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World-wide Distribution of Evergreen Lucidophyll Oak-laurel Forests*

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ABSTRACT World-wide distribution of humid evergreen forests in summer-rain warm-temperate, wet subtropical and tropical zones was screened by a number of literatures hitherto published. These forests are dominated mainly by evergreen tree species of Fagaceae, Lauraceae, Theaceae, Magnoliaceae, Hamamelidaceae and so on. Trees of this type of forests have common characters of leathery smooth leaves ready to reflect the sunshine and brighten. This type of forests are found in the lowland in the temperate region, lower and upper montane zones in the subtropical and tropical regions. As the result of it there is a divergence of nomenclature of the forest. Kira (1977) put forward a proposal of 'lucidophyll forest' as a new nomenclature of this type of evergreen broad-leaved forest, but some trees other than lucidophyll forest have lucid leaves. So I would like to propose a new term, evergreen lucidophyll oak-laurel forest for the forest under discussion.

The lucidophyll oak-laurel forests have a wide range of distribution both in the temperate, subtropical and tropical regions of Asia, New Guinea, Macaronesia, southeastern United States, Central and South America. *Nothofagus* forest is only coexisting with lucidophyll forest in New Guinea and its associated islands by making an altitudinal zone. It is commonly found in upper altitudes from the lucidophyll forest there and there is even a case that it appears between the lucidophyll forests. Taking also the character of *Nothofagus* leaves into consideration the present author think that the *Nothofagus* forest is as an evergreen lucidophyll oak-laurel forest evolved and developed in the southern Hemisphere. If it is natural, the distribution of the lucidophyll forests extends to Australia, New Zealand and southern Andes except for deciduous *Nothofagus* forests in Patagonia and Tasmania.

Key Words: evergreen broad-leaved forest / lucidophyll oak-laurel forest / tropical montane forest/ oak-laurel forest / Asian vegetation / Southeast Asia / vertical zonation / forest formation / *Nothofagus* forest.

Forest vegetation of evergreen humid forest formation in the temperate region was introduced as Lorbeerform (Griesebach, 1872), temperierte Regenwald (Schimper, 1898), Laurisilvae (Brockmann-Jerosch und Rübel, 1912). Later Rübel (1930) gave examples of the distribution of Laurisilvae; Canarias Islands, Madeira Islands, Portugal, Pacific coast of North America, Florida, Chile, Patagonia, Japan, southfacing slope of the Himalayas, Cape and New Zealand.

Schimper paid his attention to such characters of temperate rain forest as a forest of evergreen and hygrophilous trees with leaves of glabrous, entire, leathery, thick and developed cuticle, and glossy upper surface. Schimper and Brockmann-Jerosch and Rübel included *Nothofagus* forests in the southern hemisphere into temperate rain forests or Laurisilvae. The present author would like to touch upon whether *Nothofagus* should be included in laurisilva in the northern hemisphere or not.

Kira (1977 & 1991; Imanishi & Kira, 1953) put forward a proposal of lucidophyll forest as a new

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nomenclature of Laurisilvae in Asia. Lucidophyll forests are found in a wide range of Kira's warmth index between 85 and 180°C month, which corresponds to warm temperate zone, and between 180 and 240°C month to subtropical zone in East Asia.

This type of forests mainly composed of evergreen Fagaceae, Lauraceae, Theaceae, Hamamelidaceae is widely distributed in the world from southfacing slope of the Himalayas as described by Rübel and also in the other areas of Asia (Korea, China and Taiwan, India, Sri Lanka, Myanmar, Thailand, Viet Nam, Malaysia, and Indonesia), and New Guinea Island. In the tropical region the forest goes up in the higher altitudes and they are called by various names. In this paper the author would like to discuss the distribution of lucidophyll forests in Asia and in the areas other than Asia including New Guinea Island, Macaronesia, Southeast of North America, Australia, New Zealand and South America, their species composition and diversified terms for this type of forest formation, and propose a new nomenclature, lucidophyll oak-laurel forest formation.

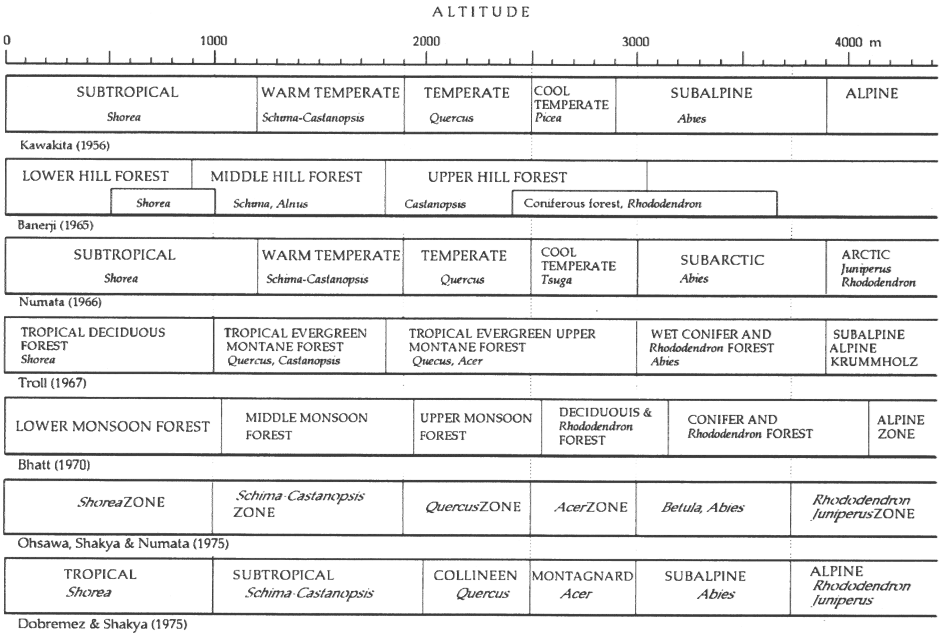
REFERENCE STUDY ON THE LUCIDOPHYLL OAK-LAUREL FORESTS IN ASIA, MACARONESIA, SE OF NORTH AMERICA, CENTRAL AND SOUTH AMERICA

1 Asia

The Himalayas (Nepal, Sikkim and Bhutan)

Various papers concerning evergreen broad-leaved forests on the Eastern Himalayas and in Bhutan were collectively shown by Ohsawa (1977) as in Table 1. On the south slope of Mt. Jolmo-lungma (Everest) montane evergreen broad-leaved forest zone was recognized between 1000 and 2500m (Chang and Chiang, 1973), and it is mainly dominated by *Castanopsis indica*, *Engelhardtia* sp., and

Table 1. Altitudinal vegetation zones of Nepal Himalaya written by many authors. (Ohsawa, 1977, by courtesy of the author.)



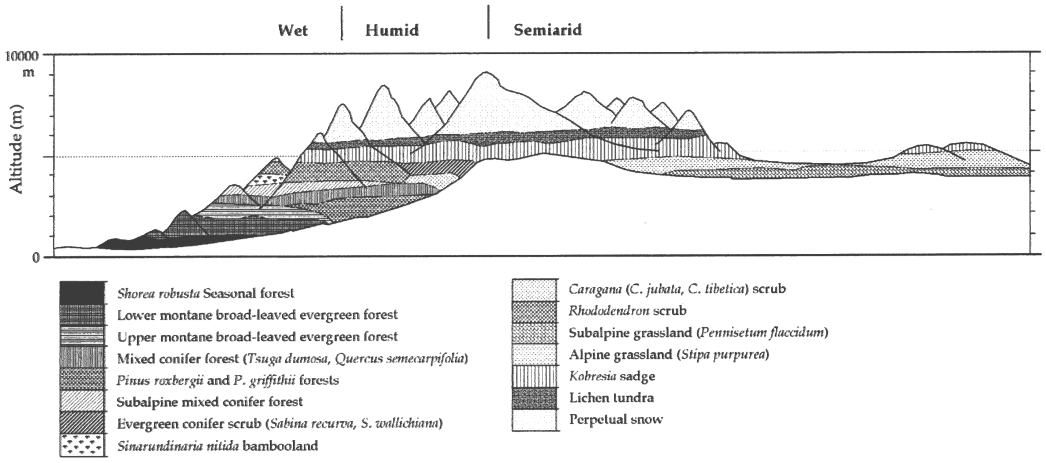


Fig. 1 Vertical zonation of vegetation around Mt. Everest (Chang and Chiang, 1973)

Schima wallichii with many subdominants of *Quercus lamellosa*, *Q. lineata*, *Q. glauca*, *Michelia excelsa* and *Lithocarpus* spp. In the upper part of the zone one conifer species, *Tsuga dumosa* (*yunnanensis*), was mixed with evergreen broad-leaved trees and eminent above the canopy. In the montane mixed conifer forest zone (2500-3000m) *T. dumosa* and *Quercus semecarpifolia* made a canopy. While on the north-facing slope of the Himalayas (Fig. 1) plants are exposed to severe desiccation, and no forests were found.

China

The lucidophyll oak-laurel forests in China are classified into subtropical and warm-temperate forest groups by the Editorial Committees for Vegetation of China (1980), for Vegetation of Yunnan (1987) and for Forests of Yunnan (1986). Forests of warm-temperate group are found in the south of Huai Hé and Qin Hé River and middle altitudes of Yunnan Province.

In Jiulianshan Forest Reserve (ca 24°30'N), various types of evergreen broad-leaved forest are found from 280m to about 1200m as subtropical evergreen broad-leaved forests (Management Station of Jiulianshan Forest Reserve, 1987). According to Chinese system of climate monthly air temperature in the range of 2-14°C is in the temperate climate, 14-22°C to subtropical and higher than 22°C to the tropical zones.

The forests in the Jiulianshan Forest Reserve are classified into 16 types; dominants and their distributional ranges are *Adinandra millettii* (440m), *Schima superba* (300-760m), *Castanopisis fordii* (530m), *C. fargettii* (600-800m), *C. carlesii* (460-1180m), *C. eyrei* (750m), *C. lamontii* (740-960m), *C. fabri* (500-1000m), *Cyclobalanopsis glauca* (400-600m), *Cy. oxyodon* (1000m), *Cy. nubium* (1100m), *Lithocarpus calophylla* (900m), *Michelia maudiae* (900m), *Litsea elongata* (900m), *Machilus thunbergii* (1100m) and *Adinandra bockiana* (1200m).

In Yunnan Province, 9 types of evergreen broad-leaved forest are recognized in the warm-temperate zone at altitudes from 1500m to 3000m. They are;

i) *Rhodoleia parvipetala forest* (2000-2600m); *Actinodaphne*, *Alseodaphne*, *Machilus*, *Neolitsea*, *Cyclobalanopsis*, *Lithocarpus*, *Manglietia*.

ii) *Lithocarpus echinophorus* forest (2000-2500m);*Cyclobalanopsis*, *Schima*, *Michelia*, *Actinodaphne*, *Cinnamomum*, *Lindera*, *Machilus*.

iii) *Lithocarpus craibianus* forest with deciduous species (2500-2600m); *Acer*, *Betula*, *Prunus*,

Quercus.

iv) *Lithocarpus variolosus* forest (2500-3000m) an uppermost type of evergreen broad-leaved forest.

v) *Lithocarpus cleistcarpus-Castanopsis platyacantha* forest (1500-2600m)

vi) *Cyclobalanopsis glaucoides* forest (1300-2300m); *Lithocarpus*, *Machilus*, *Photinia*, *Magnolia*, *Pittosporum*.

vii) *Castanopsis delavayi* forest (1700-2200m); *Pinus*, *Populus*, *Quercus*.

viii) *Castanopsis orthacantha* forest (1900-2600m); *Cyclobalanopsis*, *Lithocarpus*.

ix) *Cyclobalanopsis delavayi* forest (1900-2500m); *Lithocarpus*, single layered forest.

Four types of forests are recognized in the subtropical zone from 1000 to 1500m.

x) *Castanopsis hystrix-C. indica* forest (1000-1500m); *Schima*, *Engelhardtia*, *Machilus*, *Mischocarpus*.

xi) *Castanopsis fleuryi-Lithocarpus truncatus* forest (1300-1900m); *Cyclobalanopsis*, *Anneslea*, *Machilus*, *Syzygium*.

xii) *Castanopsis fabrii-Lithocarpus calathiformis* forest (1300-1500m); *Machilus*, *Elaeocarpus*, *Diospyros*, *Manglietia*, *Engelhardtia*.

xiii) *Machilus-Castanopsis* forest (1200-1500m); *Sloanea*, *Cyclobalanopsis*, *Lithocarpus*, *Elaeocarpus*, *Cinnamomum*, *Carpinus*.

Watanabe and Abe (1988) defined 6 zones of natural vegetation in Chienfeng Ling Forest Reserve, Hainan Dao, and tropical mountain rain forest (750-1100m) is composed of such tropical dipterocarp species as *Hopea hainanensis*, *H. excelsa* and *Vatica astrotricha* mixed with the warm-temperate species of *Quercus*, *Lithocarpus*, *Castanopsis*, *Livistona saribus*, *Altingia*, *Betula alnoides*, *Dacrydium pierrei*, *Podocarpus hainanensis*, *Keteleeria hainanensis*, etc. They considered that coexistence of the tropical species with warm-temperate species in the narrow range of altitudes may be ascribed to Massenerhebung.

Taiwan

Hosokawa (1958) described Castanopsidion taiwanianae at about 400m to 1500m and Shiion (Castanopsidion) longicaudatae between 800m and 2000m both in the southwestern wet climate of Taiwan, while in northeastern Taiwan there are Shiion stipitatae from 300m to 1500m and Cyclobalanopsidion paucidentatae from 1100m to 2600m. Lowland (subtropical climate at 600-1800m a.s.l.) and lower altitudes of mountains (warm-temperate at 1800-2250m) in Taiwan are covered by dense laurel-leaved forests (Kanehira, 1936; Hsu, 1971). The forests in subtropical zone are dominated and subdominated by *Actinodaphne mushaensis*, *A. nantoensis*, *Beilschmiedia erythrophloea*, *Cinnamomum camphora*, *C. japonicum*, *Cryptocarya chinensis*, *C. konishii*, *Persea kusanoi*, *P. thunbergii*, *P. zuihoensis*, *Neolitsea konishii*, *Phoebe formosana*, *Castanopsis hystrix*, *C. kawakamii*, *Pasania ternaticupula*, *Lithocarpus amygdalifolius*, *Quercus gilva*, *Q. semecarpifolia* ssp. *glabra*, *Michelia compressa*, and *Schima wallichii* ssp. *noronhae*.

In the upper part of the forest belonging to the warm-temperate zone the evergreen broad-leaved forests are gradually replaced by conifer species such as *Pinus armandi*, *P. taiwanensis*, *Cunninghamia konishii*, *Chamaecyparis obtusa*, *C. formosensis*, *Taiwania cryptomerioides* and *Libocedrus formosana*.

India and Sri Lanka

The temperate forests of India are grouped into montane wet temperate, montane moist temperate and

Himalayan dry temperate forests (Gopal and Meher-Homji, 1983). Montane wet temperate forests are dominated by broad-leaved evergreen species which occur both in the Himalayas and in the south Indian ranges (Nilgiri and Palni Ranges) around 10°N.

On Naga Hills, at altitudes from 1750m to 2750m on the Sikkim mountains between Nepal and Bhutan, and near Kalimpong of West Bengal two types of lucidophyll oak-laurel forests are observed. The first is mainly composed of lauraceous species such as *Beilschmiedia erythrofloia*, *Cinnamomum obtusifolium*, *Machilus edulis* and *Litsea japonica*. Canopy of the second type is mainly composed of fagaceous species, *Quercus lamellosa*, *Castanopsis tribuloides*, *Acer campbellii*, *Michelia doltsopa*, and undergrowth are of *Quercus lineata*, *Q. pachyphylla*, *Persea, Litsea*, *Viburnum*, *Daphne*, etc.

Southern wet temperate forests known as 'shola' forests (Gopal & Meher-Homji, ibid) are largely confined to steep slopes and sheltered areas in the higher altitudes of mountains. The stature of the shola forests is about 25m at most with dense closed canopy, and main tree species of it in the western Ghats are *Actinodaphne* spp., *Appolonias arnotti*, *Cinnamomum* spp., *Phoebe wrightii*, *Elaeocarpus* spp., *Gordonia obtusa*, *Euonymus crenulatus*, *Litsea wightiana*, *Meliosma wrightii*, *Michelia nilgirica*, *Photinia lindleyana*, *Symplocos* spp., *Syzygium* spp., without fagaceous species. The existence of abundant epiphytic ferns and mosses means a wet climate of the areas.

In Sri Lanka slopes facing to a monsoon collect high precipitation and those on leewards are exposed to desiccation due to dry foen wind. At altitudes from 600m to 900m wet zone of southwest slope of central highland is covered by tall forest dominated by *Doona gardneri*, *Stemonoporus*, *Myristica dactyloides*, *Ostodes zeylanica*, *Calophyllum*, *Syzygium*, and species of Lauraceae. On the dry zone forests are free from dipterocarps, and laurels (*Litsea, Cinnamomum*, *Cryptocarya*, *Neolitsea*) become important in the forest together with *Calophyllum*, *Syzygium*, *Myristica*, and *Oncospermum*. These laurel forests are, to some extent, similar with the shola forests in floral composition.

Indochina Peninsula

Oak forests locally called 'thicha' are found from 900m to 2100m in altitude in the mountain ranges of Arakan Yoma, Patkoi and on the Shan Plateau (Stamp, 1924). In the Arakan Yoma Mountains thicha forests are composed of *Quercus spicata, Q. brandisiana*, and *Q. serrata*. Near Mogok north of Mandalay *Quercus helferiana*, *Q. mespilifolia* and *Q. fenestrata* are frequent and common to the forests. In the Patkoi Mountains *Quercus pachyphylla* and *Q. thomsoni* are dominant in the thicha forests. On the Maymyo Highland *Quercus serrata* forest occupies a large area. In every thicha forest several species of *Castanopsis* are found.

Lucidophyll forests were grouped into lowland subtropical hardwood forest and high mountain hardwood forest (temperate forest) with the altitudinal range from 1100m to 2600m (Davis, 1964). The forests are mainly composed of *Castanopsis*, *Lithocarpus*, *Quercus*, *Magnolia*, and other evergreen hardwood species. The upper part of the high mountain hardwood forest contains some elements of cool temperate flora such as *Rhododendron*, *Tsuga* and *Abies*. While in the lower part of the lowland subtropical hardwood forest, there are some tropical species of *Dipterocarpus*, *Ficus*, and *Terminalia*.

In Thailand temperate evergreen forests are found in the northwestern highland above 1200m in altitude in the humid places to the top (2576m) of the highest mountain, Don Inthanon (Ogawa *et al.*, 1961). The lowest limit of the forest rises up to about 1400m in the arid places. The main component species and genera of the forest (Ogawa *et al.*, ibid; Yoda & Sahunalu, 1991) are *Castanopsis diversifolia*, *C. acuminatissima*, *Quercus* spp., *Schima wallichii*, *Magnolia*, *Michelia*, *Cinnamomum*,

Gluta usitata, *Helicia erratica*, *Diospyros ehretioides*, *D. ferrea*, *Turpinia*, etc. In the northwestern highland the forest has been replaced by 'alang-alang', a grassland composed of *Imperata cylindrica* and *Eupatrium adenophorum* and covered widely on the barren soil after shifting cultivation.

Symington (1943) classified climax formations of Peninsular Malaysia into 5 types; lowland dipterocarp forests (0-300m), hill dipterocarp forests (300-750m), upper dipterocarp forests (750-1200m), montane oak forests (1200-1500m) and montane ericaceous forests (>1500m). In a vegetation map of western Malaysia made by Wyatt-Smith (1964) montane oak forest is in the range between 1000 and 1700m. While, Burgess (1969) described the altitudinal zonation of Malayan mountains, and oak-laurel forest zone is found between 1320-1650m. Main genera and species there are *Lithocarpus* spp., *Quercus* spp., *Weinmannia blumei*, *Gironniera* spp., *Podocarpus imbricatus*, and *Melanorrhoea* spp.

Islands of Southeast Asia

Natural forests in the lowland and hill areas of Mt. Kerinci in the Barisan Mountains, Sumatra were found only in the forest reserve and restricted areas in higher altitudes than 1900m (Ohsawa, 1982). From 1900m to 2000m *Schima wallichii* var. *noronhae* forest is found with an eminent tree species, *Exbucklandia tricuspis*. Around about 2300m in altitude, forest canopy is made by *Engelhardtia spicata* and *Lithocarpus bennetti* (?). From 2350m to 2700m there is a bracken of *Gleichenia volubilis* or *Gleichenia* zone (Jacobs, 1958) which is brought about by an edaphic factor. Van Steenis (1950) thought 2400m a. s. l. was a border between montane and subalpine zones with many types of scrubs.

According to Ogino *et al.* (1984), hill oak forest of G. Gadut, West Sumatra, is found higher than 1000m, and its canopy is made by *Quercus lineata*, *Lithocarpus* and *Schima wallichii*. In a montane oak forest found in the higher altitudes than 1900m, *Tristania bakhuizenii* and *Lithocarpus* cf. *elegans* are codominant, and other important species are *Elaeocarpus stipitatus*, *Anneslea fragrans*, *Ellipanthus tomentosus*, *Weinmannia blumei* and *Myrica javanica*.

According to van Steenis *et al.* (1972) and the observation by the present author lucidophyll oak-laurel forests are well reserved in Gede-Pangrango-Halimun National Park (van Steenis *et al.*, 1972; Yamada, 1991) The lucidophyll oak-laurel forests are found in the submontane (1000-1500m) and montane zones (1500-2400m), but they have been replaced by secondary forests or cultivated land below the Cibodas Garden (1300-1425m). Species composition of the first layer of montane forests on Mt. Pangrango (3019m), West Jawa, changes gradually from 1600m to the top (Yamada, 1977) as follows.

1600m: *Schima wallichii*, *Castanopsis javanica*, *Persea rimosa*, *Lithocarpus pseudomoluccus*.
1700m: *Podocarpus imbricatus*, *Sch. wallichii*, Vernonia *arborea*, *Engelhardia spicata*.
1900m: *Sch. wallichii*.
2100m: *Sch. wallichii*, *Acer laurinum*, *Astronia spectabilis*, *Prunus arborea*, *Weinmannia blumei*.
2300m: *Lithocarpus elegans*, *Ast. spectabilis*, *Sch. wallichii*, *Myrsine affinis*, *Eurya obovata*.
2600m: *M. affinis*, *Polyosma ilicifolia* (Saxifragac.), *Symplocos sessilifolia*, *Leptospermum flavescens*.
2800m : *M. affinis*, *Schefflera* sp., *E. obovata*, *Viburnum coriaceum*, *Sy. sessilifolia*.
3000m : *M. affinis*, *Photinia notoniana*, *E. obovata*, *Vaccinium varingiaefolium*.

Around the crater rim of Mt. Gede (2958m) there are scattered priseral shrubs of *Vaccinium varingiaefolium* and *Gaultheria leucocarpa*.

Hotta (1974) discriminated 6 altitudinal vegetation zones on Mt. Kinabalu (4101m); alpine zone (>4000m), high altitude scrub zone (3800-4000m), conifer forest zone (3200-3800m), oak shrub zone

with *Leptospermum* forest, *Dacrydium* forest and oak scrub (2500-3200m), evergreen oak forest zone (1000-2500m) with evergreen oak forest and mixed oak forest as higher types, and mixed oak forest with constituents of tropical rain forest zone (0-1000m).

Kitayama (1987, 1995) classified tropical montane rain forest zone of Borneo Island into two subzones, the lower and the upper. Tropical lower montane rain forest zone (1200-1800m) is dominated by the species of *Lithocarpus*, *Quercus* and *Castanopsis*. The tropical upper montane rain forest zone (1800-3000m) corresponds to the cloud zone, and every surface of the standing and fallen trees and rocks was covered by bryophytes and lichens making mossy forest. The forests are dominated by the species of *Lithocarpus*, *Castanopsis* and *Quercus,* and they are accompanied by *Dacrydium beccarii*, *Phyllocladus hypophyllus*, *Schima wallichii, Leptospermum flavescens* and *Elaeocarpus* spp. At higher elevation than 2400m only two species of Fagaceae, *Lithocarpus turbinatus* and *L. havilandii*, are found, and at 2700m *L. turbinatus* disappear and at 3000m *L. havilandii*. A similar oak forest was reported from Mt. Trus Madi (2642m) by Kitayama *et al.* (1993).

Whitten *et al.* (1987) described 4 vertical zonations of vegetation in Sulawesi (Celebes) Island; subalpine forest (>3000m), upper montane forest (2400-3000m), lower montane forest (1500-2400m), lowland and hill forest (0-1500m). The lower montane forest zone in Sulawesi is characterized by a forest of which canopy is dominated by *Castanopsis* and *Lithocarpus*. On the mountains of Donggala and Gorontaro in the altitudes between 800 and 1200m which are lower than Whitten's proposition, this oak forest is accompanied by *Phyllocladus*, *Agathis* and *Eugenia* (Steup, 1931). The present author noticed *Castanopsis acuminatissima* zone around Lake Lindu at about 1500m in Lore Lindu National Park, Central Sulawesi.

Ueda *et al.* (1986) made a botanical research on Seram Island and five vegetation types were recognized; mangrove, lowland forest, montane forests, mossy montane and elfin forests. The montane forests occur higher than 500m. *Castanopsis buruana* is a dominant of the forest on the slope from 400 to 1400m, and *Lithocarpus celebicus* on ridges. Trees in the montane forests develop rather poorly due to calcareous soil, but a common species, *Agathis celebica*, has a large diameter. They noticed many sucker shoots around a trunk of *Castanopsis buruana*.

Dickerson (1928) discussed precisely the relationship between the flora of the Philippines and neighbouring islands and countries, but he mentioned only a few words on the oak forest. The lowland area were occupied by a number of dipterocarp species, and such dipterocarp forests give way gradually to one in which miscellaneous trees, *Quercus* and other genera, are more abundant above 800m. In the higher altitudes more or less dwarf trees are prominent with *Podocarpus imbricatus*, *Dacrydium elatum*, *Drimys piperita* and with shrubs of *Eurya*, *Eugenia*, *Vaccinium* and *Rhododendron*. Dwarf trees may be due to strong wind such as typhoons, which attack several times a year.

Hosokawa (1940) reported upper limit of laurel-leaved forest was at 2800m on Mt. Apo, Mindanao Island but not its lower limit. According to Penafiel (1995) mossy forest above 900m elevation in the Central Cordillera, Luzon Island was dominated by about 10m-high trees of *Lithocarpus jordanae*, *L. scleriana*, *L. coopertus*, *Vaccinium* spp., *Melastoma topingii*, *Eurya acuminata* with a few conifers such as *Taxus sumatrana*, *Phyllocladus stugii*, and *Dacrycarpus cumingii*. The diameter of these trees was not more than 40cm.

New Guinea and its associated islands

Brass (1941) revised the Lane-Poole's classification (1925) of the altitudinal distribution of New Guinean vegetation based on his expedition, and proposed a new system of forest zonation as follows; rain forest (0-2400m), mid-mountain forest (480-2350m), beech forest (850-3100m), mossy forest

(1500-3200m), subalpine forest (3000-4050m), and alpine grassland (>2900m).

Mid-mountain forest is dominated by *Castanopsis acuminatissima* with a few canopy species of *Lithocarpus* sp., *Engelhardia* sp., *Podocarpus imbricatus*, *Phyllocladus* sp., and *Araucaria cunninghamii*. Johns (1982) also recognized oak forest characterized by *Castanopsis acuminatissima* and other fagaceous species of *Quercus* and *Lithocarpus* from 1000m to 1500m and *Araucaria* forest (1500-2000m) as lower montane forest. At its higher altitudes these species are mixed with with *Engelhardia*, and upwards it intergrades with *Nothofagus* forest which makes mid-montane forest zone. In *Araucaria* forest *A. cunninghamii* and/or *A. hunsteinii* are emergent from a canopy which was made by oak forest components. Johns (1982) wrote that both *Araucaria* species are heliophilous and regenerate well in openings. If it is true, *Araucaria* forest may be a seral one. Womersley (1958) pointed out that *Araucaria* forests are relict forests developed in temperate climate. *Nothofagus* forest is commonly found usually above lucidophyll forest zone as mossy forest, and it is dominated by *N. grandis* at lower altitudes and *N. pullei* at higher altitudes.

Paijmans (1975, 1976) gave following 7 major environment types and many forest types in each major type of environment; beach ridges and flats (5 forest types), saline and brackish swamp (7), lowland fresh water swamp (14), lowland alluvial plains and fans (9), hills and low mountains (8), lower montane zone (11) and upper montane zone (3). *Castanopsis acuminatissima* forest is one of 11 forests of lower montane zone, and is found between 500m and 2300m, which corresponds rightly to mid-mountain forest of Brass' system. The author observed *Castanopsis* forests in 1400-2300m at Dauro Pass and Bulolo (Tagawa *et al*., 1980). *C. acuminatissima* makes sometimes a pure stand with flat canopy, and a number of coppice shoots are growing around a main stem. This forest is in places mixed with emergent conifer species of *Araucaria*, *Podocarpus*, *Dacrycarpus*, and *Phyllocladus*.

Japan and Korea

Evergreen laurel-leaved forests are commonly found in the lowland and montane region in southwestern Japan. On Yakushima Island, the forests occupy a large area from lowland to about 2000m with changing into *Cryptomeria* forest at 1200m. Dominant species of the forests upwards from lowland are *Persea thunbergii*, *Castanopsis sieboldii*, *Lithocarpus edulis*, *Quercus salicina*, *Q. gilva*, *Distylium racemosum*, *Castanopsis cuspidata*, and *Q. acuta*. Seashore of south Kyushu is partly fringed with hard-leaved scrubs dominated by *Q. myrsinaefolius* (in the sense of subgenus *Quercus*) and *Cinnamomum daphnoides*. In Yakushima the upper part of the forest is mixed with conifers such as *Cryptomeria japonica*, *Chamaecyparis obtusa*, *Tsuga sieboldii* and *Abies firma*, and these conifers increase their importance between 1200 and about 1800m. Among emergent canopies of conifer trees there are evergreen broad-leaved trees such as *Quercus, Camellia, Illicium*, *Distylium* and deciduous hardwood trees as *Stewartia*, *Kalopanax* and *Acer*.

The Nansei Islands are under humid subtropical climate. They are covered by a luxuriant growth of laurel-leaved forests dominated by *Castanopsis sieboldii*, *Quercus miyagii*, *Persea thunbergii*, *Schima wallichii* ssp. *liukiuensis*, but on the seashore and fresh and sea water swamps there are some elements of tropical strand communities and mangroves; *Ipomoea pes-caprae*, *Spinifex littoreus*, *Thespesia populnea*, *Heritiera littoralis*, *Terminalia catappa*, *Macaranga tanarius*, *Bruguiera gymnorrhiza*, *Rhizophora stylosa*, *Avicennia marina*, *Sonneratia alba*, *Nypa fruticans*, etc.

The northernmost distribution of the laurel-leaved forest is on Oshima Island, Iwate Prefecture (39°15'N) on the Pacific coast and at Iwasaki Village, Aomori Prefecture (40°34'N) on the Japan Sea coast (Ishikawa, 1972). Dominants near the northern limit of the forest are limited to *Persea thunbergii*, *Quercus acuta* and *Q. salicina* (Hattori & Nakanishi, 1985).

The evergreen broad-leaved forest in Korea in the present time are classified into 2 associations and a community by Song *et al.* (1990); Cyrtomio-Litseetum japonicae, Rumohro-Castanopsietum sieboldii, and *Quercus acuta-Daphniphyllum macropodum* community. The north limit of the forest distribution is at about 35°26'N south of Kampo (Yim & Kira, 1976). This northern limit in Korea is far south from that in Japan, because the Korean Peninsula is under the influence of more severe continental climate in winter than Japan, which is due to two warm currents running north along both Japan Sea and the Pacific coasts of Japan, Tsushima and Kuroshiwo currents.

2 Australia

According to Webb and Tracey (1981) in Queensland, northeastern Australia *Cinnamomum propincuum* dominates in a semi-evergreen microphyll vine-fern thicket under subtropical seasonal dry climate. This type of laurel forest (canopy reaches to 15m at maximum) is in the driest habitat among that of lucidophyll oak-laurel forests we have seen. A common genus of laurel family in Australia is *Cryptocarya*, and its several species are distributed in the northern tropical forests, but they do not become dominants and in most case they are companions of sub-canopy strata.

3 Macaronesia

Rivas-Martinez *et al.* (1993) classified laurisilva of Tenerife Island, Canarias Islands into three associations; *Persea* (Lauro azoricae-Perseetum indicae), *Ocotea* (Diplazio caudati-Ocoteetum foetentis) and *Erica* forests (Fayo-Ericetum arboreae). Laurisilva have been driven to the foggy higher altitudes of mountain because of little rain less than 300mm in a year in the lowland of the island.

Dias (draft paper) classified 6 vegetation zones of Açores Islands (39°N); littoral communities, wetlands, forests, shrublands, grasslands and volcanic seral communities. "laurissilva" on the Açores Islands develops from lowland to wet mountain area. In the lowland *Myrica faya -Picconia azorica* forest was seen on the mesic soils, but nowadays it is difficult to find its living samples. In the montane area the first layer of laurissilva is composed of such endemic species as *Laurus azorica*, *Ilex perado* ssp. *azorica*, *Frangula azorica* and *Erica azorica*. The stature of the forests is not higher than 10m in the present, but historical data shows that the forests grow up to 20m. In the high mountain over 1000m hyperhumid and stunted laurissilva (5m tall) or cloud-forest are found. It is dominated by *Juniperus brevifolia*, *Laurus azorica* and *Vaccinium cylindraceum* with abundant bryophytic epiphytes on the surface of trees. Over 1900m laurissilva changes into subalpine scrub which is dominated by the following Ericaceous species, *Calluna vulgaris*, *Daboecia azorica* and *Erica azorica*.

4 North America

According to Knap (1965) and Olson (1983) evergreen oak beach forests are found mixed with deciduous trees and conifers from Virginia to central Florida along the gulf of Atlantic coasts and to

Table 2. Species composition of laurisilva of the Canarias Islands. Main species are shown in the order of dominance.

Forest type	Laurel forest	*Ocotea* forest	*Erica* forest
Dominant	*Laurus azorica*	*Ocotea foetens*	*Erica arborea*
Main species	*Erica arborea*	*Laurus azorica*	*Myrica faya*
	Persea indica	*Ilex platyphylla*	*Ilex canariensis*
	Ilex canariensis	*Prunus hixa*	*Daphne gnidium*
	Prunus hixa	*Myrica faya*	*Laurus azorica*
	Myrica faya	*Erica arborea*	*Prunus hixa*

Texus and NE Mexico, and they occupy a small proportion in the total forest area of the United States. Quarterman and Keever (1962) wrote this forest as southern mixed hardwood forest. This forest is commonly seen as a small stands or a fragment of the forest along the coastal plain. In the northcentral Florida it is composed of *Gordonia lasianthus*, *Ilex opaca*, *Quercus myrtifolia*, *Q. virginiana* and its two varieties, *maritima* and *fusiformis*, *Magnolia grandiflora*, *M. virginiana*, *M. cerifera*, *Persea borbonica*, *Sabal palmetto*, etc. (Monk, 1965). The forests are mixed with deciduous trees in the northern limit of the distribution, and the rate of the evergreens fluctuates from 7 to 100%.

Küchler (1964) classified lowland climax forest near the shore into 3 minor types; oak-hickory-pine forest, southern mixed forest, southern flood plain forest. *Quercus* in these forests belongs to subgenus *Quercus* not to subgenus *Cyclobalanus* seen in Asia (Soepadomo, ibid.). *Quercus laurifolia* leaves remain on branches even in winter and in the early spring they fall simultaneously just like *Cinnamomum camphora* in Southeast China, Taiwan and Japan. Olson wrote shiny evergreen leaves and wide-spreading branches of *Quercus virginiana* were good elements for a landscape tree. The present author thinks that these oak forests are regarded as one of lucidophyll oak-laurel forest formation. Elias (1971) thought that those oak species belong to the third subgenus, *Erythrobalanus* which is an endemic group of oak in the North America.

5 Central and South America

Mexico belongs to North America, but with a view to vegetational continuity to the Central America it is convenient to discuss montane forests together with those in Central America.

Gomez-Pompa (1973) reported tropical oak forests from lowland (at the sea level) to 1700m (altitudinally upper limit of subtropical lucidophyll oak-laurel forest in Asia) and from drier areas in the northern part of the state of Veracuruz, Mexico to very wet portion of the south. The oak forest on a lava flow is dominated by evergreen *Quercus oleoides*, and other species are *Alchornea latifoli*, *Dendropanax arboreus*, *Ficus maxima*, *Sapium lateriflorum*, etc. The tropical oak forest on the soil of bad drainage was also dominated by *Q. oleoides*, but other woody species are a little different from that on lava flow.

According to Breedlove (1973), lower montane rain forest reaching 25-45m in height is composed of Lauraceae *(Nectandra sinuata*, *Ocotea rubiflora*) and Fagaceae (*Quercus oleoides*, *Q. skinneri*) with tree species of Tiliaceae, Guttiferae, Chrysobalanaceae and Euphorbiaceae. He also introduced evergreen cloud forests from 2000m to 2900m in eastern and northern Highlands and 1900m to 3200m in the Siera Madre Mountains, and the forests contain some canopy species of Lauraceae and Fagaceae, but these are not so important in the forest.

Holdridge and Budowski (1956) classified Panaman life zone into 5 types; tropical moist forest, tropical dry forest, subtropical moist forest, lower montane rain forest, and montane wet forest. Subtropical wet forest in Chiriqui State contains species of *Nectandra*, *Persea*, *Quercus*, *Podocarpus*, *Ternstroemia*, and lower montane forest (cloud forest in Porter, 1973) in Chiriqui *Persea*, *Quercus*, and *Weinmannia*.

According to Veillon and Lemprecht (1955 cited from Hueck, 1966), in lower and mid-montane forest zones of which upper limit is at 1800-2000m in the Merida Mountains, Venezuela there are forests with abundant trees of Lauraceae, Moraceae, Myrtaceae, Bignoniaceae and Araliaceae, and legume species extensive in the lowland rain forests are rare in this zone.

In the tropical rain forest zone not higher than 300m in Guyana a laurel forest dominated by *Ocotea rodioei* on sandy soil was reported by Davis and Richards (1933, 1934). This forest was extensive in the lower Mazaruni Valley, and they gave a few special features of the forest and

dominant trees; little or not buttressed, scantiness of undergrowth tree stratum and high resistance for decay. Although this forest includes a few stems of other laurels, *O. rubra* and *Nectandra* sp. and a few others of unidentified Lauraceae, but others are components of the surrounding tropical rain forest. So it is doubtful whether this forest should be a type of lucidophyll forest or not, but this phenomenon gives a suggestive hint on the origin of laurel forest in the tropical lowland area. The present author also observed a laurel forest dominated by *Eusideroxylon zwagerii* on wet sandy terrace of creek in East Kalimantan, Borneo Island.

Hueck (ibid.) described laurel forests dominated by *Phoebe porphyria* mixed with *Blepharocalyx gigantea* at 600-900m in altitude from the states of Tucuman, Salta and Jujuy, Argentina, north to Bolivia. Dominant species of this type of laurel forest is replaced by other laurels such as *Ocotea* and *Nectandra* in the north. The composition of this laurel forest is *Phoebe porphyria*, *Ocotea* spp., *Nectandra* spp., *Brepharocalyx gigantea*, *Cedrela lilloi*, *C. balansae*, *Pentapanax angelicifolius*, *Patagonula americana*, *Jacaranda mimosifolia*, *Tabebuia avellanedae*, *Cupania vernalis*, *Rapanea laetevirens*, *R. ferruginea*, *Cascaronia astragalina*, *Fagara coco*. From 800m to 1200m laurel forest changes into myrtaceous forest dominated by *Eugenia pungens* and *E. uniflora*, and upwards into 'Nogal' forest dominated *Juglans australis* and *Podocarpus parlatorei,* and 'Aliso' forest of *Alnus jorullensis*.

Lower 'Yungas' forest, or tropical rain forest in the Bolivian Andes below 2000-2500m shows similar physiognomy to the laurel forest seen in the lower montane from northern Argentina to Bolivia, and it is composed of many species of laurels such as *Huflandia* (*Beilschmiedia*), *Endlicheria*, *Nectandra*, *Ocotea* and *Phoebe* (Herzog, 1923 cited from Hueck, 1966). Large area of upper Yungas forest from 2000m to 2800m has been replaced by coffee plantations or degraded secondary tree-fern communities. Between 2800m and 3400m 'Ceja', a secondary scrub, dominated by stunted *Podocarpus nubi-genus* covers a large area.

On the bases of plant sociology Schmithüsen (1956, cited from Hueck, 1966) classified vegetation of Chile into two alliances; Lithraeon in xeric habitat with character species, *Lithraea caustica*, Cryptocaryon in humid habitat characterized by *Cryptocarya rubra*. The latter alliance contain two types of forest. One of them is 'Belloto' (*Beilschmiedia miersi*) forest below 1000m with canopy species of *Schinus latifolius*, *Citronella mucronata*, and another 'Peumo' (*Cryptocarya rubra*) forest having leathery evergreen leaves. The upper limit of its distribution gradually goes down from 1900m at 32°C to 200-300m at 36°40'.

ALTITUDINAL AND HORIZONTAL DISTRIBUTION OF LUCIDOPHYLL OAK-LAUREL FORESTS

1 Horizontal distribution

A number of references cited above show that the lucidophyll oak-laurel forest has a wide range of its distribution in latitude from 9° S to 40° 34'N and at altitudes from the sea level in the cool-temperate zone to about 3000m in the Asian humid tropics. A suggested distribution area of the lucidophyll forests in Asia is shown in Fig. 2. Lucidophyll forests in the North, Central and South America are sporadically reported, and the distribution area is not shown in the figure.

Shola forest is separated at a great distance from the main area in the Himalayas, and it is a laurel forest without oak species. A few stands without fagaceous species are known from the lucidophyll oak-laurel forests in Asia such as a few stands of East Himalayas, shola forest, small islets off from a

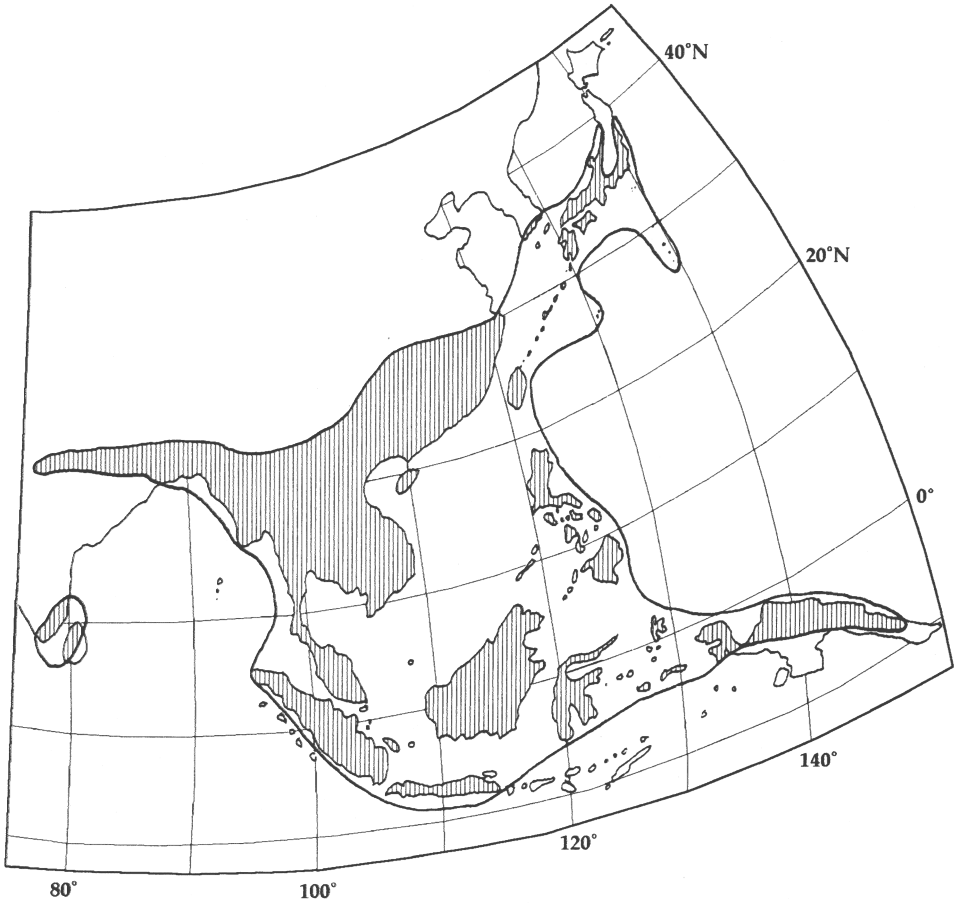


Fig. 2. Suggested distribution of lucidophyll oak-laurel forest in Asia.

large island in southwestern Japan and Macaronesian islands. It may be arisen from the difficulty of acorn dispersion into remote places, especially across the sea.

The origin of the Canarias Islands is back to the Miocene, about 2×10^7 BP (Araña & Carracedo, 1978). Plant fossils common to the Canarias Islands were widely found in the Mediterranean region. In the upper Miocene era the Mediterranean region was on the fringe of the Tethys Sea. After closing the Tethys Sea by the connection of the Africa with the Eurasia, warm temperate evergreen vegetation that had developed along the sea coast of the Tethys was enclosed into the Canarias, Madeira and Açores Islands, which is attributable to the low temperature and xeric condition in the last ice age of the Tertiary (Bramwell & Bramwell, 1990). As the North America was already isolated far remote from the Laurasian Continent in the Cretaceous Period, laurel forests on the Canarias Islands and other small Macaronesian islands in the temperate Atlantic Ocean have little correlation with southern evergreen hardwood forest of the United States.

Except for a few examples described above, the Asian lucidophyll oak-laurel forests have species of both Fagaceae and Lauraceae, but in New Guinea Island they are mainly composed of the species of Fagaceae (*Castanopsis* and *Lithocarpus*), and *C. acuminatissima* is a sole dominant in many places, for which Brass (1941) used the term 'oak forest'.

Kira's warmth index (Kira, 1945) is a kind of integrated temperature, that is, a total of monthly mean air temperatures above 5°C which is regarded as a threshold of low temperature stress for the

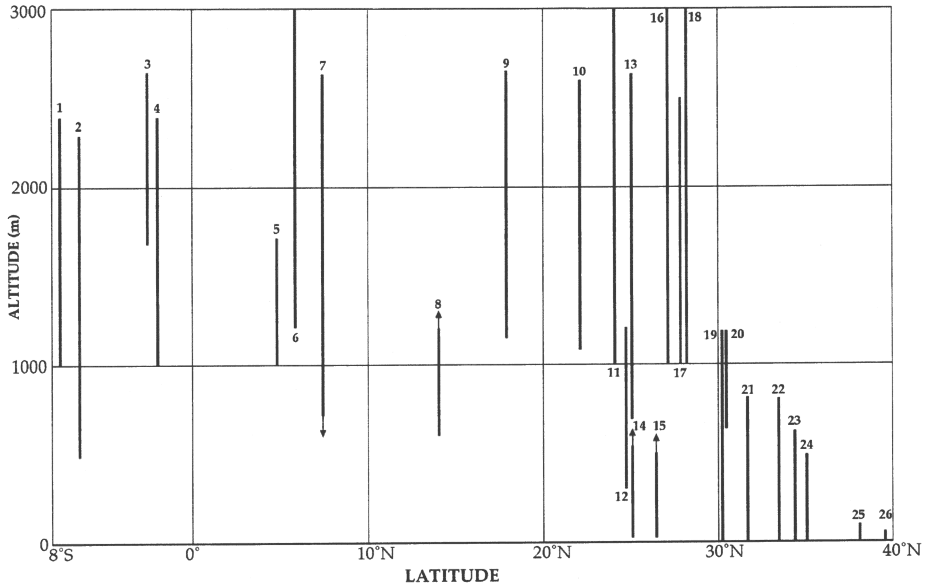


Fig. 3. Altitudinal distribution of lucidophyll forest on some selected places. Place and data source: 1 Mt. Pangrango, Jawa (Yamada, 1977); 2 Papua New Guinea (Paijmans, 1975 & 76); 3 Mt. Rantemario, Sulawesi Is. Witten, 1987;4 Mt. Gadut and the other mountains, Sumatra (van Steenis 1950, Ogino *et al.* 1984); 5 Peninsula, Malaysia (Wyatt-Smith, 1964). 6 Mt. Kinabalu, Borneo (Kitayama, 1987 & 95); 7 Mt. Apo, Philippines (Hosokawa, 1940); 8 Mt. Maquillin, Philippines (Brown, 1919); 9 Mt. Don Intanon, Thailand (Ogawa *et al.* 1961); 10 Myanmar (Stamp, 1943; Davis 1964); 11 Tenchung, S China (Editing Comm. 1987); 12 Mt. Jiulian Shan, S China (Management Station, 1987); 13 NE Taiwan (Hosokawa, 1958); 14 Ishigaki Isl., Japan (Tagawa witnessed); 15 Okinawa Isl., Japan (Tagawa); 16 Jormo Lungma (Chang & Ciang, 1973); 17 Eastern Nepal, Himalaya (Ohsawa, 1983b); 18 Sikkim, India (Gopal & Meher-Homji, 1983); 19 Yakushima Island, Japan (Tagawa, 1994); 20 Huang Shan, China (Editing comm. 1980); 21 Mt. Kirishima, Japan (Tagawa, 1977); 22 Mt. Hikosan, Japan (Tagawa); 23 Tsushima Isl., Japan (Itow, 1976); 24 Tottori, Japan (Yokogawa, 1959); 25 Sado Isl., Japan (Hattori & Nakanishi, 1985); 26 Ohshima and Konoura, Japan (Hattori & Nakanishi, 1985).

physiological function and plant growth. According to a number of studies it became clear that each vegetation zone is included in a certain range of the warmth index; tundra in 0-15°C month, evergreen conifer forest zone in 15-45/55°C month, summergreen forest zone in 45/55-85°C month, lucidophyll oak-laurel forest zone 85-180°C month, subtropical rain forest zone in 180-240°C month, and tropical rain forest zone above 240°C month.

2 Altitudinal distribution

With reference to the descriptions in the first chapter vertical distribution of lucidophyll oak-laurel forests in Asia is illustrated in Fig. 3. A downward arrow in the figure shows that the lower limit of potential distribution of the forest zone was not recognized by human disturbance given to the forests such as lumbering, firing, grazing and cultivation, and an upward arrow shows that the higher limit of the forest zone is not known because the highest peak in small islands is lower than the higher limit of the forest zone.

The lucidophyll oak-laurel forests are found between 1000m to about 2600m in a range of 10° in the north and south from the equator. In Tienhsi District (western Yunnnan), China, the upper limit of the evergreen broad-leaved forest zone reaches 3000m. At Kunming as the capital of Yunnnan and a center of Tienchung District (central Yunnan) warmth index is about 200°C month, and 85°C month is

comparable to about 2400m in altitude in Tienchung District. So the upper limit of the evergreen broad-leaved forest zone in Tienhsi is about 600m higher than that estimated from the value of warmth index. Evergreen forest in this higher altitudes is composed of evergreen tree species such as *Lithocarpus variolosus*, *L. hancei*, *Cyclobalanopsis glauca*, *Schima argentea*, with the undergrowth of *Sinarundinaria nitida* (dwarf bamboo) and a few evergreen shrubs and ferns.

Another example is given on Mt. Pangrango, montane forest there is found even in a high altitude at 3000m. The upper limit of lucidophyll oak-laurel forest zone on Mt. Pangrango is much higher than that estimated as 2550m from warmth index. At the top of the mountain it is calculated as 50.5°C month.

This extraordinary ascending of the higher limit of lucidophyll oak-laurel forest may be ascribed to two reasons; the first is due to a special local climate condition in Tienhsi, Mt. Pangrango and other high mountains in the tropical Asia, and the second is that 85°C month as the upper limit of lucidophyll oak-laurel forests in the warm-temperate region cannot be applicable to the upper limit of distribution in the tropics. In the cool-temperate region summergreen forest zone appears below 85°C month or upwards of lucidophyll oak-laurel forest zone in the montane areas, but in the tropics there is no summergreen forest zone above the lucidophyll forest zone, and the latter extends up into evergreen alpine scrubs or conifer forests mainly composed of Podocarpaceae in the tropical Asian islands and of *Tsuga*, *Abies* and *Pinus* in the Asian tropical continent.

On Mt. Huang Shan (1700m) at about 30°N, Anhui Province, *Cyclobalanopsis gracilis-Cyc. nubium* forest was reported from 1200m in altitude and *Castanopsis eyrei-Schima superba* forest from 630m (Editing Committee for Vegetation of Yunnan, 1980). As far as the vegetation maps concern, northern distribution limit of the evergreen broad-leaved forests in China does not extend to the north from 33°N because of low temperature in winter and low humidity stress. Southern small islands and sea coast of larger islands of Japan are, as already described, warmer in winter and humid by the effect of two warm currents, and the northern limit extends far north to about 39°N in the Pacific coast and 40°N in the Japan Sea coast.

Ohsawa (1993) gave a vertical profile of vegetation zones in southern and eastern Asian mountains in his discussion on latitudinal pattern of montane vegetation zonation. He thought the upper limit of Lauro-Fagaceous forest in the tropics was on about 2500m. As oak-laurel forest loses its species diversity and stature near the upper limit of distribution as well as other forests, it is difficult to determine a border line on a tailing range of distribution. In such high altitudes forest is mixed with conifers of *Dacrydium* and *Dacrycarpus* in Asian islands and *Tsuga*, *Pinus* and *Abies* in the Asian continent, so the discussion will divagate whether such a mixed coniferous forest or stunted mossy forest should be included into lucidophyll oak-laurel forest or not. The present author would not like to include conifer forests dominated by conifer trees appear on tropical high mountains into lucidophyll oak-laurel forest. Mixed forest is thought to be a transitional type of forest between two.

Only in New Guinea and New Britain Islands there is *Nothofagus* zone above *Castanopsis* zone and these two zones appear in higher altitudes in the main island than in the associate small islands as shown in Fig. 4. Evergreen *Nothofagus* forest occupies from 2200m to 3000m in the mainland of New Guinea. These altitudes correspond to 108.3° and 50.7°C month (based on the weather data at Lae), respectively, and this range of altitudes includes upper part of lucidophyll oak-laurel forest to almost all range of summergreen forest. So the upper limit of *Castanopsis* zone in New Guinea would be uplifted in much higher elevation as well as on Mt. Kinabaru, if there were no *Nothofagus* zone. *Castanopsis* zone is in a range of 1000m-2200m and 194.7°-108.3° month, which correspond to the distributional range of upper part of subtropical and lower part of warm-temperate lucidophyll oak-

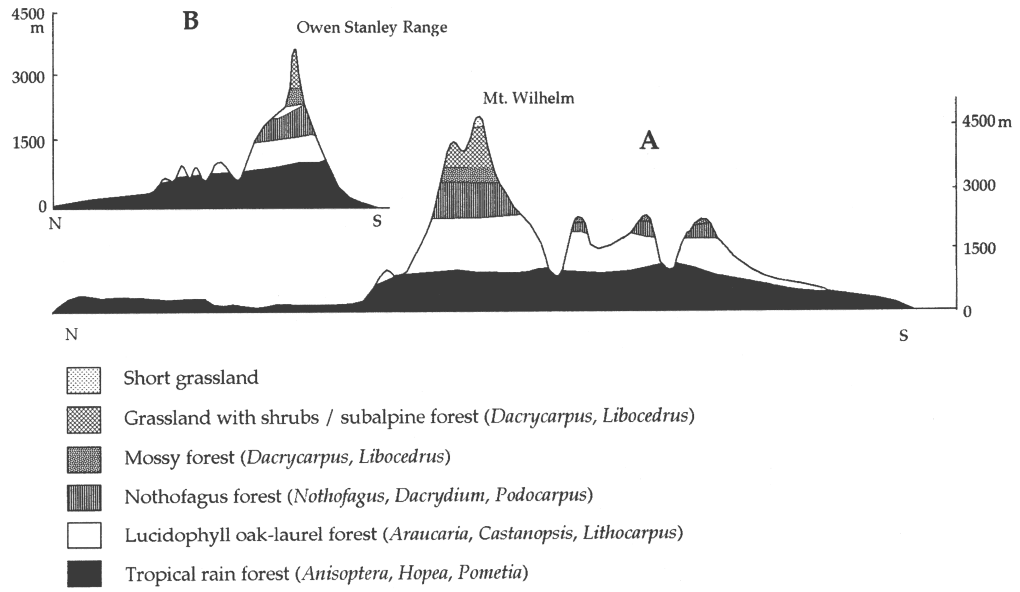


Fig. 4 Altitudinal distribution of vegetation zones in Papua New Guinea. Transverse section of Papua New Guinea along 140° E (A) and the eastern Owen Stanley Range (B). (Reprinted from Johns, 1982 by permission of the publisher)

laurel forest zones. It can be understood that lucidophyll oak-laurel forest zone in New Guinea is depressed to the lower altitudes by the invasion of *Nothofagus* zone between lucidophyll oak-laurel and conifer forest zones. Coexistence of both zones is observed only on New Guinea and New Britain Islands.

NOMENCLATURE OF THE LUCIDOPHYLL FOREST

A number of authors used a great many terms for the lucidophyll oak-laurel forests in Asia, and it causes confusion for exact understand of the forest. The terms are classified into following four groups by means of various characters of the forest. The divergence of the terms are the following.

1 Terms showing vertical distribution:
   - i. High mountain hardwood forest (1500-2100 m), Myanmar, Davis 1964
   - ii. Mid mountain forest (1700-2250 m), Papua New Guinea, Brass 1941
   - iii. Montane zone (1000-2400 m), Jawa, van Steenis *et al.* 1972
     Malaysian Peninsula, van Steenis 1935
   - iv. Montane evergreen forest (1000-2576 m), Thailand, Ogawa *et al.* 1961
   - v. Lower montane zone / forest (1000-3000 m), Papua New Guinea, Peijman 1976
     (1500-2400 m), Sulawesi, Witten *et al.* 1987
     (1000-2000 m), Thailand, Kunstadter *et al.* 1978
   - vi. Hill evergreen forest (1200 m), N Thailand, Yoda and Sahunalu 1991
   - vii. Tropical lower montane rain forest (1200-3000 m), Sabah, Kitayama 1987
   - viii. Submontane zone (100-800), Yakushima Isl., Japan, Masamune 1934
   - ix. Montane cloud forest, Ohsawa 1995, Kitayama 1995

2 Terms showing combination of climatic zone and character of leaves:

i. Cool region (1360-2100 m), Jawa, Seifriz 1923
ii. Temperate rain forest (various altitudes), Canarias Isl. etc., Schimper 1898
iii. Temperate evergreen forest (1000-2576 m), Thailand, Ogawa *et al*. 1961
iv. Temperate broad-leaved evergreen forest, USA, Olson 1983
v. Warm broad-leaved forest (1650-2600 m), China, Editing Committee for Forest of Yunnan 1986
vi. Warm-heat broad-leaved forest (1000-1650 m), China, Editing Committee for Forest of Yunnan 1986
vii. Warm temperate mixed forest (700-1800 m), Taiwan, Flora of Taiwan 1975
viii. Subtropical evergreen broad-leaved forest (600-1650 m), Taiwan, Hsu 1971

3 Terms showing leaf character:
i. Evergreen broad-leaved forest (0-l000 m), Japan, many authors
ii. (Evergreen) Laurel-leaved forest (0-l000 m), Japan, many authors
iii. Lucidophyll forest, Japan, Kira 1977

4 Terms based on species composition:
i. Laurisilva/ Laurisilvae/ Laurel forest, Brockmann-Jerosch and Rübel 1912, etc.
ii. Oak forest (Thitcha) (900-2100 m), Myanmar, Stamp 1924
iii. Oak-laurel forest (1200-l500 m), Malaysian Peninsula, Whitmore 1975
iv. Evergreen oak forest zone (1000-2400 m), Sabah, Hotta 1974
v. Montane oak forest (1200-l500 m), Malaysian Peninsula, Whitmore 1975
vi. Lauro-Fagaceous forest, Asian mountains, Ohsawa 1993
vii. Fago-Laulaceous forest, Jawa, Junghuhn 1845

5 Terms based on plant sociology
i. Lauraceo-Fagaceetea, Japan, Tok. Suzuki 1966a, 1966b
ii. Camellietea japonicae, Japan, Miyawaki & Ohba 1963

Lucidophyll oak-laurel forest in the warm-temperate climate zone makes a submontane vegetation zone, and montane vegetation zone in the tropics. As it is close to the northern limit of distribution, it goes gradually downwards to the lowland. So the terms expressing vertical distribution introduce various ways of understand in various locations concerning the distribution of the forest.

The terms which show climate such as cool, temperate, warm, warm-heat, warm-temperate, and subtropical sometimes introduce unnecessary confusion. Southeast Asian countries are mostly under the tropical climate without little fluctuation of temperature through a year, and also in higher mountains the fluctuation of monthly mean temperature is low, and there are no seasons as in the temperate. A cool night and a warm daytime are repeated everyday at higher altitudes in the mountain. It is ridiculous to use terms such as warm-temperate or temperate forests in the tropical and subtropical regions. They confounded Fuchsienklima with Camellienklima (Köppen, 1918).

NOTHOFAGUS FORESTS IN SOUTH AMERICA, AUSTRALIA AND NEW ZEALAND

New Guinean *Nothofagus* forest was already mentioned in Chapter I and II, and that in the other regions is described in this chapter.

South America

Two canopy species of *Nothofagus*, *N. obliqua* and *N. procera* are found in 'Ticke' forest in southern

Chile (Hueck, 1966). Both species are deciduous, and they become dominant of a summergreen forest found in the drier and cooler (upper and southern) climate of eastern slope of the Andes. Tique forest gradually reduces its species diversity in the south and in higher altitudes, and *Nothofagus dombeyi*, *Eucryphia cordifolia* and a conifer, *Podocarpus nubigenus*, make Patagonian evergreen rain forest (Hueck, ibid) reaching 35-40m in height. The upper limit of its distribution is about 1000m in Taitao Peninsula at 46°-47°C. Close to the southern tip of South America Magellanian evergreen rain forest (Hueck, ibid) dominated by *Nothofagus betuloides* appears. Even in the higher latitudes at 46-47°C only weak frost falls without severe winter. Main component species are *Drimys winteri*, *Lomatia ferruginea*, *Azara lanceolata*, *Maytenus magellanica* and *Podocarpus nubigenus*. The forest goes up to 400m in the Island of Tierra del Fuego (at about 54°C). It is the southernmost evergreen broad-leaved forest of the world. At higher altitudes from 400m vegetation changes into summergreen forest dominated by deciduous *Nothofagus pumilio* and *N. antarctica*. At Ushuaia, Tierra del Fuego, warmth index is 19.5℃ month, and it is in a range of sub-frigid zone in the northern Hemisphere, and at 400m in altitude it decreases to 5.9°C month, which shows it is in tundra zone, but no severe frost there.

Australia and New Zealand

Southern closed-forests in Australia are represented by *Nothofagus* forests. These forests were called cool temperate rain forests or nanophyll moss forests (Webb, 1959) *Nothofagus cunninghamii* forest is found from the sea level (annual mean air temperature is at 14℃) to 1370m (8.5℃) in Southeast of Victoria and Tasmania Island, but *N. moorei* can grow in high temperature not more than 17.3℃ in the coastal area from South Queensland to New South Wales (Howard, 1981). Another species, *N. gunnii*, is found only in Tasmania, and it does not become a dominant of forest. *Nothofag*us forests had a wide range of distribution in Australia in Tertiary era, but they have thenceforth constrained in a limited area by the climatic change and repeated forest fires. The matured *Nothofagus* forests are highly resistant to the fires because of empty undergrowth layer, but many seedlings and saplings of *Nothofagus* in the secondary young forests are ready to catch fire and it is hard to regenerate and grow into mature forests. Tasmanian beech forest is in the range between 91.3 and 15.9℃ month, which coincides with warm temperate and subfrigid zones in East Asia.

Godley (1975) wrote early settlers found the North Island of New Zealand covered by dense forests except for secondary vegetation recovering from activities of volcanoes and Maori people for their life. Vegetation of the South Island was the same, but eastern side of the island was occupied by grassland under dry climate. Forests in New Zealand are grouped into two major types; *Nothofagus* forests dominated by one or more of the 4 native evergreen *Nothofagus* species, conifer forests dominated one or more native conifers (*Agathis*, *Libocedrus*, *Podocarpus*). In comparison with Australian *Nothofagus* forests those in New Zealand are under more favorable condition for regeneration, because it is sufficiently humid for germination and low frequency of forest fire.

Godley wrote that *Nothofagus* forest was developed in the humid place with rainfall more than 635mm to 6350mm, but not found in Stewart Island and eastern part of the South Island. The forest is usually mixed with some conifers to make southern beech-podocarp forests in the lower altitudes and with *Beilschmiedia tarairi* in some places. The species composition becomes simple in the higher altitudes. Dominant species of southern beech are *N. fusca*, *N. menziesii* and *N. solandri*. It is abundant in the wetter places but poor in the dry habitat.

The upper limit of the forest reaches about 1400m around 42° S from Fig. 12a of Godley's paper. This altitude is in the range between 78.3 and 9.9℃ month on the weather data of Christchurch, and coincides to cool temperate zone at the sea level to frigid zones in East Asia.

Conifer mixed-hardwood forests show a wide range of combination of hardwood and conifers, so we have a pure stand of hardwood species in some places and of podocarps in others. Conifer species are *Agathis australis* (Araucariac.), *Podocarpus totara*, *P. hallii*, *P. spicatus*, *P. dacrydioides*, *Dacrydium cupressinum* and *Libocedrus lidwillii*. Hardwood trees mixed with conifers are *Beilschmiedia tarairi, B. tawa*, *Meterosideros robusta*, *M. umbellata*, *Weinmannia racemosa* and *W. sylvicola*. *Meterosideros robusta* germinates on the bark of trees as an epiphyte and becomes a strangler as it grows to kill its host tree. The upper limit of mixed conifer forest is at about 1200m (Fig. 12a, ibid.) around 43° 30'S. So the southern beech forests and mixed conifer forests in New Zealand are evergreen forests under the coldest climate.

The term lucidophyll forest may be applicable to the forests in the tropical, subtropical, and warm-temperate forests if there are evergreen trees with broad and lucid leaves, and to the forests in the mountain, mid-mountain, lower montane, and on the hill. If we use the term 'lucidophyll' oak-laurel forest for the evergreen broad-leaved forest dominated by laurel and/or oak species in warm-temperate and mountain areas of the suptropical and the tropical regions, *Nothofagus* forest should be included into lucidophyll oak-laurel forest because they prefer humid or wet habitat in the tropical, subtropical, temperate climates and even under the low air temperature, and *Nothofagus* has evergreen lucid leathery leaves.

Nothofagus was thought to have been evolved and diversified only in the southern Hemisphere, and in the present there are two new options; for the first option, a possible center of origin of *Nothofagus* in late Cretaceous is in the 'Weddellian Province', southern South America-Antarctic Peninsula province, and the second, its ancestral complex for *Nothofagus* is thought to be migrated from the Laurasian Continent to Australia and New Zealand through continental southern Asia and its islands including New Guinea in late Cretaceous (Hill & Dettmann, 1996). Although the origin and evolution of *Nothofagus* are different from other genera of Fagaceae, forests dominated by *Nothofagus* have developed under humid subtropical and temperate even onder subfrigid climates with mild winter.

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田川日出夫　照葉樹林の世界的分布

夏雨暖温帯気候，亜熱帯及び熱帯多雨気候に成立する照葉樹林の世界規模の分布をこれまでに報告された数多くの文献を基に調査した。この森林は主としてブナ科，クスノキ科，ツバキ科，モクレン科，マンサク科などから構成されている。この森林の樹木は共通して革質の平滑な葉をもち，その表面から太陽光を反射して光る特徴をもっている。この森林は温帯では低地に分布するが，亜熱帯や熱帯では低山地帯や高山地帯に分布する。その結果この森林は多様な名称でよばれている。吉良 (1977) は照葉樹林に lucidophyll forest という新しい呼称を与えているが，照葉樹林以外でも照葉樹が見られるので，筆者は当該の森林を lucidophyll oak-laurel forest という呼称を与えたい。

照葉樹林はアジア，ニュウギニア，マカロネシア，米国東南部，中央及び南アメリカの温帯，亜熱帯，熱帯に広く分布している。ナンキョクブナ林は唯一ニュウギニアで照葉樹林とともに同所的に分布している。そこではナンキョクブナ林は通常照葉樹林帯より上部にあるが，一部で照葉樹林帯の下にも出現する。ナンキョクブナの葉の特性からみて，ナンキョクブナ林は南半球で進化繁栄した照葉樹林と考える。この考えが妥当なら，照葉樹林の分布は，ナンキョクブナが落葉樹となっているタスマニアを除くオーストラリア，ニュウジーランド，落葉樹となるパタゴニアのナンキョクブナ林を除く南アンデスにまで広がり，大きな森林群系となる。