

Area

AREAS OF FOG IN CENTRAL AMERICA  
AND THE CARIBBEAN REGION

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## INTRODUCTION

The areas of fog in the Caribbean are located mainly in volcanoes or high mountains at elevations that go from 1,500 to 3,000 m in Central America, though at lower elevations in the West Indies. Elevation is not the main factor associated to fog formations as is the cloud level itself, which depends on humidity levels at the foot of the mountain (LaBastille & Pool, 1978). Cloud cover areas in this part of the globe are integral part of cloud forests. These ecosystems, through leaves and twigs, collect high quantities of moisture that then are transported to the soil. The quantity of water collected amounts to several centimetres of run-off that end up in lower elevation lands.

This report deals with climatic characteristics directly related to fog presence in areas within 50 Kilometres of the coast. In Central America and the Caribbean clouds are transported by northeasterly trade winds. Wind in these areas show two significant deviation, September and December (Portig, 1976). The maximum mean wind speed was observed in the winter of Barranquilla, Colombia with 29 to 32 Km h<sup>-1</sup>; and the minimum during the fall where the wind drops completely dead for hours (Portig, 1976). Maximum cloudiness is found in the Western Golf of Mexico and the east coast of Central America; and the minima along the north coast of Colombia. The rainfall, directly related to the trade winds and the topography varies considerable from region to region. The present

information is limited by the availability of resources in determining fog water collection prospects for these areas.

#### VENEZUELA

Venezuela presents an interesting anomaly. Coastal regions do not exhibit wet conditions as is to be expected for that latitude in the tropics. Instead the areas surrounded by the sea are the driest (Schwerdtferger, 1976). This area extends from 62°W westward for at least 13° of longitude and southwards to approximately 10°30'N, depending on the topography it may extend even further. In areas where the mountains are adjacent to the sea and aligned with the wind, the dry area is confined to the seaward slopes. In the western extreme the arid area extends to almost 15°N, though, diminishes eastward to only cover Margarita Island and the eastern tip of Peninsula de Paria (see Map 1).

Map 1.

Schwerdtferger (1976, p. 332) attributes this aridity to:

"a combination of large scale dynamics and local causes. General subsidence over the southern Caribbean stabilizes the atmosphere and tends to confine atmospheric moisture within the lowest 3 Km, i.e., below the trade-wind inversion."

He further explains the numerous other factors that contribute to the aridity conditions in this region. Upwelling reinforces atmospheric sinking thus increasing aridity. Though, as he explains both upwelling and aridity are the effects of the topography. "Daytime cloud suppression" is the result of afternoon circulation over the land that minimizes cloudiness thus allowing for more overland heating and again circulation and so on.

Based on Schwerdtferger's (1976) statement that "the atmospheric moisture content below the trade-wind inversion is high", it is safe to assume that fog producing clouds may be present. These clouds may be produced at lower elevations and pushed upwards by convection. The Cordillera de la Costa which serves as a barrier to these clouds could favour fog water collection.

There are particular areas that present frequent and regular cloud cover through the night. These areas are the mountains of Margarita Island, Cerro Santa Ana in the Paraguaná Peninsula (Schwerdtferger, 1976), and Rancho Grande in Aragua (Huber, 1978). A description of some of the characteristic of Margarita Island and

Maps 2 & 3.

"Rancho Grande" follows. Cerro Santa Ana do present similar characteristics but a specific description of it may come later.

Margarita Island (11°N, 64°W) constantly swept by strong east-northeasterly trade winds, receives less than 1,000 mm of rain and often less than 500 mm. Humidity increases with altitude and with eastern direction. Precipitation in the eastern lowlands has two peaks December-January and July-August. While in the west side of the Island rain has only one peak in July-August (Schwerdtferger, 1976).

Although precipitation is not known to increase with altitude, the amount of water that goes to the ground increases with it. The interception of clouds by vegetation are by no means the main reason for that increase in soil humidity. As Sugden (1986, p. 190) states:

"On most nights throughout the year the eastern mountain are capped with orographic clouds, which generally descend late in the afternoon and lift during mid-morning."

He also reports that in Cerros Guayamuri, Matasiete and Tragaplata (see Map 2), clouds descend to 350 m on the eastern sides and to 400-500 m on the western sides. On the Cerro Copey, he adds, clouds go down to 450-550 m on the east and west sides respectively.

The wind direction only changes when major weather disturbances occur within 150 Km of the Island (Sugden, 1986;

Schwerdtferger, 1976). Hurricanes and tropical storms usually disturb the eastward trade-wind. For the most part, however, the direction of the wind varies very little during the year (Sugden, 1986). Sugden (1985) observes that forests at elevations above 800 m experience constant and frequent gusty winds of more than 50 Km h<sup>-1</sup>. No obstante these strong winds cloud cover was present nightly through the year, he adds.

Sugden (1986) found that there is a clear level at which cloud forest begins which corresponds to the cloud cover. On the windward slopes at somewhat lower levels than at leeward slopes, but mainly forming a "ribbon" more or less 30 m wide. These forests would extend downward along the gullies where permanent ground water exists.

Another area of high cloud cover is "Rancho Grande" within the National Park "Henri Pittier", Aragua. This area extends between more or less 1000 to 1800 m.a.s.l. at 67°40' long.W, 10°16' lat.N in the Cordillera de la Costa (Huber, 1978), see Map 1. Beebe & Crane (1948) describe this cloud forest in some detail. The relative humidity averages 92.4% without any big changes during the day nor the year. The cloud cover doesn't leave the top of the hills even during the hottest months, March - August. During the driest months February and March, the cloud cover persists protecting the foliage and maintaining the humidity of the soil. Seifert & Seifert (1979) confirm this description. Cloud cover

starts at about 750 m on the windward slopes and at more or less 900 m on the leeward slopes. Most of the time clouds descend at around 4 p.m. until 6-7 p.m. lifting to come back again at around midnight and stay until 8 a.m. The fog collection potential of this area requires an in depth study of its surroundings and the water needs. Although the precipitation in this region averages 1,753 mm per year, the evapotranspiration may render it insufficient for domestic use.

Pittier (1939, cited by Beebe & Crane (1948)) describes other areas that seeing from the sea are covered by a thick cloud during the first hours of the morning. These clouds have an uniform and straight base, though they grow or diminish with the temperature. These areas appear in Los Andes of the Guayana as well as in the Cordillera de la Costa where "Valle de Ocumare" and "Colonia Tovar" are among the most known areas.

Sobrevilla et al. (1983) provide similar descriptions for areas between 800 and 1800 m elevation in the northern part of Cordillera de la Costa. The areas observed by these authors besides National Park Henry Pittier (1800 m) are: Sartenejas Forest (1380 m) and Forest Reserve of IVIC (Instituto Venezolano de Investigaciones Científicas) (1700 m). All these areas exhibit cloud forests due to the northeasterly trade winds and the climatological factors cited above.

## COLOMBIA

In the Caribbean lowland section favoured by the Sierra Nevada de Santa Marta an arid coast is present, see Map 1. This area is a savanna type with high atmospheric moisture especially in the Guajira Península (see Map 3). The rain in this Península is as low as 300 mm yr<sup>-1</sup>; though, "the mean relative humidity is in the range 75 - 85 %" (Schwerdtfeger, 1976). Along the coast the annual mean wind speed is 32.4 Km h<sup>-1</sup> (9 m/sec) while between 1,000 to 2,000 m.a.s.l. the wind reaches 64.8 Km h<sup>-1</sup> (18 m/sec) during the day. The wind speed diminishes upwards down to 18 Km h<sup>-1</sup> (5 m/sec) at 3,000 m.a.s.l. (Schwerdtfeger, 1976).

The aridity of this region is attributed to several reasons as stated by Schwerdtfeger (1976) and Sugden (1982):

- upwelling of cold water from the depths to the North and East as a result of topographic phenomenon.
- persistent northeasterly winds that dissipate any cloud formation.
- small scale circulation similar to "the low level coastal jet stream" Schwerdtfeger (1976; p. 361) mentioned for Venezuela. Along the coast, for reasons still not clear daily land-sea circulation which would increase rainfall are not present.

The Peninsula of Guajira is the most important area from a fog collection point of view. Sugden (1982) describes this Peninsula as predominantly flat and with three sets of hills: Serrania Cocinas, Serrania de Jarara and Serrania de Macuira, being the last one the tallest (865 m), see Map 3. The steep slopes of these mountains force the airstream up allowing for cloud formation on the windward side. However, clouds are rapidly dissipated by the strong winds, thus rainfall is rare. Arid conditions change from mid-September to mid-November when the trade-wind belt changes course. During this period "winds are mostly southwesterly, humid and moderate", thus allowing for cloud formation and rain. Though, rain falls on the slopes and in lowlands at the same time, what is not clear is whether the quantity of rain is equal on both. Consistently a thick layer of clouds persists along the slopes and above 600 m on early evenings. The same cloud cover goes down to 350 m at dawn. Sugden (1982) concludes that those clouds remain on the windward side of the hills for at least 12.5 hrs and that the cloud cover seems to be more persistent at elevations of 700 m than at 500 m.

The Serrania de Macuira experiences daily 14 hours of cloud cover and negligible precipitation for 10 months of the year (Sugden & Robins, 1979). In these mountains between 500 and 550 m.a.s.l. on the windward side cloud forest formations are present, see Map 4, (Sugden, 1982). This forest covers an area of 15 Km<sup>2</sup> with trees that go from 1 m to 10 m in height depending on their

Map 4.

exposure to the wind. Apart from the cloud forest in the 3 Serranias mentioned above, Sugden (1982) points out a couple of peaks of about 500 m high that also support this formation. Though of smaller scale (with less than 1 ha of cloud forest) Cerro Yauanauas and Cerro Ke'chuo are worth considering. As he suggests other similar peaks may well present patches of cloud forest waiting to be discovered.

The mean monthly temperatures are almost constant 28°C (Sugden, 1982) throughout the year, though they may go as low as 14°C and as high as 40°C (Chaves (1953) cited by Sugden, 1982) in the Serrania de Macuira. For every 100 m of altitude the temperature diminishes 1°C and, at 500 m the mean is 22.5°C (Sugden & Robins, 1979).

The Sierra Nevada de Santa Marta on the other hand, as Sugden & Robins (1979; p. 175) state, "depends for its precipitation on the prevailing northeasterly trade winds bringing moisture from the Caribbean Sea." Here the western slopes experience daily afternoon precipitation during the wet season and cloud cover throughout the year. The cloud cover depends on the altitude and season (wet or dry), going from 2 to 6 hours daily. The longer cloud cover was experienced at 4,000 m.a.s.l. during the wet season.

Groundwater in this peninsula emerges at certain points to form small streams, but no doubt this is the result of cloud

interception in the upper slopes (Sugden, 1982). Deforestation would disturb the watertable that is superficial around rivers, thus jeopardizing this valuable source of water for domestic use. A large number of natives in these areas are sedentary thanks to the installation of wind-pumps. Fog water collection in areas that have been deforested or are lacking of enough water supply, is an interesting alternative.

#### COSTA RICA

Following a southeasterly direction the Cordillera de Tilarán raises between 10°25' N, 84°50' W and 10°05' N, 84°30' W for about 60 km. These mountains are exposed to the northeast trade winds which are a predominant feature of the climate in this region (Lawton & Dryer, 1980). Zadroga (1981) explains that due to the small land mass of Central America, "the intertropical low-pressure trough is poorly defined over the Isthmus." Therefore, the winds carrying the extra moisture accumulated in the warm Caribbean sea are a constant feature of the highlands throughout the year.

Zadroga (1981) states that the wind blows from the Atlantic to the Pacific producing a complex rainfall distribution pattern and wind velocities. The air masses that descend on the Pacific slopes are encountered by air heated adiabatically that dissipates the clouds. The ridges and the head-walls of wind gaps, however, "are much more often exposed to blowing clouds and mist."(p. 63)

Maps 5 & 6.

Along the Atlantic Slopes of the Cordillera de Tilaran, during the dry season, from January to April, the cloud cover and wind speed are intensified (Zadroga, 1981). Wind speeds regularly exceed  $100 \text{ km h}^{-1}$  at canopy level especially during December through February (Lawton & Dryer, 1980; Rebertus, 1988). While cloud covers spill over the Pacific slopes. The elevation of this cloud banks may vary from 1,300 to 1,600 m.a.s.l. (Lawton & Dryer, 1980). The northeastern mountain slopes are most exposed to cloud cover. In this area the "buildup of convective cumulus above the Pacific slope" increases during the calm periods of the dry season (Lawton & Dryer, 1980).

Lawton & Dryer (1980; p. 104) describe, in more detail the climate of Monteverde Cloud Forest Reserve, which is located in the Cordillera de Tilaran:

"By the middle of May thunderstorms drift up the Pacific slope on local valley winds. Thunderstorm activity extends into October, with a dryer spell, the veranillo, occurring around the beginning of July. Bouts of strong trade winds continue to occur interspersed among the days of thunderstorm. In the earlier part of the rainy season the windy bouts are dry periods, but by August they are once more carrying mist across the Divide. Beginning in September thunderstorms become less frequent. The period from November through December is dominated by strong wind, low clouds and heavy mist."

This Reserve according to LaBastille and Pool (1978) covers 1,600 ha. Although, the protected area seems to be on the order of 5000 hectares (Lawton & Dryer, 1980). It is owned and operated by the Tropical Science Centre of San José. In addition to this reserve, there are other similarly important cloud forest areas,

Volcano Poas National Park and Volcano Chiripó National Park (44,000 ha) (LaBastille & Pool, 1978).

Water management professionals hydrologists, foresters and others consider the cloud forests of Costa Rica an instrument for flow regime regulation (Zadroga, 1981). They affirm that cloud cover in the highlands of headwaters regulates run-off. However, as Zadroga (1981) says there is not a quantitative analysis of the effect of cloud forests with water regimes.

Zadroga (1981) in his hydrological study of the Montane Cloud Forest has discovered that the annual run-off in the Atlantic slopes measures 102 percent! of the estimated rainfall, "the monthly run-off exceeds monthly rainfall for about 7 months of the year..." While in the Pacific slopes the run-off is only 34.5 percent the annual rainfall, more within the normal range. This large discrepancy between the Atlantic and Pacific may be due to the incomplete pluviometric installations or, which is more likely, to the "under-estimation of total catchment precipitation due to the occurrence and non-measurement of cloud moisture interception phenomena (p.69)." The months where the run-off surpasses precipitation are in fact the ones where the north-east trade winds are dominant. In those months the cloud cover is significantly low, thus allowing for the capture of the clouds by the vegetation. Zadroga (1981) calls attention to the type of vegetation that succeeds deforestation, and its consequences to run-off.

The need for fog water collection in this area may be minimal. Rainfall at the community of Monteverde (1380 m on the lee slope) averages 2,450 mm per year (Lawton & Dryer, 1980) and in the east in Peñas Blancas may go up to 9000 mm (Zadroga, 1981).

#### PUERTO RICO

As in previous countries, the climatic factors of Puerto Rico are a result of the northeast trade winds and the topography. The clouds carried by these winds precipitate mostly on the northern two-thirds of the island (Gleason & Cook, 1926). It is here where the Luquillo Mountains are located. They are the first obstacle the trade winds encounter as they come from the Atlantic.

Large masses of clouds accumulate around the peaks at night, enveloping the mountain at an average altitude of about 600 to 750 meters (Gleason & Cook, 1926; Baynton, 1968). Masses of clouds driven by the easterly trade winds ascend the mountain during the day and cover the peaks with cold moist, fog or rain, to finally pass over the upper ridges to the west and evaporate under the tropical sun (Gleason & Cook, 1926).

According to Gleason & Cook (1926) the precipitation diminishes towards the northwest. In Rio Blanco, close to Luquillo Mountains, the mean annual rainfall amounts to 2500 mm, in San Juan to 1600 mm, and in Isabela to only 1350 mm. In the western end on

the other hand, even at low altitudes, the mean rainfall exceeds 2000 mm.

The rainfall, that has reached its maximum around the main divide, decreases southwards. The western half of the south coast exhibits the lowest amounts in the whole island. The average precipitation is less than 1500 mm and in some areas less than 1000 mm. The pluviometric station with the lowest precipitation records is Potala, with an annual average of only 800 mm (Gleason & Cook, 1926).

Gleason and Cook (1926) have summarized the annual average precipitation of Puerto Rico in Map 6. The Map also shows the extent of the area prone to yearly drought.

The distribution of precipitation along the island does not satisfactory explain the abrupt change in vegetation. Gleason and Cook (1926) attribute this transition which may only take two or three kilometres to the atmospheric humidity more so than to the rainfall alone. That is how it works (p. 24):

"As air currents rise in passing over the mountains from north to south, they become cooler and loose a part of their capacity for holding water vapor, which is accordingly precipitated as rain. As they descend on the south side, the increasing pressure raises their temperature and increases their water holding capacity, without providing the necessary water to saturate them. The winds of the south side are therefore both warm and dry ..."

This explains the long periods of drought in the south side of the island. Periods without rain go from 80 to 28 days, with an average length of 21 days. Drought conditions are prevalent from December to March. Each of these months have from 22 to 27 days of drought. The wettest month is September with an average of only 7 days of drought (Gleason & Cook, 1926).

Temperature across the island does not vary a great deal; daily variations of 2.6°C (10°F) between the coast and inland; and only 1.3-2°C (5-8°F) between the warmest and the coldest month are common. The maximum variation was observed with altitude. At sea level temperatures seldom fall below 15.5°C (60°F), while in the mountain stations temperatures below 10°C (50°F) are frequent (Gleason & Cook, 1926).

The Luquillo Mountains where Pico del Este, Pico del Oeste and El Yunque are located exhibit typical cloud forest vegetation (Howard, 1968; Baynton, 1968). The increase humidity, rainfall, wind and low temperatures in this zone produce a characteristic vegetation. These factors favour the appearance of sierra palm belt at lower altitudes than in the central Cordillera (Gleason & Cook, 1926). Cloud forest also named mossy forest occupies the peaks of these mountains and descends down their flanks along the wind exposed ridges to an elevation of approximately 700 meters.

Records of precipitation for these mountains are only estimates based on observations of a few months. Weaver (1972) on his eight month study of Pico del Este noted that the mean may vary from 4572 to 6096 mm, with lowest reading from February to April. These figures are much larger than Gleason & Cook (1926) estimates of 3,400 mm per year. Weaver (1972) also observed that the rainfall on the leeward always exceeded that of the windward, which in turn exceeded that on the ridge. The average annual precipitation based on his observations reached 5400 mm on the windward ; 4800 mm on the ridge and 6000 mm on the leeward. For Pico del Oeste the records are less detailed. Average precipitation is indeed less than that recorded for Pico del Este, with an annual mean of 4533 mm (Baynton, 1968). Baynton (1968) observed that most of the rain fell during 350 days of the year and, it was more frequent at night, but more intense during the day. Ewel & Whitmore (1973) conclude that if these conditions are representative of the long-term mean values, the average year-round run-off would reach almost 300 mm per month, and in some months this value could be double. The run-off would represent 66.6 percent of the rainfall.

The Luquillo Mountains probably receive the highest rainfall and certainly the highest atmospheric humidity (Gleason & Cook, 1926; Weaver, 1972; Ewel & Whitmore, 1973). Throughout most of the year, even in the dry season the peaks are wrapped in fog. Weaver (1972) on his study of Pico del Este found that at night for the

windward and leeward plots the humidity remained at near 100 percent. During the day it only dropped slightly to 99.5 percent, especially during February, March and April. Baynton (1968) for Pico del Oeste recorded a mean relative humidity of 98.5 percent. The relative humidity for these mountains are the highest in the country.

Baynton (1968) reported that in Pico del Oeste 40 % of radiation was suppressed by cloud cover. Gates (1969) found that indeed the radiation on a horizontal surface at the peak had a value of  $0.8 \text{ cal cm}^{-2} \text{ min}^{-1}$  compared to  $1.3 \text{ cal cm}^{-2} \text{ min}^{-1}$  at San Juan. Similar values were reported for El Yunque (Briscoe, 1966 cited by Gates, 1969). There is no doubt that low radiation is the result of persistent cloud cover.

The wind in the peaks of the Luquillo mountains is almost constant so much so that the vegetation appears to a perfectly uniform level of two to three meters (Gleason & Cook, 1926). Baynton (1968) noted that winds for Pico del Oeste were strongest at night and weakest during the afternoon. The wind direction was frequently north-east and east for 81 percent of the time. Mean wind speeds of  $22.4 \text{ Km h}^{-1}$  (14 mph) at tree top level at the ridge of Pico del Oeste (Gates, 1969), and  $20.8 \text{ Km h}^{-1}$  (13 mph) for El Yunque (Briscoe, 1966, cited by Gates) were reported.

The temperature at the peak of Luquillo mountains is considerably lower (Gleason & Cook, 1926), though exact measurements are not available. Weaver (1972) has observed that temperatures may vary from 15°C to 24°C in Pico del Este. Gleason & Cook (1926) assume a decrease of temperature amounting to about one degree Fahrenheit for each 100 meters of altitude. At the peak of the Luquillo mountains the temperature is seven to eleven degrees lower than at sea level; and in the Cordillera Central as much as fourteen degrees (Gleason & Cook, 1926). Weaver (1972) adds that temperatures in Pico del Este decrease during January and February. His measurements were done under forest cover. Baynton (1968) gives an annual mean of 18.6°C for Pico del Oeste.

Besides Pico del Este (Caribbean National Forest, 1,000 m) LaBastille & Pool (1978) mentioned four more areas that are cloud forests and are being protected by the Commonwealth public forest system. They are Carite, Maricao, Monte Guilarte and Toro Negro. The cloud forest in these areas which cover 400 ha. descends hardly below 1000 meters (Gleason & Cook, 1926).

#### CUBA

Cuba is the largest and the farthest north island of the Caribbean. It extends between the 20° and the 23° parallels of north latitude, and between the 74° and 85° meridians of west longitude. The climate, as in many of its neighbouring islands is affected by the northeasterly winds and the four mountain groups. The largest

group lies in the eastern end of the island and is known as Sierra Maestra. It is here where Pico Turquillo, the highest mountain in Cuba is located. The rest are Cordillera de los Organos in the west, Sierra de Santa Clara in the centre and Sierra de las Cubitas in the east-central, see Map 7 (Seifríz, 1943).

The amount of precipitation in the whole island differs from place to place and from one year to the next. Seifríz (1943) stresses that the precipitation may vary from 1320 to 1800 mm in two locations only 29 Km apart. What makes it even more unusual is the fact that there are no topographic barriers in between. The same phenomenon is observed in the amount of precipitation Habana in the north coast receives (1092 mm) and Batabano in the south (1650 mm) (Seifríz, 1943).

According to Seifríz (1943) the amount of precipitation in no way corresponds to the type of vegetation. The so called "dry" areas of the west (Pinar del Rio province) receive 1600 mm compared to the "humid Oriente" with only 1168 mm of total annual rainfall. As Seifríz (1943) adds, "the total rainfall of all Oriente is misleading." He concludes that soil quality is the factor that determines the type of vegetation in the island rather than precipitation.

Despite the large amounts of precipitation there are areas of extraordinary dryness. These areas are located at the south slopes

Map 7.

of the Sierra Maestra. In fact, these mountains are the most important in cloud interception. They run parallel to the southeastern coast and are sufficiently high as to intercept the clouds carried by the trade winds (Seifrizz, 1943). These are the clouds that keep the northern slopes of Sierra Maestra wet while the southern slopes are comparatively dry. Seifrizz (1943) attributes the dryness of Cape Maisi (at the eastern south tip of the island) to the absence of mountains in the area. This is the same reason why the Bahama Islands are also dry, he explains. The clouds carried by the trade winds "pass by" leaving the area dry (Seifrizz, 1943).

From a fog collection point of view the area of El Llano de Maisi may hold some promises. According to Seifrizz (1943, p. 420) this region is the driest on the island, "often no rain falling from February to August, or even until October, though other parts of Orient are very wet." The reason, as he explained earlier, is the lack of topographic interception to the "moisture laden clouds" and the constant wind that sweeps across the Straight between Haiti and Cuba. The altitude at which the trade winds pass should determine whether interception of these clouds may deter fog water collection.

#### JAMAICA

Seifrizz (1943) describes rain distribution as directly related to the topography. He attributes the interception of clouds coming

from the northeast to the 2,300 to 3,000 m ridge that extends through the island from east to west. This is how he explains it (p. 384):

"These water-laden clouds carried by the trade winds at 2,000 to 5,000 feet altitude, strike the northern mountain slopes and deposit their moisture. What few roll over the high ridge are quickly dispersed by the hot dry air rising from the southern valleys. The result is a wet north coast with luxuriant vegetation, and a dry south coast sparsely covered by xerophytes."

The Blue Mountain, as Shreve (1914) describes it, lie parallel to the north and south coasts and extends for 22 miles. The highest peaks are to the west John Crow Peak (1,830 m), and to the east Blue Mountain Peak (2,265 m). Incomplete meteorological data analyzed by Shreve (1914) provides with only sketchy information of the area. Precipitation levels vary from year to year and from month to month. For three mountain stations (Cinchona, New Haven Gap and Blue Mountain Peak) the means are 2685, 2890 and 4268 mm respectively. The annual mean temperature recorded was 16.0°C. This mean temperature seems very low for that part of the Caribbean. Humidity records, on the other hand seem to be within what is expected. The average annual humidity is 84.1 percent, with July and August having the lowest readings, 79.6 and 80.4 respectively.

In regards to fog presence, Shreve (1914, p. 13) observes that:

"On the northern slopes of the range at all elevations from 4,500 feet to the summits of the highest peaks fog is prevalent from 10 a.m. to 4 p.m. on a very high percentage of the days in all months except February, July, and August. On the southern slopes the amount of fog is much less. Fog at night is rather exceptional, occurring more often, in my own observation, on the summits of the Main Ridge than below 5,800 feet."

Typically, he adds, there are two to three hours of fog each day in the mid-day or early afternoon. The windward slopes are enveloped in cloud for 70 percent of the time except during February, July and August where cloud cover persists for 30 percent of the time. The cloud cover on the main ridge of the Blue Mountains seems of similar amount to that of the windward slopes. However, the leeward has considerable less cloud cover than both windward and ridge.

The wind direction is from east to northeast having its highest force at night and in the winter season (Shreve, 1914). The speed of  $2.2 \text{ km h}^{-1}$  registered by Shreve (1914) at Cinchona does not compare with the rest of the islands in the Caribbean. This climatological factor does require more study.

## DOMINICA

Hodge (1954) describes this British Island as having a mountainous axis of north-south direction and of rugged nature. It is due to this topography that this island is so well watered. The northeast trade winds hit the eastern slopes resulting in the highest precipitation levels of the Caribbean. The average annual rainfall in the windward area is 3,200 mm; while at leeward is 2,590 mm. The average for the whole island 2,895 mm (Hodges, 1954) is indeed much higher than the average (2,290 mm) mentioned by Stehlé (1945). The leeward coast considered "dry" surpasses the annual precipitation of leeward coasts anywhere in the Caribbean. Hodges (1954) concludes that the mountain summits possible collect 10,100 mm of rain yearly.

Dominica has the largest forest area in the British Commonwealth of the eastern caribbean. Undisturbed forests could be found in the Morne Trois Pitons National Park (7,500 ha), where the highest elevation is 1,425 m (LaBastille & Pool 1978).

From the description Hodge (1954) and LaBastille & Pool (1978) Dominica does not seem to need any extra water. Fog water collection, though possible would be unnecessary.

## EL SALVADOR

Daugherty (1973) briefly describes the area of cloud forest cover in this country. The only remaining cloud forest is Montecristo which extends in the northwestern highlands into Guatemala and Honduras. Unfortunately he does not give the extent of this area in hectares. Daugherty's main concern is of conservation of the area which is badly eroding due to forest clearing. Fog water collection could be used to restore part of this forest and to stabilize the watershed.

## DOMINICAN REPUBLIC

Pico Duarte, 3,175 m.a.s.l. is the highest peak in the Caribbean and part of the Armando J. Bermúdez National Park (78,000 ha). Cloud forests may consist largely of tall oaks and pines at 3,000 m (LaBastille & Pool 1978).

## MEXICO

A potential cloud-forest site for a park is the Cordillera de Chiapas (LaBastille & Pool, 1978) of unknown surface. And on the eastern slopes of Eastern Sierra Madre, Tamaulipas another area of cloud forest for a potential park is located (Ezcurra & Becerra, 1987).

## HONDURAS

Quesada (1988) reports on the contribution of "La Tigra" cloud forest to the potable water problem in Tegucigalpa. This 75 Km<sup>2</sup> National Park contributes "with 25 minor intakes and small dams" to the treatment plant. He also points out that the treatment cost is 23 times less than a conventional watershed. The declaration of this park in 1980 has greatly contributed to the water supply of Tegucigalpa. Quesada reports that this park provides 40% of the water consumed in this city. In an area where only 40% of the population counts with piped water and where the price of water may be as high as "50 times the average cost of the minimum public fare" it is important to find or increase the collection of fog water.

LaBastille & Pool (1878) called for the preservation of the northern mountains around La Union.

## GUATEMALA

The cloud forest here consists largely of tall oaks and pines at 3,000 m.a.s.l. The private Quetzal Cloud Forest Reserve (ca 400 ha) is located on Volcano Atitlán and the Cuchumatanes Mountains (LaBastille & Pool, 1978).

## MARTINIQUE

The average annual rainfall is 2,269 mm (Stehlé, 1945) with maximus in September, October and November, the rain gages were located in the Xerophytic forest. The average relative humidity is 76.66 percent (idem) and the mean temperature is 25.64 °C.

## GUADALUPE

The average annual rainfall is 1,732 mm, for the xerophytic forest (Stehlé, 1945) with drought periods during the winter (February, March and April). The relative humidity is very similar to that of Martinique (idem).

The leeward average annual rainfall is 3,567 mm in Jacob (Pearce & Smith, ?).

## TRINIDAD

## WEST INDIES

Other potential areas of cloud forest in this area include as pointed out by LaBastille & Pool (1978):

St Kitts (Mt. Misery, 1,075 m),

Nevis (Nevis Peak, 990 m), (Howard (1968, p. 389) states that

"within the Leeward islands [St. Kitts and Nevis] have peaks of sufficient altitude to develop the cloud or mist cover necessary for the development of mossy forest. ... A small amount of mossy forest type of vegetation is found on the higher peaks of Mt.

Misery, Camp's Mountain, and Verchild's Mountain. ... A comparable type is present in restricted areas at the summit of the principal peak on Nevis."

Guadeloupe (Soufrière, 1,435 m),  
Montserrat (Chance Peak, 920 m),  
Martinique (Mt. Pelée, 1,400 m),  
St. Lucia (Mt. Gimie, 925 m), . The average annual rainfall is  
2,138 mm (Stehlé, 1945)  
St Vicent (Soufrière, 1,220 m),  
Grenada (Mt. St. Catherine, 840 m),  
Trinidad (El Aripo, 941 m), with a cloud forest formation at the  
summit of this mountain (Howard, 1968);  
Cuba (Pico Turquino, 1974 m) and  
Jamaica (Blue Mt., 2,250 m) .  
Barbados exhibits an average annual rainfall of 1,536 mm (Stehlé,  
1945). Stehlé (1945) as Seifríz (1954) seem to agree in  
associating topographic features to the amount of rainfall an  
island receives. For this reason, Stehlé (1945) affirms that this  
island is the driest and flattest of all the Caribbean.

#### PANAMA

Cloud forests starts at elevations of 2,400 m. and composed  
predominantly of wild figs and magnoliaceous trees. At Volcano  
Barú National Park the cloud forest is between 1,800 to 3,475 m of  
elevation (LaBastille & Pool, 1978).

## REFERENCES

- Baynton, Horold W. 1968. The Ecology of an Elfin Forest in Puerto Rico, 2. The Microclimate of Pico del Oeste. Journal of the Arnold Arboretum, Vol. 19, No. 4, pp. 419-430.
- Beebe, W. & J. Crane. 1948. Ecologia de Rancho Grande, una Selva Nublada Tropical en el Norte de Venezuela, Buletin de la Sociedad Venezolana de Ciencias Naturales. No. 73.
- Daugherty, Howard. 1973. The Montecristo Cloud-Forest of El Salvador - A Chance for Protection. Biological Conservation, Vol 5, No. 3, pp. 227-230.
- Ezcurra, Exequiel and Judith Becerra. 1987. Experimental Decomposition of Litter from the Tamaulipan Cloud Forest: A Comparison of Four Simple Models. Biotropica, Vol 19, No. 4, pp. 290-296.
- Gates, David M. 1969. The Ecology of an Elfin Forest in Puerto Rico, 4. Transpiration Rates and Temperatures of Leaves in Cool Humid Environment. Journal of the Arnold Arboretum. Vol. 50, No. 1, pp. 93-98.
- Gleason, H.A. and M.T. Cook. 1926. Plant Ecology of Porto Rico. Part 1 and 2. Scientific survey of Porto Rico and the Virgin Islands. Vol 7, pp. 173 + 50.
- Hodge, W.H. 1954. Flora of Dominica, B.W.I. Lloydia, Vol 17, No. 1, pp 52.
- Howard, Richard A. 1968. The Ecology of an Elfin Forest in Puerto Rico, 1. Introduction and Composition Studies. Journal of the Arnold Arboretum. Vol 49, No. 4, pp. 381-418.
- Huber, O. 1978. Light Compensation Point of Vascular Plants of a Tropical Cloud Forest and an Ecological Interpretation. Photosynthetica, Vol 12, No. 4, pp. 382-390.
- LaBastille, Anne & Douglas J. Pool. 1978. On the Need for a System of Cloud-forest Parks in Middle America and the Caribbean. Environmental Conservation, Vol 5, No.3, pp. 183-190.
- Pearce, E.A. and C.G. Smith. 19?. The World Weather Guide, Hutchinson, London.
- Portig, W.H. 1976. The Climate of Central America. World Survey of Climatology, Vol 12, pp. 405-457.
- Quesada Matco, C.A. 1988. La Tigra Cloud Forest and the Meaning of its contribution to mitigate Tegucigalpa's Potable water

- crisis. Nature Management & Sustainable Development Intl Congress, Groningen, Netherlands, Dec 6-9, p. 107(8).
- Rebertus, Alan J. 1988. Crown Shyness in a Tropical Cloud Forest. Biotropica, Vol. 20, No. 4, pp. 338-339.
- Schwerdtfeger, Werner. 1976. Climates of Central and South America. World Survey of Climatology, Vol 12.
- Seifert, R.P. and F.H. Seifert. 1979. A Heliconia Insect Community in a Venezuelan Cloud Forest. Ecology, Vol 60, No.3, pp. 462-467.
- Seifrizz, W. 1943. The Plant Life of Cuba. Ecological Monographs, Vol 13, No. 4, pp. 375-426.
- Shreve, Forrest. 1914. A contribution to the Physiological Plant Geography of Jamaica. A Montane Rain-Forest, Carnegie Institution of Washington. Washington, D.C. pp 87.
- Sobrevilla, C.; N. Ramirez and N.X. de Enrech. 1983. Reproductive Biology of *Palicourea fendleri* and *P. petiolaris* (Rubiaceae), Heterostylous Shrubs of a Tropical Cloud Forest in Venezuela. Biotropica, Vol 15, No 3, pp. 161-169.
- Sugden, A.W. & R.J. Robins. 1979. Aspects of the Ecology of Vascular Epiphytes in Colombian Cloud Forests, I. The Distribution of the Epiphytic Flora. Biotropica, Vol. 11, No. 3, pp. 173-188.
- Sugden, Andrew W. 1982. The Vegetation of the Serrania de Macuira, Guajira, Colombia: A contrast of Arid lowlands and an Isolated Cloud Forest. Journal of the Arnold Arboretum, Vol. 63, No. 1.
- \_\_\_\_\_. 1985. Leaf Anatomy in a Venezuelan Montane Forest. Botanical Journal of the Linnean Society, Vol 90, pp. 231-241.
- \_\_\_\_\_. 1986. The Montane Vegetation and Flora of Margarita Island, Venezuela. Journal of the Arnold Arboretum, Vol. 67, No. 2.
- Weaver, Peter L. 1972. Cloud Moisture Interception in the Luquillo Mountains of Puerto Rico. Carib. J. Sci., Vol 12, No. 3-4, pp. 129-144.
- Zadroga, F. 1981. The Hydrological Importance of a Montane Cloud Forest Area of Costa Rica. Tropical Agricultural Hydrology, Ed. by R. Lal and E.W.. Russell, John Wiley & Sons Ltd. pp. 59-73.