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CHIHUAHUAN CLIMATE

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ABSTRACT

As a result of increased pressure being exerted upon arid, and particularly semiarid zones to improve the use of renewable resources, a data base in excess of five megabytes representing monthly climate values has been verified and recorded on computer tape. The climate averages and generalizations used in this study are based upon information from approximately 140 weather stations in the desert. These data are being used to identify and characterize the features of weather and climate in the Chihuahuan Desert. Because climatic values and topographic features are generally homogenous, regional climatological analysis provides significant aid in identifying introduced plants with economic potential. One of the more dramatic findings of this study was the importance of tropical revolving storms, some of which reach hurricane intensity, as a source of precipitable water. Based upon a limited sample, it was found that approximately 55% of the annual precipitation falling in El Paso, Texas, was the result of tropical revolving storms. A scenario using the de Martonne aridity indices with the mean and minimum and maximum extreme precipitation for stations in the State of Chihuahua clearly illustrates the potential for desertification and other problems with the use of natural resources.

RESUMEN

Como resultado de presiones crecientes sobre zonas áridas, y especialmente en zonas semiáridas para mejorar el uso de recursos renovables, se he verificado y grabado en cinta de computadora una base de datos en exceso de cinco megabytes que representan valores climáticos mensuales. Los promedios y generalizaciones climáticas empleados en este estudio se basan en informes de aproximadamente 140 estaciones meteorológicas ubicadas en el desierto. Se usan estos datos para identificar y clasificar los aspectos del tiempo y clima en el Desierto de Chihuahua. Ya que los valores climáticos y los aspectos topográficos por lo general son homogéneos, un análisis climatológico regional es necessario para identificar plantas introducidas que muestran potencial económico. Uno de los descubrimientos más dramáticos de este estudio revela la importancia que tienen las tormentas circulares tropicales, algunas con fuerza de huracán, como fuente de agua precipitable. Basado en una muestra limitada, se observó que aproximadamente el 55 por ciento de la precipitación anual obtenida en El Paso, Texas, es el resultado de estas tormentas circulares tropicales. Un escenario que emplea los índices de aridez de Martonne con promedio, mínimo y máximo de precipitación en el Estado de Chihuahua indica claramente el potencial para la desertificación y otros problemas asociados con el uso de recursos naturales.

The most recent comprehensive and detailed delineation of the world's deserts is the UNESCO/Man and the Biosphere (MAP) map entitled "World Distribution of Arid Regions" published in 1979 at a scale of

1:24,000,000. In order to emphasize the "slow transformation of biological situations and the great variability of climatic phenomena" (UNESCO 1979 p. 12) in the arid regions, 44 different cartographic categories were used to show the gradations within the world deserts. Detailed planimeter measurements taken from this map indicate that 30% of the earth's land surface is hyperarid (5.6%), arid (12.8%), and semiarid (11.9%). Another 10% is categorized subhumid, and subject to desertification. Only 4% of the world's hyperarid and arid zones are located in North America. The Chihuahuan Desert embedded in the center of North America's subtropical latitudes, accounts for more than a third (35.7%) of the continent's total. This desert spans more than 11° of latitude, and covers 357,000 km^2 or 15% of North America (Fig. 1). Nearly three-fourths of this arid zone is in Mexico, where it accounts for 13% of the national territory and represents the largest desert in Mexico. Approximately a third of the desert is in the State of Chihuahua from which this arid zone derives its name. Aridity and the associated problems of land use are a particularly acute problem in Mexico where 53% of the national territory is considered arid (22%) and semiarid (31%) and an additional 40% of the land area experiences long seasonal drought (planimeter measurements).

REGIONAL GEOMORPHOLOGY

The Chihuahuan Desert is situated between two significant elongated orographic barriers which parallel the coastlines. These mountains are the Sierra Madre Occidental on the west, and the Sierra Madre Oriental on the east. The high intermountain plateau occupying the area between the sierras serves as an elevated heat source that triggers instability and lifts the moist air up the slopes of the mountain ranges lying to the east and west of the Chihuahuan Desert (Mosiño 1964, Mosiño and García 1974). Thus, the air currents release most of their moisture by forced lifting on the seaward slopes of the mountains. To the north, the sierras become more fragmented, but the desert is farther from the sources of moisture. The more poleward continental location, and lack of continuous barriers results in more intense and frequent exposure to cold, dry, arctic air. The cross ranges in southern Coahuila and northern Zacatecas with approximately a dozen peaks higher than 3000 m, dam or deflect lower air currents, and significantly modify, through the adiabatic process, intruding air masses from the south.

Basin and range topography characterizes the Chihuahuan Desert. This province is an area of northwest-trending mountain ranges and coalescing basins. Because there are very few through-flowing rivers, there are few areas of erosional lowlands. As a result, nearly the entire desert has a basin level of 900–1200 m. Generally, the Chihuahuan Desert slopes from

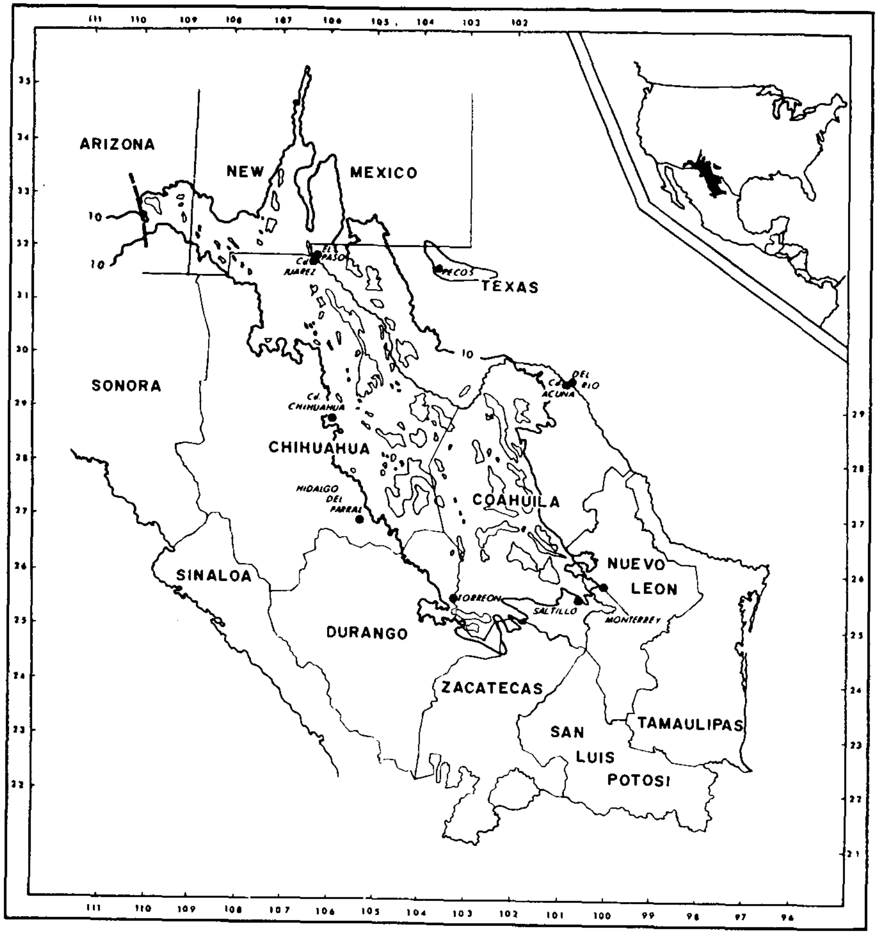

FIG. 1. The Chihuahuan Desert delineation by Schmidt (de Martonne 1926). Mountain masses which are too high and hence too cool and moist to be classified desert are also indicated.

the central and western portions to the lower eastern margins. Most mountain peaks rise 600–1200 m above the Quaternary alluvium-filled bolsons. Ranges composed of Cretaceous limestone rocks dominate the eastern and central desert. Tertiary volcanic rocks typify the mountains found to the west and north.

Mountainous landscape features are important because they foster orographic lifting, dictate drainage patterns, and create biotic "island habitats." Based upon planimeter measurements taken from maps with a scale

of 1:500,000 and 1:250,000 used in conjunction with Landsat imagery, Pérez (1979) and Robinson (1981) delineated and categorized landforms in the Chihuahuan Desert as identified by Clements et al. (1957). Working independently, Pérez classified 11.6% of the arid zone as "Desert Mountain," whereas Robinson arrived at a value of 23.5%. Although inherent problems in terrain classification involving complexity, scale, and association make it virtually impossible to make precise distinctions among the land surface form categories (Mabbutt 1968), planimeter measurements were made of those areas having an altitude above 1800 m. Based upon personal observations, coupled with the relatively homogenous bolson of 900–1200 m, any landform protruding above 1800 m could be classified as a "Desert Mountain" with a very high degree of confidence. Also, the 1800 m level is the upper limit of the Chihuahuan Desert based upon climatic analysis (Fig. 1, Schmidt 1979). Nearly 12% of the surface area in the Chihuahuan Desert is above 1800 m in altitude. Therefore the average of 18% seems to be a reasonable value to accept for those areas designated as "Desert Mountains." A comparison of land surface forms for four arid zones by Clements et al. (1957) indicates that mountains occupy 38–47% of the surface area.

Physiographic testimony to the aridity of the Chihuahuan Desert is the fact that nearly two-thirds of this region is associated with interior-drainage basins (planimeter measurements by author). The bolsons de Mapimi and de los Muertos account for approximately 85% of the surface area having closed basins. The watershed of the Río Grande (Río Bravo del Norte) and the Río Conchos are the only significant drainage systems in the Chihuahuan Desert. Historically, the Río Conchos supplied approximately 18% of all the water that entered the Río Grande (Tamayo and West 1964).

SOURCE MATERIALS AND METHODS

It is true that in the past a lack of basic information has hampered the analysis of weather and climate in the Chihuahuan Desert. But this statement is no longer entirely valid. Instrumental observations of precipitation and temperature data are available for a large number of weather stations spread throughout this arid region. A large part of the former, data-shortage problem stemmed from the difficulty of obtaining climatic data for the Mexican portion of the desert. Although this problem is not completely solved, there are several monumental sources of data that should be consulted when pursuing topics requiring climatological information for the Mexican portion of the Chihuahuan Desert. Major published sources of data for Mexico are: the Servicio Meteorológico Nacional (SMN 1976) Normales Climatologicas: Período 1941–1970; the Instituto de Geografía work which includes García's 1970 Carta de Climas, Climas: Precipitacion y Probabilidad de la Lluvia en la Republica Mexicana y su Evaluacion (dates vary 1975, 1977); Mosiño and García (1974) The Climate of Mexico; García and Mosiño (1981), Cantidad de Lluvia Más Frecuente (Moda) en la Republica Mexicana; and the Direccion General de Geografía del Territorio Nacional (1981), Atlas Nacional del Medio Físico. For additional information pertaining to the climatology of Mexico's arid zones see Schmidt (1981).

Climatic data for Texas, New Mexico, and Arizona were obtained from state and annual climatological summaries of the National Weather Service, NOAA. Four sources of information and data which are very useful are: The Climate of New Mexico (Tuan et al. 1973); The Climate of Texas and the Adjacent Gulf Waters (Orton 1964); the Monthly Data System of the Texas Water Oriented Data Bank (Texas N.R.I.S. 1983); and New Mexico Climatological Data: Monthly and Annual Means 1850–1975 (Gabin and Lesperance 1977).

An excellent source of climatic data has been made possible through the efforts of Alvarez G., Chief of Meteorology and Geography for the State of Chihuahua. Since 1957, his office has collected, compiled, and published climatic data taken from a large number of public and cooperative weather stations throughout the state (Alvarez 1958 and various years thereafter).

In 1981, climatic data compilation for the State of Chihuahua under the direction of the author was funded by a grant from the Consejo Nacional de Ciencia y Tecnología (CONACYT) with F. Rincon V. as executive director. A five megabyte data base representing monthly values for 204 stations was verified and recorded on computer disk. Additional data and methodology of analysis for the northern arid region (RAN) resulted through the author's involvement with the Systems Analysis in Arid Zones (ASZA) project working jointly with the Research Center in Applied Chemistry (CIQA) in Saltillo, Coahuila. Funding was provided by the InterAmerican Development Bank and CONACYT under the overall direction of E. Campos L. The climatic averages and generalizations used in this study are based upon information from approximately 140 weather stations in the Chihuahuan Desert.

Because a substantial number of weather reporting stations had missing monthly data scattered throughout the record, the mean annual averages for temperature and precipitation for the State of Chihuahua were generated from individual monthly averages for each station. This method provided averages based upon considerably more data than if the mean annual average was derived using only those years which had all 12 monthly values.

The following sections of this paper pertaining to temperature and precipitation are based in part upon work previously published by Schmidt (1975, 1979, and 1983).

RESULTS

Temperature conditions.—Temperature conditions found in the Chihuahuan Desert are rather mild and constant, varying little from year to year. The average annual temperature for the entire desert is 18.6°C, with station averages ranging from 14°–23°C (Fig. 2). Nearly half of the mean annual temperatures are within 2°C of the average. Only a few stations have recorded extreme temperatures higher than 50°C, or lower than −15°C. Although temperatures are fairly similar throughout this arid zone, the highest annual and monthly temperatures and the longest frost-free seasons occur in the lower altitudinal and latitudinal locations. Almost 90% of the Chihuahuan Desert lies at an altitude between 1100 m and 1500 m. The average of the climatic stations is 1235 m. At comparable altitudinal locations, the average annual temperatures in the northern portion of the Chihuahuan Desert are about 3°–4°C cooler than those in the south.

As is typical of arid continental regions, large diurnal and annual tem-

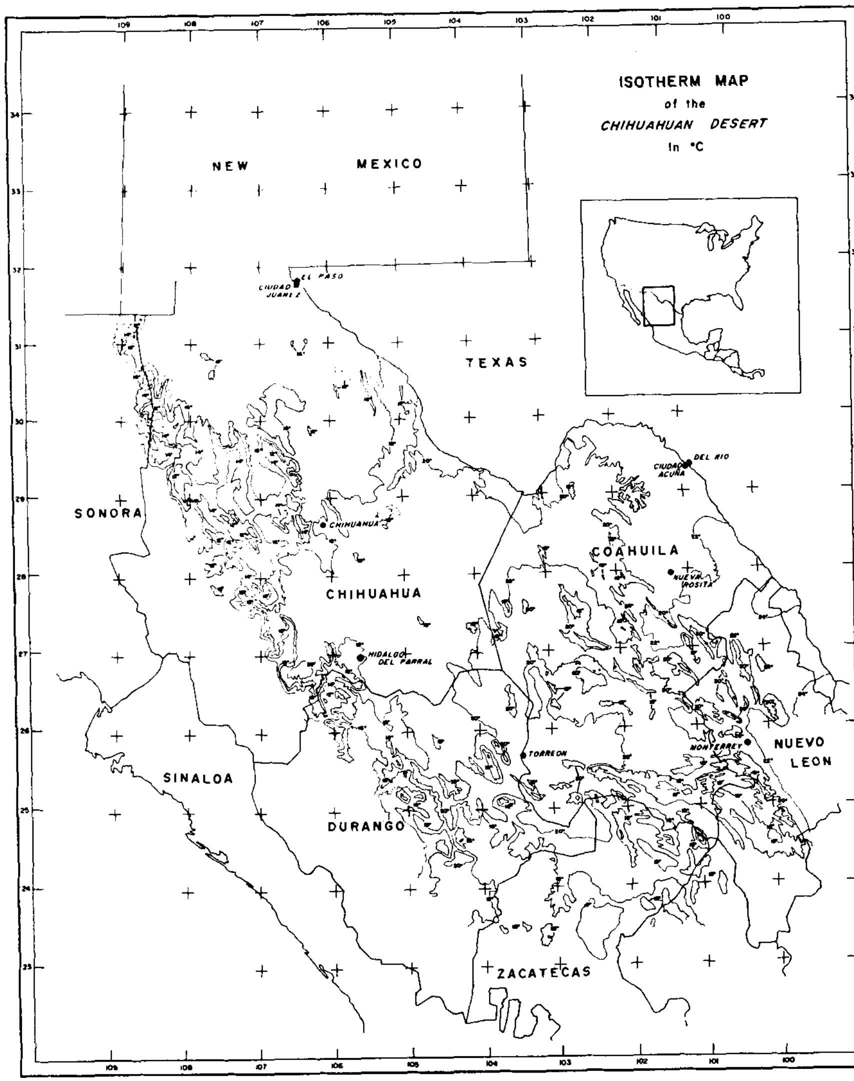

FIG. 2. Isotherms for the northern arid region of Mexico (García 1970).

perature ranges are common. Although the average hottest monthly temperatures (25°–30°C) are very similar throughout the Chihuahuan Desert, it is largely the colder winter months (January <10°C) in the north that account for the cooler average annual temperatures. The passage of the more well-developed portion of cold fronts in the northern Chihuahuan Desert especially poleward of 29°N, although seldom severe, does create more variable and cooler weather in the winter. The increased influence of frontal activity in the north is exemplified by the larger mean annual temperature range of approximately 22°C compared to a range of about 14°C in the south. January temperatures vary from 10°–15°C in the central and southern portions of the desert. During the winter in north-central and eastern Mexico, 80–95% of all negative temperature changes were the result of synoptic cold fronts (Hill 1969). The average temperature drop caused by cold fronts was 6°C.

There is a strong relation between the occurrence of the temperature maximum shift and the onset of the summer rainy season (Mosiño and García 1974). The highest monthly temperatures in central Mexico occur in May. By June, the heat wave moves over the southern two-thirds of the Chihuahuan Desert, and in July the northern and far-eastern portions of this arid zone achieve their maximum temperatures. It should be noted that seldom is the temperature difference between June and July more than 1°C.

Diurnal temperature ranges are usually large, varying from 15°–20°C. Although based upon a limited data set, the largest diurnal temperature ranges generally occur in the spring, and the smallest ranges are recorded in late summer. In the southern portion of this arid zone, the month with the maximum range is March. In the northern portion of the Chihuahuan Desert, May has the largest diurnal temperature ranges. The minimum range of temperatures occur during September in the south, and during August in the north. As might be expected, the minimum range is closely associated with the month which receives the greatest precipitation.

In order to increase the utility, and to validate the raw data, dispersion graphs were constructed comparing altitude and mean annual temperatures for arid and semiarid stations in the State of Chihuahua (Figs. 3, 4). Similarly, plots were made showing the relation of altitude and frost-free days (Figs. 5, 6). The curve-fit lines on all of the graphs are similar; the major difference being that stations in the arid zone are in general located at lower altitudes than those of the semiarid regions.

Precipitation conditions.—The scant quantities of precipitation received in the Chihuahuan Desert stem from a combination of orographic barriers, domination by subtropical high pressure cells, and continentality. Nearly the entire arid zone is 400–700 km from the nearest sources of precipitable water—the Gulf of Mexico and the eastern tropical Pacific Ocean. Aridity is more the result of orographic barriers than continentality (Fig. 7). One of the driest regions within the Chihuahuan Desert is the Laguna Mayran area near Torreon, Coahuila, but it is also an area which is closest to the oceanic moisture sources.

The mean annual precipitation for the Chihuahuan Desert is 235 mm

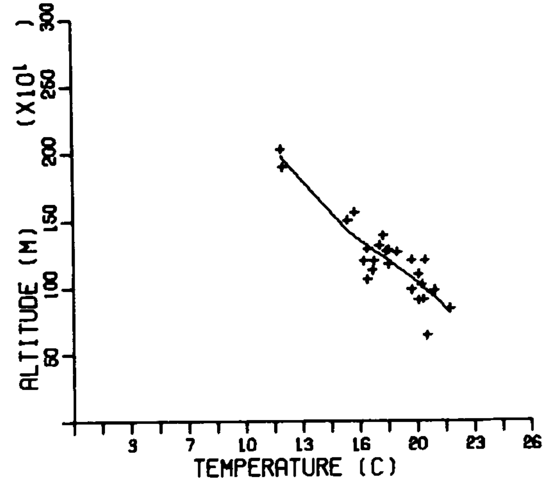

FIG. 3. The relationship of temperature to altitude at arid zone (Ia ≤ 10) stations in the State of Chihuahua.

with a range of approximately 150–400 mm. Nearly two-thirds of the stations have annual totals between 225 and 275 mm (Fig. 8). No portion of this arid zone has experienced a year without recording precipitation, although only 5.5 mm were recorded at Maclovio Herrera, Chihuahua, in 1965. The Chihuahuan Desert is not nearly as dry as many other arid zones in North America. For example, the mean annual precipitation of the entire Baja Peninsula is 153 mm, which compares with the lowest annual rainfall totals for the interior desert (Hastings and Turner 1965). The Baja Peninsula also has the lowest average rainfall totals in North America with 32 mm at Puerto Cortés, Baja California Sur, 33 mm at Bataques, B.C. Norte, 36 mm at Bahia Magdalena, B.C.S., and 37 mm at Delta, B.C.N. (Servicio Meteorológico Nacional 1976).

In the Chihuahuan Desert most of the precipitation falls during the summer in the form of rain from the thundershowers. Hail-producing thunderstorms also occur, but they seem to be less frequent and of lower intensity than those found on the Great Plains. The northern portion of this arid zone usually receives some snowfall during the cooler half of the year. An average of about two snowstorms can be expected each year, although seldom does snow remain on the ground for more than a day or two.

Nearly all locations in the Chihuahuan Desert receive more than 70% of their annual precipitation during the warmest half of the year (May through October), with maximum rainfall occurring in July and August

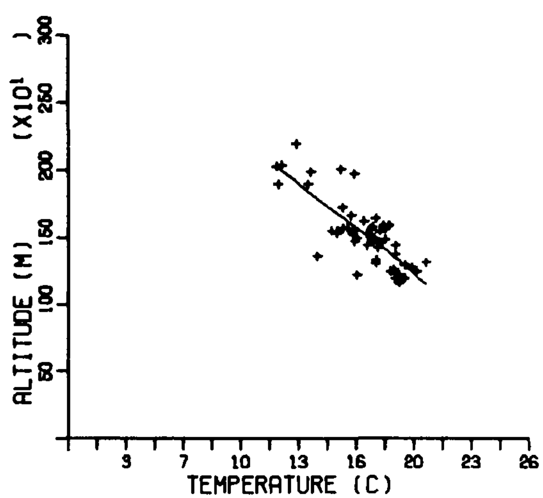

FIG. 4. The relationship of temperature to altitude at semiarid zone (Ia ≤ 10–20) stations in the State of Chihuahua.

(Figs. 9, 10). No station has a winter maximum precipitation, but several months without appreciable moisture are not uncommon. The mean minimum of precipitation occurs during the spring, especially in the months of February and March (Sands 1959). Because most of the Chihuahuan Desert is in the lee of the Sierra Madre Occidental and other mountain ranges to the west and north, and is located more equatorward on the continent, this arid zone does not have a winter rainy season like that of northern Sonora and the Arizona Uplands. The seasonality of precipitation is the major distinction between the warm deserts of North America (Schmidt 1983).

A detailed isohyetal map of mean annual precipitation in the Mexican northern arid region, based upon García's (1970) monumental work is shown in Fig. 8. A more valuable method of mapping areas having considerable variation in rainfall, although based upon data from a much smaller number of stations, is García and Mosiño's (1981) map series for Mexico showing the mode (Fig. 11), coefficients of variation, and gamma and beta distributions.

Although orographic barriers are effective features in preventing moisture from being swept into the interior of the continent, there is not a strong correlation between altitude and precipitation within the desert (Figs. 12, 13). Apparently the 1000 m altitudinal difference of the arid stations (Fig. 12) does not provide significant lifting to create orographic precipitation. There is a much stronger correlation between orographic

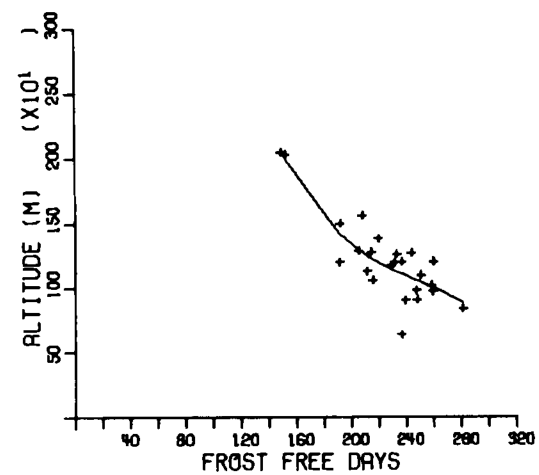

FIG. 5. The relationship of frost-free days to altitude at arid zone (Ia ≤ 10) stations in the State of Chihuahua.

lifting and precipitation with the higher altitude, semiarid locations (Fig. 13).

Atmospheric circulation.—Monthly geostrophic wind charts for the 500 and 300 mb pressure surfaces indicate that a zonal westerly flow of wind persists over the Chihuahuan Desert for more than two-thirds of the year (Lahey et al. 1958, 1960). In June prevailing easterly winds extend to about 25° with a westerly flow prevailing poleward of 28°N. Between the latitudes 25°N and 28°N winds exhibit no distinct pattern. In the months of July and August, an easterly flow predominates over all of the desert except the far northern region in New Mexico. In September, the easterly flow is confined to the area south of the 27°N parallel, and completely disappears from the desert by October.

It is during the summer months that circulation around a warm upper level high-pressure cell shifts westward. Clockwise circulation around the Bermuda high-pressure cell brings moist air from the Gulf of Mexico into the Chihuahuan Desert. The influx of moist tropical air is accompanied by higher relative humidity, increased cloud cover, and thunderstorms. The much smaller quantities of precipitation received during the winter are the result of mid-latitude cyclones transporting moist Pacific air into the region.

Years recording precipitation totals considerably higher than normal are occasionally the result of greater rainfall in the normally drier autumn, late winter, and early spring months. Precipitation occurring during these periods often results from a special tropospheric circulation associated

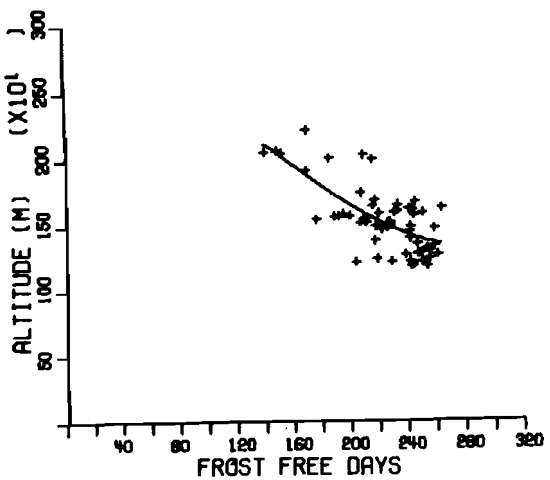

FIG. 6. The relationship of frost-free days to altitude at semiarid zone (Ia 10–20) stations in the State of Chihuahua.

with a Southwest Cutoff Low-pressure system (Jetton 1966). These lows, which have been separated from the main band of the westerly winds, form over the southwestern United States, adjoining Mexico, and the adjacent Pacific Ocean. Generally cutoff lows remain in this area for

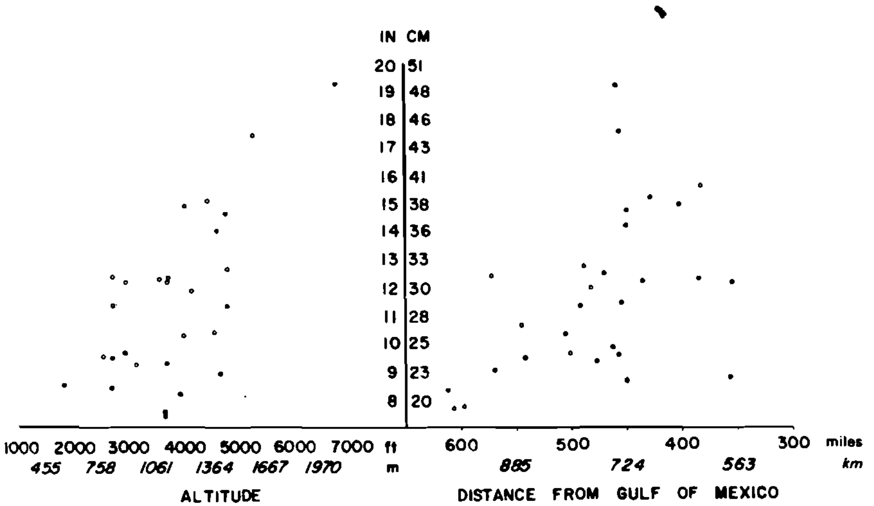

FIG. 7. The relation of precipitation to distance from the Gulf of Mexico for stations in Trans-Pecos, Texas (Lloyd and Schmidt 1980).

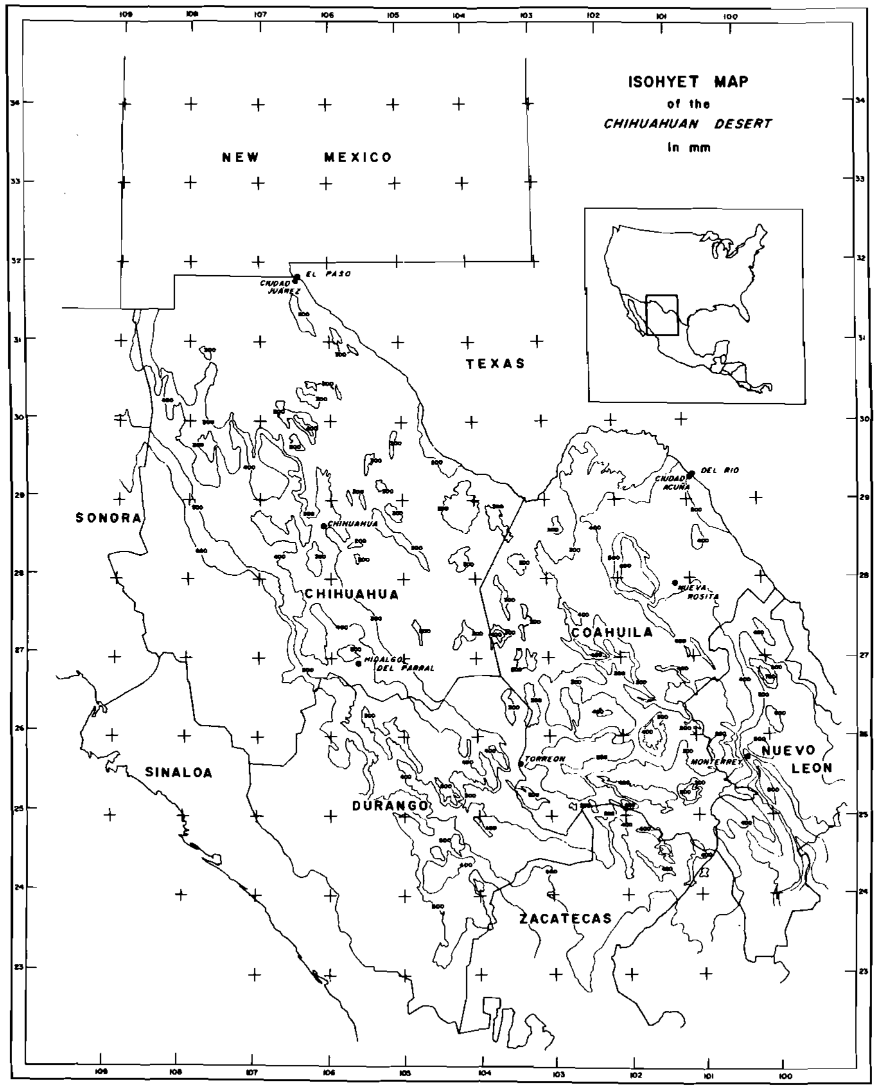

FIG. 8. Isohyets for the northern arid region of Mexico (García 1970).

several days, then they move northeastward and intensify. The counterclockwise circulation around this low pressure center results in a southerly influx of moisture from the Pacific Ocean (Webb 1971). Further research concerning the cutoff low is needed to provide a more comprehensive analysis of precipitation variability in the Chihuahuan Desert.

Tropical revolving storms.—The impact of tropical revolving storms,

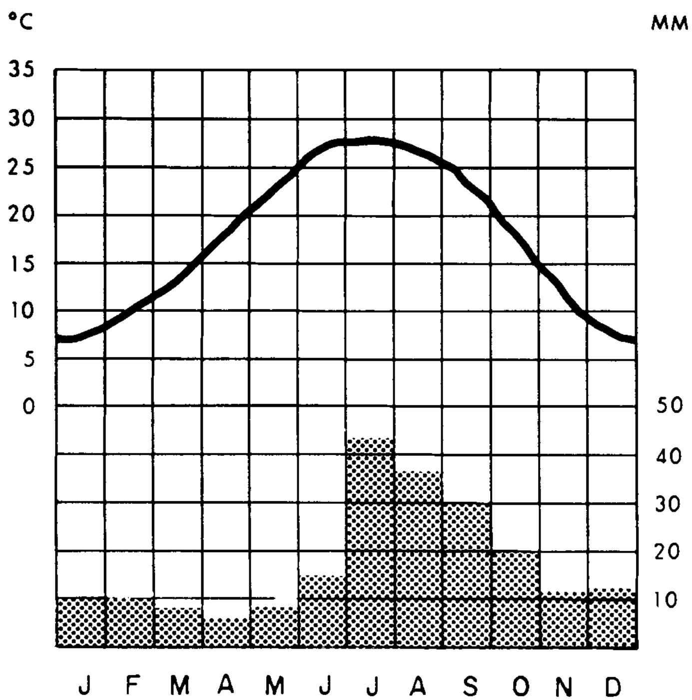

FIG. 9. Precipitation and temperature for El Paso, Texas.

which sometimes reach hurricane intensity, on the warm deserts of North America is gradually being placed into proper perspective as sources of precipitable water. Work by Rasmusson (1967) and Hales (1972, 1974a, b), and complemented by Tubbs (1972) and Brenner (1973), demonstrated that the Gulf of California is a major source of summer moisture for northwestern Mexico and the adjoining southwestern United States. Earlier work by Jurwitz (1953), Bryson and Lowry (1955), and Green and Sellers (1964) had indicated that moisture in the Sonoran Desert was almost entirely derived from the Gulf of Mexico.

The significance and proportion of tropical revolving storms as a source of moisture for the Chihuahuan Desert has not been completely solved. It seems reasonable to accept, in general, that water vapor in the atmosphere over the Chihuahuan Desert during the summer comes from the Gulf of Mexico. Further, it has been found that powerful storms in both the Gulf of Mexico and in the tropical eastern Pacific Ocean are responsible for most of the heaviest and widespread rains occurring in the interior desert (Schmidt 1983). These storms are also responsible for most of the

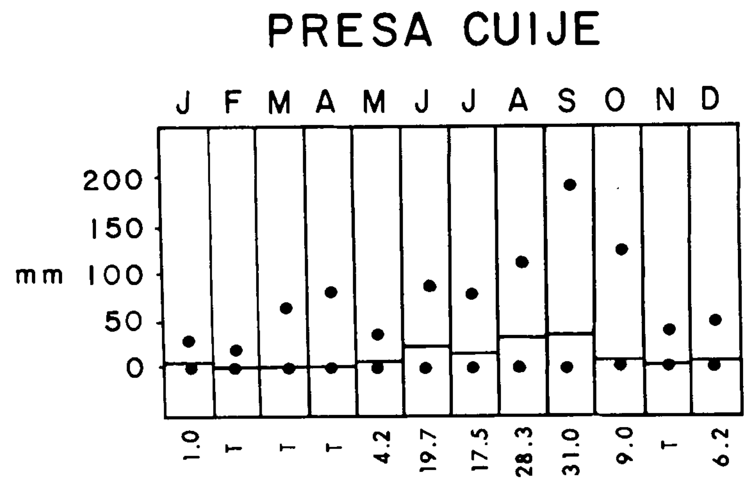

FIG. 10. Precipitation distribution and monthly range for Presa Cuije, Coahuila.

large deviations in precipitation totals from year to year, especially those deviations occurring during the warm season.

Sadler's (1964) pioneering work using satellite imagery to detect tropical cyclones in the eastern Pacific Ocean found that approximately three-fourths of these storms are not detected by conventional observations. The "Atlas de Huracanes" (Luna 1979) is an excellent and very welcome

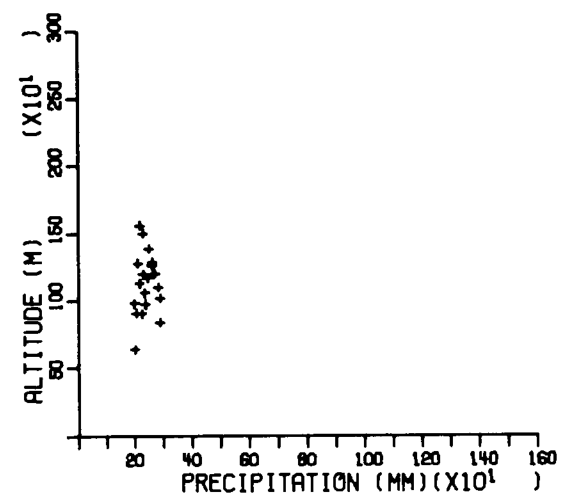

FIG. 11. The relationship of annual precipitation to altitude at arid zone (Ia ≤ 10) stations in the State of Chihuahua.

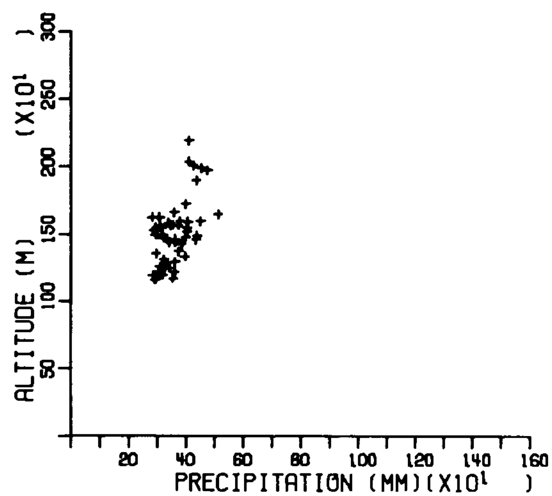

FIG. 12. The relationship of annual precipitation to altitude at semiarid zone (Ia 10–20) stations in the State of Chihuahua.

source of information concerning the frequency and trajectory of hurricanes affecting North America from 1952–1977.

More recently, the author obtained satellite imagery for the summer months of 1971–1980 to analyze the occurrence and characteristics of tropical revolving storms affecting the Chihuahuan Desert. Analysis of this source of information, used in conjunction with the U.S. Daily Weather Maps, indicates that these storms, from both the Gulf of Mexico and the eastern-tropical Pacific, are frequently of sufficient size and intensity to supply the atmosphere of the interior desert zone with relatively large quantities of water vapor. Using prolonged or significant daily rainfall for El Paso, Texas, during the summer months as a criterion, satellite imagery was used to determine the source of the moisture. Deleting isolated thunderstorms, which were unrelated to tropical revolving storms, it was found that approximately 45% of the precipitated moisture was derived from the eastern-tropical Pacific and 55% from the Gulf of Mexico (Schmidt 1983). Based upon information for the years 1973–1975, and 1978, it was found that approximately 55% of the annual precipitation falling in El Paso was the result of tropical revolving storms. When these storms move near the east and west coast of Mexico and establish strong cyclonic circulation, it normally takes at least one and one-half days for the moisture to reach deep into the interior desert. The large quantity of moisture placed into the atmosphere by these storms usually results in continuous cloud cover, reduced daytime temperatures, and light to moderate rains.

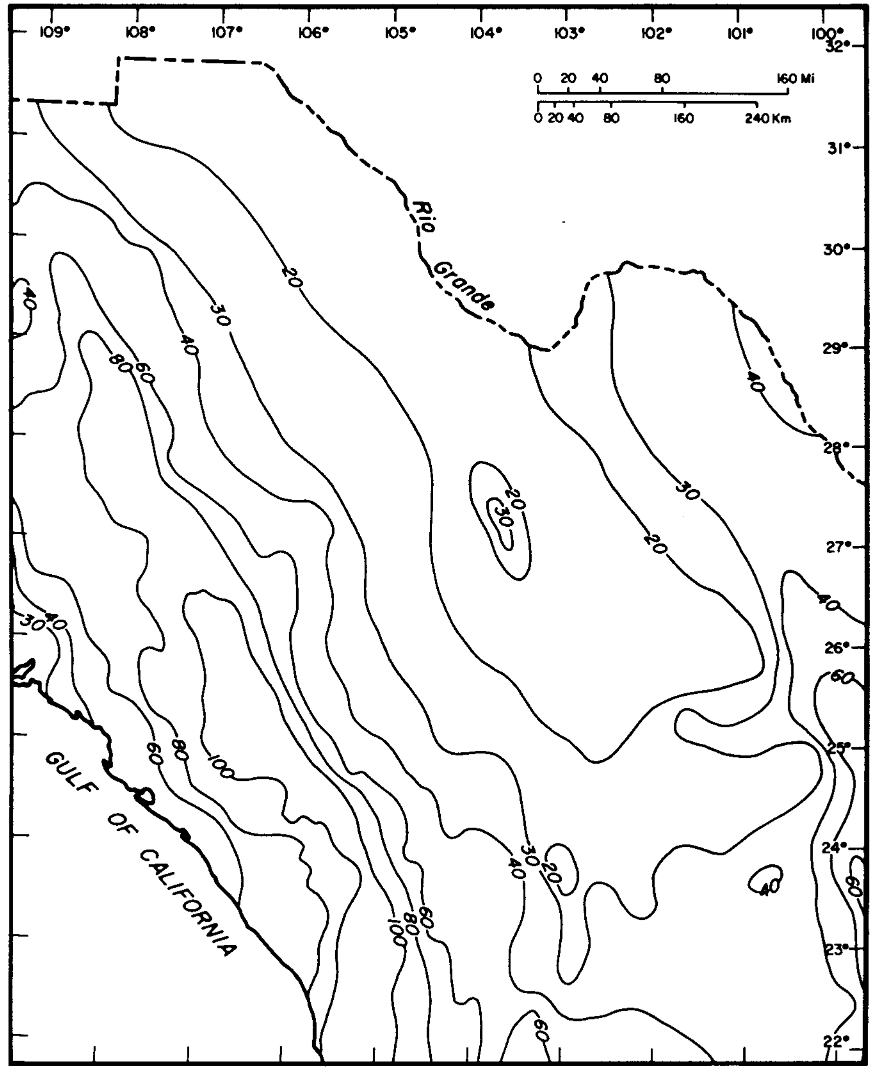

FIG. 13. The frequency of precipitation in the northern arid region of Mexico based upon the mode (adapted from García and Mosiño 1981).

Mosiño and García (1974) indicate that the presence of a major upper-air trough over the Mexican Plateau has a strong bearing upon the likelihood of an existing tropical storm entering either the Pacific coast or the Gulf coast. In contrast, the presence of a high-pressure cell or ridge in a strategic location over the landmass can block a storm's progress

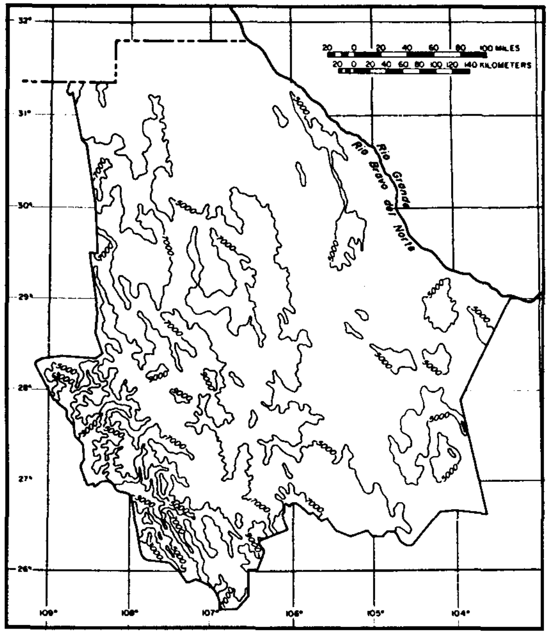

FIG. 14. Topography in the State of Chihuahua.

preventing landfall or penetration of moist air inland. Also, strong westerly winds aloft, associated with an upper-level high-pressure system, can shear the top off a storm and quickly dissipate its energy. High pressure over land or strong westerly winds frequently cause tropical revolving storms to move in a northeasterly direction and miss the Mexican gulf coast. Similarly, a storm off the west coast of Mexico which normally moves northwesterly and parallel to coastlines, may recurve and come onshore. The cold California current prevents tropical-eastern Pacific storms from penetrating into higher latitudes. Sadler's (1964) study concluded that wind shear produced by westerlies overlying lower-level northeast trades is the dominant dissipating influence on hurricanes in the eastern-Pacific Ocean. Pruszka's (1983) analysis of selected tropical storms affecting the El Paso, Texas, region indicates that tropical storms which make landfall between Tampico, Tamaulipas, and Corpus Christi, Texas, on the east coast, and northward up the Gulf of California from Los Mochis, Sinaloa, on the west have the greatest effect on the northern Chihuahuan Desert. The moist residue from storms that land in these locations usually tracks north and inland. More equatorward landfalls undoubtedly have a similar impact on the southern portion of the Chihuahuan Desert.

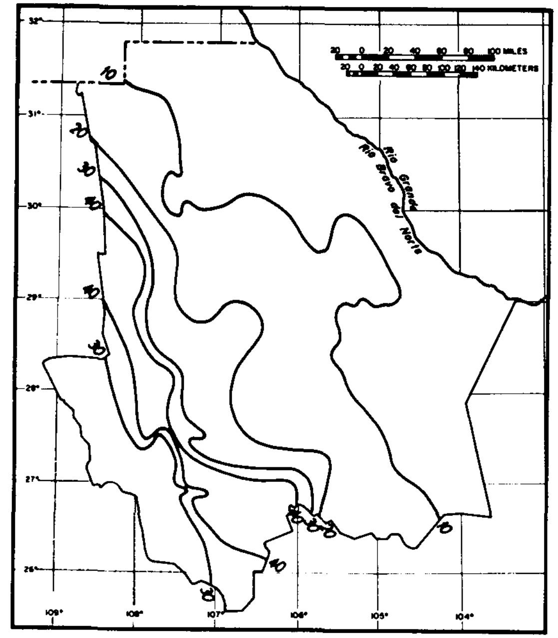

FIG. 15. Climatic zones based upon the de Martonne (1926) Aridity Index using the mean annual precipitation.

Spatial climatic variations.—In order to illustrate the temporal spatial changes that can occur through the dynamics of weather and climate, the State of Chihuahua was mapped using the de Martonne Aridity Index (1926, Figs. 14–17). The selection of this classification was discussed by the author in two previous papers (Schmidt 1975, 1979). The aridity indices were derived using the formula:

$$I_a = \frac{Pmm}{T°C + 10}$$

According to de Martonne (1926), an index of aridity value below 5 generally characterizes the true deserts; indices of approximately 10 correspond to dry steppes; values of about 20 to the prairies; and above 30 forest dominates. The mean annual temperature for each station was used with the mean, minimum, and maximum precipitation recorded at 176 localities. Mean annual temperatures were used in the calculations because they stabilize statistically with very few values, whereas those areas having low precipitation totals exhibit considerable deviation from year to year. Although the minimum or maximum precipitation does not necessarily

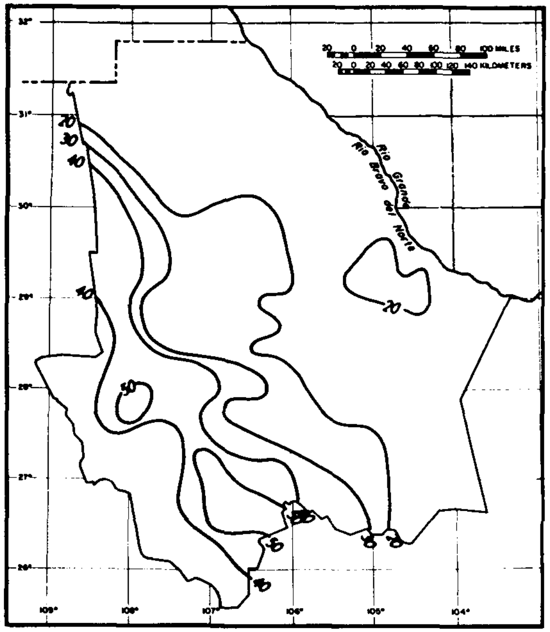

FIG. 16. Climatic zones based upon the de Martonne (1926) Aridity Index using the minimum extreme precipitation.

occur in the same year for all stations, the potential shift in the various climatic regions is dramatic, especially in the arid and semiarid zones (Table 1). This scenario clearly illustrates the potential for desertification and other problems associated with utilizing natural resources in fragile environments.

DISCUSSION

The intent of this study is to identify and characterize the weather and climate in the Chihuahuan Desert. It is true that in the past the lack of basic climatic information in Mexico has hampered research activities. But this statement is no longer entirely valid. A sizeable climatological data base does exist, although much of the information needed for climatological analysis in Mexico, especially upper-air observations, is not readily available. In contrast, the Mexican national physical atlas and the large-scale mapping projects, especially those by the Instituto de Geografía (UNAM) and published by DETENAL, are generally more detailed and comprehensive than those produced by public agencies in the United States. As more and more pressure is exerted on arid, and particularly

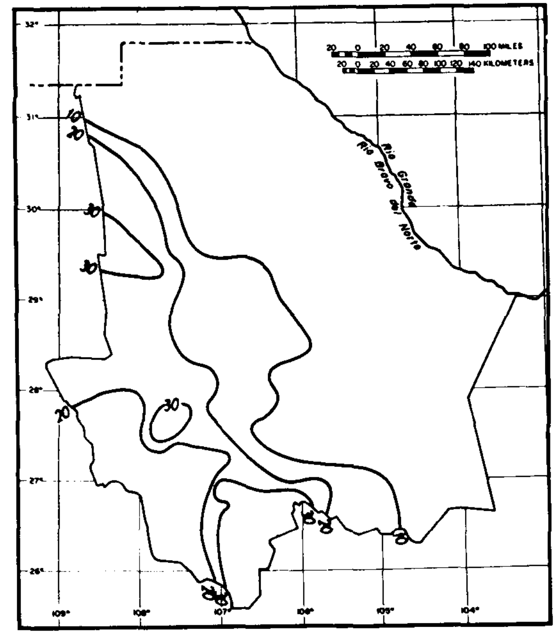

FIG. 17. Climatic zones based upon the de Martonne (1926) Aridity Index using maximum extreme precipitation.

semiarid zones, to increase their productivity of renewable resources, there arises a definite and very basic need to greatly improve our knowledge of the existing climatic and environmental conditions. In addition, it should be remembered that the natural resource base of the desert is fragile and its management requires careful application of climatic information in conjunction with other environmental factors.

A major challenge in the study of arid zones is understanding and applying the climatic and physical environmental information to the distribution of natural vegetation, and then using this information to pinpoint or to expand the producing area of native plants, or to introduce other suitable plants with economic potential. Because arid zones are not generally associated with conventional agricultural and forestry endeavors, non-traditional methods of using climatic information and applying it to the terrain must be sought. Arid regions often seem impervious to scientific and technological developments. This imperviousness is one of the most important reasons for the general lack of development, and for the low standard of living common to arid regions.

The study of deserts and their unique problems are of great interest and

TABLE 1

PERCENT AREA AND CHANGE IN SPATIAL DISTRIBUTION OF CLIMATIC ZONES IN THE STATE OF CHIHUAHUA BASED UPON THE DE MARTONNE (1926) INDEX OF ARIDITY (IA)

Ia	Mean	Min.	Change	Max.	Change
10	26	60	+34	—	−26
10–20	43	22	−21	49	+6
20–30	16	13	−3	24	+8
30–40	7	5	−2	12	+5
40–50	8	—	−8	12	+4
50	—	—	—	3	+3
	100	100		100	

benefit to the United States and Mexico. Approximately 37% of the United States (excluding Alaska) is considered arid and semiarid. In Mexico, 53% of the land is classified as desert, while another 40% experiences long seasonal droughts. These climatic realities coupled with the rough topography, which dominates much of the Chihuahuan Desert account for the very limited use of plants for food, fiber, and fuel. The potential for improving agriculture management of natural vegetation, and increasing the utility of these marginal lands certainly does exist, but precisely how, when, and where is not clear.

Most of the desert land in the Chihuahuan Desert is used for extensive grazing, but native plants, such as yucca (*Yucca* spp.) and agave (*Agave* spp.) fiber plants, candelilla (*Euphorbia antisiphilitica*) for wax, guayule (*Parthenium argentatum*) as a source of natural rubber, and mesquite (*Prosopis* spp.) for fuel offer commercially exploitable alternatives for this large tract of little-used land. More traditional crops, such as grapes, and deciduous fruits, may prove to be productive ventures in the more moist foothill regions of the mountains in this area of basin and range topography, particularly when coupled with water conservation methods.

Recent work by Lambert and Reid (1981) and Harper (1983) have shown that analytical techniques from plant ecology hold promise for finding relations between biota and their environment in large biogeographic regions. Gradient analysis, including polar ordination, together with discriminant analysis, and the several forms of regression analysis have proven effective. Hopefully, this methodology, with refinements, will eventually prove useful in promoting proper utilization and management of renewable resources in the Chihuahuan Desert.

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