# PATTERN OF RAINFALL DISTRIBUTION IN THE CENTRAL PACIFIC COAST OF MEXICO

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ABSTRACT. The Central Pacific coast of Mexico can be classified into four zones, each showing different rainfall patterns. As a result of tropical cyclone influence in the Pacific coast, the level of rainfall probability differs between zones. Such influence is revealed in the total annual rainfall, in the seasonality and in the monthly rainfall pattern.

## Introduction

Both deterministic and stochastic factors may have a strong influence on ecosystem dynamics (Holling 1986). The first are phenomena that can be predicted (e.g. temperature) and the second are erratic and less predictable events (e.g. rainfall). The relative importance of these factors in ecosystem dynamics depends on their nature as limiting factors. Rainfall seasonality is the most important factor which influences the structure and dynamics of tropical dry ecosystems (Murphy and Lugo 1986). Seasonality represents a dominant ecological force when temporal biological activities, like growth and reproduction, are synchronized with water availability (Murphy and Lugo 1986; Riech and Borchert 1984; Swain *et al.* 1990; Wright and Cornejo, 1990). Other factors can also influence the phenology of tropical species (Murphy and Lugo, 1986), such as temperature (Walter 1971) and photoperiod (Medina 1983; Bullock and Solís-Magallanes, 1990).

The influence of inter-annual variation in water availability is important in the tropical dry ecosystems. When this variation is high, random events determining annual rainfall can significantly influence the structure, composition and dynamics of the ecosystem (Murphy and Lugo 1986). Regions with tropical cyclonic influence have an important random factor influencing their rainfall pattern. For this reason, it is important to know the predictability of rainfall. In this paper we analyze the rainfall patterns of the Central Pacific Coast of Mexico, and their predictability.

## Study area

The Central region of the Pacific coast of Mexico extends from the State of Nayarit to the States of Jalisco and Colima (between 22° 30'N and 18° 30'N, Fig. 1). The dominant vegetation type is tropical deciduous forest (Rzedowski 1978). The most important feature of this ecosystem is the marked rainfall seasonality (Bullock 1986). The rainfall pattern in this region is affected by two main elements: the influence of the trade winds and the influence of the Pacific cyclone. The trade winds have their origin in the anticyclone located in the eastern United State (known also as the Bermuda high pressure cell) with a ridge extending southwestward into Mexico (Mosiño 1964). The trade winds explain, in part, the summer rainfalls of June and July in the area.

Tropical cyclones, however, have a crucial importance in determining the total annual precipitation (Jáuregui 1967, 1987). They occur sometimes in June and July, but mostly in August, September and October (Table 1). Since the factors determining cyclonic incidence are very erratic, the rainfall pattern in the coast becomes largely influenced by a random element (De Ita-Martínez and Barradas 1986).

The probability of cyclonic incidence along the Central Pacific coast is not uniform. Jáuregui (1987) points out that the Pacific coast has three zones with different incidence probability: the higher incidences occur between Topolobampo and Puerto Vallarta (50%), the intermediate ones between Manzanillo and Acapulco (29%), and the lower incidences between Puerto Vallarta and Manzanillo (21%). The influence of the cold California Stream explains these differences. This stream modifies the cyclonic trajectories and this effect becomes more important in September and October at 20°N by the heating of sea water at this latitude (Jáuregui 1987).

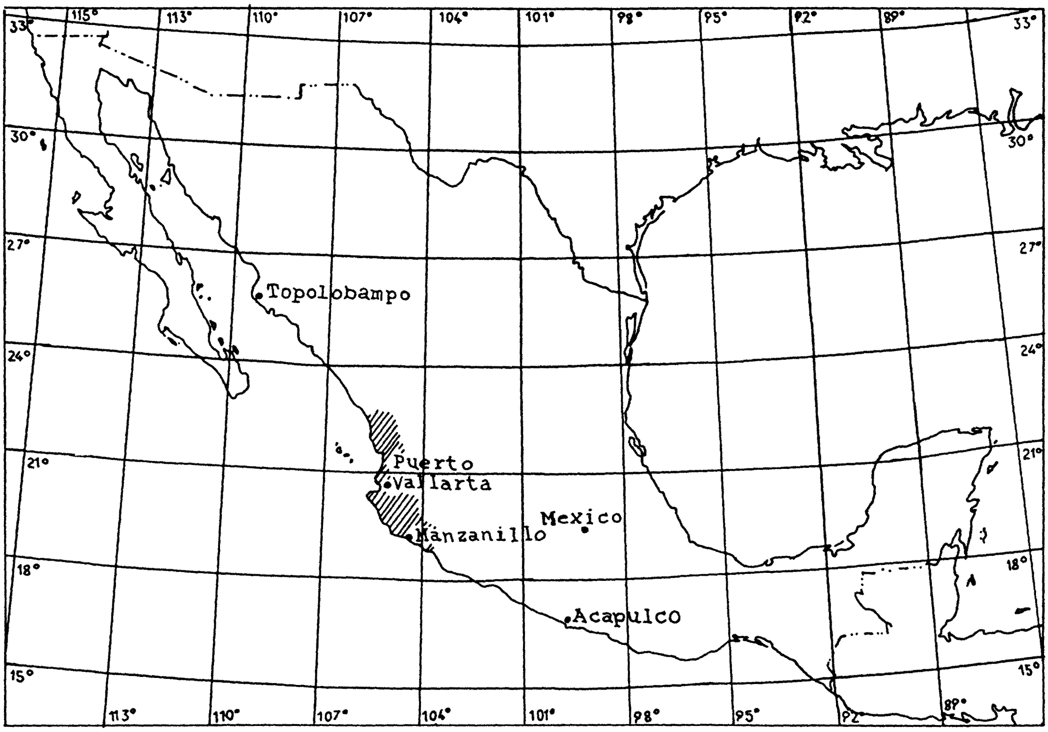


Fig. 1. Localization of the Central Pacific Coast, Mexico.

## Methods

Monthly rainfall data were obtained from 18 meteorologic stations (having records for at least 25 years) distributed along the coasts of the States of Nayarit, Jalisco and Colima. The stations were clustered into four zones: north (five stations), central (three stations), south (seven stations) and inland (three stations, Table 2). For the first three zones the stations were grouped following the cyclonic incidence zones described by Jáuregui (1987). The last zone corresponds to stations located above 1000 m of altitude. Total annual precipitation was related to latitude and altitude using regression analysis. The frequency distribution of the monthly and total series was analyzed using the gamma probability density function (Ezcurra and Rodrigues 1986). The gamma- distribution analyses were run in a Pascal program written for IBM-PC computers and compatibles (Valiente 1988). For both series, the goodness of fit was evaluated by a G-test (Sokal and Rohlf 1981). The rainfall concentration was analyzed using the parameters of the gamma distribution for the total series after Ezcurra and Rodrigues (1986). The parameters used were the amount of rain of a typical rainy month ( r ), the rainfall concentration or the number of rainy months ( p ) and the equitability which is a relative measurement of rainfall concentration ( E ).

For the analysis of rainfall seasonality in each zone, the monthly probability value of 100 mm of rainfall was used. This limit was chosen because

Table 1. Monthly relative frequencies of cyclones occurring in the NW mexican pacific coast between 1953 to 1978 (Jaúregui 1987)

| Months | J | J | A | S | O |
|---|---|---|---|---|---|
| Frequencies | 0.11 | 0.10 | 0.21 | 0.38 | 0.19 |

Table 2. Annual rainfall, amount of rain of a typical rainy month (r), rainfall concentration (p) and equitability (E) for the stations of the Central Pacific coast of Mexico.

| Station | Annual Rainfall | r | p | E | Zone |
|---|---|---|---|---|---|
| Santiago (S) | 1221.1 | 259.66 | 4.68 | 0.39 | North |
| San Blas (SB) | 1509.5 | 322.02 | 4.68 | 0.39 | North |
| Puerto Vallarta(PV) | 1468.0 | 291.15 | 5.04 | 0.42 | North |
| Cajón Peña (CP) | 1433.8 | 284.44 | 5.04 | 0.42 | North |
| El Chiflón (EC) | 1363.5 | 255.52 | 5.40 | 0.45 | North |
| Ixtlán (I) | 858.6 | 171.52 | 5.04 | 0.42 | Inland |
| Mascota (Ms). | 981.0 | 174.51 | 5.76 | 0.48 | Inland |
| El Grullo (EG) | 781.0 | 144.80 | 5.76 | 0.48 | Inland |
| Higera Blanca (HB) | 649.1 | 108.28 | 6.00 | 0.50 | Central |
| La Huerta (LH) | 1025.9 | 186.94 | 5.64 | 0.47 | Central |
| Cihuatlán (Ci) | 827.5 | 158.26 | 5.52 | 0.46 | Central |
| Comala (Co) | 922.8 | 204.04 | 5.04 | 0.42 | South |
| Buena Vista (BV) | 1121.6 | 224.07 | 5.16 | 0.43 | South |
| Coquimatlán (Cq) | 830.6 | 150.30 | 5.52 | 0.46 | South |
| Manzanillo (Mz) | 827.5 | 184.30 | 5.28 | 0.44 | South |
| Armeria (A) | 705.5 | 112.85 | 6.36 | 0.53 | South |
| Tecoman (T) | 705.2 | 122.45 | 6.12 | 0.51 | South |
| Callejón (Ca) | 873.7 | 161.91 | 5.40 | 0.45 | South |

90% of the plant species studied at the Jalisco Coast show leaf flushing after this rainfall threshold (Bullock and Solís-Magallanes 1990). The frequency of months with more than 100 mm rainfall was fitted to a logistic regression model with two factors (months and zone) using Generalized Linear Models through the GLIM (1985) package.

## Results

### *Annual Precipitation*

As a general rule, in the Mexican Pacific coast aridity increases with latitude. However, in this study region there was a significant positive correlation ($P < 0.02$) between annual rainfall and latitude (Fig. 2). In contrast, altitude was not significantly correlated to annual rainfall ($P = 0.71$).

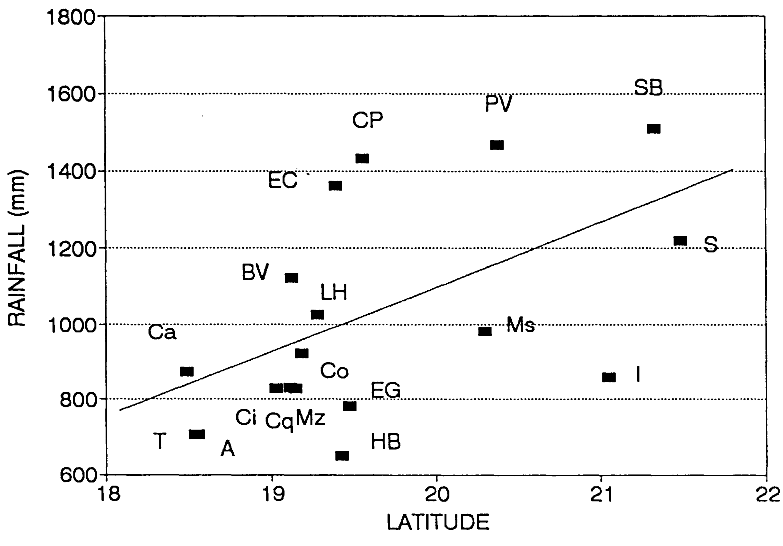


Fig. 2. Regression analysis between annual precipitation and latitude. The letters correspond to the names of stations in Table 2.

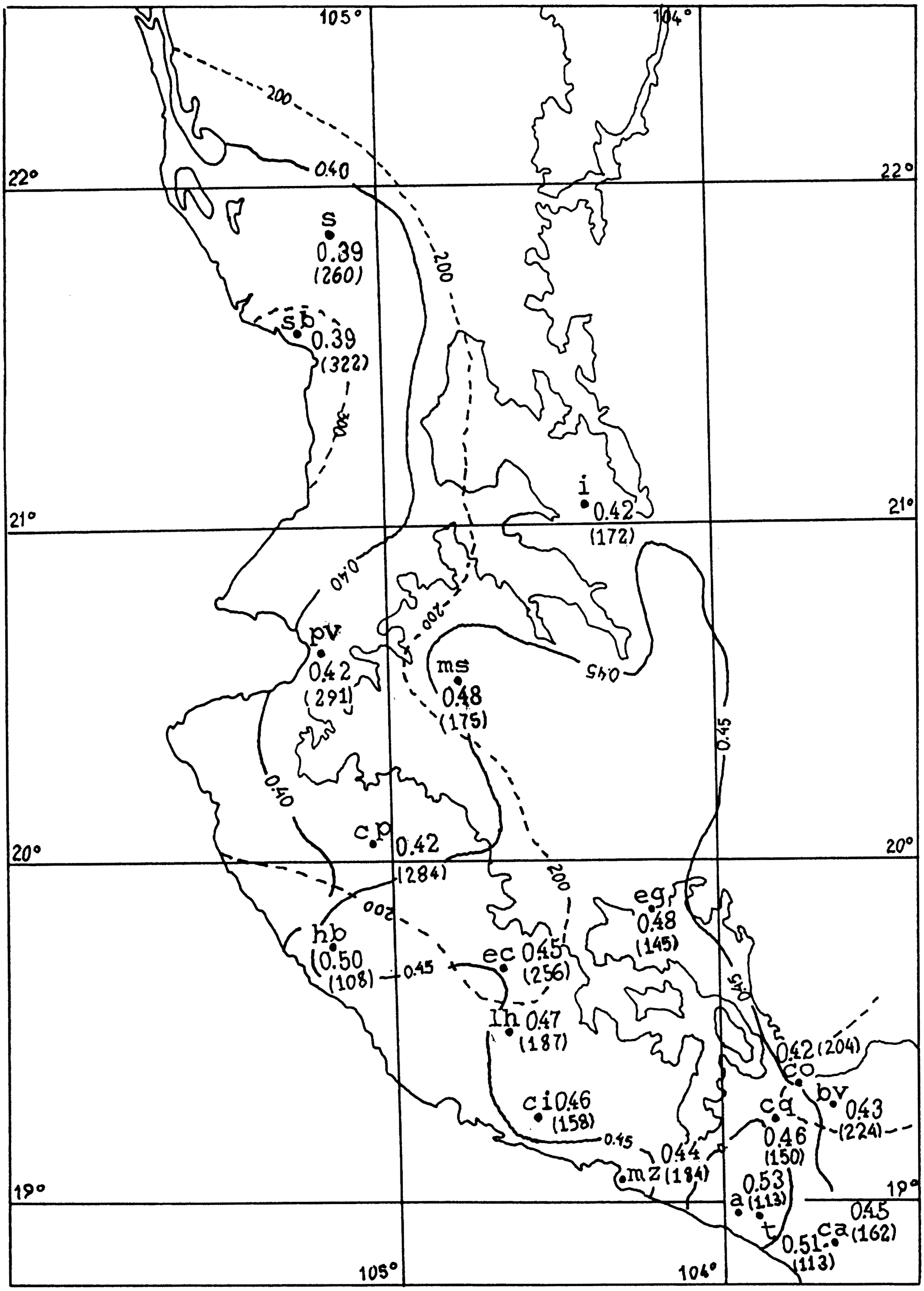
105°
104°
22°
21°
20°
19°
200
0.40
0.45
300
s 0.39 (260)
sb 0.39 (322)
i 0.42 (172)
pv 0.42 (291)
ms 0.48 (175)
c.p 0.42 (284)
hb 0.50 (108)
ec 0.45 (256)
eg 0.48 (145)
lh 0.47 (187)
ci 0.46 (158)
mz 0.44 (184)
co 0.42 (204)
bv 0.43 (224)
cq 0.46 (150)
a 0.53 (113)
t 0.51 (113)
ca 0.45 (162)

Table 3. Significance levels for the parameters of the logistic regression model ($R^2$=0.94).

| Source of variation | Deviance (G-value) | d.f. | P | $R^2$ |
|---|---|---|---|---|
| Model | 4436.4 | 215 | <0.001 | 0.94 |
| Zone | 34.1 | 3 | <0.001 | 0.01 |
| Month | 4163.5 | 11 | <0.001 | 0.88 |
| Interaction | 238.8 | 33 | <0.001 | 0.05 |
| Residual | 294.5 | 168 | | |

Table 4. Monthly significant differences between zones using the estimates of the logistic regression model (N: north, I: inland, C: central and S: south).

| Zones | Estimates | Standard Error | Significance Level |
|---|---|---|---|
| June | | | |
| N vs I | 1.285 | 0.6589 | 0.05 |
| N vs C | -1.549 | 0.6184 | 0.01 |
| I vs C | -2.835 | 0.7002 | 0.01 |
| I vs S | -1.847 | 0.5818 | 0.01 |
| July | | | |
| N vs C | -4.870 | 1.163 | 0.01 |
| N vs S | -4.187 | 1.102 | 0.01 |
| I vs C | -4.795 | 1.197 | 0.01 |
| I vs S | -4.112 | 1.138 | 0.01 |
| August | | | |
| N vs C | -3.379 | 0.9321 | 0.01 |
| N vs S | -3.238 | 0.8478 | 0.01 |
| I vs C | -2.845 | 0.8846 | 0.01 |
| I vs S | -2.704 | 0.7952 | 0.01 |
| September | | | |
| N vs I | -3.388 | 1.188 | 0.01 |
| N vs C | -3.382 | 1.188 | 0.01 |
| N vs S | -3.733 | 1.106 | 0.01 |
| October | | | |
| N vs I | -1.381 | 0.664 | 0.05 |
| N vs S | -1.347 | 0.483 | 0.01 |
| December | | | |
| N vs S | -3.159 | 1.149 | 0.01 |
| C vs S | -3.324 | 1.155 | 0.01 |

### *Seasonality*

Equitability ( E ) values increased from north to south. In the north zone the threshold values for a typically rainy month ( r values) were greater than in the south (Fig. 3). The rainfall probability of 100 mm defined five rainy months (June to October) and seven dry months (November to May; Fig. 4). The frequency of months with more than 100 mm rainfall fitted well to the logistic regression model. The three components of the model were statistically significant, with months as a statistical factor explaining 88% of the deviance (Table 3).

Every zone had a significantly different rainfall pattern. The rainfall probabilities for the central and south zones were lower than for the northern zone. However, at the end of the rainy season (November) and during the dry season, all zones showed similar rainfall probabilities (Fig. 4). Only in the rainy months (June to October) and in December, some zones were statistically different (Table 4). These differences were greater in July, August and September.

Fig. 3. Distribution of the values of equitability ( E ) (—) and the amount of rain of a typical rainy month ( r )(---) at the Central Pacific coast. The letters correspond to the names of stations in Table 2, the associated numbers are the E values; the r values are in parentheses.

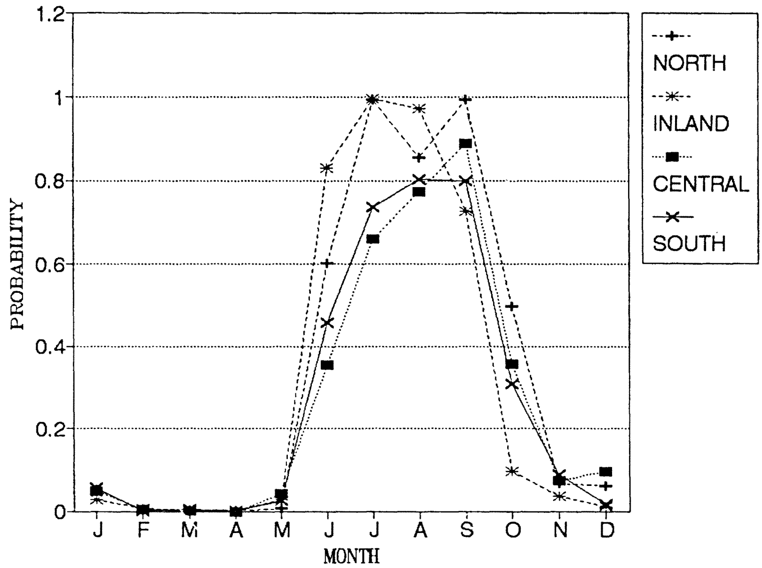


Fig. 4. Monthly 100 mm rainfall probabilities in the four zones of the Central Pacific coast of Mexico.

*Monthly Rainfall Pattern*

The region showed three kinds of monthly rainfall patterns: 1) a bimodal pattern with peaks in July and September, in the northern zone; 2) a skewed pattern where the first rainy months were the important ones (June, July and August), in the inland zone; and 3) a skewed pattern where the last rainy months, particularly September, were the important ones, in the central and southern zones (Fig. 4).

**Discussion**

Tropical cyclones are the most important element in the rainfall patterns of the Central Pacific coast of Mexico. The different probability of cyclonic incidence influences: 1) the spatial distribution of the total annual precipitation (Fig. 2), 2) the rainfall seasonality (Table 4 and Fig. 4) and 3) the monthly rainfall patterns (Fig. 4).

*Annual precipitation*

The stations of the north zone had average annual rainfall values greater than 1000 mm (Table 2). This zone has the major cyclonic influence in the region. For this reason, it seems possible that the relationship between the cold California Stream and the cyclonic trajectory is determinant in the distribution of rainfall patterns at a regional scale.

*Seasonality*

The rainfall pattern of the north zone has a higher degree of predictability than the central and south zones. $\underline{E}$ values were lower in the northern than in the central and southern zones, but in the northern zone precipitation was higher (Table 2). The same conclusion can be drawn from the rainfall concentration ($\underline{p}$) values. The central zone had one rainy month more than the north zone, but the rainfall probability was lower (Table 2 and Fig. 4).

*Monthly Rainfall Pattern*

The cyclones clearly influence the monthly rainfall patterns in the region. Every zone showed a distinct pattern (Fig. 4). The cyclone influence in the central and south zones occurs mainly at the end of the rainy season. For this reason, both zones had greater rainfall probabilities in winter. The incidence of cyclonic influence later in the year decreases the probability of rainfall in June at both zones. On the other hand, the importance of cyclonic rainfall decreases with distance from the coast. In the inland zone other factors such as altitude appeared to be more relevant. The importance of altitude in this zone is related to the incidence of convective winds which dominate in June. That is the reason why in the first rainy month, the inland zone had the greatest rainfall probability in the region (Table 4).

Every zone had a distinctive rainfall pattern. The north zone with a high level of predictability, the inland zone with little cyclonic influence, the south zone with a more random pattern and the central zone with a variable pattern and a high frequency of erratic events (i.e. winter rains; Table 4). These patterns have two main components: the predictability of the first rains and the general predictability of rainfall during the wet season.

The inland zone had a high level of predictability at the beginning of the rainy season (June), but it decreased as the rainy season progressed. The greater difference was between the north zone and the central and south zones. The north zone had the higher levels of predictability during the rainy season, while the other two were more influenced by random events. Under these conditions the plant species have to confront zones with different rainfall probabilities. The species in the north zone face a predictable rainfall pattern, while in the central and south zones they confront a more variable pattern. In these last two zones, rainfall variability may be an important factor limiting or determining the presence of certain species.

For this reason, the response of plant species to cope with the seasonality should be different in each zone. Where rainfall predictability is high, leaf flushing is mainly influenced by photoperiod or temperature. In zones with a random rainfall pattern growth may be triggered by a minimum rainfall threshold at the start of the rainy season. Finally, the rainfall pattern also influences the agroecosystems. There is a strong relationship between maize phenology and the rainfall pattern. The predictability levels of rainfall and the topography are the principal limiting factors of annual crops on the coast of Jalisco (De Ita-Martínez *et al* 1991). For this reason, the rainfall pattern is considered as the main constraining factor in the land use in this region.

## Summary

1. The different probabilities of cyclonic influence affects the rainfall patterns of different zones at the Central Pacific Coast of Mexico. Cyclone influence can be detected in the amount of annual rainfall, in the degree of seasonality and in the monthly rainfall pattern.

2. The probability of cyclonic incidence is higher at the north zone. For this reason, this zone is the moistest of the Central Pacific Coast of Mexico.

3. The predictability of the seasonality is different in each zone. Seasonality in the north zone is very marked. It has higher levels of rainfall predictability during the rainy months and low frequencies of rain events in the dry months. In contrast, the central zone is more influenced by random events.

4. Every zone has a distinct monthly rainfall pattern. The rainy months differ due to varying levels of cyclonic influence. Potentially, an accurate evaluation of the predictability of the rainfall patterns is of great importance in the study of the phenology of tropical species. The influence of seasonality on plant phenology has been acknowledged, but the randomness and predictability of the seasonality has not been contemplated.

5. The rainfall pattern also affects land use; low levels of rainfall predictability determine the development of economic activities with low economic investment (i.e. extensive pasture).

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## References

*Bullock, S.H.*, 1986: Climate of Chamela, Jalisco, and trends in the south Coastal region of Mexico. *Arch. Met. Geoph. Biocl.* 36: 297-316.

*Bullock, S.H. and Solís-Magallanes A.*, 1990: Phenology of canopy trees of a tropical deciduous forest in Mexico. *Biotropica* 22: 22-35.

*De Ita-Martínez, C. and Barradas V.L.*, 1986: El clima y el patrón de distribución agrícola en una Selva Baja Caducifolia en la Costa de Jalisco, México. *Biótica* 11: 257-245.

*De Ita-Martínez, C., Sarukhán J. and Maass J.M.*, 1991: Land use patterns on a tropical deciduous forest ecosystem on the Pacific coast of Jalisco, Mexico. submitted to Agroforestry Systems.

*Ezcurra, E. and Rodrigues V.*, 1986: Rainfall patterns in the Gran Desierto, Sonora, Mexico. *Journal of Arid Environment* 10: 13-28.

*GLIM*, 3.7, 1985. The Royal Statistical Society, London.

*Holling, C.S.*, 1986: The resilience of terrestrial ecosystems: local surprises and global change. In: Clark W. C. and

Munn R.E. (eds.): *Sustainable development of the Biosphere* Cambridge University Press: 291-320.

*Jáuregui, E.*, 1967: Las ondas del Este y los ciclones Tropicales de México. *Ingeniería Hidráulica de México* 21: 197-208.

— 1987: Vulnerabilidad de las costas del NW de México a los ciclones Tropicales del Pacífico Nororiental. Memoria de la meteorología un modelo de cooperación internacional SARH, México: 9-18.

*Medina, E.*, 1983: Adaptations of tropical trees to moisture stress. In: Golley F.B. (ed.): *Tropical rain forest ecosystem: structure and function* New York. Elsevier: 225-237.

*Mosiño, P.A.*, 1964: Tiempo superficial y configuraciones del flujo aéreo superior en México. *Geofísica Internacional* 4: 117-168.

*Murphy, P.G. and Lugo, A.E.*, 1986: The ecology of tropical dry forest. *Ann. Rev. Ecol. Sys.* 17: 67-88.

*Reich, P.B. and Borchert R.*, 1984: Water stress and tree phenology in a tropical dry forest in the lowlands of Costa Rica. *Journal of Ecology* 72: 61-74.

*Rzedowski, J.*, 1978: Vegetación de México. Limusa. 432 p.

*Sokal, R.R. and Rohlf, F.J.*, 1981: *Biometry* Freeman and company.

*Valiente, L.*, 1988: Programa Gamma. Centro de Ecología, UNAM, México.

*Swain, M.D., Lieberman, D. and Hall, J.B.*, 1990: Structure and dynamics of a tropical dry forest in Ghana. *Vegetatio* 88: 31-51.

*Walter, H.*, 1971: *Ecology of tropical and subtropical vegetation* New York, Van Nostrand Reinhold Co. 539 p.

*Wright, S.J. and Cornejo, F.H.*, 1990: Seasonal drought and leaf fall in a tropical forest. *Ecology* 71: 1165-1175.