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HEADQUARTERS
QUARTERMASTER RESEARCH & ENGINEERING COMMAND
U S ARMY

TECHNICAL REPORT
EP-63

WET TROPICS: LIMITS AND CHARACTERISTICS

QUARTERMASTER RESEARCH & ENGINEERING CENTER
ENVIRONMENTAL PROTECTION RESEARCH DIVISION

SEPTEMBER 1957 NATICK, MASSACHUSETTS

HEADQUARTERS
QUARTERMASTER RESEARCH & ENGINEERING COMMAND, US ARMY
OFFICE OF THE COMMANDING GENERAL
NATICK, MASSACHUSETTS

30 September 1957

Major General Andrew T. McNamara
The Quartermaster General
Washington 25, D. C.

Dear General McNamara:

The inclosed report, based on an analysis of standard reference literature, delimits the wet-tropical regions of the world and describes the outstanding characteristics of their environment. It distinguishes "core areas" which most authorities agree in defining as wet-tropical, and "transition areas" which have certain features of the wet tropics or have wet-tropical conditions for only part of the year. It was found that 15 percent of the total land area of the world falls into these categories.

The report will be useful to Army planners and technologists because it provides a basis for determining the general extent and location of areas where items for tropical issue are required. Such information furnishes some broad guidance for that portion of the research and development program aimed at assuring adequate protection for troops in areas where wet-tropical stresses prevail.

Sincerely yours,

C. G. Calloway
C. G. CALLOWAY
Brigadier General, USA
Commanding

1 Incl
EP-63

HEADQUARTERS QUARTERMASTER RESEARCH & ENGINEERING COMMAND, US ARMY
Quartermaster Research & Engineering Center
Natick, Massachusetts

ENVIRONMENTAL PROTECTION RESEARCH DIVISION

Technical Report
EP-63

WET TROPICS: LIMITS AND CHARACTERISTICS

Jack V Chambers
Geographer

Paul C Dalrymple
Geographer

Harding Jones
Geographer

REGIONAL ENVIRONMENTS RESEARCH BRANCH

Project Reference:
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Foreword

Although much is known about the past problems of military activity in wet-tropical environments, many as yet unexplored factors could affect military operations within the tropics. The debilitating effect of wet-tropical climate upon man and the destructive effect upon equipment and supplies is considerable. Without preventive measures, metals rust overnight, leather mildews rapidly, stored clothing and tentage rot within a few weeks, and food products spoil quickly because of insect infestation and mold.. Furthermore, close attention must be given to maintaining the operational capabilities, health, and morale of troops, and to assuring that supplies are delivered where and when they are needed.

Little has been done to classify and define the wet tropics according to military operations, in spite of the awareness of their military importance. This preliminary survey defines the wet tropics according to general environmental characteristics, and is one step in a militarily acceptable delineation of wet-tropical limits.

AUSTIN HENSCHEL, Ph.D.
Chief
Environmental Protection
Research Division

Approved:

JAMES C. BRADFORD, Colonel, QMC
Commanding Officer
QM R&E Center Laboratories

A. STUART HUNTER, Ph.D.
Scientific Director
QM Research & Engineering Command

CONTENTS

ABSTRACT

This report defines and briefly describes the wet-tropical areas of the world. They lie between 25°N and 25°S latitudes, and cover about 15 percent of the world's land surface. This area was determined by using as indices to world distribution 16 authoritative maps of climate, vegetation, and soil. "Core" areas and "transitional" areas were distinguished; the core areas were studied in more detail, since transitional areas are wet-tropical for only part of the year.

The wet tropics were analyzed according to three main environmental elements: climate, vegetation, and soil. Most climates between the 25° parallels of latitude, excluding mountains and deserts, vary from hot-wet to warm-humid. Transitional areas have a lower annual amount of precipitation, and become seasonally dry at greater distances from the core area. Vegetation type in the tropics is largely a function of rainfall, varying from tropical rain forest in wet areas to deciduous forest, savanna woodland, and thorn woodland in drier areas. Wet-tropical soils are in the general category of laterites, but are complex and vary from place to place.

The uniformity of core area environment is interrupted by topographic diversity, of which interior plains are by far the most extensive physiographic type, and represent the fullest development of wet-tropical areas.

This report includes 7 photographs of typical tropical vegetation and 20 maps showing the world distribution of elements of tropical environment.

WET TROPICS: LIMITS AND CHARACTERISTICS

1. Introduction

The limits of the wet tropics vary greatly according to different defining criteria. For example, areas classified as wet-tropical in one particular vegetation study may be differently classified in terms of certain climatic classifications. Nevertheless, many sources are in substantial agreement on the presence of sizable "core" areas in tropical latitudes where moisture and temperature are constantly high. In these core areas, tropical rain forest vegetation (Fig. 1) and lateritic soils predominate.

Fig. 1. "Core" area: Tropical rain forest, Barro Colorado Island, Panama Canal Zone.

The general character of the wet tropics gradually changes from the core areas to the peripheral area; a dry season of varying length is characteristic of much of this transitional zone. The inner margin of the transitional wet-tropical zone has a short dry season of one or two months duration, whereas the outer margin has drought for longer periods. Tropical forests are less luxuriant when there is an extended drought. As aridity increases outward from the core areas, the forest yields to patches of scattered trees and grasses (Fig. 2), and finally, beyond the limits of the transitional area, to vast expanses of tropical grasslands and low shrubs (Fig. 3).

a. Method of Delimitation

In this study, 16 authoritative delimitations of elements of wet-tropical environments were used for comparison and analysis. From the superimposition of these delimitations, a composite map (Fig. 4) was drawn, using the relevant classifications of these authorities. Wet-tropical core areas were demarked where the elements coincided on 14 or more maps. Broad transitional zones surrounding the core areas represent areas of partial agreement where from 2 to 13 authorities were in accord. The major problem of demarkation occurred at the outer fringe of the transitional zone where environmental characteristics varied greatly from those of the core zones. According to this system of classification, 4 percent of the world's land area is within the wet-tropical core area and 11 percent is transitional, making a total of 15 percent that is wet-tropical to some extent.

Fig. 2. Inner transitional area, wet tropics, Ivory Coast, Africa

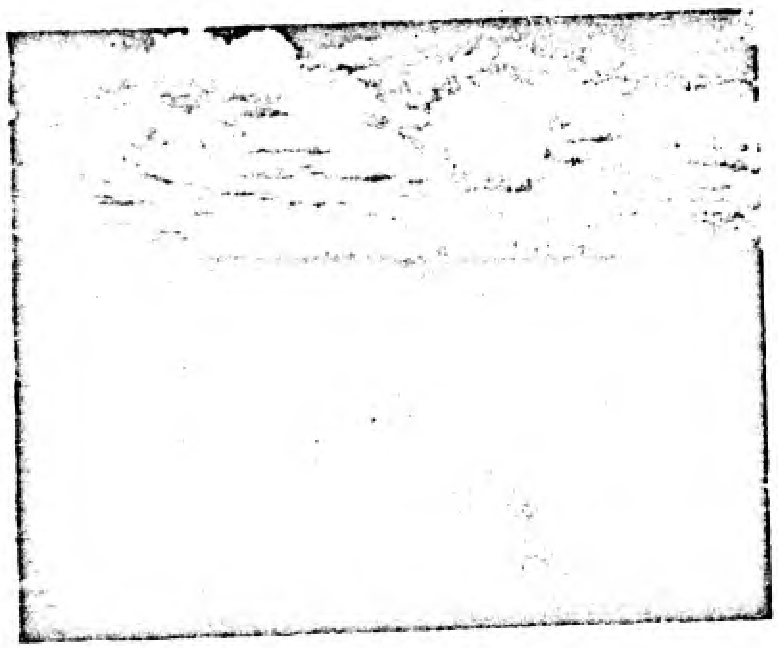


Fig. 3. Outer transitional area: tall savanna of the Menam Basin, West Central Thailand

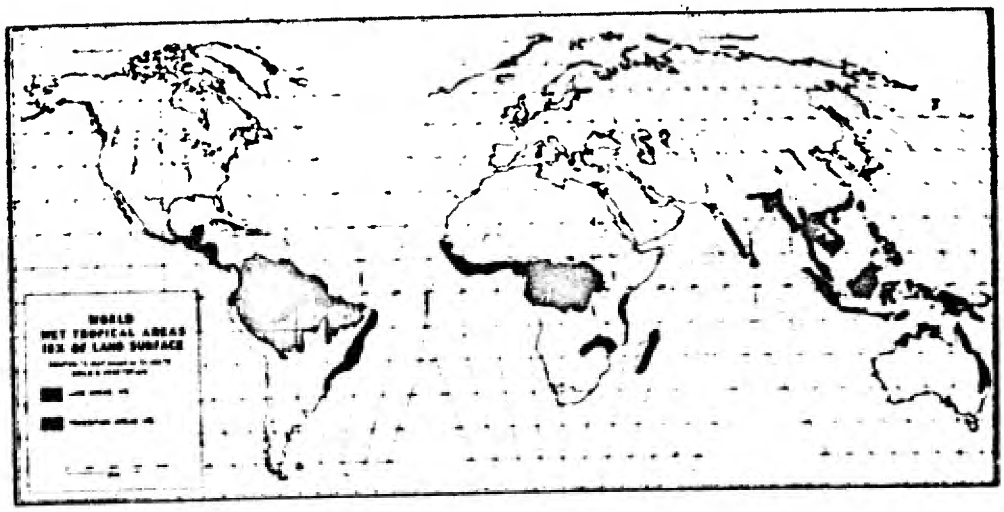


Figure 4

b. Location

The wet-tropical areas encircle the earth approximately between latitudes 25°N and 25°S, and are interrupted only by oceans, mountains, and desert areas. The Amazon and Congo Basins are the largest continuous areas of wet tropics. South America is the widest continent at the Equator, and Africa the second widest; this accounts in part for the extensive wet-tropical areas in these two continents. Asian and Australian wet-tropical areas, on the other hand, are small by comparison to those of South America and Africa, and are mostly on tropical islands lying between continents.

The chief elements of the environment, other than relief, are climate, vegetation, and soils. Their characteristics in the wet tropics are summarized in the following sections.

2. Climate

a. General Characteristics

The equatorial barometric pressure trough migrates from 5°S in January to about 12° to 15°N in July. This migration of the so-called "doldrums" influences the formation of clouds, rainfall, and tropical storms. The "heat equator" migrates with the equatorial trough, with an average annual position at about 5°N. Even though the mean annual temperature range near the Equator is only a few degrees, a fluctuation of one degree is much more noticeable than it is in midlatitudes.

There are three general types of annual temperature curves characteristic of tropical stations: oceanic, equatorial, and subtropical.

An oceanic climate has a late summer maximum and a late winter minimum; this is typical of the South American coast, exposed to the easterly trade winds, and of many Pacific islands. Equatorial climates have little seasonal variation; Recife, Barbados, Belem, and Quito are examples of this type. Subtropical climates, located 12 to 18 degrees from the Equator, have a maximum temperature in late spring before the rainy season, and a higher maximum after the rainy season in late summer. Variations of this type are found in the monsoon countries. Local factors often affect the temperature in such a way as to produce a curve which is unique for the station and which does not fit any of these broad general temperature regimes.

Rainfall also coincides closely with the average position of the equatorial trough. A tropical rainfall regime is far more complicated than the temperature regime; only two rainfall regimes have gross features recognizable throughout the tropical world. In addition to the areas that have a high rainfall throughout the year, extensive areas have alternating rainy and dry seasons.

Tropical rain falls mostly from cumulus-type clouds. The number of days with brief afternoon showers is high, although the rainfall effectiveness in the tropics is lower than in temperate climates because of the higher rate of evaporation. Evaporation increases with temperature and wind speed. This higher evaporation rate is a major factor in making life more agreeable in the tradewind zone than in most other tropical areas.

The variability of annual rainfall in wet-tropical areas is generally low; in the wetter areas it is less than 15 percent of the mean annual amount. The variability is 80 to 100 percent on the drier margins, however, and it increases as the amount of average rainfall decreases.

b. <u>Interior Plains</u>

The climate of the interior plains is characteristically hot, wet, and oppressive. Duration of sunlight is reduced by the frequent cloudiness. The seasonal range of temperature is very low, and the diurnal range is relatively small. Readings above 95°F are rare. Bartholomew's[1] map of annual temperature extremes (Fig. 5) shows the small range of temperature in the wet tropics. The approximate diurnal range is 10 (F) degrees greater than the annual range. Precipitation is a function of latitude in the tropics, and is usually abundant throughout the year except on the outer margins of the transitional zone. The map of mean annual precipitation (Fig. 6) illustrates the relationship between heavy rainfall and the interior plains. The sky, clear in mid-morning, becomes cloudy about noon, and by mid-afternoon convective showers develop and continue intermittently until early the next morning. Rain showers are brief and frequently violent; several inches may fall within a few minutes. Within 3 degrees north or south of the Equator, rain falls during all

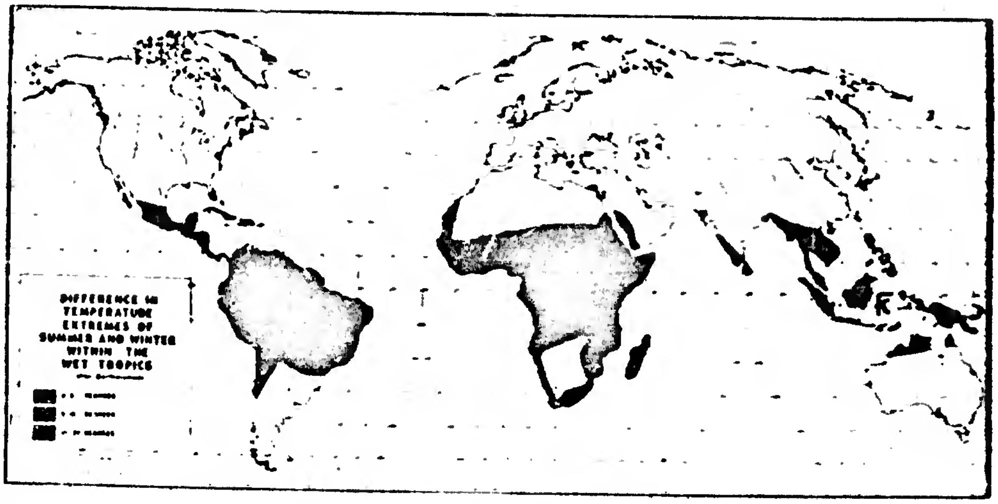


Figure 5

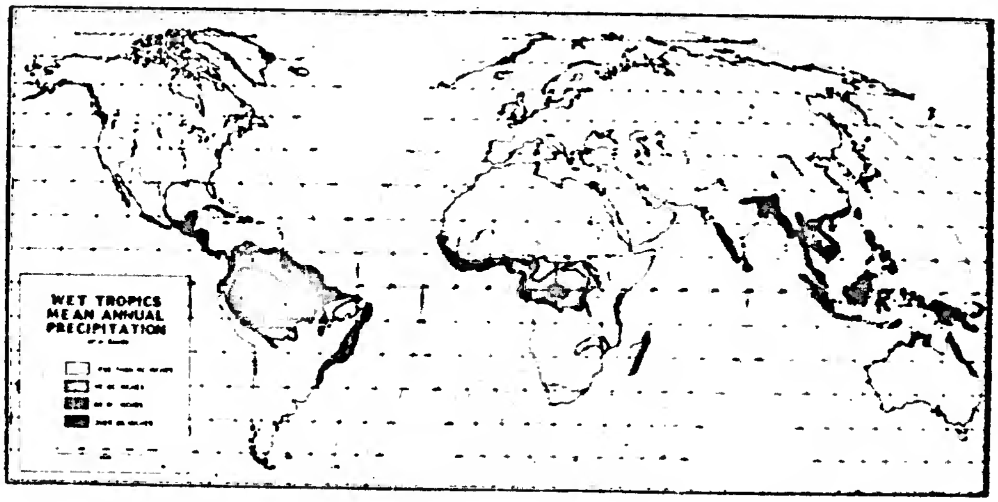


Figure 6

seasons of the year, and between 3 and 10 degrees, north or south of the Equator, there are two rainy seasons yearly. With increasing distance from the Equator, the rainfall maxima follow each other closely and finally merge into one maximum in the transitional areas. Although winds are generally light, tropical showers are often accompanied by strong gusts that could hinder military operations. Trees are frequently blown over in such storms, and may become obstacles to the movement of motorized equipment.

c. Mountains

The character of tropical mountain climates is determined primarily by altitude. The dry-bulb temperature of the free atmosphere within the troposphere decreases at an average of 3.3 (F) degrees per 1,000 feet increase in altitude. The amount of rainfall increases up to a zone of maximum precipitation, which, according to C. Braak[4], is usually about half the height of the mountain, and then decreases with additional altitude. Relative humidity tends to rise with increased elevation, until an altitudinal zone of saturation is reached, usually in the montane rain forest. Wind speed is affected by location and exposure, and the size and shape of the mountain. Generally, however, wind speeds increase with elevation. Cloudiness increases, and consequently, the amount of sunshine decreases with altitude. The climate is characterized by a small seasonal temperature range and a relatively large diurnal temperature range. Some leeward or rain-shadow mountain slopes, with sunny skies, low humidities, and low rainfall, are desert-like rather than wet-tropical.

d. Coastal Lowlands

The climate of all coastal regions tends to be moderated by the ocean. The diurnal temperature ranges are smaller, and temperatures are lower than in the interior. However, some of the heaviest precipitation within the wet tropics occurs along coasts with onshore winds and storms. Showers are most prevalent in mid-afternoon, although they may occur during any part of the day or night.

e. Maps

Climate is the best of the three criteria used for delimiting the wet tropics because of precise comparability of data throughout the world. Two classifications of climate are especially noteworthy: those of Köppen[14] (Fig. 7) and Thornthwaite[21] (Fig. 8). Both systems are based on quantitative values, but differ in the climatic elements employed.

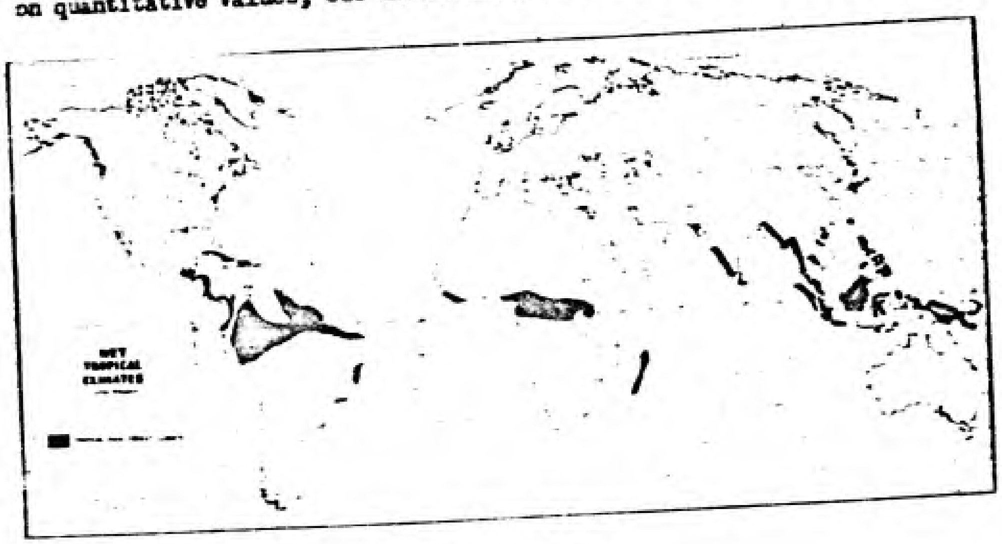


Figure 7

Köppen assumed that the critical limits in the distribution of various types of vegetation were climatic, and attempted to establish empirical climatic values that would approximately delimit the various vegetational zones. Köppen defined climatic types according to temperature and precipitation, and used the mean monthly isotherms of the warmest and the coldest months for a climatic boundary between "tropical" and non-tropical areas. He established the critical temperature for the coldest month for the tropical climate as 64.4°F. He divided the wet-tropical climate of the world into two general types: the tropical rain forest type, constantly wet, with at least 2.4 inches of rain in the driest month; and the tropical savanna type, seasonally dry, with one or more months receiving less than 2.4 inches of rain. He designated an exaggerated savanna type, with extremely heavy seasonal rainfall and deciduous forests, as the monsoon climate. The seasonally dry type is characterized by a short dry season which coincides with the period of winter or low sun. Heavy rains during most of the year compensate for the short dry spell in the tropical monsoon climates. Köppen used the values he considered significant in distinguishing the tropical rain forest from tropical savanna vegetation.

Figure 8

Thornthwaite's climatic system is determined by comparing precipitation and potential evapotranspiration, which, in turn, is derived from mean monthly temperatures (Fig. 8). Precipitation effectiveness, seasonal concentration of rainfall, and thermal efficiency are the most significant climatic elements in Thornthwaite's system, and the relative importance of each depends upon its effect. In this system, mean monthly temperature for wet-tropical climates must be at least 68°F; mean monthly precipitation must be at least 6.82 inches. Mean monthly precipitation for humid tropical climates must be at least 1.96 inches. To maintain wet-tropical conditions, at least 4 inches of rainfall per month are necessary when mean monthly temperatures are 86°F and above, and at least 3 inches of rainfall when mean monthly temperatures are between 68° and 86°F.

Four other climatic maps are included in this report. Jones and Whittlesey[13] (Fig. 9) based a climatic system, modified from several published classifications, on seasonal temperature and on the amount and seasonal distribution of rainfall. Finch and Trewartha[7] (Fig. 10) made a somewhat modified and simplified version of Köppen's map. Bartholomew[1] (Fig. 11) outlined a climatic zone that is described as "hot, with heavy rainfall throughout the year." The Koppen and Geiger[15] climatic map (Fig. 12), revised by Geiger in 1953, employs more recent data, superseding their 1928 map.

Figure 9

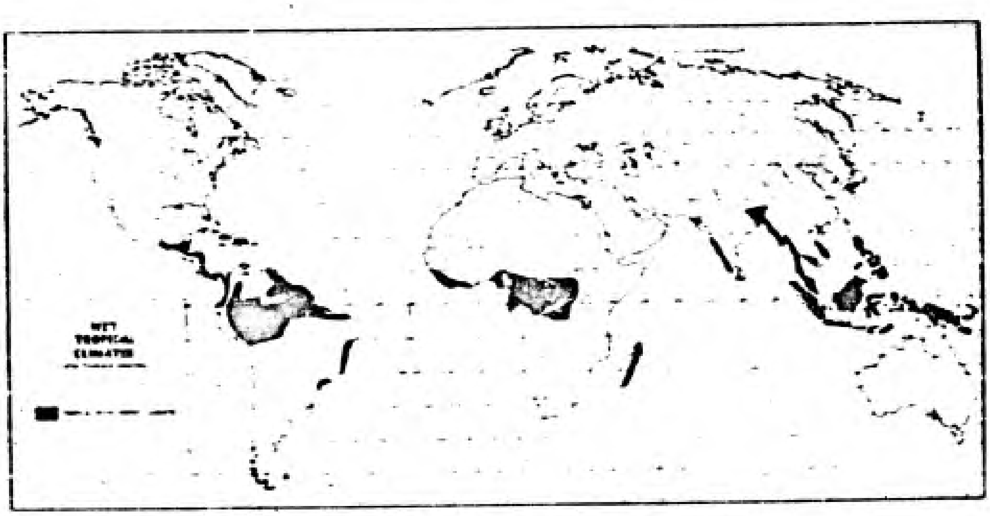


Figure 10

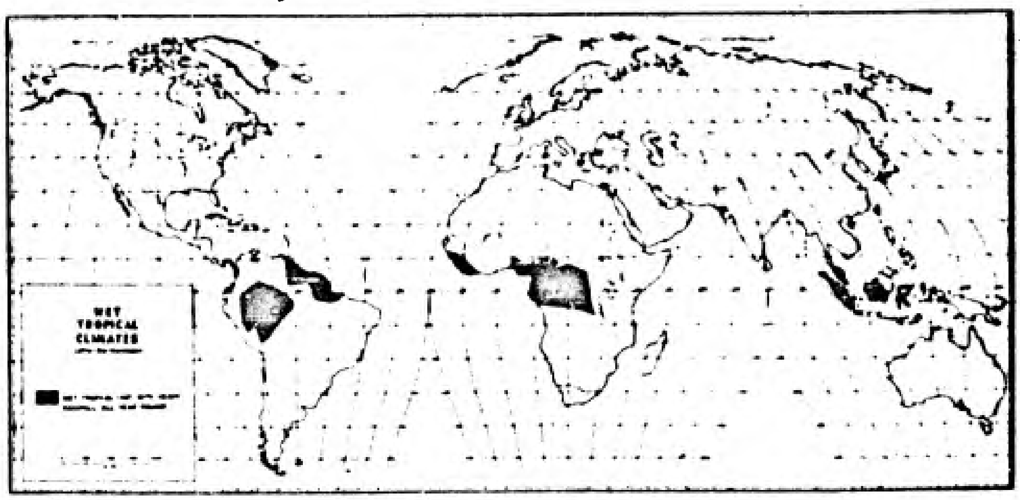


Figure 11

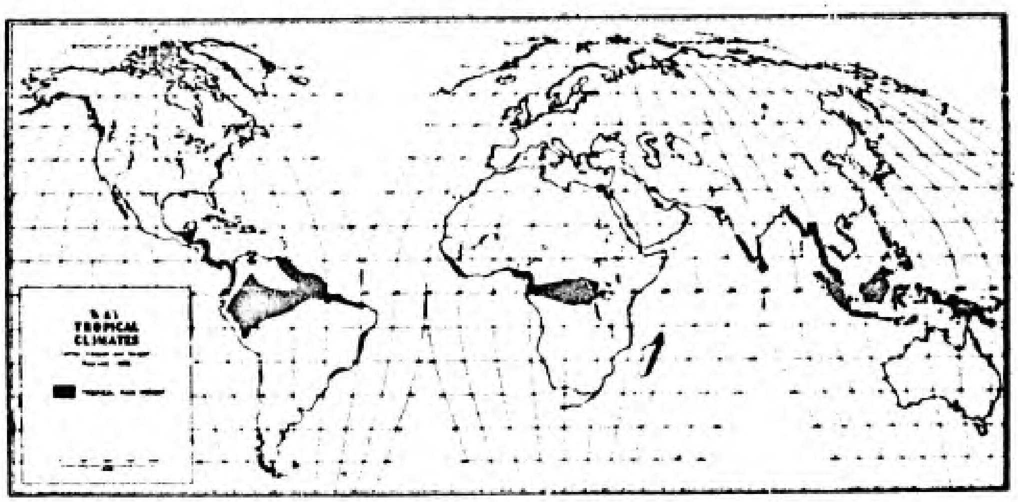


Figure 12

3. Vegetation

a. General Characteristics

There are four main types of vegetation associated with humid tropical areas: rain forest, deciduous forest, savanna woodland, and thorn woodland. Tropical rain forest is the principal vegetation of the core areas, with deciduous forest, savanna woodland, and thorn woodland predominating in the transitional areas. There are other vegetation types of smaller extent, such as mixed forest, swamp forest, and mangrove forest.

The evergreen tropical rain forest is usually a community of co-dominants, with numerous species, although the trees have a superficial uniformity in appearance and structure. Several tree layers and a closed canopy overhead characterize the forest, and woody climbing plants and epiphytes abound.

The vegetation in the transitional areas has an open woodland appearance, except where favorable groundwater conditions and infrequent fires allow forest growth. The trees of the deciduous forest are generally leafless during the dry season, shorter than those of the rain forest, and form a broken canopy with thick undergrowth. Savanna woodland usually has deciduous trees less than 50 feet high, able to resist the prolonged drought of the dry season; it is poor in woody undergrowth but rich in herbs and grasses. Trees and bushes grow in scattered groups and in strips of "gallery forests" bordering rivers. Thorn woodland is more drought-resistant than savanna woodland, but resembles it in height and foliage.

b. Interior Plains

In tropical interior plains, tropical rain forest is the prevalent vegetation type. Optimum conditions for its development exist where the climate is uniformly hot and wet, and the soils are wet but not waterlogged. There are usually three superposed strata of tree crowns in most rain forest communities. The strata are likely to be ill-defined, and are seldom recognized by casual observation because of the mixture of species and the varying heights of the trees. The trees of the highest level of the canopy usually vary from 90 to 120 feet in height; scattered trees, commonly 150 to 180 feet high, extend above the canopy here and there. Much of the daylight is blocked out, and the forest floor is dark and relatively free of undergrowth. A layer of fallen trees and decayed vegetation accumulates on the forest floor. Many of these trees have flattened or buttressed trunks. A dense thicket of shrubs and small trees grows along the banks of streams and in the driest areas where daylight penetrates to the ground. Epiphytes, lichens, and lianas are found in abundance on the branches and trunks of the trees.

There is no single established definition for tropical deciduous trees. Most authorities regard evergreen trees as those which hold a substantial number of leaves throughout the year, and deciduous trees as those which lose all leaves for a part of the year. Richards[20] regards deciduous species as those that become bare, or almost so, if only for a few days. Deciduous species, as thus defined, are numerous even within the rain forest, occurring almost entirely among the tallest trees. The transition from the rain forest to deciduous forest is usually very gradual and is characterized by a decrease in the number of species and a shift of dominance from evergreen to deciduous trees. Alternation of distinct wet and dry seasons favors development of deciduous trees.

A variation of the tropical rain forest is found in the swamp forests of the tropics. This vegetation forms under conditions of impeded drainage and seasonally waterlogged soils. A type of forest comparable to the peat bogs of temperate areas develops in such habitats, and has been termed "tropical moor forest" (Richards[20]). Herbaceous swamps develop where the ground is waterlogged most of the year. Vegetation varies in size from tall herbs about 6 feet high and woody plants 12 feet high to simple floating mats.

Areas of savanna grassland covering from a few square feet to several hundred acres are scattered throughout the interior plains. Tall bunch grass, as high as 12 feet, is interspersed with bare patches of earth and stunted trees. Open savannas, with scattered trees and grassland, may occur by the degradation of forest or savanna woodland by excessive cultivation or burning, but in some cases they are probably the result of soil conditions unfavorable to the growth of trees.

Thorn woodland is a mass of foliage and flowers during the rainy season, but is bare during the dry season. Trees are small in diameter, spaced far apart, and often protected by thorns.

Natural vegetation has been disturbed and altered by man in many parts of the wet-tropical core areas. Liberia in Africa and Java in the East Indies are examples of areas where there are many tree crop plantations, row planted and systemically maintained. Here there is very little undergrowth. However, many abandoned agricultural clearings are now occupied by dense, fully developed second-growth vegetation. Shifting cultivation of subsistence crops in temporary clearings is widespread in the tropical forests, resulting in extensive areas of dense second-growth forest.

c. Mountains

Tropical mountain vegetation is usually arranged in several distinct altitudinal zones. Vegetation on the lower slopes is a slightly modified version of the rain forest of the interior plains. However, in some parts of the tropics the heavier rainfall on the mountains allows the growth of evergreen rain forest where the lowland vegetation is tropical deciduous forest. At higher altitudes, mountain vegetation generally becomes less dense, trees affected by wind exposure are not so tall, fewer species are represented, and a proportionate increase of temperate species is noted. The average leaf size becomes smaller, and buttressing of trees eventually disappears at higher altitudes.

The altitudinal limits of the vegetation zones are different from mountain range to mountain range, and even on the same mountain, because climatic elements vary so greatly from place to place. The vegetation zones are lower on coastal mountains than on those inland, and are lower on isolated ridges than on extensive ranges. According to van Steenis[24], in Malaysia the tropical rain forest gives way to submontaine rain forest at about 1,500 feet elevation, and the submontane is replaced by montane forest at about 3,000 feet. Lane-Poole[17] distinguished the "lower montane forest" in New Guinea as at between 1,000 and 5,000 feet. Beard[2] recognized the lower montane forest in Trinidad at from 800 to 2,500 feet. Lebrun[18] described a transitional forest zone between the tropical rain forest and the montane rain forest in the eastern Belgian Congo at from 3,500 to 5,500 feet.

The lower montane rain forest in the coastal mountains is slightly modified by salt spray and winds which inhibit density and growth. Coastal forests are generally thinner and less rich in species than those of the interior mountains.

d. Coastal Lowlands

Coastal lowland vegetation is commonly arrayed in a zonation of dominant species paralleling the coast. These zones can be correlated with the frequency of tidal immersion, the nature of the substratum, the activity of accretion and erosion, and the salinity of the ground water.

The mangrove formation (Fig. 13), perhaps the best known of the tidal land vegetation types, is a complex of evergreen trees and shrubs covering large areas fringing sheltered tropical shores. It is characterized by dark green, shiny foliage and an almost impenetrable tangle of aerial roots. The vegetation varies from poor scrub several feet high to trees 70 feet high. Characteristic locations are along coastal mud flats, estuaries of rivers, shallow lagoons, and on river deltas. The most intensively studied mangrove areas are in Florida and the Malay Peninsula. Mangrove vegetation is confined chiefly to brackish water, thriving between the limits of low and high tide. Richards[20] does not limit the mangrove to tidal-influenced shores, but states that mangrove may grow from below the level of ebb tide to above the level of flood tide, and that they are even found on coasts where there are no tides at all.

Nipa palm (Fig. 14) borders the brackish estuarine areas of the mangrove, and is less tolerant of salt water; it is therefore on the landward and upstream sides of the mangrove. These palms grow in dense stands from 25 to 30 feet high, with leaves 10 to 15 feet long. Trees are spaced farther apart towards the inland side, and the forest gives way to a thicket of vines, ferns, shrubs, and herbs.

The pes-caprae formation (named for its dominant species, Ipomoea pes-caprae or beach morning glory) is a mixed community of plants widespread on tropical beaches. Many of its species send runners over the surface of the sand. Near the sea its growth is relatively open, but inland the density of vines increases until it presents a serious obstacle to movement of personnel and vehicles.

e. Maps

Vegetation is a useful indicator of wet-tropical environments.

Fig. 13. Mangroves along Manbere River, New Guinea

Fig. 14. Nipa palm along river in Thailand

In this study the accompanying maps show forest types only as representing true wet-tropical conditions; transitional savannas and savanna woodlands have been excluded. Eight vegetation map sources were used in this study. James'[11] map (Fig. 15) of world vegetation distinguishes three types of tropical forest: rain forest or selva, semideciduous forest, and scrub forest. Although the last two of these types grow in regions that are only seasonally wet-tropical, they are present in some of the transitional areas, but have not been included on the map.

Figure 15

The maps by Richards[20] (Fig. 16) and Goodall and Darby[8] (Fig. 17) are composites based on the work of regional specialists for various parts of the world. Richards' area of African rain forest also includes the mixed deciduous (dry evergreen) forest because the boundary between these types is incompletely known. Goodall and Darby show separate maps for the various continents, using different vegetation categories in each. Therefore it was not possible to delineate separate types on a world map. For this reason the map (Fig. 17) simply shows areas which Goodall and Darby represent as occupied by various types of tropical forests, whether designated as tropical rain forest, Andean tropical forest, mangrove swamp forest, or monsoon woodland.

Küchler's[16] vegetation map (Fig. 18) is well known to American geographers. His approach is physiognomic. He uses various formulas to designate types of vegetation according to character, height, and density; subdivides the broadleaf evergreen type into trees and shrubforms; broadleaf evergreen trees are considered here to be wet-tropical, and the shrubform as subtropical. The "Mediterranean" type of vegetation, which Küchler shows also as broadleaf evergreen, has been eliminated from consideration in this study because it is not wet-tropical.

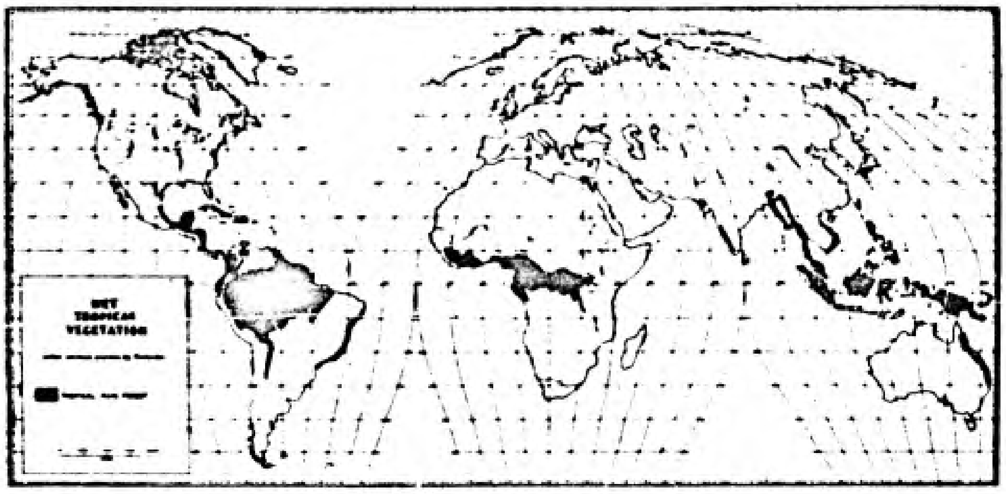
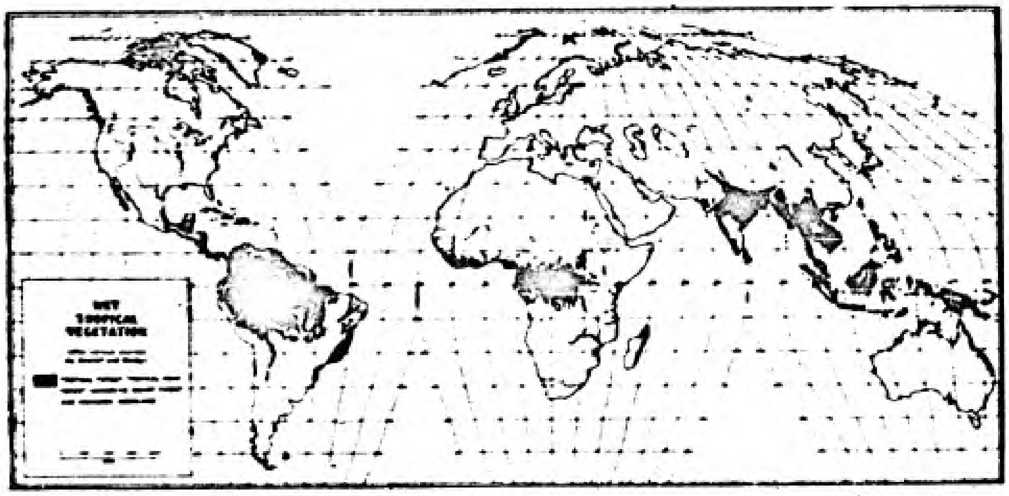


Figure 16



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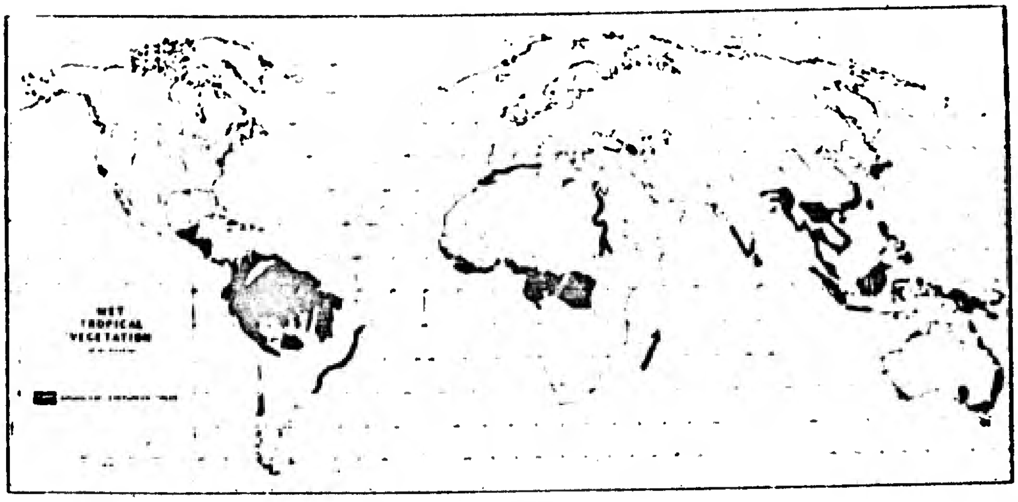

Figure 18

Four vegetation maps, those of Hammond[10] (Fig. 19), Bartholomew[1] (Fig. 20), Brockman-Jerosch[6] (Fig. 21), and Finch and Trewartha[7] (Fig. 22), delimit tropical rain forests. Bartholomew's rain forest areas are more extensive in South America and Africa but less extensive in the Asian and Australian areas than those of Hammond. Brockman-Jerosch and Finch and Trewartha depict what are roughly the same areas. Finch and Trewartha have not indicated the presence of any rain forest on the continent of Australia or in Indochina, whereas Hammond shows rather extensive rain forests in these areas.

4. Soils

a. General Characteristics

Humid tropical soils vary in structure and properties, both physical and chemical, as much as the soils of any other climatic zone. However, the majority of the wet-tropical soils share certain important characteristics in that they are usually red or yellow; they are generally loamy or clayey, but often sandy in the superficial layers; they are almost invariably acid; they are low in humus content which is chiefly confined to the upper horizons; and the clay fraction is rich in alumina and poor in silica.

b. Interior Plains

Tropical soils vary considerably from one area to another. The older soils, on surfaces not subject to present-day alluviation, are reddish, with strong concentrations of iron and aluminum, a type commonly known as laterite. The surface of this soil is coarse and well-drained and dries out rapidly after a rain. All the soils are highly leached with the mobile particles deposited below the surface in a layer which eventually may become a hardpan. Boggy alluvial soils have developed on the flood plains and deltas of water courses from muds which were deposited during flood stages. Swamp soils are divided into two separate groups: those with little humus accumulation and those with a surface layer of peat or humus. The former are far more extensive, although the latter have been more thoroughly studied by soil scientists.

Weathering in the wet tropics is largely a chemical process; erosion is rapid and its effect on the soil is often considerable. The intensity of sheet erosion is seen by the muddiness of tropical rivers. The brown coloring is due to finely dispersed colloidal humus compounds.

c. Mountains

Tropical mountain soils vary from area to area, depending primarily upon elevation, slope, and exposure. There is an increase in the humus content of the soil with increasing elevation, and the red earths give way to yellow earths. Soils are immature as a result of intense erosion on the slopes. Rocky, well-drained soils have developed on steep slopes. Rocky soils are deep at lower elevations, shallow at higher elevations. Boggy alluvial deposits predominate in ravines and valley bottoms. Conditions conducive to landslides and soil creep are found in many areas where the slopes are wet and steep.

d. Coastal Lowlands

Many types of soils have developed along the tropical coastal lowlands. Alluvial muds and sands have been left by the sea on the tidal flats, and deposited on deltas and floodplains by rivers. Sandy and loamy soils have been formed from older water deposits and wind-blown material on the non-tidal areas. Most coastal soils are young, and have not developed a distinct profile.

e. Maps

Distribution of soils shows the least agreement with other physical elements used as indices of wet-tropical conditions. However, two soil maps for the wet tropics are worth noting. The 1948 map of K.D.Glinka, Hermann Stremme, Curtis Marbut, and others[8] (Fig. 23) merits attention as a soils reference. In the classification of Glinka et al, four soil types indicate wet-tropical conditions: laterites, reddish savanna soils, tropical red earths, and mangrove swamp soils. A. C. Orvedal (in Goode[9]) presents a refined soils map (Fig. 24) in which the laterites are subdivided into two groups: those that have developed under an alternating wet and dry tropical regime, and those that have developed under a continuously wet tropical regime. The latter subdivision is more representative of the true wet tropics.

Figure 19

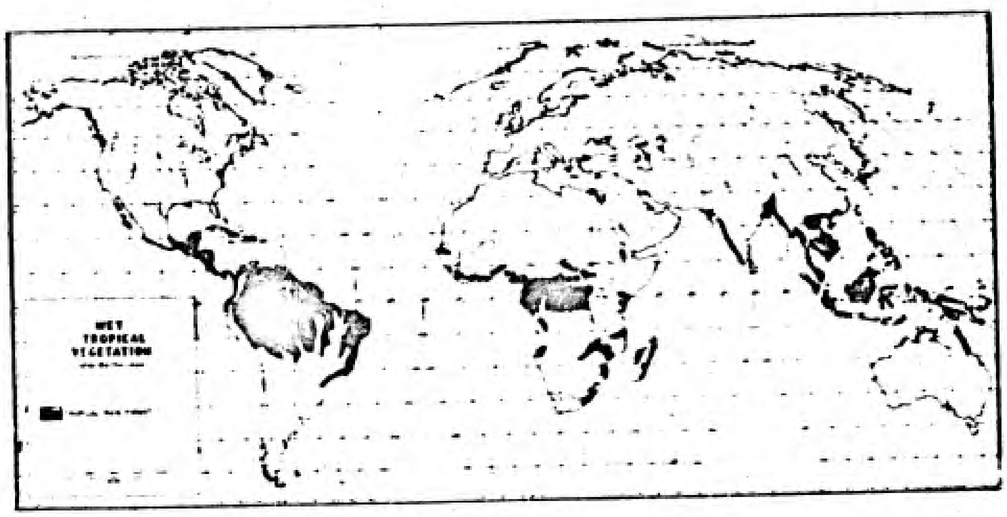

Figure 20

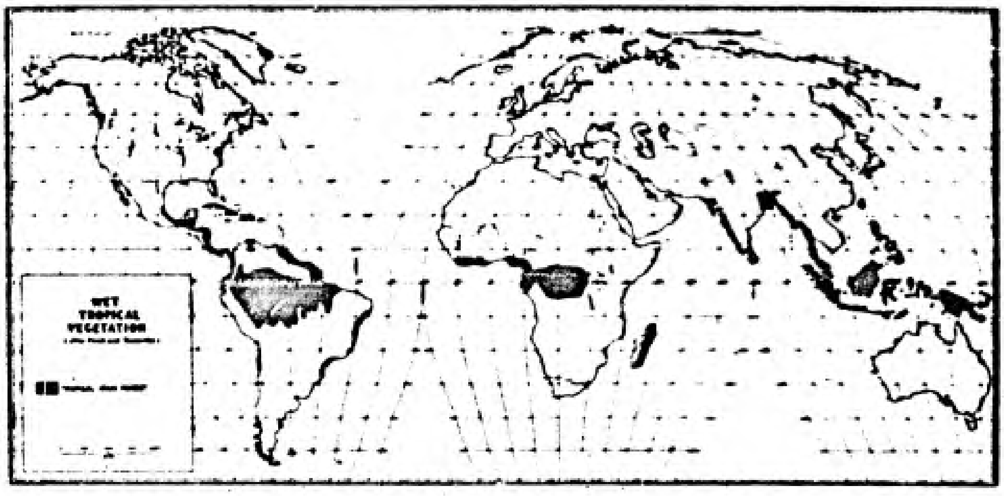

Figure 21

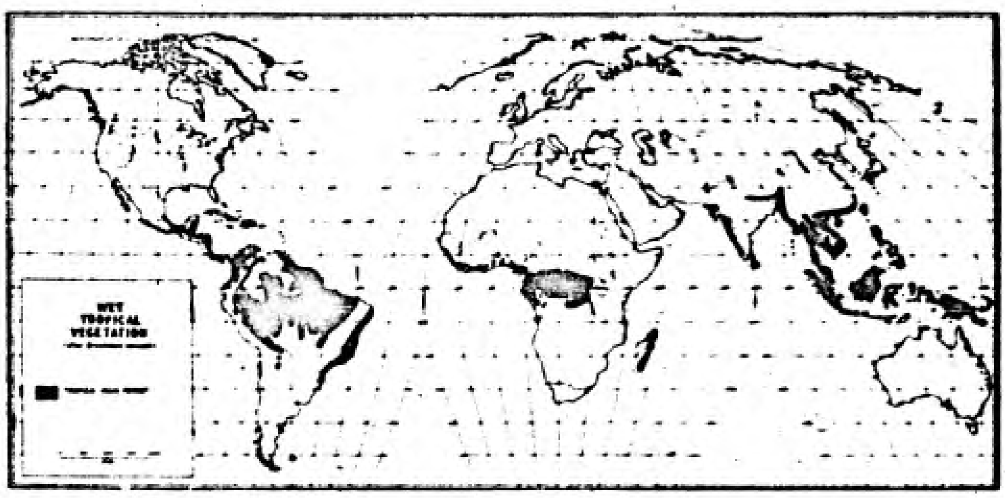

Figure 22

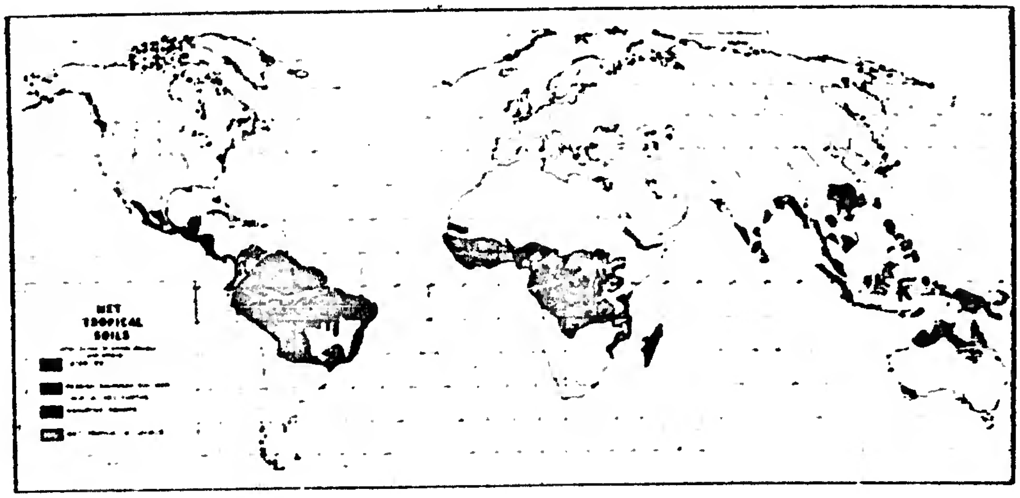

Figure 23

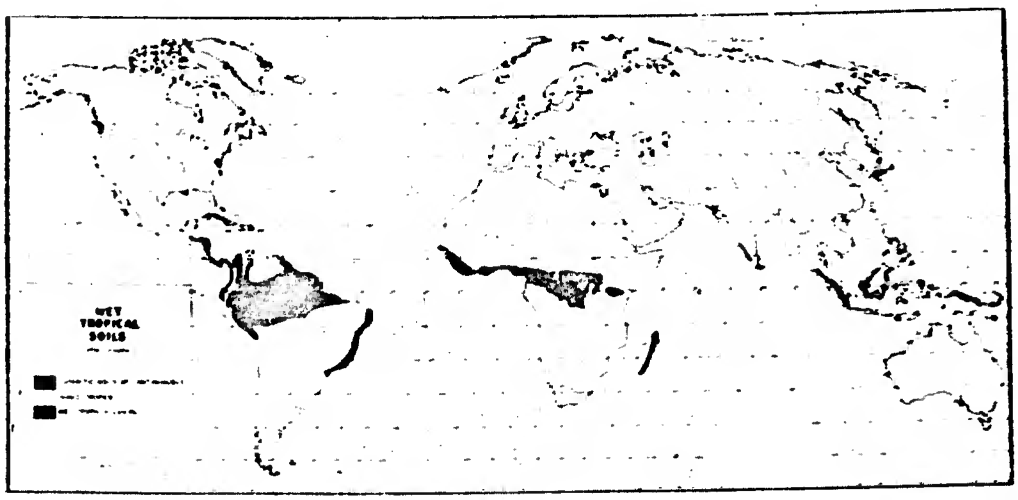

Figure 24

5. Environments

a. General Characteristics

The core area, as found from comparison of sources already mentioned, has definite characteristics which describe the wet-tropical environment. Wet-tropical environments are dominated by tropical rain forests and are generally found in some of the most inaccessible areas of the world. Settlement has been greatest at coastal locations within the transitional zone of the wet tropics, where seasonality favors agriculture and proximity to the sea gives an outlet for the marketing of both the vegetable and mineral wealth of the hinterland. Settlement in the core areas is small by comparison, and is confined chiefly to coastal strips and certain islands. Roads, fields, and other facilities soon are overgrown by the vegetation if they are not continuously kept in an improved state.

There is a general year-round stability to the temperature of wet-tropical areas, whether in the South American Amazon basin, the African Congo, or in Malaya. Nevertheless, certain environmental differences are observable from place to place. Because these differences are largely associated with changes in landform, three subdivisions of wet-tropical areas are recognized: interior plains, mountains or highlands, and coastal lowlands. Interior plains are the most extensive type. Mountains or highlands may fringe or separate the interior basins, and coastal lowlands may be continuations of each of the above types.

b. Interior Plains

The Amazon and Congo Basins are the two largest and best known examples of wet-tropical interior plains. The same factors of abundant precipitation, high humidity, boggy soils, and dense forest are found to a lesser extent in the interior reaches of many smaller rivers such as the Mamberamo River of northwestern New Guinea and the Kahajan River of southeastern Borneo.

Most of the military problems associated with a frontier territory in the wet tropics apply to the interior plains. Problems in the transitional areas may be seasonal, but they are continually present in core areas. The partially waterlogged soils create problems of movement, especially along the flood plains of water courses (Fig. 26), where troop mobility may be inhibited. Dense growth obstructs travel in forests, along stream banks, and around clearings, and drastically reduces the operational effectiveness of tanks and trucks. All roads and trails constructed within the forest are soon overgrown by fast-growing secondary vegetation. Troops operating in the interior plains are vulnerable to ambush, for the dense, fast-growing vegetation makes detection difficult. By the same token, camouflage and concealment are very effective under the dense tree canopy. Spoilage of food and deterioration of equipment are serious problems in the wet tropics, for the climate is conducive to rust, mold, and mildew. A season of less rainfall, or perhaps a short dry season, may tend to reduce these effects in the transitional area. Insect-borne and bacterial diseases are still a problem of military importance. Malaria, one of the most prevalent diseases, is particularly severe in swampy areas. The distribution of heavily infested areas of malaria is shown by Brierly[5] (Fig. 25). Heat exhaustion is always a menace to the health of a soldier in wet-tropical climates, for body temperatures are easily raised to the danger point when evaporation is retarded.

Figure 25

c. Mountains

Tropical rain forest gives way to lower montane rain forest on forested tropical mountains (Fig. 27). This community is moisture-soaked evergreen, lower and simpler in structure but poorer floristically than the lowland forest. The lower montane rain forest is succeeded at higher altitudes by montane rain forest, often called mossy forest, consisting of dwarfed, crooked trees and an overwhelming abundance of epiphytes.

Tropical mountains have served as bastions of military defense throughout history. In World War II, for example, the Owen Stanley Range of New Guinea was the setting for stubborn opposition on the part of the Japanese. Rugged terrain and dense vegetation necessitate the use of specialized equipment and tactics. Vehicular traffic is greatly curtailed, and in places impossible. Foot travel is made difficult by steep slopes, rock outcrops, dense understory vegetation, and a slippery matting of rotting vegetation on the ground. Ambush can be easily effected because visibility is limited to a few yards. Spoilage of food, deterioration of equipment, disease, and heat exhaustion are also problems in mountain terrain. However, these are less serious than in the interior plains, because slightly lower temperature and greater wind circulation contribute to a more healthful mountain climate.

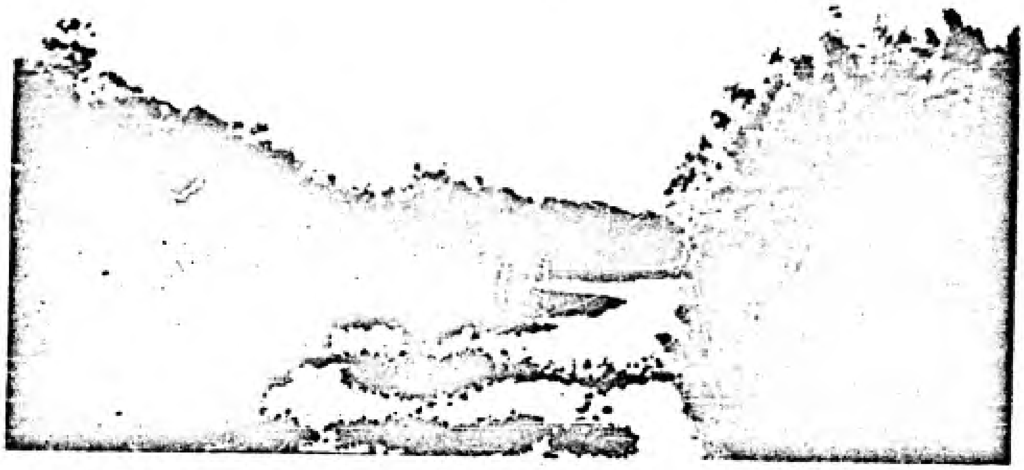

Fig. 26. Dense river-bank vegetation within tropical rain forest, Cambodia.

Fig. 27. Lower montane rain forest, Pangsaw Pass Hill (4,265 elevation), Stilwell Road, India.

d. Coastal Lowlands

The third type of tropical environment is represented by the numerous coastal plains of the wet tropics, such as those of the East Indies and the Guianas, and, in a less extreme form, of the Panama Canal Zone. These lowlands include tidal as well as non-tidal areas.

Coastal features are sometimes rugged and irregular where mountains border the sea, as in Ecuador, with headlands, cliffs, and estuarian lowlands dominating the shoreline. The lowlands are generally the collecting and distributing centers for commercial enterprises of coastal mountains.

Many operational and supply centers are associated with coastal lowlands, particularly areas of tidal mud flats. The fringing mangrove and salt swamp forests, with their tangles of prop roots and buttressed trunks, become inundated by several feet of water at high tide, and transit is limited to small hand-propelled boats. Wide expanses of untrafficable mud flats prohibit most vehicular traffic at low tide. In nontidal coastal lowlands, the close-growing trees in the modified rain forests, and boggy soils in the fresh-water swamps, prevent the most effective use of tanks and other heavy equipment. Camouflage is effective in the mangrove forests and in the modified tropical rain forests. It is almost impossible to store food and equipment in tidal areas, except upon raised platforms or on floating rafts. Special protection for stored items is necessary in the nontidal lands to prevent corrosion of metals by wind-carried salt nuclei and the high moisture content of the air, and to prevent spoiling of foodstuffs, textiles, and leather, by bacteria, insects, and mildew. Insect-borne diseases constitute a serious hazard in the coastal lowlands, especially in the fresh water and tidal swamps where malaria is prevalent. Heat exhaustion, however, is less wide-spread than in interior plains, since sea breezes lower the temperatures.

5. Summary

The wet tropics cover about 15 percent, or one-seventh, of the world's land surface, and are situated between 25°N and 25°S latitudes. Within these limits, certain core areas are recognized where there are high temperatures, abundant precipitation, lateritic soils, and dense, fast-growing vegetation throughout the year. The core areas constitute less than one-third of the total area of the wet tropics, and are surrounded by much broader expanses of modified or transitional wet-tropical conditions.

The uniformity of core area environment is interrupted by topographic diversity. Interior plains are by far the most extensive physiographic type, and represent the fullest development of wet-tropical areas. The Congo and Amazon Basins are the best known examples of this type.

Tropical mountains have an altitudinal zonation of vegetation which has developed as a result of decreasing temperature, abundant rainfall, increasing wind speed, and amount of cloudiness. Coastal lowlands of the core area represent a third major type. A zonal arrangement of vegetation types has developed as a result of tidal flooding, accretion and erosion, salinity of the ground water, and the nature of the substratum.

In the periphery of the wet tropics the rainfall regime includes a dry season, the length and severity of which chiefly determines the character of the environment. The dry season increases in duration largely with distance from the core areas until, at the outermost margin of the transitional zone, there are 4 to 6 months of drought.

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