The vegetation types of the Brazilian Amazon

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CHAPTER 7

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CONTENTS

7.1. INTRODUCTION

In this chapter we try to analyse the principal variations in the forms of vegetation in the Brazilian Amazon, and the practical ways in which the inhabitants of the region classify and name these variations. Because more than half of the Amazon region is situated in Brazilian territory, the concepts analysed here can be, for the most part, extrapolated for all of Amazonia.

7.2. THE AMAZONIAN VEGETATION AND ITS PHYSIOGNOMIC CHARACTERISTICS

The Amazon region is a physiographic and biological entity which is well-defined and distinct from most of the rest of South America by its dense forest, and large biomass. It should be emphasised that this broad physiognomic view is not based on a superficial, or purely scenaric interpretation but rather on one from the origin and evolution of the region as a single unit. The relief for example, is very important because it is related to the division of the region into older and younger areas, it has geological implications, hydrological implications and is closely related to the origin of the region.

The hydrographic basins are very important in relation to the flora. Physiognomically the forest is uniform, but, when analysed in detail, the composition varies a great deal from place to place and there is a very evident correlation between the similar forest types and the hydrographic basins. Adolfo Ducke, one of the botanical experts of the region, believed that the floristic division of the Hylaea is linked to the rivers. The opinions of renowned zoologists and limnologists corroborate this from faunal evidence.

Another important factor in the floristic and vegetational diversity of the area is the effect of the ocean level which has, in the past, caused erosion and sedimentation. Recently much discussion has arisen about the climatic variation (particularly the climatic fluctuations of the Pleistocene) which has affected the vegetation, and is discussed separately in Chapter 8 of this volume.

Amazonia occupies a vast area of South America, nearly 6,000,000 km^2, with more than half of this in Brazilian territory. The enormous area of dense forest is continuous around its perimeter, while in the interior there can be interruptions, or places where small or relatively large non-forest formations occur. The forest region usually appears physiognomically uniform; however, when examined in detail, considerable local variations of vegetation and floristic composition are encountered.

The term 'vegetation' refers to the life-forms which are associated, in various ways, in each area, or are the result of the adaptations which better adjust it to environmental variations. Ecological and environmental variations always exist, even in areas which are relatively close to one another, creating a large number of niches for the different species. The vegetation types are therefore physiognomic or landscape patterns which are practically differentiated and named by the local people. The floristic differentiation is somewhat more subjective and depends on the species found in association with one another. We intend to outline the former types of vegetation which are easily recognised by local people, yet make good sense botanically.

The detailed study of the variations which occur in the vegetation and flora is a complex issue. However, in an overview, major groups of physiognomic variation patterns can be established. The practical classification which is used regionally in Amazonia is based primarily on the relief, and it recognised two principal types of vegetation: terra firme and inundated formations (várzea and igapó). As Amazonia is basically a forest region, the terra firme and várzea forests are of primary importance, the non-forest types of vegetation are more restricted in area and of less importance.

Before giving a detailed analysis of Amazonian vegetation, it is necessary to take a general and superficial look at the vegetation of the tropics as a whole. Because Amazonia is part of a larger universe, vegetation of the humid tropics, there are many worldwide physiognomic and functional similarities.

7.3. GENERAL NOTIONS ABOUT TROPICAL VEGETATION

It is generally accepted that the colonisation of the earth by plants had a point of origin and an evolutionary development, but there is little to document this history. However, even today certain areas occasionally open up for new colonisation and provide evidence of how plants occupy new areas. This occurs, for example, in clearings caused by storms, natural changes in river courses, and new lands arising from volcanoes. In tropical areas, clearings tend to be invaded by plants in such ways that the biomass gradually increases until it reaches a climax. In this evolutionary process there is a time when competition begins between these species, and at this point natural selection begins to play a more important role.

When the whole globe is analysed in terms of vegetational cover and their variations, two principal areas become evident: the tropical region and the temperate or cold region. The tropical region is that in which natural selection is primarily governed by competition to capture and use light and water. In cold regions, a third factor enters into play, temperature. In the case of the lowland tropics, plants do not need to develop specialised mechanisms to adapt to temperature variations because, by definition, the temperature is elevated and uniform for the whole year. For this reason, the protection of buds which serve as the base for the classification of life-forms by Raunkiaer is not as important for the humid tropics.

Theoretically, the tropical region is the region up to 23° 27' north and south of the equator. This belt, however, can vary a lot depending upon the climate, altitude and other factors. The humid tropics (mainly forest vegetation) are differentiated from the arid tropics (with largely non-forest vegetation) by their humidity.

In the tropics, natural selection depends mainly on competition for either light or water, but usually not on both at the same time. This is because under optimal conditions (when there is no lack of water) the biomass tends to be high and the plants tall, and the plants use cover (which produces shade) as a means of eliminating competitors since there is no competition for water. When there is a shortage of water, the plants cannot form a large biomass, and are unable to cover all of the three-dimensional space which is available. Consequently, the sun penetrates to the ground and light is, therefore, not an object of competition. This is an important aspect in order to understand tropical vegetation. The structure and function of the vegetation is dependent on this, as are the association of small, medium and large sized species, the distribution of individuals by size categories, by age classifications, by means of reproduction, by growth increments and their position in successions.

The only other factor of such importance as light and water is that of the avoidance of predators, which abound in tropical forest. However, this does not express itself so much in the form of the forest, but rather in the chemistry of the plants (*see* Janzen, Chapter 11, this volume) or in special adaptations such as ant associations (*see* Benson, Chapter 13, this volume).

One characteristic of the humid tropics is the large number of associated species in any area. This leads to complex interrelations among themselves, with the fauna, and with the physical environment which fosters competition, symbiosis, commensalism and parasitism. In some places, restrictions on plants' lives may arise through limiting stress factors. In this case the plant species must specialise. This affects the floral composition of the area and can give rise to specially adapted endemic species, and it generally causes decreased biomass.

The difficulties or restrictions to development which affect tropical plants, are usually related to the lack of or excess of water. The lack of water is often seasonal. For example, in rocky and shallow soils a short drought can have serious consequences. In the case of an excess of water such as when the water table is near the surface, it can rise to the surface in the rainy season and the aeration of the soil is disturbed, impeding root respiration.

Also, it is important to emphasise that the quantity of biomass of a particular vegetation type is not necessarily correlated with soil fertility. Massive forests can develop on soils of a very low fertility, by the developmental process of a slow gradual increase. This ultimately results in a closed ecosystem, in which the nutrients are stored in the plants themselves, and thanks to a good system of retention, the insignificant loss caused by leaching, is compensated for by nutrients which come with rainwater. In such a complicated ecosystem, primary production depends on secondary production (decomposition), on the live parts which die and disintegrate and are recycled back into the system.

7.4. REGIONAL NAMES FOR PRINCIPAL TYPES OF VEGETATION OF BRAZILIAN AMAZONIA

Amazonia falls within the humid tropical region and is largely covered by climatically controlled vegetation which extends over a vast area. Since relief plays an important role on the vegetation type, the vegetation is divided into two principal groups, the terra firme vegetation and the inundated vegetation (várzea and igapó). Inundated vegetation is defined as all the flood plains (Moura, 1943) and any areas which become flooded by the rise of the water table on a seasonal or permanent basis.

Within Amazonia there has been much confusion over the local terms for inundated vegetation: várzea and igapó. In lower Amazonia igapó is used for the areas where flooding is more pronounced, but in upper Amazonia it is used for blackwater flooded areas. Here we have adopted the terms as defined in Prance (1979) where várzea is used for areas flooded by muddy or whitewaters and igapó for areas flooded by black and clearwaters.

A practical way to express the differences between vegetation types is to correlate the differences with the index of biomass. Similar types of vegetation have approximately the same biomass. Biomass can be expressed by the basal area of trees per hectare, using individuals of 30 cm or more in circumference. On this basis, the exceptionally large forests can exceed 40 m^2 of basal area. The open forests or vine forests usually are between 18 and 24 m^2, and open grass savannahs will register zero.

The estimate of the biomass can be expressed in several ways. The weight is difficult to obtain and the volume involves estimates of height which vary from person to person. For practical purposes, the basal area is very useful and is easily obtained.

The principal vegetation types as they are locally known are shown in the following summary:

1a. Widely distributed vegetation formations
  2a. Forest formations of relatively dense biomass
    3a. Forest on terra firme (*mata densa*)

- 4a. Dense forest
- 4b. Open forest formations (*mata aberta*)
  - 5a. w/o vines and palms
  - 5b. w/palms
  - 5c. w/vines (Liana Forests)
  - 5d. Dry forest
  - 5e. Montane forest
- 3b. Várzeas and igapós, seasonal and permanent swamp
  - 6a. Forest on clay soil (muddy river water)
    - 7a. Várzea forest of Upper Amazonia
    - 7b. Várzea forest of Lower Amazonia
    - 7c. Estuarine Várzea forest
    - 7d. Lower Rio Branco Swamps (*chavascal or pantanal de Rio Branco*)
  - 6b. Seasonal igapó forest on white sand
- 2b. Savannah and other low biomass non-forest vegetation
  - 8a. Terra Firme Savannah
    - 9a. Open Savannah
    - 9b. Orchard Savannah (*campo coberto*)
    - 9c. Roraima Savannah
    - 9d. Rock Outcrop formations (*campo rupestre*)
    - 9e. Coastal Savannah
  - 8b. Várzea Savannah
- 2c. Amazonian Caatinga and Campina, oligotrophic formations on white sand
- 1b. Vegetation covering restricted areas
  - 10a. Mangrove swamp
  - 10b. Restinga
  - 10c. Buritizal (*Mauritia* formations)
  - 10d. Pirizal or cariazal

7.5. GENERALISATIONS ABOUT FOREST FORMATIONS

Forest as defined here is dense vegetation which develops in the places where conditions allow the formation of an appreciable quantity of biomass (depending on the humidity of the area), thus allowing associated species to compete for light. This occurs when the basal area reaches something above 10 m^2 per hectare. Forests are characterised by their lack of grasses and sedges (Poaceae and Cyperaceae) between the trees. The denser the forests, the cleaner the forest floor, with the decrease of shrub like plants, herbaceous plants and vines. Lianas climb directly to the crown and do not block the area between the trees.

In the forest the orientation of the branches becomes important, the plants must adapt themselves to positions where they will receive enough light. Consequently the architecture of the branches plays an important role. For this reason, the physiognomy of forest plants is unique. This can be seen when the forest trees are isolated and survive in man-made clearings. These trees have very irregular asymmetrical crowns and expand their branches in directions which in the forest have more light. For this reason it is very difficult to present an adequate picture in a forest profile diagram, as used by various authors to illustrate the supposed stratification of crowns in the forest (Fig. 7.1).

A very interesting subject is the analysis of the lianas of a forest to understand how they reach the crown. There are vines which climb straight up looking like a normal plant initially, and only entwine

Fig. 7.1. A profile of dense terra firme forest near Altamira, Pará, Brazil.

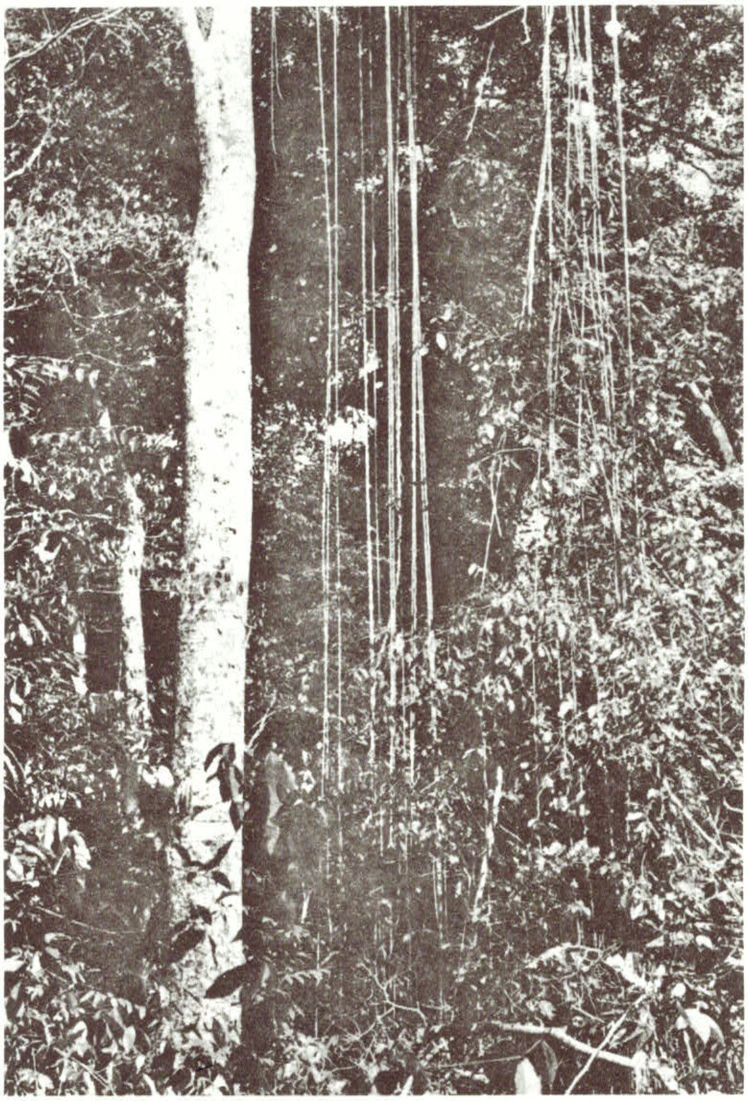

Fig. 7.2. The cord-like roots of epiphytes which eventually reach the soil hang down from plants on the high branches of trees.

when they reach the canopy. Some species of liana begin their growth as an erect tree-like plant and only later turn into a vine, for example, Krukoff (1942: 253) refers to some species of *Strychnos* with this growth habit. Other species have a marked dimorphism between the young and adult stages. Some Araceae and Bignoniaceae when young are slender climbers which grow up the trunks of large trees, pressed firmly against the bark. When they reach a certain height the leaves and stem change completely so that an uninitiated person would never associate the two together because of their completely different appearance.

There are also semiepiphytes which begin their growth as epiphytes, i.e. they germinate in the trees and in their juvenile stage are epiphytes which obtain enough light, and are adapted to conserve and to

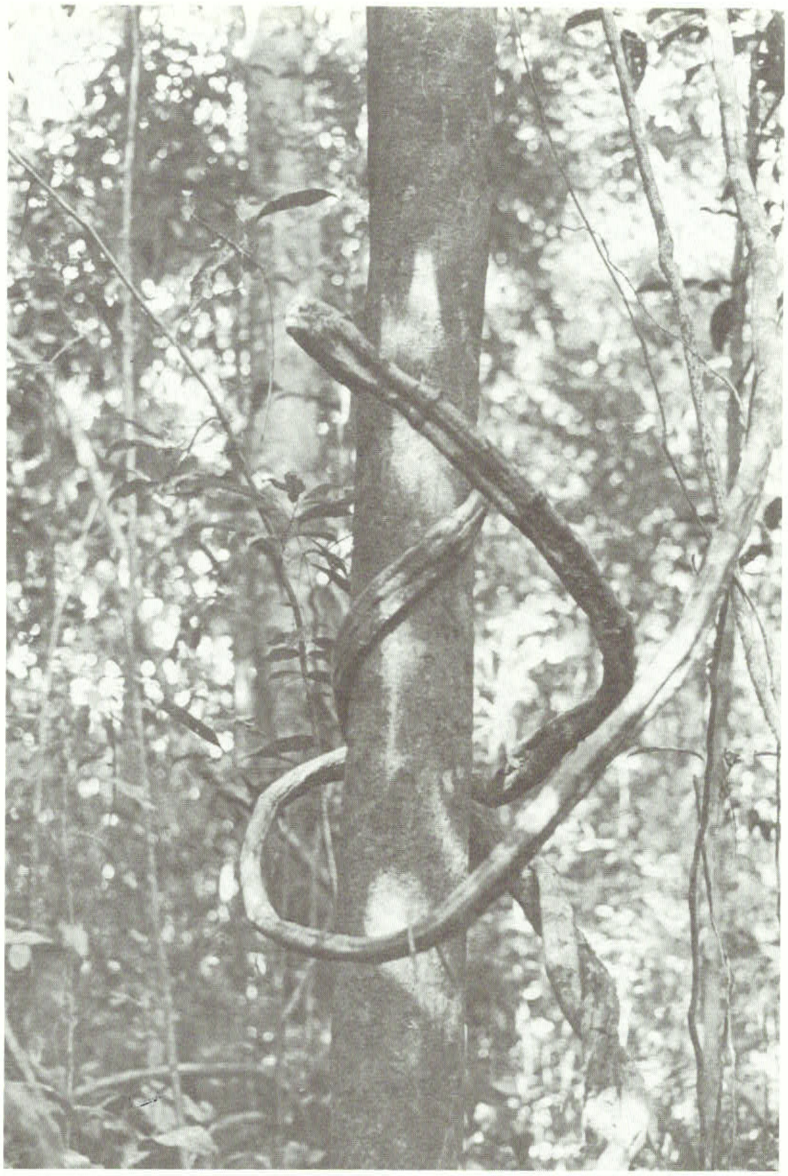

Fig. 7.3. Robust woody lianas are a characteristic of dense Amazon forest.

capture water. However, they then produce pendant cord-like roots that can be seen swinging in the wind (Fig. 7.2). In time these roots grasp the trunks of their host trees and when the roots reach the soil and plentiful water they lignify and change the plant into an independent individual.

Strangling plants (Pires and Dobzhansky, 1956) are a variation of this habit. These plants begin as epiphytes and after the roots reach the soil they enlarge and rapidly increase in number. They also fuse with other roots to form a column which completely surrounds the trunk of the host tree which disappears inside this jacket and generally dies. However, in some cases both crowns survive as is

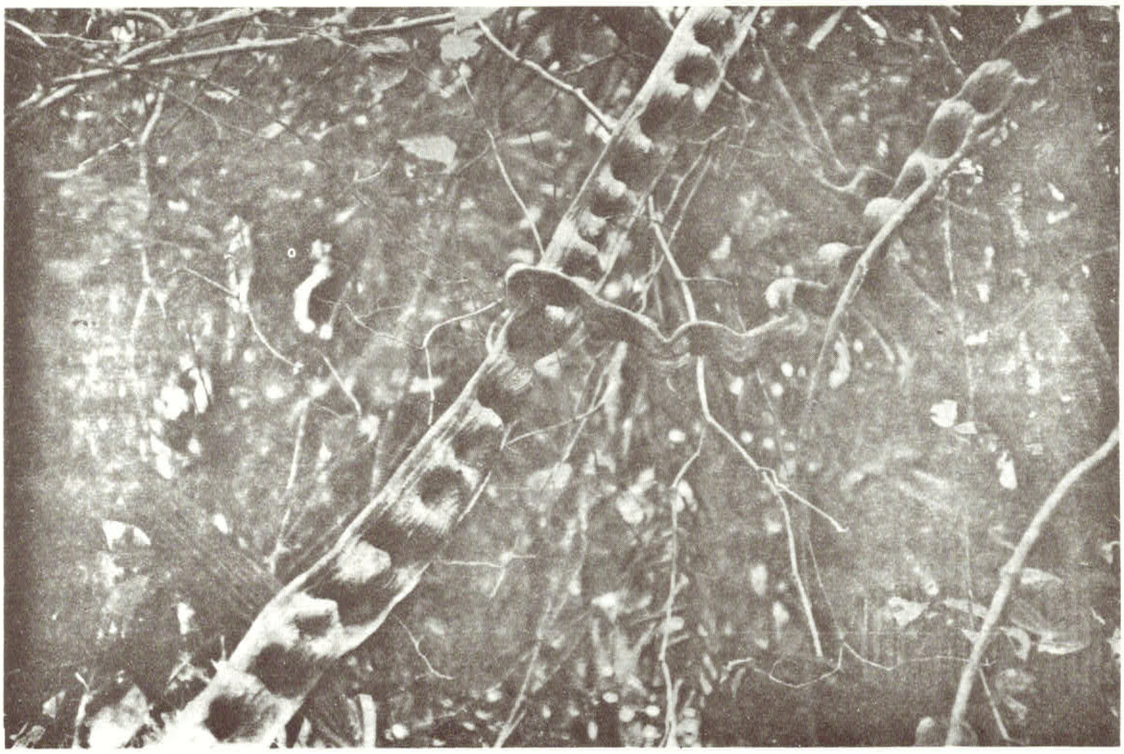

Fig. 7.4. Lianas have many interesting growth forms such as the *Bauhinia* locally called 'turtle ladder'.

frequent with strangling *Clusias*. With strangling figs (*Ficus*) the host tree usually dies. In this case the roots turn into the trunk. In non-forest formations climbers are not abundant and when they exist they are slender herbaceous vines. Robust woody lianas are a phenomenon of the forests (Figs. 7.3, 7.4). The abundance of epiphytes on the branches and trunks of the trees including mosses and tiny ferns is an indication of high humidity and the absence of a prolonged dry season. High relative air humidity also encourages the presence of epiphytes.

In the tropical forest it is common to find plants with specific ant associations (Ducke and Black, 1954, page 6 and *see* Benson, Chapter 13, this volume). These ant cavities, hollow stems, modified petioles, stipules and leaf bases are described in Chapter 13. The myrmecodomatia appear even when the plants are cultivated in the absence of ants. The quantity of ant plants shows the importance of defence mechanisms against predators in the Amazon forest.

The roots of the Amazon forest trees are generally rather shallow even where the soil is deep. There is a greater quantity of organic material in the process of decomposition in the upper layers of the soil because the greater part of the nutrients are in the plants themselves and in the decomposing plant parts. Since roots are shallow, tree falls are rather frequent.

When the seeds of light-demanding species germinate, they produce seedlings that are not able to reach the adult stage in the dark forest. These species need natural clearings to develop further. Examples include the Brazil nut (*Bertholletia excelsa*), piquiá (*Caryocar villosum*), angelim (*Dinizia excelsa*). With these species small individuals are not found in mature forests.

The maximum age of a tree varies from species to species. As a general rule species which grow rapidly die more quickly. The incidence of death, based on our own data, tends to be more or less uniform by percentage in the different classes of trunk diameter. In mature forests there is much variation in the growth of the trunk diameter, and this is not necessarily correlated with age. There are trees of the same species and the same diameter class that show very different growth patterns. Zero growth over an extended period is common. Light is so important for plants that are poorly located and receive very little light, that it reduces or completely stops growth. Natural clearings play a very important role, allowing light demanding species the possibility of growth and regeneration. Natural clearings are caused by winds, storms, lightning, and the natural fall of large mature trees which are often entwined by lianas and may consequently uproot several other trees when they fall.

There are many other causes for the death of trees, but the main ones include having reached their maximum age, strangling lianas, lightning, fungal attack, and trunk boring insects. Attack by these insects is very important and there are many special adaptations by trees to survive this attack. There are trees that can renew damaged bark with great facility. Others produce thin roots below the dead bark, which thicken and fuse, finally forming a type of bridge that reunites the dead bark. *Ormosia nobilis* is an example. An interesting adaptation to survive damage is found in various palms (*Astrocaryum*, *Bactris*) which have an extremely hard part of the wood on the outside and soft interior equivalent to a trunk with the heart wood outside and the soft wood within.

Another important characteristic of dense tropical forests is that they are fireproof, even when attempts are made to set fire within the standing forest.

As a general rule, there is great species diversity in tropical forests, which indicates the large number of ways in which the plants can make use of the environment. This is adaptation to many niches.

Since there are large numbers of plant and animal species and microorganisms, interacting among themselves, variation within a species is extremely important. Therefore there is a tendency in plant species towards unisexuality. Even many species whose flowers are morphologically hermaphrodite, actually function as unisexual. There are also many examples of self sterility.

One of the most curious adaptations is monocarpy. In *Tachigalia myrmecophila*, for example, we have a tree species which takes many years to attain maturity and flowering. It produces its abundant crop of wind dispersed fruits once, and then dies. It is difficult to say what is the adaptive advantage for a species with this mechanism. Perhaps it can be explained because the death of the tree opens a clearing for its offspring which develop under its crown and these light demanding seedlings can then quickly replace the parent tree.

There are many species which, in order to survive, use both sexual reproduction and vegetative reproduction. For example in *Goupia glabra*, *Caryocar villosum*, and *Platonia insignis*, when the tree falls or is cut down, many sprouts occur from the roots and these may form new trees. Apomixis can also occur. For example, Maguire (1976) took seeds of a species of *Clusia* to greenhouses in New York and obtained fertile seedlings of this dioecious plant.

In the Amazon forest where there are large numbers of species growing together, true dominance of one species does not occur. However, there are generally a number of species, five or ten or even sometimes up to thirty, whose total number of individuals is more than 50% of the total number of trees. These are the most important trees in the forest and the rest are rare and are represented only sporadically.

Certain authors have discussed sample plots of vegetation as if they represented uniform vegetation formation. However, in practice our extensive sampling has shown that there is always a variation of floristic composition from one area to another if it is a little apart. For this reason, when one samples an increased number of plots, the species number always increases gradually because of the number of species represented by a single individual. In other words, when one plots a graph of area against number of species, the curve never truly reaches the asymptote, because one always comes across new species found for the first time. Because of the rarity of some individuals, in order to include all the species one would have to continue the sampling process indefinitely until it included the entire forest.

Theoretically, each species has an area of distribution which can be mapped and on this map the density of these species varies considerably from one locality to another. Thus, the floristic composition of a certain area or sample corresponds to the superimposition of all the distribution maps of the different species represented there, and it will vary more between the more distant samples than between samples close together.

There are some species which are much more important in their definition of the landscape. For example, the *Parkias* have a curious type of branching. Some species have extremely striking flowers, such as members of the Vochysiaceae and the genus *Tabebuia*. Certain groups can be readily recognised by the form of the plant, as in the palms, which are always quite striking.

The forest on terra firme dominates the largest percentage of the area of Amazonia. Most of it consists of undulating terrain at low altitudes, rarely rising above 200 m, and most of it below 100 m. As one moves away from the Amazon river, up the tributaries, one reaches a point where rapids begin. This is where one reaches the crystalline shields both to the north and to the south.

Both the vegetation types and floristics show that there is a strong correlation between these formations and the different river basins. Certain river basins are associated with certain vegetation types and certain groups of species. This has been shown from both botanical and zoological data, and limnologists are now studying the associated physical environment.

7.6. TERRA FIRME FORESTS

7.6.1. Dense forest

Dense forest is the formation with the greatest biomass, with a clear understory, and occurs where environmental conditions are optimal and there are no limiting factors such as a scarcity or an excess of water. It has been described in general terms above.

7.6.2. Open forest without palms

This is a variation of the forest landscape where the biomass is considerably lower and is generally slightly above 20 m^2 basal area per hectare, and the trees are lower. Since there is a greater penetration of light, there is a tendency for shrub and liana species to develop well, and the forest floor is much more densely covered by vegetation. In this forest, even though it is much lower, occasional scattered individuals of very large trees occur. The lower biomass can be caused by a lower water table, by the impermeability of the soil, by poor drainage or by conditions which do not permit good root penetration, or by the occurrence of relatively long dry seasons and a lower relative humidity. Aridity, whether it is seasonal or not, causes diminution in the abundance of epiphytes. These forests are not notably seasonally deciduous and they are also not affected by fire.

7.6.3. Open forest with palms

This formation is similar to the preceding, with trees of about the same height in the same density and of a similar floristic composition (Fig. 7.5). It occurs more frequently than the forest without palms. The most frequent palms are *Orbignya barbosiana* (babaçu), *Oenocarpus distichus* and other species of the genus (bacaba); *Jessenia bataua* (patauá), *Euterpe precatoria* (açaí da mata), and *Maximiliana regia* (inajá). One of these species may dominate or they may occur mixed together. In this type of forest, there are

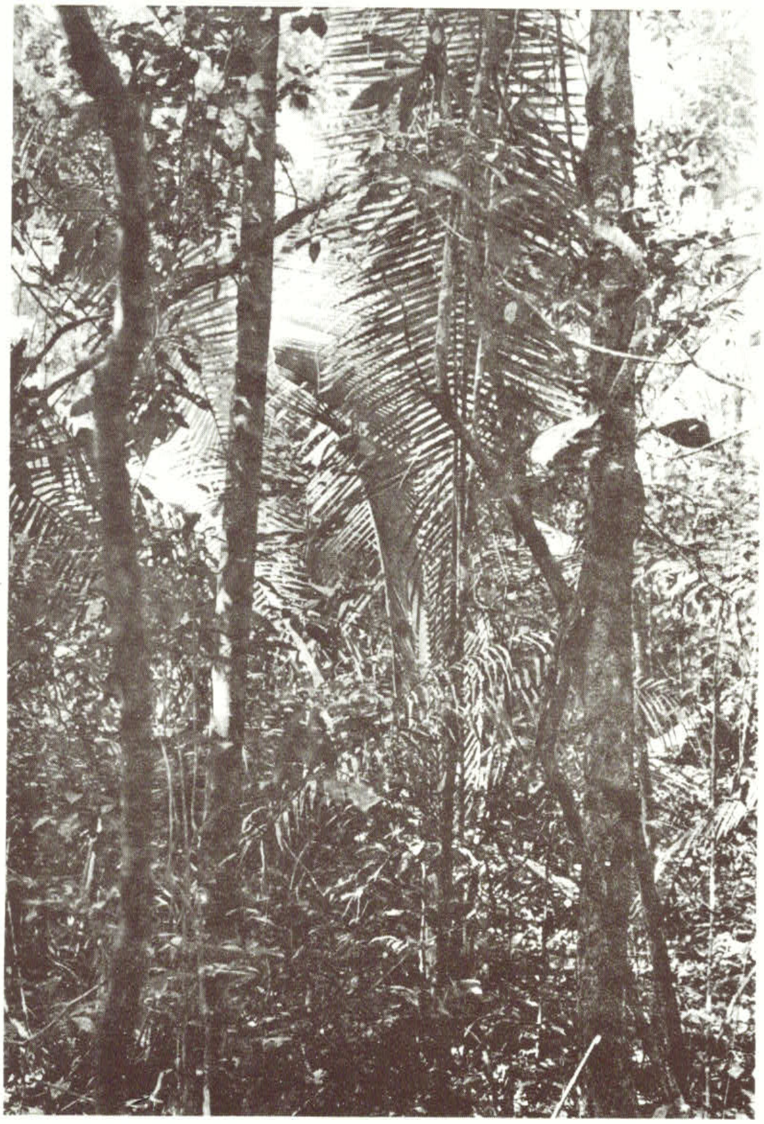

Fig. 7.5. Open forest with palms near the Xingu river in Pará. The dominant palm here is babaçu (*Orbignya*).

frequently a large number of Brazil nut trees (*Bertholletia excelsa*). Sometimes there are concentrations of *Phenakospermum guianense* (sororoca), which looks banana-like, but, when seen in aerial photographs, is quite similar to palm trees.

7.6.4. Liana forest

This is a variety of open forest which generally has an abundance of lianas (Figs. 7.6, 7.7). In many places it also contains babaçu palm and the Brazil nut, either together or separately. It is a variation of the Amazon vegetation that is of special importance because of the vast area which it occupies, covering

Fig. 7.6. A tree draped in lianas, typical of liana forest, Rio Itacaiunas, Pará.

hundreds of square miles. However, liana forests are generally not continuous. They are usually intermeshed with dense forests without lianas forming a complex mosaic. This type of forest occurs in abundance along the Trans-Amazon highway from Marabá up to the Xingu River with less frequency as far as the Tapajós River. To the south it extends to the southern limit of Amazonia to the boundary of the cerrado of Central Brazil. Small patches of liana forest occur scattered well into the region of Sararé.

A particular river where liana forest dominates is the Rio Itacaiunas, which runs from west to east joining the Tocantins in Marabá. The region of Serra Norte and Serra dos Carajás, with one of the richest iron deposits in the world, is also rich in liana forest.

Liana forest characteristically occurs on geologically ancient terrain with a somewhat elevated altitude with rich mineral deposits such as iron, aluminium, manganese, nickel, gold and many others. The liana families that are characteristic of this region and most important in this formation are Leguminosae,

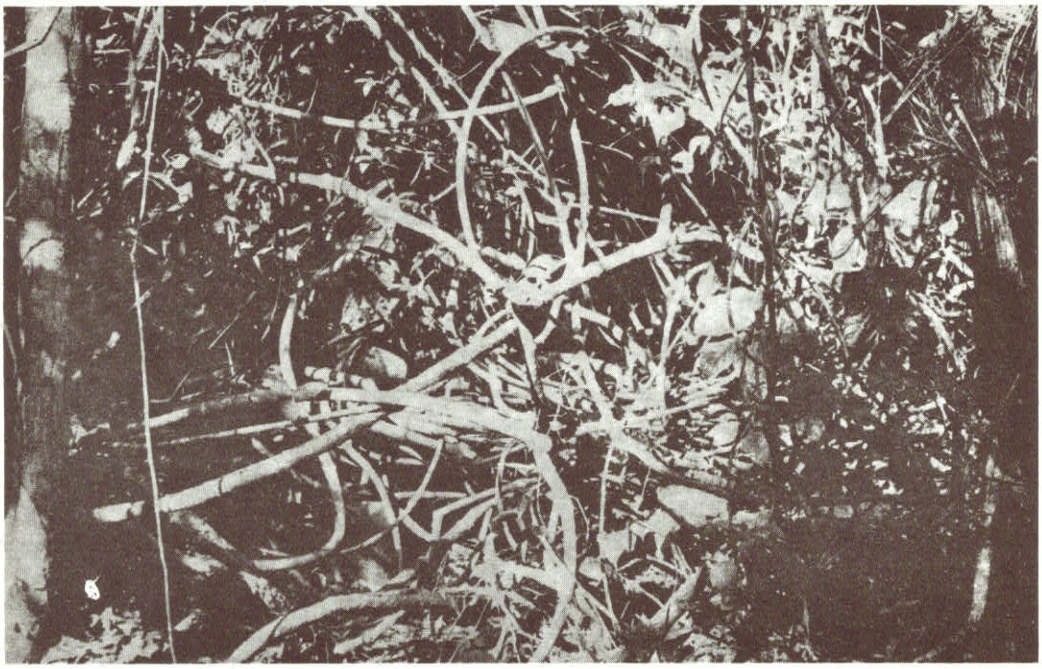

Fig. 7.7. The floor of liana forest is often impenetrable because of the quantity of liana stems.

Bignoniaceae, Malpighiaceae, Dilleniaceae and Menispermaceae. An interesting genus is *Bauhinia* which has both lianas and trees in this formation, whereas in the rest of Amazonia, only liana species of *Bauhinia* occur. In this formation most trees are *Bauhinia* spinous except *B. bombaciflora* which has enormous flowers, hence its name.

Falesi (1972) studied the soils along the Transamazon and did not find any correlation between the types of soil and the vegetation. For example where he found terra roxa (Nitosols of the FAO/UNESCO soil classification) of good fertility, many types of vegetation occurred: dense forest, open forest, with or without lianas or palms. In this area of terra roxa, the vegetation is quite variable between each of these different types. Falesi did his analysis at the highest level of soil divisions. For a better study and more detailed correlation between soil and vegetation, greater soil details are needed, especially about the depth of the water table and the drainage characteristics (*see* Jordan, Chapter 5).

The various forms of open forest are quite similar both in size and density of trees and their floristic composition. The major differences are in the presence or absence of lianas and of palms. The most frequent palm is the babaçu, the oil yielding seeds of which are used economically in the state of Maranhão, but not in the rest of Amazonia, because of the lack of a tradition and because there are other less strenuous sources of employment in the rest of the region.

It is important to note that in these types of open forest, gigantic trees occur sporadically spread throughout the forest. These very tall trees are principally: *Bertholletia excelsa*, *Hymenaea parvifolia*, *Bagassa guianensis*, *Tetragastris altissima*, *Astronium gracile* and *Ampuleia molaris*. In low and more humid places near the streams, *Swietenia macrophylla* occurs quite frequently. This is the much sought after mahogany or mogno and it is now threatened with extinction. Other common species are *Acacia* *polyphylla*, *Sapium marmieri*, *Castilla ulei*, and *Myrocarpus frondosus*. *Castilla ulei* was much exploited during World War II for its rubber latex. The wood of *Myrocarpus frondosus*, is excellent and is being exported under the name conduru de sangue or roxinho. Although the liana forests are generally located in southern Amazonia, there are patches also north of the river. For example, in the Rio Jari basin and principally in Roraima territory.

7.6.5. Dry forest

This is a formation of transition forest that is occasionally found in the southeastern part of Amazonia on the border between Amazonia and Central Brazil. In this region, the climate is much more seasonal and dryer with lower relative humidity, with the result that in the dry season, the trees lose some of their leaves. There is therefore, a tendency towards semideciduous forest, and a seasonal influence on the vegetation landscape is apparent. Dry forest occurs in small clusters that do not occupy large areas. There are also dry forests in Roraima territory where they are more abundant.

Throughout Amazonia there are some trees that lose their leaves but are not truly synchronised, either with the season or with each other and so cannot be considered part of a deciduous vegetation type. The dry forests are different and leaf fall occurs at a time determined by the season.

Along the rivers and the streams in the flooded areas, the vegetation is typical of that of the Amazonian várzeas and is not deciduous. Some species common in the dry forests are: *Geissospermum sericeum*, *Cenostigma macrophyllum*, *Physocalymma scaberrimum*, *Lafoensia pacari*, *Magonia glabrescens*, *Sterculia striata*, *Erythrina ulei*, *Vochysia haenkeana*, *V. pyramidata*; *Orbignya barbosiana*, *Combretum leprosum*, *Bowdichia virgilioides*. This region is not rich in endemic species. One of the common trees of the flooded areas is the blue-flowered *Qualea ingens*.

Dry forests physiognomically very similar, but with very different floras, are found in Roraima territory where the following species are common: *Centrolobium paraense*, *Mimosa schomburgkii*, *Richardella surumuensis* and *Cassia moschata*.

The analysis of the distribution of the babaçu palm is most important in understanding the forest that used to exist in the "Meio Norte" region through the states of Maranhão and part of Piauí. Babaçu is common throughout this large region bordering Eastern Amazonia, which today is not forested. It is a transition between the Amazonian hylaea and the cerrado of Central Brazil.

Before its destruction by man, all this babaçu region was forested with open and dry forest types. But the climate in this eastern part is seasonally drier with a lower relative air humidity. Thus, when man cut down these forests and burned them, the vegetation was gradually transformed into pure stands of babaçu without any other type of tree.

In 1943, the senior author had the opportunity to study areas of these forest types, which existed between Santa Filomena and Itapicuru, along the railroad from São Luiz to Terezina, places where today there is no forest left and are typically covered by pure stands of babaçu. This is largely because the babaçu palm is well adapted to fire resistance.

There is a certain similarity between the dry forests and the cerradão of Central Brazil, but the cerradão is taller cerrado as its name would indicate, with typical cerrado species and cerrado physiognomy with a greater amount of xeromorphism, thick barks, tortuous branches with short internodes, while the dry forest has a physiognomy affected by the arrangement of the branches on the trees which are arranged in adaptation to the penetration of light. Ratter *et al.* (1973) studied some examples of dry forest in Mato Grosso between Serra Roncador and the headwaters of the Xingu River.

7.6.6. Montane forests

Montane forests, as the name indicates, are forest formations which are differentiated by their altitude and rocky soil types. Most of the Amazon region can be classified as a plain, which although quite undulating in certain areas, is generally below 200 m above sea level. Mountainous regions occur only at the extremities of Amazonia. To the north, at the boundary between Venezuela and Guyana, there is a mountain region of exceptional botanical interest. This region, which is known by American authors as Guayana, has a fascinating flora (Fig. 7.8). Biological interest in the region was stimulated by the Tate expedition which made spectacular collections. Since then, various groups have studied these mountains, above all, the group of Basset Maguire, who has published much of his studies under the title 'Botany of the Guayana Highlands', published in the Memoirs of the New York Botanical Garden.

The montane vegetation of Amazonia is closely related to the vegetation of rocky places and can either be forests or open formations (Fig. 7.9). Shallow soils and rocky places, even in regions of high rainfall, suffer extreme drought, even in the short dry periods of the year, since there is no retention of water in the soil.

Humidity increases with altitude in the montane regions, and because the air is saturated with humidity, there is a great deal of mist, exemplified by the name of Brazil's tallest mountain, Pico da Neblina (the mountain of mist). As a consequence, the mountains have a large number of mosses, lichens, small pteridophytes, which form carpets over rocks and cover the trunks and branches of woody vegetation. It is not rare to find a carpet of lichen over rocky soils, giving a most spectacular landscape.

The steeper slopes have a tendency towards sparser vegetation because of their reduced water retention capacity. On the less steep slopes, much denser forest usually develops. As altitude increases,

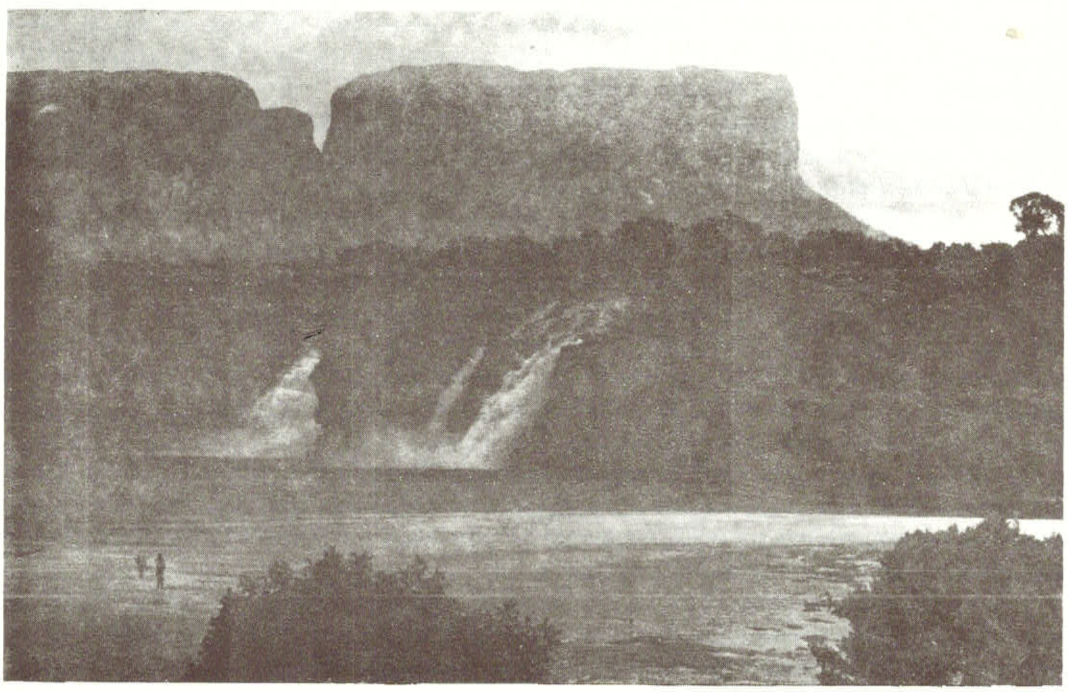

Fig. 7.8. The montane forest formations are well developed in the table top mountains of tepuis of the Guayana Highland of Venezuela, here seen in Canaima National Park.

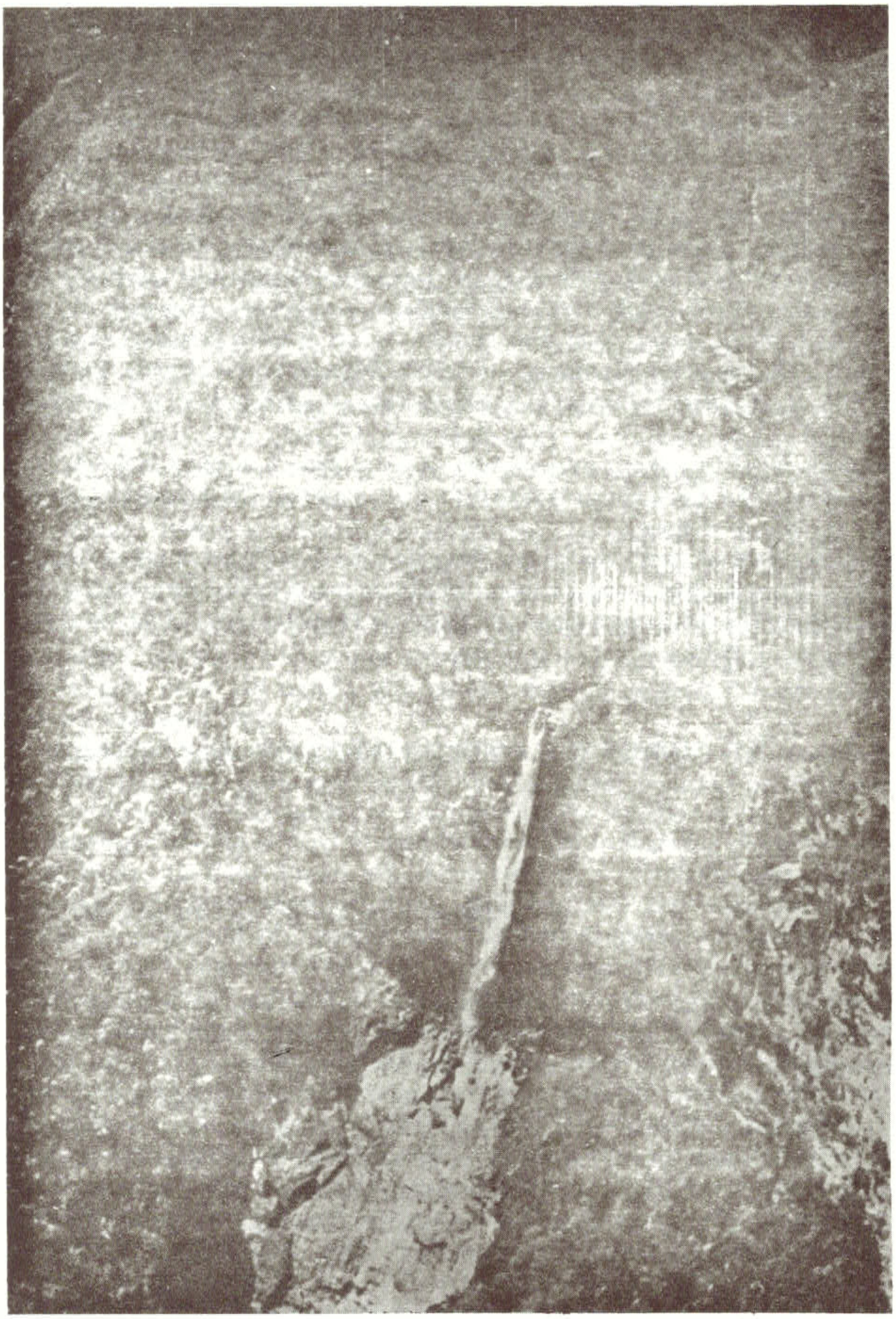

Fig. 7.9. Aerial view of Serra Araca and isolated Sandstone mountains in Amazonian Brazil.

biomass usually diminishes and the trees become smaller until eventually there is no longer a forest of any type. On Serra Neblina the tree line is about 2600 m, and this occurs throughout Guayana. In the Andean region, according to Livingstone and Van der Hammen (1978) the forests extend higher to about 3200 or 3500 m.

On the top of the mountains, the vegetation is sparse and trailing and often confined to the crevices between the rocks. In a habitat like this, on the top of Serra Neblina, the small unusual plant, *Saccifolium bandeirae* in a monotypic family, with sack-like leaves, was collected.

Physiognomy and floristic composition of the vegetation also become special with increase in altitude. The family Theaceae (*Bonnetia*, *Archytaea*, *Ternstroemia*), become much more important, and also certain Guttiferae (*Clusia*, *Tovomita*), and large Bromeliaceae such as *Brocchinia* or the smaller *Dyckia*, as well as robust members of the Eriocaulaceae and Poaceae. Various plant families which are rarely represented or absent from the lowland hylaea become frequent: Ericaceae (*Psammisia*), Cunoniaceae (*Weinmannia*), Cyrillaceae (*Cyrilla*), Winteraceae (*Drymys*), Podocarpaceae (several species), Dipterocarpaceae (*Pakaraimaea*) and Sarraceniaceae (*Heliamphora*, which has leaves adapted to trap insects).

The mountains of Guayana that lie to the west are in a much more humid region and do not suffer the effects of fires. But this is not so to the east in Roraima where the mountains have been considerably altered by the effects of fire.

In the Andes there are much higher mountains than those of Guayana, with other types of montane vegetation — Yungas, Punas, and Páramos, which are not described here because they are not truly Amazonian. Summary information about those types of vegetation can be found in Cabrera and Willink (1973) and Hueck (1972).

7.7. INUNDATED FORESTS (VÁRZEAS AND IGAPÓS)

Várzeas and igapós are regional terms applied both to types of soil and vegetation, denoting excess humidity or swampy conditions, or in other words, any ground that is not terra firme. Igapó is applied here to black and clearwater areas and várzea to muddy water inundation. Várzeas are formed by sedimentary ground that during its formation was influenced by fluctuation in sea levels.

The two principal types of inundation forests also differ in their soil. Várzea is formed by flooding with muddy water rivers, such as the Amazonas and the Madeira, and igapós by flooding with clear- and blackwater rivers without sediments, such as the Rio Negro, the Tapajós and the Arapiuns.

Because of this difference in water property the clay soil várzeas, as a general rule, have higher river banks (natural levees), since the larger and heavier particles are deposited first. In the várzeas and igapós on sandy soil and clearwater, this tendency to deposit new material does not exist and the soil is at a much lower level along the margin of the river. Thus, in this black and clearwater type of flooded area it is common to find in the dry season sandy beaches with trees on them, which in the rainy season are transformed into a type of inundated forest where the lower part of the trunk is completely under water. This is the typical landscape that one finds along the clearwater river. The subject of the difference between inundated forests was explained in great detail in Sioli (1951).

The várzeas have soils that are much more fertile than is usual in Amazonia because the soils originate from the fertile soils of the Andean region. However, until recently, the várzeas have been little used by people of the interior because traditional Amazonian agriculture is based on cassava, the roots of which rot even in the presence of the slightest flooding.

Pierre Gourou (1950) estimated that the inundated forests cover 2% of the surface of the Brazilian Amazonia excluding the water surface. However, more recent data show that they cover a considerably larger area. For example, in the region of the lower Rio Branco from Caracaraí to the confluence with the Rio Negro, including the basins of its tributaries Xeruini, Catrimani, Univini, Ajarani, Anauá, and also as far as the Jauaperi, there is an extraordinarily large region on low ground in which these rivers only flow independently in the dry season since the flooding is continuous between them in the rainy season. The region is covered with a low type of igapó forest. There are a few places where terra firme reaches right to the margin of the rivers and in these areas it is called *barrancos*, the term for high river banks. The few inhabitants of the region have their houses on these high river banks because in the other areas in the flood season the entire riverside area is inundated. In this region streams with crystalline or transparent water and blackwater are common. These rivers, which are practically without sediments, form a peculiar environment where it is common to find the boats of fishermen seeking ornamental fish. There are many very attractive little fish, some of which it has not been possible to raise in captivity or even in other streams, so they are caught in that region for export to aquaria.

Some typical plants of the flooded forest are *Sclerolobium aureum* (tachi), *Couma utilis* (sorva, the latex of which is coagulated to form chewing gum), *Exellodendron coriaceum*, *Parinari campestris*, *Euphronia hirtelloides*, *Chaunochiton loranthoides*, *Ambelania laxa* (molongo, a tree with extremely light wood) and *Leopoldinia piassaba* (which yields the much used piassaba fibre). In non-forested clearings *Lagenocarpus guianensis*, *Micropapyrus viviparoides*, *Dichromena* ssp., *Fimbristylis* ssp. and other Cyperaceae occur. On the river margin *Euterpe oleracea* is common but terra firme trees such as the Brazil nut, *Bertholletia excelsa*, are found only on the high river banks above flooding. Throughout Roraima territory, this vegetation type, as well as any other physiognomically similar (low and rhachitic) vegetation, is called by the collective term 'chavascal', whether forest, non-forest, terra firme or várzea. However, chavascal is a confusing term, and like igapó, it is not used consistently throughout the region, since there are also chavascals both on terra firme and marshy grounds and the term as applied locally covers woody through herbaceous vegetation types.

There are three principal types of clay soil várzeas: (a) those of the Upper Amazon which are not associated with fields of Canarana (grass meadows), (b) those of Lower Amazonia associated with robust grass meadows, (c) estuarine várzeas subject to flooding from the influence of tidal backup.

7.7.1. Clay soil várzeas without robust grass meadows

These are the várzeas that are found in the Upper Amazonas (Rio Solimões), from Manaus above and also along the major muddy water rivers such as the Madeira (Fig. 7.10). The forest is continuous, or is broken up by lakes only, and is not associated with areas of thick robust grassland. The várzeas have rich vegetation in the understory especially in the region of the upper Solimões, where there are abundant members of the Scitamineae (the ginger, maranta and heliconia families). Huber (1909), pointed out with good reason that the várzeas of the Upper Amazon are much richer than those lower down. Between the rivers Japurá and Içá there is a large area of these várzeas which is intersected with branches of the rivers locally called paranás, igarapés, and furos, as well as a large number of lakes that are linked to the principal river in such a way that in the flood season the Amazon river is extremely wide at this point.

In the rainy season the main river and its tributaries rise considerably during the floods which last for 5 months. At this time a large number of whole trees and tree trunks can be seen floating in the river, because large areas of the river banks are torn off as the water level rises. The lakes are very rich in large fishes and the numerous streams have an extraordinary variety of small fishes, some of which look most unusual, for example, one exactly like a cigar or one which always remains upsidedown or another which mimics a dead leaf.

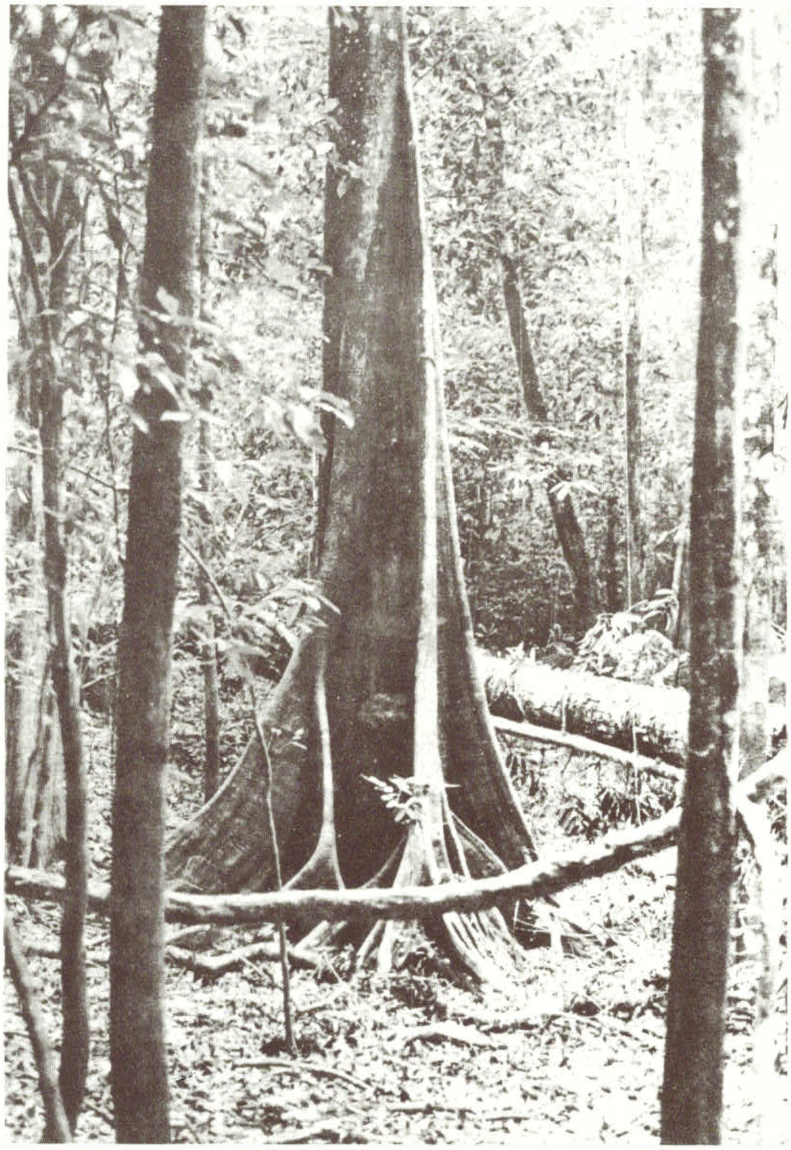

Fig. 7.10. Clay soil várzea forest.

Ducke and Black (1945) pointed out that várzea species tend to have a softer wood than those of the terra firme. Lateral expansion of the trunk into buttresses is frequent in the várzea. Seeds are often light and have many different mechanisms to cause flotation such as spongy tissue or hollow areas or a light mesocarp. In some cases it is the seed that floats; for example in *Hevea brasiliensis*, the rubber tree. In others the entire fruit floats; for example in *Montrichardia*, a riverside Araceae.

Some of these floating seeds are collected commercially, for example the seeds of the andiroba (*Carapa guianensis*) and the ucuuba (*Iryanthera surinamensis*), which both contain an oil. There are several examples of well-known seeds used commercially, yet for many years without botanical names because

Fig. 7.11. The banks of the Rio Xingu.

Fig. 7.12. Canarana (robust grassland) várzea of the lower Amazon near Uaça, Pará.

they were collected entirely from floating masses in the river. For example *Acioa edulis* was finally described by Prance in 1973 and *Curupira tefeënsis*, was described by Black in 1948. Both of these are important oil yielding seeds, which had been used by local people for many years before they were described botanically.

7.7.2 Clay soil várzeas with grasslands of canarana

These are the typical várzeas of lower Amazonia (Fig. 7.12). They exist in the region where the Amazon river is very broad, especially between Monte Alegre and Itacoatiara and the lower part of the Madeira River. They cover the area of lower Amazonia from the mouth of the Rio Negro down to the mouth of the Xingu River. The lower Amazon várzeas are characterised by narrow stretches of forest on the higher ground beside the principal rivers and their tributaries, both paranás and igarapés. Behind the forests are meadows of robust grass known as canarana. These grass meadows tend to be lower and more flooded the further they are away from the river margins and they go right up to the edge of the terra firme. The lowest parts of all are open lakes. These lakes vary greatly in their size and can be very large in the rainy season and become smaller in the dry season. When the waters recede the open ground that appears quickly becomes covered with grass, augmenting the area of the meadows. Some of these lakes can cover tens of kilometres such as Lago de Maicurú and Lago Grande, in the region of Monte Alegre.

The arboreal species, which are most common are *Crataeva benthamii* (capitari), *Cordia tetrandra* (uruá), *Trichilia singularis*, *Pithecelobium multiflorum*, *Muntingia calabura*, *Bombax munguba* (munguba), *Hura crepitans* (açacu), *Cecropia paraënsis* and other species of *Cecropia* (imbaúba), *Calycophyllum spruceanum* (pau mulato), and *Salix martiana* var. *humboldtiana* (salgueiro, oeirana, which occurs mainly on the muddy beaches that are in the process of deposition). The grasses that form the meadowlands and which are associated with this type of várzea are described under the várzea meadows.

7.7.3. Estuarine várzea

The estuarine region is defined as that which occurs below the confluence of the Rio Xingu, and it includes the enormous Marajó Island which is about 40,000 square kilometres.

The estuarine várzeas (Fig. 7.13) are on clay soil formed by muddy water and they have an extraordinary abundance of palms (of relatively few species) and their flooding is caused by tidal movements rather than the annual river cycle. The other two types of várzea described above are flooded for about 5 months by the rise of the rivers during the rainy season. The estuarine várzeas are flooded by tidal backup twice a day. The seasonal rain has little effect on flood level in this region because the river is so extraordinarily broad and so close to the sea. The highest tides which cause the greatest flooding, happen twice a year; in September during the dry season and March to April in the rainy season. Some of the estuarine várzea forests have an extremely high biomass and consequently areas where there is much exploitation of timber, for example around Breves and Curralinho. The southwest portion of Marajó Island is largely várzea forest, apart from the areas that are upland and on terra firme.

The most abundant palms in estuarine várzea are murumurú (*Astrocaryum murumuru*), jupati (*Raphia taedigera*), açaí (*Euterpe oleracea*), Inajá (*Maximiliana regia*), bacaba (*Oenocarpus distichus*), patauá (*Jessenia bataua*), caraná (*Mauritia martiana*), buriti or miriti (*Mauritia flexuosa*), as well as other smaller species such as ubim (*Geonoma* ssp.).

Fig. 7.13. Estuarine, tidal várzea at Aurá, Belém, showing the pneumatophores (air breathing roots) *Symphonia globulifera*.

7.7.4. Igapós on white sand areas

These are riverside forests along certain parts of the clearwater rivers such as the Tapajós and the Arapiuns. They are white sand margins that are covered by trees (Fig. 7.14). In the dry season the trees are growing on pure white sand. In the flood season their trunks are underwater so that one is able to pass through the crowns of the trees in a canoe. These are the true igapós, or temporary igapós.

It is also a curious fact that the parts of this forest nearer to the rivers are the parts that are most flooded, in contrast to the clay soil várzeas with their natural levees.

Among the most common igapó trees are various members of the Myrtaceae, *Triplaris surinamensis* ('tachi', whose hollow branches are occupied by an ant, of the same name, that is very aggressive with a nasty sting), *Piranhea trifoliata* (piranheira), *Copaifera martii* (copaiba), *Alchornea castaniifolia* (oeirana). On one of these beaches, near to Maués, the very interesting plant *Polygonanthus amazonicus* (Rhizophoraceae) was collected. This plant has been much discussed in the literature because of its uncertain systematic position. It is one of the rare examples of an extremely local endemic in this type of habitat.

The area occupied by igapó is small along most rivers. However, as mentioned above, in the lower Rio Branco it can cover an extremely large area linking the basins of the Rios Xeruini, Catrimani, Univini and the igapó of the Anauá and Jauaperi.

7.8. SAVANNAH VEGETATION

As can be seen from the above, forest vegetation types cover the majority of the Amazon Basin. However, there are many interesting open savannah areas. No accurate estimate of the amount of forest versus savannah has been made, but with present remote imagery it should be possible.

Fig. 7.14. White sand igapó, beside Rio Negro near Manaus showing one of the characteristic palms *Leopoldinia pulchra*.

In Amazonian Brazil the general term for non-forest vegetation types is campo. In order to make an important distinction here, the patches of open vegetation areas of washed out white sand will be described separately under the names caatinga and campina. They represent a completely different vegetation form that is a transition between the forest and non-forest vegetation type.

The savannah formations that are not on white sand are classified into two main types, those on terra firme and those on várzea. The savannahs on terra firme may either be open grassland areas without woody vegetation, dominated by grasses with the basal area of $0-2\ m^2$ per hectare or they may be more woody savannah types with a strong representation of woody plants, however generally not exceeding 5

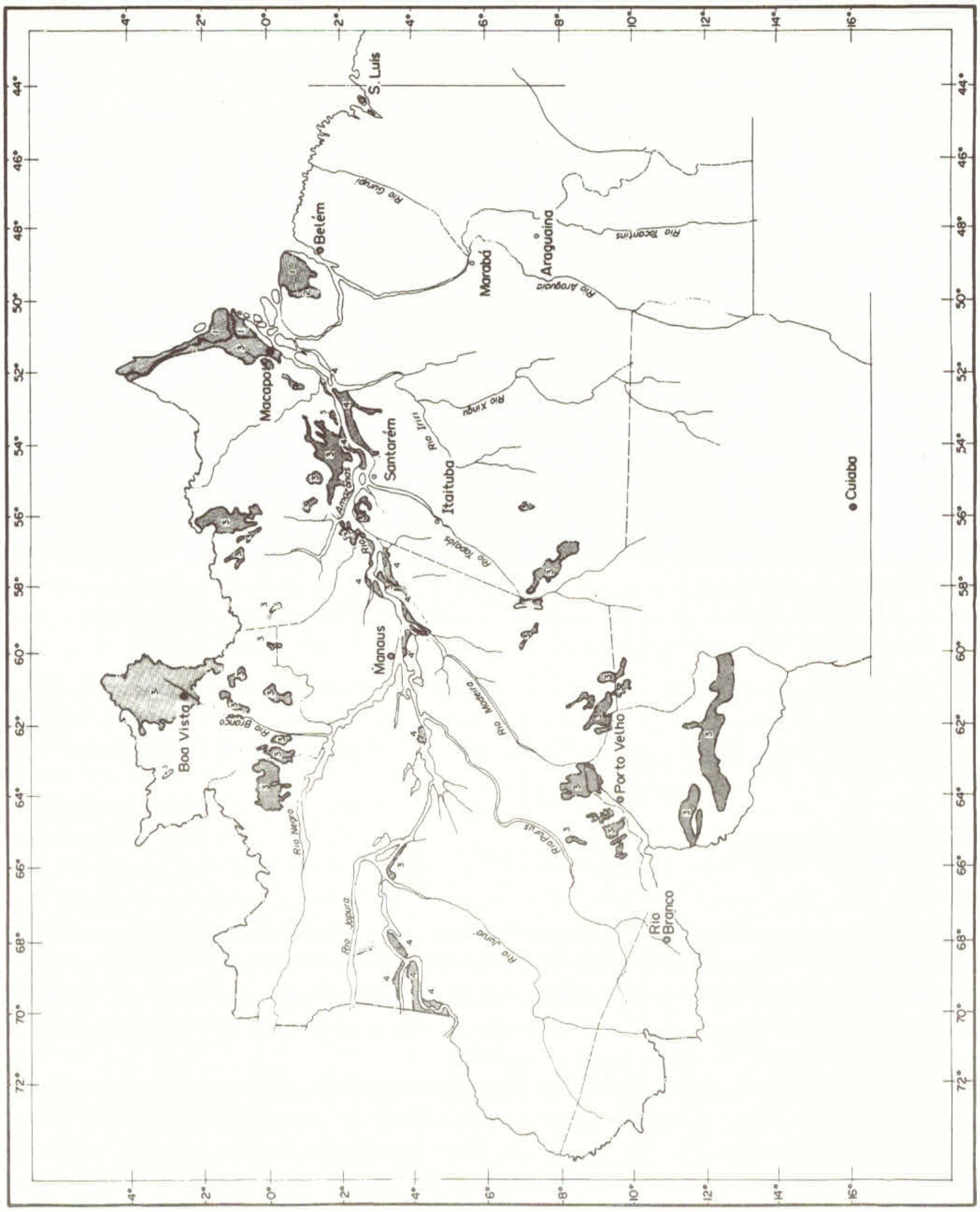

Fig. 7.15. Map of Amazonian Brazil, showing the principal areas of savannah and open vegetation: 1, littoral savannah; 2, Marajó terra firme savannah; 3, Amazon terra firme savannahs; 4, riverine flooded savannah.

Fig. 7.16. The cerrado of central Brazil.

m^2 per hectare (measuring trunks of 30 cm in circumference and above). The soil types of terra firme savannahs are varied. They may be on rocky soil such as the campos rupestres or they may be on deep soils which retain water much better, as in the majority of savannahs on terra firme.

7.8.1. Savannahs on terra firme

Apart from the generalisations made above, there are little data available separating and defining true savannahs on terra firme and savannahs on rocky soil (campos rupestres). Therefore, there is much confusion between these two vegetation types, and we do not have an accurate idea of the proportion of each vegetation type. The two types can exist side by side as they do in the cerrados of Central Brazil (Fig. 7.16), where there are many campos rupestres.

Beard (1946), Richards (1966) and other well-known authors, have proposed that there were no tropical grassland savannahs that were a true climatic climax. It was suggested that they were produced through human action helped by fire. However, there is no doubt that the grassland savannahs existed long before the arrival of man in Tropical America. This is supported with floristic, geologic, geomorphologic, and palynological data (Wijmstra and van der Hammen, 1966; Livingstone and van der Hammen, 1978). The area occupied by these formations however, may have increased through the action of man and fire.

Various authors have used the term 'cerrado' for the savannahs that exist within Amazonia, including Projeto RADAMBRASIL. This term is of recent introduction and is not used by the locals in the region. Also the Amazon savannahs are rather different formations from the central Brazilian cerrado.

Some Amazonian savannahs are physiognomically very similar to the cerrados of Central Brazil. For example, some of the savannahs of Marajó Island, especially those around Joanes or Curralinho. They have some species in common, but they are quite different in soil and climate. In Central Brazil there is a well-defined dry season and the air humidity can be very low and the soils are also very deep. Consequently, roots are also deep and specialised to reach water at considerable depth, when the upper part of the soil is dry. There is also a much greater incidence of plants with vegetative reproduction and organs that are fire resistant such as subterranean trunks, xylopodia, for example, *Anacardium humile* (the dwarf cashew), *Parinari obtusifolia*, *Andira humilis* and *Chrysophyllum suboliferum*. In the cerrados of Central Brazil when the soil is scraped off by a tractor, there immediately is a large amount of sprouting from vegetative organs, previously under the soil. In the Amazonian savannahs, the situation is quite different, and the roots are much more superficial and there are not so many vegetative parts that guarantee asexual reproduction. In addition, the climate is more humid and the relative air humidity higher, generally above 80%. Also in the Amazonian savannahs, there is never such a dense arboreal cover in the more closed type of savannah, whereas in the cerrados the dense cerrado is common and is quite similar to the dry forest.

The non-forested areas of Amazonia are located principally in the northeastern half of Marajó Island, the Atlantic coast of Amapá, in the middle and upper Trombetas River, and in Roraima territory. To the south of the Amazon river there are much smaller open areas such as the savannahs of Puciari-Humaitá (*see* Braun and Ramos, 1959) in the lower Purus region and the campos rupestres of Serra do Cachimbo, which has been estimated to be 16,000 km^2 (Soares, 1948). In addition there are various small patches of open vegetation scattered throughout the region. In total, the savannahs on terra firme, cover between 100 – 150,000 km^2 or between 3 – 4% of Brazilian Amazonia. In addition to some species that are common to all areas, there are some of restricted range and groups of endemic species vary from one location to another. Some patches of savannah are floristically poor (such as in Amapá), others are quite rich such as on the Rio Trombetas (Ariramba and Tiriós and in Roraima).

The term savannah, which according to Lanjouw, is of Carib origin, is a rather vague and imprecise term that includes all types of non-forest vegetation, not only in Tropical America but in all the world. The savannahs of the Trombetas, described by Egler (1960), Cruls (1950) and Sampaio (1933), reach Suriname in the region of the Tiriós. Following Cruls (1950), General Rondon estimated that the area of the Trombetas savannahs is 40 – 50,000 km^2.

The terra firme savannahs have some species that are typical of the cerrados: *Curatella americana* (caimbê), *Anacardium microcarpum* (caju-i), *Salvertia convallariodora*, *Hancornia speciosa*, *Qualea grandiflora*, *Byrsonima crassifolia* (murici), *B. verbascifolia*, *Antonia ovata*, *Tabebuia caraiba*, and some grasses of the genus *Trachypogon* (various species), *Leptocoryphium lanatum*, and *Rottboellia*.

As well as those species common to Amazonian savannahs and cerrados of Central Brazil, there are local variations and groups of species endemic to each region. Thus, the different savannahs are quite distinct from each other.

7.8.2. Littoral savannahs

These savannahs occur in the coastal part of Marajó and in the Bragança region of Pará and are characterised by a cover of creeping grasses and shallow soil and frequent lakes. The commonest grass is *Paratheria prostrata*. In the lakes there are common aquatic plants, including some floating grasses of the várzea savannahs of lower Amazonia, *Cyperus giganteum*, *Thalia geniculata*. Various Pontederiaceae are common including in Bragança, the striking floating Scrophulariaceae, *Benjaminea utricularioides*. The babaçu palm is common in the savannahs of Bragança. The savannahs of Perizes and Jatuba and Anajatuba in Maranhão, are similar to the littoral savannahs of Pará (campos de Bragança).

7.8.3. Savannahs of Roraima

The Roraima savannahs (Fig. 7.17) are considered separately here because there are some differences from the rest of the Amazon savannahs on terra firme. Almost throughout the region they are open savannahs with few trees. They have numerous swampy places, which form either lakes or patches of swamp, where a large concentration of buriti palm (*Mauritia flexuosa*) occurs.

In the radar images of this region, the clumps of buriti palm appear as characteristic white lines, a feature that is not found either in the Amazon savannahs or in the cerrados of Central Brazil. In the classification of RADAMBRASIL, they are the areas called steppe savannah.

The typical species of the arboreal cerrado also occur in this region with the exception of *Hancornia*, and *Salvertia*, but in addition there is a considerable amount of endemism.

The Roraima savannahs are species rich and they reach into Guyana, in the region of the Rupununi River, where they have the same physiognomy as in Brazil. According to the Savannah Report of the McGill University (1966), the Roraima – Rupununi savannahs cover 54,000 km^2 with 41,000 in Roraima territory and 13,000 in Guyana. The Venezuelan and Colombian llanos are quite similar to the Roraima savannahs. For a definition of the Venezuelan savannah types see Huber (1982) who distinguished clearly between the llanos type savannah and Amazonian savannah.

The Roraima savannahs are not completely uniform. To the south they are much flatter, to the north they are more undulating and lie between various hills. They also have a more sandy soil and there are patches of white sand in this region. In low places, there are swamps of the vereda or varjão type, as it is called in Central Brazil, where the water table reaches the surface and *Mauritia* palms dominate. Also in these areas which are very acid, are *Xyris*, Eriocaulaceae (*Paepalanthus* and *Syngonanthus*), *Cephalostemon*, *Abolboda*, *Rapatea* and sometimes small species of the carnivorous *Drosera*.

7.8.4. Campo rupestre

The campos rupestres or open formations on rocks, are generally confused with open savannah and the orchard savannah on terra firme, but they are quite different physiognomically and floristically. They develop on rocks and in rocky terrain, because they suffer drought in the dry season despite the

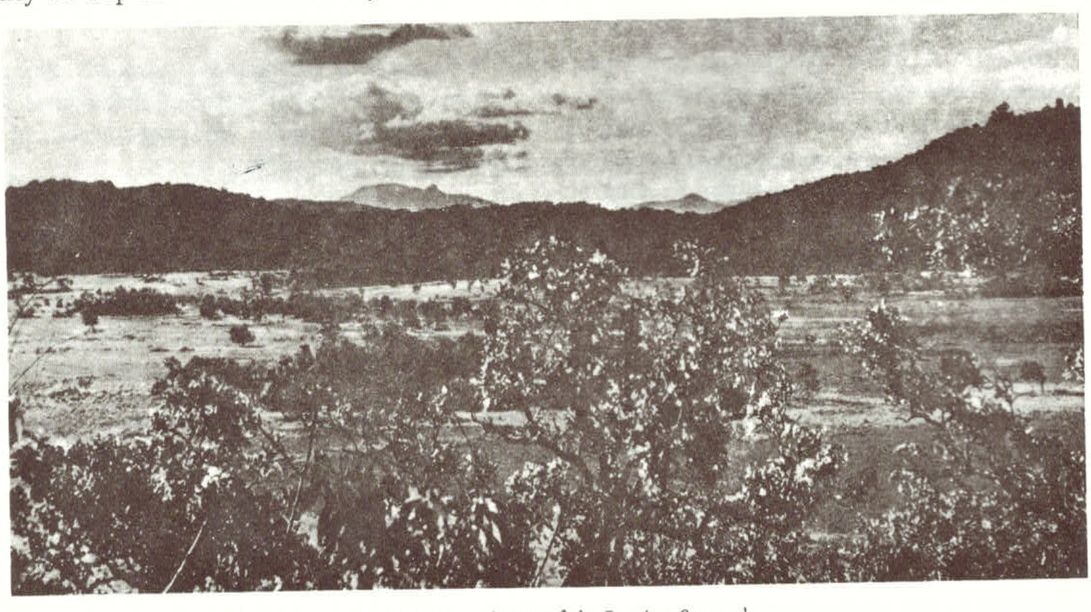

Fig. 7.17. General view of the Roraima Savannah.

Fig. 7.18. Campo rupestre at Rio Cururu showing *Vellozia* a characteristic genus of this formation.

equatorial humid climate, and because there is no possibility for water retention and all rainfall runs off immediately.

Typical species of orchard savannah and cerrados do not occur here, such as *Curatella americana*, *Hancornia speciosa*, *Salvertia convallariodora*, and *Qualea grandiflora*. As substitutions there are various species of *Byrsonima*, *Clusia*, *Norantea*, *Vellozia*, certain Bromeliaceae (*Bromelia*, *Dyckea*, etc.) and many Eriocaulaceae (*Paepalanthus* and *Syngonanthus*). Lichens are also frequent and cover many of the rocks.

Campos rupestres are quite common also in Central Brazil where they have been much confused with cerrados (Eiten, 1982). For example, Serra do Cipó, in Minas Gerais, much cited in the literature because of its interesting landscape with a large number of Velloziaceae (Fig. 7.18), is mostly campo rupestre and not cerrado.

In Amazonia, Serra do Cachimbo, in the southwest of Pará, has an area of campo rupestre which covers a considerable area, estimated at about 16,000 km^2 (Soares, 1948). Another large patch is the Campos of the Rio Cururú, in the Tapajós River basin. At Ariramba, on the River Trombetas, both conventional savannah and campos rupestres (Fig. 7.19) occur (Egler, 1960).

The Canga or ironstone vegetation, which occurs on Serra dos Carajás (see Secco and Mesquita, 1983), over the iron deposit, is a special form of campo rupestre. On this formation, various extra-Amazonian species are common such as, *Pilocarpus microphyllus*, which occurs also in Piauí and Maranhâo in the north central region, the extra-Amazonian genus *Callisthene* is represented by *C. microphyllus* of Central Brazil, which only occurs within Amazonia on Serra Carajás. Also on Carajás, the curious and beautiful treelet *Norantea goyasensis* occurs. The branches of this thick barked treelet sometimes lengthen and turn it into a vine.

Fig. 7.19. Campo rupestre at Ariramba, Pará.

A detailed and accurate analysis of the amount of terra firme savannahs (both open and orchard types) would show that there is actually much less than current estimates indicated because they have included campo rupestre in that category. The same is true for the cerrado region of Central Brazil.

The Amazonian montane forests also show a strong affinity to campo rupestre and some could even be classified as floresta rupestre (i.e. forest on rock). In the mountain areas there has been a great accumulation of organic matter because although they sometimes endure short dry periods, the forest is maintained because of the high air humidity and mist.

7.8.5. Inundated savannah of lower Amazonia

In order to understand inundated savannah it is necessary to recall what was said above about the várzea forests of lower Amazonia (Sections 7.6.2 and 7.6.3). In this alluvial region between the Rios Negro and Xingu and especially between the Rio Madeira and the city of Monte Alegre, there are many large channels of the river and also small ones between islands (paranás, igarapés and furos). In this area sediments are deposited by the muddy river and the large particles filter out near the margins, building them up into várzea forests on levees. Beyond these margins the area is covered by grassland meadows and many lakes. In the five month rainy season the area of water shrinks considerably. The exposed ground is soon colonised by grasses which greatly enlarges the area of meadows.

There are various large grasses which are generally called canarana or false cane; *Echinochloa polystachya* (canarana peluda). *E. spectabilis* (canarana erecta), *Hymenachne amplexicaulis* and *H. donacifolia* (rabo de rato), *Leersia hexandra* (andrequicé), *Paspalum platyaxis* (taripucú), *Luziola spruceana* (uamá), *Panicum elephantipes*, *Paspalum fasciculatum* (muri), wild species of rice (*Oryza perennis*, *O. alta*, *O. latifolia*, *O. grandiglumis*). Other common species of grass are *Eragrostis hypnoides*, *E. glomerata*, *Paspalum orbiculatum*, *P. guianense*, and in the Cyperaceae: *Scirpus cubensis*, *Cyperus luzulae*, *C. ferax*, and *Scleria geniculata* (see Black, 1950).

Shrubs and small vines: *Artemisia artemisiifolia* (artemija), a very common shrub which becomes more frequent when there is excessive grazing and which can sometimes completely dominate areas: *Ipomoea fistulosa*, (manjorana or algodão bravo), a shrub that invades pastures and with sap toxic to cattle, *Polygonum punctatum* (erva de bicho), *Justicia obtusifolia*, *Alternanthera philoxeroides*, *Capironia fistulosa*, *Sesbania exasperata*, *Thalia geniculata*, *Hyptis mutabilis*, *Aeschynomene sensitiva*, *Mimosa pigra*, *Montrichardia linifolia*, *Sphenoclea zeylanica*, *Clematis aculeata*, *Cassia reticulata* (mata pasto), *Phaseolus lineatus*, *Rhabdadenia macrostoma*, and *Clitoria triquetum*.

Floating species: *Ceratopteris pteridioides*, *Eichhornia azurea*, *Salvinia radula*, *Neptunia oleracea*, *Pistia stratiotes*, *Lemna* sp. Also some of the grasses already cited may float: *Leersia hexandra*, *Luziola spruceana* and the various species of *Oryza* (Black, 1950).

A large number of the grasses detach and float freely and are seen descending the Amazon river together with trees that have separated. These floating islands may also contain various animals, including the manatee, an animal actually in danger of extinction. The rivers that have lakes and flooded grass are also very rich in their fish fauna.

These open areas of canarana exist only in the lower Amazon between the mouth of the Xingu river and the mouth of the Amazon and also in some of the rivers of the Amapá that flow into the Rio Oiapoque, Rio Uaçá, Caripi and Urucauá. They also exist in a low lying region in the headwaters of the Xingu river or its tributaries the Rios Culiseu, Jatobá and Ronuro between 12 and 13° and 53 – 54°W. The majestic marsh deer are common in this region because although there are Indian tribes there, they do not hunt them because of their religious taboos. These are all muddy rivers that are subject to the tidal bore and are rich in fish and turtles (Pires, 1964).

The fields of canarana are much used as pastures but the ranches of the region lose many head of cattle annually in the flooded season because the entire region is inundated and there is little terra firme. The soils are fertile, are used for jute plantations, and have much potential for the mechanised cultivation of rice during the dry seasons. These are areas that have their fertility renewed each year by the deposit of sediments. They are an Amazonian resource of great value which has not yet been fully exploited.

7.9. CAATINGAS AND OTHER OLIGOTROPHIC SERAL VEGETATION

Amazonian caatinga, campina, campinarana, chavascal, charravascal are words that are used to signify the same vegetation or small variations of a group of vegetation types that are well defined and are characterised because they grow over pure leached white sand. The name caatinga is also used in Northeastern Brazil but there it is a term for a completely different type of arid vegetation. In this report Amazonian caatinga is treated separately from other open formations because it ranges from completely open through to closed vegetation types. It is difficult to separate these into specific associations because there is complete continuity from the open types to the closed forest formation on white sand.

Fig. 7.20. Campina on white sand at Serra do Cachimbo, Pará.

The caatinga is characterised as a form of vegetation that develops in a climate suitable for forest, but limiting factors restrict the vegetation cover and the species have adapted to the various stress factors. These are the nutrient poor soil and the seasonality caused either by the flooding of the soil which removes the air necessary for root respiration, or extreme drought caused by the excessive porosity of the sand not permitting ascent of water by capillarity. In the first case, since the soil is shallow, the water table is near the surface and can rise above the surface in the rainy season. In the second case, the water table is deep and the deep area of pure sand causes periodic drought. Since these factors vary over a gradient from forest soil to the soils with extreme stress, the plants will increase their biomass to an extent dependent on local conditions. If it is possible to accumulate a large amount of biomass, the plants may also use the factor of shade as part of their adaptation, shading other individuals.

The caatingas are a special type of vegetation (Fig. 7.20). They have a peculiar flora that is reflected in their different physiognomy. The number of species per unit area is generally less, but since the caatingas offer a great variety of different habitats from one location to the next, the sum total is an extremely rich flora that is very interesting and poorly known.

There are a certain genera of plants that are characteristic of caatingas: *Clusia*, *Tovomita*, certain genera of Ericaceae, *Lissocarpa*, *Byrsonima*, *Sipapoa*, *Pagamea*, *Retyniphyllum*, *Zamia*, *Barcella*, *Platycarpum*, *Henriquesia*, genera of Rapataceae, Xyridaceae, Haemodoraceae, some characteristic species such as *Hevea rigidifolia*, *Compsoneura debilis*, *Hevea camporum*, and *Phyllanthus atabapoensis*. Some Amazonian caatingas do not have grasses or sedges, such as those of the Rio Uaupés, *see* Pires and Rodrigues (1964); Rodrigues (1961); Ferri (1960); Vieira *et al.* (1962). Some caatingas, such as those of the Rio Anauá, a tributary of the Rio Branco are rich in grasses and especially Cyperaceae. An important genus of Cyperaceae in this formation is *Lagenocarpus*.

Fig. 7.21. Lichens covering the ground of a white sand campina near Manaus.

The caatingas have a xeromorphic aspect, thick leaves, thick bark, and an abundance of lichens and mosses on the branches and on the soil surface. Sometimes the soil surface is covered with a spongy mat of *Cladonia* (Fig. 7.21). *Sphagnum* is less frequent.

The caatingas of the Rio Negro were the first to be described and have been much cited in the literature since the time of Spruce (1908), but caatinga exists in large or small patches scattered throughout all of Amazonia (Fig. 7.22). In each region they are slightly different, and tend to have different local names. In Roraima, the common name is chavascal, and there are arboreal chavascais and also shrubby and herbaceous ones. The Dutch authors who have worked in Suriname use the term White Sand savannahs, and for the arboreal caatinga, White Sand Savannah Forest.

7.10. VEGETATION COVERING SMALL SPECIALISED AREAS

There are some vegetation types that cover small areas, but are quite distinct. They are less important, but four types should be mentioned here. Mangrove forest, Restinga, *Mauritia* swamp (Buritizal) and Pirizal.

7.10.1. Mangrove forest

The mangroves occupy a small area of Amazonian Brazil in a narrow littoral belt that is subject to salt water inundation. It is a vegetation type poor in species number, and is quite uniform. The principal species, almost always present in Brazilian mangrove are *Rhizophora mangle* (mange, mangue verdadeiro,

Fig. 7.22. Campina forest with epiphyte laden trees near Manaus.

mangue vermelho), *Avicennia nitida* (siriuba, mangue branco), *Laguncularia racemosa*, *Conocarpus erecta*. Beside these species, a few others are occasionally encountered: *Pterocarpus officinalis*, *Hibiscus tiliaceus*, *Annona palustris*, and *Pithecelobium cochleatum*. In areas of extreme clay salt beaches, the small grass, *Spartina brasiliensis* (paraturá, capim estrepe) occurs. This can form carpets which bind the soil. The prostrate vegetation that covers certain areas of mud is generally called *apicum* (Huber, 1909).

Rhizophora mangle is quite variable as a species and some authors have described varieties. Lindeman and Mennega (1963) treat these varieties as three different species: *Rhizophora mangle*, *R. harrisonii* and *R. racemosa*. According to Huber (1909), variety *typica* is abundant in the Costa de Salgado, going up the rivers as far as 20 km from their mouths, whereas variety *racemosa* is much more local in the coast of Marajó Island and extending from there up to Guiana. The Siriuba, *Avicennia* or white mangrove, penetrates inland for a considerable distance up the zone of fresh water, high into the estuary, whereas the true mangrove (*Rhizophora*) only extends as far as the influence of salt water. Areas of mangroves are more common on the west part of the coast between Ilha Maracá and the Rio Oiapoque. In this part, the region is all muddy. There are no sandy beaches, such as occur further to the east. This is caused by the effect of the marine current which pushes the sediments to the west (Pires, 1964).

Because of the small area that is occupied, mangrove is not of great economical importance in Brazil. Up to 1945, thermo-electricity in São Luis in the state of Maranhão was generated from mangrove wood, but today, little use is made of the wood.

7.10.2. Pirizal

This is a form of vegetation that occurs in small restricted areas (Fig. 7.23). They are shallow lakes or puddles with stagnant water that is dark and transparent, with a large quantity of rooted plants with upper parts out of the water. The most frequent plants are *Cyperus giganteus* and *Thalia geniculata* as well

Fig. 7.23. A pirizal near Mazagão Velho, Amapá.

as floating aquatics or plants with floating leaves. For example, *Salvinia*, *Eichhornia*, *Sagittaria*, *Cabomba*, *Nymphaea*, *Limnanthemum*, *Eleocharis*, and other species of Cyperaceae. The mauritia palm may grow around the margins. These pirizais are common in Amapá, in an area along the coast, in the region of Mazagão and Mazagão Velho. They occur as enclaves in the midst of dense forest. In the grassy meadows in the Rio Uaçã, Caripi and Uracauá, at the mouth of the Rio Oiapoque, there are also enclaves in the grassland, which are called Cariazal. Cariá is the indigenous name for *Diplasia karataefolia* and other robust Cyperaceae. On the Island of Marajó, also in the Savannah, there are similar formations which are called Mondongo.

It is interesting to note that in these peculiar lakes, there is a small species of turtle known as Muçuã, which is much cherished as a food in regional dishes. When the waters recede, a large part of the area becomes dry. The local residents often set fire to the vegetation causing the turtles to flee and then they can be hunted in large quantities. Even though trade in turtles is currently prohibited, this predatory hunting continues, threatening the extinction of this species.

In Amapá, they are removing sand from the bottom of these lakes, which indicates the nature of the soil. These pirizais seem to be unique to the estuarine area of Amazonia.

7.10.3. **Buritizal** (*Mauritia* formation)

In various parts of the estuary, in low várzeas which are formed in the middle of the river, one finds dense, practically pure stands of *Mauritia flexuosa* (locally called buriti, Fig. 7.24). The rather large area covered by these stands, justifies separating this as a special type of várzea. There are other places in

Fig. 7.24. *Mauritia flexuosa*, the dominant palm of the Burutizal formation.

Amazonia where buriti is present, but the vegetation is quite different. For example, the buritizais of the Roraima savannahs discussed above form narrow corridors within the savannahs and should be classified differently (*see* the section on the Roraima savannahs).

7.10.4. Restinga (coastal sand dune)

Restinga is the vegetation that develops in sand dunes. It has a xeromorphic aspect and resembles the physiognomy of the Amazonian caatingas.

In Amazonia, the restingas are of minor importance with few species, but in Bahia there are restingas that extend over large areas and are very interesting, having a rich flora with endemics. They have as yet been poorly studied. A good example is the restinga of Maraú.

From Amazonia to Rio de Janeiro, the restingas are morphologically very similar. Common species are *Chrysobalanus icaco*, *Hisbiscus tiliaceus*, *Byrsonima crassifolia*, *Ipomoea pes-caprae*, *I. asarifolia*, and *Manilkara triflora*.

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