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# RAINFALL OF NORTHERN MEXICO

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In the course of an investigation of the desert areas of northern Mexico it has been necessary to give attention to the adjacent plant formations, which commonly have some ecological relationships to the desert. In the study of the physical conditions it is almost obligatory that the whole of northern Mexico be taken under consideration. This is particularly true of the precipitation, which is primarily controlled by broadly operative factors, and does not always stand in close correlation with the vegetation.

By "northern Mexico" is here understood the eleven northernmost states of the republic, comprising all of it that lies north of the Tropic of Cancer, and embracing about half the country.

The only important source of rainfall data for Mexico is the publications of the Mexican Meteorological Service, which has been in continuous operation for over 50 years. There are long and excellent records for most of the state capitals and other large cities. In each state there are records of varying length and completeness kept by voluntary observers. There are also numerous short records taken at ranches, mine and lumber camps. In the present work the data for the period 1921 to 1940 have been used. For this period there is a larger number of stations than for any previous period of the same length. It has been deemed more important to use records that are contemporaneous than to take advantage of the few long ones. Many of the recent records are not complete for the 20-year period. None less than 15 years long have been used.

Maps of the distribution of rainfall in Mexico have been published from time to time by the Mexican Meteorological Service and by climatologists and geographers in other countries. These are necessarily very general in character and

are not of great significance to the student of plant or animal life, who is concerned with the intimate variations that accompany an extremely complex topography.

The geographical structure of northern Mexico is simple in its larger features and very intricate in its details. Broad plains rise from the coasts on the east and west. Nearly parallel to each of the coasts stand the eastern and western Sierra Madre ranges. Between these ranges lies the central plateau, which rises gradually from the Rio Grande. While much of the plateau is flat or rolling, it also supports many isolated hills and mountains. The most intricate topography is on the oceanward faces of the two mountain ranges and among the larger mountains of the plateau.

So complex is the interplay of conditions by which the vegetation is controlled that it is difficult to use a knowledge of the communities in one locality as a basis for predicting the character of the communities in another and presumably similar locality. So closely are contrasting communities of plants interwoven that general climatic data are manifestly of only remote relation to the controlling conditions for such communities. In the narrow canyons of Sinaloa, for example, the shaded slopes are covered with highly mesic herbs and ferns and the trees bear epiphytic orchids and *Psilotum*, while the sunny slopes within 100 m. are dominated by *Acacia*, *Agave* and cacti, and the more gentle slopes just above are clothed with evergreen oaks, pines, *Ceanothus* and *Arctostaphylos*.

The mean annual rainfall is not a highly important datum in itself. Five or ten years of additional observations may make a substantial change in the mean of a short record. In arid climates

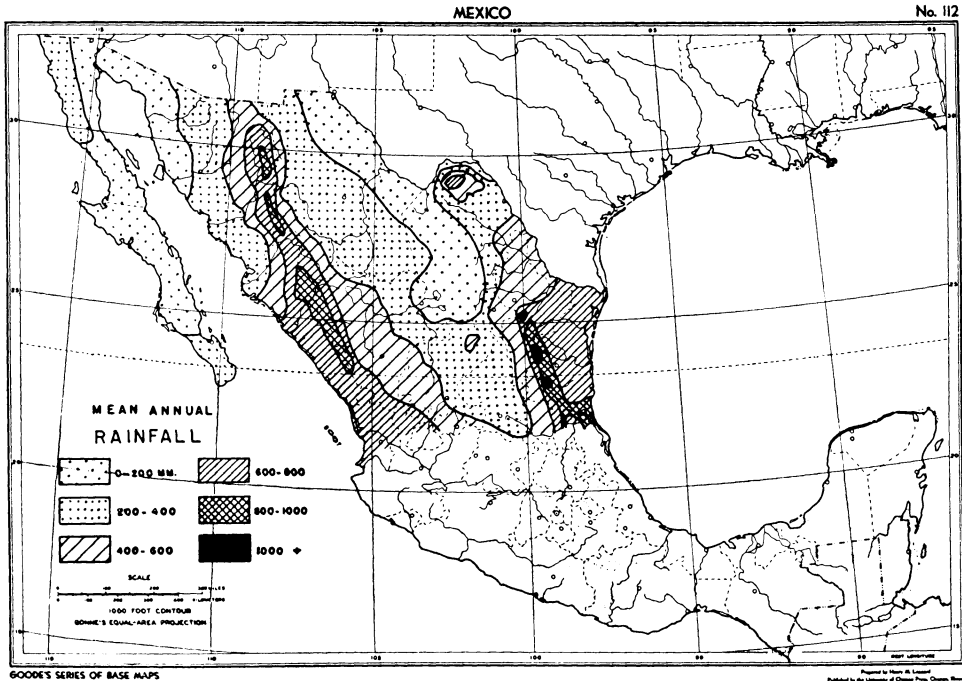


FIG. 1. Mean annual rainfall in northern Mexico.

in particular the actual annual total is almost invariably far below or above the mean, which is chiefly useful as a very general basis for investigation of other aspects of the rainfall.

A provisional map of the distribution of mean annual rainfall (fig. 1) has been based on records from 44 stations, courteously supplied by the Mexican Meteorological Service, and on estimates for the high parts of the Eastern Sierra Madre, based on the work of Muller ('39). The regions with less than 200 mm. of rain are entirely in the Sonoran and Chihuahuan Deserts. The regions with 200 to 400 mm. are partly desert and partly grassland, encinal or chaparral. The regions with 400 to 600 mm. are occupied by grassland, cactus-acacia grassland, encinal, short-tree forest or arid bushland. The regions with 600 to 800 mm. are pine forest, short-tree forest, thorn forest or arid bushland. Higher rainfall is in pine or fir forest or in tropical rain forest.

Throughout northern Mexico, except the extreme northwest, the principal rainfall is in the months May to September. The rain-bearing storms have their origin in the Caribbean area as a result of the heating which accompanies the advent of summer. The gradual march of the rainy season across the Mexican plateau determines the monthly distribution of precipitation. This movement can be followed by comparing the monthly rainfall maps, which show a great uniformity in the march from year to year. May is marked by heavy rain in Chiapas, Tabasco and Vera Cruz as well as in northern Tamaulipas. The rest of the country is relatively dry, with no precipitation on the Pacific coast, except the small area of waning winter rain in northern Baja California. In June heavy rains fall along both of the mountain ranges and light rains visit the entire plateau. The Pacific coast is still dry as far south as Mazatlan and there is no rain in the

lowlands of Sonora and Baja California. In July heavy rains are still more widespread and light rains extend into Sonora and southern Baja California. August conditions are very similar to those of July, except that many localities in the northeast show the midsummer depression which is characteristic of that region, and no rain falls in southern Baja California. September is the month of maximum rainfall for most stations on the Gulf of Mexico and in and near the Eastern Sierra Madre. Rain then begins to wane in the Western Sierra Madre as well as in northern Chihuahua and the lowlands of Sonora. The conditions in October are an almost exact return to those of May.

In arid and semi-arid climates an important aspect of the rainfall is its wide variation from year to year. At some of the driest stations in northern Mexico the rain of the wettest years is 12 to 16 times that of the dryest years (table I). At Mulege, Baja California, the annual total has been as low as 1 mm. (1924, 1925 and 1926), and as high as 329 mm. (1934), with a total of 810 mm. for the three years 1934, 1935 and 1936. Such violent fluctuations are naturally of great importance to the vegetation.

On account of the continental position of northern Mexico the monthly distribution of rainfall shows progressive differences from east to west and smaller ones from north to south. Characteristic phases of the differences in monthly distribution from the Pacific to the Gulf of Mexico are illustrated by the records for Ensenada, Nogales, Chihuahua City, Cuatro Ciénegas and Matamoros, a stretch of 1600 km. (fig. 2). At Ensenada, Baja California, the period of greatest rainfall is in December, January and February, while the precipitation for the five months from May to September is low. This is the type of monthly distribution found thence northward along the Pacific coast. At Nogales, Sonora, the maximum rainfall is in July and August, while there is a minor maximum

TABLE I. *Extremes of annual rainfall*

	Low- est	High- est	Ratio
	mm.	mm.	
East Coast:			
Monterrey.....	242	750	3.1
Saltillo.....	207	478	2.3
Central Plateau:			
Chihuahua.....	266	642	2.4
San Luis Potosi.....	240	475	1.9
Villa Ahumada.....	78	401	5.1
Camargo.....	170	486	2.8
Matehuala.....	189	541	2.8
Nazas.....	126	520	4.1
Charcas.....	146	645	4.4
Cuatro Ciénegas.....	78	197	2.5
Colonia Lardo.....	95	493	5.2
San Juan de Guadalupe.....	72	873	12.1
West Coast:			
Ures.....	272	873	3.2
Altar.....	146	400	2.7
Guaymas.....	144	387	2.6
San Luis.....	28	105	3.4
Quiriego.....	398	1075	2.7
Mazatlan.....	387	1062	2.7
Baja California:			
La Paz.....	33	553	16.7
Santa Rosalia.....	23	287	12.4
Mulege.....	1	329	329.0
Colon, Panama.....	2718	3912	1.4

period in the winter, culminating in January, the dryest months being April, May and June. This is the typical biseasonal monthly distribution found throughout the eastern edge of the Sonoran Desert. At Chihuahua City July, August and September show the annual maximum, while the winter months are dry and have only a very weakly expressed maximum. At Cuatro Ciénegas, Coahuila, the low annual total shows a spread of the summer rainy period from May to October and an isolated maximum in December, which only slightly exceeds the amounts for the summer months. The slight depression for July and August at Cuatro Ciénegas is more pronounced at other plateau stations, resulting for nearly all of them in an early maximum and a late maximum for the summer rainfall period, which is here more prolonged than in Sonora and Chihuahua. At Matamoros, Tamauli-

pas, the early maximum of summer rainfall is in May and June and the second maximum in September and October. A moderate rainfall is sustained through the winter but there is no winter maximum.

A cross section of northern Mexico exhibits great differences in mean annual rainfall as well as in its monthly distribution. Annual totals may, however, be closely matched at widely separated localities. At Ensenada, Nogales and Monclova (east of Cuatro Cienegas on the inner coastal plain) the mean annual rainfall is not greatly different, being 340 mm., 371 mm., 386 mm. respectively, but vegetation and flora are widely unlike at these stations, characterized respectively by winter rain, biseasonal rain and summer rain. The vegetation of the three localities is respectively chaparral, evergreen oak woodland and arid bushland. It is doubtful if a single native plant is common to the floras of Ensenada and Monclova. The differences in the character of the vegetation must be attributed largely to the monthly distribution of rainfall. In spite of the weight of historical factors the difference in flora must be ascribed in part to the same condition.

The changes in monthly distribution of rainfall encountered on going south along the west coast are much less, and reside chiefly in the transition from the biseasonal type exhibited at Nogales to a nearly uniseasonal type. The change is well exemplified in the records for Nogales, Santa Ana, Guaymas, Culiacan and Mazatlan, a stretch of 1000 km. (fig. 3). At Nogales there is a single winter maximum in January while at Santa Ana there happen, in the present phase of the record, to be maxima in December and February. At Guaymas the summer rainy period is in July, August and September, as in the preceding stations. The winter maximum in December is followed by six months of very low precipitation. At Culiacan, Sinaloa, the monthly distribution is much like that at Guaymas, with the summer maximum in August, a winter maximum in December and an almost equally dry period from January to May. At Mazatlan the principal change from this pattern is in the great increase in the rainfall of July, August and September. The percentage of the annual precipitation which falls in July, August and September at these five stations shows a gradual increase from north to south,

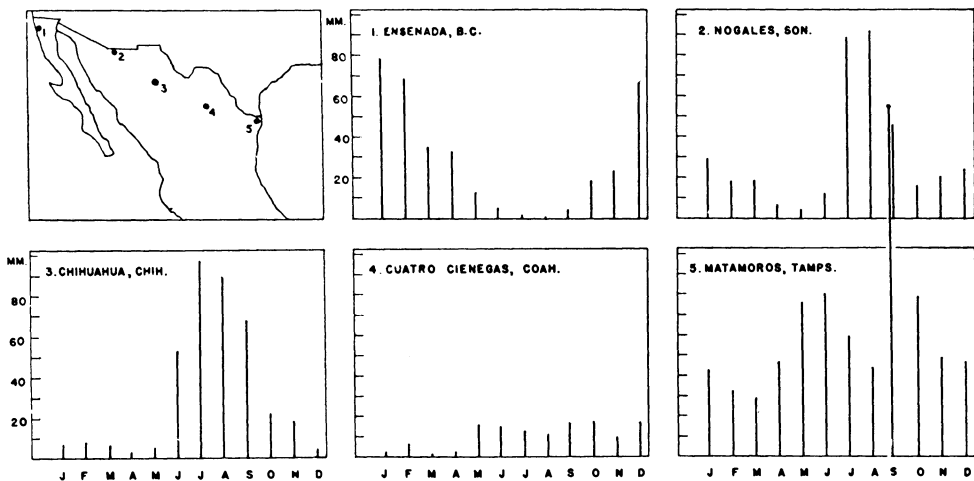


FIG. 2. Monthly distribution of rainfall in northern Mexico.

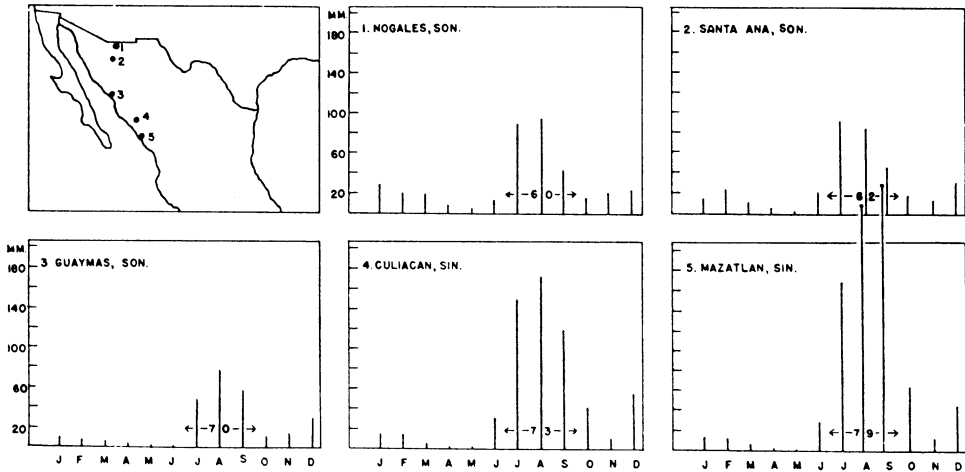


FIG. 3. Monthly distribution of rainfall in northwestern Mexico.

being respectively 60, 62, 70, 73 and 79 per cent. The corresponding decrease in the winter and early spring rain results in a very dry period during the first six months of the year south of northern Sonora.

A significant change in the rainfall between Nogales and Mazatlan is the great increase in the annual mean from 250 mm. at Guaymas to 603 mm. at Culiacan and 852 mm. at Mazatlan. It is noteworthy, however, that the principal part of the increase is in the three summer months and that the first half of the year is nearly as dry at Culiacan and Mazatlan as it is at Guaymas. The dry winter and spring and the very wet summer constitute the thorn-forest climate, which prevails in Sinaloa and far to the south.

An important aspect of precipitation in arid and semi-arid regions is the duration and frequency of rainless periods. In the lack of records of daily rainfall it has been necessary to express this datum in terms of months. Eighteen 20-year records and five 15-year records have been used to illustrate the distribution of this feature (table II). Monterrey, Saltillo, Chihuahua City and San Luis Potosi all lie just outside the desert and appear to be rarely visited by more than

a single month of drought. Other stations in the Chihuahuan Desert have registered from 3 to 7 consecutive months without rain. On the west coast, in

TABLE II. *Rainless periods*

	Longest number of consecutive rainless months	Number of periods of three months or more
East Coast:		
Monterrey.....	1	1
Saltillo.....	0	0
Central Plateau:		
Chihuahua.....	0	0
San Luis Potosi.....	1	1
Villa Ahumada.....	3	2
Camargo.....	4	2
Matehuala.....	5	2
Nazas.....	5	4
Charcas.....	5	4
Cuatro Cienegas.....	6	2
Fresnillo.....	6	3
Colonia Lerdo.....	6	4
San Juan de Guadalupe...	7	4
West Coast:		
Ures.....	4	3
Altar.....	4	9
Carbo.....	5	10
Guaymas.....	5	13
San Luis.....	7	9
Quiriego.....	7	9
Mazatlan.....	8	7
Baja California:		
La Paz.....	7	16
Santa Rosalia.....	9	11
Mulege.....	11	18

the Sonoran Desert, dry periods of 4 to 8 months have visited all of the stations. The longest period, 8 months, was recorded at Mazatlan in the thorn-forest. In Baja California the available records indicate rainless periods of 7 to 11 months.

A datum closely related to the above is the number of times, in a 20-year record, that rainless periods of three months have recurred. The comparative aridity of the Chihuahuan and Sonoran Deserts is well expressed in the range of 2 to 4 periods in the former and 3 to 13 in the latter. In Baja California rainless periods of 3 months are the rule rather than the exception.

In all arid regions exceptionally heavy rains occur at long intervals. Unusually rainy periods of several weeks are even less frequent. At Santa Rosalia, Baja California, the mean rainfall for September is 47 mm. In September 1939 a single storm of about two hours yielded 189 mm., which exceeded the annual mean of 123 mm. At San Juan de Guadalupe, Durango, the mean for July is 71 mm. In 1934 the total for July was 294 mm., which is not, however, in excess of the annual mean of 377 mm. At Linares, Nuevo Leon, the mean for August is 61 mm. In August 1938 a severe three-day storm raised the monthly total to 895 mm., well above the annual mean of 758 mm. Storms which register heavy rains so far in excess of the normal are more common at low elevations on or near the coasts than they are on the central plateau. The runoff from exceptional rains builds up the water content of the beds of the streamways and also of the *ciene-gas*, *playas*, *llanos* and other enclosed or nearly undrained areas. Exceptional rains stimulate germination and their effect often persists long enough to assure the establishment of young plants that would perish if they had appeared after a rain too light to wet the soil thoroughly. For the major part of the plant population the excessive rains are of little im-

portance in comparison with the drought periods.

The altitudinal ranges of the types of vegetation found in northern Mexico are closely associated with the local amounts and seasonal distribution of rainfall. There is no universal relation between altitude and rainfall, and consequently none between altitude and vegetation. The relations which hold true in a given area—perhaps a very small area—are widely different in other places.

The gradients of altitudinal change in rainfall are controlled by the distance from the sea, by prevailing winds, by the steepness of slope of the land masses or mountains that are involved, and by the summit altitude of such mountains. The influences exerted on vegetation by the resulting rainfall are further complicated by temperature conditions, slope exposure, underlying rock and soil and other conditions.

Knowledge of the topography of Mexico and of the distribution of its rainfall is sufficient to illustrate amply the influence of the one on the other. Very few data are available, however, for elucidating the exact relation of altitude to rainfall, or of rainfall to vegetation, in any of the higher mountains of northern Mexico. Muller ('39) has described the vegetation of Cerro Potosi (elev. 3800 m.), one of the highest elevations in the Eastern Sierra Madre, and has given a vivid picture of the moist conditions that prevail on its upper slopes in summer. His estimate of the annual precipitation at the summit is 2250 mm., which is about three times that of stations on the inner coastal plain near the eastern base of the Sierra Madre.

Along the western base of the Eastern Sierra Madre the plateau receives approximately half as much rainfall as the lowland area east of the mountains, although it is about 1000 m. higher. Near the mountains there is no such "rain shadow" effect as is found in northern Baja California, but at a distance of 80 to 100 km. west of the Sierra Madre the

precipitation falls to amounts of 250 to 350 mm.

Little is known about the behavior of the rainfall in the Western Sierra Madre. The summer storms approach from the east, and heavy rains begin in the mountains at least a month before they reach the lowlands of the Pacific and Gulf coastal plain. Immediately east of the Western Sierra Madre on the grassland benches of Chihuahua and Durango, at elevations of 1500 to 2000 m., the rainfall ranges from 450 mm. to 550 mm. The only stations at comparable altitudes on the western slopes have means of 760 to 983 mm. (Choix and Badiriguato, Sinaloa). It is doubtful if there are any localities in the Western Sierra Madre at which the rain exceeds 1500 mm.

The highest and most sustained lowland rainfall of northern Mexico is in the southeast, on the coast and in the foothills of southern Tamaulipas. The conditions are exemplified in the record for

Tampico, which has an annual mean of 1267 mm. Heavy rains occur throughout the period from June to October, with the maximum in September. March and April are dry, with 12 mm. and 10 mm. respectively, but there is adequate rain in all the other months.

There is therefore a strong contrast between the east and west coasts at the same latitude, as illustrated by the records of Mazatlan and Tampico. Tampico has 50 per cent more rain than Mazatlan, five very rainy months instead of three, and two dry months instead of six. These appear to be the principal conditions determining the presence of arid thorn-forest at Mazatlan, and the northernmost beginnings of rain forest at Tampico.

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