

Present-Day Forest Refuges In Northeastern Brazil

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ABSTRACT Present-day forest refuges exist in northeastern Brazil. They occur at elevations of over 500 m as forest islands within the arid caatinga that surrounds them, and are locally called *brejos*. Thirty-one of these refuges have been identified. Plant species reached these forest areas at times of greater humidity when continuous forest existed. Examples of species now confined to the *brejos* include *Phyllostylon brasiliensis* Capanema, *Caesalpinia peltophoroides* Benth., *Manilkara rufula* Miq., *Myrocarpus fastigiatus* Fr. All., *Huberia ovalifolia* DC., *Rubus brasiliensis* Mart., *Lamanonia speciosa* (Camb.) L. B. Smith, *Gallezia gorarema* (Vell.) Moq., *Prunus sphaerocarpa* Sw., and *Podocarpus lambertii* Klotz.

Conversely, dry region species have become isolated by extensive areas of forest and *cerrado* and are also in refuges in northeastern Brazil. Examples include *Prosopis ruscifolia* Griseb., *Schinopsis brasiliensis* Engler, *Anadenanthera macrocarpa* (Benth.) Brenan, *Amburana cearensis* (Fr. All.) A. C. Smith, and *Phytolacca dioica* L.

THE PUBLICATIONS OF Haffer (1969), Vanzolini (1970), Müller and Schmithüsen

(1970), Vuilleumier (1971), Van der Hammen (1972) and others have contributed significantly to the solution of problems in animal speciation during the relatively dry and cool climate periods of the Pleistocene and upper Pliocene when populations were confined to refuges within the Amazon region. Little reference is made to the vegetation in these works, and when reference is made, only the Amazonian vegetation is discussed.

These authors have tried to show the role of refuges within Amazonia in the preservation of the genetic pool. Speciation has taken place following isolation into separate populations. These new genetic entities have later filled the Amazon area and some have even spread beyond it. An example of this is found in Vanzolini (1970), who discussed the fauna of the *brejos* of northeastern Brazil. The question of refuges for plant species in Amazonia was discussed more specifically by Prance (1973), whose arguments were based on the distribution of various plant families.

The *brejos* and some other areas of northeastern Brazil are present-day refuges for both plant and animal species. They have a more humid and cooler climate than the arid caatingas which surround them. The term *brejo* is applied to a type of vegetation restricted to certain areas of northeastern Brazil. *Brejo* literally translated means a low, depressed area with poor drainage in which the soil remains waterlogged for relatively long periods, i.e., a swampy area. In northeastern Brazil (the states of Bahia, Sergipe, Alagoas, Pernambuco, Paraíba, Rio Grande do Norte, and Ceará) the term *brejo* is applied differently. It is applied to those hills that are exposed at right angles to humid winds (mainly from the southeast) and are forest-covered because their eleva-

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tion causes the air to cool, with condensation of humidity and consequent precipitation. The lower temperatures are also due to altitude. Under these conditions, in contrast to the low sparse vegetation of the surrounding caatinga, that of the slopes becomes gradually denser and higher and becomes forest where trees of 25–30 m in height and 1 m in diameter may occur. Examples of the large trees are *maçaranduba* (*Manilkara rufula* Miq.), *jucá* (*Caesalpinia leiostachya* (Benth.) Ducke), and *pau d'algo* (*Galesia gorarema* (Vell.) Miq.).

Scientific study of the brejos began with the work of Oliveira and Andrade-Lima (1948) and continued with Andrade-Lima and Caldas Lins (1964), Andrade-Lima (1964a), and Vasconcelos Sobrinho (1971). Each of the above works described and defined the brejos, and discussed the factors which cause them to exist, and some mentioned briefly the role of the brejos as faunal refuges. The purpose of this paper is to discuss the function of brejos as refuges of flora and also to mention the refuges of northeastern Brazil in habitats other than brejos. These other refuges are equally important to the dynamics of the regional floristics and vegetation.

We now have a good knowledge of the plant species that occur in the brejos and the other northeastern refuges. However, it is still too early to state definitely at what period the continuous vegetation cover occurred or to know at what time the continuous forest cover was split apart, resulting in the isolation of the refuges which are scattered over a wide area (fig. 15.1). We cannot even be certain whether the forested area is still shrinking today or whether, the arid vegetation attained its maximum extension sometime in the past, and is now in a new phase of coalescence.

Examples of disjunct distributions are numerous and diverse. They seem to indicate that we are not dealing with a set of cases derived from a single historic event, but with diverse cases resulting from a diversity of historical processes. This can be illustrated by the three following patterns that occur in northeastern Brazil.

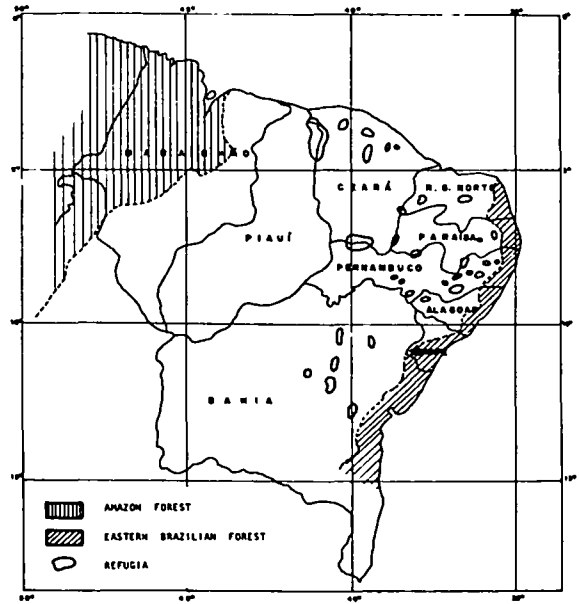


Figure 15.1 The present day forest refuges of northeastern Brazil.

1. Species of humid environments which tolerate reasonably high temperatures, occurring in disjunct areas separated by a barrier of drier climate.
2. Species in refuges formed by local topoclimates with lower average temperatures, these, like the first category, being confined to refuges by warmer climates in the intervening space.
3. Species of semiarid climates—these are the opposite of the last type, their disjunct areas of dry climate being separated by a barrier of variable humid climates and forests.

Good examples of the first category (species of humid environments in enclaves surrounded by arid vegetation) are the brejos of the northeast located within the sertão region (the drier area with the arboreal caatinga) which has a higher mean temperature. The second category includes some brejos that are still linked climatically to the northeastern tropical rain forest and are dependent on the Polar-Atlantic Front. The front causes them to have lower temperatures and greater humidity and cloud cover than is typical for their latitude.

The present paper concentrates mainly on those species characteristic of humid environments, which in the northeast are now confined to elevations because the intervening area is occupied by caatinga, a vegetation of semiarid climate zones.

The flora of the brejos, now isolated in patches on the tops of hills, must have reached the area before the caatingas invaded the area and isolated the brejos. It is thus necessary to consider briefly the origin of the caatingas and their flora.

The caatingas consists of arboreal or shrubby formations which are deciduous and of which many members are spinous. Cactaceae and Bromeliaceae are an important element of most caatingas. Northeastern Brazil also has small areas of other vegetation types such as evergreen forest and cerrado, but most areas of these vegetation types have been turned into agricultural land, mainly for the production of sugar cane.

The caatingas, because of their present day isolation, were originally thought to be an autochthonous vegetation. However, as the result of numerous studies (Ducke 1953; Schnell 1961, 1966, 1971; Rizzini 1963; Andrade-Lima 1964b; and others), and of my current work, it has been shown that they have a largely alien origin, especially at the generic level, and to a lesser degree at the species level. There is a predominance of taxa which appear to have reached the area by a southwest-northeast migratory route, but the actual floristic composition of the caatingas can only be explained through the recognition of other routes, still not well defined. The source of the majority of caatinga taxa appears to have been the northern part of the Argentinian-Paraguayan-Bolivian chaco. Although this is as yet not proven, there appears to have been more than one expansion of this xeric flora between the end of the Tertiary and the last period of glaciation, whenever more arid climates predominated over the South American continent.

Ab'Sáber (1977) also postulated the multiple expansion of xeric vegetation types into areas of Brazil occupied today

by forests or cerrados when he concluded "One can only map the areas which were more frequently invaded by predominantly dry systems. . . . which occurred several times in the Quaternary and invaded the area which is dominated today by tropical ecosystems." However, he does not give evidence of the various invasions of the floras diversely tolerant of the ranges of humidity and temperature that occurred in South America between the Tertiary and the present day.

Rizzini (1963), commenting on the allochthonous nature of the caatinga flora, observed that of the total flora probably only the genera *Fraunhoferia*, *Auxemma*, and *Xerotecoma* are peculiar to the caatinga. However, it should be pointed out that Gentry (1976) placed *Xerotecoma* in synonymy under *Godmania*, leaving only *Auxemma* and *Fraunhoferia* as exclusive caatinga genera. Rizzini recently added a third genus, *Apterokarpos*, which is confined to the caatingas of northern Bahia and southwest Pernambuco. Whatever the exact number of endemic genera, it is obviously too small to suggest that the caatinga has its own unique flora which arose in the region.

A few examples will be given of species or genera from various parts of Brazil or beyond which are now isolated in the islands of the brejos of northeastern Brazil, which function as refuges and protect their species from the invasion of the surrounding caatingas.

Phyllostyllon brasiliensis Capanema : According to Carauta (1971) occurs from Argentina to Mexico and is cited in Brazil from Ceará, Pernambuco, Espírito Santo, Minas Gerais, Rio de Janeiro, Paraná and Santa Catarina. In Pernambuco it was collected on Serra do Cumunati in the municipality of Aguas Belas; Serra da Baixa Verde in the municipality of Triunfo, and Serra Negra in the municipality of Inajá. In all three cases this species was represented by trees of 10-12 m height and perfectly adapted to their environment. In this example and in the others which follow below the collection data always mention Serra

(hill or mountain) which would have on its summit the moist vegetation characteristic of the *brejos*. There is a distance of 2,000 km, mainly covered by caatinga, between these northeastern hills and Rio de Janeiro, which forms an effective ecological barrier between the populations of the northeast and the southeast. *Phyllostylon* is a typical example of a moist forest species which occurs in refuges within the arid northeastern region.

Caesalpinia peltophoroides Benth. : This is also isolated in the *brejos*. It is common in Tijuca forest in Rio de Janeiro and also occurs in the state of Alagoas where it is found in a humid forest environment on the eastern slopes of hills in the municipality of Colônia Leopoldina. It also occurs on the upper part of Serra de Taquaritinga at an altitude of 1000 m, close to the border of the State of Paraíba well within the caatinga region. This is the only refuge in which *C. peltophoroides* is known.

Manilkara rufula Miq. : This is much more tolerant. It is found in the semideciduous forest of the municipality of Jaguaquara, Bahia and does not occur in the low and dry area to the north but reappears in upland refuges in the states of Alagoas (Mata Grande), in Pernambuco (Inajá on Serra Negra, Brejão, Pesqueira on Serra de Ororubá, Gravatá on Serra das Russas, Bezerras on Sapucarana, Buíque on Serra de São José), and in Paraíba (Areia). These disjunct localities are evidence of the wide distribution of this species in its migrations.

The genus *Myroxylon* (whether or not it is considered monotypic) is similar and is distributed from northern Argentina to Mexico (except most of Amazonia). In northeastern Brazil it is always found in the refuges of the humid hills as is confirmed by collections between Caetés and Garanhuns in Pernambuco, from the *brejos* of Natuba in Paraíba, and from other hills.

Myrocarpus fastigiatus Fr. All : This is less frequent in the northeastern refuges. According to Hueck (1972) it is part of the flora of Espírito Santo and Rio de Janeiro and was collected only once in a northeastern refuge, Brejão in Pernambuco.

Huberia ovalifolia DC. was originally known from the sands of Copacabana, from restingas, and from the Corcovado, all in Rio de Janeiro, as well as in Minas Gerais. It has now been collected in a single northeastern locality, Brejo da Madre de Deus, Pernambuco, at an altitude of 850 m.

In the same area and on Serra dos Cavalos, Caruaru, Pernambuco there are several other species which survive at altitudes above 600–650 m, for example, *Rubus brasiliensis* Mart. and *Smilax nitida* Griseb., both characteristic of the flora of Rio de Janeiro.

Lamanonia speciosa (Camb.) L. B. Smith is even more adaptable and is present in southern Brazil, São Paulo, Rio de Janeiro, Minas Gerais, Bahia (Serra de Jacobina) and in various northeastern mountain refuges.

Gallezia gorarema (Vell.) Moq. has approximately the same distribution as the last species but requires greater humidity. It is a member of the flora of the states of Rio de Janeiro and São Paulo and has dispersed to the northeast where today it is found on only a few mountains such as the northeastern part of Borborema in Paraíba, near the town of Bananeiras.

Anchieta is an example of a genus which needs high humidity but is tolerant of lower temperature. It is distributed from Argentina to São Paulo, Rio de Janeiro, Minas Gerais and Goiás. In the northeast it was collected in the humid and elevated part of Gravatá municipality (isolated from the coastal forests only in its northern part, covered by caatinga), and on the upper slopes of Serra de Aratanha, Pacatuba municipality, Ceará, where it is surrounded by caatingas.

It could be thought that only species from climates with lower average temperature than that of the caatinga are found in the northeastern mountain refuges. There are, however, species widely distributed in a subxerophytic environment such as *Goniorrachis marginata* Taub., which is common in the dry areas of Bahia (Feira de Santana, Riachão do Jacuípe, Brejão etc.), absent north of Jacobina, but reappears in

Pernambuco in the Cumunati refuge in Aguas Belas municipality. The environmental difference between the caatingas of Bahia, where this species is common, and the caatinga area between Bahia and Cumunati, must be small. Although small, the difference is enough to interrupt a continuous distribution.

Pentapanax warmingianum (L. March.) Harms is another example of a southern species (forests of Alto Uruguai in Rio Grande do Sul and western Paraná) which also occurs in refuges in the northeastern mountains. This species was found 12 km west of Jacobina and 49 km west of Campo Formoso, Bahia and, further north, surrounded by caatinga, in the hills of Varas and Umã in Pernambuco and Serra de Santana in Rio Grande do Norte.

The presence of *Prunus sphaerocarpa* Sw. in the flora of Serra de Baturité, Ceará is notable. This species is frequent in subtropical mountains of the south and south-east (Ducke 1959).

Various other examples could be cited to demonstrate the existence of refuges for southern species in the humid highlands or brejos of northeastern Brazil, but the species cited above are enough to demonstrate this clearly. However, it is also important to draw attention to the fact that these brejos refuges also contain Amazonian species. There is a certain zonal pattern in the refuges. The species and genera of the southeastern flora are more common in the brejos that lie further inland in the states of Alagoas to Rio Grande do Norte, while those of the Amazonian flora are better represented in the humid mountains nearer to the coast, especially, between Pernambuco and the border of Ceará and Piauí.

A few examples of Amazonian species in the upland refuges of the northeast may be cited.

Apeiba tibourbou Aubl., common in Amazonia and also present in the forests of eastern Brazil, is found in the brejos of Areia, Paraíba and the Serra or Chapada do Ibiapaba, Ceará. The babaçu palm (*Orbignya martiana* B. Rodr.) is another example cited by Rizzini (1963). This species

is widespread in Amazonia and reappears, surrounded by caatingas, in the upper parts of the Serras Ibiapaba, Meruoca, Uruburetama, Baturité, Maranguape, and Aratanha in Ceará, Serra da Borborema in Areia, Paraíba and on the humid slopes of the Serra do Araripe in Ceará and São José in Pernambuco. The Amazonian Rubiaceae, *Hillia parasitica* Jacq., also occurs in the Serras Aratanha and Maranguape in Ceará. The beautiful *Norantea guianensis* Aubl. (Marcgraviaceae), also an Amazonian species, is found on the humid part of Serra do Ibiapaba, Tiangua municipality, Ceará.

Langsdorffia hypogaea Mart., a widespread species of tropical South America, occurs on the upper parts of Serra de Maranguape (see Ducke 1959) and Serra de Buíque, Pernambuco.

Viola surinamensis (Rol.) Warb. is in a refuge on the upper slopes of Serra do Ibiapaba, Viçosa do Ceará municipality, Ceará.

An as yet unidentified species of the Amazonian genus *Elvasia* was collected in the uplands of Serra da Mascarenha, Pernambuco. Unfortunately this species, whose flowers have not been collected, may never be identified since the vegetation of that mountain was cut down and may never regenerate. This is not an isolated occurrence for there is a general tendency to deforest these mountains. It is therefore urgent to make a detailed study of these refuges, and such a study is now underway.

A less typical example is *Parkia platycephala* Benth. which occurs in the mid-Tocantins of Pará (Ducke 1959), is widely distributed on the flattened sandstone mountains of Piauí and Ceará (Ibiapaba and Araripe), and even reaches Bahia.

These few examples confirm the paleodistribution of Amazonian species into northeastern Brazil prior to the process of the emptying of the large northeastern depressions which allowed the enlargement of the area of caatingas and isolated the Amazonian species in the higher altitudes of the moderate northeastern relief.

The second type of refuge in the north-

east, sheltering species that persist in the refuge because of the lower temperature of the forested brejo, is characterized by the presence of *Podocarpus sellowii* Klotz., as on Serra dos Cavalos, Caruaru municipality, in Pernambuco. The surrounding area is all caatinga. The mountain is forested and very moist, and contains several representatives of other floras as mentioned above. *Podocarpus sellowii*, however, is confined to a small part of the high slope of the mountain which faces towards the southeast, the direction of the prevailing humid and cooler wind which blows most of the year. *Podocarpus* is well adapted to this small restricted area and produces abundant seedlings while individuals of all ages occur and develop well.

A second example is *Podocarpus lambertii* Klotz., a species which is common in the subtropical region of southern Brazil, but persists in the refuge of the highest parts (1,012 m) of Chapada Diamantina, Morro do Chapéu, Bahia.

The third type of refuge of northeastern Brazil contains subxerophytic and xerophytic species which are common elsewhere in arid areas but are found in disjunct parts of the northeast. These species are isolated by large areas of forest and cerrado from other populations of their kind and are thus also a contemporary refuge.

The best example of this is *Prosopis ruscifolia* Griseb. which is common in the Argentinian *monte* and *chaco* and in Paraguay. This species migrated to northeastern Brazil in the drier climate phase. However, only one very old tree appears to remain near Cachoeira do Roberto, Afrânio, Pernambuco (see Neiva & Pena 1916; Ducke 1953). The region where the northeastern *P. ruscifolia* occurs is on the plateau between the basins of the Parnaíba and São Francisco rivers. Other individuals have probably disappeared through the progressive erosion of the area and it is possible that no other trees of *Prosopis* will ever be found in the region.

Many other species show this same disjunction between the Argentinian-Paraguayan-Bolivian *chaco* and northeastern

Brazil which, however, have larger populations. These have been cited by various authors (Ducke 1953; Rizzini 1963; Schnell 1971; Hueck 1972; and others). A few examples are: *Schinopsis brasiliensis* Engler with two varieties *brasiliensis* and *glabra* Engler; *Anadenanthera macrocarpa* (Benth.) Brenan; *Amburana cearensis* (Fr. All.) A. C. Smith; *Pterogyne nitens* (Kunth) Benth.

Phytolacca dioica L. merits separate discussion. This species is common in Argentina, Uruguay, and southern Brazil in areas which cannot be considered arid, but it reappears in the xeric caatinga east of Campo Formoso, Bahia where there are many individuals scattered through the community. These are, however, confined to a rather small area at altitudes between 500 and 800 m. The unusual nature of this disjunction leads one to question whether it is of human origin through the transport of seeds for cultivation. However, the integration of *P. dioica* into the landscape and the lack of a reason for bringing this species such a long distance argue against human dispersal. Furthermore this species also occurs in Peru (Record & Hess 1949), which is even further from its center of distribution, a fact that confirms that this species had a wide natural paleodistribution. It has now become fragmented into three populations through climatic changes in the intervening areas.

A larger number of species and genera could be mentioned, but there is not space here to give an exhaustive list. I have given examples which clearly demonstrate the existence of these disjunctions and their bearing on the refuge situation.

Future continental climate changes could produce connections between the far distant areas with xerophytic floras should they produce drier climates, or a general flora more tolerant of humid climate if the reverse occurs. Whatever the future, the moderately humid climate of today in northeastern Brazil is not so dry as to allow the whole region to be covered by caatinga, nor is it humid enough to replace the caatinga with forest.

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