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On the global position of the evergreen broad-leaved (non-ombrophilous) forest in the subtropical and temperate zones *

Zur globalen Stellung des «Lorbeerwaldes» in den subtropischen und temperierten Zonen

by

Frank KLOETZLI

1. INTRODUCTION

Evergreen broad-leaved forests occur all over the world in the warmer zones, from the warm-temperate zone, where they form the climax, to the drier (sub-)tropical high mountains, where they may grow from the montane to the subalpine belt.

* Herrn Prof. Dr. Dr. h.c. Heinrich Walter zum 90. Geburtstag gewidmet

Certainly, the latest monograph on the 'Evergreen Broad-leaved Forest' gives a thorough and valuable picture of all types of this kind of forest in all parts of the world. It includes all types of more or less humid forests between the tropical rainforest and the sclerophyllous woodland. The question of feasibility of such a simplification arises, however. Is it realistic to include such different forest types as the temperate rainforests of New Zealand and Chile (e.g. the 'Valdivian'), the laurineous forests of Japan and China and the eastern African oreal/ subalpine forests into one unit?
With the following I shall try to point out the special transient position of the 'Laurineous Forest' (or 'Evergreen Broad-leaved Forest s.str., compare SONG 1983 'Vegetation region'; ELLENBERG and MUELLER-DOMBOIS 1967, 'temperate evergreen, seasonal broad-leaved forest'; WALTER 1979, 'temperierter immergrüner Wald') towards wetter and drier types (e.g. temperate rainforest, tropical montane sclerophyllous woodland), and to define the specific characteristics of such a biome under the so-called 'Shanghai-climate', dominated by monsoon influence.

2. LIMITING FACTORS

a. Laurineous forests are thermophilous, with higher temperatures during the growing season than the average summergreen deciduous forests. Although there is considerable overlap between these two types, the limits may be given by the number of days and intensity of frost or late frost (see b). However, during the growing season the average temperature lies around 20-25°C from July to September, and is often higher, especially in eastern China, southern Japan and southern Florida (SONG YONGCHANG 1983; Table 1).

b. Laurineous forests are sensitive to frost. Temperatures rarely are much lower than -5°C. When temperatures are lower there is often a protective snow layer (Japan), or temperatures do not remain as low for a long time. Late frosts are rare, they always leave their marks and give a harsh draw-back in vitality of the typical laurineous species.

c. **Laurineous forests are sensitive to drought**, thereby separated well from sclerophyllous woodlands where a special type occasionally occurs, but only on edaphically or mesoclimatically more favourable situations, e.g. on ravine sites. Horizontal precipitations (mist) may also allow their installation, e.g. oreal to subtropical forests on (sub-)tropical high mountains. On the average, precipitations are high all year over (Japan, Florida), except under typical monsoon climates, where two months of drought may be tolerated, in many cases softened by the effect of mist banks.

Table 1. Climatic differences between laurineous and deciduous forest (after SONG YONGCHANG 1983, 'Vegetation region II')
Tab. 1. Klima-Unterschiede zwischen Lorbeer- und sommergrünem Laubwald

Climatic parameters	laurineous forest	deciduous forest
mean annual temperature (in °C)	16-20 (E) 15-18 (W)	8 - 14
mean minimum temperatures of the coldest month (in °C)	3- 8 (E) 8-10 (W)	-15 - -1
mean maximum temperatures of the warmest month (in °C)	26-29 (E) 20-22 (W)	24 - 28
frost-free period (in days)	240-330	180-220
precipitations: (% during growing season) 900-2000 mm/year 500-900, respectively	20-40 (E) 5-15 (W)	60-70

3. CHARACTERISTICAL FEATURES

Laurineous forests generally have oak-like ('gnarled') to beech-like (slender, smooth-barked) stems and show all forms between the typical sclerophyllous to the ombrophilous tree (compare e.g. Castanopsis, Cinnamomum and Persea resp.).

Normally, laurineous forests bear soft-leathery to almost sclerophyllous, nearly mesophyllous and partly even larger leaves. Some genera may be called typically 'laurophyllous' (evergreen broad-leaved), e.g. Camellia, Citrus, Persea, Rhododendron ponticum, Castanopsis, Cinnamomum in eastern Asia, Rapanea, Syzygium, Maesa etc. in eastern African high mountains).

Table 2. Characteristical genera in laurineous forests in China (after SONG 1983)
Tab. 2. Charakteristische Gattungen in den Loorbeerwäldern Chinas

trees, evergreen broad-leaved (mostly Fagaceae, Lauraceae)

Cyclobalanopsis	Elaeocarpus	Acer
Castanopsis	Sloanea	Prunus
Lithocarpus	Michelia	
Machilus	Altingia	more xeromorphous character
Phoebe	Symplocos	where winters are warm/dry
Cinnamomum	Daphniphyllum	
Schima	Manglietia	where limestone parent rock prevails additional occurrence of deciduous species of the same genera

trees, coniferous (mostly montane)

Cephalotaxus	Podotaxus	Cathya
Taxus	Keteleeria	Fokienia
Pseudotaxus		

shrubs

Rhododendron	Lindera	Gardenia
Vaccinium	Neolitsea	Dammacanthus
Camellia	Lisea	Ardisia
Eurya	Lasianthus	Maesa
Symplocos	Randia	

herblayer with

ferns	Poaceae	Zingiberaceae
Cyperaceae	Liliaceae	Araceae

Only few creepers are conspicuous, but plenty of epiphytes (ferns, incl. Hymenophyllaceae) cover the older branches. The herb layer is generally rich in ferns; sometimes coriacious or hydrophilous plants may also prevail. (Table 2).

4. DELIMITATIONS TOWARDS OTHER FORMATIONS (BIOMES)

Temperate rainforests (e.g. Valdivian rainforest, rainforests in southwestern New Zealand as typical examples; photos 16-18) have more (and more) evenly distributed rainfalls, more even temperatures, and have more or less no frosts (see HUECK 1966, OBERDORFER 1960). They may show similar features, but are more hydrophilous and present more biomass. Subtropical rainforests are warmer, similar to montane tropical rainforests and often transitional to tropical rainforests.

Sclerophyllous forests (woodlands) (e.g. Mediterranean area, California, central Chile, South Africa, subtropical to tropical high mountains) have less and more sporadical rain, especially in winter, regular frosts, summer-drought and mostly or partly regular fires (see DI CASTRI et al. 1981). In transitional situations features may be very similar (limits of sclerophyllous to laurineous biome).

Temperate deciduous forests (e.g. in contacting areas: northern Japan, southeastern America, etc.) are rather similar, but have extremer (minimum-) temperatures and colder winters. There are many transitional zones with laurophyllous species in the bottom-layer and shrub-layer, some even reach the warmer central European regions (see details in SONG YONGCHANG 1983).

Figure 19 gives a general view on types 1 to 5, their position regarding climatic conditions, and their transitional types; Fig. 20 shows their position on a worldwide scale giving typical climate diagrams.

5. TYPES OF LAURINEOUS FORESTS

According to the above mentioned factors the following types of laurineous forests can be distinguished (compare also Table 3):

First type: Climax (Zonobiom)
This type is represented by the lowland forests in eastern Asia, southeastern America as well as by the subtropical highland forests in the Himalaya which are very similar in structure (see e.g. SONQIAO 1985, MIYAWAKI and OKUDA 1979, DOBREMEZ and SHAKYA 1975, KNAPP 1973; OHSAWA et al. 1986, for the Himalaya in subtropical to cool-temperate examples). (Figs. 1, 2, 3).

Second type: Climax (Orobiom)
High montane to subalpine tropical forests form a scattered area in eastern Africa, northwestern Andes and southeastern Asia but are very much alike due to the convergence in the form of leaves and stems (KNAPP 1965, OVINGTON 1983). (Fig. 7).

Third type: Climax (partly Zono-biom, partly Orobiom)
In the southern hemisphere they occur either in the montane area or e.g. in the southern longitudinal valley in Chile, as a transitional zone between temperate rainforest and deciduous forests (KLOETZLI 1983). (Fig. 4).

Fourth type: Cloud forest (Orobiom)
Some cloud forests belong to the laurineous forest. They occur on (sub-) tropical mountains (e.g. Canary Islands and eastern Africa), above (sub-)tropical dry forests (and thorn scrub) and below the actual subalpine tropical forest of the sclerophyllous or ericaceous type (OVINGTON 1983, KLOETZLI in print, KNAPP 1973, KUNKEL 1976). (Fig. 6).

Fifth type: Ravine forest (Pedobiom)
The last somewhat aberrant type occupies ravine(-like) sites in the sclerophyllous biome (e.g. Mediterranean mountains, western Himalya, southern Californian ranges, southwestern/southeastern Australia; see also KEAST 1981, KNAPP 1965).

6. TRANSITIONAL TYPES

As can be concluded from the mentioned situations, the laurineous forest is bordered by many other biomes (e.g. rainforest, dry forest, deciduous forest, coniferous forest, to mention just a few). Due to the central position of 'Laurineous Forests' a great number of transitional types may be seen in the mountains, e.g.:

- from boreal coniferous forests to coniferous forest with laurophyllous species (e.g. British Columbia, moist montane coniferous forest with Tsuga, Thuja, Abies, from the Himalaya to Japan)
- from temperate deciduous forest to deciduous forest with laurophyllous species (e.g. pontical and hyrcanic deciduous forest in Turkey and Iran, southwestern Ireland, northern parts of southeastern America) (Figs. 10, 11)
- from sclerophyllous forest to ravine forest with laurophyllous species
- from temperate rainforest to sclerophyllous forest with laurophyllous species in different gradations (e.g. edaphically drier areas in the southern longitudinal valley of Chile; compare also Fig. 10)
- from subtropical or temperate rainforests to actual laurineous forest due to accentuated periods with less rain (but no drought) and mostly deeper temperatures, also in mountainous areas (e.g. in subtropical to temperate mountains of the Australian eastern coast) (Figs. 8, 9)
- from (tropical montane) laurineous forests to tropical montane dry forests with less influence of mist (Fig. 12)
- from laurineous forest to sclerophyllous forest or woodland with laurophyllous species (e.g. thermophilous coastal areas in southeastern Japan) (Figs. 13, 14)
- from laurineous forest to coniferous forest with laurophyllous species due to unfavourable climatic and/or edaphic conditions (e.g. mire-margin, rock-site, frost-hollow in southeastern Asia). (Fig. 15).

Table 3. Legends of the figures 1-20 of different types of laurophyllous (= laurineous) forests and examples of transitional types

Tab. 3. Legenden zu den Abbildungen 1-20 der verschiedenen Loorbeerwälder und Beispiele der Uebergangstypen

Fig.	Type	Locality	Tree species
1	1, lowland	Japan, Kyushu, Kirishima near Kagoshima, ca. 600 m, 1.9.1984	Machilus thunbergii, Cinnamomum japonicum, Actinodaphne lancifolia, Distylium racemosum
2	1, (sub-)montane	Nepal, Gokarna Forest, near Kathmandu, ca. 1300 m, 21.8.1983	Quercus glauca, Castanopsis tribuloides, Schima wallichii, Ilex sp., Acer oblongum, Osmanthus fragrans, Alnus nepalensis, Myrsine semiserrata, Ehretia acuminata, Engelhardtia spicata, Stranvaesia glaucescens, Michelia kisopa
3	1, montane	Nepal, near Kathmandu, on Phulchoki, ca. 1900 m, 22.8.1983	Quercus glauca, Q. lanata, Lithocarpus spicata, Carpinus viminea, Symplocos spp., Sorbus cuspidata, Acer oblongum, Quercus lamellosa, Rhododendron arboreum, Lyonia ovalifolia, Litsea pulcherima, L. citrata, Pieris formosa, Berberis wallichiana, Mahonia acanthifolia, Rubus spp.
4	3, montane laurophyllous forest	Australia, New South Wales, Barrington Tops, ca. 900 m, in bassin, 18.8.1981	Nothofagus moorei, Doryphora sassafras, (ridge: Eucalyptus obliqua), Anodopetalum biglandulosum, Zieria arborea etc.
5	1, lowland laurophyllous forest, transition to subtropical moist forest	U.S.A., Florida, Everglades, ca. 10-20 m, 20.3.1980	'Hammock vegetation' with Osmanthus americanus, Quercus sp., Brumelia sp, Callicarpa americana, Myrica cerifolia, Ilex vomitoria, Persea borbonia, Sabal palmetto (in the understory)

Table 3 (continued)

Fig.	Type	Locality	Tree species
6	4, cloud forest	Kenya, Marsabit Nat. Park, ca. 1700 m, April 1977	Allophylus abyssinicus, Apodytes dimidiata, Pygeum africanum, Afrocrania volkensii, Cassipourea malosana, Olinia usambarensis etc.
7	2, tropical montane laurophyllous forest	Kenya, Aberdare Nat. Park, near Thomsons' Falls, ca. 2300 m, April 1977	Aningeria adolfi-friderici, Chrysophyllum gorungosanum, Ocotea kenyensis, Polyscias kikuyensis, Ekebergia, Macaranga etc.
8	transition lowland warm-temperate rainforest to laurophyllous forest	Northern New Zealand, 60 km E of Auckland (Waitakaruru), ca. 150 m, 13.9.1981	Nothofagus truncata, Knightia excelsa, Podocarpus ferrugineus, Phyllocladus trichomanoides, Cyathea dealbata, C. medullaris, Dacrydicarpus cupressoides, Metrosideros robusta, Beilschmiedia tawa
9	transition laurophyllous to montane warm-temperate rainforest in bassin	Australia, New South Wales, Blue Mountains, ca. 1000 m 26.8.1981	Eucalyptus oreades, E. viminalis, Acacia elata, Ceratopetalum apetalum, Doryphora sassafras, Cyathea australis, Dicksonia antarctica
10	transition submontane laurophyllous to deciduous forest with laurophyllous understory	Chile, N of Puerto Montt, near La Union and Ca. Pelada, ca. 450 m, 7.10.1981	Nothofagus obliqua, Laurelia philippiana, Persea lingua (Chusquea quila)

Table 3 (continued)

Fig.	Type	Locality	Tree species
11	transition lowland deciduous to lauro-phyllous forest with laurophyllous under-story	Ireland, near Killarney, ca. 150 m, 1971 (Photo N. Kuhn)	Quercus petraea (Rhododendron ponticum),
12	transition tropical montane dry forest with laurophyllous under-story to laurophyllous mist forest	Kenya, Marsabit Nat. Park, ca. 1400 m April 1977	Combretum sp., Cordia, Diospyros, Dombeya, Croton, Terminalia spec. understory partly as Fig. 6
13	transition laurophyll-ous forest to sclero-phyllous woodland	Japan, Honshu, near Shimoda (Izu-Peninsula), ca. 100 m 5.9.1984	Quercus phillyraeoides, Pittosporum tobira, Elaeagnus umbellata
14	transition laurophyll-ous forest to mixed sclerophyllous/Juni-perus rock scrub	Japan, Honshu, near Shimoda (Izu-Peninsula), ca. 50 m 5.9.1984	Juniperus chinensis, Pinus thunbergii
15	transition laurophyll-ous/deciduous forest to bog scrub	Japan, Honshu, near Numata (Tanbara Bog), ca. 1200 m 15.8.1984	Fraxinus longicuspis, Fagus crenata, (Alnus, Acer, Sorbus, Prunus, etc.), understory with Ilex crenata, Menziesia pentandra, Thujopsis dolabra-ta, Vaccinium smallii

Table 3 (continued)

Fig.	Type	Locality	Tree species
16	submontane, subtropical rainforest	Australia, Queensland, Lamington Nat. Park, ca. 800 m 6.9.1981	Argygrodendron trifoliolosum, Geissois benthamii, Ficus watkinsiana (Cyathea reichhoferi)
17	lowland warm-temperate rainforest	Australia, Tasmania, Styx R., ca. 300 m 29.8.1981	Eucalyptus regnans, Nothofagus cunninghamii, Dicksonia antarctica, Atherospermum moschatum, Anodopetalum biglandulosum, Zieria arborea etc.
18	montane cool-temperate rainforest	Southern New Zealand, near Haast Pass, Mt. Aspiring Nat. Park, ca. 560 m 19.9.1981	Nothofagus menziesii (Podocarpus hallii)
19	Position of the evergreen broad-leaved forest in a diagram of yearly mean temperature and yearly mean precipitation		
20	Distribution of laurineous forests on a worldwide scale and typical climate diagrams including the neighbouring biomes		

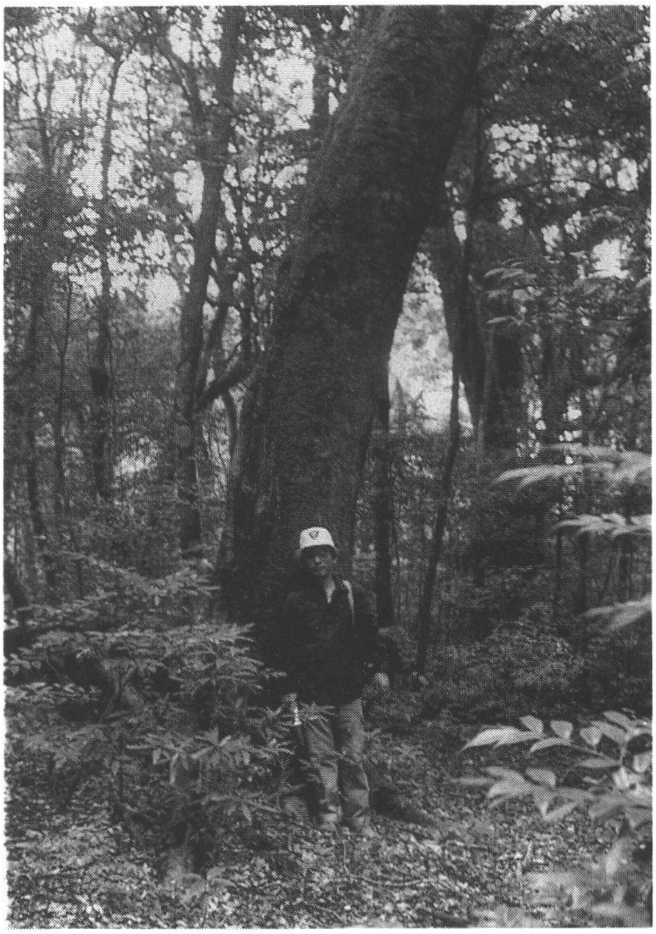
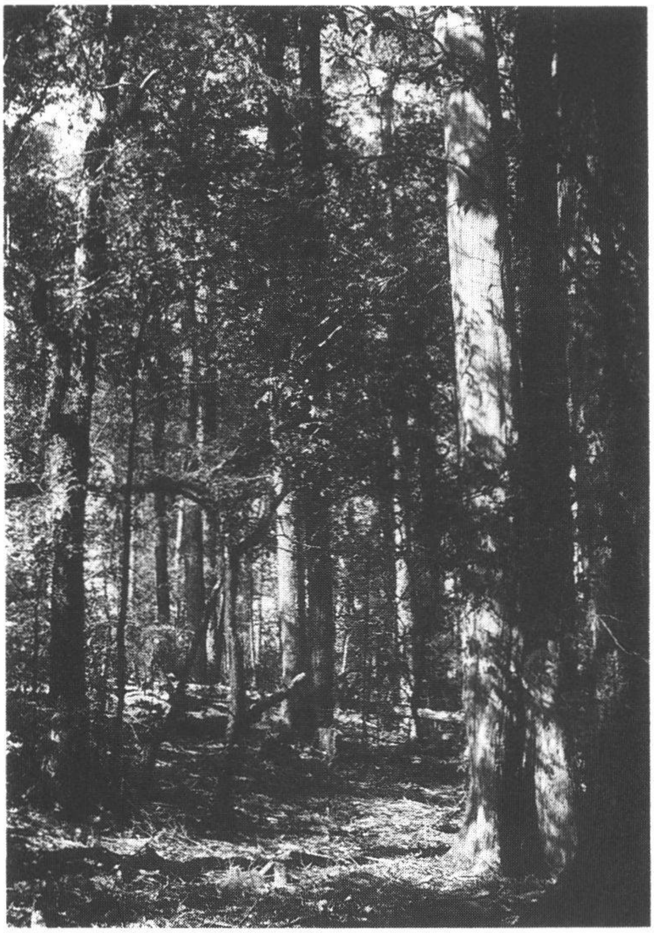


Abb. 1 (oben), Abb. 2 (unten) - Fig. 1 (above), Fig. 2 (below)
Legenden s. Tabelle 3 - Legends see Table 3



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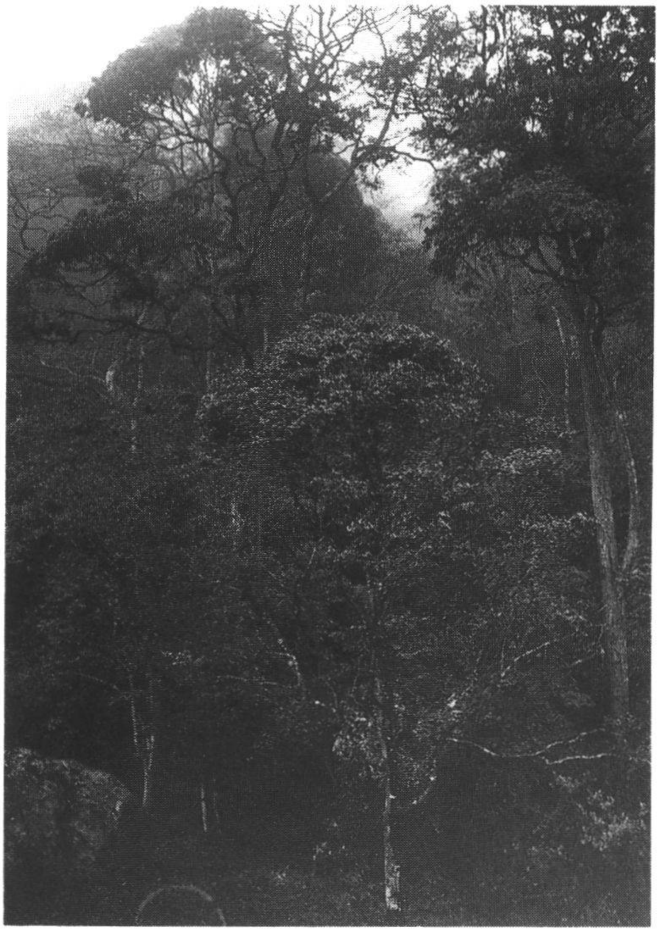

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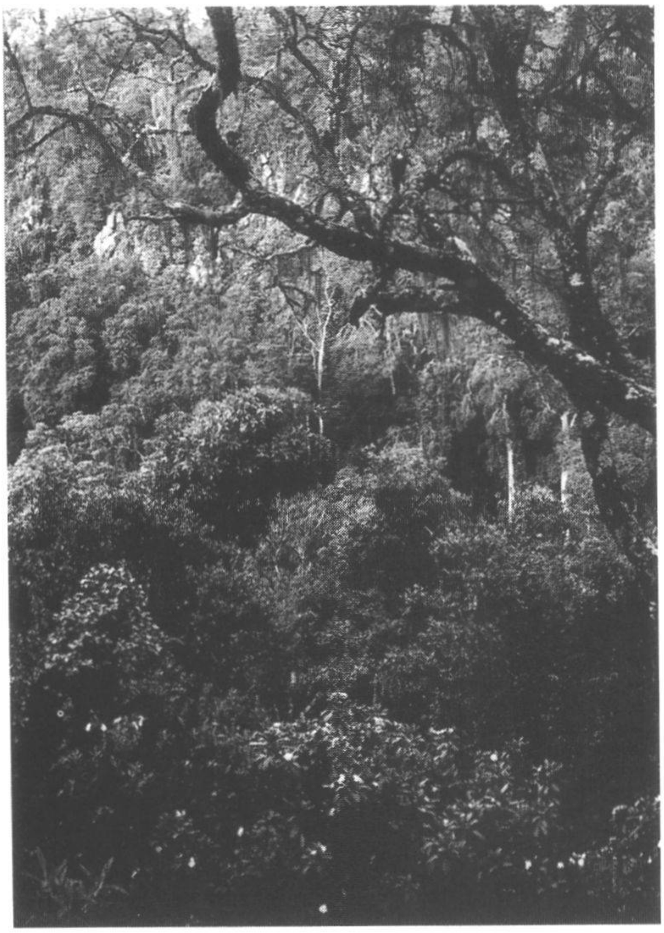


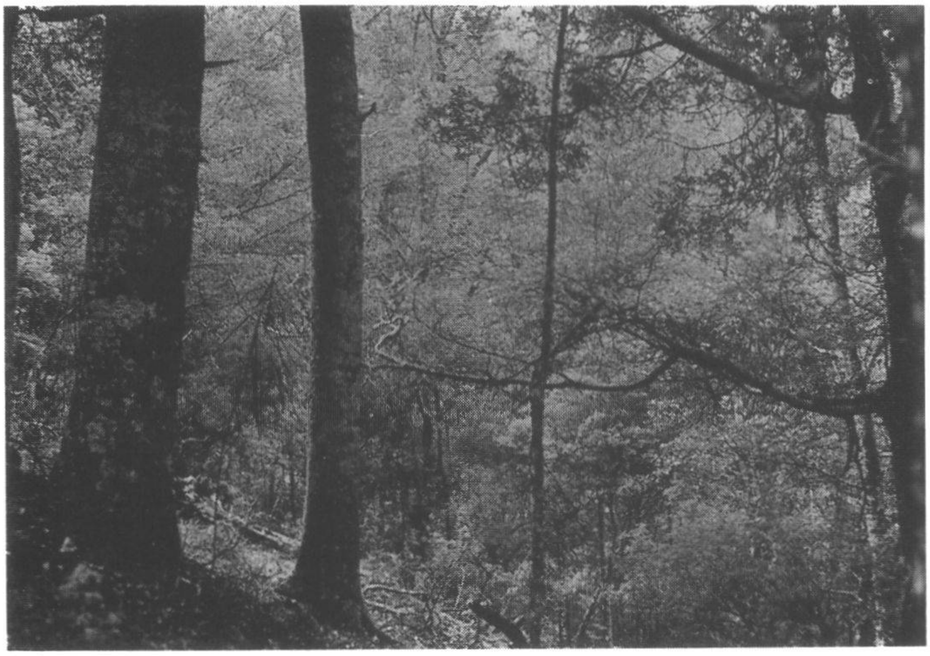


Abb. 7 (oben), Abb. 8 (unten) - Fig. 7 (above), Fig. 8 (below)
Legenden s. Tabelle 3 - Legends see Table 3

Abb. 9 (oben), Abb. 10 (unten) - Fig. 9 (above), Fig. 10 (below)
Legenden s. Tabelle 3 - Legends see Table 3

Abb. 11 (oben), Abb. 12 (unten) - Fig. 11 (above), Fig. 12 (below)
Legenden s. Tabelle 3 - Legends see Table 3

Abb. 13 (oben), Abb. 14 (unten) - Fig. 13 (above), Fig. 14 (below)
Legenden s. Tabelle 3 - Legends see Table 3

Abb. 15 (oben), Abb. 16 (unten) - Fig. 15 (above), Fig. 16 (below)
Legenden s. Tabelle 3 - Legends see Table 3

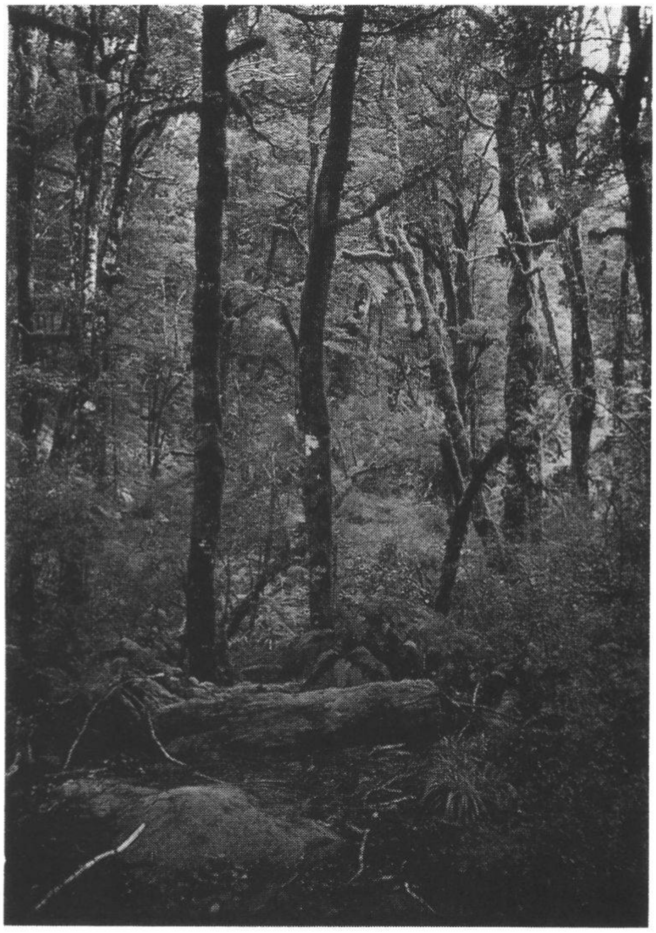


Abb. 17 (oben), Abb. 18 (unten) - Fig. 17 (above), Fig. 18 (below)
Legenden s. Tabelle 3 - Legends see Table 3

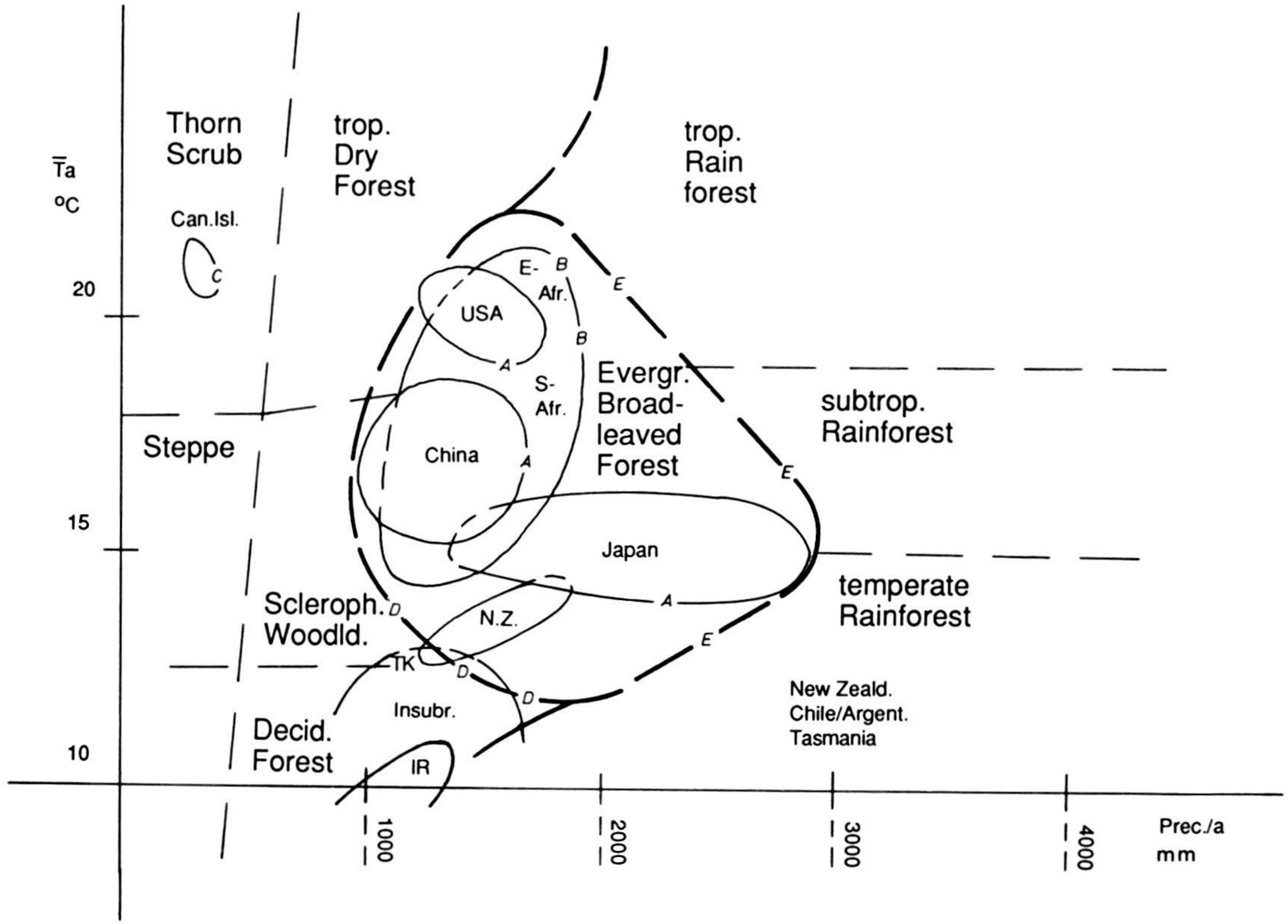


Fig. 19. Position of the evergreen broad-leaved forest in a diagram of yearly mean temperature and yearly mean precipitation.

Abb. 19. Diagramm der jährlichen Mitteltemperaturen und -niederschläge: Lage der immergrünen Laubwälder

Fig. 19 (continued)

Delimitations according to climate diagrams of WALTER and LIETH (1960-1967). Interrupted straight lines (after STOCKER 1965).

Insubr. = Cool to warm-temperate foothills of southern parts of the Central Alps

IR = Southwestern Ireland (Kerry). Stations of northwestern Turkey at the cooler end of New Zealand stations

Can.Isl. = Canary Islands. Cloud forest above thorn scrub, station in the lowlands

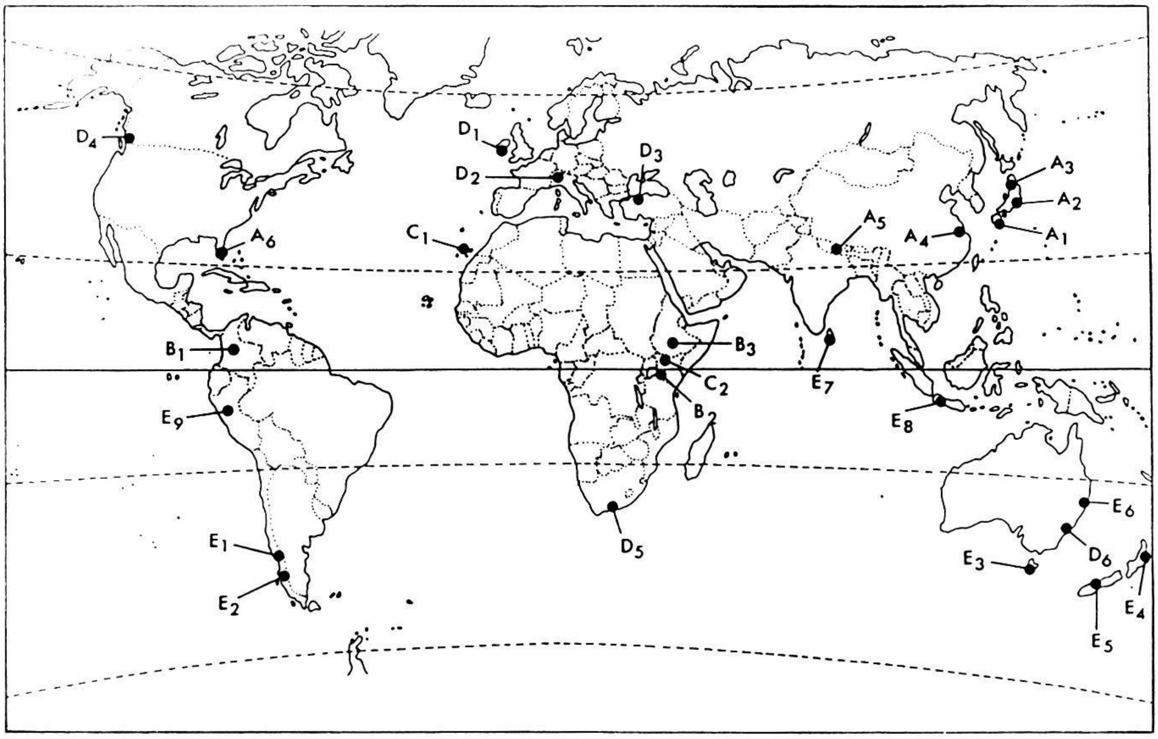
Letters A, B, C, D and E within the curves:

A Typical stations
B Tropical montane
C Mist belt
D Transitional types
E True rainforest

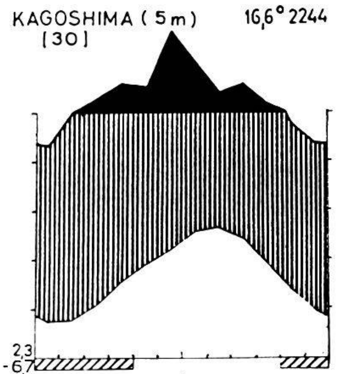
Differential factors besides medium temperature and precipitations are also late frost: limit to the deciduous forest.
Type of precipitation line (less curved): limit to temperate rainforest; do. dropping in the season: limit to sclerophyllous woodland (to be considered with type of temperature line)
Limits between evergreen broad-leaved forest, deciduous forest, rainforest and sclerophyllous woodlands often depend on minimum temperatures and summer precipitations.

Fig. 20 (p. 191-193). Distribution of laurineous forests on a worldwide scale and typical climate diagrams including the neigbouring biomes.

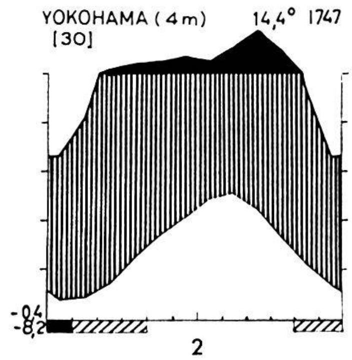
Abb. 20 (S. 191-193). Weltweite Verbreitung der Lorbeerwälder mit typischen Klimadiagrammen der angrenzenden Biome.



A. Typical stations



1



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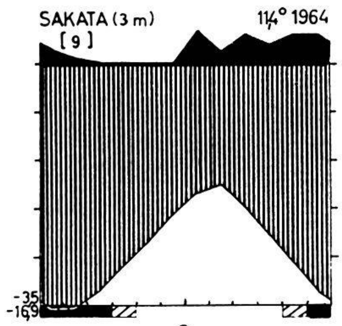

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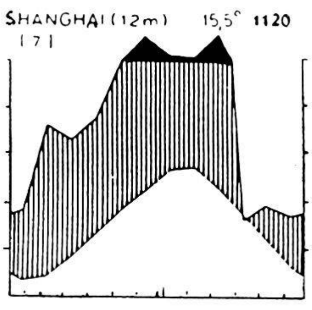

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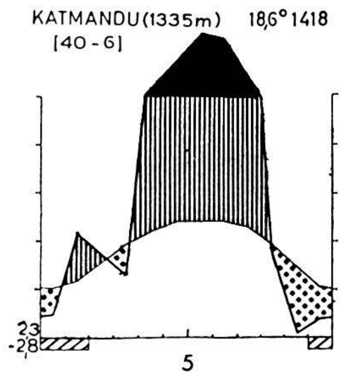

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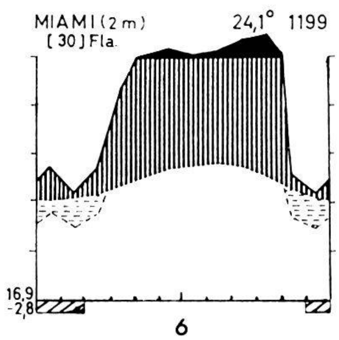
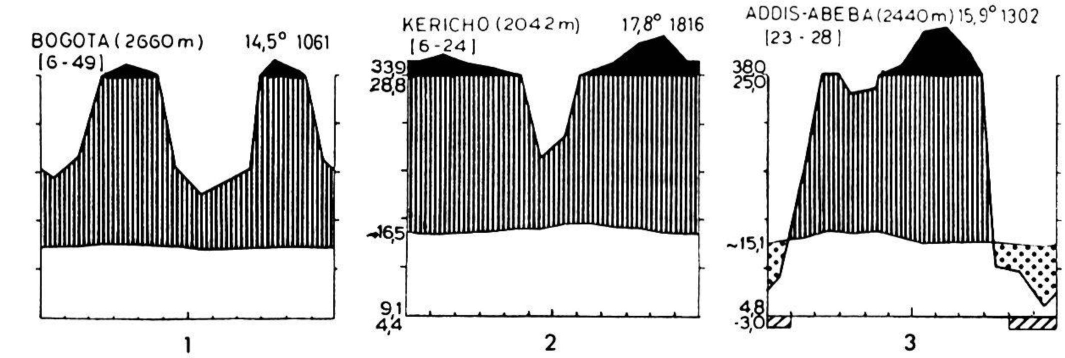
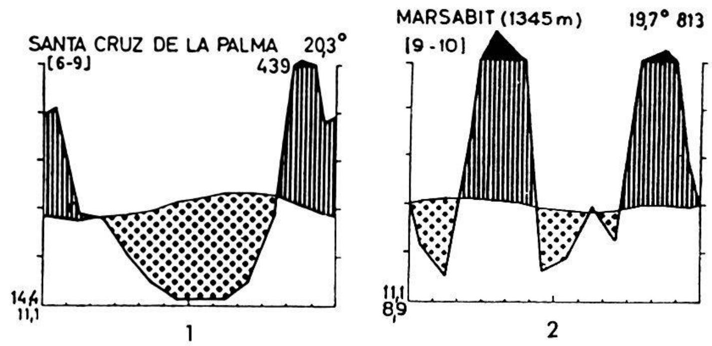


6

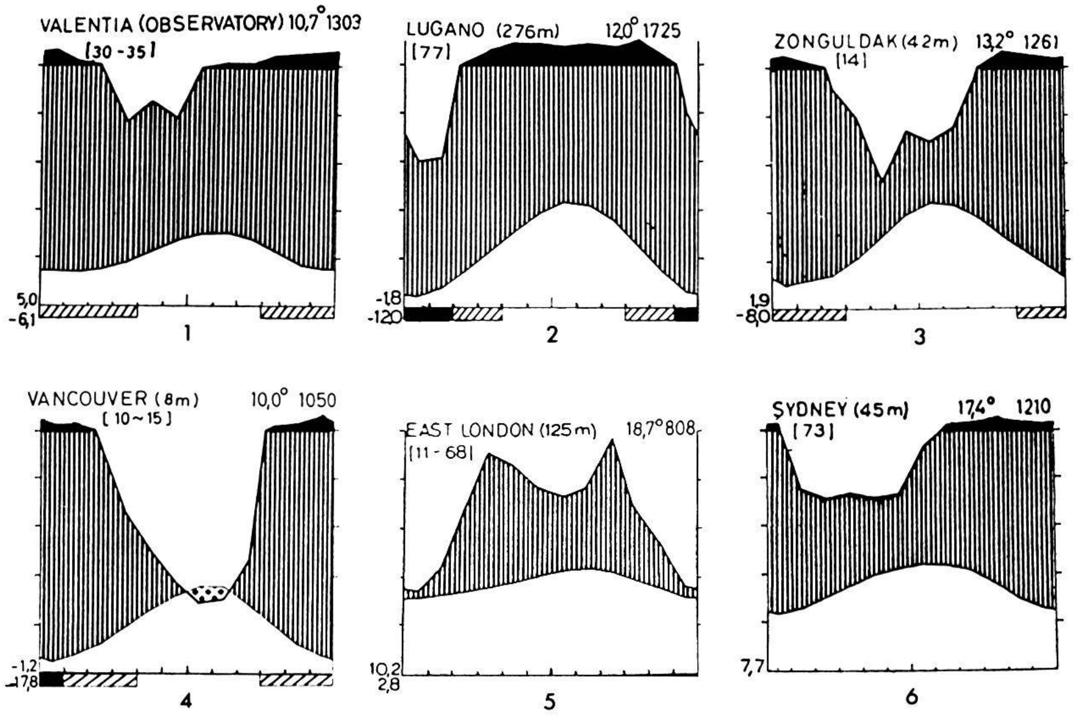
B. Tropical montane



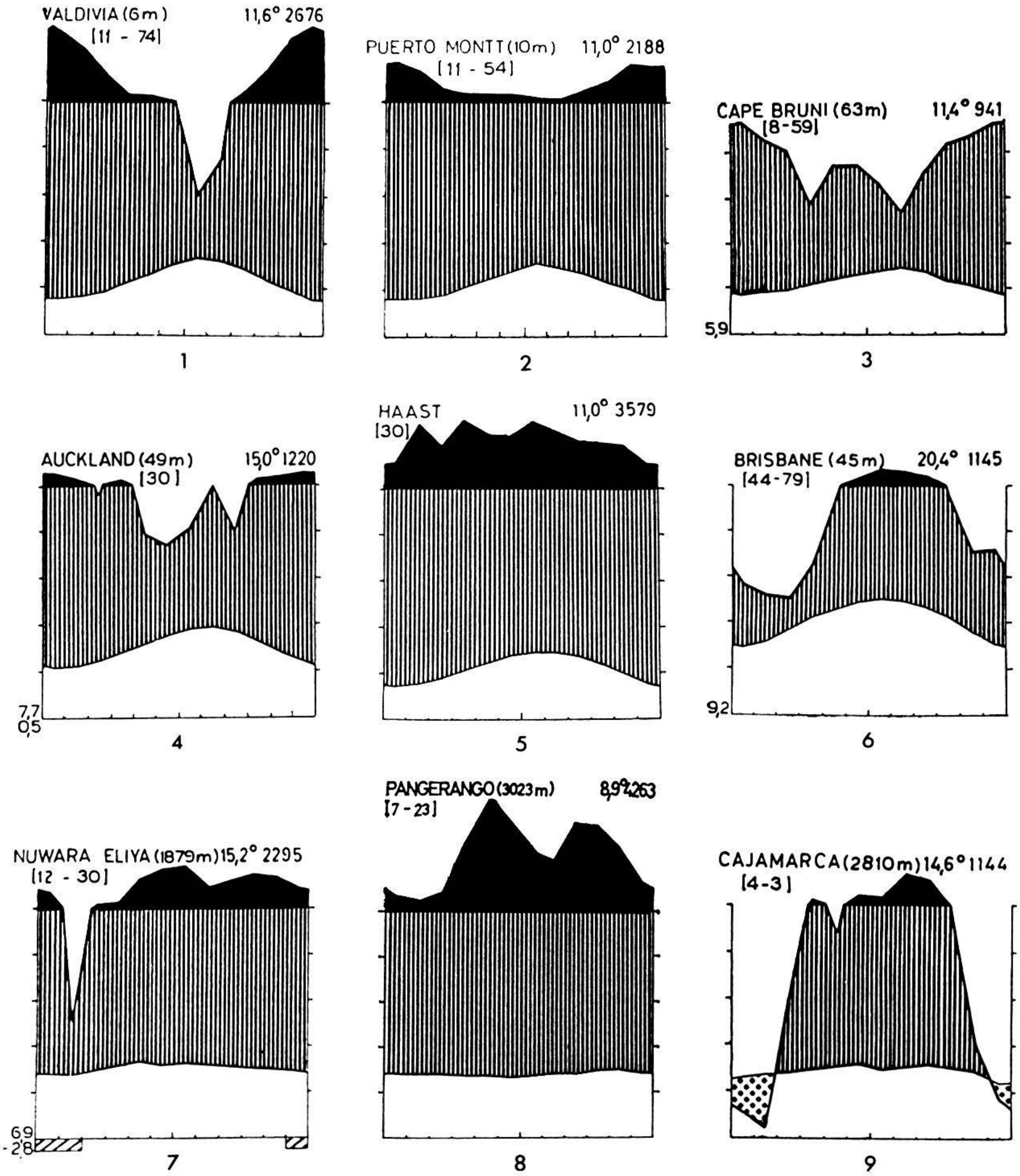
C. Mist belt



D. Transitional types



E. True rainforest



SUMMARY

1. **Limiting factors.** Evergreen broad-leaved forests are
   - thermophilous (20-25 ^{o}C in the growing season)
   - sensitive to frost (around 0 ^{o}C, rare down to -10 ^{o}C, rarely late frosts)
   - sensitive to drought (precipitations generally high the year over or at least in the growing season or in drier seasons edaphically favourable or high horizontal precipitations [mist]).
2. **Characteristic features. Stems** show all forms between the typical sclerophyllous to the ombrophilous tree. **Leaves** are normally softly coriaceous to almost sclerophyllous and nearly mesophyllous, partly quite large. **Ferns** are often dominant as epiphytes and herb layer plants.
3. **Delimitations.**
   - **Temperate** (subtropical) rainforests have generally more and more evenly distributed precipitations, more even temperatures and hardly (severe) frost.
   - **Sclerophyllous woodlands** have less and more sporadical rainfalls, predominantly in winter, regular fire influence.
4. **Types**
   a. **Climax** under so-called 'Shanghai-climate' (incl. lowland forests from 1000 m up to 2500 m a.s.l. in the eastern Himalaya) (Zonobiom).
   b. **Climax** on drier oreal subalpine belts of (sub-)tropical mountains (mostly 2500-3000 m a.s.l.) (Orobiom).
   c. **Climax** between temporate rainforest and deciduous forests of the humid southern hemisphere (partly Zonobiom, partly Orobiom).
   d. **Cloud forest** on (sub-)tropical dry mountains above semi-arid submontane forests and below sclerophyllous or ericaceous subalpine woodlands (Orobiom).
   e. **Ravine forest** as an exceptional type (Pedobiom) in the sclerophyllous biome.
   f. There are many **transitional types** to the neighbouring biomes, also to coniferous forest (e.g. Pacific coast of northern America).

ZUSAMMENFASSUNG

1. **Begrenzende Faktoren.** Lorbeerwälder sind
   - thermophil (20-25 ^{o}C in der Vegetationsperiode)
   - frostempfindlich (um 0 ^{o}C, selten unter -10 ^{o}C, selten Spätfröste)
   - trockenheitsempfindlich (meist hohe Niederschläge das ganze Jahr über, oder mindestens während der Vegetationsperiode, oder aber in Trockenzeiten zumindest unter edaphisch günstigen Bedingungen, oder schliesslich mit hohem Nebelniederschlag).
2. **Charakteristische Merkmale. Stämme** zeigen alle Formen zwischen dem typischen Hartlaub- und dem typischen Regenwaldbaum. **Blätter** sind normalerweise schwach lederig bis fast sklerophyll oder mesophyll, teilweise ziemlich gross. **Farne** sind oft dominant als Epiphyten und in der Krautschicht.
3. **Abgrenzung**
   - **Regenwälder** (temperierte und subtropische) haben meist mehr und re-

gelmässiger verteilte Niederschläge, ausgeglichenere Temperaturen und kaum (stärkere) Fröste.

- **Hartlaubwälder** haben weniger und eher sporadischen Niederschlag, vor allem im Winter sowie regelmässige Feuer.
- **Sommergrüne Laubwälder** ertragen kältere Winter und häufigere Spätfröste sowie extremere oft trockenere Sommer.

4. **Typen** (Schwerpunkte)
   a. **Klimax.** Ostasiatisches sog. "Shanghai-Klima" (inkl. Niederungs- und Hügelwälder bis 1000-2500 m ü.M. im östlichen Himalaya) (Zonobiom).
   b. **Klimax.** Im Bereich der trockneren orealen bis subalpinen Höhenstufen (sub-)tropischer Gebirge (meist um 2500-3000 m ü.M.) (Orobiom).
   c. **Klimax.** Zwischen temperiertem Regenwald und sommergrünem Laubwald der humiden südlichen Hemisphäre (z.T. Zonobiom, z.T. Orobiom).
   d. **Nebelwald.** Auf subtropischen trockenen Gebirgen oberhalb semiaridem submontanem Wald und unterhalb sklerophyllem oder erikoidem subalpinem Buschwald (Orobiom).
   e. **Schluchtwald.** In stärker abweichender Form. Verteilt im Hartlaub-Biom (Pedobiom).
   f. **Uebergänge.** Sehr häufig zwischen den benachbarten Biomen, auch zu Nadelwald (Pazifikküste im Nordwesten Nordamerikas).

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