Appendix D
Classifications of Forests

The task of describing and attempting to explain the wide diversity in forest ecosystems of the Tropics has occupied biologists, ecologists, and foresters for well over a century.

Temperate Zone scientists, comparing tropical with temperate ecosystems, have concluded that the differences are generally only of degree. De Laubenfels (1975, p. 38) states that "it cannot be fairly said that there is any kind of vegetative formation in the middle latitudes that can be successfully segregated from corresponding tropical types. It is only possible to identify floristic divisions and the unique features that separate any given plant or set of plants from any other." As two examples, tropical plants are frost sensitive, and temperate plants need variations in day length or temperature to complete their life cycles.

De Laubenfels (1975) listed a number of physiognomic characteristics that distinguish four major plant formations: rain forest, seasonal forest, woodland, and desert. He considered a continuous understory to be a characteristic of rain forests. Seasonal forests are not structurally distinct, but have only scattered trees beneath their canopies; they also include trees that may become defoliated for several weeks. Forests differ from woodlands in that they have continuous canopies, gaps between the tree crowns and the ground, and juvenile trees either at random or concentrated in forest openings. De Laubenfels also concluded that prolonged drought eliminates the delicate, shade-enduring plants.

Attempts to characterize and differentiate tropical forest ecosystems have generally involved grouping observations into classes, the members of which share common characteristics (Havel 1980). This grouping may be followed by attempts to relate classes to underlying environmental conditions. Classification implies an assumption that differences among members of each class are less than differences between classes.

Generally acceptable classifications of tropical forests have proved elusive. When external factors (such as climate and soil) are used as criteria, the resulting categories have mostly lacked validity (De Laubenfels 1975). Where vegetation characteristics reflect external factors, it is more logical to use the vegetation characteristics as classifiers. Species do not generally serve to classify plant formations, and little can be made of individual plant forms because of aggregations of different plant forms. Grubb and others (1963) even find using the number of vegetative stories to be questionable in separating types of tropical forests. They conclude that any attempt at a universal system of classification obscures as many truths as it reveals. Havel (1980) agrees that because of the great variety of physiognomic and environmental characteristics used to classify forests for various purposes, no one classification is best in all circumstances. He points out that the description and classification of forest types are still unsettled despite the recent surge of interest in ordination, which, in contrast to classification, is primarily concerned with continuities and gradients, whether physiognomic or environmental.

Schimper's System

In 1898, Schimper assembled what was then known about the general significance to plants of water, heat, light, air, soil, and animal life. Schimper considered woodland, grassland, and desert to be climatic, depending primarily on the amount and distribution of rainfall and on the desiccating influence of atmospheric moisture-saturation deficits and air movement. He concluded that flora are primarily distributed according to temperature. Schimper also concluded that abrupt transitions among woodland, grassland, and desert are determined chiefly by soil. He termed plant communities reflecting general moisture and temperature regimes and local soil conditions as climatic or edaphic "formations."

Schimper defined woodland as vegetation dominated by woody plants, and included "forest" (if closed), "bushwood" (if shrubs were more abundant than trees), and "shrubwood" (if entirely of shrubs). He concluded that woodlands grow where rainfall is generally more plentiful than in grassland areas. However, it is not continuous rainfall but rather continuous moisture availability within reach of tree roots that produces woodlands. Schimper's edaphic woodlands included "fringing forests" along rivers and lakes with moving water and swamp forests near stagnant water. Among the latter are mangroves.

Schimper used the term "rain forests" for the natural vegetation of tropical regions that are constantly moist. He concluded that rain forests typically receive more than 200 cm of precipitation annually, although in some areas, 150 cm produces vegetation with rain forest attributes. In the Amazon, where annual rainfall of more than 200 cm is the exception, luxuriant forests are confined to the riverbanks.

Schimper described the rain forests as presenting a variety of green colors, few visible flowers, a tangle of lianas, straight-trunked trees, and abundant undergrowth. Terrestrial herbaceous vegetation is developed only in the lighter portions of the forests, and grasses are insignificant. The tree stems are covered with diverse epiphytes. The struggle of the plants for light is evident everywhere.

Schimper concluded that the forests of the interior of Brazil south of the Amazon should be classed as "monsoon forests," his term for the type of forest nearest to rain forests in moisture availability. This type of forest trends into savanna and thorn forest over large areas. He considered the thorn woodland (the caatinga with thorny Cactaceae and Mimosaceae) to be intermediate between the Amazon forests and the savannas (campos) to the south.

He also referred to the significant effect that mountains have on vegetation, not only on the slopes themselves but also in the flatter areas that surround them. There, rainfall exceeds that of lowlands and may produce rain forests of exceptional luxuriance. The vegetation on lower mountain slopes in the equatorial Tropics contrasts with vegetation of the lowlands chiefly in composition. Generally, the trees in tropical montane rain forests are evergreen and lack plank buttresses. Their appearance is more massive, their branching is more pronounced, and their leaves are smaller and thicker than those of the lowlands trees. Lianas are fewer and thinner; epiphytes may be more luxuriant, but they are smaller and tend to be mosses or ferns rather than phanerogams. Equatorial mountains and outer tropical lowlands are ecologically closely allied. In the outer Tropics at upper elevations, the montane forests become temperate (deciduous).

On tropical mountains above the montane forests, Schimper describes a transition through an elfin wood of short, branchy trees with xerophilous foliage to an alpine region. The successive elevational belts produce xerophilous shrub, alpine grassland or steppe, and finally alpine desert. In dry regions, only the montane belt may be forested.

In summary, Schimper recognized the following formations of woodland vegetation in the Tropics:

Climatic	Edaphic
Lowland rain forest	Swamp forest
Montane rain forest	Littoral woodland above high tide
Monsoon forest	Littoral woodland below high tide
Savanna forest	Forest of limestone soil
Thorn woodland	Forest of humus soil
	Forest of silicaceous soil

Schimper provided much groundwork for more recent attempts to characterize tropical forests. Burtt-Davy (1938) concluded that Schimper's primary reliance on climate for vegetation classification and the subdivision of climatic zones on the basis of the habit or physiognomy of plant life made it especially useful to foresters, who have "multifarious duties, both administrative and executive that preclude them from being ecologists pure and simple." P. W. Richards (1961) concluded that Schimper underestimated edaphic influences on vegetation types in the wet Tropics, where they are less evident than in the seasonal Tropics but equally important.

Chipp's System

A classification combining vegetative physiognomy with edaphic and climatic bases was proposed by Chipp (Tansley and Chipp 1926). Chipp's tropical woodland categories were as follows:

Closed forest—grass generally absent

1. Rain forest—lower altitudes, temperature high, dry season short, if any; where confined to belts along water courses, termed "fringing forest"
2. Mountain forest—higher altitudes, temperature moderate, generally subject to mist and clouds
3. Mangrove—groundwater salty or brackish

Parkland—trees in groups or isolated, herbaceous cover partial or continuous, lianas generally absent

1. Transition—belts or islands of closed forest surrounded by grass areas with trees
2. High grass, low tree savanna—trees in groups or occurring singly, short and gnarled stems; grass 2 to 4 m tall
3. Open woodland—no closed canopy, groundcover herbaceous with grass predominating
4. Orchard country—trees occurring singly, scattered through grass; often with palms
5. Thorn country, low thorn—heavy trees with spiny shrubs, grass cover rarely continuous.

Burtt-Davy (1938) considered this system imperfect because it did not cover all existing types, such as deciduous forest, it had overlap, and it was vague as to the boundaries of some types.

Champion's System
An extension of the use of physiognomy in classifying tropical forests was offered in 1936 by a forester stationed in India (Champion 1936a). He proposed the following classification:

Wet forest (24 m tall or more)

1. Wet evergreen (rain forest)—dense, entirely or almost entirely evergreen
2. Semi-evergreen—dominants include deciduous trees, but evergreens predominate
3. Moist deciduous—dominants mainly deciduous, but subdominants and lower stories largely evergreen; top canopy rarely dense.

In addition, Champion recognized 10 wet edaphic types (such as bamboo brake) and 8 seral types (such as beach, tidal, freshwater, swamp, and river rain forest).

Dry forest

1. Dry deciduous—canopy rarely more than 24 m high, entirely deciduous
2. Thorn forest—canopy more or less broken, deciduous
3. Dry evergreen—usually less than 18 m high, often dense, hard-leaved evergreen trees predominant.

Champion also recognized 12 dry edaphic types (such as inland dune), 4 primary seral types (such as dry riverain), and 3 secondary seral types (deciduous, deciduous scrubby, and savanna).

Montane subtropical forest

1. Wet—broadleaved, largely evergreen
2. Moist—pine associations predominant
3. Dry evergreen—low xerophytic forest and scrubs.

Burtt-Davy's System
Struck by the similarities in the classifications Chipp and Champion derived in distant regions, Burtt-Davy (1938) concluded that separate classifications should not be necessary. Using the life form of dominant trees in mature associations, Burtt-Davy proposed a composite classification of formations and distinguished three hierarchical plant communities:

1. Association—the fundamental floristic unit of vegetation, based on Tansley and Chipp's (1926, p. 9–10) definition: "The largest unit which consists of a definite assemblage of species (usually with definite dominants) and adequate habitat. Named by the dominant or dominant and codominant species."
2. Formation type—woodland, grassland, or desert, distinguished by the physiognomy of their dominants
3. Formation—a group of associations that resemble each other in general physiognomy and in climatic or edaphic habitat more closely than they resemble any other association; usually named on the basis of physiognomy or climatic or edaphic habitat (evergreen forest).

Burtt-Davy's classification of tropical forest formations follows:

A. Moist woodland
  1. Moist climatic formations
    a. Woodland evergreen rain forest, including lower montane evergreen rain forest
    b. Semi-evergreen rain forest
    c. Moist deciduous forest
    d. Upper montane rain forest
    e. High montane conifer forest
    f. Montane bamboo forest
    g. Alpine elfin woodland
  2. Moist edaphic formations
    a. Riparian woodland
    b. Freshwater swamp forest
    c. Palm swamp
    d. Mangrove woodland
    e. Littoral woodland

B. Dry woodland
  1. Dry evergreen forest
  2. Savanna woodland
  3. Thornland

For each formation, Burtt-Davy gave synonyms, definitions, general descriptions, habitat, climate, and subformations. His moist woodlands are separated from dry woodlands on the basis of available water, not just rainfall. Nevertheless, his moist formations generally receive more than 120 cm of rainfall per year, and the dry formations less. Upper montane refers to elevations 1,500 m or higher in the equatorial Tropics. Alpine elfin woodland is generally 2,900 m or higher.

Beard's System

Beard (1944b) considered Burtt-Davy's work an attempt to correlate nomenclature and harmonize classification systems, and he was strongly influenced by its physiognomic approach, which was based on the study of community structure as determined by the occurrence of major types of plants (Beard 1973). He concluded that the physiognomic basis of classification meets all the essential requirements for the treatment of climax tropical formations. Structure and life form can be reduced to exact measurements in the field, and for types so recorded, the structure and life form of any desired formation may be mathematically defined. Structure is diagrammed from actual measurements. Life form can be expressed mathematically in percentages in various ways, such as stating that 56 percent of the trees forming the topmost story of the forest have compound leaves. Once this has been done, he points out, a worker elsewhere in the Tropics can determine the structure and life form of any forest community in the area and can readily tell how it compares with the "norm." An essential feature of the assessment is the profile diagram shown in figure D–1 (Beard 1949). Beard used a strip about 8 m wide by 60 m long.

Beard's formation series are defined by habitat. His classification includes one rain forest formation, six seasonal forests, two dry evergreen forests, nine montane forests, four swamps, and four marsh or seasonal swamps. He describes each formation in detail and then presents the following key to arborescent vegetation for use in the field (Beard 1944b):

1. Palms dominant or present in large numbers
   2. Tall palms, up to 20 m or more, emergent over lower woody or herbaceous growth
      3. Fan palms over a dense thicket of bushes and small trees 5 to 10 m high .... palm marsh
      3'. Fan or pinnate palms over low and irregular herbaceous or woody undergrowth with scattered small trees .... palm swamp
   2'. Palms not emergent
      3. Palm brake—low forest about 10 m high composed mainly of palms with no large trees, very luxuriant herbaceous ground vegetation, abundant moss and epiphytes .... mountain community
      3'. Marsh forest—forest with two tree strata, the upper consisting of scattered trees up to 25 to 30 m, the lower consisting mainly of palms and forming the canopy at 10 to 15 m .... lowland community

1'. Thicket of bamboo .... bamboo brake

Figure D–1.—*Profile diagram of lower montane rain forest in St. Lucia (Beard 1949).*

1". Woody growth dominant, palms and bamboos not abundant
- 2. Tree growth over 10 m high
  - 3. Deciduous species present .... seasonal forest
    - 4. Tree strata 3, less than half of the individuals in the topmost story deciduous .... evergreen seasonal forest
    - 4'. Tree strata 2, the upper open and with over two-thirds of individuals deciduous .... deciduous seasonal forest
  - 3'. Forest entirely evergreen (or nearly so)
    - 4. Tall forest with large trees forming a continuous canopy at 20 m or more above ground
      - 5. Tree strata 3 or 4, dominants 40 m or more tall, leaves predominantly compound .... rain forest
      - 5'. Tree strata 2, dominants about 30 m tall, leaves predominantly simple .... lower montane rain forest
      - 5". Tree strata 2, dominants about 20 m tall, leaves simple, abundant moss, tree ferns present .... montane rain forest
    - 4'. Lower forest without continuous canopy or with a canopy formed below 20 m from the ground
      - 5. Pine forest .... mountain pine forest
      - 5'. Broadleaved trees
        - 6. Tree strata 2, the upper formed of scattered trees up to 30 m, the lower closed and forming the canopy at about 15 m .... xerophytic rain forest
        - 6'. Tree strata 1, sometimes 20 m high, usually lower
          - 7. Stilt roots or erect pneumatophores present; inundated tidally with brackish water .... mangrove woodland
          - 7'. Sinuous plank buttresses or stilt roots and knee-shaped pneumatophores present; inundated with fresh water .... swamp forest

2'. Tree growth less than 10 m high
- 3. Species predominantly spinescent or thorny
  - 4. More or less closed woodland of microphyllous, thorny trees 3 to 19 m high .... thorn woodland
  - 4'. Open vegetation with abundant column cacti and prickly pears .... cactus scrub
  - 4". Exceedingly sparse growth with large bare patches of soil .... desert
- 3'. Armed species few or absent
  - 4. Vegetation markedly windswept
    - 5. Trees covered thickly with moss and epiphylls; abundant epiphytes and climbers; a high mountain community ..... elfin woodland
    - 5'. Moss scarce, no epiphylls, epiphytes and climbers very rare; a seashore community .... littoral woodland
  - 4'. Vegetation not markedly windswept
    - 5. A fairly open woodland containing some stout temperate genera present; high mountains .... frost woodland
    - 5'. A dense woodland or thicket of small, branchy tree tropical genera .... lowland marsh woodland

Beard's system is easiest to apply in the areas where his familiarity with the vegetation was greatest, the Antilles and northern South America. One feature that has appeal is his listing of prominent species for each formation; this facilitates approximation where no climax vegetation remains. Fanshawe (1954) used the scheme to identify eight types of forests in Guyana.

Limitations exist in using Beard's classification system. It requires a knowledge of the climax forest, a disappearing resource. Therefore, there is already a need to key it into secondary forests, possibly using related physiognomic criteria. Another criticism comes from Grubb and others (1963), who consider it too reliant on stratification. Nevertheless, the principle of a system based on physiognomy, depending on natural rather than contrived representations of the features of each habitat, has much in its favor.

Beard (1953, 1967) made an intensive study of savanna vegetation, defining tropical American savannas as "communities comprising a virtually continuous, ecologically dominant stratum of more or less xeromorphic herbaceous plants, of which grasses and sedges are the principal components, and with scattered shrubs, trees or palms sometimes present." He concluded that in tropical America all climates, given suitable soil conditions, can and do support woody vegetation of some kind. The driest climates in tropical America support woodlands, never savannas. Savanna life forms indicate a response to soil rather than climate. He concluded that there is no such thing as a grassland climate in tropical America.

Beard contrasts tropical Africa and Australia with tropical America. In tropical Africa and Australia, annual rainfall of less than 100 cm is the rule rather than the exception. The grassy woodlands, savannas, and steppes of those regions are entirely absent in tropical America. Grasses are inconspicuous in American deciduous seasonal forests, thorn woodlands, and cactus scrubs. There are, nevertheless, large areas of grasslands in tropical America and, indeed, the word "savanna" is of Amerindian origin (Beard 1967). Savanna vegetation is fire hardy. Savannas are often swept by fires, but they do not depend on fire, being an edaphic climax vegetation type. They occur in areas of 100 to 300 cm of rainfall annually. They are, however, subject to impeded drainage and have intermittent perched water tables with alternate periods of waterlogging and desiccation, the latter too severe for tree growth. Sombroek (1966), who studied Amazon soils, agrees as to the essentially edaphic origin of the vegetation.

The term "derived savanna" refers to savannas generated by clearing or burning, practices that lead to increased drying of upper soil layers (Young 1969).

The Holdridge System

Holdridge's (1978) classification of world climates into life zones designates each with the name of a vegetative formation. The system, applied throughout Central America, northern South America, and some of the Greater Antilles, is useful in relating homoclimes (climatically similar environments). The system assumes that two annual average phenomena, rainfall and biotemperature define vegetative formations and relegates to a lower order seasonal and edaphic effects, considering them responsible for associations. Beard (1973) concluded that this approach puts some disparate types of vegetation in the same compartments and separates some similar types into different compartments. There is no doubt that in many areas zone limits cross continua at points not sharply reflected in the vegetation. Budowski (1964a) notes the possibility of providing for associations reflecting edaphic, hydric, or atmospheric phenomena within life zones. He also concludes that lack of fit may be due to human disturbances in the vegetation. Holdridge (1967) has proceeded to define associations within his life zones that are physiognomic. He set different limits of elevation for his altitudinal belts, depending on whether the basal zone is tropical or subtropical (table D–1).

In a similar effort, van Steenis (1972), concerned with the islands of Melanesia (latitude 5° S. to 20° S.), designated areas below 1,000 m in elevation, "tropical"; those from 1,000 to 1,500 m, "subtropical"; those from 1,600 to 2,400 m, "montane"; and those from 2,500 to 4,000 m, "subalpine."

In contrast to Holdridge, Troll (1958) emphasized climatic seasonality in his classification scheme, using the number of what he terms "humid months" as the sole criterion for separating wet from dry formations (table D–2).

The Unesco System

An attempt to standardize the classification of vegetation worldwide was made by a Unesco committee (Anon. 1978b). The international aegis of the organization and early favorable reactions to its approach (Kuchler and Montoya-Maquin 1971) suggest that it may become widely used. The tropical and subtropical formations recognized are as follows:

- I. Closed forest (at least 5 m tall and tree crowns interlocking)
  - IA. Mainly evergreen (canopy never without green foliage)
    - IA1. Tropical ombrophyllous forest (rain forest) (neither cold nor drought resistant)
      - IA1a. Evergreen lowland forest
      - IA1b. Submontane forest
      - IA1c. Montane forest (broadleaved, needle-leaved, microphyllous trees and bamboo)
      - IA1d. Subalpine forest
      - IA1e. Cloud forest (epiphytes; gnarled, broadleaved, needle-leaved, microphyllous trees)
      - IA1f. Alluvial forest (riparian, occasionally flooded, seasonally waterlogged soil)
      - IA1g. Swamp forest (broadleaved trees and palms)
      - IA1h. Bog forest
    - IA2. Tropical and subtropical evergreen seasonal forest
      - IA2a. Lowland
      - IA2b. Submontane (broadleaved, needle-leaved trees)
      - IA2c. Montane (no tree ferns)
      - IA2d. Dry subalpine

Table D–1.—Life zones within the Tropics

	Mean biotemperature (°C)				
	>24°C Tropical	18–24°C Premontane and subtropical	12–18°C Lower montane	6–12°C Montane	3–6°C Subalpine
Mean annual precipitation (cm)					
>800	Rain forest				
400–800	Wet forest	Rain forest	Rain forest		
200–400	Moist forest	Wet forest	Wet forest	Rain forest	
100–200	Dry forest	Moist forest	Moist forest	Wet forest	Rain forest
50–100	Very dry forest	Dry forest	Dry forest	Moist forest	Wet forest
25–50	Thorn woodland	Thorn steppe		Steppe	Moist forest
12.5–25	Desert Scrub	Desert scrub		Dry scrub	
Potential evapotranspiration/year (cm)	>141	106–140	71–105	36–70	18–35
Elevation range (10^3 m)					
Tropical at sea level	0–1	0–2	1–3	2–4	3–4.5
Subtropical at sea level		0–1	0–2	1–3	

Source: Holdridge 1967.

- IA3. Tropical and subtropical semideciduous forest
  - IA3a. Lowland
  - IA3b. Montane or cloud
- IA4. Subtropical ombrophyllous forest (very local)
- IA5. Mangrove
- IA9. Tropical and subtropical, evergreen, needle-leaved forest
  - IA9a. Lowland and submontane
  - IA9b. Montane and subalpine
- IB. Mainly deciduous forest
  - IB1. Tropical and subtropical drought-deciduous forest
    - IB1a. Lowland and submontane
    - IB1b. Montane and cloud
- IC. Extremely xeromorphic forest
  - IC1. Sclerophyllous (leather leaved trees) dominated by extremely xerophytic forest
  - IC2. Thorn forest
  - IC3. Mainly succulent forest

- II. Woodland
  - IIA. Mainly evergreen woodland
    - IIA1. Broadleaved
    - IIA2. Needle-leaved
      - IIA2a. With rounded crowns *(Pinus)*
      - IIA2b. With evergreen sclerophyllous understory
      - IIA2c. Without evergreen sclerophyllous understory
  - IIB. Mainly deciduous woodland
  - IIC. Extremely xeromorphic woodland

- III. Scrub (mainly composed of caespitose (clumped) woody phanerophytes 0.5 to 5.0 m tall)

- IV. Dwarf scrub.

Table D-2.—Drought influence on forest types

No. of humid months	Lowland type	Lower montane type
11–12	Evergreen	Montane
10	Semi-evergreen	Montane
7–9	Moist deciduous	Moist (valleys)
5–6	Dry deciduous	Dry (valleys)
2–4	Thorn	Thorn
1	Desert scrub	Desert scrub
0	Desert	Desert

Source: Troll 1958.

Regional and Subregional Vegetation Types

As the classification of forests is gradually based on more intimate knowledge of their character from place to place, an important subsequent step is the description of regional vegetation types. For tropical America, the outstanding example is Hueck's (1957) description of the natural vegetation of 33 tropical regions of South America (table D–3, fig. D–2). He gives a general description of the climate, structure, and the composition of the vegetation, and lists the species of economic importance in each region. Such works strengthen or correct broader systems of classification and are a necessary preliminary to land-use planning and management.

On a subregional scale, some of the forests of tropical America have been classified in great detail. An example is in the Amazon Basin (Aubreville 1961; Dubois 1971; Ducke and Black 1953; Pires 1974; Prance 1978, 1982; Veloso 1962). The Amazon valley supports perhaps a million plant and animal species, more than 50,000 of which are higher plants, about one-fifth of the world's total. The following classification system and volume of the forests vary more with soil than with climate; volume is highest near Caxuana, Brazil, with 200 cm of mean annual rainfall:

Terra firme—Forests are not subject to flooding covering some 85 percent of Amazonia. Their composition varies greatly. On loamy soils, the trees are tall, canopy is dense, lianas are large, and groundcover is sparse. Wood volume ranges from 160 to 270 cubic meters per hectare. On sandy soils, the forest is significantly poorer with mostly large trees. Wood volume is 100 to 150 m^3/ha.

Table D-3.—Regions of tropical South America according to type of vegetation

1. The delta of the Amazon
2. The forests northeast of the Amazon (Paru-Jari)
3. The Tocantins and Gurupi regions
4. The middle and lower Xingu and the Tapajos
5. Rios Madeira and Purus
6. The western hyleia
7. The northwest hyleia (Rio Negro)
8. Flooded forests of the Amazon and lower Madeira
9. Acre, Beni, Mamore, and Griapore
10. The hyleia near the Andes
11. Caqueta, Vaupes, and Guainia
12. Tributaries of the right margin of the Orinoco
13. The Guianas
14. The delta of the Orinoco
15. The Tucuman-Bolivian forest
16. Forests of the eastern slope of the central Andes
17. High-altitude forests of the northern Andes
18. Rain forests of the Pacific and the Caribbean
19. The Colombian-Venezuelan tradewind forests
20. The coastal forests of Brazil
21. Subtropical forests of eastern and southern Brazil
22. Araucaria forests of southern Brazil
23. Dry forests of the true Chaco
24. The eastern Chaco
25. The Santa Cruz-Trinidad savanna region
26. Forests of the Velasco mountain region
27. Typical campos Cerrados
28. Moist and wet forests of the Cerrados
29. Typical caatinga
30. Moist forests of the caatinga region
31. The Babassu palm region
32. Dry forests of the Caribbean coasts of Colombia and Venezuela
33. The interior valleys of the Andes

Source: Hueck 1957.

Varzea—Forests are subject to periodic flooding, except blackwater (see "igapo" below) covering about 55,000 km^2. They tend to be denser than the terra firme forests but less rich in species. Buttresses and respiratory roots are common.

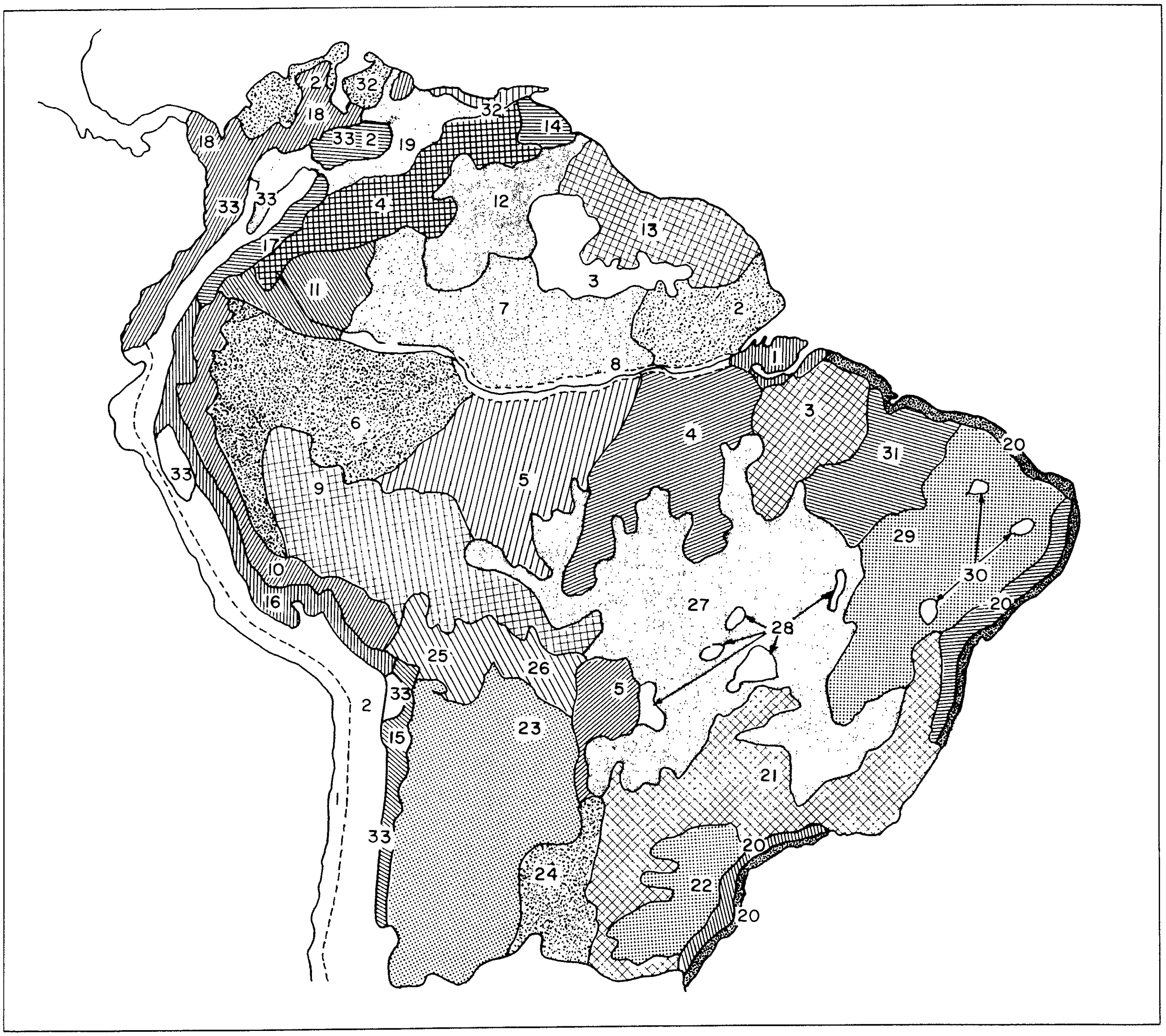

Figure D–2.—*Hueck's 33 vegetation regions of tropical South America; table D–3 defines the circled numerals (Hueck and Seibert 1988).*

Tidal varzea—Forests are flooded twice daily with fresh water; similar to seasonal varzeas. They contain palms, *Guazuma, Hevea, Symphonia,* and *Virola.*

Seasonal varzea—Forests are along clearwater rivers that flood annually for weeks. They contain *Carapa, Ceiba,* and *Hura.* Along blackwater rivers, they may contain *Virola.*

Rain varzea—Forests are flooded because of heavy rains, not by rivers. They contain *Carapa, Ceiba,* and *Virola.*

Igapo—Swamp forests are flooded annually by blackwater rivers and permanently waterlogged covering about 15,000 km². Blackwater rivers in the Amazon Basin generally drain areas of white sand. The color is caused by humic acids originating from incomplete decomposition of organic matter. This water is highly acid and, in stagnant areas, low in oxygen (Carter 1934, Medina 1978). Trees of few species tend to be short, twisted, and sclerophyllous. These areas contain *Bombax, Cecropia,* and *Hevea.*

Savanna—Trees are low and sparse covering about 30,000 km².

Campina—Trees are low and much branched growing on leached, white sands and covering about 115,000 km².

Montane vegetation—These are forests of the basin fringe, with high endemism.

Coastal vegetation—Forests are on sand dunes, covering about 10,000 km² composed mostly of *Chrysobalanus.*

Mangrove—Forests are subject to marine tidal influence near mouths of rivers. They have few species, short trees, low volumes, and cover about 1,000 km².

For general descriptions of tropical forests, broad classifications with little detail have been used. For example, Haig and others (1958b), in a worldwide treatment of the subject, used the following simple scheme:

- Wet evergreen—dominants entirely or mainly evergreen; typically 200 cm or more of rainfall annually, with little or no water deficiency
- Moist deciduous—dominants mainly deciduous; 125 to 200 cm of rainfall annually, 4 to 6 months dry
- Dry deciduous—dominants entirely deciduous or almost so, less than 125 cm of rainfall per year
- Mangrove
- Bamboo
- Conifers

Mangroves

The total area of mangroves in the world is estimated to be about 2,500,000 ha, at least 75 percent of which is in the Eastern Hemisphere (Molski 1970). Mangroves grow along protected seashores and saline estuaries to latitudes as high as 30°, withstanding brief frosts at the extremes (Cintron 1982). The seven mangrove species of the Western Hemisphere are not obligate halophytes but escape vegetative competition by tolerating a saline environment. Mangroves fed by inland waters are among the most productive ecosystems on the planet. They contribute to the stability of rapidly accreting shorelines, but the extent to which they promote accretion itself is unclear.

There are three general types of mangroves: riverine (estuaries with continuous waterflow and low salinity), fringe (areas with a pronounced gradient in topography or tidal amplitude), and basin (areas with a low gradient and sluggish water). Riverine mangroves produce about 24 g of organic matter per square meter per day, whereas fringe mangroves produce about 13 g, and basins about 18 g (Cintron 1982). Litterfall ranges from 2 to 4 grams per square meter per day.

Cerrado Vegetation

Cerrado vegetation is so extensive and distinctive that it deserves further description. It is semideciduous, xeromorphic vegetation covering some 1.5 million km² in central Brazil (Ferri 1961). It gives way to mesic (medium moisture conditions) forests on the west and southeast, to caatinga on the northeast, and to chaco on the southwest (Eiten 1972). The soils are usually deep, rainfall ranges from 130 to 200 cm annually, and 3 to 5 months are almost without rain. The rainfall in the driest month may be 1 to 3 cm, compared with 4 to 20 cm along the Amazon, where the effective dry season averages only 2 weeks (Eiten 1972). The tree roots in cerrado may go down 10 m. Evidence of adequate groundwater is seen in the high rate of transpiration.

Eiten (1972) describes cerrado as having tall, woody plants characterized by thick bark, leaning and twisted trunks, twisted boughs, thick twigs, open crowns, and large leaves (table D–4). The cerrado region ranges from arboreal woodlands to open savannas and pure grasslands and has soils with low nutrient contents and high available aluminum (Latosols). There is no evidence that large areas formerly in forest have become cerrado. Conversely, cerrado protected from fire shows no tendency to succeed to forest. It occurs solely on certain geological formations and soils (Eiten 1972).

The Instituto Brasileiro de Geografia e Estadistica recognizes the following types of cerrado (Eiten 1972):

1. *Cerradao*—arborescent woodland

2. *Cerrado*—low forest, closed or slightly open scrub

3. *Campo cerrado*—tree and scrub savanna

4. *Campo sujo* or *limpo*—grassland, pure or with dwarf shrubs.

Table D–4.—Stand characteristics of cerrado forests

Type of cerrado	Trees (no./ha)	Basal area (m^2/ha)	Stem height (m)
Cerrado	1,092	16.5	5.9
Tipico	819	10.2	5.2
Ralo	616	6.1	4.4
Campo	273	2.1	3.8

Source: Eiten 1972.

Ferri (1961) contrasts caatinga with cerrado. Caatinga may be either deciduous or evergreen. Deciduous caatinga has low transpiration; evergreen caatinga is more like cerrado, with high rates of transpiration. Deciduous caatinga receives about 50 cm of rainfall annually; while evergreen may receive 200 cm. Ferri explains the poverty of these formations as being due to limited nutrients in evergreen caatinga, limited water in deciduous caatinga, or combinations of both.