THE DROUGHT REGION OF NORTHEASTERN BRAZIL

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THE outstanding geographical circumstances affecting northeastern Brazil are its periodic droughts. A vast literature on the subject exists in Brazil, but it is scarcely known outside the country.[1] A general picture of the region and its problem will here be presented.[2]

The drought region of northeastern Brazil is generally described as comprising the states of Ceará, Rio Grande do Norte, Parahyba, Pernambuco, Alagoas, and Sergipe, about one-tenth of the state of Piauhy, and the portion of the state of Bahia north of the Rio Itapicurú, the southern boundary of the region being the Rio Itapicurú to its source and thence a line drawn westward to the springs that form the source of the Rio Gurgueia in the state of Piauhy. The region thus defined has an area of some 540,000 square kilometers and a population of about 5,600,000.

LANDFORMS[3]

To the traveler approaching the drought region from the Atlantic it appears as a gently sloping surface broken in many places by hills, some with sharp profiles, others gently rounded, occurring in ranges or separated from one another by nearly level or only slightly undulating terrain. The western and southern horizons are broken by more conspicuous ranges of mountains, with flat tops and steep slopes. The coastal zone, which is three to eighteen kilometers wide, is composed of clays and soft sandstones and, in some parts, low limestone cliffs. The coast is bordered by a belt of mangroves, through which meander numerous small streams, forming many lagoons and marshes; about a dozen larger, perennial rivers reach the sea through funneled mouths that are often obstructed by alluvial bars and small islands.

[1] Beitrag zu einer Bibliographie der "Seccas"-Literatur, *Ibero-Amerikanisches Archiv*, Vol. 3, 1929–1930, pp. 99–105.

[2] See also F. W. Freise: Der Mensch im Dürregebiete des Nordostens von Brasilien, *Geogr. Zeitschr.*, Vol. 43, 1937, pp. 433–445.

[3] A summary account of geological investigations is given by J. C. Branner: Outlines of the Geology of Brazil to Accompany the Geologic Map of Brazil, *Bull. Geol. Soc. of America*, Vol. 30, 1919, pp. 189–337.

For details the *Publicações* of the IFOCS (Inspectoria Federal de Obras contra as Seccas, Ministerio da Viação e Obras Publicas, Rio de Janeiro, 1910 and following years) are to be consulted; for example, Roderic Crandall: Geographia, geologia, supprimento d'agua, transportes e açudagem nos estados orientaes do norte do Brazil: Ceará, Rio Grande do Norte, Parahyba, *Publ. No. 4*, 1910 (2nd edit., 1923); H. L. Small: Geologia e supprimento d'agua subterranea no Ceará e parte do Piauhy, *ibid., No. 25*, 1913 (2nd edit., 1923); R. H. Soper: Geologia e supprimento d'agua subterranea no Rio Grande do Norte e Parahyba, *ibid., No. 26*, 1913 (2nd edit., 1923); *idem:* Geologia e supprimento d'agua subterranea em Sergipe e no nordéste da Bahia, *ibid., No. 34*, 1914 (2nd edit., 1923). As the organization of the Inspectoria has undergone several fundamental modifications since 1915, the plan for regular publications on the northeast has not been carried out for a long time.

FIG. 1—Drought areas of northeastern Brazil. 1, states usually included in the division northeastern Brazil; 2, drought region outside "northeastern" Brazil. Scale of map 1 : 9,750,000.

The interior back of the coastal zone is composed mostly of a large variety of crystalline rocks in which gneisses and micaceous schists predominate and which are broken in many places by granitic and dioritic intrusions now laid bare by surface erosion. Complexes of sandstones alternating with thin layers of limestones cover the Archean basement to a thickness of 500 to 700 meters. Four principal areas of such rocks are shown on the map (Fig. 2), and many isolated patches are scattered over the whole region. Time has left of the once continuous cover only flat-topped *taboleiros* (table mountains) and isolated knobs rising to elevations of 700 to 900 meters above sea level. The lack of well preserved fossils precludes an exact statement regarding the geological age of the strata, but they are generally believed to be Cretaceous.

Uplift and folding have disturbed the continuity of the sedimentary rocks in many places, and the surface is dissected in several directions by broad, shallow valleys in which continuously flowing streams are

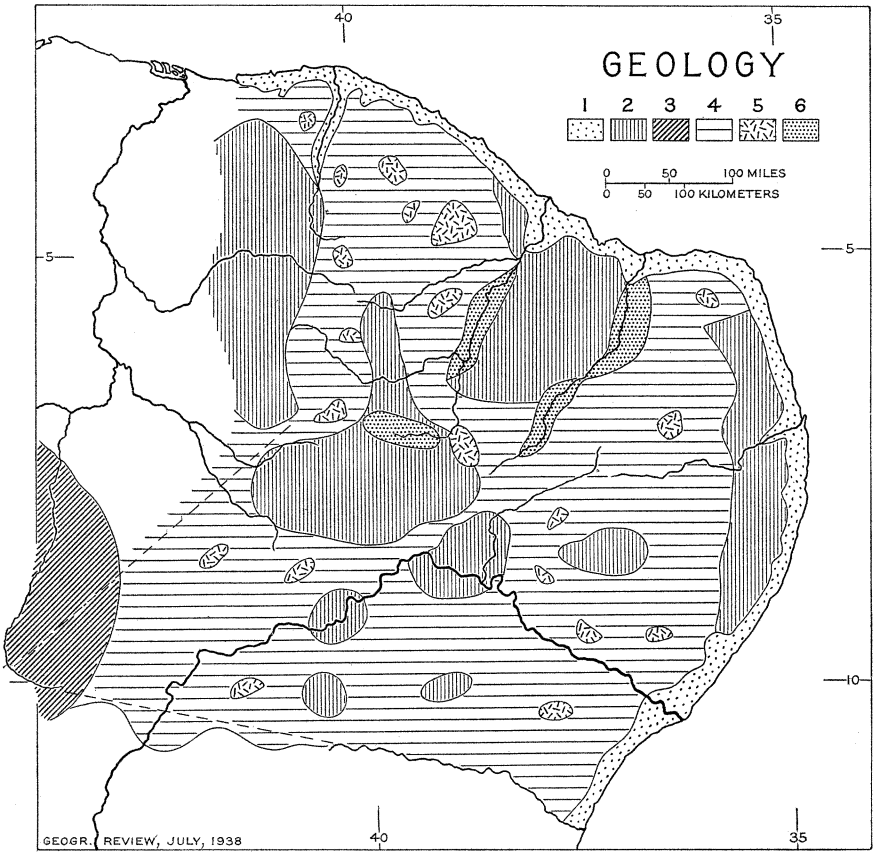

FIG. 2—Geologic sketch map of northeastern Brazil: 1, Quaternary; 2, Cretaceous; 3, Permian(?); 4, gneisses and micaschists; 5, granitic intrusives; 6, main districts of *vasantes*. For sources see footnote 3. Scale of map 1 : 9,750,000.

the exception. Most of the rivers are merely lines of elongated pools during the rainy season (Fig. 6) and completely dry mule tracks during the greater part of the year. The only forests are narrow strips of moderately dense growth along the lower, perennial sections of the rivers and on hillsides that regularly receive moisture in the form of dews or driving mists (Fig. 7). Elsewhere the natural vegetation is limited to caatinga characterized by thorny shrubs that branch out just above the ground and are provided with a network of long, thin roots that spread out a few inches below the surface and are thus adapted to scarcity of soil moisture.

The principal disintegrating agent is solar heat, which is operative many hours daily from a cloudless sky. The cracking and splintering effect of insolation on the schistose and fine-grained surface rocks is great, and the surface is therefore widely strewn with sand and dust. Gentle rains dissolve much of the soluble material, and the resulting

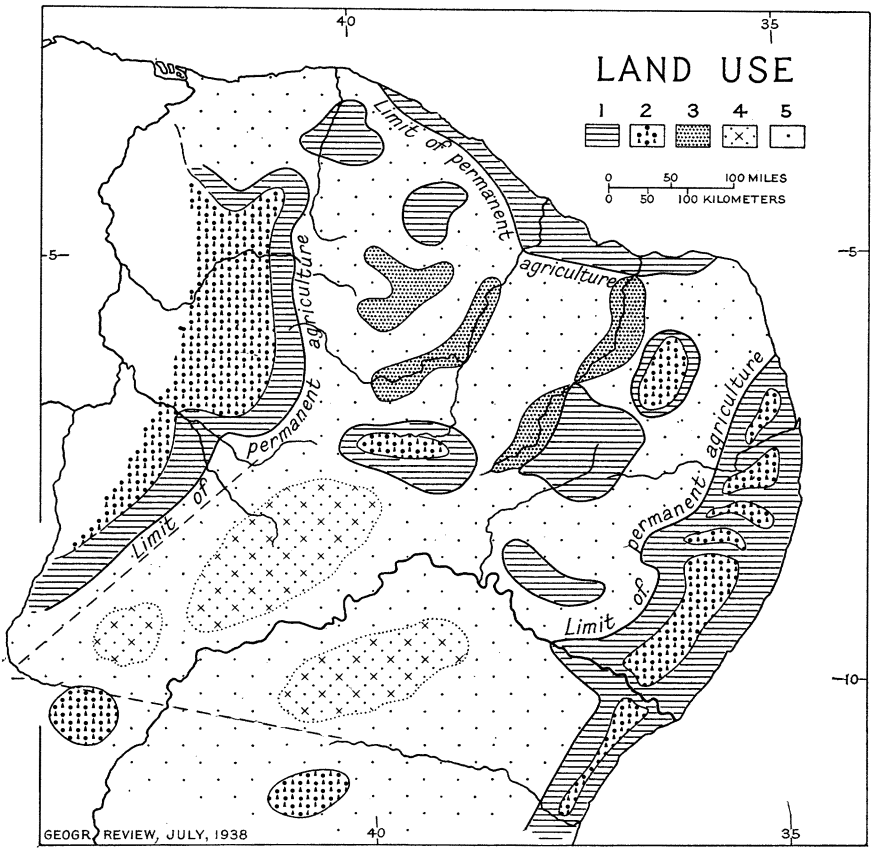

FIG. 3—Forested and agricultural areas of northeastern Brazil. 1, permanent agriculture; 2, virgin forest; 3, *vasantes;* 4, continuous caatinga; 5, largely bare rock, scant vegetation is mainly cacti and wild pineapple. Scale of map 1 : 9,750,000.

The official publication of the Ministry of Agriculture, Mappa Florestal do Brasil, by Gonzaga de Campos, Rio de Janeiro, 1906 (2nd, unrevised edit., 1926), has been consulted; it gives the (estimated) status about the year 1900.

salt solutions corrode the deeper strata; heavy rains wash the splintery mass down the slopes, and it collects in depressions, forming sandy salt-water pools, which, if they do not dry up at once, support a scant growth of halophilous grasses.

In heavy rains, long continued and covering wide areas (which only rarely occur), appreciable quantities of coarser material are washed down and deposited in such a manner as to form concave barriers behind which water is impounded. These are the *vasantes* (literally, shallow water beds), which are eagerly sought for and at once used by the firstcomers for primitive plantations of *Manihot* roots, water beans, and melons. The total area of these vasantes in the region is about 60,000 hectares (see Fig. 3 for distribution and for a photograph of a *vasante* see Fig. 6).

Climatological Data

The federal government maintains 20 meteorological stations in the drought region, the Inspectoria Federal de Obras contra as Seccas (the federal bureau for combating the drought) has about 140 rainfall stations, and the railroad companies and navigation companies on the Rio São Francisco coöperate in collecting temperature and rainfall data.[4] The total of the data assembled, however, is not sufficient to permit more than a few generalizations on the climate of the northeast.

On Figure 4 the line of 25° C. mean annual temperature divides the region, about 35 per cent being in the zone of equatorial climate and 65 per cent in the zone of subtropical climate. The average of the recorded temperature maxima is 36° C.; the average of the minima is 18.6°. The highest and lowest recorded temperatures are 41.5° and 11.6° respectively. The number of hours of full sunshine a year ranges from 2684 to 3301; the average taken from the records of the Inspectoria is 2845 hours. The highest temperature observed on bare soil is 66.6° (at 2 p. m.). The prevailing winds are southeast, east, and northeast, occurring 35, 22, and 14 per cent of the time respectively. The median wind velocity is less than 2.5 meters a second. Air movements of more than 10 meters a second are exceptional.

Eight per cent of the region receives not more than 10 inches of rain annually. About 25 per cent lies between the 10-inch and 25-inch rainfall lines, and the remaining 60 per cent has an average recorded rainfall of more than 25 inches. The annual rainfall in the coastal zone is larger than that in some parts of the ever humid mid-southern states of Brazil. These data would seem to indicate that it is not a deficiency of annual rainfall that is the subject of complaint in the drought region. The periodic droughts and floods are rather a result of the uneven distribution of the rainfall, in both time and place, to which is added the difficulty of retaining and utilizing the water that actually falls.

In good (normal) years about 90 per cent of the rain falls in the period from December to April or early May. Five to eight per cent of the rain in a good year falls in gentle showers at the beginning of the rainy season in October. These are the *cajú* rains, so called because they bring to leaf and flower the *Anacardium* tree, the fruit of which, the *cajú*, is edible, and they are considered a favorable omen for the coming season. During the rest of the rainy season the rain pours down in heavy showers lasting from a quarter to three-quarters of an hour over an area of a dozen hectares or so to perhaps some two square kilometers. Rains lasting several hours and rains extending over five

[4] In addition to the IFOCS publications given in footnote 3, the fundamental work consulted for the maps is Henrique Morize: Contribuição ao estudo do clima do Brasil, 2nd edit., Minist. da Agric., Indust. e Commerc., Observatorio Nacl. do Rio de Janeiro, Rio de Janeiro, 1927, which gives observations down to the year 1920. For a discussion of the first (1922) edition see Mark Jefferson: New Rainfall Maps of Brazil, *Geogr. Rev.*, Vol. 14, 1924, pp. 127–135.

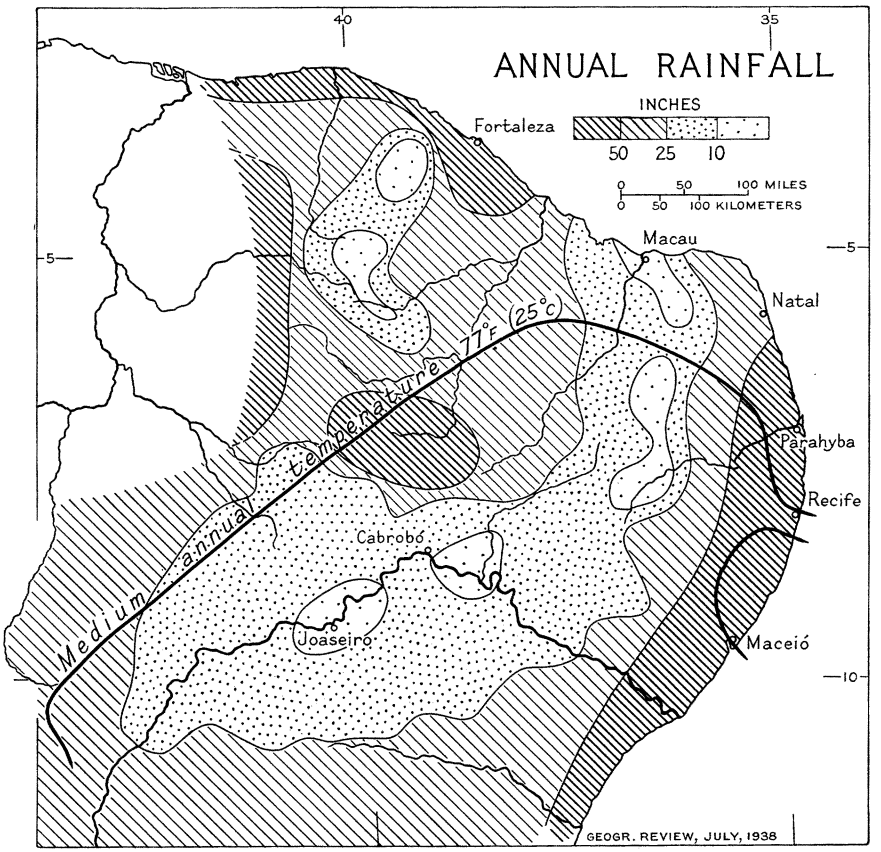

FIG. 4—Mean annual rainfall of northeastern Brazil. The isotherm of 25° C. mean (for "medium" on map read "mean") annual temperature is also shown.

square kilometers or more are extremely rare. Rather frequently the whole rainfall of a month is concentrated in three to five showers not more than a day apart.

There are wide departures from the characteristic rainfall of a good year. In typical dry years the cajú rains are very scanty or fail almost entirely and, although rather copious rains may be recorded in December or January or both, the March-April-May rains, which in good years bring 60 per cent of the total rainfall, fail entirely. In years of excessive rainfall, which causes disastrous floods, the cajú rains fall at the usual time, and a normal year is predicted; but the period from January to the March equinox is entirely dry, and all the rain of the season falls in April and the early part of May, often in sheets rather than in drops. If either of these departures from the normal occurs, there will be lack of food for man and beast. The failure of the March-April rains kills both the plantings made after the cajú rains and the natural fodder. The April-May excessive rain

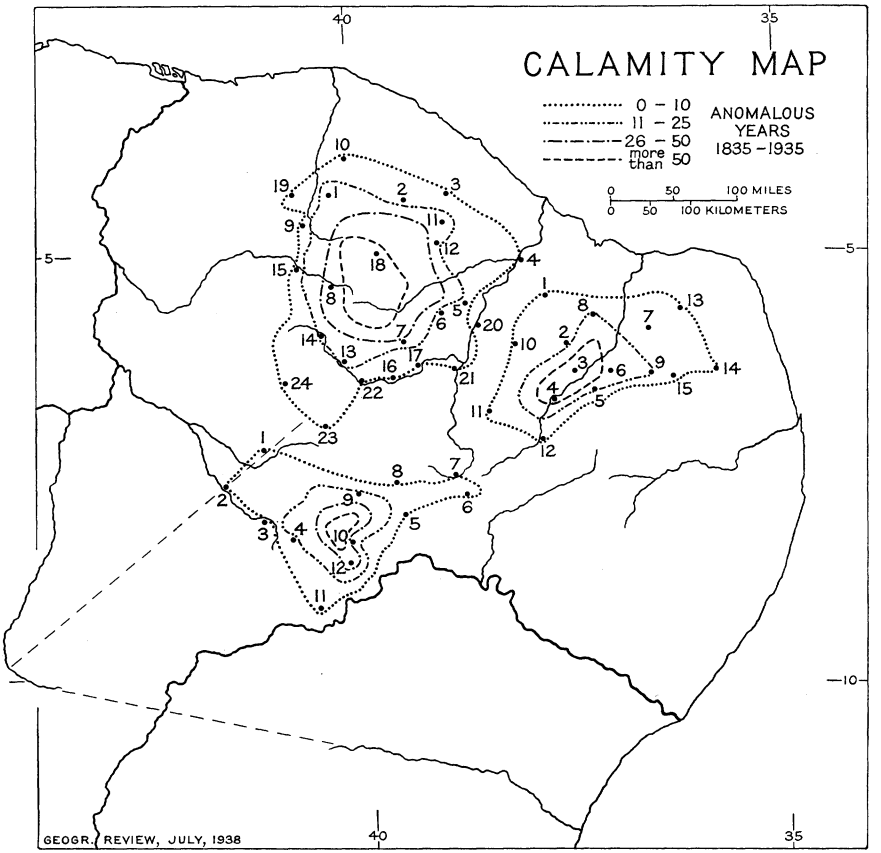

FIG. 5—"Calamity" map of northeastern Brazil showing areas particularly subject to drought or flood. On the basis of the available data three areas marked by severity of conditions are distinguishable (cf. Fig. 1). Scale of map 1 : 9,750,000. Key to localities:

Ceará: 1, Santa Quiteria; 2, Canindé; 3, Baturité; 4, Limoeiro; 5, Riacho do Sangue; 6, Cachoeira; 7, Lages; 8, Independencia; 9, Nova Russas; 10, Santo Antonio; 11, Cangaty; 12, Quixadá; 13, Arneiróz; 14, Tauá or Taúhá; 15, Crathéus; 16, São Matheus; 17, Iguatú; 18, Boa Viagem; 19, Ipú; 20, Pareiro and Jaguaribe-mirim; 21, Icó; 22, Saboeiro; 23, Campos Salles; 24, Coronzó.

Rio Grande do Norte and Parahyba: 1, Apody; 2, Patú; 3, Brejo da Cruz; 4, Pombal; 5, São João; 6, Caicó; 7, St. Anna do Mattos; 8, Augusto Severo; 9, Acary; 10, Páo dos Ferros; 11, Cajazeiras; 12, Piancó; 13, Lages; 14, São Bento near Santa Cruz; 15, Picuhy.

Pernambuco: 1, Jaicós; 2, São Julião; 3, Paulista; 4, Amaranta; 5, Leopoldina; 6, Belmonte; 7, Macapá; 8, Granito; 9, Ouricury; 10, Baixio Grande; 11, Corrego Secco, near Petrolina; 12, Jatobá.

kills by rot such vegetation as may have developed under semidrought conditions. A somewhat rarer departure from the normal occurs when the rainy season begins with heavy cajú rains and rain continues until February or later. This kills the germinating seeds or, according to the most acceptable hypothesis, produces very watery roots, bulbs, and tubercles and also enormous stalks of cane or maize without a correspondingly large sugar content and grain.

These remarkable variations in rainfall in both time of occurrence and area covered have given rise to a conviction on the part of the

inhabitants that every part of the northeast is hit at least once by drought and once by floods every twenty years and that, of the remaining years, only a third to a fifth are really good years in which agriculture can be profitably carried on. The tradition of scarcity of rainfall held by the older residents of the region has been investigated by the writer on the basis of a long series of authentic data.[5] The results are plotted on Figure 5, on which curves connect those places

FIG. 6—River bed with pools (foreground) and *vasante* (center). Near Quixadá, Ceará. (Courtesy of Director of Agriculture, Fortaleza, Ceará.)

where, in the century from 1835 to 1935, 0–10, 11–25, 25–50, and more than 50 years were marked by deficient or overabundant or irregularly distributed rainfall. Certain areas of major or minor intensity in rainfall irregularity thus become evident: one in Ceará, one in Rio Grande do Norte and Parahyba, and one in western Pernambuco. If the records were more complete, other such regions would probably be found. It should be noted that the curves of "equal calamity" on Figure 5 coincide appreciably with the curves of low rainfall, at least for the Ceará region.

The ground on which the rain falls is bare over extensive areas and is generally well heated. Most of the water immediately evaporates or is fixed within the dust cover, where it dissolves mineral matter and acts as a disintegrating agent in the lower strata. The small

[5] A summary of droughts in Ceará is given by Studart in the *Revista Trimensal do Instituto do Ceará*, Vol. 38, 1924, pp. 29–32. For 1918 to 1936 and for the other states in the region since 1840, the year in which droughts were first vigorously discussed in Parliament, the Rio de Janeiro *Journal of Commerce*, *Annals of Congress*, travelers' notes, and biographies of statesmen have been consulted by the writer; the IFOCS library and the Archives of the Federal Ministry of Public Works offered much information, which is here duly acknowledged.

amount of rain water that remains on the surface does not long remain pure even where men or animals have no access to it, for, as has been said, it dissolves saline matter and eventually deposits its mineral load on the margin of the collecting pool. The water that sinks into the earth is generally definitely lost because it does not form abundant, continuous, long-lasting ground-water basins, from which it might flow in springs or where it could be reached by dug or bored wells.

FIG. 7—Forest at the margin of Jaguaribe River, Ceará. (Courtesy of Director of Agriculture, Fortaleza, Ceará.)

Although there is underground water in the gneisses and micaceous schists and near the granitic intrusions, the supply is scanty. Even where abundant, the water is often too saline for irrigation or for drinking purposes. Of the sandstone areas, the one most productive of underground water is the Ibipaba Range in western Ceará, where there are several water horizons between the strata. The drought region does not profit from it, however, because the strata dip to the west and the water comes to the surface only on the Piauhy side of the mountains. All other sandstone mountains, remnants of the once-general Mesozoic cover, are entirely lacking in ground water. Such cultivated areas as there are in them—for example, the east and south sides of the Araripe Range (the Chapada do Araripe)—owe their moderate fertility to the constant watering by dews.

MAN'S STRUGGLE AGAINST THE DROUGHT

Before discussing what man has done to overcome, or at least to alleviate, climatic adversity, it is necessary to review briefly the his-

tory of the colonization of the northeast.[6] About fifty or sixty years after the discovery of the coastal region the present state of Pernambuco was the best-known part of northeastern Brazil. The European population was about 2000; four towns had been founded (Olinda, in 1537; Iguarassú, in 1550; Goyanna, in 1560; and Recife, in 1561), and there were several dozen sugar mills. Each sugar mill represented a concession (*sesmaria*) of 2 to 12 square miles in a narrow strip running inland from the coast. The work on the sesmaria was done by the Europeans and their slaves; the cattle roved freely in the hinterland and were cared for by Indian cowboys. European employees on the latifundia who wished to become independent were allowed to settle on the outskirts of the sesmarias as *sitiantes* (commanders of strongholds against the invasion of hostile Indians) or as *vaqueiros* (cattle raisers). When, in 1625, the Dutch attempted to establish settlements on the coast, an uninterrupted zone 100 kilometers wide was occupied by planters, and the most distant vaqueiros lived inland as far as the Cariry and the Araripe Mountains, respectively 120 and 350 kilometers from the coast. At the same time the western mountains of Ceará were already occupied by Europeans who had penetrated inland from the north coast.[7] In form the inland establishments invariably consisted of a small area, generally fenced in, for primitive cultivation surrounded by common land or land at least to which no one was able to establish a well defined claim. The people of these hinterland settlements have always been preponderantly devoted to cattle raising, their agricultural activities being confined to the raising of a few food crops that do not grow wild. Among the farmers of the coastal region this type of agriculture has been known from the earliest times as *roça de matuto* (backwoods farming).

Because of the abundance of open space the inhabitants of the northeast in the sixteenth and seventeenth centuries experienced no difficulty whatever in a dry season. They simply moved to a location where there was enough moisture in the soil to satisfy their modest demands, and their livestock they let shift for themselves. Even in the eighteenth century, in which there were nineteen periods of general drought and nine of excessive and detrimental rains,[8] no steps were taken by local or provincial authorities.

In 1715, owing to the discovery of gold, diamonds, and emeralds by explorers penetrating to the central plateau from São Paulo, there

[6] See F. J. Oliveira Vianna: O povo brazileiro e sua evolução, *in* Recenseamento do Brazil realizado em 1 de Setembro de 1920, Vol. 1, Introducção, Minist. da Agric., Indust. e Commerc., Direct. Geral de Estatistica, Rio de Janeiro, 1922, pp. 277–400; reference on pp. 281 ff.

[7] These details are from a report by a Jesuit missionary, Luiz Figueira, to his superiors in 1608. Studart states that the Tabajara Indians, living on friendly terms with the whites, have known of the periodic drought years from time immemorial.

[8] Concerning the dry periods and inundations see, in addition to the publications cited in footnote 5, the publication of the Ministerio da Agricultura "Circulação dos productos agricolas e custo da vida em relação aos artigos de alimentação no Brasil 1921–23," Rio de Janeiro, 1925.

began a continuous and at times very heavy emigration of the planters of the northeast, with their slaves and all their other possessions, to the mining districts of Minas Geraes and Bahia. Fields and crops in the coastal region were hastily abandoned, and it is estimated that at least half a million people, including about 300,000 slaves, left the region. The cattle herders subsequently moved from the drought areas of the interior to the abandoned outer edges of the coastal region and, in part at least, turned to agricultural pursuits. When, in the last quarter of the eighteenth century, coffee growing began in the states of Maranhão and Pará, a great many of the inhabitants of the coastal region (civilized Indians, as well as landowners and slaves, from the sugar mills still operating) emigrated northward, and once again a large number of cattle breeders moved from the interior to the deserted latifundia. This new wave of emigration is estimated to have drained away some 120,000 to 150,000 persons. These two emigrations were decidedly not caused by periods of severe drought. In fact, the emigrations coincide with the normal periods of 1710 to 1720 (the exodus to Minas Geraes), 1725 to 1745 (the rush to the diamond fields of Bahia), and 1780 to 1790 (the trek to the coffee regions of the north).

Because of the rather rapid succession of dry periods in the first quarter of the nineteenth century (1804, 1808–1809, 1816–1817, 1823–1825) there was a great drain on the population of the northeast. This was particularly due to the fact that by then coffee had definitely won supremacy over sugar, which suffered increasing competition from other countries and also from the sugar beet. This emigration was toward the south where the *zona da matta* (the virgin forest) of Matto Grosso, the Parahyba Valley, and the adjoining parts of São Paulo had been transformed into a veritable ocean of coffee. It is estimated that in this last emigration before the abolition of slavery, involving not only the landowners themselves but slaves, cattle, and all other belongings, 200,000 to 220,000 people, eight-tenths of whom were slaves, left the coastal region of northeastern Brazil. The remnant consisted almost entirely of such persons, whether free or slave, as were either unfitted for, or definitely hostile to, any progressive methods in the occupation and use of the land. The cattle that were not taken to the south moved over the western and southern divides during the dry periods, and spread out over Goyaz and Matto Grosso, to become the progenitors of the enormous herds of wild stock that now rove the grasslands of these two states.

Not until 1880, when an extremely severe general drought that lasted three years drove some 250,000 people out of the northeast, did the imperial government decide to take preventive measures. Actually it was the emperor's initiative rather than studies carried out or projects proposed by any department of the government that

led to the construction of retaining dams in regions known to have suffered repeatedly from drought. Forty-nine dams, most of them primitive earthworks paved with stone, were built between 1880 and 1889, the last year of the empire. Their capacities ranged from 50,000,000 to 250,000,000 cubic meters. The dam at Quixadá, in the state of Ceará, had the largest storage capacity. This dam is the only one of those built during this period that has survived; all the others were washed away because of neglect or sudden excessive pressure. Many of the reservoirs quickly filled with sediment or were not able to hold water because of rapid evaporation or seepage.

During the first two decades after the fall of the empire very little was done to combat drought. The exploration of Acre Territory, mainly by emigrants from the northeast, where labor conditions had been adversely affected by the abolition of slavery, the rubber boom in the Amazon Valley that began in the nineties, and the expansion of coffee growing in the central states were continually drawing people from the northeast, with the result that plenty of room was always left for those unfitted for emigration to lead their usual half-nomad, pauper lives. Some half a dozen dams of rather precarious construction were built during this period (1889 to 1910), but not a stone of them remains.

Not until 1910, when the Inspectoria Federal de Obras contra as Seccas was organized, did the government begin to substitute extensive geological, botanical, and climatological surveys for guesswork as the basis for determining the kind of measures best suited to combating drought. Along with these studies a great deal of educational work was done in attempts to improve agricultural methods. By the end of 1936 the construction division of the Inspectoria had 116 dams under construction to provide reservoirs that when filled would hold a total of 1,917,000,000 cubic meters of water. Fifty-six of these reservoirs, with a total capacity of 621,000,000 cubic meters, have now been completed. The location of the most important is shown on Figure 8. Up to the present these reservoirs have never been all filled at the same time; the greatest amount stored at any one time was about 44 to 47 per cent of total capacity. An overflow at any of the dams is usually celebrated as a miracle.

In addition to these federal projects, work has been begun on 89 municipal reservoirs, with a total storage capacity of 145,000,000 cubic meters. The local authorities are being financially supported and technically assisted by the federal or state government or both. Twenty-five of these reservoirs, with a capacity of 35,000,000 cubic meters, have been completed. Furthermore, industries, small villages, and farmers have undertaken to build small reservoirs with maximum capacities of 200,000 cubic meters under the technical guidance and financial support of federal, state, and municipal governments. Of

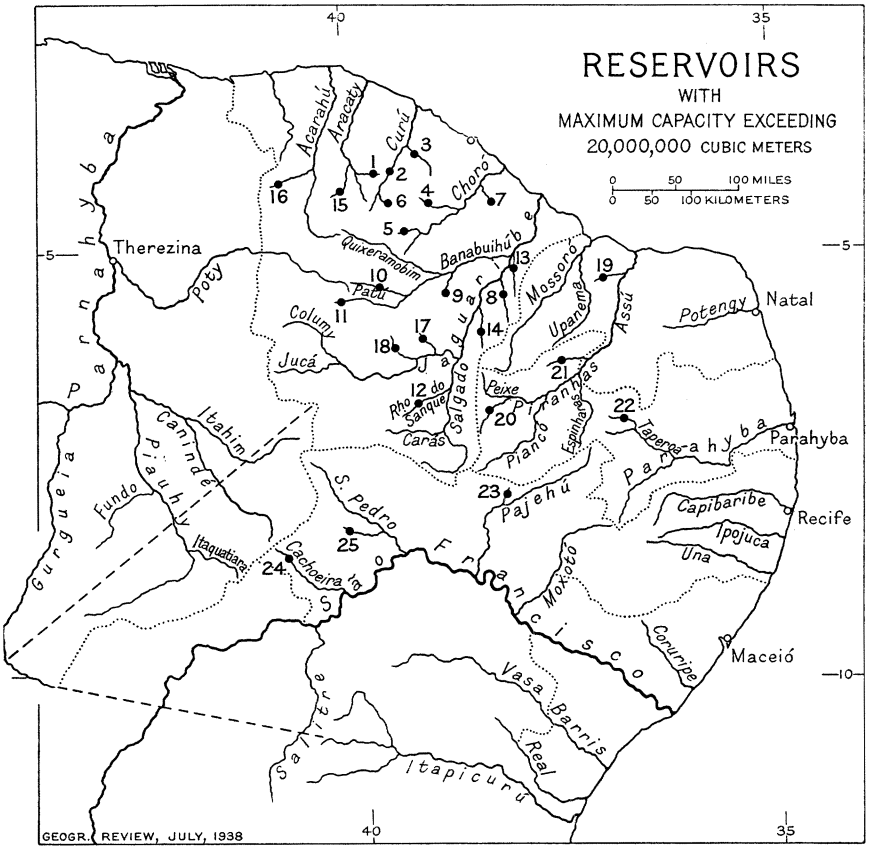

FIG. 8—Map showing location of reservoirs with a capacity of over 20,000,000 cubic meters. Key, with maximum storage capacity in millions of cubic meters and height of dam in meters:

	Mill.cu.m.	*m.*		*Mill.cu.m.*	*m.*
1 Patos	320	35	13 União	110	22
2 General Sampaio	305	38	14 Iracema	110	18
3 São Joaquim	265	29	15 Forquilha	88	21.5
4 Choré	255	34	16 Jaibara	82	30
5 Cedro	235	32	17 Feiticeira	64	17
6 Feijão	180	22	18 Lima Campos	58	19
7 Bahú	155	26.5	19 Itans	81	16
8 Limoeiro	148	18.8	20 Piranhas	155	41
9 Morada Nova	125	21	21 Santa Luzia	22	15.7
10 Pedra Branca	115	27.5	22 Soledade	20.5	18
11 Benjamin Constant	115	23.8	23 Villa Bella	58.5	48
12 Riacho do Sangue	110	—	24 Cachoeira	49.5	17.5
			25 Pedra d'agua	29	11.5

160 reservoirs planned, with a total storage capacity of about 18,000,000 cubic meters, 35, with a total capacity of 1,300,000 cubic meters, are now ready. When the reservoirs now planned are actually constructed, there will be all together about 360 reservoirs, which should be able to store 2,680,000,000 cubic meters of water.

The net of feed canals planned for federal and municipal reservoirs

totals 18,000 meters. About 14 per cent of this is now ready to carry water. Twenty-one thousand hectares are now under a somewhat regular regime of irrigation, but the area irrigable by the network of canals now completed is about twice this size. It is believed that when completed the system (exclusive of the small reservoirs) will be able to provide irrigation water for about 180 square kilometers. At present the water stored in reservoirs covers about 56,000 hectares, the largest area being that of the Piranhas reservoir in the state of Parahyba, which has 155,000,000 cubic meters of water on 2800 hectares. The evaporation in this reservoir is about 1950 millimeters a year.

Frequent changes in administration, the necessity of adjusting plans and supervision to local intelligence and at best only moderate experience in the kind of work involved, the lack of skilled or even industrious workmen, and, finally, the extension of the work over too large an area are the chief reasons for the slow progress made on the construction program. Up to the present the expenditure on dams and canals has amounted to about $70,000,000.

Borings for wells have been made, 5 to 8 inches in diameter and from 15 to 130 meters in depth, in areas of deep disturbance in the gneisses and crystalline schists near intrusions of granitic laccoliths and also through sandstone and the few limestone patches. About $8,000,000 has been spent on these borings, with the following results: of 302 borings in gneisses and micaceous schist, 63 were failures, and of the 239 successful borings, 114 yielded good water and 125 inferior water; and of 87 borings in sandstone, 26 were failures, and of the 61 successful borings, 24 yielded good water and 37 inferior water. Hence of the total number of 389 borings, 22.9 per cent were failures, 35.5 per cent yielded good water, and 41.6 per cent yielded inferior water.

The hourly flow of water from the successful borings varies greatly. The average flow to a well is about 3500 liters; the largest hourly flow recorded was 5500 liters continuously for 10 days. Water is considered "good" when it has less than 1500 milligrams of salt to a liter; the salt content of "inferior" water may be as high as 3500 milligrams a liter. Both the quantity and the quality of the water in a single well may vary greatly, even in a single season and where no connection with the precipitation in the contributing areas can be discovered. Almost all the water obtained from bored wells is used for household purposes and for watering cattle. Not more than a dozen wells in the region are used for irrigation. It is safe to say that an important part of the supply is willfully wasted, since the native is obstinately disobedient to rules of economy. He prefers to wait for a rain before he sets about his planting, and coöperation in digging a small ditch in order to profit from a surplus of underground water is commonly not even considered. Furthermore, the writer is very doubtful whether

the educational work of the Inspectoria Federal de Obras contra as Seccas will succeed in modifying this state of mind.

Other measures for improving the water supply of the region, rather more Utopian in nature, have also been discussed. Since 1912 the diversion of a part of the waters of the Rio São Francisco into the basin of the Jaguaribe has been the subject of some study.[9] This gigantic task would involve the construction of a main canal about 500 kilometers long that would tap the São Francisco at Petrolina and open into the upper course of the Jaguaribe and of several branches, to eastern Pernambuco, Parahyba, and eastern Ceará, for example. It is believed that the diversion of about one-fourth of the minimum water supply of the Rio São Francisco, or about 280 cubic meters a second, would be enough to feed the side canals to the semiarid states and to supply 45 to 60 cubic meters a second to the Jaguaribe. So far as topography and technique are concerned, the plan seems feasible, but it is questionable whether funds could be found to finance it. Furthermore, it is uncertain whether the supply of water that it is estimated would be furnished to the branch canals would be sufficient to permit the irrigation of "at least" 240,000 hectares for 6 hours every sixth day, as is asserted in the plans for the project.

As it is generally believed that the periodic occurrence of both droughts and floods is partly due to the steady destruction of the forests, reforestation occupies an important position in plans for the region. The possibilities for carrying it out, however, are very poor, to say the least. Suitable soils with a humus cover adequate for the small trees, enough soil moisture to maintain a young forest, and varieties of timber sufficiently acclimated to the peculiar conditions are all lacking and can be developed, if ever, only by hard, painstaking work for several generations. Up to the present almost nothing practical has been done on these preliminaries.[10] Furthermore, there is strong evidence that man is utterly powerless here. Not only Indian traditions concerning droughts but, what is more significant, discoveries of the remains of forests in the middle of the present semiarid region indicate that the region is passing through the last period in a cycle that has involved the first occupation of bare rock by inferior plants, the birth and growth of forests, their decay as the result of chemical processes of destruction,[11] the invasion of caatinga, the starving out of the caatinga, and the final reappearance of bare rock. To take up arms against this process of nature would seem to be beyond the strength of man.

[9] J. Bouchardet: Os problemas do Norte, Rio de Janeiro, 1912.

[10] F. W. Freise: Die Waldverhältnisse im Dürregebiet des Nordostens von Brasilien; Anfänge, Pläne und Möglichkeiten der Aufforstung, *Zeitschr. für Weltforstwirtschaft*, Vol. 4, 1936–1937, pp. 307–330.

[11] F. W. Freise: Erscheinungen des Erdfliessens im Tropenurwalde, *Zeitschr. für Geomorphologie*, Vol. 9, 1935–1936, pp. 88–98.

The raising of xerophilous plants has proved more encouraging. Among these are cacti, for essential oil from the seeds; rockroses, for labdanum; several species of *Eriodendron* (native names: *paineira*, *barriguda*, *pao de kapk*), for fats and essential oils and fibers and also as supports for vines grown to shade young plants. On the whole, however, these experiments are still of too little importance to permit any conclusions regarding general applicability.

To complete the picture, mention should be made of attempts at breeding fish in the reservoirs and of road construction. Both are complete failures so far as present experience goes: fish breeding because the fish cannot adapt themselves rapidly enough to the changing salinity of the water, so that rain or a period of heavy evaporation results in their total extinction; road construction because it annually increases by many hectares the amount of bare and exposed ground without contributing effectively to improvement in transportation. Motorcars are not used; the mule driver incorrigibly follows the time-honored beeline tracks from one place to another; and the cattle drives—for example, from the highlands of Maranhão or Piauhy to Bahia or farther south—follow the edge of the caatinga because of the little food to be obtained from cacti or wild pineapples or move from one water hole to another directly across the slight elevations or through the dry river beds.

Prospects for the Region

Whether the supplying of water to the drought region of northeastern Brazil can be realized on the gigantic scale proposed in the projects for water storage or stream diversion seems doubtful. If any real improvement of the region can be expected from the present activities of the various public and private agencies, it will be for the benefit only of future generations of the inhabitants. Much more detailed work will have to be done before even a part of these vast projects can be carried out in the field. Perhaps those periodic calamities, which not only affect the northeastern states but have their repercussions throughout the life and economy of all Brazil, could be at least mitigated, if not overcome, by a controlled and methodical evacuation of the regions most frequently hit by drought, by limiting reservoir construction to those areas where the incidence of drought is not so severe, and by shifting agricultural activities to such special crops as are really suited to semiarid country.