MOIST TROPICAL FORESTS: STRUCTURE, FUNCTION AND MANAGEMENT

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Keywords: Biodiversity, carbon dioxide (CO2), chlorophyll fluorescence, ecophysiology, irradiance, mineral nutrients, photosynthesis, productivity, rainforest, respiration, seasonality, seedlings, shade plants, sun plants, transpiration

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Summary

Tropical rainforests are our natural heritage on our home planet. They are of immense emotional and cultural value and also of outstanding importance for science, ecology and economy. To develop a basis of understanding, this chapter describes scientific knowledge and approaches of research on various levels.

First, we note that moisture is a decisive factor for the delineation of a variety of types of wet tropical forests that we must distinguish due to varying degrees of seasonality of precipitation, so that we can speak of "*moist tropical forests*" but rarely of tropical "rainforest" in a strict sense. Second, we consider the structure of moist tropical forests in the horizontal and vertical dimensions of space. The horizontal structure is determined by an extraordinarily high biodiversity of species and life forms. It is not a stable or homeostatic equilibrium of a climax association but a vividly oscillating mosaic of destruction and repair in gap successions. The vertical structure is given by gradients of ecologically important parameters, such as irradiance, carbon dioxide, temperature and humidity and nutrients from the top of the canopy down to the forest floor. Third, we explore the physiological ecology of photosynthesis in the moist tropical forests with their sun and shade adapted plants, the stress due to excess irradiance energy and protective mechanisms to dissipate excess energization of the photosynthetic apparatus. Conversely, where light is a limiting factor in the deep shade on the forest floor we see the spatiotemporal dynamics of light-flecks and fathom their

importance for photosynthetic productivity. Fourth, drought shows up as an unexpected type of stress in moist tropical forests especially for the establishment and survival of seedlings and thereby affecting tree population dynamics of the forests. Finally, while we survey the current destruction of moist tropical forests and lament the death of values due to destruction we also allude to alternatives of sustainable use and regeneration.

1. Introduction

The darkness and loneliness of deep and dense forest has always frightened man. One can find that in many old fairytales. Dark and sinister powers reside in the mysterious forests. Right from the beginning of the development of human culture forest was cleared to establish settlements and gain arable land. Even in the present times, enraged by incidents of natural catastrophes, in which falling trees and landslides with forests threatened man, a call arises to even remove the forest altogether. For example, after an exceptionally strong rain, which happens about every two hundred years, had swept down substantial areas of the tropical cloud forest from the steep granite slopes of the northern coastal range of Venezuela, (Figure 1) there were frantic cries by a lot of public and the media to clear the forest altogether.

Figure 1. Southern slope of the northern coastal mountain range of Venezuela with cloud forest on top and traces of forest land slides.

This cloud forest is one of the very few remaining and most valuable ecological heritages of such a typical and characteristic moist tropical forest, and the ecologists had great trouble eventually succeeding to prevent its destruction. Even Alexander von Humboldt in his book “Journey to South America” wrote:

“If one has spent many months in the dense forests along the Orinoco, if one got used there to seeing the stars only near the zenith like looking upwards from the bottom of a well as soon as one leaves the bed of the river, then wandering over the steppes has something pleasant and attractive in it; …..one enjoys the feeling to be able to look around so well."

However, he returns to the forest going on writing: "Yet, this comfort is not of long duration. If, wandering for eight to ten days, ….. one feels in oneself the demand for more variable impressions, one longs for the sight of the huge trees of the tropics."

"More variable impressions", is precisely the point. Although savannas and cerrados have their own deeply moving beauty, and there is even some unsavory competition arising that when tropical rainforests are better protected human population pressure increasingly turns to destruction of savannas, with their extraordinary diversity, tropical rainforests have most outstanding values. These values are emotional as Alexander von Humboldt alludes to, scientific due to the many important basic problems they pose and questions they ask, ecological, by stabilizing huge areas of the global environment, and commercial.

Before we turn to the latter aspects in this chapter we must develop a scientific understanding of the ecology of moist tropical forests. First we need to differentiate various types of tropical forests and subsequently assess the dynamic and variable horizontal and vertical structure of moist tropical forests. Then we shall consider the impact of environmental factors affecting the ecophysiological performance of plants in moist tropical forests, the most important ones being irradiance and astonishingly also periods of drought. Finally we can address the problems of large scale destruction and non-sustainable commercial use of moist tropical forests and possible alternatives.

2. Types of Tropical Forests

Figure 2. Rainforest of French Guiana viewed from the top of a granite inselberg.

The major areas of the world still covered with wet tropical forest are in the Zaire basin of Africa, in West Brazil and Amazonia and in the Guyana highlands of South America and in New Guinea. When we fly over such a forest in a small aircraft or in a helicopter or when we stand on top of an inselberg emerging from the forest we may get the feeling of a vast non- structured green ocean—the tropical rainforest (Figure 2). However, in actual fact, the tropical rainforest is of an immense diversity and a very complex horizontal and vertical structure. Moreover, when we ask the question of what tropical rainforest really is and how we might define it, we are immediately confronted with the observation that there is a large variety of different types of tropical forests. Strictly speaking, an evergreen tropical rainforest should not be subject to any degree of seasonality.

Theoretically this occurs only directly at the equator and about one degree of latitude north and south of it. At increasing distances from the equator cycles of wet and dry seasons pertain with increasingly extended dry seasons. This can be illustrated by climate diagrams as shown, for example, in Figure 3 for stations at and south of the equator in the tropical forest areas of South America and Africa. In the climate diagrams according to a precise scheme as defined by HEINRICH WALTER and explained in Figure 3 mean monthly temperatures and mean monthly precipitation are shown against the months of the year.

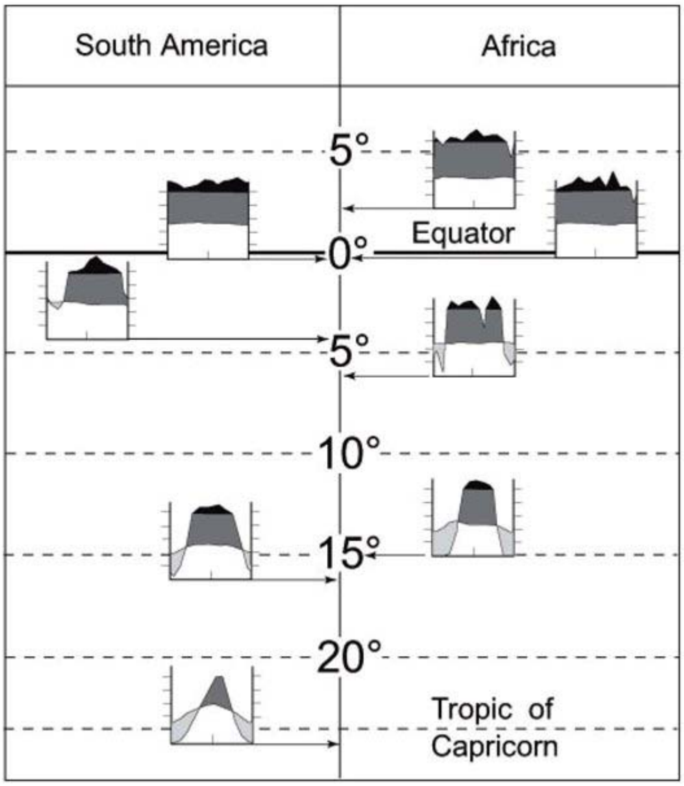

Figure 3. Climate diagrams with increasing distance from the equator in South America and Africa as indicated by the arrows pointing to the latitude scale. In the climate diagram scheme developed by HEINRICH WALTER the months of the year are plotted on the abscissa starting with January for the northern and with July for the southern hemisphere. The mean monthly temperatures and precipitation are plotted on the ordinate so that at mean monthly precipitation between 0 and 100 mm one unit of scale corresponding to 10 °C gives 20 mm precipitation or the ratio of scale is 1 °C : 2 mm precipitation. At mean monthly precipitation above 100 mm the precipitation scale is

reduced to 1/10, and the ratio is 1 °C: 20 mm precipitation. Where the precipitation curve is above the temperature curve areas of the graph are here represented in grey for up to 100 mm precipitation and colored black above 100 mm precipitation which indicates humid periods of the year. Where the precipitation curves are below the temperature curves areas of the graphs are dotted indicating arid periods of the year. The stations shown for South America are at 45 – 208 m altitude and the stations for Africa at 370 – 1055 m.

Humid periods are indicated by precipitation curves above temperature curves and marked by grey and black color. Arid periods are indicated by precipitation curves below temperature curves and are marked by dotting. In Figure 3 the stations at the equator and at about 2 ° N are humid throughout the year. At the two stations close to 5 ° S short dry seasons are already clearly expressed, they are much longer at the two stations at about 15 ° S and quite extended at the station near 24 ° S in South America. This is a gradual change and the question of how long a dry season may be or of how short it must be to still speak of tropical rainforest is a matter of taste. Thus, when VOLKMAR VARESCHI in the late 1970s listed the answers to the question of how much area of Venezuela was covered by tropical rainforest given by eight different authors he obtained values between 65 % and 0 % (Figure 4). Evidently "tropical rainforest" is an ambiguous term and we should try and distinguish various types of moist or wet tropical forests.

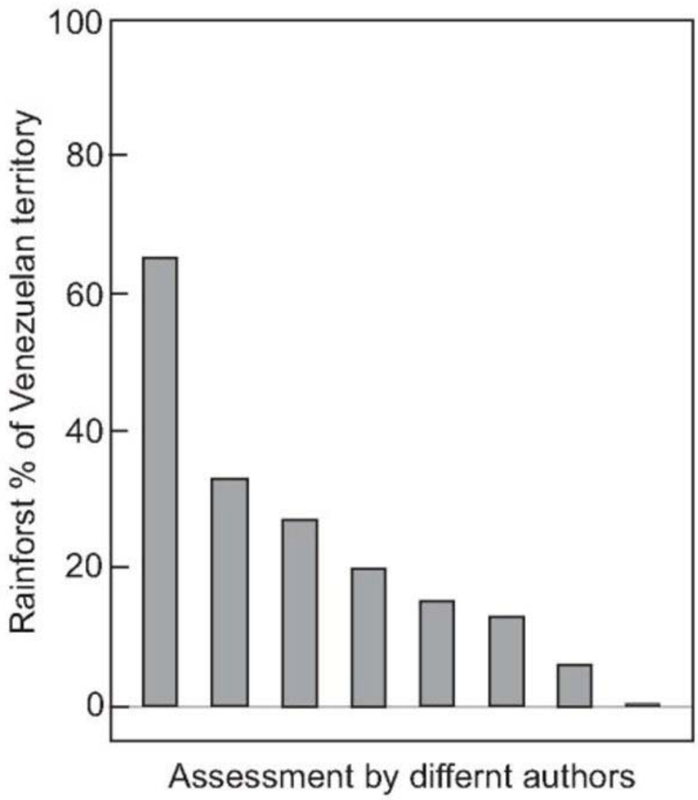

Figure 4. Estimates of the per cent coverage of the area of Venezuela by tropical rain forest according to the assessments of 8 different authors.

Different types of tropical forest as we have alluded to above are mainly determined by moisture, i.e. the annual input by precipitation, and seasonality, i.e. the number of dry months per year. These factors interact so that at very high annual precipitation the number of dry months may be larger than at lower precipitation to still support moist tropical forest. This can be illustrated in diagrams such as those of Figure 5, where forest types of India and Venezuela are compared according to the nomenclature used by different authors covering the two areas. The range of high precipitation and short dry seasons allowing evergreen rainforest and rainforest in India and Venezuela (A and a, respectively, in Figure 5) is very similar. The ranges for semi-evergreen rainforest and trade-wind forest in both areas also largely overlap (B and b, respectively in Figure 5), however, the wet monsoon forest in India (C in Figure 5) is within the range of the trade-wind forests of Venezuela on the drier side. On the wetter side of dry monsoon forest in India (D in Figure 5) we find drought deciduous forest in Venezuela (d in Figure 5). The driest forests are thorn bush forest and thorn scrub plus cactus forest (E and e in Figure 5). This illustrates basic similarities as well as the many regional peculiarities.

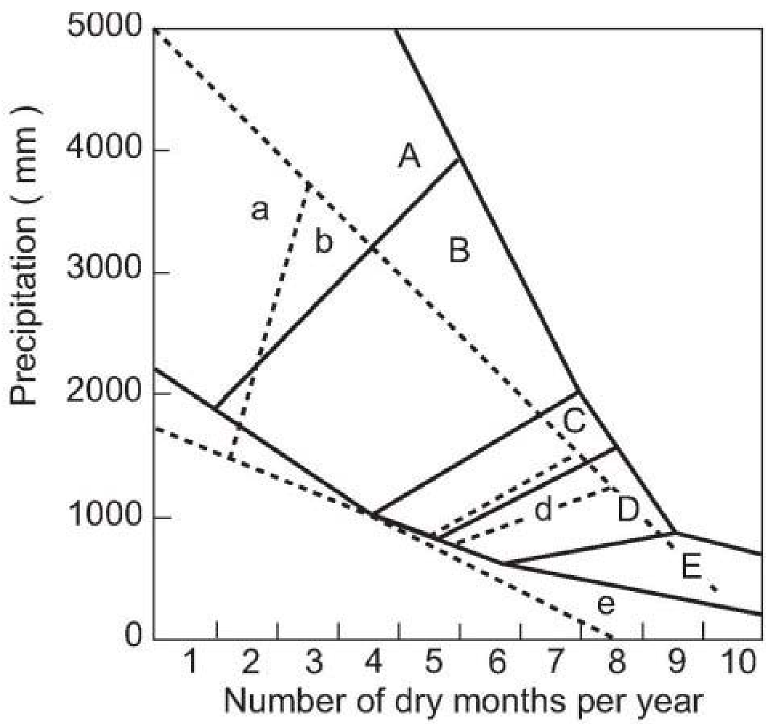

Figure 5. Different forest types as separated by ranges of annual precipitation and the extension of the dry seasons (number of dry months per year) in India and in Venezuela according to two different authors. Upper case letters and solid lines: India, with A = evergreen rain forest, B = semi-evergreen rainforest, C = wet monsoon forest, D = dry monsoon forest, E = thorn bush forest; lower case letters and broken lines: Venezuela, with a = rainforest, b = trade-wind forest, d = drought deciduous forest, e = thorn scrub and cactus forest.

This also makes it clear that when speaking of moist or wet tropical forests we can not be very precise when we include evergreen rainforest, semi-evergreen rainforest, trade wind forest and wet monsoon forest (A-C, a-b in Figure 5) but exclude the other types of forests which are clearly quite dry. Another important factor shaping the structure of forests is altitude and we distinguish

- lowland rainforest,
- lower montane rainforest,
- upper montane rainforest,
- cloud forest,

where the latter due to the effects of wind and nutrient limitations may develop to a so called elfin forest with dwarf forms of the tropical tree species. Furthermore, the degree of continentality may play a certain role, e.g. in the famous example of the Atlantic rainforest of Brazil.

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Biographical Sketch

Ulrich Lüttge was born in 1936 in Berlin, Germany. Education: Biology and Chemistry, Ludwig Maxmilian-University of Munich, Germany. 1960 Promotion to Dr. rer. nat. at Technical University of Darmstadt (TUD), Germany with a thesis on "The composition of nectar and the mechanism of its secretion". 1960 - 1965 Assistant at the Instiute of Botany of the TUD. 1964 Habilitation with a thesis on

"Studies on the physiology of glands of carnivorous plants". 1965 Dozent at the Institute of Botany of the TUD. 1970 Appointment on the Chair of Botany at the TUD. 1971 – 1972 Dean of the Department of Biology at the TUD. Lecturer at the School on Biophysics of Membrane Transport of the Polish Academy of Sciences: 1977, 1979, 1988, 1990, 1992, 1994, 1997. 1979 – 2000. Trustee of the Studienstiftung des Deutschen Volkes. Lecturer in summer schools of the Studienstiftung des Deutschen Volkes: 1985, 1989, 1992, 1994, 1996, 1999. Regents Lecturer of the University of California: 1982, 1999. 1992 Election to Academia Europaea. 1996 Award of the Price for the European Science of the Körber-Foundation, Hamburg, together with Prof. Dr. G. Gottsberger, University of Ulm, Germany, for the project "Ecosystems of tropical canopies". 1996 Election as member to Deutsche Akademie der Naturforscher Leopoldina, as Senator 2003 - 2007. 1988 – 1998 Editor-in-Chief of BOTANICA ACTA, Journal of the German Botanical Society. 1999 – 2002 Editor-in-Chief of PLANT BIOLOGY, Journal of the German Botanical Society and the Royal Botanical Society of the Netherlands. Since 2000 Managing Editor of TREES: STRUCTURE and FUNCTION. 1993 - 2000 Chairman of the Sonderforschungsbereich Molecular Ecophysiology of Plants of the DFG. 2002 Nomination as an honorary member of the German Botanical. Society. Foreign member of the Académie d' Agriculture de France. Research: Molecular ecophysiology of plants, membranes and membrane proteins; ecophysiology of plants in the tropics; biological clock and non-linear dynamics of the metabolic cycle of crassulacean acid metabolism. Over 500 publications and 13 books partially with repeated editions. Married 1962, three children, five grand children.