* | . . K | SE China |
| *Pasania kawakamii* | G Y . | **endemic** to Taiwan |
| *Quercus stenophylloides* (=*Cyclobal. st.*) | . Y . | **endemic** to Taiwan |
| | | |
| Flacourtiaceae | | |
| *Idesia polycarpa* | . Y . | Central China to Japan |
| | | |
| Grossulariaceae (< Saxifragaceae) | | |
| *Itea parviflora* | G Y . | **endemic** to Taiwan |
| | | |
| Guttiferae | | |
| *Garcinia multiflora* | . . K | southern China |
| | | |
| Hydrangeaceae (< Saxifragaceae) | | |
| *Hydrangea chinensis* | . Y . | W and S China, Philipp., Ryukyus |
| | | |
| Illiciaceae | | |
| *Illicium arborescens* | . . K | **endemic** to Taiwan |
| | | |
| Juglandaceae | | |
| *Engelhardtia roxburghiana* | . . K | (India to Malaysia, W and S China) |
| | | |
| Lardizabalaceae | | |
| *Stauntonia hexaphylla* | G . K | Japan, Ryukyus |
| *Stauntonia* sp. | . Y . | (genus: eastern Asia) |
| | | |
| Lauraceae | | |
| *Actinodaphne nantoensis* | . Y . | (now in *Litsea acuminata*) |
| *Beilschmidia erythrophloia* | G Y K | Hainan, Ryukyus |
| *Beilschmidia tsangii* | . . K | SE China (Guangdong) |
| *Cinnamomum insularimontanum* | . Y . | **endemic** to Taiwan |
| *Cinnamomum randaiense* | G . . | **endemic** to Taiwan |
| *Cryptocarya chinensis* | . . K | SE China, Ryukyus |
| *Litsea acuminata* | G Y . | Japan |
| *Litsea nakai* | . . K | **endemic** to Hengchun Peninsula |
| *Machilus japonica* | G Y . | Japan, Ryukyus, S Korea |
| *Machilus kusanoi* | G . . | (now in *Persea japonica*) |
| *Machilus thunbergii* | G Y K | China, Korea, Japan |
| *Machilus zuihoensis* | . . K | **endemic** to Taiwan |
| *Neolitsea buisanensis* | . . K | **endemic** to Taiwan |

| (Angiospermae: Dicotyledonae) | Stands | Distribution outside Taiwan |
|---|---|---|
| Leguminosae | | |
| *Bauhinia championii* | G . . | southern China |
| *Desmodium* sp. | . Y . | (genus: temperate and tropical) |
| *Mucuna macrocarpa* | G . . | Malaysia, Polynesia |
| *Pithecellobium lucidum* | . . K | Hong Kong, Hainan, Ryukyus |
| Loganiaceae | | |
| *Strychnos henryi* | . . K | **endemic** to Taiwan |
| Magnoliaceae | | |
| *Michelia compressa* | G Y K | S Japan, Ryukyus |
| Melastomataceae | | |
| *Astronia ferruginea* | . . K | northern Philippines |
| Moraceae | | |
| *Ficus* sp. (apocynoid) | . . K | (genus: tropical/subtropical) |
| *Ficus erecta* | G . K | *s.l.*: India to Malaysia, Japan |
| *Ficus formosana* | . . K | *s.l.*: S and N China |
| *Ficus nipponica* (=*F. sarm.* v. *nipponica*) | . Y . | China, Ryukyus, Japan |
| *Ficus sarmentosa* var. *henryi* | G . . | southern China |
| *Ficus tannoensis* | G . . | **endemic** to Taiwan |
| *Morus australis* | . Y . | India to Indonesia, Japan |
| Myrsinaceae | | |
| *Ardisia cornudentata* | . . K | **endemic** to Taiwan |
| *Ardisia crenata* | G Y . | southern and SE, Ryukyus, Japan |
| *Ardisia quinquegona* | . . K | Malaysia, S China to Ryukyus |
| *Ardisia sieboldii* | . . K | S Japan, Ryukyus, Bonins |
| *Embelia lenticellata* | . Y . | **endemic** to Taiwan |
| *Maesa formosana* (now in *M. tenera*) | . Y . | S China, SE Asia, Japan |
| Myrtaceae | | |
| *Syzygium euphlebium* | . . K | **endemic** to Hengchun Peninsula |
| Oleaceae | | |
| *Jasminum hemsleyi* | . Y . | **endemic** to Taiwan |
| *Osmanthus marginatus* | . . K | southern China to Ryukyus |
| *Osmanthus matsumuranus* | . Y . | Khasia to S China, SE Asia |
| Piperaceae | | |
| *Peperomia reflexa* | G . . | pan-tropical |
| *Piper kadsura* | G Y K | Japan, Ryukyus, S Korea |
| Polygonaceae | | |
| *Polygonum* sp. | . Y . | (genus: cosmopolitan, esp. N Hem.) |
| Proteaceae | | |
| *Helicia formosana* | . . K | **endemic** to Taiwan |

| (Angiospermae: Dicotyledonae) | Stands | Distribution outside Taiwan |
|---|---|---|
| Ranunculaceae | | |
| *Clematis alsomitrifolia* | . Y . | Ryukyus |
| *Clematis* sp. | . Y . | (genus: widespread in temperate) |
| Rosaceae | | |
| *Eriobotrya deflexa* | . Y . | **endemic** to Taiwan |
| *Prunus phaeostica* | . . K | Assam and southern China |
| *Rubus swinhoei* | . Y . | southern China |
| Rubiaceae | | |
| *Damnacanthus indicus* | . Y . | East Asia |
| *Gardenia jasminoides* | . . K | S China, SE Asia, to Japan |
| *Lasianthus plagiophyllus* | . . K | S China to Ryukyus, Philippines |
| *Lasianthus* sp. | . . K | (genus: paleotropics) |
| *Litosanthes biflora* | . . K | tropical Asia |
| *Mussaenda parviflora* | . Y . | **endemic** to Taiwan |
| *Psychotria rubra* | . . K | S China, Hainan, Ryukyus, Japan |
| *Psychotria serpens* | . . K | SE Asia, China to Japan |
| *Tarenna gracilipes* | . . K | **endemic** to Taiwan |
| *Tricalysia dubia* | G . . | China, Japan |
| Rutaceae | | |
| *Evodia roxburghiana* (in *E. merrillii*) | . Y . | **endemic** to Taiwan (N and S tips) |
| *Zanthoxylon nitidum* | . . K | Moluccas, New Guinea, Ryukyus |
| *Zanthoxylon scandens* | . Y . | India to Borneo, S China, Ryukyus |
| Sabiaceae | | |
| *Meliosma rigida* | . . K | Himalaya to China, Japan |
| Salicaceae | | |
| *Salix* sp. | . Y . | (genus: colder regions except Australia) |
| Schisandraceae | | |
| *Schisandra arisanensis* | G Y . | **endemic** to Taiwan |
| Staphyleaceae | | |
| *Turpinia formosana* | G Y . | **endemic** to Taiwan |
| Symplocaceae | | |
| *Symplocos cochinchinensis* | . Y . | India to SE Asia, Malesia, Japan |
| *Symplocos glomerata* | . . K | India to Malaysia, Hainan |
| *Symplocos wikstroemifolia* | . . K | Malaya, SE Asia, S & central China |
| Theaceae | | |
| *Adinandra formosana* var. *hypochlora* | . . K | **endemic** to Taiwan |
| *Eurya glaberrima* | G . . | **endemic** to Taiwan |
| *Eurya hayatai* | . . K | **endemic** to Taiwan |
| *Eurya leptophylla* | G Y . | **endemic** to Taiwan |
| *Eurya strigillosa* | G . . | Ryukyus |
| *Gordonia axillaris* | . Y K | *s.l.*: S China and SE Asia |
| *Schima superba* | G Y . | southern China, Ryukyus |
| *Schima superba* var. *kankoensis* | . . K | **endemic** to Taiwan |
| *Ternstroemia gymnanthera* | . Y . | Indo- Malay to Philipp., S China, Japan |

| (Angiospermae: Dicotyledonae) | Stands | Distribution outside Taiwan |
|---|---|---|
| Thymeleaceae | | |
| *Wikstroemia taiwanensis* | . . K | (none given; not Japan or China) |
| Urticaceae | | |
| *Boehmeria* sp. | . Y . | (genus: tropical to N subtropics) |
| *Pellionia radicans* | G . . | Central-south China, Japan, Ryukyus |
| *Procris laevigata* | G . . | tropical Asia, Malaysia, Africa |
| Verbenaceae | | |
| *Callicarpa formosana* | . Y . | Philippines, SE and S China, Ryukyus |
| *Callicarpa remotiflora* | . . K | now **endemic** *C. remotiserrulata* |
| Vitaceae | | |
| *Parthenocissus himalayana** | G Y . | Himalaya to southern China |
| *Tetrastigma formosana* (= *T. formosanum*) | G Y . | Ryukyus |
| Unknown | | |
| unknown shrub sp. | . Y . | (not *Itea* or *Paederia*) |
| unknown canopy tree sp. | . Y . | (not *Itea*) |