Climatic Types of Water Balances in the Tropics

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Abstract

One of the most important climate criteria of the tropics is the absence of thermic seasons. Thus, hygric seasons become more relevant for ecosystem functioning and are of special importance for plant growth. Within this chapter different climate types of the tropics are discussed on the basis of their annual water budget. The humid climate type appears across the rain equator within or close to the ITCZ. It is distinguished by a clear water surplus and all months show a positive water balance in the long-term mean. The semi-humid climate type prevails at a certain distance from the Equator and the ITCZ. It is characterized by a distinct rainfall seasonality and the occurrence of more than 3 -4 arid months. In terms of the arid climate type the arid period is in general longer than the humid period and precipitation amounts decrease almost towards zero within the desert areas.

Keywords

Tropics • Climatic Types • Hygric seasons • Humid Climate Type • Semi-Humid Climate Type • Arid Climate Type

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L. Pancel, M. Köhl (eds.), *Tropical Forestry Handbook*,
DOI 10.1007/978-3-642-54601-3_2

One of the most important climate criteria of the tropics is the absence of thermic seasons. Thus, hygric seasons become more relevant for ecosystem functioning and are of special importance for plant growth. Within this chapter different climate types of the tropics are discussed on the basis of their annual water budget. In opposition to the frequently used diagram type of Walter and Lieth (Fig. 1, right sketch, Walter and Lieth 1960–1967), the presented diagram type (Fig. 1, left sketch) shows the real number of humid and arid months, by comparing the monthly precipitation amounts to monthly landscape evaporation rates (calculated after Henning and Henning 1984). The geographic position of the different measuring sites presented in sections "Humid Climate Type," "Semi-Humid Climate Type," and "Arid Climate Type" is given in Fig. 2.

Humid Climate Type

The humid climate type appears across the rain equator within or close to the ITCZ. It is distinguished by a clear water surplus and all months show a positive water balance in the long-term mean. Within this humid climate type, arid phases may only occur at irregular and short intervals, and a negative water balance may prevail not longer than 1 to 2 months (Lauer 1993). These dry phases are often conditioned by circulation-dynamic processes and may cause first seasonal marks in the leaf production and the blooming period of tropical plants. This might be the case within the seasonal tropical rainforests where a seasonal drop of leaves could be documented for singular tree species whereas the understory remains always evergreen. As shown by Fig. 3, annual temperature curves are in general very uniform across the humid tropics with only small fluctuations between the dry and rainy phases. There again, monthly precipitation amounts are often highly variable

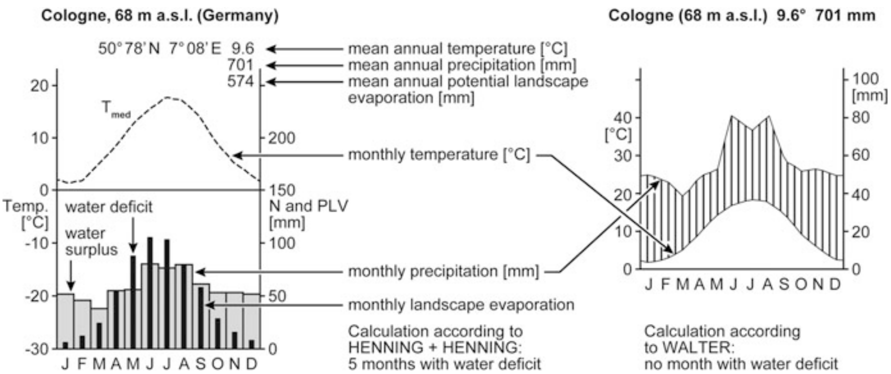

Fig. 1 Explanations of the presented climate diagrams (Richter 2001, Henning & Henning 1984 and Walter & Lieth 1960-1967)

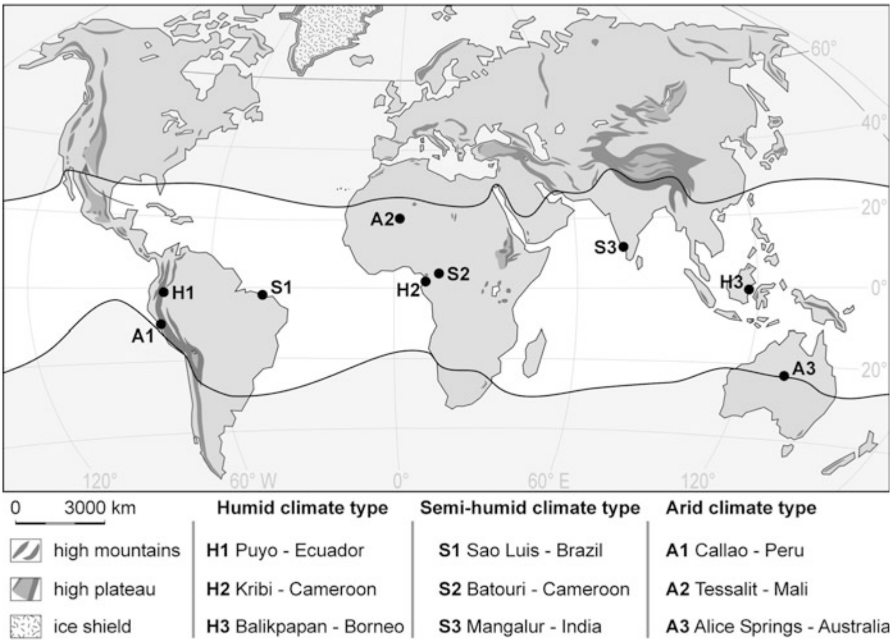

Fig. 2 Geographic position of the different climate measuring sites

over the course of the year. This could be best demonstrated by an example from equatorial Africa where the typical tropical rainforest climate could be demonstrated by the climate diagram of the Kribi weather station in Cameroon (Fig. 3). At Kribi, the annual mean temperature is 22.2 °C and annual rainfall adds up to 3,019 mm. Rainfall maxima occur twice a year during May and September/October and the climate of Kribi could be characterized as an ITZC (Intertropical Convergence Zone) climate type where both rainfall maxima depend on the course of the sun. Despite the strong monthly precipitation differences, no arid months exist and monthly precipitation sums are always higher than monthly landscape evaporation rates. Leaving the African continent, Balikpapan is given as an example of the Indo-Malayan evergreen rainforest. The station is located at the east coast of Borneo and also demonstrates a positive water balance all over the year. The annual mean temperature is 18.8 °C and annual rainfall is 1,189 mm with monthly amplitudes between 152 and 258 mm. The amount of potential land evaporation is 1,165 mm. Compared to the weather station of Kribi, monthly precipitation variations are considerably smaller and there is only a weak seasonality with almost no effect of the position of the sun. The daily precipitation regime of Balikpapan is characterized by regular tropical downpours with thunderstorms and rain in the afternoon. In general, the climate of the island of Borneo is affected by the north monsoon streaming from the north Pacific and China and the south monsoon from Australia

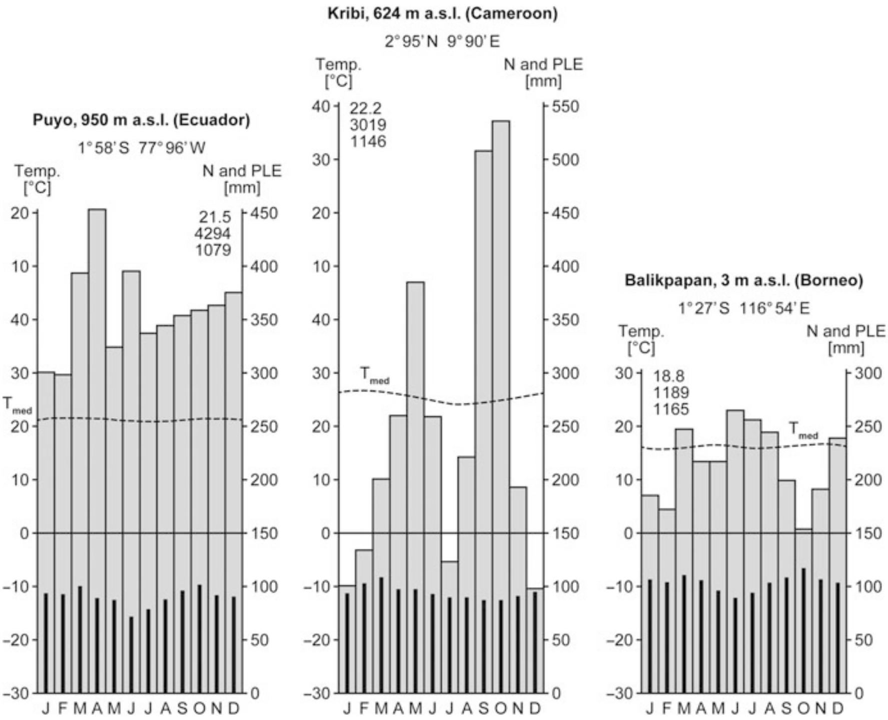

Fig. 3 Climate diagrams from the humid tropics (Richter 2001, Henning & Henning 1984). For legend and geographic position, refer to Figs. 1 and 2

and the Indian Ocean. Thus, monthly precipitation amounts are strongly influenced by different wind regimes. In Amazonia, the regions of highest rainfalls are situated in the northwestern and western parts toward the slopes of the eastern Andean escarpment. Here, the tropical climate is also wet all over the year with no cold or dry season. The climate station of Puyo is located close to the Equator in the upper part of the Amazon and demonstrates well the water budget of the evergreen rainforest in the northwestern Amazon region (Fig. 3). Annual rainfall is 4,249 mm whereas evapotranspiration only adds up to 1,079 mm. Compared to Kribi and Balikpapan, there is almost no seasonality in matters of monthly precipitation amounts. During summer Puyo receives its rain from solsticial rains and in winter from orographic precipitation brought up by trade winds as well as by easterly waves (Lauer 1993). Precipitation amounts are more than three times higher in Puyo than in Balikpapan and still clearly higher than in Kribi. Nevertheless, vegetation does not differ principally between these areas, and all three sites are dominated by an evergreen tropical forest where the plant cover is characterized by the most important tropical life forms trees, lianas and epiphytes. Even the high rainfall seasonality at Kribi does not affect this general pattern, as long as air humidity and precipitation amounts are high all over the year and rainfall amounts remain higher than evapotranspiration rates (Richter 2001).

Semi-humid Climate Type

The semi-humid climate type of the tropics prevails at a certain distance from the Equator and the ITCZ. It is characterized by a distinct rainfall seasonality and the occurrence of more than 3–4 arid months. In general, the two solar-induced precipitation maxima of the equinoctial periods converge and are converted into a twin and/or single rainfall maximum. At the same time the transient dry period shortens (small dry period) and the winter dry period (large dry period) extends (Lauer 1993). The climate diagram of São Luís demonstrates this well for the east coast of Brazil (Fig. 4). Here, mean annual temperature is 26.7 °C, annual rainfall adds up to 1,956 mm, and the annual land evaporation rate is 1,345 mm. The local warm season lasts from September to December and the rainfall maximum occurs once a year during September/October when northeasterly winds dominate Richter (2001). The water balance of São Luís is characterized by a short dry season from February to June, when evaporation rates exceed precipitation amounts clearly. Due to the clear rainfall seasonality, the vegetation close to São Luís is dominated by wet savannahs and mangroves at the coast. A second example for the semi-humid climate type is given from the African continent. At Batouri (Cameroon) the annual mean temperature is 23.5 °C, annual rainfall is 787 mm, and the annual land evaporation is 1,011 mm (Fig. 4). The rainfall seasonality of the region is marked by two precipitation maxima, one of them in the early summer and one in the early autumn. These maxima occur after the crossing of the sun through the ITCZ. The annual relation between evaporation and transpiration is negative, although 9 months show a positive water balance and only 3 months are arid. Complementary, the climate measurement series of the Mangalore station (India) demonstrates the semi-humid climate type for the Asian tropics. Here, the annual mean temperature is 27.1 °C, precipitation adds up to 3,293 mm, and landscape evaporation is 1,272 mm. The climate of Mangalore is characterized by a single rainfall maximum during June/July. From November to May the climate is arid and the local vegetation type is a semievergreen rainforest. According to Lauer (1993), the water stress during the dry phase is partly compensated by ground and soil water and the critical edaphic dry limit for plant growth in not reached. Due to the clear dry period and the strong climatic seasonality, the vegetation type of this region may also be called monsoon forest. This forest type could be differentiated into a humid type (3–4 arid months) or into a semi-humid type (more than 4 arid months). Whitmore (1975) has described the semievergreen monsoon forest type as a forest which shows – in comparison to the equatorial rainforest type – lower tree formations with a reduced diversity of species and less biomass. However, these forest types may also be

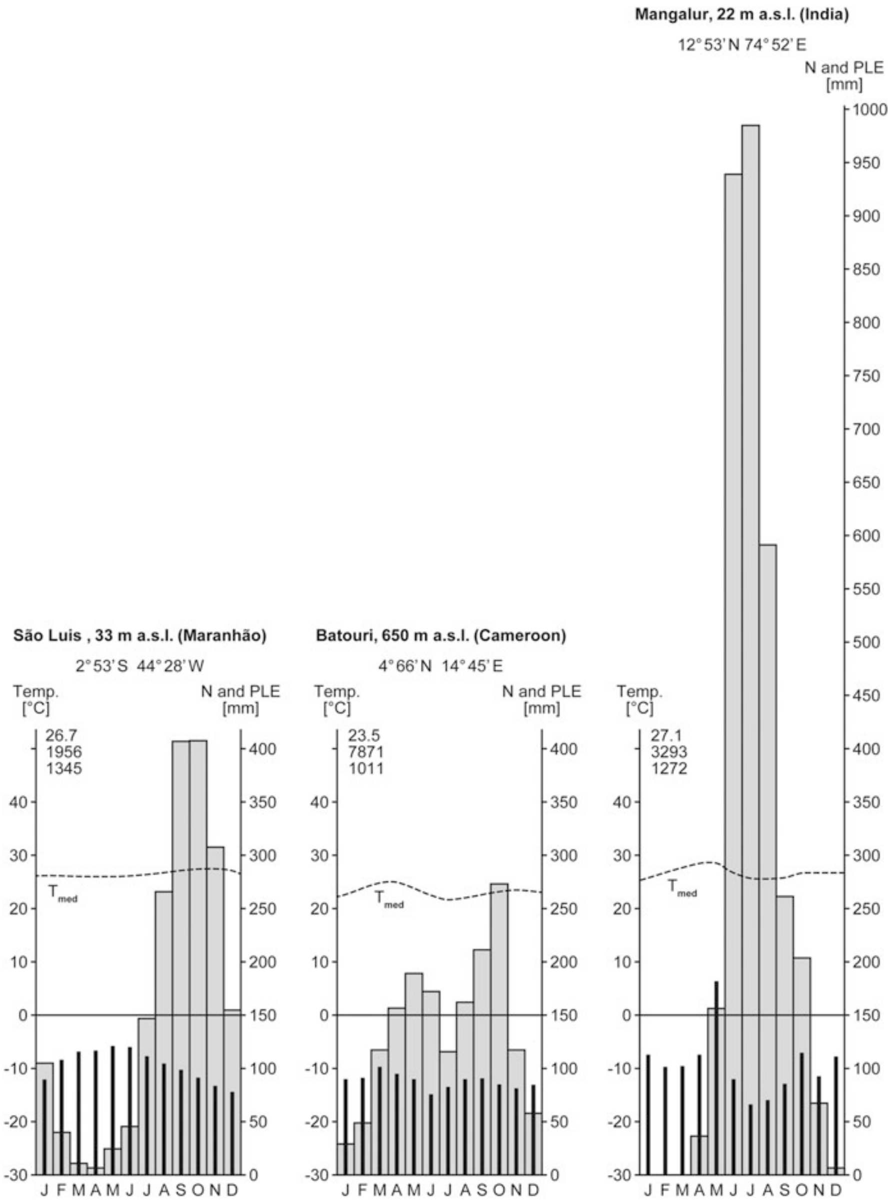

Fig. 4 Climate diagrams from the semi-humid tropics (Richter 2001, Henning & Henning 1984 and Lauer 1993). For legend and geographic position, refer to Figs. 1 and 2

regarded as part of the evergreen rainforest region and do not only occur on the west coast of the Indo-Malayan Archipelago but also in the region of the southern Himalayan Mountains, in the African Gulf of Guinea close to Mount Cameroon, in Liberia, and on the Columbian and Panamanian west coast (Lauer 1993).

Arid Climate Type

In the areas of the descending air masses of the Hadley circulation, the climate type of the border tropics changes to arid. Here, the arid period is in general longer than the humid period and precipitation amounts decrease almost toward zero within the desert areas. At the same time these regions are characterized by extreme climatic contrasts: Highest temperatures were recorded in the deserts of El Azizia (57.8 °C, Libya) or in Furnace Creek Richter (2001) (56.7 °C, Death Valley, USA), while annual rainfall amounts vary strongly from year to year. Walter and Breckle (1991) have shown for the Australian desert annual differences from 18 to 344 mma^{-1} and even higher differences (ratio 1:50) for the Sechura Desert in northern Peru. Even in the annual precipitation observations, the arid regions are quite different. This becomes apparent by comparing different arid climate types from Africa, Australia, and South America. The climate of Tessalit (Mali, North Africa; Fig. 5) is distinguished by a clear thermal as well as hygric seasonality. The annual mean temperature is 28.4 °C, varying from 20 °C in January/December to more than 35 °C between June and July. The local rainfall regime is distinguished by tropical summer rainfalls during June to September, and the potential landscape evaporation is always higher than monthly precipitation. In Australia the annual rainfall distribution is quite different within the arid climate type. At Alice Springs the mean annual temperature is 20.6 °C and monthly temperature fluctuations are between 12 °C in December/January and 29 °C in June/July. The temporal precipitation pattern is controlled by the regional precipitation regime, and little rainfall amounts can be observed all over the year with a slight rainfall maximum from June to September. The average annual rainfall is 252 mm and the annual landscape

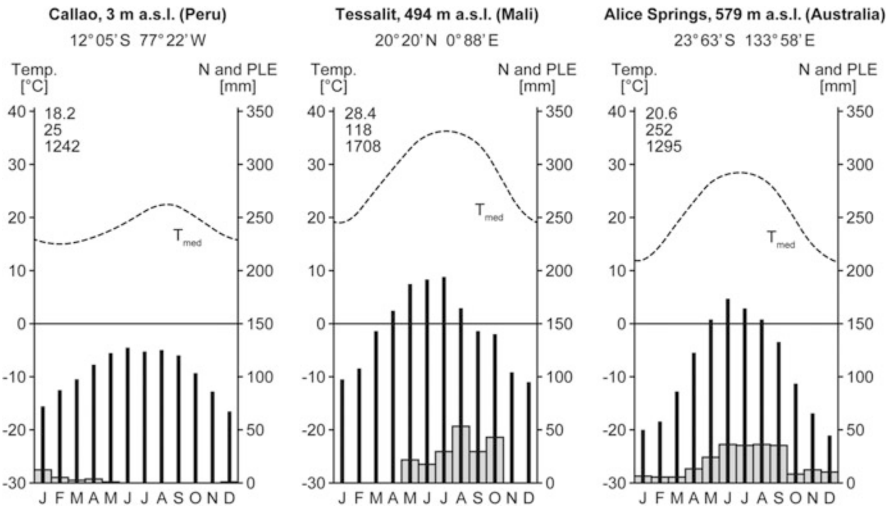

Fig. 5 Climate diagrams from the arid tropics (Richter 2001, Henning & Henning 1984). For legend and geographic position, refer to Figs. 1 and 2

evaporation rate is 1,295 mm. Evaporation rates are higher than precipitation amounts all over the year which makes it a semiarid climate type, but its strong aridity makes it a desert climate. Another arid climate type could be described for the west coast of South America. Callao is located at the pacific coast of Peru close to Lima. Its precipitation regime is characterized by winter rains from December to March and annual rainfall adds up to 25 mm. However, these rainfalls are not the consequence of changing pressure systems but mainly result from drizzling rain during the cool fog season (Richter 2001).

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