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Reasons for the limitation of mangrove along the west coast of northern Peru

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Abstract

Along the west coast of South America mangroves are found only outside the area influenced by the cold Peruvian Current. At 6° S (near 'Cerro Illescas') the current turns west to the open sea in the direction of the Galapagos Islands. Dense mangrove vegetation with a tree height up to 15 m occurs only north of 3° 35′ S from the delta of the river Tumbes (Peru). At 3° 44′ S some small individuals of *Rhizophora* and at 5° 30′ S a small stand of *Avicennia* can be found. In the transition zone between 3° 35′ and 6° S no mangrove forest occurs. The reasons for the lack of mangal in the transition zone are:

(1) Evapotranspiration and atmospheric humidity show significant differences between the mangrove region and the transition zone. In this zone soil conditions like salinity, water and organic matter content and the geological structure can also be considered as inhibiting mangrove growth.

(2) Topographic conditions in this zone are not suitable for mangal and the lack of a regular annual flow from rivers provides a sharp limit for the existence of mangal in the delta of the river Tumbes. Nevertheless, cultivation of mangrove species south of the mangrove region is possible and seems promising.

Introduction

Studies on the distribution of mangrove vegetation often consider only the macroclimatic and oceanographic factors for latitudinal mangrove growth (Blasco, 1984; Chapman, 1976, 1977; Pannier & Pannier, 1977; Walter, 1977; West, 1956). These authors refer to climatic data from Walter & Lieth (1960) and Walter *et al.* (1975), and show climatic diagrams of Guayaquil (Ecuador) at 2° 8′ S in the semi-arid zone with a warm summer and mild winter (Blasco, 1984) and Trujillo (Peru) at 8° 2′ S in the absolute arid coastal desert of Peru. Between these two stations air temperature, rainfall and ocean temperature differ considerably; from a zone with abundant coastal vegetation near Guayaquil one passes to a coastal zone practically without any vegetation near Trujillo. The surface temperatures of the ocean in summer and winter near Trujillo are about 17° to 18 °C (Zuta & Guillen, 1970). This low temperature is due to the cold Peruvian Current which follows the west coast of South America up to 6° S at a point called 'Cerro Illescas' in northern Peru. At this point the current leaves the coast and turns west in the direction of the Galapagos Islands. The coast north of 6° S is always influenced by the warm equatorial current. However, mangroves in dense formations occur from the north only up to 3° 35′ S to the delta of the river Tumbes. No mangal is found south of this

* Data were collected in 1984 while the first author investigated the mangrove area of northern Peru near the city of Tumbes. Logistic facilities provided by Prof. Dr H.-W. Koepcke, Institute of Zoology and Museum of Zoology, University of Hamburg, and by the scientific staff of the Institute of the Sea of Peru (IMARPE) at Tumbes are gratefully acknowledged. We also thank Dr Oscar Tovar, University of 'San Marcos', Lima, for identification of collected plants and the Peruvian Institute of Meteorology (SENAMHI) for climatic data made available to us.

limit with the exception of some small individuals of *Rhizophora* at 3° 44′ S near the village of Bocapán and a small stand of *Avicennia* at 5° 30′ at the mouth of the Piura River in Peru, while generally a warm water fauna is found north of 6° S (Koepcke, 1961, 1974). An explanation for the sharp limit of the mangrove vegetation on the west coast of South America at 3° 35′ S will be given in this paper.

Localities and methods

Detailed studies concerning biological, climatic and edaphic factors were carried out from April to September 1984 following Steubing (1965). The study area is located in the north of Peru (Fig. 1). Two stands with apparently similar conditions were chosen. The first one (1) was located in the mangrove area near the village of Puerto Pizarro at 3° 29′ S and 80° 29′ W; the second one (2) was located at 3° 44′ S and 80° 44′ W near the village of Bocapán, about 30 km to the south, without natural mangroves. While in stand 1 *Rhizophora harrisonii* Leechm. is dominant in a monospecific forest type, fringed landward by *Avicennia germinans* (L.) Stearn., *Laguncularia racemosa* (L.) Gaertn. and *Conocarpus erecta* Jacq., in stand 2 only some small specimens of *A. germinans* and *R. harrisonii* were found. Soil samples were taken from both stands and the vegetation composition determined. Also the growth of planted *Rhizophora* seedlings was followed. Climatic data were collected from 9 h to 18 h once an hour, seven days per stand, from April to September 1984. Therefore these results do not represent the climate as recorded in a standard climatic station; these data are useful to compare the microclimates of the two stands and to point out their differences during the time of observation (Clüsener, 1985). Soil samples of four horizons were analyzed for their salt content and a set of sieves was used for estimating the particle size distribution calculated as percentage of weight.

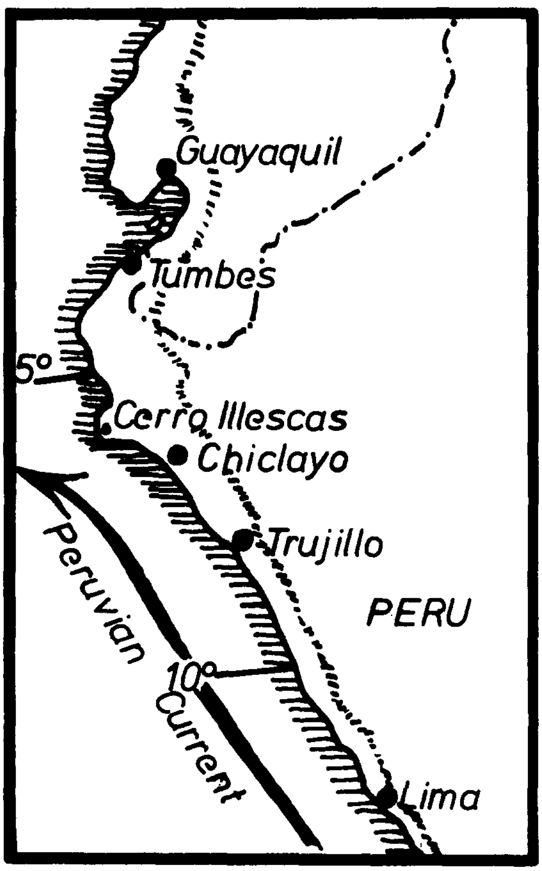

Fig. 1. Map of North Peru and South Ecuador (from Walter & Breckle, 1983/4, modified).

Results

Climatic data from North Peru

The pacific *Aw*-region, according to Köppens (1931) classification, or the so called region of the macroterm arid forest, verdant in the rainy period, exhibits the mangrove forest only at one point before the Ecuadorian frontier with some individuals of *Bombax* sp. The climate of the remaining region is determined as *Bsh(w)*, or so-called steppe and semi-desert of the South Ecuadorian and North Peruvian coast (Koepcke, 1961, 1976). Generally there are three months of heavy rainfall in this region with a typical rain period in the summer of the southern hemisphere. Mean annual rainfall is about 200 mm, in years with the 'Niño'-phenomena rainfall can reach values of 1000 mm and more. Mean temperature is 24.5° with an amplitude of only 3°, mean of maxima is 28°, absolute maximum 36°, mean of minima is 22°, absolute minimum 16°. Oceanic surface temperature in winter is 24°, in summer 28° (Petersen, 1939). Relative humidity in summer is 80 to 90%, in winter 70 to 80%, mean annual evaporation is 700 to 1000 mm. Petersen (1939, 1951) indicates the principal wind direction in summer as N-NE, in winter as SW. 200 hours of sunshine per month are indicated with a minimum in August and a maximum in December (ONERN, 1983).

Microclimatic studies

Monthly means of microclimatic measurements are shown in Table 1. Temperature in °C of the air

Table 1. Microclimatic data from the two stands.

	Stand	April	May	June	July	August	September
T	1	28.2	26.4	25.3	24.3	24.1	23.9
	2	28.3	27.1	26.6	25.1	25.2	24.2
Ts10	1a	31.0	29.2	27.5	27.1	27	27.6
	1b	26.8	25.7	24.5	23.6	23.4	23
	2	29.6	28.5	28.6	27.4	27.9	26.6
Ts2	1a	32.4	30.9	29	28.3	28.3	29.8
	1b	27.4	26.2	24.8	23.9	23.8	23.4
	2	31.9	30.6	30.2	29.2	29.6	28.6
MT	1	23.1	22.1	21.1	20.3	19.9	20.2
	2	23.3	21.7	21.4	19.7	20.4	21.4
H	1	73.5	74.3	77.3	74.7	78.3	76.2
	2	73.3	70.5	67	68.9	72.5	71.1
WSD	1	7.6	6.6	5.6	5.7	4.7	5.2
	2	7.7	7.9	8.5	7.5	6.5	6.5
E	1a	0.34	0.28	0.25	0.25	0.28	0.28
	1b	0.23	0.15	0.15	0.16	0.17	0.16
	2	0.44	0.41	0.46	0.44	0.45	0.39
L	1a	61700	56100	45800	44200	48000	54800
	1b	4600	3500	2800	3000	3300	4000
	2	74300	62900	62100	62300	62100	56700
C	1	5.1	5.8	7.4	6.3	6.7	6.3
	2	4.5	4.0	5.8	5.2	6.2	7.6
Wv	1	2.87	2.9	3.6	3.2	3.5	3.2
	2	3.56	3.2	3.6	3.8	2.4	3.3
Wd	1	NW, W, NE	NW, W	NW, W, NE	NW, W	NW, W	NW, W
	2	NW, W, SW	N, NW, W	N, NW, W	N, NW, W	N, NW, W	N, NW, W
R	1	11	0.1	3.4	0	0	0.1
	2	5	0	0	0	0	0

(T), of the soil at 10 cm depth (Ts10) and 2 cm depth (Ts2), minimum temperature (MT), humidity (H) in %, water saturation deficit (WSD) in %, evaporation (E) in ml per hour, light intensity in Lux (L), degree of cloudiness (C) in a 0–10 scale, velocity (Wv) according to the Beaufort-scale and direction (Wd) of wind and rainfall (R) in ml were measured at the two stands. In stand 1 measurements concerning Ts10, Ts2, E and L were taken in the shadow of the mangrove forest (b) and in a vegetation-free zone (a). Only the main wind directions are mentioned.

Climatic conditions in both stands can be considered as almost identical, but evaporation, humidity, light intensity and water saturation deficit show clear differences. In stand 2 evaporation values lie 1.5 times higher, water saturation deficit is considerably higher, humidity is 5 to 11% lower, light intensity is about 10% higher. Comparing the Ts10 and Ts2 data from stand 1a with the data of stand 2 no significant difference can be noticed. E and WSD, however, are lower at stand 1 due to the transpiration of the dense vegetation at this stand. Therefore abiotic factors show aggravated conditions for mangrove growth in stand 2.

Table 2. Soil conditions.

horizon soil depth (cm)	stand		a 0–2	b 10–12	c 25–27	d 50–52
Wc (%)	1		26.5	24.3	34.5	55.2
	2		21.5	20.4	16.9	17.2
pH	1		7.2	6.1	4.8	5.2
	2		8.2	8.3	8.4	8.5
Si (% of dry matter)	1	10	0	0	0	1.1
		2	0.02	0.15	1.2	0.8
		1	0.08	0.02	0.4	0.9
		0.5	0.2	0.15	0.4	1.9
		0.2	7.1	5.2	6.5	22.3
		0.1	59.4	59.7	55.1	40.3
		< 0.1	32.8	35.2	36.1	32.2
	2	10	0	0	0	0
		2	0.8	1.1	6.2	0.8
		1	2.4	5.4	10.3	1.7
		0.5	7.9	14.8	24.1	7.1
		0.2	22.4	20	36.4	48.5
		0.1	23.7	26.9	12.9	20.4
		< 0.1	42.4	31.8	9.8	20.5
Om (%)	1		4.4	3.2	6.6	11.3
	2		2.6	2.4	0.8	1.2
S (–) bar	1		21.5	25.4	31	39.8
	2		30.6	23.2	11.5	14.2
Sr (mg CO_2 $m^{-2}h^{-1}$)	1		60.7	60.7 (±62.5)		
	2		37.2	37.2 (±15)		

Soil conditions and plant growth

Soil parameters like water content, salinity calculated as osmotic pressure, pH, organic matter content, soil respiration, depth of aeration, soil particle size and granulometry prove stand 2 as non optimal for mangrove growth. Table 2 shows the results. At stand 1 oxygen from the air can penetrate only 10 cm into the soil, at stand 2 at least 50 cm. Water and organic matter content and salinity show the same trends at the two stands. While at stand 1 the values from horizon a to d increase, they decrease at stand 2. pH values at stand 1 range from neutral to acid, at stand 2 they are always alkaline. Size of particles at stand 1 is ≤0.1 mm, at stand 2 mostly between 0.1 and 0.2 mm. Salinity at stand 1 shows nearly the same or higher values as seawater, at stand 2 horizon c and d have half seawater salinity. Soil respiration shows at both stands a high standard deviation of the values, at stand 1 soil respiration is slightly higher than at stand 2. These data show, that soil conditions at stand 2 can be estimated as inhibiting mangrove growth. Some seedlings of *R. harrisonii* were planted at stand 1 in the vegetation-free zone and at stand 2, to observe their growth for 5 and 3 months respectively.

In the 5-month experiment from April to September the mean value of shoot length increase was 108% in stand 1 and 52% in stand 2. In the 3 months plantation from May to July the length of increase was 76% in stand 1 and 32% in stand 2; however, the increase in the plant weight dry matter was 33% in stand 1 and 37% in stand 2. The higher values of weight in stand 2 are in agreement with the findings of Pannier (1959) that mangrove seedlings growing in water with a lesser salt content have a higher water content. The higher length values in stand 1 suggest better growth conditions for this stand.

Discussion

Factors inimical to a regular mangrove development in stand 2 are both of a climatic and edaphic nature. From a climatic point of view, adverse features are higher evaporation, water saturation deficit and lower humidity of the air; from an edaphic point of view alkaline nature, lower water content, bigger size of soil particles and lower content of organic matter are detrimental. These abiotic factors, as well as the coastal geomorphology, determine the mangrove growth along the coast of North Peru in the transition zone between 3° 35′ and 6° S. Most of the investigated area is high or elevated coast not appropriate for mangroves. In the remaining regularly flooded areas of the coast such as along the river mouths up to 'Cerro Illescas' at 6° S, plantations of mangrove species are successful. Therefore, the zone under the influence of the cold Peruvian Current, a major limiting macroclimatic factor, always stated in the older literature, can be ruled out for the existence of mangroves. Pannier & Pannier (1977) were the first to look for reasons other than the cold current to explain the distribution of mangal in Peru, but they did not carry out any investigations. Further research is necessary to discover if there had been mangroves in this region at earlier times. However, the mangrove area itself is under pressure and in danger of destruction. Intensive shrimp farming is changing the whole ecological situation and is capable of destroying the small mangrove forest existing in Peru.

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