Vegetation Communities and Soils in the National Park of Brasília

Paulo Cezar Mendes Ramos

Ph. D. in Geography
University of Edinburgh

1995

DECLARATION

I am responsible for composing this dissertation. It represents my own work and where the work of others has been used it is duly acknowledged.

Edinburgh, 08/02/94

Paulo Cezar Mendes Ramos

Acknowledgements

I am most grateful to the Conselho Nacional de Desenvolvimento Científico e Tecnológico (CNPq) and to the Instituto Brasileiro do Meio Ambiente e dos Recursos Naturais Renováveis (IBAMA) for funding this research and to the National Park of Brasília (PNB), Department of Botany of the University of Brasília, the Soil Laboratory of the Centro de Pesquisa Agropecuária dos Cerrados (CPAC - EMBRAPA), University of Edinburgh - Department of Geography and to the Royal Botanic Garden of Edinburgh, for the facilities provided.

It is my privilege and pleasure to acknowledge the help and friendship of my supervisors, Dr. Peter Furley and Dr. James Alexander Ratter.

I am deeply indebted to Dr. Ary Teixeira de Oliveira-Filho for helping me with advice and information concerning the multivariate analysis programs, for determination of plants and for his friendship.

I am particularly grateful to my colleagues Neilton Rodrigues (Rei) and Raimundo Iris Sobrinho (Índio) for the support in the field work and friendship.

My special gratitude to Gordon John McMillan for many reasons, including help with English and advice on some chapters of the thesis. But, especially for accepting me as his flat mate, introducing me as a friend to his family and friends, and providing me with a happy life in Scotland.

I am also especially grateful to Chris Minty for the facilities in the soil laboratory, for his continual cheerful assistance and for being such a good friend. I should also like to thank the staff of the Geography Department and the Royal Botanic Garden of Edinburgh for their friendship.

In Brazil the following gave me invaluable help during the course of my field work: Carolyn Elenore Barnes, Benedito Alísio da Silva Pereira, Luiz Nasser, Jamil Macedo, Marilusa Araujo Granja e Barros, Enilton Antônio Nascimento, Sérgio A. Almeida, Paulo Guimarães, Fernando, Grilo, Djalma, Henrique and Rui Rabelo.

In the UK I would like to thank the following for their diverse contributions to this work: Mônica Decanini, Christoph Corves, Delia Peres-Castiñera, Sam Bridgewater, Jo Chittenden, Marcelo Nascimento, Dora Vilela, Selma Zawadzki, Mônica Wachowicz, Lyria Oliveira, Manoel Cláudio da Silva Júnior, Nanci Friedman, Loretta Lees, Sheila Paul, Mary Ann, David Robinson, David Cumings, Mike Cressey, Peter Short, Abdul Ghaffar, Luiz Gazolla, Marcela Venturim and Cláudio Bohrer.

I am specially indebted to Ana Paula Leite Prates, who patiently helped editing this thesis.

Above all I should like to thank my parents and my children, who encouraged me throughout the hard period of this work.

ABSTRACT

This research is an initial step in a long term study of vegetation communities of the Brasília National Park. The vegetation contained within this reserve is representative of an increasingly threatened savanna ecosystem (known locally as cerrado), which extends across much of central and northern Brazil.

An intensive study focusing on both the principal woody vegetation communities of the National Park and their associated soils was undertaken. Data were collected from two years of continual fieldwork between October 1990 and 1992. This was the first systematic survey of its kind ever to be carried out within the National Park of Brasília.

Vegetation and soils were selected for analysis from a total of 26 sample sites using the point center quarter method (PCQ). There was considerable heterogeneity in the species composition of the sites sampled. While this can be largely attributed to soil moisture gradients, other factors such as variations in fertility and topography, or the presence of ironstone layers and sandstone outcrops, are all seen to be influential. Even so, the dynamics of these vegetation communities cannot be fully appreciated without considering the important role of fire in this context and furthermore stochastic factors no doubt play a part.

This study confirms that the cerrado ecosystem has a highly diverse flora. Nine different plant communities were identified within the National Park; cerrado open scrub (campo sujo), cerrado scrub (campo cerrado), cerrado scrub with emergents (Vochysietum), campo rupestre, cerrado rupestre, cerrado *sensu strictu*, as well as dry, wet and flooded gallery forests. Within these different communities, (and especially the gallery forests), species diversity was high: in all, a total of 380 woody species with individuals $\geq$ 5cm basal girth were recorded.

Having interpreted these data using a variety of statistical packages, various management decisions and research priorities arising from the results are explored. In this way, appropriate strategies relevant to the future conservation of the cerrado ecosystem are identified.

Tables of contents

List of Tables

List of figures

Figure no. page

Chapter 1

Introduction and statement of the problem

1.1 Savannas of the world

Savannas are tropical ecosystems characterised by a continuous, well developed herbaceous layer consisting mostly of heliophilous C_4 grasses and sedges that show clear seasonal relationships to water stress, and an open, discontinuous layer of trees and shrubs (Frost et al., 1986). Tropical savannas cover extensive areas in Africa, Asia, Australia and South America (Fig. 1), occupying about 40% of the tropics (Solbrig, 1991).

Recent synthesis of savanna research reveals that soil moisture, soil nutrients and herbivory are the principal determinants of savanna structure and function (Huntley & Walker, 1982; Bourlière, 1983; Sarmiento, 1984; Tothill & Mott, 1985; Frost et al., 1986; Walker, 1987).

Soil moisture availability and soil nutrient status are the key factors affecting both the balance between grasses and woody plants, and the patterns of primary production. These in turn influence herbivory and the frequency and intensity of fire. Human activity is another important determinant of savanna structure (Frost et al., 1986).

Thus, the principal factors determining savannas can be distributed along two axes (Frost et al., 1986): one related to plant available moisture (PAM), and the other to plant available nutrients (PAN).

1.2 The Neotropical savannas

The Neotropical savannas cover an area over two million km^2, extending from Central America and the Caribbean to Paraguay and South-eastern Brazil (Fig. 2).

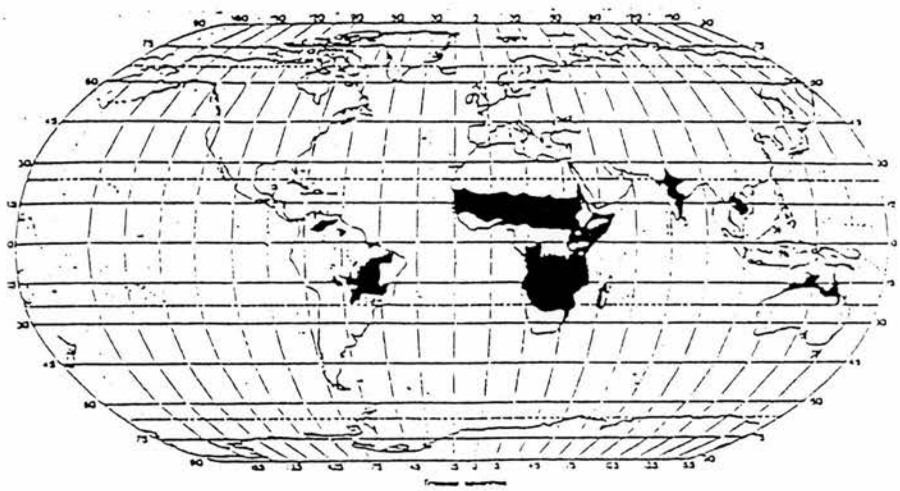


Figure 1 - Geographical distribution of tropical savannas (after Bourliere, 1983)

Figure 2 - Principal savanna regions of Central and South America.

1) Cerrado, 2) Llanos Moxos, 3) Llanos de Orinoco, 4) Gran Sabanna, 5) Savannas of the R Branco/Rupunini, 6) Coastal savannas of the Guianas, 7) Amazonian campos; 8) Llanos Magdalena, 9) Savannas of Miskito (after Sarmiento, 1984).

Various lines of evidence show that they are very ancient and were probably established by the early Tertiary or even earlier (Ab' Saber, 1971, 1977, 1981; van der Hammen, 1983; Emmerich, 1990). A dynamic flux in the areas occupied by neotropical savannas and forests occurred during the climatic fluctuations of the Quaternary, with expansion of the savannas during glacial periods in the temperate regions of the world and expansion of the forests during interglacials (Sarmiento & Monasterio, 1975; Flenley, 1979; Prance, 1982).

The wide variety of the Neotropical savannas can be classified along two main axes of variation: structural and ecological (Sarmiento, 1983). The structural gradient comprises a gradual variation from an open treeless grassland to closed woodland. The ecological axis is based on seasonality of the ecosystems, and is divided into four major categories (Sarmiento & Monasterio, 1975): (1) Semi-seasonal savannas appear under weak seasonal variation, with one and sometimes two very short dry seasons producing a slight water stress. They occur as disjunct patches in areas otherwise covered by rain forests. (2) Seasonal savannas, which are the most widespread, are characterised by a rather long period of water deficiency. (3) Hyperseasonal savannas are subjected to alternate periods of water shortage and waterlogging during each annual cycle. They occur in areas which are poorly drained for much of the year. Finally, (4) are the marshy savannas that experience long periods of water excess. They occur in wet sites on valley sides or tableland margins throughout the region.

1.3 The Brazilian savannas

The Brazilian savannas are called *cerrados* in the plural. The word *cerrado* in Portuguese means 'dense' or 'closed' and designates a vast phytogeographic province of Brazil (Eiten, 1978).

Cerrado is the natural vegetation of poorer soils in Central Brazil and covers an area about 200 million hectares, representing some 23% of the country's surface.

1.4 **Ecophysiological aspects**

The cerrado trees and shrubs are of low contorted form with thick, corky, fire-resistant bark. Many have sclerophyllous leaves with thick cuticles, sunken stomata, and greatly lignified and sometimes silicified tissues. The xeromophic aspect of the vegetation led to a number of workers concluding that it suffered seasonal water stress (Rawischter, 1942; Ferri, 1943; Goodland, 1971). However, the fact that even at the climax of the seasonal drought many plants maintained green leaves, caused some to question this (Rawischter, 1942; Ferri, 1943). Based on further studies, they concluded that the soil water reserves should be easily reached by the deep root systems of the trees and shrubs of the cerrado, and they showed that these maintained open stomata and active transpiration throughout the day in all seasons (Rawischter et al., 1943; Ferri & Coutinho, 1958; Ferri, 1955; Schubart & Rawischter, 1950). The adaptive significance of the high transpiration rates found in cerrado plants is that it may help to maintain a favourable carbon balance, and promote the mass flow of nutrients, particularly the highly mobile cations such as calcium and magnesium (Goldstein & Sarmiento, 1987).

The presence of underground organs (xylopodia) in young and even established trees and shrubs provides an efficient mechanism of water storage. This permits young plants to survive in adverse situations, such as those brought about by the dry season and by fires (Rizzini & Heringer, 1962, 1966; Rizzini, 1965; Labouriau, 1966).

The high root/shoot biomass ratio gives an indication of the relative development of below-ground parts. In cerrado ecosystems, as is general in savannas, fire, water and nutrient regimes seem to favour a strategy of stress tolerance through the increase development of underground parts (Sarmiento et al., 1985).

1.5 Soil aspects

Alvim & Araújo (1952) and Waibel (1948) were the first authors to highlight the xeromorphic aspects of the cerrado vegetation and relate them to chemical soil parameters. Their work gave rise to the hypothesis of oligotrophic scleromorphism. According to this, low soil mineral nutrient availability and aluminium toxicity are considered the factors responsible for the development of sclerophylly in cerrado plants (Arens, 1958a, 1958b, 1963; Arens, Ferri & Coutinho, 1958).

The cerrado soils are defined as Latosols (Oxisols, USDA Soil Taxonomy, 1975). Sand, sandy loam and clay are their predominant textural classes (Feuer, 1956). They are deep, well drained, acid and very poor in terms of mineral nutrients, and frequently reveal ironstone layers (Furley, 1985; EMBRAPA, 1978; Benema, 1963).

In the Brazilian Central Plateau, these soils were formed over ancient surfaces, distributed over plateaus (*chapadas*), which are highly weathered (Benema et al., 1963; Ab' Saber 1963, 1971).

The predominant clay minerals are kaolinite, quartz, gibbsite, Fe oxides and hydroxides (Macedo and Bryant, 1987).

There is a good correlation between soil colour and the kind of iron oxide present. The dark-red and the reddish zones of the Red-Yellow Latosols exhibit haematite and goethite mineralogy, whereas goethite is the main Fe component in the yellowish zones (Schwertmann, 1971; Rodrigues & Klant, 1978; Volkoff, 1978; Kampf & Schwertmann,1983; Macedo & Bryant, 1987, 1989).

The concept of soil fertility and vegetation community gradients in the cerrado regions have received special attention from researchers. Differences in soil resources have been reported between cerrado, dystrophic cerradão, eutrophic cerradão and mesophytic forests (Goodland, 1971; Goodland & Pollard, 1973; Ratter et al., 1976; Lopes & Cox, 1977; Ratter et al., 1978a; Ribeiro et al., 1982, 1983, 1985; Furley & Ratter, 1988; Ratter et al., 1988; Cesar et al., 1990; Ratter, 1992).

However, structural variations in vegetation in terms of density and size of trees and shrubs observed in the typical cerrado vegetation communities cannot be directly related to fertility gradients of soils. They result from the complex interaction of the factors such as the effective soil depth, influenced by differing drainage conditions, slope variations and the water table (Rodrigues, 1977; Ribeiro et al., 1982; Haridasan, 1992).

Along the valley bottoms the gallery forests have developed on acidic soils with low base saturation and high aluminium concentrations. Only the top-soil horizons present significant differences in respect to mineral nutrients compared with upper slope formations, provided by the higher amount of organic material (Furley 1985, 1992; Ratter, 1992).

An inverse relationship has been observed between the cerrado vegetation gradient biomass and aluminium availability in the soils (Goodland & Pollard, 1973). Nevertheless, studies on the aluminium contents in leaves of cerrado trees and shrubs concluded that high concentrations of this cation were not associated with low contents of phosphorus or other essential nutrient minerals (Haridasan, 1982). The precise determining effect of aluminium on natural plant communities remains uncertain.

1.6 Vegetation and phytosociological aspects (brief review of relevant literature)

Martius mentioned some common species of the cerrados of Minas Gerais in 1824 (Eiten, 1972), but it was Warming (1892) who carried out the first ecological study of this vegetation.

Eiten (1972) presented an important synthesis about concepts, distribution and ecological aspects of cerrado. Rizzini (1963, 1979) and Heringer et al. (1977) provided lists of the principal woody species of cerrado region, and compared the cerrado with other important floral regions of Brazil.

Phytosociological studies in Central Brazil gained a further impetus from the Xavantina - Cachimbo expedition, organised by the Royal Society, from 1967 to 1969, with the co-participation of Brazilian institutions (Martins, 1989).

Frequency and abundance of woody species were estimated in gallery forests, mesotrophic forests, cerradão, and different categories of cerrado, in several areas in Mato Grosso, Goiás, Brasília, Minas Gerais and São Paulo (Ratter, 1971, 1980, 1987; Ratter et al., 1973, 1977, 1978a, 1978b, 1988b, 1989; Furley & Ratter 1988; Furley et al. 1988). These studies established the floristic composition and vegetational structure, and were related with abiotic factors and to edaphic properties in particular. Based mainly on the fertility gradient, diagnostic trees and shrubs species were distinguished and established as indicators of distinct plant communities.

A group of researchers from São Paulo state (Universities of São Paulo, Campinas and Rio Claro), have added an important contribution in this field (Martins, 1989).

For the Federal District (Brasília), Ratter (1980) and Furley (1985) developed studies of the soils and vegetation of Fazenda Água Limpa, the research station of the University of Brasília. These studies motivated the development of several research initiatives on the phytosociological and soil relationships in the region.

Ribeiro (1985), Ribeiro et al., (1983) and Ribeiro & Haridasan (1990) observed interesting relations between soil factors and phytosociological parameters, in some areas of cerrado and cerradão in the Distrito Federal. Felfili & Silva Junior (1988, 1992) studied some areas of cerrado, cerradão and gallery forests in the Federal District. Ramos (1989) studied a dry mesotrophic forest on limestone-derived soils, in Federal District.

1.7 The importance of fire within the cerrado landscape

The mineral nutrient cycle is strongly influenced by fire. Combustion accelerates the nutrient cycling processes through the mineralization of the aerial biomass and by depositing the remaining ashes at the soil surface. Fire also accelerates nutrient loss to the atmosphere by gas emission and smoke (Wells, 1971; Coutinho, 1979).

After a burn, an increase of some mineral nutrients has been observed in the superficial soil layers of savanna vegetation. Contents of P, Ca, Mg and K stay higher for about three or four months, before returning to their previous or lower levels (Cavalcanti, 1978; Coutinho,1980; Batmanian, 1983; Viro, 1984; Kellman, 1985).

Volatile elements such as N and S can be lost during the vegetation burning (Coutinho, 1979). While the burnt areas export volatile elements, an input of nutrients also occurs through the precipitation of solid particles or dissolved substances in rain water (Coutinho, 1979, 1980). It was observed in Pirassununga - SP that around 1/6th of the exported minerals were returned within a year, (Coutinho, 1979).

Natural fires have been a common feature throughout geological time. However, human activities have increased their frequency and impact (Flenley, 1979). Indigenous use of fire for hunting, crop management and also for tribal wars in Brazil preceded the arrival of the Potugueses colonisers in the 16th century (Moreira, 1992). The Kayapó indigenous population has been using fire as a management tool for centuries, in order to induce the fruit production of some cerrado species (Anderson & Posey, 1985). Charcoal fragments found in cerrado soils have been dated to 8,600 B.P. (Coutinho, 1981).

Fire is a strong determinant of cerrado plant communities (Moreira, 1992). Fire-adapted morphological structures of cerrado plants, (e.g. thick corky bark) which may differ according to species, are important factors for their establishment in areas subjected to periodic fire (Rachid-Edwards, 1956; Coutinho, 1982, 1990; Moreira, 1992).

Fire has a great influence on the life-cycle of cerrado species, and in many it is the trigger for flowering and/or dehiscence of fruits, dispersion of seeds, etc (Coutinho, 1977). Fire often induces changes in species composition and consequently, structure in savanna communities (Menaut, 1977; San José & Fariñas, 1983). Among the cerrado woody plants fire tends to favour species that have protected meristems and/or that have the capacity to resprout from underground meristems on rootstocks (Coutinho, 1982, 1990).

Fire does not cause significant mortality in established cerrado plants but causes a top-kill (death of aerial parts of the plant, which generally resprout soon after) on smaller individuals. So, periodic fires bring about a stratification of the tree density, being detrimental for the recruitment of trees (Ramos, 1990; Moreira, 1992).

Suppression of fires increases the density, cover and basal area of trees, favouring the establishment of fire-sensitive species of cerradão and forests. Protection of fire in cerrado areas can gradually turn the vegetation into cerradão (Coutinho, 1978a; Ratter, 1980). Conversely, cerrado areas subjected to repeated fires over a long period tend to suffer progressive reduction of the arboreal component, and can eventually be transformed into *campo sujo* (Ramos, 1990; Moreira, 1992).

Nevertheless, the detailed effects of fire on structure, species heterogeneity and plant recruitment are virtually unknown for the cerrado. What is known, however, is that fire is a crucial factor in creating a diversity of physiognomies (Moreira, 1992).

1.8 The problem

Soil fertility is considered by many authors to be a major determinant of the physiognomic gradient found in the cerrado vegetation (Goodland & Pollard, 1973; Lopes & Cox, 1977; Queiroz Neto, 1982). However, some authors could not find a simple relationship (Ribeiro, 1983; Furley & Ratter, 1988; Oliveira-Filho et al., 1989).

Evident correlation of vegetation structure and floristic composition with soil fertility were observed by comparing the mesotrophic cerradão and the calcium-rich mesotrophic forest with the dystrophic cerradão and other cerrado vegetation types (Ramos, 1989; Furley, 1992; Ratter, 1992; Ratter et al. 1973, 1977, etc.).

The present study aims to identify phytosociological patterns in the National Park of Brasília and to examine whether the vegetation communities are related to soil properties. Distinct communities, are compared and classified, by means of phytosociological patterns and soil properties.

The question to be investigated can be summarized as follows:

1. What are the phytosociological characteristics of the vegetation communities ?
2. What are the characteristics of the soils?
3. To what extent do soil properties determine the distribution of the vegetation communities?

Chapter 2

The Area of Study

2.1. Localisation

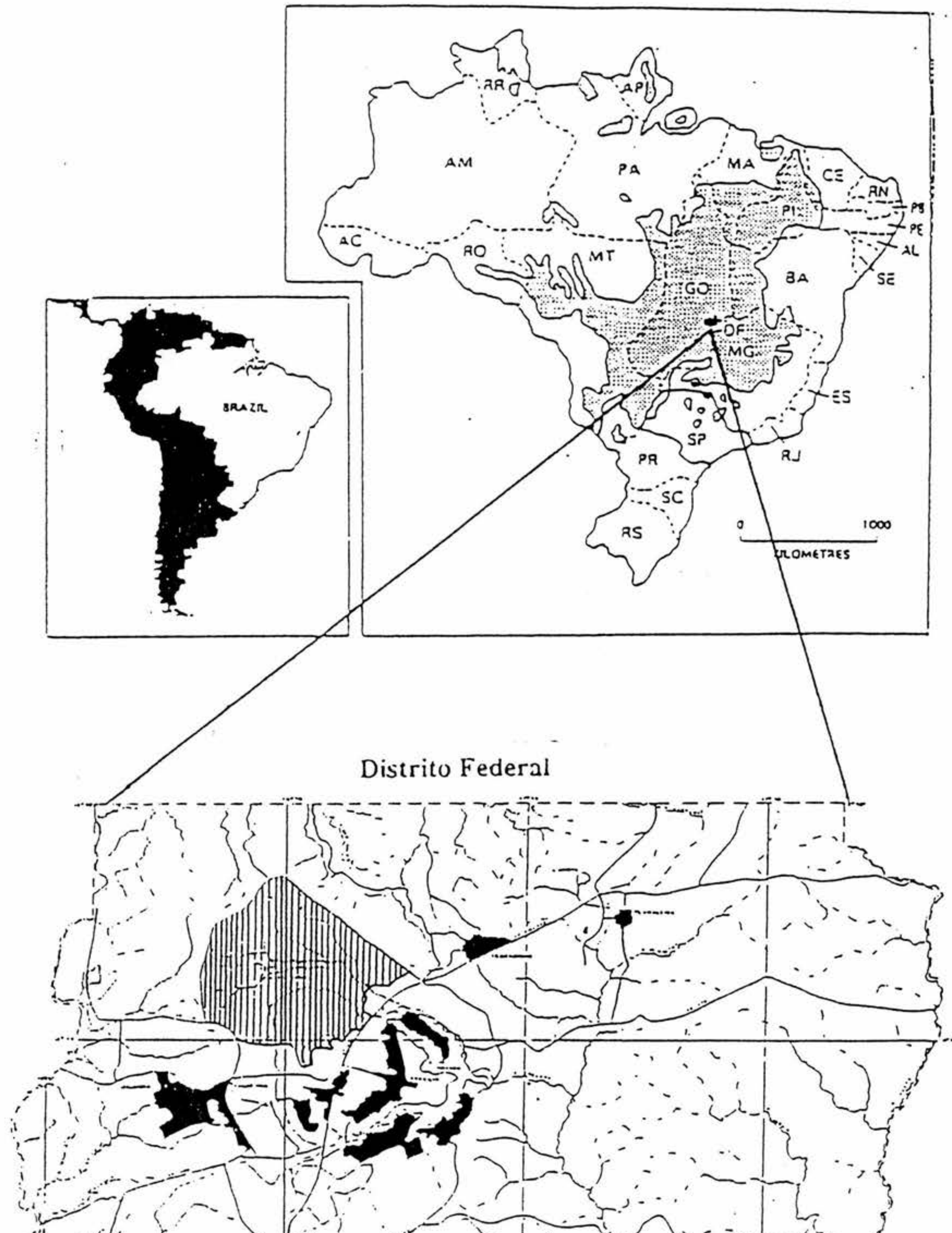
The Brasília National park was established on 29th of November, 1961, by a federal Decree. Its area is about 28,000 ha, and it is located between $15^{o}35'$ - $15^{o}45'$S and $48^{o}05'$ - $47^{o}53'$W, in the Distrito Federal, in the Central West region of Brazil (Brasil, 1979) (Fig. 3).

From a biogeographic point of view, the national Park belongs to the morphoclimatic and phytogeographic domain of the *cerrados* (Ab'Saber, 1970). On a local scale, according to the Land System of Cochrane et al. (1985) it belongs to the *Terras Altas da Superfície da Pratinha*, in other words the high table-lands of Pratinha.

It is important to note that the national Park is situated in the core area of the *cerrados* (Ab'Saber, 1981; Azevedo & Caser, 1979) and is therefore, representative of a substantial region within the Brazilian savanna.

2.2. Climate

The region has a seasonal tropical climate, with a distinct dry season, usually from April to September. During the remainder of the year there is a wet season, characterised by heavy rainfall (average of 1,526 mm), high atmospheric humidity, less bright sunshine and greater cloud cover. Temperatures average around 25^{o} C, with a relative humidity average of about 80%, which can drop to less than 50% from May to September (Eiten, 1984), (Table 1).



Source: Atlas of the Distrito Federal - CODEPLAN - 1984.

Figure 3 - Localization of the Brasilia National Park

Brasília National Park

Brasília city and suburbs

Distribution of cerrado vegetation

Table 1. Climatic summary of the Distrito Federal based on two stations (1961-1980)

Average annual temperature, 25.4° C
Coldest months, June and July, average 18.3° C
Absolute minimum, 6.0° C
Warmest months, September and October, average 31.5° C
Average of yearly maximum, 28.3° C
Absolute maximum, 34.5° C
Average annual precipitation, 1526 mm
Average sum of the three driest months, June, July and August, 10.5 mm
Average of driest month, August, 1.9 mm
Average sum of the three wettest months, November, December, and January, 770 mm
Average of wettest month, November, 279.0 mm
Maximum recorded rainfall during 24 hours, 132.8 mm
Average annual evaporation, 1586 mm
Months with most evaporation, August and September, 234-256 mm
Month with least evaporation, March, 76 mm
Average relative humidity, 50-51 % in August and September, to 80-82% in December and January between rains
Driest recorded relative humidity, 13 %
Average annual insolation, 2409 hours; dry months with over 200 hours per month, wet months less but with over 130 hours per month

(after Eiten, 1984)

The Distrito Federal falls into Köppen's Aw - savanna subtype of the Tropical Rain Climate category (Brasil, 1979), tropical with a definite dry season, with a difference between the average temperatures of the coldest and warmest months less than 5°C. In Gaussen's classification, the area belongs to the Xeroquimenic region - dry winter (EMBRAPA, 1978).

2.3 Geology

The region constitutes an anticlinorium exhibiting a semidomic shape, whose axis slopes E-SE. The nucleus of that structure is formed from slates and metasiltites, dissected by the erosive effects of geomorphic processes, while superposed quartzites remain, forming a ring-like feature, around Brasília. Because of this, the Paranoá river and its tributaries, of which the National Park watercourses are part, form an annular pattern (EMBRAPA, 1978).

Pre-Cambrian, Tertiary and Quaternary rocks appear in the stratigraphic column for the region. From the Pre-Cambrian, the Paranoá Formation, Bambuí Group, is represented, and it is composed essentially of quartzite, phyllite, metasiltite and slate, dominated by quartzite and phyllite (CODEPLAN, 1976). The base is formed by massive reddish brown slate, covered by a quartzite layer of about 20-25 meters thick and, above them, a lateritic cover characterises the table-land of the Chapada da Contagem (EMBRAPA, 1978).

The Tertiary is represented by the table-land formations (*chapadas*), that are composed of detrital-lateritic covering. Different erosion cycles have resulted in plateau, terraces and pediplains, covered by thin detritic deposits, partially lateritic, that can be sandy, silty or clayey. The regional topography is limited by these lateritic layers that vary from a few centimetres to five meters thick.

The Quaternary is represented by alluvial deposits distributed along water courses, composed mainly of pebbles, sand and clay (EMBRAPA, 1978).

2.4 Geomorphology

According to Ab'Saber (1981) the cerrado occupies in its core area, the interfluves of a huge plateau and is referred as the *Domínios Tropicais dos Planaltos Aplainados Interpenetrados pelas Matas de Galeria* (Tropical domains of table-lands, interpenetrated by gallery forests) (Ab'Saber, 1977). These 'Domains' are spread over an area of about 2 million square kilometres and are composed of plateaus of complex structure on crystalline and sedimentary surfaces. The plateaus may or may not be covered by lateritic deposits. The soils are generally poor. The slopes are gentle and pediplain and terrace levels offer evidence for the climatic changes during the Pleistocene (Bigarella et al., 1975).

The Distrito Federal is situated on the highest parts of the Brazilian Central Plateau. Its relief configuration composes broad and undulating levels known as chapadas, long even slopes (pediplains and pediments) extending from the chapada bases and residual hills to valleys, and areas dissected by the drainage of the local rivers. Both the chapadas and the pediplains or pediments are the result of geomorphic processes during the Cenozoic producing residual flattening. The chapadas have been moulded through etchplanation processes, during the Tertiary and the pediplains and pediments by pediplanation and pedimentation processes, starting in the Pliocene and stopped during the Quaternary by phases of dissection along valleys (Novaes Pinto, 1990).

The drainage cuts into the pediplains and chapadas forming the long and narrow watercourses where the gallery forests and marshy palm groves (veredas) are found in valley bottoms.

On wet grasslands surrounding the heads of the gallery forests, and on interfluves, fields of scattered earth hummocks (*murundus*) are sometimes found bearing cerrado vegetation on their tops (Eiten, 1984; Araujo Neto et al, 1986; Furley, 1986; Furley & Oliveira, 1990; Novaes Pinto, 1990).

The landscape of the National Park covers three levels of erosion: the first lies between 1,050 and 1,000 meters, where the landscape undulates gently; the second is between 1,100 and 1,200 meters, where the relief is often quite steep and some cliffs stand out; the third lying above 1,200 meters is the table-land of the *Chapada da Contagem* which forms the watershed between the Amazon and Paraná basins (Brasil, 1979).

The relief levels are part of the Plateau Region (*Região de Chapadas*) and Paranoá Depression (*Depressão do Paranoá*), which compose the geomorphological macro units of the Distrito Federal (Novaes Pinto, 1990).

2.5 Soils

The soils of Brasília National Park have been classified as Latosols (Oxisol, USDA - Soil Survey Staff, 1975), Hydromorphic soils and Cambic soils (EMBRAPA, 1978).

Among these soil classes, the Latosols are the most widespread in the area (EMBRAPA, 1978; Camargo et al., 1986; Richter & Babbar, 1991). In the National Park of Brasília, they cover areas of the Contagem plateau and the slopes of Paranoá depression.

The Hydromorphic soils are found supporting gallery forests or wet grasslands in the valleys, or occur in localities where the water table emerges at the base of convex slopes.

The Cambic soils are found on steep slopes, generally on the plateau shoulders (EMBRAPA, 1978).

A hydro-topographic gradient in the *cerrado* landscape is perceptible, showing a gradual change in the soil colour pattern. Well drained soils, with medium to clay texture, deep and reddish, occupy the highest levels of the table-land, giving way, gradually, to shallower yellowish soils along the slopes, down to the valleys, while at the same time the depth of the water table decreases (Cole, 1958; Benema, 1963; Ab'Saber, 1963).

The Latosols can be subdivided, according to the amount of the free Fe oxides, into Dark-Red and Yellow-Red (Adamoli et al., 1985; Camargo et al., 1986). However, recent studies indicate that the colour hues are not controlled by the amount but by the nature of iron oxides present. This variation in colour is attributed to the haematite and goethite found in the soils. The clay fraction of the Latosols of the Distrito Federal is composed mainly of kaolinite, gibbsite, amorphous materials, iron oxides and quartz. In some Latosols kaolinite predominates, whilst in others gibbsite is more common, demonstrating the different weathering conditions which are related to the amount of gibbsite in the soil (Rodrigues & Klant, 1978).

The Latosols are considered to be the most weathered of all soils and their dominant characteristics are associated with low silica/sesquioxides ratio, low base exchange capacity, low activity of clays, and low content of weatherable minerals (Wilding et al., 1983). These soils have strong to moderate acidity, with the pH varying between 4.0 and 5.5 and their textures range from clay to sand, the former being represented mainly by the iron oxides and aluminium hydroxides (Goedert, 1985).

The Hydromorphic soil class includes those soils which have a water table at or near the surface throughout the year or seasonally and have developed as a result of the influence of surface water. They can be found generally in valleys, on flat areas exposed to periodic floods, or on slopes where water flooding occurs (Eiten, 1984; Haridasan, 1990).

The wet grasslands (*campo limpo*), the *Mauritia flexuosa* palm groves (*vereda de buritis*) and the damp gallery forests are associated with Hydromorphic soils (Eiten, 1984).

The Cambic soil profiles are not so developed as the Latosols, basically because of the dynamic nature of the relief on the steep slopes where they occur. Their diagnostic characteristic is the presence of a B Cambic horizon (USDA - Soil Survey Staff, 1975). In the National Park they develop from phyllites, metasiltites, slates and quartzites, forming dystrophic soils where *cerrados*, *campos cerrados*, *campos rupestres* and eventually forests are established (EMBRAPA, 1975; Haridasan, 1990; Cavedon & Sommer, 1990).

2.6 Vegetation

The Phytogeographical Province of the *Cerrado* spreads over the Central Brazilian region, which includes part of south of Mato Grosso, Mato Grosso do Sul, Goiás, Tocantins, the west of Bahia, the west of Minas Gerais, and the Distrito Federal. The *cerrado* vegetation area extends to the south of Maranhão and Pará, north of Piauí, and as a narrow strip of land into the state of Rondônia. Disjunct areas can be found in the States of São Paulo, Amapá, Roraima, and in some small areas of the Northeast region, between the *caatinga* (a characteristic vegetation of the semi-arid region) and the Atlantic Forest on the coast (Eiten, 1990). This vegetation province covers approximately 2 million km^2, representing about 23% of the land surface of the country, exceeded only by the Amazonian forest with 3.5 million km^2 (Furley & Ratter, 1988).

The word *cerrado* has been used to characterise a distinct vegetation type. As a biogeographical term, it indicates the area of distribution of a vegetation complex in which, in terms of area, the cerrado vegetation is the most important. The term cerrado can also be used in a *sensu lato* to indicate all the different structural forms of this vegetation type such as *cerradão, cerrado, campo sujo* and *campo limpo*, or *sensu stricto*, to denote a particular node in the vegetation continuum corresponding to a fairly closed woodland (Eiten, 1978, 1986).

The nearest international equivalent of the *cerrado* is the word savanna, and despite the use of this term in the most recent Brazilian vegetation classification (Brasil, 1982; Veloso et al., 1991), the term cerrado is used here as it is well accepted, unambiguous and appropriate (Goodland, 1971; Eiten, 1986).

Cerrado vegetation occurs in a seasonal climate with a distinct dry season of about five months, generally over old plateau surfaces where deep and weathered soil has developed. The soils are acid, very poor in mineral nutrients, and rich in exchangeable aluminium. The cerrado woody plants have very deep root systems which allow them to transpire and renew their leaves even during the dry season. They exhibit scleromorphism which is probably related to oligotrophy of the soils rather than to measures to reduce transpiration (Ratter, personal communication).

Differences in density, height and cover of woody plants, floristics, and soil characteristics have all been used to distinguish the different plant communities in the *cerrado* region. Although efforts have been made to establish a universal classification using terms of world-wide currency (Beard, 1944; Eiten, 1972) most of papers on the vegetation of the cerrado region refer to the different vegetation types using more or less the following mixed terminology: gallery forest, mesophytic forest, *cerradão, cerrado, campo sujo, campo limpo, vereda,* and *campo rupestre.*

2.6.1 Gallery forest

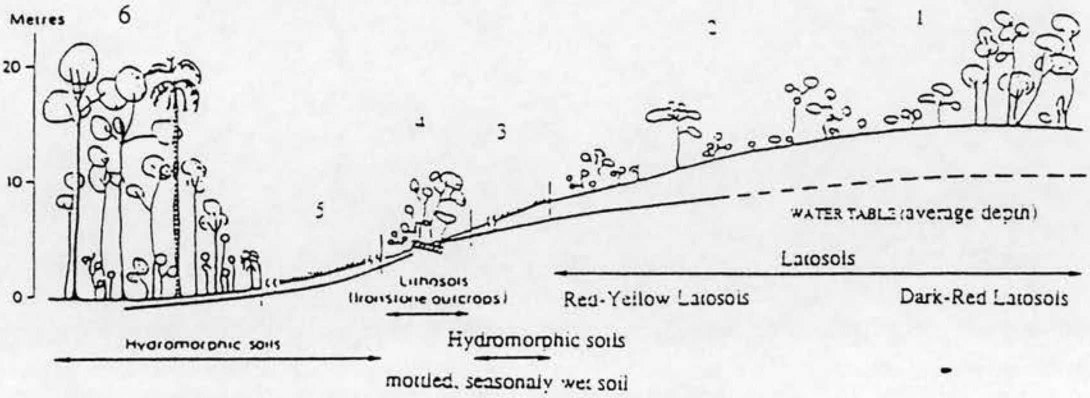
The gallery forest is a typical evergreen tropical forest vegetation located along the watercourses in valley bottoms. Physiognomy and species distribution patterns vary according to topographical conditions and characteristics of the terrain. Slope and drainage of the areas clothed in gallery forests vary greatly so the substrate can be anything from comparatively dry to waterlogged. Soils are generally Hydromorphic, Cambic or Latosols. The canopy is up to 20 to 30 meters in height and sufficiently closed to provide a 80 to 100% crown cover (Eiten, 1972; Ratter, 1980; Felfili, 1993).

The density of trees is variable, but the flooded forests are denser and poorer in number of species of woody plants than the drier ones (Ratter, 1980). The gallery forest of each stream generally shows a particular floristic composition, as well as a variation in physiognomy and community related to zonation, changing from the margins abutting on other vegetation types (campo limpo, vereda, campo sujo, cerrado or cerradão) to the valley bottoms (Ratter, 1980).

In the drier areas, the floors of the galleries are covered by a continuous layer of litter, mainly composed of dead leaves and woody material from fallen branches and trunks of trees and shrubs. Young trees are common as well as some herbs and shrubs. Large trees with thick trunks (dbh ≥ 30cm) of *Copaifera langsdorffii*, *Emmotum nitens*, *Hymenaea courbaril* var. *stilbocarpa*, *Maprounea guianensis*, *Qualea dichotoma* and *Virola sebifera* are common. *Belangera ternata*, *Callisthene major*, *Machaerium acutifolium*, *Pseudobombax longiflorum* and *Tapirira guianensis* are characteristic tree species of the drier margins, forming a boundary with cerrado or campo sujo (Ratter, 1980; Felfili, 1993).

Where the streams have not cut deep banks swampy conditions occur and a rather different flora occurs. Here *Protium* sp., *Calophyllum brasiliense* and *Tapirira guianensis* are important canopy trees (to 25 m) while in the understorey the rhizomatous palm *Geonoma schottiana*, the tree fern *Cyathea* sp., and larger shrubs such as *Malanea macrophylla* and *Miconia nervosa* are common. The muddy floor of the marshy gallery forest is covered by a layer of dead leaves and woody material in varying stages of decomposition usually stabilised by a root tangle. A number of tree species such as *Richeria obovata*, *Ferdinandusa speciosa* and *Byrsonima umbellata* are very characteristic of the margin of swampy gallery forest abutting on to damp campo limpo.

Near the edges of some gallery forests, on peat soils, there is a dense bush of thin, small trees and shrubs where the principal species are *Euplassa inaequalis*, *Ferdinandusa speciosa*, *Hedyosmum brasiliense*, *Malanea macrophylla* and *Miconia chamissois*. Moving towards to the interior of these forests, thicker and taller trees of *Calophyllum brasiliense*, *Protium* sp., *Belangera ternata*, *Talauma ovata* and *Xylopia emarginata* are a



b

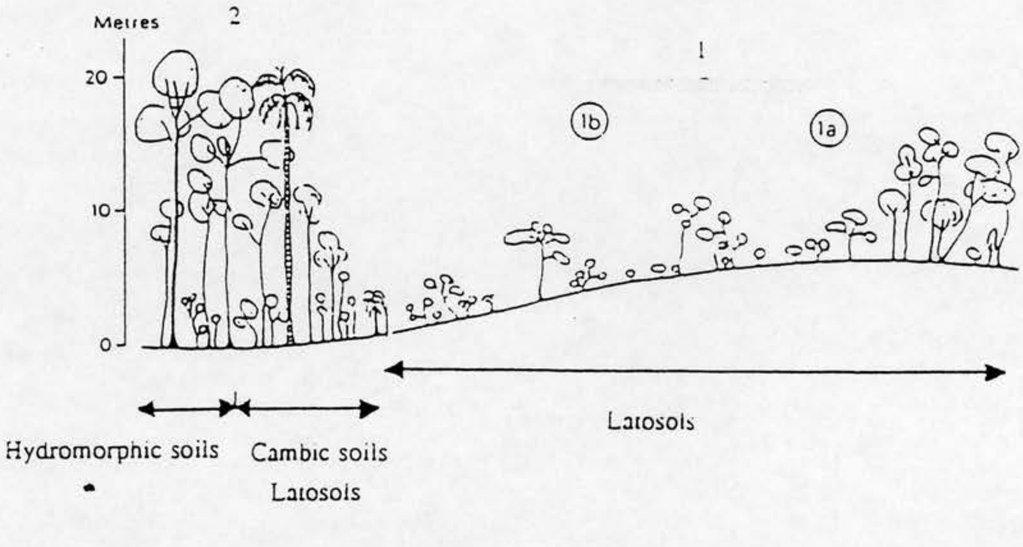


Figure 4 - Characteristic toposequence of plant communities and soils found over sloping topography in the National Park of Brasília:

(a) 1) cerrado *sensu stricto*; 2) cerrado scrub (campo cerrado); 3) cerrado open scrub (campo sujo); 4) cerrado scrub with emergents (Vochysietum) on ironstone outcrops, cerrado rupestre on sandstone outcrops and campo rupestre on Lithosols; 5) campo limpo (grass and sedges communities) or grass communities with patches of woody cerrado on upraised mounds (campo de murundus); 6) gallery forest.

(b) 1) cerrado *sensu stricto* or, 1a) cerrado *sensu stricto*, 1b) cerrado scrub, all on Latosols; 2) gallery forest on Cambic soils (semideciduous) or on Latosols in the fringes with cerrado vegetation, and on Hydromorphic soils in the lower parts of the catena, near the water courses.

very important. In these flooded areas, tree species often develop characteristic root systems showing adaptations such as buttress roots, stilt roots, "breathing-pegs" and "knee-roots" (Ratter, 1980).

In flooded sites where the water levels are higher, *Xylopia emarginata* is the absolute dominant tree, and the tall palm, *Mauritia flexuosa,* creates an attractive landscape along their margins.

2.6.2 Cerrado "sensu lato"

In the cerrado communities of the Distrito Federal there is a physiognomic gradient of woody vegetation (Fig. 4) that changes in a continuum from campo limpo to cerradão. Cerrado *sensu stricto* represents the penultimate stage of closing of the vegetation by trees and shrubs: the original meaning of the vernacular term was that the vegetation was too closed to be penetrable when riding on a horse (Ratter, personal communication).

These physiognomic categories of the cerrado vegetation are mainly related to a topographic gradient of soil-water relationships (Furley, 1985; Oliveira-Filho et al., 1989). The cerrado *sensu stricto* or cerradão can occupy the highest, best-drained portions of the gradient, on Dark-Red Latosols, and essentially are found on the same type of soils, where more frequent burning has occurred cerrado *sensu stricto* tends to be more frequent than cerradão.

Occurrence of campo sujo is generally related to the higher levels of the water-table during the rainy season, but can also be a result of excessive burning of the cerrado (Ratter, 1980; Coutinho, 1980). Campo limpo commonly occurs in humid places, generally over the lower slopes and in the bottoms of the valleys (Goodland, 1971; Coutinho, 1978; Eiten, 1972, 1984; Haridasan, 1990).

The campo limpo is a predominantly herbaceous vegetation type where grass and sedge species are dominant and rare shrubs may appear. It is found on Hydromorphic soils or Lithosols in such habitats as wet interfluves and strips alongside the gallery forests, and is sometimes dotted with earth mounds. The mounds are called murundus in Portuguese and the landscape of damp campo limpo bearing them is called campo de murundu.

The murundus are earth mounds of variable size, form and height. They are usually circular or elliptic in outline, generally ranging from one to three meters diameter, and are often more than one meter in height. They support cerrado species on their summits, which are made up of Latosols and beyond the reach of the wet season water-table (Ratter, 1980; Ribeiro et al, 1983; Eiten, 1984). Work carried out in the Distrito Federal has demonstrated the origin of murundus predominantly by a differential erosion process promoted by runoff (Furley, 1986; Araujo Neto et al., 1986), although in other localities termite action may be the principal cause (Furley & Oliveira, 1990).

Vereda is typically a grove of the tall fan-palm *Mauritia flexuosa* , generally associated with flooded areas along the gallery forests or in seepage areas on slopes.

Campo sujo (Portuguese for 'dirty field') is a form of cerrado *sensu lato* dominated by the herbaceous layer, but with sparse occurence of shrubs and often some trees. It is generally associated with shallow Yellow-Red Latosols, and also with Lithosols (Eiten, 1972). The herbaceous layer is many times richer in species than the shrubby component, and many species of Gramineae, Compositae, Leguminosae, Rubiaceae, and Myrtaceae are very important constituents. The shrubs are often dwarfed specimens of *cerrado* tree species .

A characteristic shrubby community consisting principally of *Myrsine guianensis, Vellozia flavicans, Connarus suberosus* var. *fulvus*, and *Kielmeyera coriacea* is found in some areas. Its occurence seems to be related to the depth of the water table.

Cerrado *sensu stricto* and the somewhat more open campo cerrado constitute the most important vegetation in the central Brazillian region in terms of area. They are usually associated with a range of soils from Dark-Red and Yellow-Red Latosols, Cambic soils and Lithosols. The herbaceous layer contains the same species that occur in the *campo sujo*, where mainly grass species share dominance with the sub-shrubs (Eiten, 1972; Ratter, 1980). The trees and shrubs are scleromorphic, with thick bark, leathery and/or pubescent leaves, and are mainly evergreen (Furley & Ratter, 1988). The heights of trees are usually about 3 to 10 meters and the crown-cover is between 1 to 70%, from campo cerrado to dense cerrado *sensu stricto* (Eiten, 1972; Ribeiro et al., 1982a, 1982b). The commonest species of trees are *Vochysia thyrsoidea, Pterodon pubescens, Qualea grandiflora, Q. parviflora, Caryocar brasiliense, Eriotheca pubescens*, while *Kielmeyera coriacea, Erythroxylon suberosum, Connarus suberosus* var. *fulvus* are very common as shrub species. The palm trees *Syagrus comosa* and *S.flexuosa* are common shrub components, and the monocotyledonous *Vellozia flavicans* is also an important shrub (Ratter, 1980).

2.6.3 Cerradão

Cerradão (the Portuguese augmentative of cerrado) is the closed forest form of cerrado *sensu lato*, representing the ultimate end of the vegetation gradient. Here trees present erect trunks with a canopy at about 8 to 15 meters, and a crown cover between 70 and 100%. The herbaceous layer is less dense than in other forms of cerrado *sensu lato* as a result of shade, and in closed sites different species may appear. The commonest tall trees of cerradão in the Distrito Federal are *Bowdichia virgilioides, Blepharocalyx salicifolia, Siphoneugena densiflora, Emmotum nitens* and *Caryocar brasiliense.*

Some cerradão tree species are rarely or never found in more open forms of cerrado, e. g. *Emmotum nitens, Callisthene major* and *Siphoneugena densiflora,* but these and various others, such as *Copaifera langsdorffii, Anadenanthera peregrina, Astronium fraxinifolium* and *A. urundeuva* are common in mesophytic forest. As has been pointed out in works considering Central Brazilian vegetation (Ratter et al., 1977; Rizzini, 1979), the cerradão and mesophytic forests share many floristic elements.

2.6.4 Campo rupestre

The *campo rupestre* is a vegetation type that occurs in the Distrito Federal on Cambic soils outcrops of quartzite or sandstone, or on shallow, sandy soils, derived from those rocks, and is humid only during the rains, drying out during the dry season (Eiten, 1984). It is predominantly herbaceous, but contains some small, often rachitic, trees about 2 to 3m tall which give from 1 to 10% cover. Many campo rupestre species have small, leathery leaves, and a common growth form is the low subshrub of ericoid form.

Many species of the campo rupestre are endemic, and characteristic well-represented families are the Velloziaceae, Compositae, Eriocaulaceae, Melastomataceae, Xyridaceae, Iridaceae and Gramineae (Ribeiro et al, 1983).

2.7 Fire

Fire has been shown to be the cause of changes in cerrado vegetation structure, and is regarded as an important factor for the existence of many savannas in Africa and Australia, as well as grasslands, prairies and chaparrals in the USA (Coutinho, 1980).

In grassland and woodland savannas, the fire succession is essentially a vegetative recovery process. It is rapid, lasting one year under humid tropical conditions, and up to four years in semi-arid savannas, creating great changes in plant populations. At least in grassland and mesic savannas, the fire regimen is a crucial determinant factor (Kruger, 1984; Frost, 1986).

Fire has been reported to stimulate the expansion of the herbaceous flora, at the expense of the arboreal and shrubby element, changing areas of cerradão into cerrado *sensu stricto* or campo sujo (Goodland, 1979; Ratter, 1980; Ramos, 1991; Moreira, 1992).

Despite the inadequate knowledge about fire as an ecological factor in the cerrado (Coutinho, 1982), it is quite evident that fire plays an important role on structure and physiognomy (Moreira, 1992).

In the cerrado areas of central Brazil, fire has been a seasonal event, and the amazing extension of annual burnt areas has caused concern to the authorities. Specific programs on fire research, prevention, combat and education have been developed in the last few years by official agencies.

The National Park of Brasília has suffered seasonal fires to varying degrees, depending on factors such as the amount of rainfall, duration of the previous rainy season, quantity of dry combustible material present (which depends on the previous fire history) and of course on the prevention programs (personal observations).

Chapter 3

The nature and distribution of soils within Brasília National Park

3.1 Introduction

The first detailed studies on the soils of cerrado region started in the nineteen sixties (Bennema, 1963), and only since the seventies have they developed significantly (Adamoli et al., 1986).

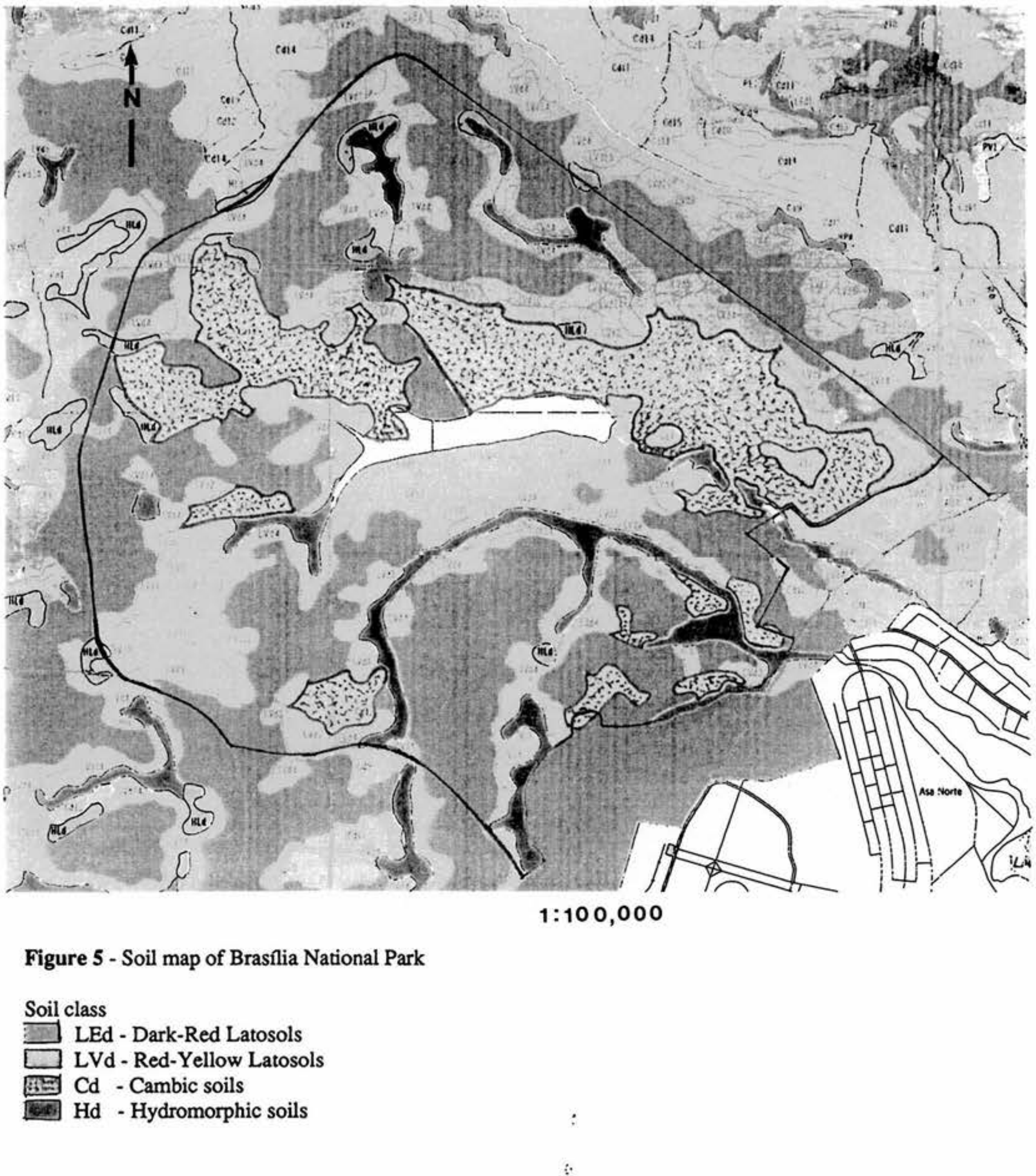
The development of soil studies in central Brazil is associated with the expansion of the agricultural frontier and the establishment of Brasília as a new capital of the country towards the end of the 1950s. However, it was only after the inauguration of EMBRAPA (the national agricultural research agency) in 1973 and the establishment of its Centre for agriculture research of the cerrado (CPAC), which was charged with undertaking the necessary studies for developing regional agriculture, that there was a major stimulus in the study of cerrado soils.

Within the Distrito Federal, soil research was greatly advanced by the publication in 1976 of the soil survey carried out by EMBRAPA (CPAC), resulting in the production of a 1:100,000 scale soil map (EMBRAPA, 1978).

Nevertheless, the present work is the first detailed study of soils in the National Park of Brasília. The research basically aims to characterise the soils associated with the distinct vegetation communities and also to analyse the relations between soil type and the geomorphic characteristics within the typical cerrado terrain of the National Park.

3.2 The soil classes of the National Park

Brazilian soil classification corresponds to that of the US Soil Taxonomy (Soil Survey Staff, 1975) and, at lower categorical levels, the Brazilian system places special



1:100,000

Figure 5 - Soil map of Brasília National Park

Soil class
- LEd - Dark-Red Latosols
- LVd - Red-Yellow Latosols
- Cd - Cambic soils
- Hd - Hydromorphic soils

emphasis on colour, base saturation, and vegetation (Sanchez, 1976). The soil classification system adopted in the present research is based on the EMBRAPA (1978) soil survey of the Distrito Federal.

The principal soil classes found in the National Park (Fig. 5) are Dark-Red Latosols, Red-Yellow Latosols, Cambic soils, and Hydromorphic soils (EMBRAPA, 1978).

These soil classes are based mainly on the type of B horizon, base saturation percentage, clay activity, type of A horizon, textural class and drainage class. They are subdivided into distinct phases that constitute different soil map units (Appendix 1). The criteria for phase determination take into consideration the vegetation, relief, rockiness, and the presence or absence of pebbles and ironstone (EMBRAPA, 1978).

3.2.1 Dark-Red Latosols

Dark-Red Latosols are distributed over about 38% of the National Park area. They are mineral soils, very deep, with moderate (ochric) A horizons, latosolic (oxic) B horizons, medium to high clay textures, and are rich in aluminium and iron oxides. They are generally dystrophic, and strongly to extremely strongly acidic (EMBRAPA, 1978). This group of soils is always related to level or gently undulating terrain associated with plateaus and long, gentle convex slopes. They generally cover the highest lands of the National Park. They are fine textured soils which have developed in a detrital-lateritic cover derived from the weathering of Tertiary or earlier strata. Those soils with medium to coarser textures have originated from the decomposition of quartzite (EMBRAPA, 1978).

3.2.2 Red-Yellow Latosol

Red-Yellow Latosols are distributed over approximately 33% of the National Park area, according to the EMBRAPA survey. They are mineral soils that contain an ochric A horizon, and a latosolic B horizon, They are dystrophic, with medium to high clay textures. They are also deep, well to strongly drained, and are moderately to strongly acidic (EMBRAPA, 1978). They have been formed by the same weathering and geomorphic processes as the Dark-Red Latosols. In the National Park, they are generally distributed on level, gently undulating terrain. They are normally situated below the Dark-Red Latosols in the catenary sequence (Fig. 4), reflecting periodic moistening leading to hydration of metal oxides such as iron resulting in more yellowish colours (Macedo & Bryant, 1987).

3.2.3 Cambic soils

Cambic soils are characterised mainly by the presence of a Cambic horizon (Soil Survey Staff, 1975) and cover about 22% of the National Park area. Weatherable minerals are still evident and are generally found in the B horizon. There is little or no discernible clay accumulation, and they are shallow soils, with thin ochric A horizons. The B horizons are irregularly superimposed over C horizons, with gravel, stones, concretions, and rock fragments throughout the profile. The soils also show low base saturation, high silt content, low activity clay, and high aluminium contents (EMBRAPA, 1978).

In the National Park they mostly cover steep slopes. They form a continuous east-west belt, crossing the central-north parts of the area. They can also be found in some disjunct patches, in the Bananal and Acampamento stream basin in the southern parts of the Park.

3.2.4 Hydromorphic soils

Hydromorphic soils are the least well represented soil group in the area, covering around 7% of the National Park. They are distributed along the valley bottoms, where gallery forests can be found with associated campo limpo and the veredas. They are also common in some interfluves where the water table emerges at the surface.

In the National Park the Hydromorphic soils group is represented by Undiscriminated Hydromorphic soils, Dystrophic Hydromorphic Laterites and Allic Hydromorphic Podzols.

3.2.4.1 Undiscriminated Hydromorphic soils

Of the Hydromorphic classes, the Undiscriminated Hydromorphic soils are the most important in terms of area, and are found in three phases. The phase determined by the occurrence of the gallery forests, is the one best represented in the area, followed by the soil phases associated with campo limpo and veredas.

The three phases could not be separated on the EMBRAPA soil map. They represent a soil complex that could not be distinguished at the sampling intensity applied in the soil survey. The phases are referred to as Slightly Humic Gley, Humic Gley and Organic soils.

The Slightly Humic Gley soils are characterised by water table influence, which can be permanently near the surface or may oscillate during the year. The top horizons are organo-mineral, overlying a grey soil layer, which indicates oxygen stress and iron reduction. Mottles of yellow and red colours can be found throughout this grey layer, and are related to water-table fluctuations. They are relatively recent soils, undeveloped, shallow, and with clay as the predominant textural fraction. They are badly-drained, dystrophic or allic. They have an A horizon which is mostly organic and about 10 to 20cm deep (EMBRAPA, 1978).

The Humic Gleys are also organo-mineral soils. This soil group has higher levels of water saturation than the Slightly Humic Gleys. The higher water levels give these soils a thicker organic A horizon about 20 to 40cm deep (EMBRAPA, 1978).

The Organic soils are dystrophic or allic, poorly developed and essentially organic. They are formed by the accumulation of dead plant material in different stages of decomposition and accumulate in flooded areas. They are black, with high carbon contents (EMBRAPA, 1978).

3.2.4.2 Hydromorphic Laterite

The Hydromorphic Laterite soils are predominantly argillic. They are dystrophic and badly-drained. Their principal characteristic is the colour of the redox soil environment, which results from the oscillation of the water table. They are mottled with a plinthic C horizon (EMBRAPA, 1978).

3.2.4.3 Hydromorphic Podzols

The Hydromorphic Podzols are soils with a prominent (umbric) A horizon and a podzolic B horizon, generally formed below a well differentiated A2 eluvial horizon. They are badly to imperfectly-drained in their lower horizons. They develop from psammitic deposits, where the water-table forms seepage flushes (EMBRAPA, 1978). According to EMBRAPA (1978), this soil group is represented in the National Park by a single small patch covered by campo limpo. This soil group is not represented in the soil profile network set up in the National Park during the field work.

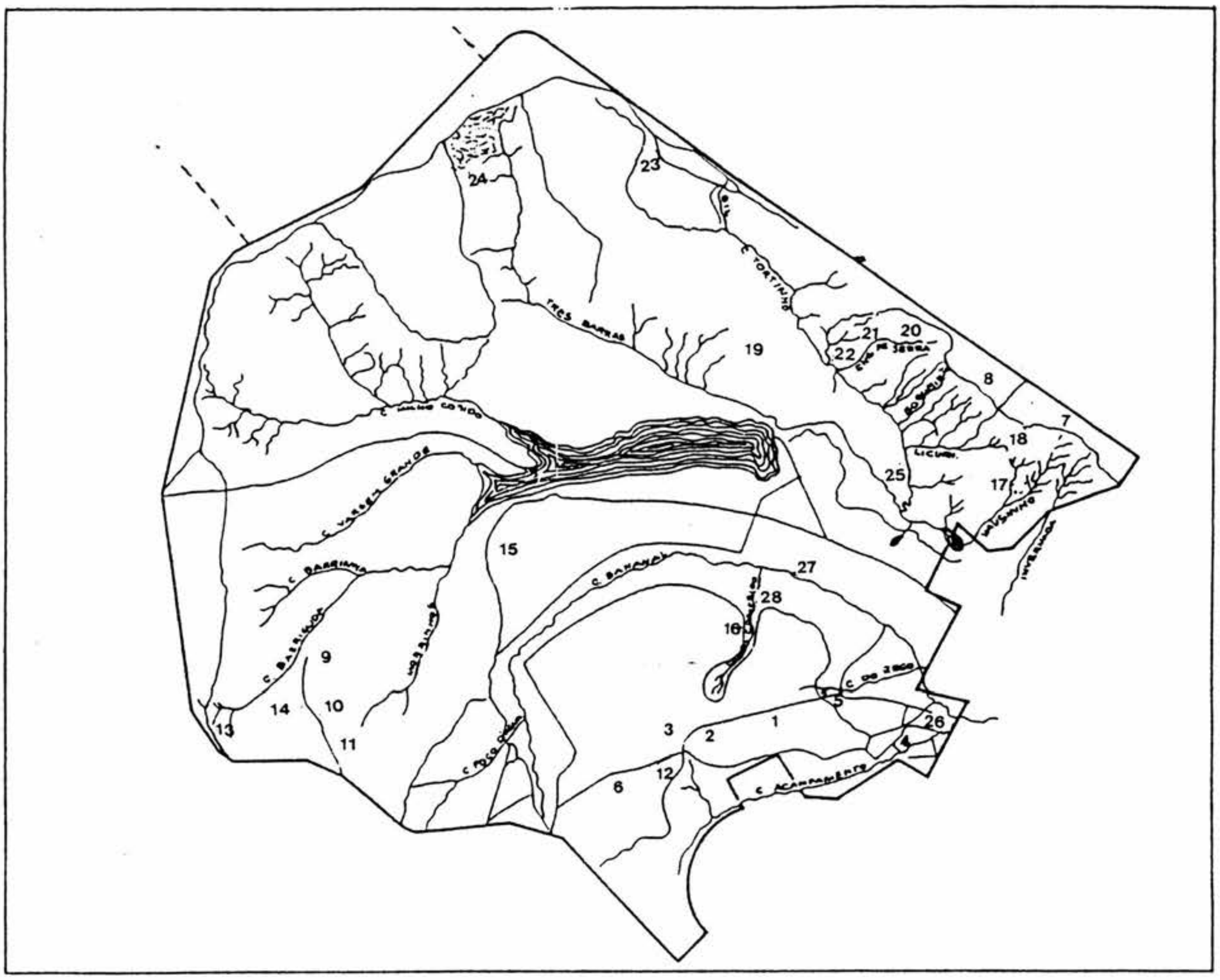


Figure 6 - Localization of the sample sites in the National Park of Brasília.

1 CERRADO NOVO SETOR; 2 CAMPO SUJO NOVO SETOR; 3 MURUNDU; 4 PISCINA 1; 5 CRISTAL; 6 CERRADO MATO GROSSO; 7 TORRE 1; 8 CERRADO TORRE; 9 CAMPO LIMPO TRES BURACOS; 10 CERRADO TRES BURCOS 2; 11 CERRADO TRES BURACOS 1; 12 CAMPO SUJO MATO GROSSO; 13 BARRIGUDA; 14 VOCHYSIA 1; 15 BARRAGEM; 16 CERRADO CAPÃO COMPRIDO; 17 INVERNADA; 18 RAPVELL; 19 TREMBLEYETUM; 20 VOCHYSIA 2; 21 CERRADO PALMAS; 22 PALMAS; 23 CERRADO TORTINHO; 24 TRES BARRES; 25 ARNICAS; 26 CEMAVE; 27 BANANAL; 28 CAPÃO COMPRIDO

3.3 General pattern of vegetation, topography and drainage and their relation to soil

The soils of the cerrado region are distributed in a mosaic-like pattern, and distinct vegetation communities can be found associated with particular situations. A model of the broad relation between topography, drainage, soil and vegetation has been presented in Fig 4.

A number of authors have found strong correlation between increased biomass production in the gradient of the cerrado woody vegetation from campo sujo to cerradão and increasing soil fertility (Goodland & Pollard, 1973; Lopes & Cox, 1977). However, data from other authors have not supported these relationships, and show that the variations of tree and shrub densities in different cerrado physiognomic forms are not necessarily determined by the soil fertility (Ribeiro, 1983).

These apparently contradictory results can be partly explained by the occurrence of two floristically and pedologically different forms of cerradão (Furley & Ratter, 1988). Mesotrophic cerradão characterised by the presence of the tree species *Magonia pubescens* and *Callisthene fasciculata* is found on mesotrophic soils while dystrophic facies cerradão relates to more dystrophic soils (Ratter, 1971; Ratter et al., 1973, 1977; Araújo, 1984). Apart from these characteristic forms of cerradão on mesotrophic or dystrophic soils, the existence of other typical physiognomic categories of cerrado vegetation does not seem to be directly related to differences in soil fertility. The occurrence of this continuous gradient of the cerrado vegetation (from cerradão to campo limpo) seems to be related according to some authors to a combination of factors such as soil depth, presence of a concretionary ironstone layer, variations in the topography and in the depth of the water-table (Eiten, 1972; Haridasan, 1992).

Most research on soil-plant relations in the cerrado region has focused on cerrado *sensu stricto* and on *cerradão* typically on Latosols. However, the vegetation communities of the Brasília National Park exhibit variable physiognomy and floristic composition and their relationships with soil will be explored after an examination of soil properties.

3.4 Methods

In order to characterise the soils associated with the vegetation communities surveyed in the National Park and to investigate their interrelationships, soil profiles were sited in each vegetation community. A total of 26 profiles were dug to a depth of approximately 1.50m and soil samples were collected and analysed for each horizon. The vegetation communities from where the soils were surveyed are listed in Table 2. Details on the vegetation characteristics are given in the next Chapter. The localities of the sample sites in the National Park are shown in Fig. 6.

Table 2 - Soil profile numbers and the related vegetation sample sites

Profile no.	Sample site	Vegetation community	Soil class - map unit
1	CERRADO NOVO SETOR	Cerrado *sensu stricto*	Dark-Red Latosol - LEd3
2	CAMPO SUJO NOVO SETOR	Cerrado open scrub (campo sujo)	Red-Yellow Latosol - LVd4
3	MURUNDU	Cerrado scrub (campo cerrado)	Hydromorphic soil - HLd
4	PISCINA 1	Gallery forest	Cambic soil - Cd4
5	CRISTAL	Gallery forest	Dark-Red Latosol - LEd1
6	CERRADO MATO GROSSO	Cerrado *sensu stricto*	Dark-Red Latosol - LEd3
7	TORRE 1	Cerrado open scrub (campo sujo)	Red-Yellow Latosol - LVd13
8	CERRADO TORRE	Cerrado *sensu stricto*	Dark-Red Latosol - LEd6
9	CAMPO LIMPO	Campo limpo (grassland)	Hydromorphic soil - HLd
10	CERRADO TRES BURACOS 2	Cerrado scrub (campo cerrado)	Red-Yellow Latosol - LVd9
11	CERRADO TRES BURACOS 1	Cerrado scrub (campo cerrado)	Red-Yellow Latosol - LVd9
12	CAMPO SUJO MATO GROSSO	Cerrado open scrub (campo sujo)	Red-Yellow Latosol - LVd4
13	BARRIGUDA	Gallery forest	Red-Yellow Latosol - LVd1

Table 2 - Soil profile numbers and the related vegetation sample sites (cont.)

Profile no.	Sample site	Vegetation community	Soil class - map unit
14	VOCHYSIA 1	Cerrado scrub with emergents (Vochysietum)	Red-Yellow Latosol - LVd11
15	BARRAGEM	Cerrado *sensu stricto*	Red-Yellow Latosol - LVd6
16	CERRADO CAPÃO COMPRIDO	Cerrado *sensu stricto* (marginal to a gallery forest)	Dark-Red Latosol - LEd3
17	INVERNADA	Cerrado rupestre	Cambic soil - Cd14
18	RAPVEL	Cerrado scrub (campo cerrado)	Red-Yellow Latosol - LVd13
19	TREMBLEYETUM	Thicket of *Trembleya parviflora*	Plinthic - HLd
20	VOCHYSIA 2	Cerrado scrub with emergent (Vochysietum)	Red-Yellow Latosol - LVd11
21	CERRADO PALMAS	Cerrado rupestre	Cambic soil - Cd18
22	PALMAS	Gallery forest	Cambic soil - Cd4
23	CERRADO TORTINHO	Cerrado *sensu stricto*	Dark-Red Latosol - LEd2
24	TRES BARRAS	Gallery forest	Red-Yellow Latosol - LVd1
25	ARNICAS	Campo rupestre	Cambic soil - Cd19
26	CEMAVE	Gallery forest	Cambic soil - Cd4

(Profiles numbered in order of field analysis; soil unit codes after EMBRAPA (1978), see Appendix 1).

Soil profiles were described following the methodology outlined in Brazilian manual of description and soil collection (Lemos & Santos, 1984).

Chemical and granulometrical analyses were carried out by the EMBRAPA-CPAC soil laboratory, from which were obtained the sand, silt, and clay textural fractions , pH (H_2O), Al, H + Al, Ca + Mg, C, N, P, K, and Na. The Organic Material Percentage (O.M.%), the Cation Exchange Capacity (CEC), the Percentage Base Saturation (V%) and the Al saturation were calculated as follows (Kiehl, 1979):

% O.M. = C % x 1.724

V% = S/T x 100

S = Ca + Mg + K + Na

CEC = T = Ca + Mg + K + Na + H + AL

Al Sat % = (Al/S + Al)x 100

The following methods of soil analysis were used by EMBRAPA (adapted from Vettori, 1969):

1. Texture: For the estimation of silt and sand, 20 grams of air-dried fine soil were dispersed by NaOH 1N, in 100ml of distilled water. The textural fractions were analysed by pipette. For the clay fraction the sample was dispersed in distilled water.

2. pH was determined in water (2:1 water soil ratio).

3. Ca + Mg and Al were determined by extraction with KCl 1N; Ca + Mg was measured by titration with EDTA, and the Al by titration with NaOH, using a bromothymol indicator.

4. P, K, and Na were extracted with HCl 0.05N, plus H_2SO_4 0.025N (Mehlich or North Carolina extractant). The measurement of K and Na was carried out by flame photometry, and the detection of P was made by colorimetry in a phosphomolybdate complex, with ascorbic acid as the reducer.

5. Total acidity (H + Al) was obtained using a 1N calcium acetate extractant solution at pH 7.0. The determination was made by titration with NaOH, in the presence of phenolphthalein.

6. C content was analysed by the Walkley-Black method. Total Nitrogen was measured by the Kjeldahl method. The total organic matter was estimated from the C figures (x 1.724).

The limits and frequency classes for different soil properties (low, medium and high) accord with the recommendations of Malavolta (1976) and Kiehl (1979). The limits were based on production x soil nutrient concentration curves, obtained for cultivated plants.

Table 3 - Soil properties of Brasília National Park (The gaps in the table represent data lost in the soil laboratory in Brazil)

Profile Number PN	Horizon	Depth cm	pH (H2O)	Al cmol/kg	H + Al cmol/kg	Al Saturation %	O. M. %	N %	C %	C/N	Ca+Mg cmol/kg	P ppm	K ppm	clay %	silt %	coarse sand %	fine sand %	B/A horizons ratio	textural class	K cmol/kg	V%	S cmol/kg	CEC cmol/kg
1	A1	0 - 10	4.80	1.05	10.30	76.04	3.95	0.23	2.29	9.96	0.24	1.40	29.00	71	19	5	5		very clayey	0.09	3.11	0.33	10.63
1	A2	11 - 27	4.10	1.20	2.40	61.54	3.57	0.26	2.07	7.96	0.14	0.20	-	73	14	4	9	1.04	very clayey	0.61	23.81	0.75	3.15
1	B2	79 - 140 +	5.30	0.01	3.10	10.00	1.30	0.10	0.75	7.54	0.09	0.60	0.00	75	16	5	4		very clayey	0.00	2.82	0.09	3.19
2	A1	0 - 10	4.90	0.68	8.00	62.15	3.85	0.22	2.23	10.15	0.27	1.30	46.00	32	11	5	52		loamy clay sand	0.14	4.92	0.41	8.41
2	A2	11 - 20	4.90	0.39	7.80	66.57	2.79	0.20	1.62	8.09	0.13	0.80	21.00	71	19	5	5	1.15		0.07	2.45	0.20	8.00
2	B1	21 - 38	5.00	0.15	4.60	55.04	2.12	0.10	1.23	12.30	0.11	0.50	4.00	79	15	2	4		very clayey	0.01	2.59	0.12	4.72
2	B2	39 - 150 +	5.40	0.01	2.40	9.09	1.54	0.05	0.89	17.87	0.10	0.60	0.00	39	9	7	4		clay sand	0.00	4.00	0.10	2.50
3	A1	0 - 7	4.90	0.68	9.10	57.19	4.52	0.24	2.62	10.92	0.39	1.40	38.00	67	18	3	12		very clayey	0.12	5.30	0.51	9.61
3	A2	7 - 25	4.80	0.36	7.20	59.79	3.71	0.21	2.15	10.25	0.17	0.90	23.00	70	18	4	8			0.07	3.25	0.24	7.44
3	A3	26 - 57	-	-	5.10	-	2.74	0.13	1.59	12.23	-	-	-	-	-	-	-	1.02		-	-	-	-
3	B1	58 - 88	5.10	0.15	4.70	56.33	2.02	0.12	1.17	9.76	0.11	0.60	2.00	71	22	3	4		very clayey	0.01	2.41	0.12	4.82
3	B2	89 - 160	4.75	0.90	2.90	74.38	1.25	0.10	0.73	7.25	0.08	1.70	-	69	20	4	7		very clayey	0.23	9.66	0.31	3.21
4	A1	0 - 22	-	-	9.30	-	3.75	0.21	2.18	10.36	-	-	-	75	15	5	5			-	-	-	-
4	A2	23 - 40	4.80	0.92	8.20	78.28	3.32	0.21	1.93	9.17	0.18	1.00	24.00	21	5	7	67		loamy clay sand	0.08	3.02	0.26	8.46
4	A3	41 - 51	4.80	0.95	8.40	79.65	3.13	0.20	1.82	9.08	0.18	0.90	20.00	75	16	5	4	1.41	very clayey	0.06	2.81	0.24	8.64
4	B1	52 - 108	4.90	0.48	5.80	69.00	2.12	0.14	1.23	8.78	0.20	0.60	5.00	79	13	5	3		very clayey	0.02	3.59	0.22	6.02
4	B2	109 - 125	5.10	0.15	4.00	51.72	1.68	0.11	0.97	8.86	0.14	0.60	0.00	82	6	4	8			0.00	3.38	0.14	4.14
5	A1	0 - 11	5.50	0.10	11.40	0.86	6.64	0.53	3.85	7.27	11.34	3.00	69.00	31	36	7	26		loamy clay	0.22	50.34	11.56	22.96
5	A2	12 - 36	5.70	0.08	6.80	1.03	3.99	0.32	2.31	7.23	7.53	1.40	50.00	70	16	3	11			0.16	53.06	7.69	14.49
5	B1/2	37 - 140 +	5.70	0.07	4.20	1.12	2.50	0.20	1.45	7.25	6.00	1.00	51.00	-	-	-	-			0.16	59.46	6.16	10.36
6	A1	0 - 10	5.30	0.18	11.80	2.62	7.51	0.47	4.36	9.27	6.45	2.50	80.00	81	14	2	3		very clayey	0.25	36.22	6.70	18.50
6	A2	11 - 29	5.00	0.32	7.30	45.21	3.18	0.16	1.84	11.53	0.30	0.80	28.00	67	21	3	9	1.01	very clayey	0.09	5.04	0.39	7.69
6	B1	30 - 70	4.97	1.40	3.20	76.92	2.40	0.13	1.39	10.71	0.13	0.60	-	74	14	3	9		very clayey	0.29	11.60	0.42	3.62
6	B2	71 - 160 +	4.53	-	-	-	2.30	0.24	1.33	5.56	0.20	0.60	-	76	17	3	4			0.10	-	-	-
7	A1	0 - 28	4.14	1.80	5.50	80.85	2.26	0.15	1.31	8.74	0.37	0.70	18.00	20	7	7	66		loamy clay sand	0.06	7.20	0.43	5.93
7	A2	29 - 53	4.90	0.92	3.10	86.89	1.25	0.09	0.73	8.06	0.12	0.70	6.00	30	13	10	47		loamy clay sand	0.02	4.29	0.14	3.24
7	B1	54 - 62	4.90	0.59	1.70	80.95	0.87	0.08	0.50	6.31	0.12	0.50	6.00	74	18	2	6	2.36	very clayey	0.02	7.55	0.14	1.84
7	B2	63 - 100	5.00	0.30	1.30	-	0.48	0.06	0.28	4.64	0.18	0.30	-	69	23	5	3			-	-	-	-
7	B3	101 - 130 +	4.23	0.76	1.70	58.91	0.34	0.07	0.20	2.82	0.10	0.40	-	34	28	3	35		loamy clay	0.43	23.77	0.53	2.23

Table 3 - Soil properties of Brasília National Park - (cont.)

Profile Number PN	Horizon	Depth cm	pH (H2O)	Al cmol/kg	H + Al cmol/kg	Al Saturation %	O. M. %	N %	C %	C/N	Ca+Mg cmol/kg	P ppm	K ppm	clay %	silt %	coarse sand %	fine sand %	B/A horizons ratio	textural class	K cmol/kg	V%	S cmol/kg	CEC cmol/kg
8	A1	0 - 12	4.90	0.88	7.30	51.72	3.27	0.19	1.90	9.98	0.74	2.00	26.00	21	3	16	60		loamy clay sand	0.08	10.12	0.82	8.12
8	A2	13 - 34	4.90	0.28	2.60	63.27	1.35	0.09	0.78	8.70	0.15	0.80	4.00	19	3	14	64	1.55	loamy sand	0.01	5.88	0.16	2.76
8	B1/2	35 - 102	5.00	0.03	1.70	23.08	0.91	0.11	0.53	4.80	0.10	0.60	0.00	31	1	11	57		loamy clay sand	0.00	5.56	0.10	1.80
8	IIC	103 -140 +	5.10	0.00	1.10	0.00	0.72	0.10	0.42	4.18	0.10	0.60	0.00	33	3	17	47		loamy clay sand	0.00	8.33	0.10	1.20
9	A1	0 - 20	5.00	1.27	11.10	65.25	6.06	0.30	3.52	11.72	0.46	2.00	69.00	43	21	3	33		clay	0.22	5.74	0.68	11.78
9	A2	21 - 34	4.80	0.66	6.30	80.11	3.71	0.22	2.15	9.78	0.12	0.90	14.00	48	23	3	26		clay	0.04	2.54	0.16	6.46
9	B1	35 - 63	5.10	0.30	4.00	63.65	2.07	0.14	1.20	8.58	0.14	0.50	10.00	59	7	17	17	0.97	clay	0.03	4.11	0.17	4.17
9	B2g	64 - 127	5.20	0.05	2.50	24.31	1.25	0.10	0.73	7.25	0.14	0.60	5.00	27	17	6	50		loamy clay sand	0.02	5.86	0.16	2.66
9	B3g	128 - 150 +	5.40	0.00	1.30	0.00	0.82	0.06	0.48	7.93	0.11	0.50	3.00	46	26	2	26		clay	0.01	8.41	0.12	1.42
10	A1	0 - 8	4.90	0.58	5.80	49.69	3.51	0.18	2.04	11.31	0.49	1.30	31.00	60	16	2	21		clay	0.10	9.19	0.59	6.39
10	A2	9 - 21	4.80	0.26	4.20	62.26	2.21	0.13	1.28	9.86	0.12	0.60	12.00	38	7	7	48	0.87	clay sand	0.04	3.62	0.16	4.36
10	B1	22 - 47	5.10	0.06	3.40	34.04	1.59	0.11	0.92	8.38	0.11	0.80	2.00	43	27	6	26		clay	0.01	3.31	0.12	3.52
10	B2	48 - 148 +	5.40	0.01	1.10	10.00	0.82	0.05	0.48	9.51	0.09	0.40	0.00	42	10	7	41		clay sand	0.00	7.56	0.09	1.19
11	A1	0 - 5	4.47	0.56	8.90	37.33	3.99	0.20	2.31	11.57	0.43	0.50	-	45	13	4	38		clay	0.51	9.55	0.94	9.84
11	A2	6 - 15	4.80	0.42	5.80	65.41	3.03	0.15	1.76	11.72	0.15	0.70	23.00	41	15	3	41	1.08	clay	0.07	3.69	0.22	6.02
11	B1	16 - 36	5.00	0.09	3.80	38.90	2.21	0.09	1.28	14.24	0.11	0.50	10.00	41	14	3	42		clay	0.03	3.59	0.14	3.94
11	B2	37 - 144 +	5.30	0.01	1.50	11.11	1.20	0.09	0.70	7.73	0.08	0.40	0.00	52	10	3	35		clay	0.00	5.06	0.08	1.58
12	A1	0 - 7	5.00	0.44	9.10	45.51	4.14	0.22	2.40	10.92	0.37	0.80	50.00	-	-	-	-			0.16	5.47	0.53	9.63
12	B1	7 - 27	-	-	5.70	-	3.08	0.19	1.79	9.40	-	-	-	64	19	9	8		very clayey	-	-	-	-
12	B2	27 - 150 +	-	-	2.30	-	1.73	0.10	1.00	10.03	-	-	-	68	14	8	10		very clayey	-	-	-	-
13	A1	0 - 5	5.30	0.18	10.60	4.03	6.16	0.35	3.57	10.21	4.05	2.60	77.00	59	17	4	20		very clayey	0.24	28.82	4.29	14.89
13	B1	5 - 44	5.00	0.26	5.10	61.62	2.36	0.16	1.37	8.56	0.14	0.60	7.00	70	17	6	7	1.15	very clayey	0.02	3.08	0.16	5.26
13	B2	44 - 79	-	-	2.10	-	1.25	0.10	0.73	7.25	-	-	-	69	16	2	13		very clayey	-	-	-	
13	B2 1	79 - 150 +	5.40	0.01	1.50	8.33	1.16	0.11	0.67	6.12	0.11	0.40	0.00	65	20	2	13			0.00	6.83	0.11	1.61
14	A1	0 - 14	5.00	0.91	5.90	70.32	3.18	0.15	1.84	12.30	0.29	1.60	30.00	15	3	5	77		sandy loam	0.09	6.11	0.38	6.28
14	B1	14 - 40	5.20	0.40	3.00	72.96	1.54	0.09	0.89	9.93	0.12	0.60	9.00	53	11	23	13	2.87	clay	0.03	4.71	0.15	3.15
14	B2	40 - 150 +	5.30	0.04	2.00	27.95	0.87	0.09	0.50	5.61	0.10	0.50	1.00	33	5	4	58		loamy clay sand	0.00	4.90	0.10	2.10
15	A1	0 - 8	4.80	0.93	7.00	77.00	3.18	0.20	1.84	9.22	0.19	1.00	28.00	52	5	21	22		clay	0.09	3.82	0.28	7.28
15	B1	8 - 50	5.10	0.37	4.60	73.80	2.21	0.13	1.28	9.86	0.10	0.60	10.00	52	8	20	20	0.88	clay	0.03	2.78	0.13	4.73
15	B2	50 - 150 +	5.30	0.03	1.90	23.08	1.06	0.08	0.61	7.69	0.10	0.40	0.00	40	45	10	5		clay silt	0.00	5.00	0.10	2.00

Table 3 - Soil properties of Brasília National Park - (cont.)

Profile Number PN	Horizon	Depth cm	pH (H2O)	Al cmol/kg	H + Al cmol/kg	Al Saturation %	O. M. %	N %	C %	C/N	Ca+Mg cmol/kg	P ppm	K ppm	clay %	silt %	coarse sand %	fine sand %	B/A horizons ratio	textural class	K cmol/kg	V%	S cmol/kg	CEC cmol/kg
16	A1	0 - 3	5.80	0.01	5.90	0.17	6.26	0.32	3.63	11.35	5.70	1.70	57.00	42	32	11	15		clay	0.18	49.91	5.88	11.78
16	B1	3 - 20	5.50	0.03	6.40	1.08	4.76	0.22	2.76	12.55	2.64	0.70	36.00	40	29	6	25	1.19	clay	0.11	30.08	2.75	9.15
16	B2	20 - 150	5.30	0.01	2.50	7.34	1.83	0.12	1.06	8.85	0.12	0.40	2.00	60	26	8	6			0.01	4.81	0.13	2.63
17	A1	0 - 8	5.00	0.71	2.70	63.70	1.35	0.10	0.78	7.83	0.32	1.30	27.00	11	6	16	67		sandy loam	0.08	13.03	0.40	3.10
17	B1	8 - 23	5.00	0.60	1.60	64.94	0.39	0.07	0.23	3.23	0.28	0.80	14.00	10	8	19	63	1.95	sandy loam	0.04	16.84	0.32	1.92
17	B2	23 - 40	4.60	1.30	3.50	85.37	1.44	0.09	0.84	9.28	0.16	0.90	20.00	33	40	5	22		loamy clay	0.06	5.98	0.22	3.72
17	C	40 - 150 +	4.80	0.92	1.70	87.51	0.48	0.08	0.28	3.48	0.10	0.70	10.00	21	13	5	61		loamy clay sand	0.03	7.17	0.13	1.83
18	A1	0 - 15	5.00	0.90	1.00	67.97	0.67	0.07	0.39	5.55	0.33	1.20	30.00	14	4	9	73		sandy loam	0.09	29.78	0.42	1.42
18	B1	15 - 70	5.00	0.23	1.40	66.54	0.63	0.10	0.37	3.65	0.10	0.60	5.00	79	15	2	4	3.86		0.02	7.63	0.12	1.52
18	B2	70 - 150 +	5.30	0.01	4.10	9.75	2.07	0.10	1.20	12.01	0.08	0.50	4.00	29	7	8	56		loamy clay sand	0.01	2.21	0.09	4.19
19	A1	0 - 15	4.80	0.81	7.30	68.84	3.66	0.20	2.12	10.61	0.26	0.90	34.00	24	7	10	59		loamy clay sand	0.11	4.78	0.37	7.67
19	B2	15 - 115	5.30	0.00	0.80	0.00	1.01	0.08	0.59	7.32	0.08	0.50	0.00	24	12	6	58	1.00	loamy clay sand	0.00	9.09	0.08	0.88
19	C	115 - 150 +	5.60	0.00	0.00	0.00	0.48	0.07	0.28	3.98	0.09	0.50	0.00	24	4	23	49		loamy clay sand	0.00	-	0.09	0.09
20	A1	0 - 19	4.90	0.78	4.50	61.32	2.12	0.04	1.23	30.74	0.42	1.30	23.00	63	21	6	10			0.07	9.86	0.49	4.99
20	B2	19 - 110	5.20	0.33	2.20	71.53	0.87	0.10	0.50	5.05	0.10	0.70	10.00	18	2	17	63	0.29	loamy sand	0.03	5.63	0.13	2.33
20	C	110 +	5.40	0.01	0.30	4.00	0.48	0.05	0.28	5.57	0.24	1.00	0.00	30	13	10	47		loamy clay sand	0.00	44.44	0.24	0.54
21	A1	0 - 5	5.30	0.38	4.60	12.60	2.74	0.17	1.59	9.35	2.36	2.90	88.00	20	10	6	64		loamy sand	0.28	36.43	2.64	7.24
21	B2	5 - 28	4.70	1.25	3.90	77.27	1.73	0.11	1.00	9.12	0.28	1.00	28.00	23	12	7	58	1.15	loamy clay sand	0.09	8.62	0.37	4.27
21	C	28 - 75	4.80	0.83	2.00	56.68	0.67	0.10	0.39	3.89	0.60	0.70	11.00	24	12	6	58		loamy clay sand	0.03	24.08	0.63	2.63
21	R	75 - 150 +	5.00	0.39	0.50	80.20	0.14	0.07	0.08	1.16	0.09	0.60	2.00	19	27	2	52		loamy sand	0.01	16.15	0.10	0.60
22	A1	0 - 10	4.90	2.28	14.20	46.37	6.45	0.36	3.74	10.39	2.38	3.20	82.00	24	13	5	58		loamy clay sand	0.26	15.66	2.64	16.84
22	A2	10 - 40	4.90	2.82	10.40	87.79	3.90	0.22	2.26	10.28	0.32	1.30	23.00	27	14	5	54		loamy clay sand	0.07	3.63	0.39	10.79
23	A1	0 - 5	4.90	0.71	12.10	55.21	5.34	0.27	3.10	11.47	0.46	1.00	37.00	61	19	8	12		very clayey	0.12	4.54	0.58	12.68
23	B1	5 - 15	5.00	0.35	7.60	57.72	3.56	0.21	2.06	9.83	0.20	0.70	18.00	74	16	5	5	1.25	very clayey	0.06	3.26	0.26	7.86
23	B2	15 - 150 +	5.30	0.01	2.60	6.25	1.88	0.10	1.09	10.90	0.15	0.50	0.00	79	12	3	6			0.00	5.45	0.15	2.75
24	A1	0 - 11	4.60	2.44	20.20	76.28	7.65	0.47	4.44	9.44	0.53	1.90	73.00	30	6	8	56		loamy clay sand	0.23	3.62	0.76	20.96
24	B1	11 - 25	4.80	1.22	11.30	78.31	5.25	0.36	3.05	8.46	0.20	1.20	44.00	75	14	2	9	2.53	very clayey	0.14	2.90	0.34	11.64
24	B2	25 - 70	5.00	0.33	4.30	66.40	2.26	0.16	1.31	8.19	0.12	0.60	15.00	77	15	2	6		very clayey	0.05	3.74	0.17	4.47
24	C	70 - 150 +	5.30	0.03	2.00	25.00	0.91	0.06	0.53	8.80	0.09	0.50	0.00	14	5	5	76		sandy loam	0.00	4.31	0.09	2.09
25	A1	0 - 3	5.20	0.61	5.80	29.33	5.01	0.29	2.91	10.02	1.25	2.60	70.00	55	18	2	25		clay	0.22	20.21	1.47	7.27
25	B2	3 - 10	4.90	1.16	5.50	66.84	3.80	0.21	2.20	10.50	0.45	2.20	40.00	20	23	12	45	0.36	loamy clay sand	0.13	9.47	0.58	6.08
25	R	10 - 150 +	5.20	0.57	0.90	43.64	0.19	0.04	0.11	2.76	0.73	0.50	2.00	9	30	2	59		loamy sand	0.01	45.00	0.74	1.64
26	A1	0 - 10	6.10	0.00	9.50	0.00	18.58	0.95	10.78	11.34	15.28	3.70	179.00	-	-	-	-			0.56	62.51	15.84	25.34
26	B1	10 - 40	5.30	0.40	7.90	7.85	3.95	0.34	2.29	6.74	4.26	1.70	138.00	36	32	16	16		loamy clay	0.43	37.26	4.69	12.59
26	C	40 +	5.40	0.42	2.00	19.42	0.72	0.09	0.42	4.64	1.63	0.70	36.00	29	60	3	8		loamy clay silt	0.11	46.56	1.74	3.74

Although the critical limits of mineral nutrients for native plants are not precisely known, the frequency classes indicated for the cultivated plants are useful as comparative figures.

3.5 Results

The results obtained in the present study from the soil profile descriptions and soil chemical analysis permitted the comparison of the sites studied with those of the EMBRAPA soil survey map . The raw data of the soil properties are presented in Table 3. The patterns of the soil properties are given in Figs. 7 to 24 showing the distribution of the soil parameters in A and B horizons, for each vegetation type. The full soil profile descriptions are given in Appendix 2.

3.5.1. The variation within mapped soil classes

Despite the great value of the EMBRAPA soil map, it was not sufficiently detailed to relate to vegetation communities on minor topographic and drainage features within the National Park. The soil profiles and analyses revealed patterns that did not accord well with the EMBRAPA survey, suggesting that a number of phases or even soil classes mapped by EMBRAPA on the National Park should be revised. Table 4 gives the soil units which were found to be different from the EMBRAPA survey.

Table 4 - Proposed changes to the soil map of the Brasília National Park

Profile no.	EMBRAPA map units *	Suggested change
3	Hi3	HLd
4	Cd12	Cd4
5	LEd3	LEd1
9	LVd13	HLd association (plinthic)
14	LVd11	LVd10
18	LVd13	LVd10
19	Cd12	HLd association (plinthic)
22	Cd4	Cd (medium texture phase)
23	LEd3	LEd2
24	HLd	LVd1
26	LVd2	Cd (medium texture phase)

Obs: LEd = Dark-Red Latosols; LVd = Red-Yellow Latosols; HLd & Hi = Hydromorphic soils; Cd = Cambic soils

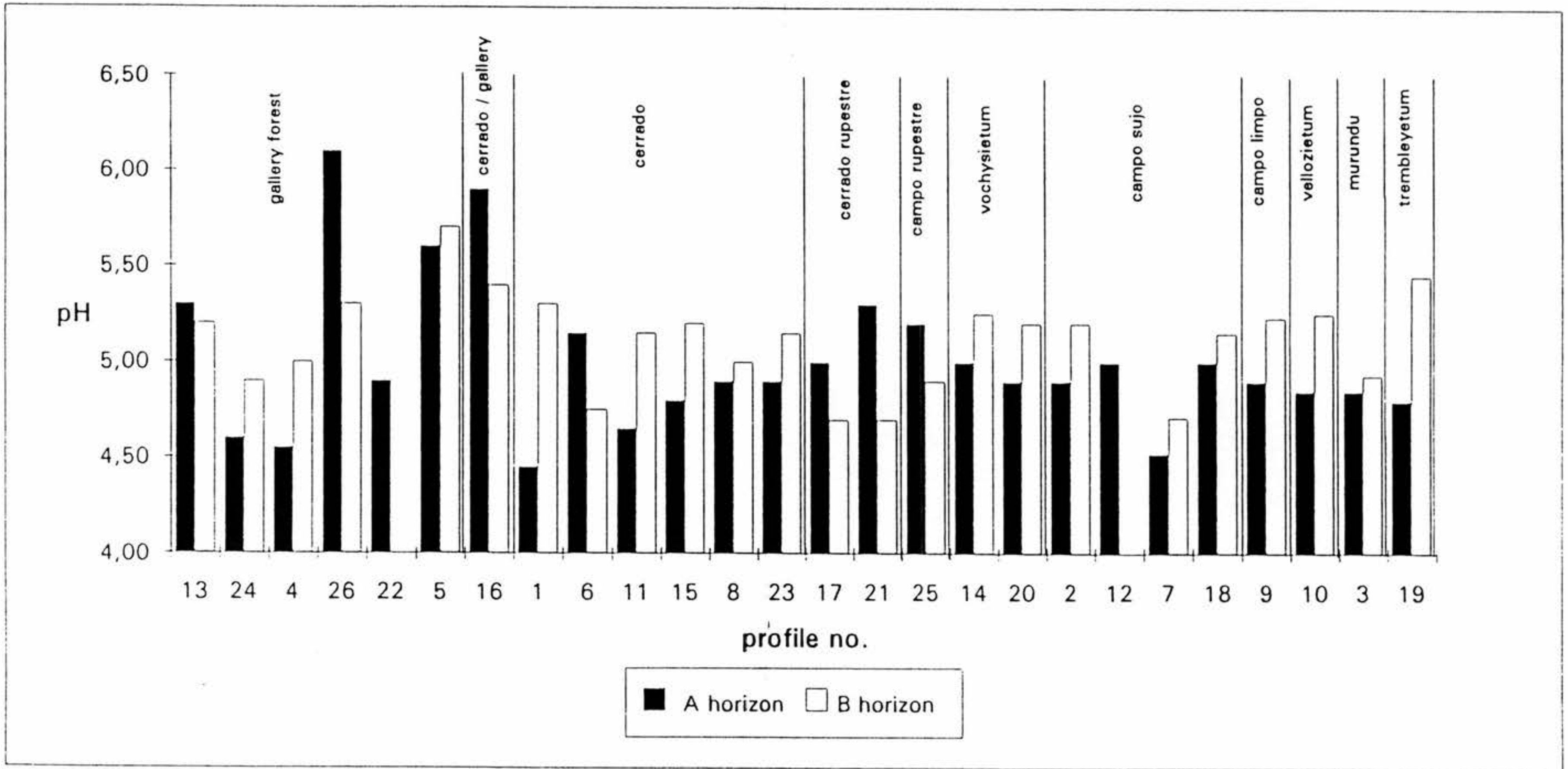


Figure 7 - pH of the soils of Brasília National Park (gaps represent data lost in the soil laboratory in Brazil)

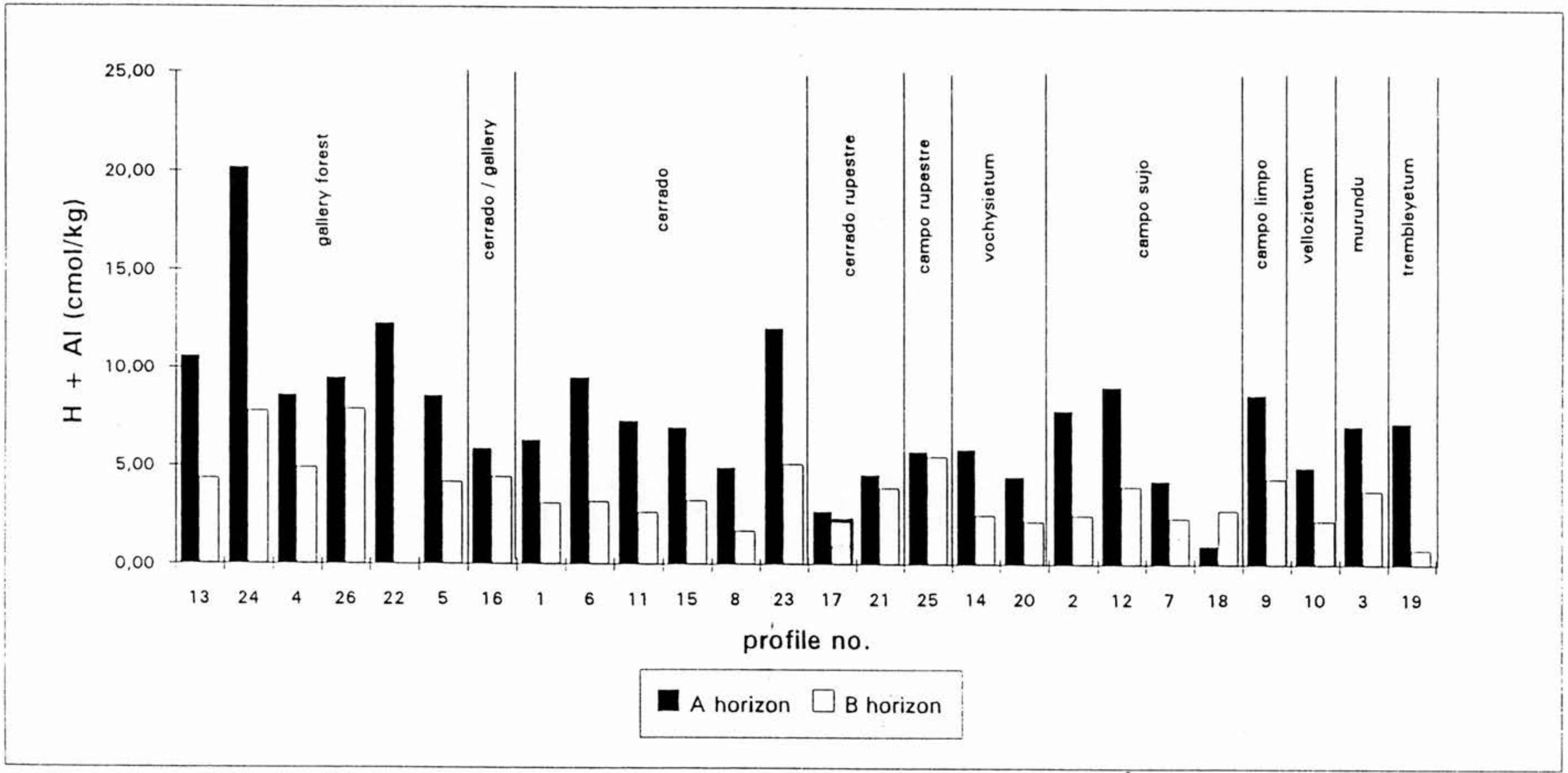


Figure 8 - H + Al in soils of Brasília National Park (gaps represent data lost in the soil laboratory in Brazil)

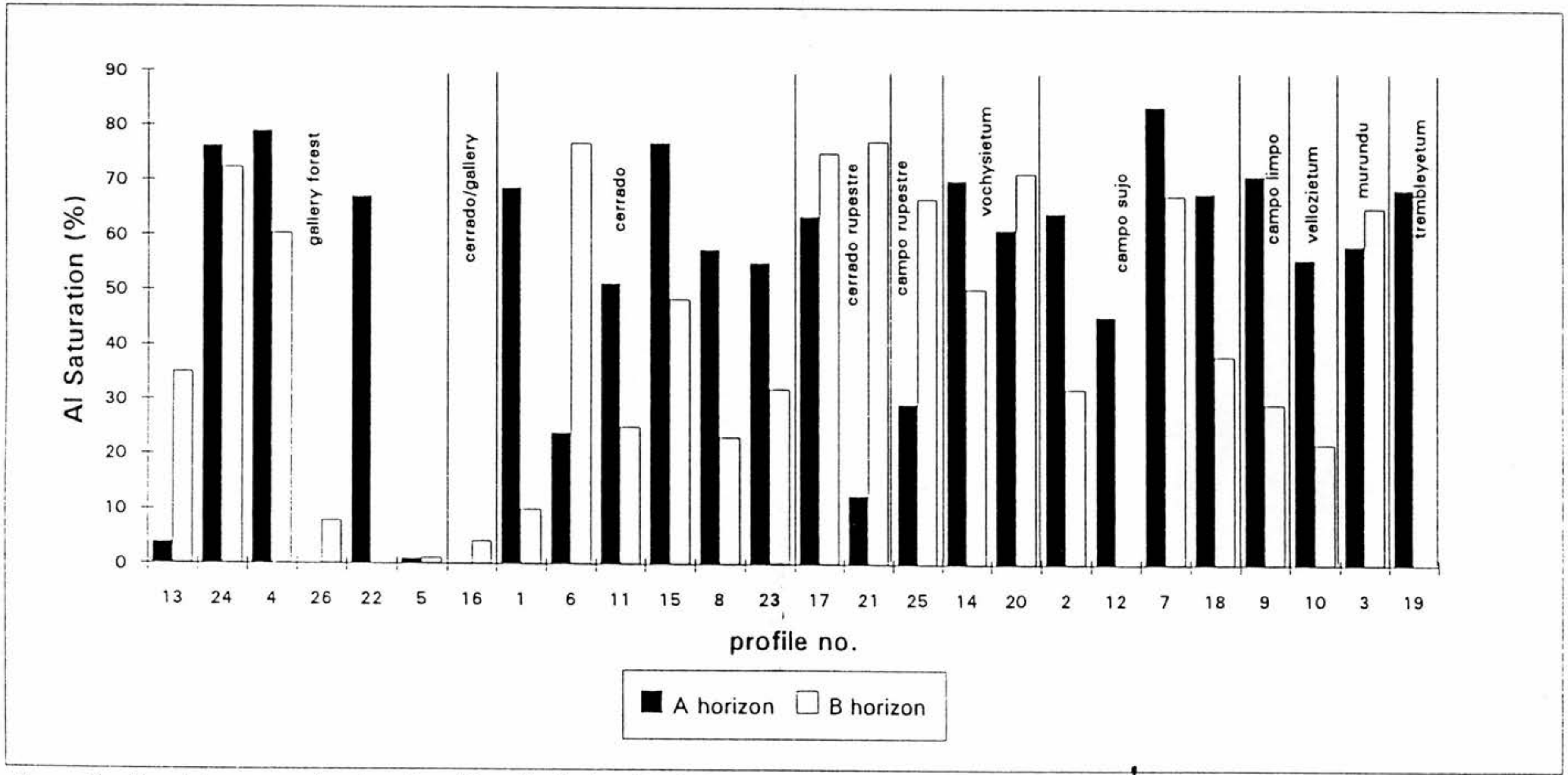


Figure 9 - Aluminium saturation in soils of Brasília National Park (gaps represent data lost in the soil laboratory in Brazil)

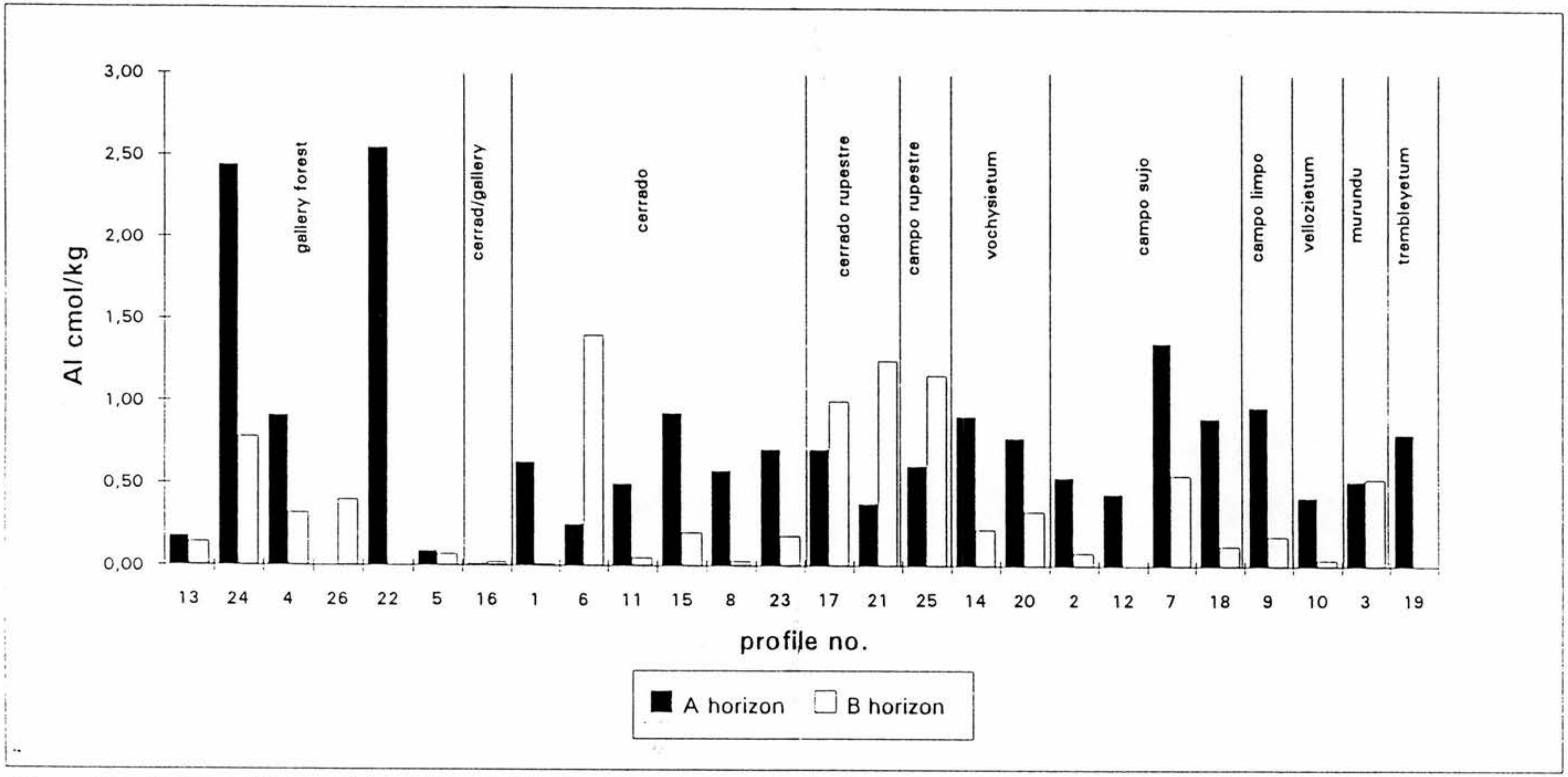


Figure 10 - Exchangeable aluminium contents in soils of Brasília National Park
(gaps represent data lost in the soil laboratory in Brazil)

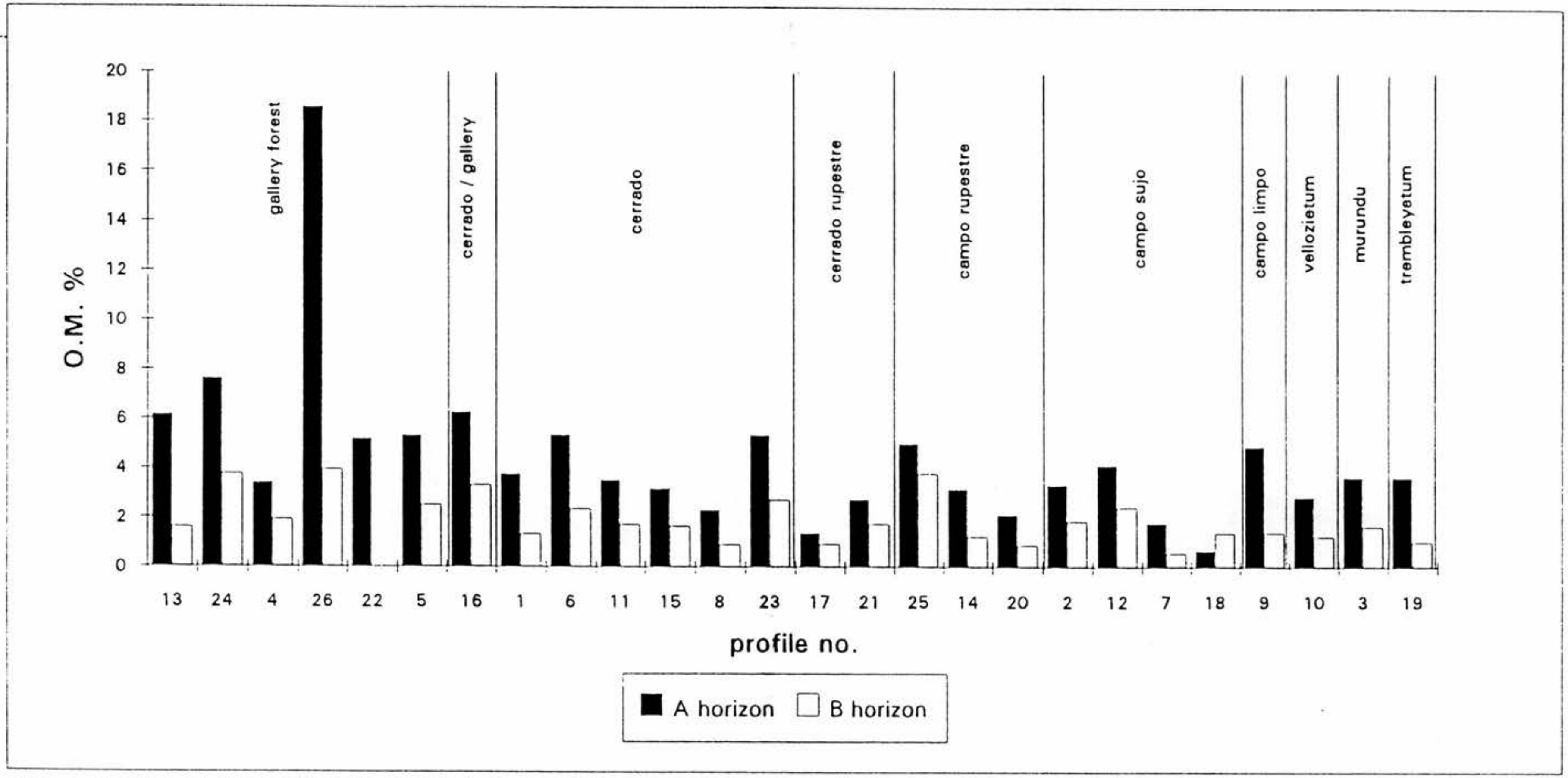


Figure 11- Organic matter in soils of Brasília National Park
(gaps represent data lost in the soil laboratory in Brazil)

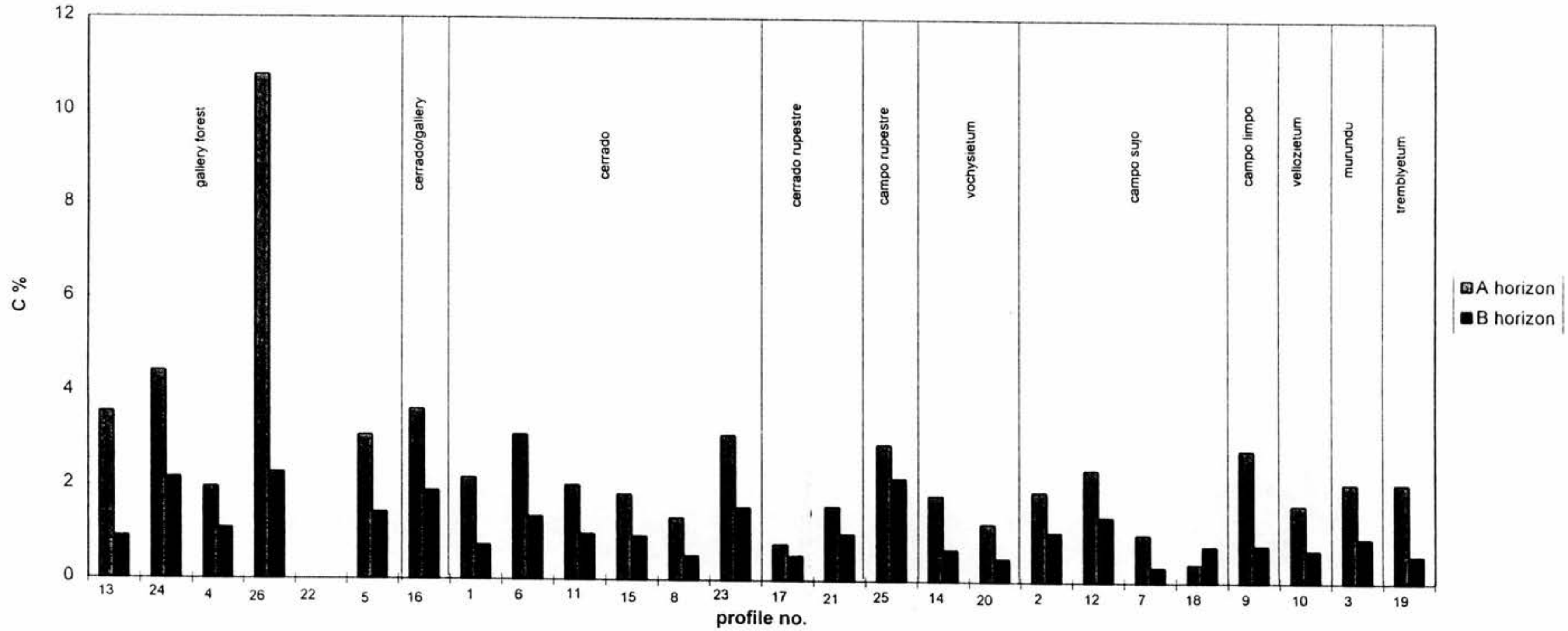


Figure 12 - Carbon percentage in soils of Brasília National Park (gaps represent data lost in the soil laboratory in Brazil).

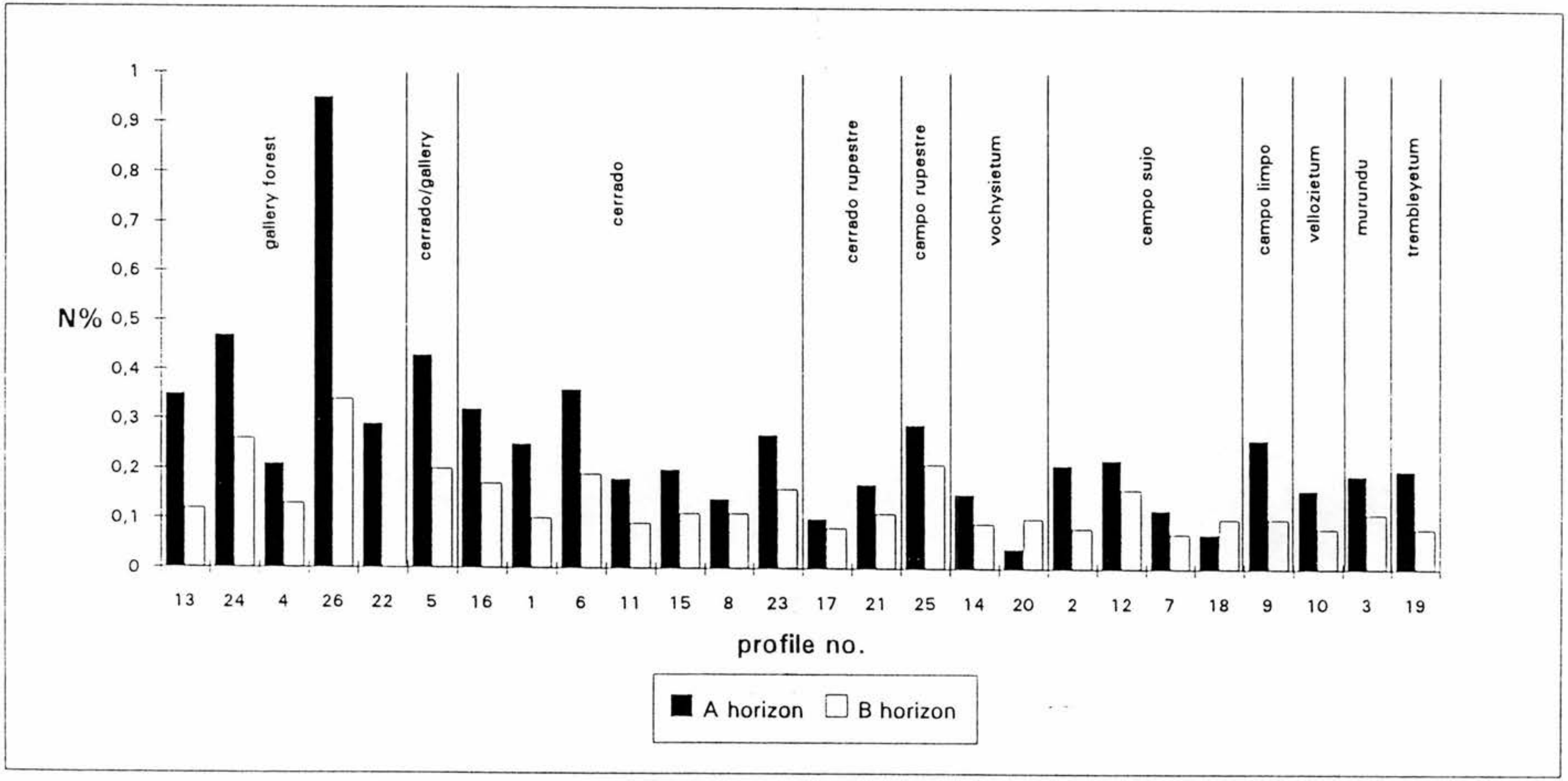


Figure 13 - Nitrogen contents in soils of Brasília National Park
(gaps represent data lost in the soil laboratory in Brazil)

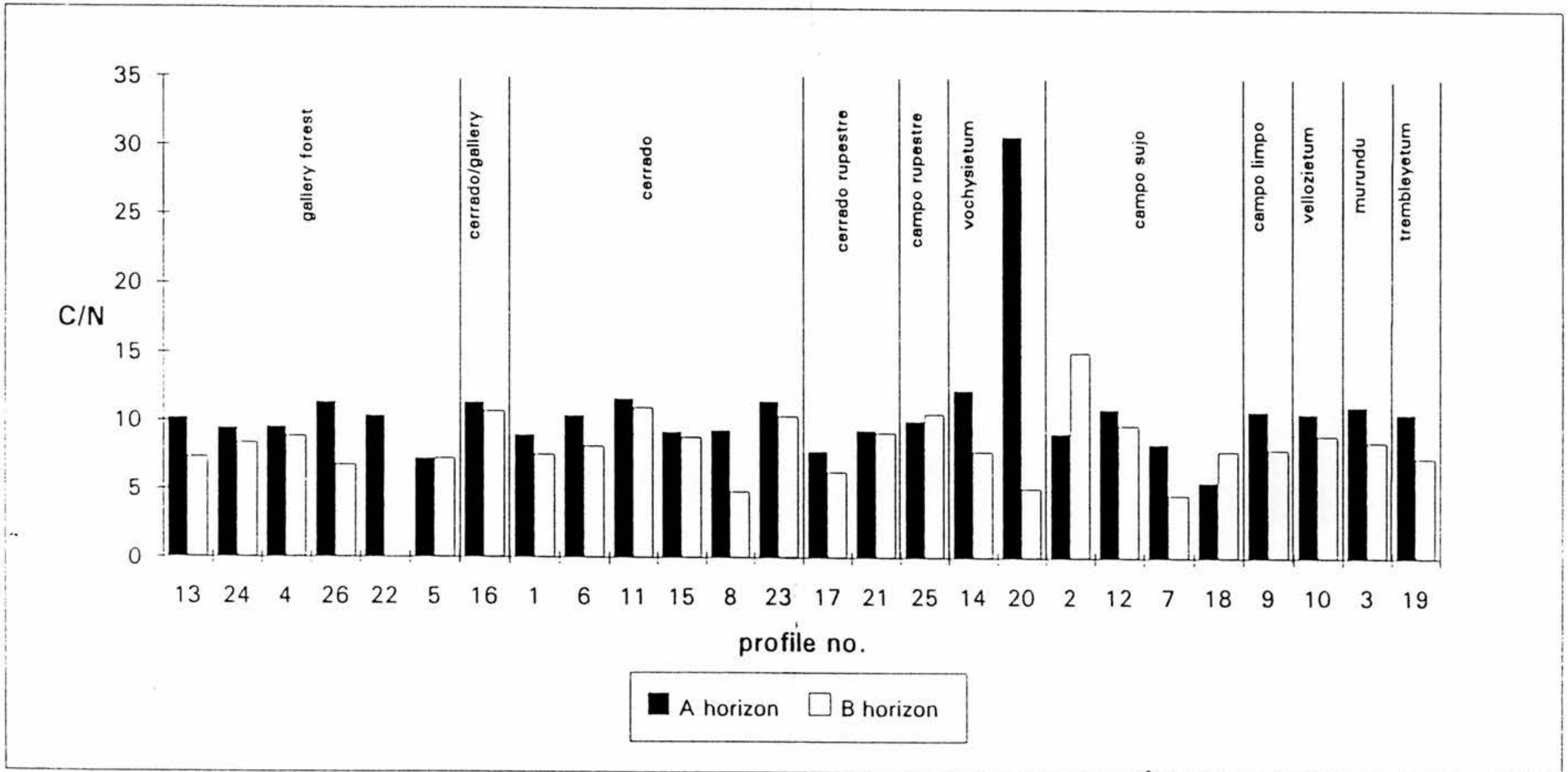


Figure 14 - C/N ratio in soils of Brasília National Park
(gaps represent data lost in the soil laboratory in Brazil)

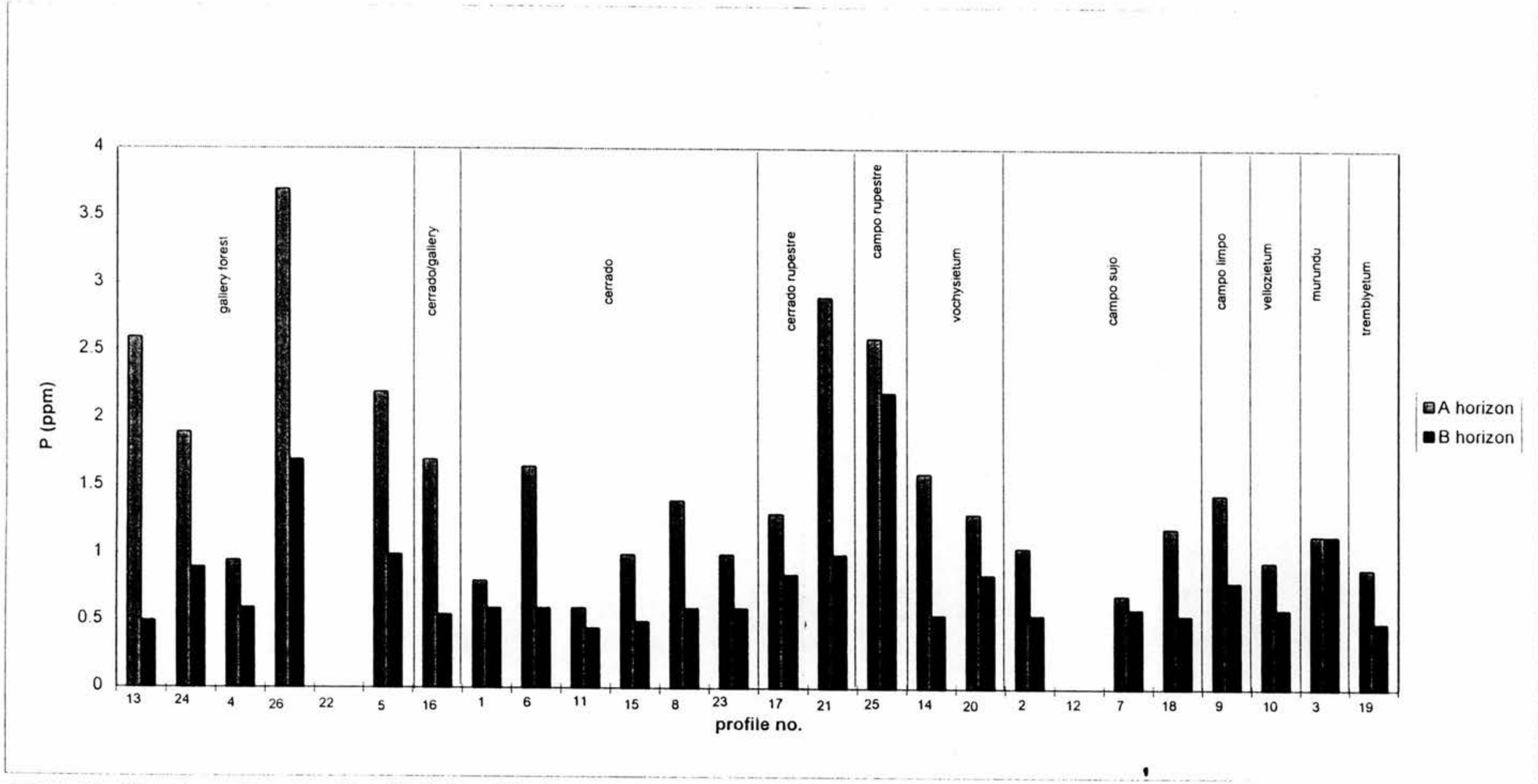


Figure 15 - Phosphorus in soils of Brasília National Park
(gaps represent data lost in the soil laboratory in Brazil).

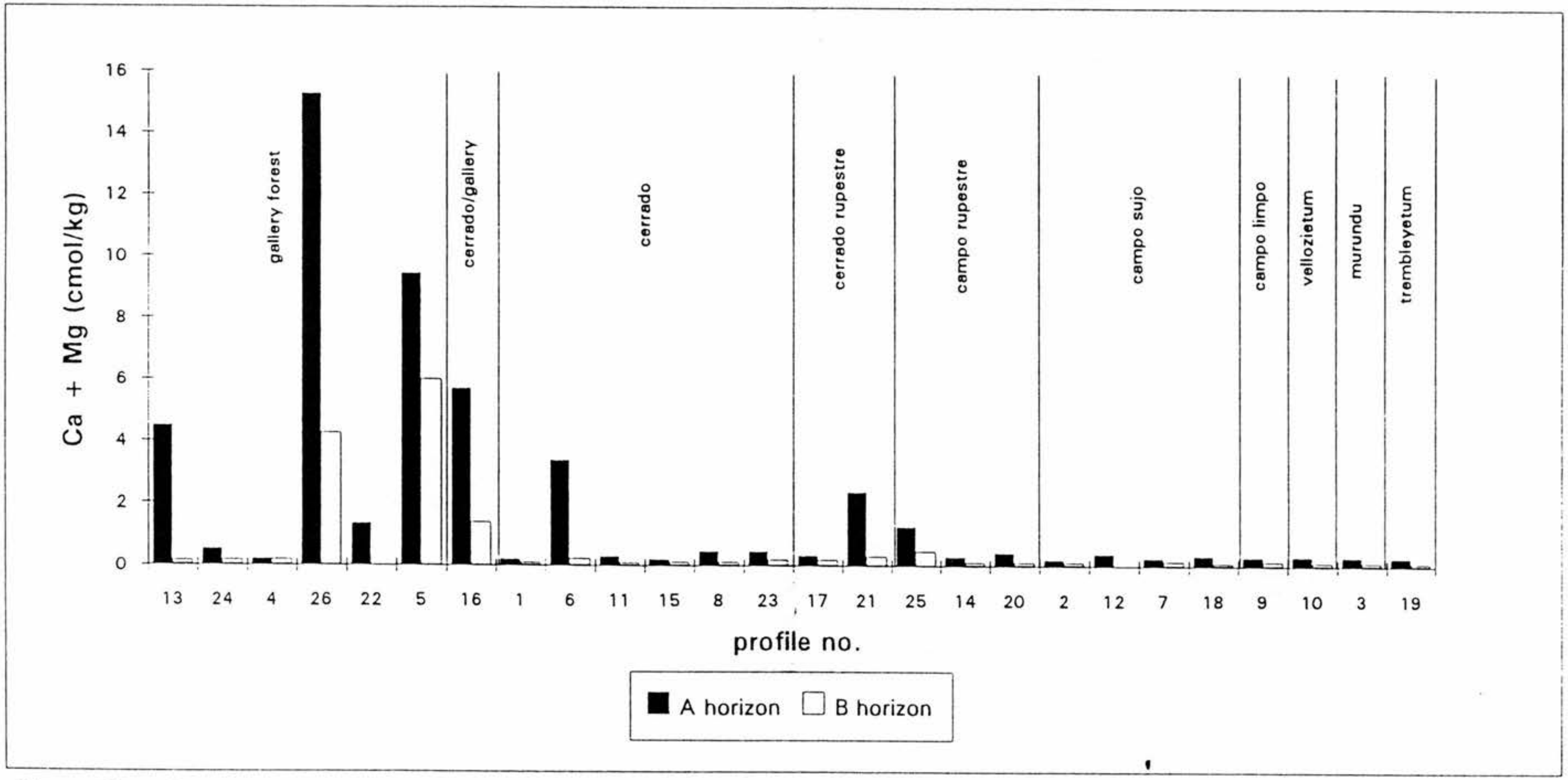


Figure 16 - Ca + Mg contents in soils of Brasília National Park
(gaps represent data lost in the soil laboratory in Brazil)

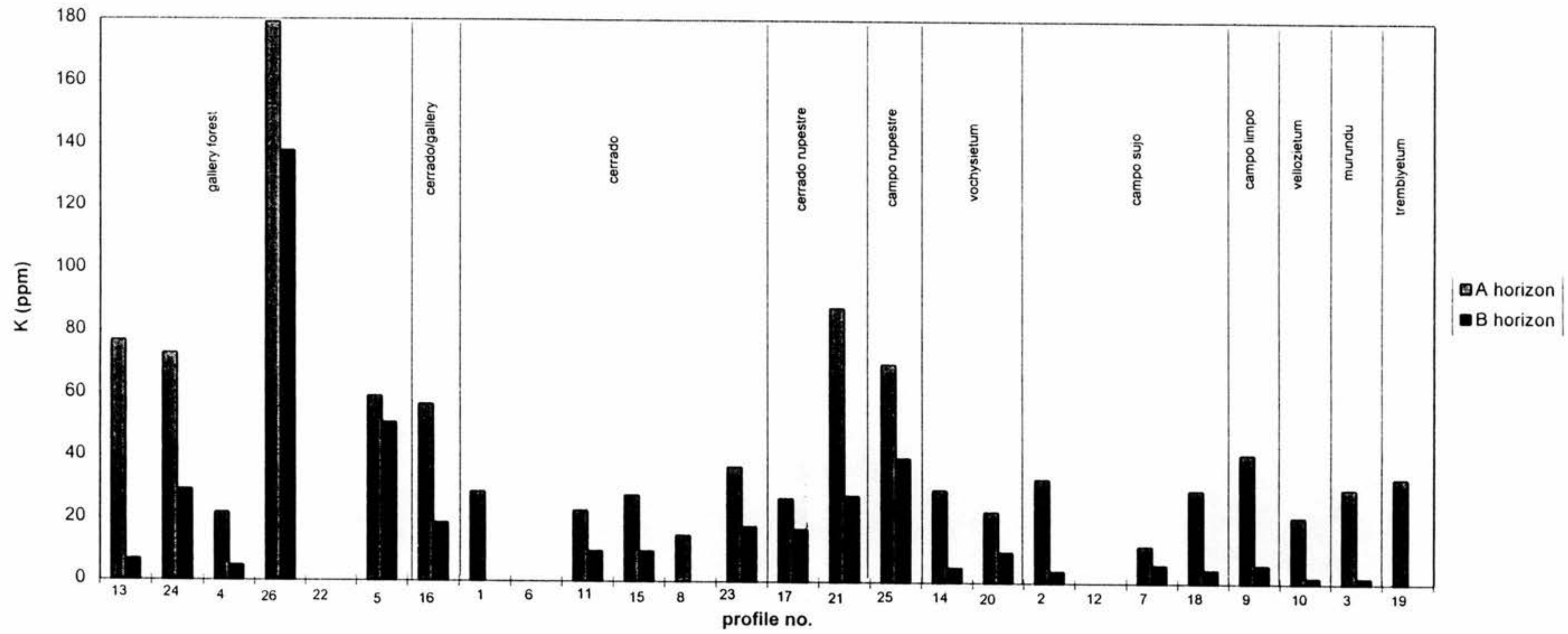


Figure 17 - Potassium in soils of Brasília National Park
(gaps represent data lost in the soil laboratory in Brazil).

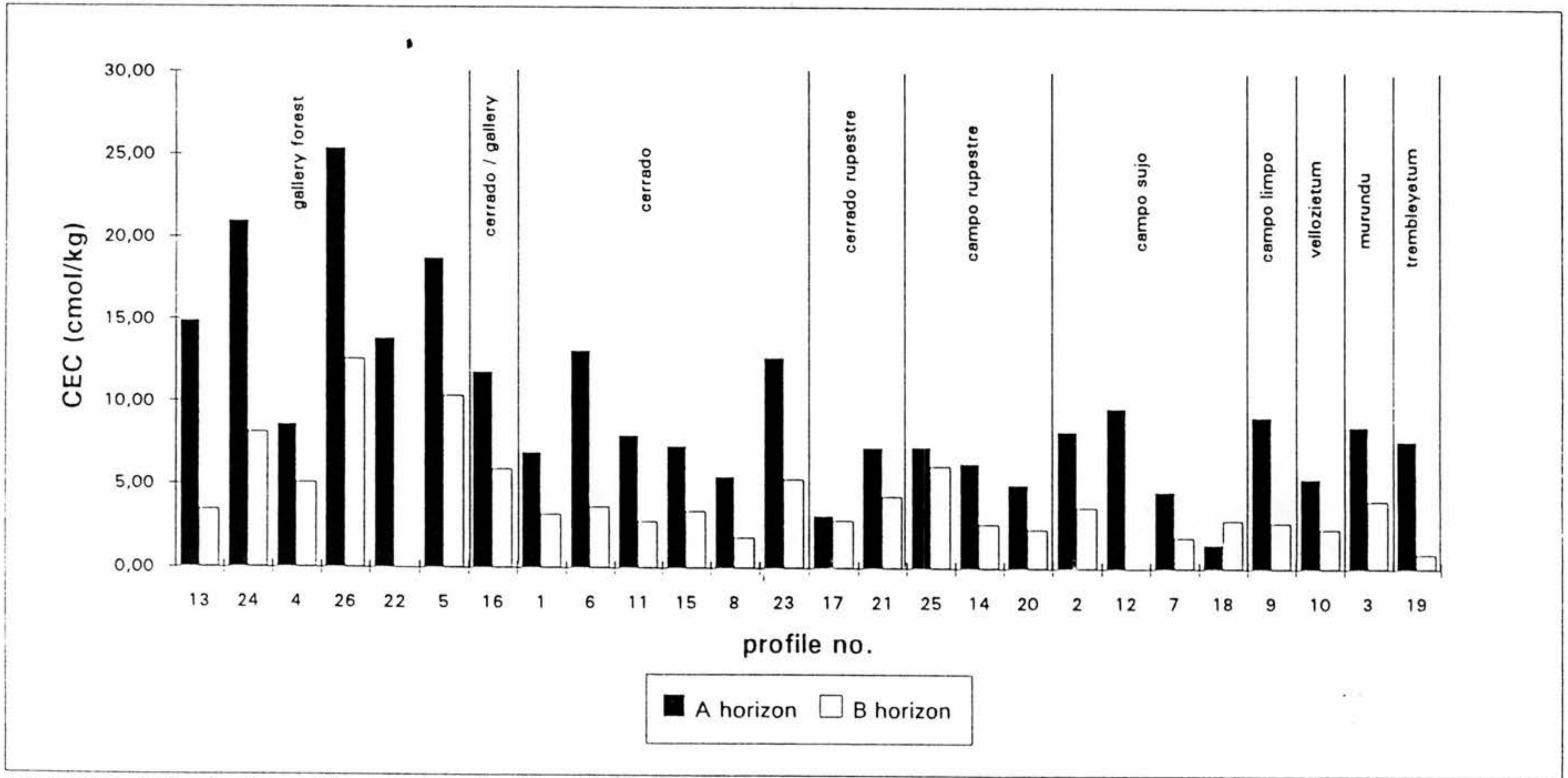


Figure 18 - Cation Exchange Capacity in soils of Brasília National Park
(gaps represent data lost in the soil laboratory in Brazil)

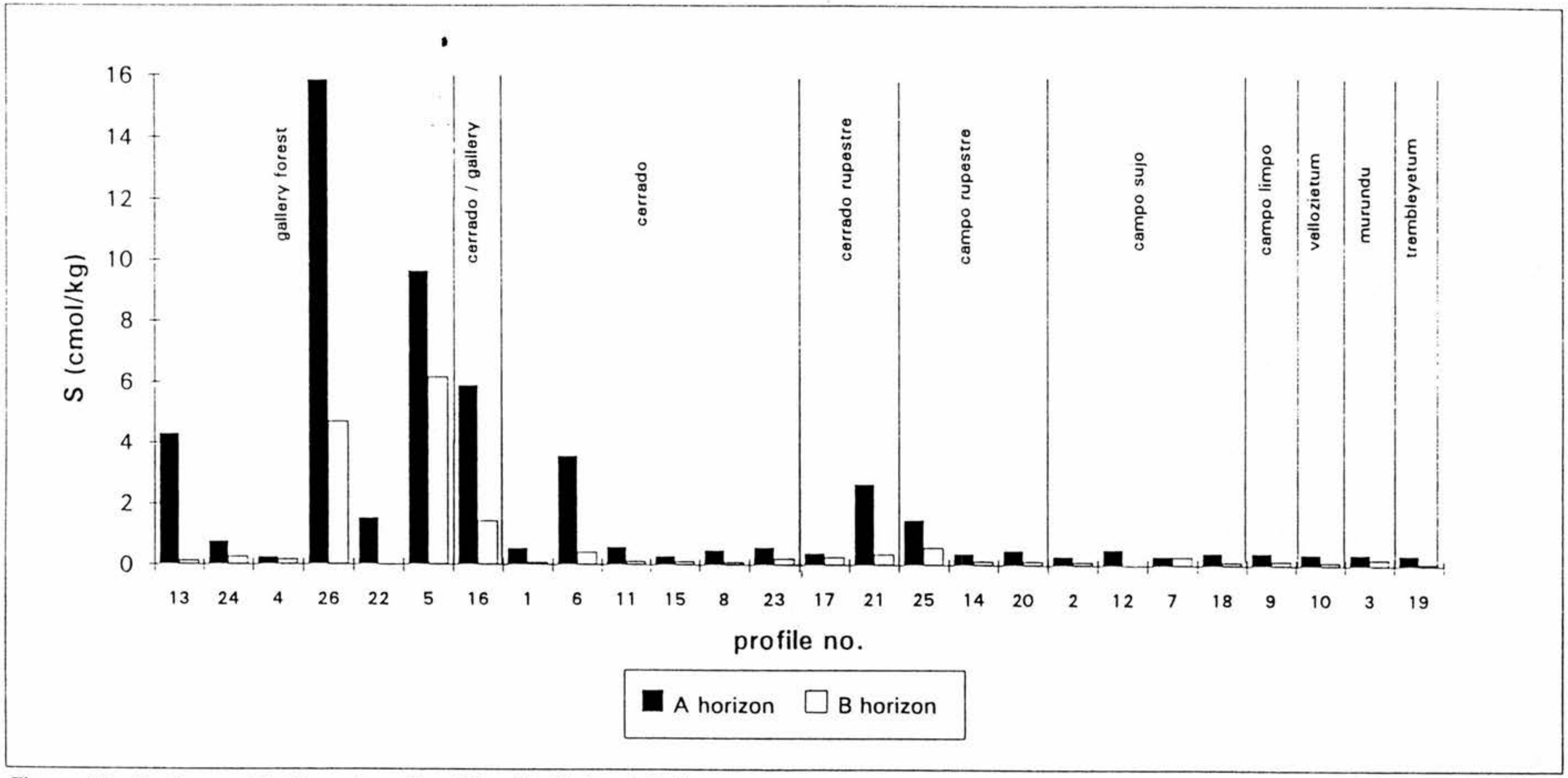


Figure 19 - Exchangeable Bases in soils of Brasília National Park
(gaps represent data lost in the soil laboratory in Brazil)

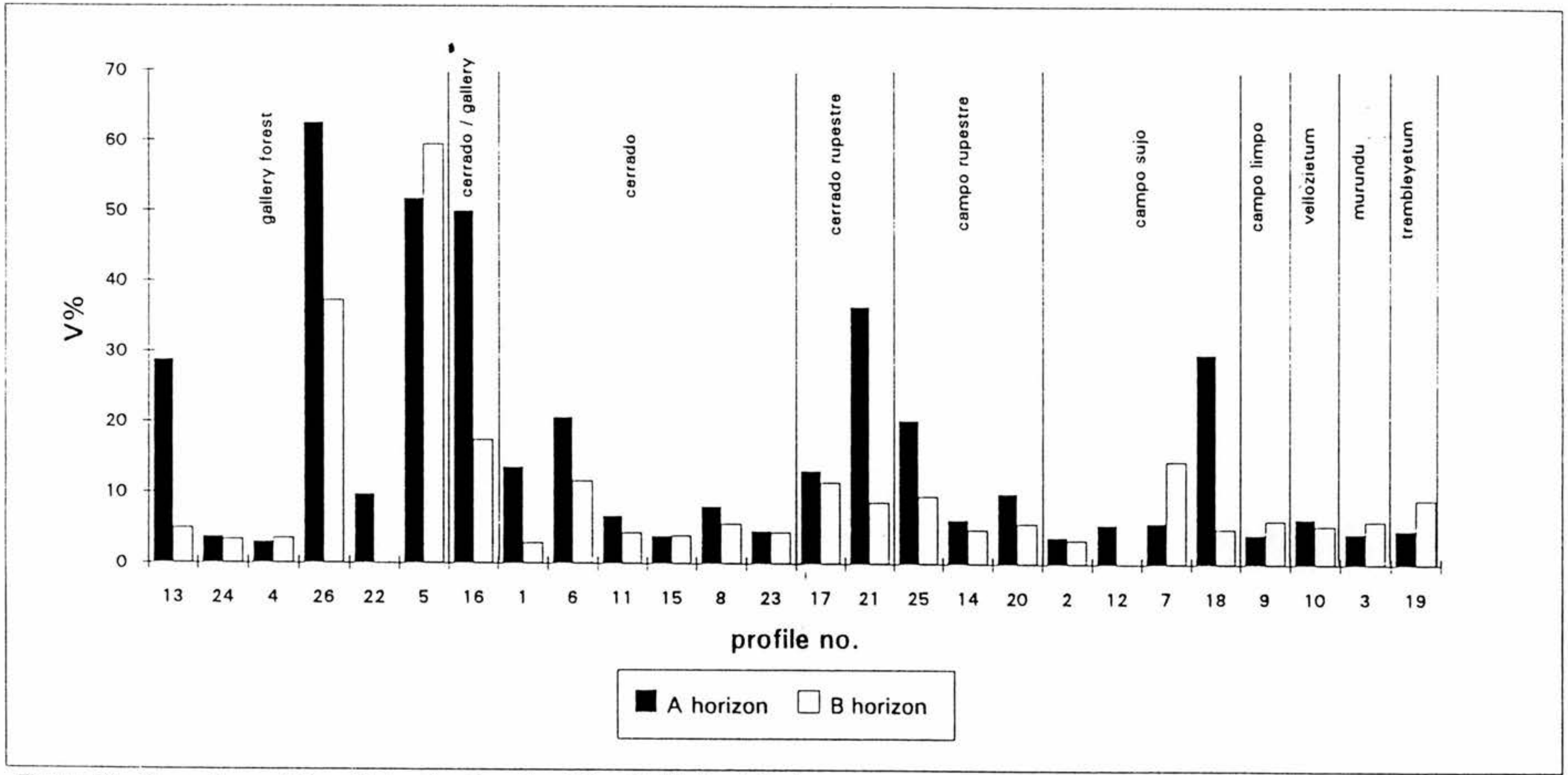


Figure 20 - Percentage of Base Saturation in soils of Brasília National Park
(gaps represent data lost in the soil laboratory in Brazil)

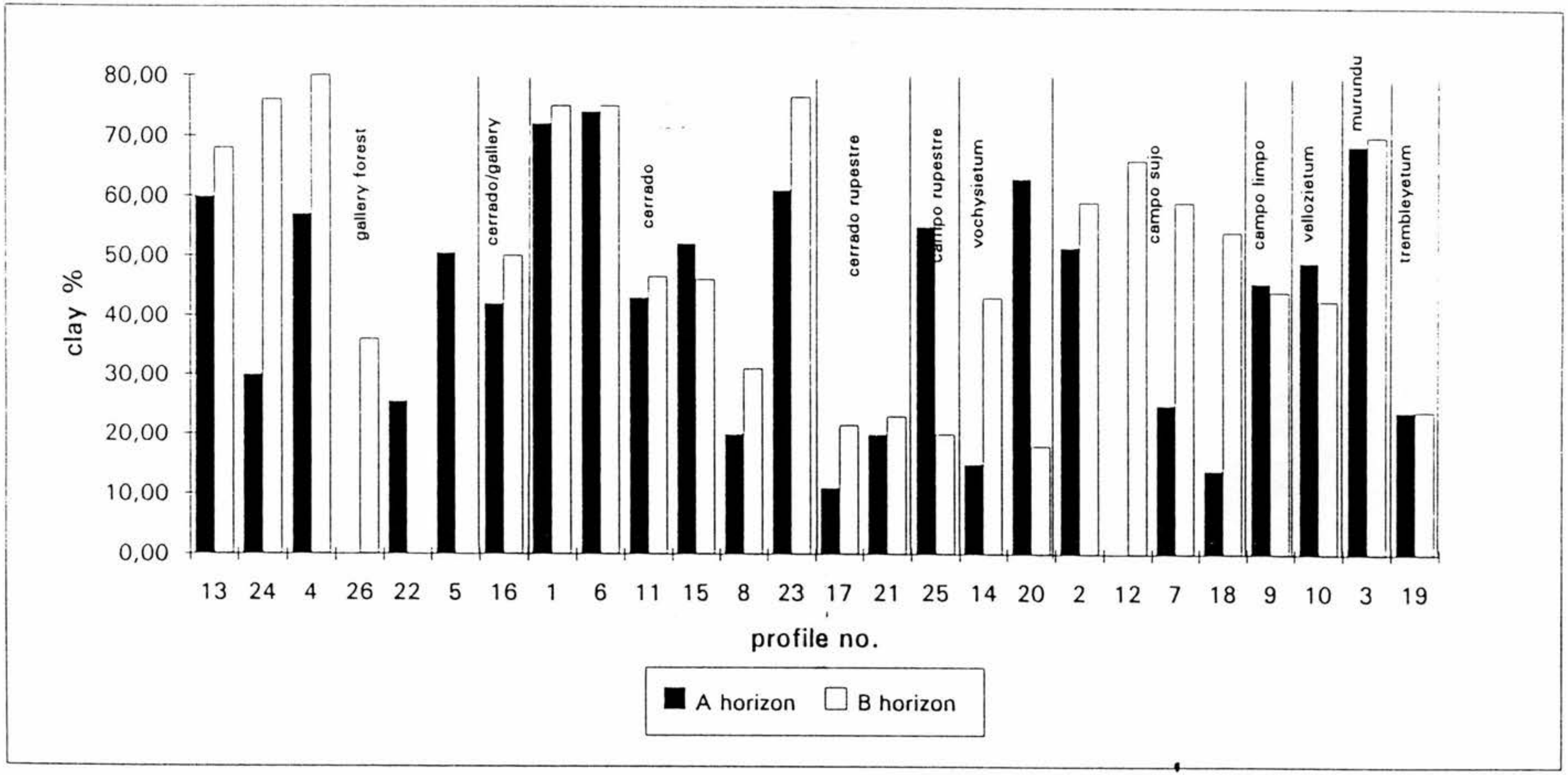


Figure 21 - Clay in soils of Brasília National Park
(gaps represent data lost in the soil laboratory in Brazil)

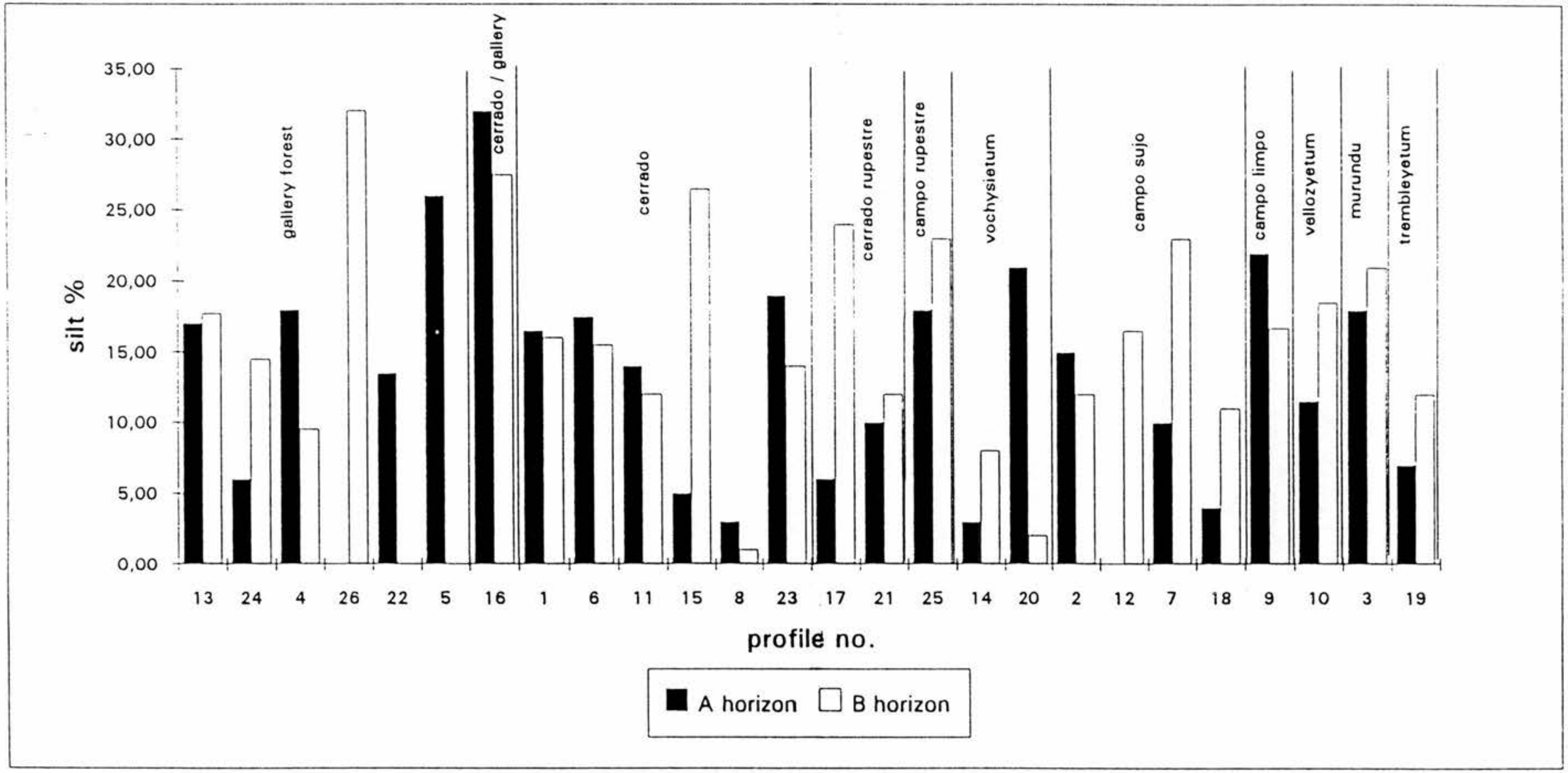


Figure 22 - Silt in soils of Brasília National Park
(gaps represent data lost in the soil laboratory in Brazil)

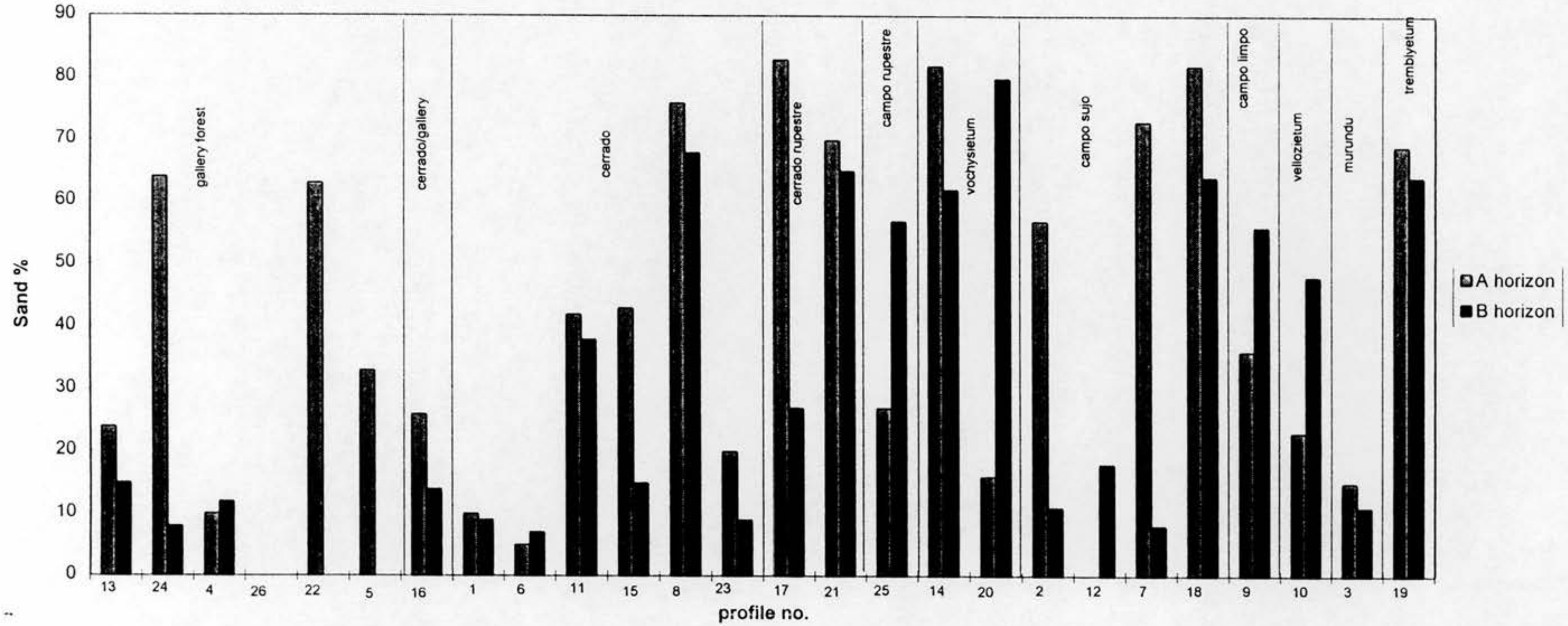


Figure 23 - Sand in soils of Brasília National Park
(gaps represent data lost in the soil laboratory in Brazil).

Figure 24 - Textural classes in soils of Brasília National Park
(gaps represent data lost in the soil laboratory in Brazil)

3.5.2. Physical and chemical soil characterisation

Soil properties were analysed in order to characterise the selected sites, and in an attempt to relate the determinant soil properties of different plant communities.

The soil analysis data are presented in Table 3, and Table 5 shows the ranges and averages for the A horizons. The soil profile descriptions are given in Appendix 2.

Table 5 National Park Soil Analyses (A horizons)

	Min.	Max.	Mean	SD (n = 26)
pH (unit)	4.10	6.10	5.0	± 0.40
Al (cmol/kg)	0.00	2.82	0.78	± 0.80
H + Al (cmol/kg)	0.00	20.20	7.71	± 3.60
O.M. (%)	0.14	18.58	4.19	± 2.90
C (%)	0.08	10.78	2.43	± 1.70
N (%)	0.04	0.95	0.24	± 0.20
C/N (unit)	1.16	30.74	10.40	± 3.70
P (ppm)	0.20	3.70	1.44	± 0.80
Ca + Mg (cmol/kg)	0.08	15.28	1.71	± 3.40
K (ppm)	0.00	179.00	30.03	± 32.93
S (cmol/kg)	0.08	15.84	1.77	± 3.40
CEC (cmol/kg)	0.09	25.34	9.39	± 5.50
V (%)	2.21	62.51	13.80	± 16.50
SAND (%)	5	83	37	± 25.30
SILT (%)	1	60	14	± 7.70
CLAY (%)	9	82	45	± 21.60

3.5.2.1 pH

The pH values found in the soil profiles of the National Park agree with previous work in the cerrado region, which observed that the cerrado soils are of medium acidity. In the National Park soils (see Tables 3 and 5), about 41% of the pH values are grouped as very acid (< 5.0), 53% are considered acid (5.0 to 5.5), 5% belongs to the class of the moderately acid soils (5.5 to 6.0), and only 1% are considered as slightly acid to neutral (> 6.0).

The moderately acid soils were found in profile no. 5 (see Table 3), in a gallery forest site (CRISTAL) and in a cerrado in the edge of a gallery forest in profile no. 16 (CERRADO CAPÃO COMPRIDO), both in Dark-Red Latosols. The slightly acid pH was also found in profile no. 26 in a gallery forest sampling (CEMAVE) in a Cambic soil.

The pH values shcw a general tendency to increase with profile depth (Fig. 7). However, within profiles no. 6, 16, 17, 21, and 26 the reverse occurs. This decrease in pH with profile depth is likely to be related to the higher Ca + Mg content of the surface horizons. In profile no. 17 the decrease of pH with depth parallels an observed increase in the Al saturation and Al content in the B horizon.

3.5.2.2 Al, H + Al and Al saturation

Although the tolerance levels and mineral requirements are not precisely known for most of the native cerrado plants, critical levels for cultivated plants have been used to interpret the soil chemical properties. Thus, contents above 1.0 cmol/kg of Al, 20% of Al saturation, and 5.0 cmol/kg of H + Al are considered high, and toxic for the cultivated plants (Goodland, 1971b; Goodland & Ferri, 1979; Lopes & Cox, 1977; Malavolta, 1976).

The Al distribution in frequency classes show that 48% of the results belong to low levels (0.0 to 0.3cmol/kg), 37% are considered medium (0.4 to 1.0), and 15% high (>1.0) (Malavolta, 1976).

Approximately 74% of the profiles had Al saturation above 20%.

The frequency class distribution of H + Al reveals that 43% of the soils are considered to possess high total acidity (> 5.0), 36% medium (2.0 to 5.0), and 21% low (< 2.0).

In general, the A horizons revealed higher Al, H + Al and Al saturation contents than the B horizons (Figs. 8, 9 and 10). In the National Park, the titrated acidity (H + Al) was higher for the forest profiles than for the cerrado ones. This might be related to the amount of organic matter which is higher in the soil surface and within the gallery forest than in the cerrado sites.

3.5.2.3 Organic material, N%, C% and C/N

The amount of organic matter found in the soil profiles shows that 33% of the values are low (<1.50%), 26% are medium (1.50 to 2.50), and 41% of the values are high (> 2.50%). The frequency classes of C are distributed as 32 % low (< 0.8 %), 24 % medium (0.8 to 1.4 %), and 44 % in high values (> 1.4 %). The distribution of N contents shows that 13 % of the values are considered low (< 0.08 %), and the remaining 87 % are medium (0.08 % to 1.4 %).

The values of O.M. %, C %, and N % in the soil profiles, generally show the same pattern (Figs. 11, 12 and 13). This was expected because of their well known, strong inter-correlation (Kiehl, 1979). The A horizon percentages are generally higher than those of the B horizons and the soil profiles located in the gallery forests showed higher values for these properties than those in the cerrado.

The mean values of the C/N ratio, or the stage of humification of the soil organic materiai, varies for most tropical soils between 10 and 15 (Kiehl, 1979; Brady, 1984; Goedert, 1985). In the National Park soil profiles, about 68 % of the C/N ratios were found in the low distribution class (C/N < 10), 25 % of the values were considered as medium, between 10 and 12, while 7 % of the ratios were considered high, (C/N > 12%) (Fig. 14). The ratios can be explained as a result of the mineralization of nitrogen, which is variable throughout the year, reaching its highest concentration during the rainy season (Goedert, 1986). The high values might be directly related to recent litter accumulation, and indirectly to high acidity and low availability of Ca and Mg, or possibly to both these factors acting together (Kiehl, 1979).

3.5.2.4 Phosphorus

Most soils of the cerrado have low total phosphorus contents with very low quantities in extractable form. Less than 0.1 % of phosphorus is found in the soil solution, and more than 90 % is in an adsorbed state (Goedert, 1986) and therefore not readily available to plants.

All the analysed profiles in the National Park have low concentrations of P. Amongst them, 65 % have concentrations of P below 1.5 ppm, 26 % stand between 1.5 and 2.0 ppm, and only 9 % of the profiles have contents of P higher than 2.0 ppm.

Most of the P is concentrated in the A horizons as a result of the strong correlation between P and organic matter (Brady, 1984) (Fig. 15). The gallery forest soils have higher contents of P than the cerrado. A slightly higher content of P was found in some Cambic soils carrying cerrado vegetation.

3.5.2.5 Ca + Mg

These cations are generally found in low quantities in the cerrado soils, which are acid and strongly weathered (Goodland, 1979; Lopes & Cox, 1977a, 1977b; Cochrane, 1989).

The quantities of Ca + Mg in the soil profiles show that 91 % of the figures are below 3.0 cmol/kg, which is considered very low, and only 2 % of the values are medium (3.00 to 5.00 cmol/kg), and 7 % high (> 5.0 cmol/kg) (Malavolta, 1976; Kiehl, 1979).

Profile no. 26 in a Cambic soil associated with a gallery forest had the highest contents of Ca + Mg in the National Park (15.28 cmol/kg). Profile no. 5 in a Dark-Red Latosol also associated with gallery forest showed the second highest value of Ca + Mg (11.34 cmol/kg).

3.5.2.6 Potassium

Most of the cerrado soils show values below the 60ppm of potassium regarded as the critical level for cultivated plants (Goedert, 1986; Goodland 1979).

About 67 % of the soil profiles had low contents of K (<38ppm), 26 % showed medium values of K (38 to 96 ppm), and 7 % of the soils analysed had contents considered high (> 96 ppm).

The A horizons have higher contents of potassium than B horizons (Fig. 17), as expected because of the positive correlation between potassium and organic matter (Goodland, 1986).

In the National Park, the K values seem to be independent of soil class, but profiles 26 and 21, both in Cambic soils, presented the highest values of this cation.

3.5.2.7 Cation Exchange Capacity - CEC, Exchangeable Bases - (S) and the Percentage Base Saturation - (V)

The exchangeable bases (S) of the soil profiles indicates that 89 % of the profile analyses have low contents of bases (< 2.62cmol/kg), 7 % have medium (2.62 to 6.30), and only around 4 % have high quantities of bases (> 6.3).

About 52 % of the CEC values of were low (≤ 4.62), 40 % medium (4.62 to 13.30), and 8 % considered high (> 13.30) (Malavolta, 1976; Kiehl, 1979).

The frequency classes of distribution of the base saturation (Malavolta, 1976; Kiehl, 1979) shows that 85 % of the computed values are very low (< 25 %), 10 % are low (25 to 50 %), and the remaining 5 % medium (50 to 70 %). These numbers confirm the poverty and the high acidity of these soils. The levels of bases such as Ca and Mg are relatively low, so Al tends to be the dominant cation.

The results show that the soil classes cannot be directly associated with fertility, since different classes had either higher or lower levels of mineral nutrients (see Table 3). The parent material, the vegetation cover, the amount of organic material, the topographical situation and so on, are all important factors related to the fertility of the soils (Brady, 1984). The A horizons have higher values than B horizons (Fig. 18 to 20) which is related mainly to the concentration of organic material in the soil surface.

3.5.2.8 Sand, Silt and Clay

By the criteria of family classes (Soil Survey Staff, 1975), 62 % of the samples were classified as clayey (> 35 % clay), 32 % were loamy (18 to 35 % clay), and 6 % were sandy (< 18 % clay).

These data show that the studied sites vary quite widely in texture. They range from clayey to sandy, and include most of the other intermediate classes (Fig. 21).

The textural fractions do not show any pattern between the soil classes. All soil classes can have greater or lesser contents of clay or sand, but in general all of them have low contents of silt..

The A horizons have generally higher percentages of sand than the B horizons, which generally have higher amounts of clay (Figs. 22 and 24). The silt percentages are variable between the A and B horizons, some have higher percentages in the B and some in the A horizons (Fig. 23).

In the Latosols, the B horizon may have the same, or a higher percentage of clay than the A horizon, but the Textural Ratio between B and A horizons (B/A) cannot by definition, exceed 1.8 (Kiehl, 1979). However, in the National Park, some soils classified as Latosols according to the EMBRAPA soil survey, were found in the present study to have a B/A ratio higher than the limit defined for a Latosol (see Table 3). This clay accumulation is characteristic of Ultisols (Brady, 1984).

3.5.2.9 Colour

Soil colour characteristics in field conditions reveal a wide range for the component hue. About 26 % of the B horizons are 2.5YR, 24 % are 5YR, 22 % are

7.5YR, 26 % are 10YR, and only one horizon shown 10R, but none are 2.5Y, 5Y or 5R. In relation to value, 91% of the samples had a range from 4 to 6. For chroma, 91.4 % of the samples ranged from 6 to 8. The dominance of yellowish colours observed in the soil profiles is indicative of a low contents of organic matter and low CEC in the soils (Kiehl, 1979). Another important point to be inferred from the colour patterns are that most of them are represented by a transitional soil phase, between the well-drained Dark-Red Latosols and the Hydromorphic Soils. This colour pattern gives evidence of a moisture gradient (Macedo & Bryant, 1987) which is certainly reflected in the distribution of the vegetation communities (see the catena model in Fig. 4).

3.5.2.10 Soil depth, Ironstone layer and Soil water regime

The National Park lies in an area of very variable topographical conditions. There are nearly flat areas on the plateau, gentle slopes leading to wide and long valleys, and steep slopes in narrow and deep valleys, plus microtopographical variations caused by the existence of resistant materials, and ironstone concretions. In combination with drainage and other geomorphological factors, the soil cover results in a mosaic-like distribution. These landscape features create a very diverse morphology in the soils. Some are deep and well drained and others are shallow, varying with the presence or absence of outcrops. All of these soil characteristics combined with the variations in soil mineral availability create a very dynamic and variable soil environment, that contributes enormously to the habitat diversity in the area.

In the National Park the Dark-Red Latosols consist of deep, well-drained soils, free of concretions or outcrops. Some Red-Yellow Latosols are well drained and also free of ironstones or outcrops, while others contain ironstone concretions. However, a common characteristic of the Red-Yellow Latosols is the oscillation of the water-table depth, which attains levels near the soil surface during the wet season, especially in the lower parts of the catenas. The Red-Yellow Latosols localised in the borders of the Contagem plateau, generally contain ironstone layers. The Cambic soils in the Park are generally shallow with or without ironstone layers or outcrops, but most of these soils are associated with sandstone outcrops. Descriptions of the soil profiles are given in the Appendix 2.

3.6 Discussion

From the analysis of the results obtained in this soil study, three main aspects emerge:

1. The inadequacy of the EMBRAPA soil survey of the Distrito Federal in terms of soil classification of the National Park.
2. The characteristic relationships between soil morphology, topography and drainage.
3. The spatially varied physical and chemical characteristics, forming a complex and rapidly changing environment for plant growth.

3.6.1. Soil classification

Examination of the soil profiles shows evidence of existing gaps in the EMBRAPA soil survey of the Distrito Federal, which failed to map important soil units in the National Park. In fact the EMBRAPA survey did not study any profiles within the National Park; the soils there were mapped using information from areas considered similar in other parts of the Distrito Federal. Although such mapping by analogy was a valid strategy for the aims of the EMBRAPA soil survey, a more detailed and accurate soil map on a scale compatible with the needs of management purposes is of great importance for the National Park.

3.6.2. Soil morphology, topography and drainage relations

The soil class distribution in the National Park is related to the geomorphic surfaces as originally described by Feuer (1956), consisting of an older erosion surface at between 1000 and 1200 m elevation and a second erosion surface constituting the pediment from 800 to 1000 m.

Dark-Red and Red-Yellow Latosols cover most of these erosion surfaces on level or gently undulated terrain, carrying mainly cerrado vegetation. Sloping down from the plateau border to the pediment, ironstone layers are commonly found. At these places, deep, concretionary Red-Yellow Latosols develop, carrying cerrado scrub (campo cerrado) communities and cerrado scrub with emergent trees. Cerrado open scrub communities (campo sujo) cover the shallower patches of this type of soil (See catena in Fig. 4).

On steeper slopes and ridges, typically Cambic soil profiles have developed. Semideciduous forests, cerrado rupestre and campo rupestre are found on this type of soil, but the last is found in shallower patches of lithosol.

Hydromorphic soils develop in the recently deposited material represented by terraces and recent alluvial deposits. They are covered by damp gallery forests, veredas and campo limpo. The presence of Hydromorphic soils in crest-slope transitions in the higher parts of the pediment and in some slopes shows the influence of lateral water movement, which seems to affect much of the distribution of cerrado communities in the National Park.

Similar soil and related vegetation distribution is described in a soil mineralogy study at the research station of EMBRAPA - CPAC (Rodrigues & Klamt, 1978), and at Fazenda Água Limpa, Distrito Federal (Ratter, 1980; Furley, 1985) confirming the direct relationship between the distribution of cerrado plant communities and the geomorphic features of Central Brazil (see Fig. 4).

The close relationship between topography, drainage and soil types is reasonably well known for the central cerrado region. Macedo & Bryant (1987) for instance, studied what they called a hydrosequence of Latosols in Central Brazil. These authors describe a similar pattern of the soil distribution along the natural drainage sequence to that found in the National Park of Brasília. As in the National Park, the well-drained Dark-Red Latosols are located in the upper parts of the plateau (chapada), poorly drained Hydromorphic laterites are found in the edges of the chapada, and Red-Yellow Latosols in intermediate drainage positions. Plinthite was described in the zone immediately below the average depth of the water-table.

Only one representative profile was described as Plinthic in the National Park. This profile (no. 19, Table 3) is located on the upper slopes near the border of the Contagem chapada, whose water drains to the Tres Barras stream. At this site, the level of the water-table oscillates near the soil surface throughout the year. The soil is sandy with reddish mottles widespread in the profile.

3.6.3. Physical and chemical characteristics of soils in the National Park of Brasília

3.6.3.1 Topography and drainage influences.

The textural classes are variable in the soils of the National Park, some profiles showing a high content of clay whilst others are sandy. In general, small differences of texture and a low content of silt were observed from the surface to the base of the profiles, features which are characteristic of Latosols (Bennema, 1963). However, some profiles show high values for the B/A horizon ratio, which should be lower (> 1.8) in Latosols according to Brady (1984). Such clay accumulation is more characteristic of Ultisols (USDA - Soil Survey Staff, 1975) and suggests that such profiles are transitional to Podzols in the Brazilian classification.

The clay accumulation observed in some soil profiles (profiles no. 7, 14, 18 and 24) might be related to past soil genetic processes involving soil-water relations (Macedo & Bryant, 1987).

According to Macedo & Bryant (1987), the hypothesis of development of Red-Yellow Latosols is related to the continuous dissection of the peneplains covered previously by Dark-Red Latosols. The progressive widening of the valleys, caused retreat of the plateau escarpment to its present position. These recent geomorphic processes and the climatic change from a drier macro climate to a seasonal wet climate have resulted in the rise of the water-table. The hydrological conditions of the Red-Yellow Latosols associated with the presence of organic compounds near root surfaces may have induced selective reduction, dissolution and removal of haematite from the upper horizons of the soils and/or transformed this clay mineral to goethite.

This elevation of water-table levels, which is indicated as the controlling factor in the development of the Red-Yellow Latosols, can be also associated with the observed clay accumulation in the B horizons.

The first assumption is that, these argillic soils associated with Latosols typically occupy positions in the catena which are younger or less stable than the position occupied by the Latosols themselves (Macedo & Bryant, 1987). This seems to be the case in the National Park, where the Latosols are found on more level and stable areas.

The other assumption is that the translocation and deposition of clays are explained by the usual model. This supposes that clays are dispersed when dry soils are initially wetted, then move downward with percolating water. Redeposition results largely from a sieving effect as water is withdrawn by capillarity into the soil aggregates, leaving the suspended clays as coatings on the surface of peds (Macedo & Bryant, 1987).

All the soil profiles which contained an argillic horizon seem to correspond with Macedo & Bryant (1987) assumptions. They are situated in less stable sites than the typical Latosols and the water-table levels oscillate near the soil surface during the rainy season.

The colours of most B horizons of the soil profiles showed a Red-Yellow hue, value and chroma, that according to Kiehl (1979), are characteristic of well-drained soils. In the National Park they are represented mainly by an intermediary soil phase, between the better-drained Dark-Red Latosols and the Hydromorphic class. This pattern is typically found on the sloping catenas in the central cerrado region (Macedo & Bryant, 1987). The predominant colours are also indicative of nutrient-poor and weakly organic soils (Kiehl, 1979).

As described before in this Chapter, the colours of the Latosols are correlated with the kind of iron mineral present. According to Macedo & Bryant (1987) the Dark-Red Latosols have haematite and the reddish zones of the Red-Yellow Latosols have haematite and goethite, whereas goethite is the only iron component in the yellowish zone of the Red-Yellow Latosols. This can also be a result of weathering, with the removal of haematite changing the colour of the soil matrix from red to yellow.

The same process of removal of haematite described by Macedo & Bryant (1987), might be the controlling factor for the translocation and deposition of clay observed in some soil profiles.

3.6.3.2 Chemical factors.

Although there is an important diversity of soil types with different properties in the National Park, it is now possible to make a number of broad generalisations, based on the results found in the present study. Most of the soils are acidic, have low cation exchange capacity and contain high levels of aluminium saturation. These characteristics agree with various previous studies such as Goodland (1971) who studied the soil-plant relations of the cerrado of Minas Gerais state, Queiroz Neto (1982) in his synthesis of cerrado soils, Furley (1985) studying the soils of Fazenda Água Limpa, in Brasília and Furley & Ratter (1988) in their review of soil resources, plant communities and development of the cerrado. The figures of cerrado soil properties can be seen in Table 6, and figures for other plant communities in the cerrado region are given in Table 7.

Profile no. 26, Table 3, on a Cambic soil and profile no. 5 on a Dark-Red Latosol, both from sites carrying gallery forest, are unique in the pattern of National Park soils. These two profiles can be classified as mesotrophic, with regard to their high contents of mineral nutrients, mainly Ca + Mg. Profiles no. 6 and 16 (both in Dark-Red Latosols covered by cerrado vegetation) and profile no. 13 (Red-Yellow Latosol carrying gallery forest), also show higher levels of Ca + Mg in their A horizons although much lower than 5 or 26 and should also be considered as mesotrophic.

Table 6 Range and median values of soil properties in the Brazilian cerrado

Soil properties	Median	Range	Comment
pH (H_2O)	5.0	4.3 - 6.2	Nearly 50% have high acidity (≥ 5)
Ca (meq/100ml)	0.25	0.04 - 6.81	96% below lower limit recommended for agriculture
Mg (meq/100ml)	0.09	0.00 - 2.02	90% classified as low (queries over use of ex. Mg values)
K (meq/100ml)	0.08	0.02 - 0.61	85% classified as low
Effective CEC (meq/100ml)	1.1	0.35 - 8.10	84% <2 meq/100ml, indicative of high weathered soils
Al saturation (%)	59	1.1 - 89.4	79% over 40% saturation (levels considered toxic for crops)
P (μg/ml)	0.4	0.1 - 16.5	Over 90% of soils had only 1/5th of critical level (taken as 2 μg/ml)
Organic matter (%)	2.2	0.7 - 6.0	Contributes little to the effective CEC
Zn (μg/ml)	0.60	0.2 - 2.2	80% below critical level (at 0.8 μg/ml)
Cu (μg/ml)	0.65	0.0 - 9.7	70% below critical level (at 1.0 μg/ml)
Mn (μg/ml)	7.6	0.6 - 92.2	37% below critical level (at 5.0 μg/ml)
Fe (μg/ml)	32.5	3.7 - 74.0	No deficiency or toxicity levels but influences P fixation
Clay (%)	33.5	4.5 - 72.4	High clay contents related to P fixation and water holding capacity
Colour hue	5 yr	40% of freq. distribution	Indication of well drained soils
" value	4	45% of freq. distribution	"
" chroma	6	50% of freq. distribution	"

After Lopes & Cox (1977), (Compiled from Furley & Ratter (1988))

Patches of mesotrophic soil are widespread in Central Brazil, and have been mentioned by Ratter (1971), Ratter et al. (1973, 1977), Araújo (1984) and Ramos (1989). All these authors studied associations of characteristic vegetation communities which are considered indicators of mesotrophic soils, such as mesotrophic cerradão and mesotrophic forests. Table 7 shows the principal soil properties characteristics of the dystrophic and mesotrophic cerradão.

Table 7 Analyses of surface layers (0 - 15cm) of mesotrophic and dystrophic cerradão

Vegetation	Locality	pH (H_2O)	Ca*	Mg*	K*	Al*	P**	N (%)
1 Mesotrophic facies cerradão	Vale de Sonhos, MT	6.0	4.35	0.58	0.30	0.0	87	0.26
2 Mesotrophic facies cerradão	Padre Bernardo, GO	5.4	3.25	0.82	0.16	0.62	108	0.23
3 Mesotrophic facies cerradãao	Pandeiros, MG	6.5	7.58	1.36	0.08	0.0	50	0.14
4 Dystrophic facies cerradão	Nr Cascalheira, MT	4.7	0.13	0.04	0.14	1.53	96	0.20
5 Dystrophic facies cerradão	Nr Botanic Gardem, DF	4.8	0.20	0.17	0.1	1.0	45	0.18
6 Dystrophic facies cerradão	Planaltina, DF	4.5	0.08	0.10	0.10	2.36	180	0.28

1- 4 from Ratter *et al.* (1977); 5, Ratter, previous unpublished data; 6, Ribeiro (1983) (0 - 20cm).

* cmol/kg; ** ppm

Compiled from Furley & Ratter, 1988.

3.7 Conclusions

Initially, it is important to mention that this is the first detailed soil study of the National Park of Brasília. A stratified set of soil samples covering the total area of the Park was taken, related principally to the main vegetation communities. Topography and drainage were also considered, since it has been shown in this and other studies that they bear a close relationship to soil class distribution.

The EMBRAPA soil survey of the Distrito Federal which was the basis of the soil classification used in this study, has been shown by the soil analyses and field observation to be insufficiently detailed to distinguish the variability of the soils of the National Park. Since the Park was not actually sampled during the EMBRAPA survey of the Distrito Federal, it will be necessary to produce soil assessments, based on systematic soil survey at a scale compatible with its management requirements.

Geomorphic characteristics such as topography and drainage, were shown to be important determinant factors in the distribution of soil classes. The depth of the soil, the water regime (level of the water-table) and the presence of ironstone and outcrops are shown to be important determinants of soil distribution.

The chemical properties of the National Park profiles indicate that in general, the soils are strongly acidic, have low cation exchange capacity and contain high levels of aluminium saturation. However, a group of mesotrophic soil profiles were found having higher quantities of mineral nutrients, especially Ca + Mg.

The principal objectives of this study are to characterise the soils associated with the most important vegetation communities of the Park, and to provide data on soil properties determining cerrado vegetation distribution.

Although valuable information has already been obtained, some further studies can be suggested here:

1. Some soil profiles show an accumulation of clay in their B horizons, suggesting the existence of a transitional soil class. These soil profiles need to be further investigated and if the presence of argillic horizons is confirmed, the soil classification will need to be modified.

2. Detailed studies of the drainage and monitoring of water-table need to be undertaken to establish more exact and quantified relationships with the vegetation communities.

3. Some sites in the National Park have shallow soils that either remain saturated with water throughout the year, or experience seasonal water-logging. In such areas, Fe and Mn can play an important limiting role, and the more tolerant species of plants can take advantage and become dominant. So studies relating the water regime and the tolerance of some cerrado woody plant species to it, as well as the effects of trace elements such as Mn and Fe could be important in the search for determinant factors and need further investigation.

According to Foy (1984), quoted by da Silva (1991), manganese toxicity is one of the principal factors limiting plant growth in acid soils. Studying the content of nutrients in leaves of most common tree species in three gallery forests in the Distrito Federal, da Silva (1991) found toxic levels of Mn in 28 of the 72 species studied.

4. Quantitative relationships between relative plant growth and soil nutrients is an important aspect for investigation at least for indicator plant species of the principal soil units. This would indicate plant nutritional requirements and help us to understand their dynamics in the communities.

5. Further sampling areas carrying similar soil units should be studied to provide further data relevant to soil/vegetation interrelationships.

6. This study was not able to cover all the National Park plant communities. For example, some flooded areas carrying campo limpo and veredas could not be included. The anthropogenic sites within the Brasília National Park were also excluded from this study. In future the work should be extended to include these areas.

Finally, the present soil study has demonstrated a number of important characteristics of the soil environment of the principal vegetation communities of the National Park. It also provides a basis for future studies in the Park, providing information for monitoring and management.

Chapter 4

Phytosociology and floristics of the vegetation communities of the National Park of Brasília

4.1 Introduction

Although the flora and vegetation of the Brasília National Park have been studied since the 1970s analysis has been far from systematic. A number of publications do exist, but they, like the botanical material which has been deposited in the regional herbaria, are very incomplete. Before outlining the objectives of this study therefore it is relevant to present a brief history of the recent botanical research in the National Park of Brasília. This allows us to recognise gaps in existing knowledge and thus identify priority areas of research.

The management plan of the National Park of Brasília (Brasil, 1979) provides the first list of families and species in this area. It also presents tables with mean values for the number of individuals per hectare in gallery forest, dense cerrado and open cerrado. Unfortunately it fails to mention either the sample site locations or methods applied in the survey.

In the course of the 1980s two significant research projects were undertaken in the National Park of Brasília. The first was the vegetation study of the RADAMBRASIL project (Brasil, 1982) which established three phytoecological stations in cerrado areas at the National Park, each covering about 1 ha. Shrubs and trees of 10 cm diameter or more at a height of 30 cm from the ground were recorded. In total 46 species were found, of which *Qualea parviflora, Dalbergia miscolobium, Caryocar brasiliense,* and *Ouratea hexasperma* had the highest IVI (Importance Value Index, see item 9, p. 82). Density ranged from 1400 to 2800 individuals/ha, and basal area varied from 8 to 16m^2/ ha.

The second study was undertaken by Oliveira et al. (1982) working with the point center quarter (PCQ) method in a cerrado *sensu stricto*. They analysed woody plants with a girth ≥ 10cm, at a height of 30cm from the ground for individuals up to 2m tall (shrubs), and at 1.30m from the ground (gbh) for individuals > 2m tall (trees). They found 45 species belonging to 28 families. The height of trees and shrubs ranged from 1.4 to 4.0m, the density of trees was 567 individuals/ha and the density of shrubs was 692 individuals/ha. The basal area was 9.0m²/ha for trees (individuals ≥ 2m tall) and 6.4m² for shrubs. In the tree layer species such as *Styrax ferrugineus, Dalbergia miscolobium, Qualea grandiflora, Ouratea hexasperma, Eremanthus glomerulatus, Pouteria ramiflora* and *Kielmeyera coriacea* were recorded as having the highest IVI. The most important species of shrubs were *Ouratea hexasperma, Connarus fulvus* and *Syagrus* sp., followed by *Kielmeyera coriacea, Syagrus comosa, Roupala montana, Erythroxylum tortuosum* and *Salacia crassifolia*.

In the 1990s the focus of research has shifted from taxonomy and basic phytosociological studies to an emphasis on conservation and management. A project called *The Biogeography of the Cerrado Biome: zoning of biotic resources for management and conservation* (Brasil, 1990; Felfili et al., 1993) is currently being developed by a group of scientists from the University of Brasília, IBGE (Brazilian Geographic and Statistical Institute), EMBRAPA (Brazilian Agency for Agricultural Research) and the Brasília Botanic Garden. The project aims to investigate the heterogeneity of the biota within and between systems, propose an environmental zoning system, investigate the distribution patterns of the biota, and identify priority areas for conservation of cerrado genetic resources.

This project sampled some non-flooded gallery forests and areas of cerrado *sensu stricto* in the National Park of Brasília. Ten quadrats of 20 x 50m were set-up in the cerrado areas, and transects subdivided into quadrats of 10 x 20m were laid out in the gallery forests. Shrubs and trees ≥ 5cm diameter at 30cm from the ground were sampled in the cerrado quadrats, and of the same diameter at a height of 130cm for the gallery forests.

The research recorded 1036 individuals/ha belonging to 56 species in the cerrado. *Ouratea hexasperma, Caryocar brasiliense, Dalbergia miscolobium, Kielmeyera coriacea*, and *Vochysia rufa* were the species with the highest IVI. The Shannon and Wiener diversity index was 3.34, and basal area 8.32m^2/ha.

The same project recorded 67 species belonging to 29 families from the gallery forest areas. The estimated plant density was 1645.4 individuals/ha, and the basal area was 32.7m^2/ha. The Shannon and Wiener diversity index was 3.38.

The vegetation and flora of the National Park of Brasília were analysed in a recent review of its management plan (FUNATURA, 1992). Although the description of the vegetation and a list of species are included in this review, it is of limited value as it fails to present new quantitative data.

A range of phytosociological studies have now been carried out on the vegetation of the Federal District, providing a reasonable basis of information for the region (see Chapter 1) . Even so, most of these studies have been concerned exclusively with areas of gallery forests, cerradão, and cerrado *sensu stricto*. The result is that important vegetation associations of the full range of physiognomic forms of the cerrado continuum (Veloso, 1948) have been overlooked. In focusing attention on precisely this topic, the research presented here seeks to further current understanding of the cerrado.

The objectives of this study are as follows:

1. To identify distinct plant communities, with physiognomic and floristic individuality in the National Park of Brasília.
2. To establish permanent sample areas in these distinct plant communities, in order to provide data of temporal change, thus enabling future studies of population dynamics.

3. To investigate these distinct communities through their basic phytosociological parameters.

4. To analyse their structural and floristic patterns.

5. To contribute to the overall knowledge of the determinants of tropical savannas.

4.2 Materials and Methods

A systematic survey of the plant communities of the National Park of Brasília at reconnaissance level was made by covering the whole area by micro-light aircraft flights, by car, and on foot. Interpretation of aerial photography on a scale 1:40,000 and of TM LANDSAT 5 image 1:100,000 were also carried out for the location of sample sites.

The sample sites were chosen according to physiognomic and floristic characteristics. The point-centered quarter method as described by Mueller-Dombois & Ellenberg (1974), was used to inventory the vegetation. In this plotless method points are sited along a line at fixed intervals not less than twice the maximum interplant distance in the area (established at the outset by measurements between random pairs of plants). The area around the point is divided into four quarters and in each the point-plant distance, girth and identity of the nearest individual for each size-class is recorded. Vouchers specimens for taxa unrecognised in the field were collected and are lodged at the herbarium of the University of Brasília (Brazil), UB, and at the Botanic Garden of Edinburgh (UK.), E..

Because of limitations of time and resources available, the intensity of sampling varied according to the area covered and the species-richness of different plant communities. The species-richness of some sites was estimated by qualitative observation during the preliminary studies and by reference to information from the literature (Ratter, 1991). Plant communities considered species-poor or covering smaller areas, were sampled at fewer points. Thus, 20, 30, 40, 60 or 100 points were established at different sample sites according to these factors. The total number of sites sampled was 26, eight in gallery forest and 18 in cerrado vegetation.

In forest areas points were located at 10m intervals along the transects. In cerrado two qualifying girth classes were recorded, ≥ 5cm and ≥ 30cm at base, so that data on relative importance of species as larger and smaller individuals could be obtained and the distances between points was varied, being at 10m intervals for individuals ≥ 5cm girth at the base, and at 20m intervals for individuals with girth ≥ 30cm. The difference in inter-point distances adopted to survey the cerrado areas is due to the sparser distribution of larger trees and shrubs in this vegetation. Plants with a basal girth < 5cm were excluded, as were those shorter than 50cm.

The girths were measured by tape. Heights up to 5m were measured with a graduated pole, while those above that were estimated, using the height of the tree relative to the pole as a rough guide.

Analysis of the structure of plant communities was achieved by arranging the data in girth and height frequency classes (Table 8). Graphs were then constructed to display the plant size distribution in terms of percentage for each sampled area.

Table 8 - frequency classes of girth and heights

forest	girth (cm)	height (m)
	1 5 - 15	1 0.5 - 2.0
	2 15 - 30	2 2.0 - 4.0
	3 30 - 45	3 4.0 - 6.0
	4 45 - 60	4 6.0 - 8.0
	5 60 - 90	5 8.0 - 10
	6 90 - 120	6 10.0 - 15.0
	7 > 120	7 15.0 - 20.0
		8 > 20.0
cerrado	girth (cm)	height (m)
	1 5 - 15	1 0.5 - 1.0
	2 15 - 30	2 1.0 - 2.0
	3 30 - 45	3 2.0 - 4.0
	4 45 - 60	4 4.0 - 6.0
	5 60 - 90	5 6.0 - 8.0
	6 > 90	6 8.0 - 10.0
		7 10.0 - 12.0
		8 > 12.0

The phytosociological parameters were obtained using the software FITOPAC2, written and developed by Dr. George J. Shepherd, of the Botany Department of the University of Campinas - UNICAMP, São Paulo state, Brazil.

The data obtained from the point-centered method allow the following parameters to be calculated:

1. Basal area of trunk.
2. Mean distance between plants (D) = Total point-plant distance / no. plants
3. Absolute density (abs. dens.) = Area / D^2 (therefore no. trees per ha = 10,000 / D^2)

This can also be calculated for each species using the formula:

(no. trees of sp. in quarters / total no. trees in quarters) x (total no. trees in 10,000m^2)

4. Absolute frequency (abs. freq.) = Percentage of points at which a species occurs
5. Absolute dominance (abs. dom.) = Total basal area (m^2) of a species per ha
6. Relative density of a species =

= (no. of individuals of the species / total no. individuals) x 100

7. Relative frequency of a species =

= (frequency of the species / sum of the frequency of all species) x 100

8. Relative dominance of a species =

= (total basal area of the species / total basal area of all species) x 100

9. Importance value index (IVI) =

= relative density + relative frequency + relative dominance

Importance Value Index is designed to give an estimate of relative importance of taxa in the communities.

4.3 Diversity and evenness

The diversity of a community is dependent on the number of species and evenness with which the individuals are apportioned among them. Thus, to describe community diversity it is necessary to consider these two factors (Pielou, 1975).

The Shannon-Wiener index or Shannon index, is an estimate of diversity which is based on the proportional abundance of species, taking both evenness and species-richness into account (Pielou, 1975; Magurran, 1988).

1. Shannon-Wiener diversity index (H')

$H' = -\sum p_i \ln p_i$

p_i = the proportion of individuals found in the i^{th} species.

p_i is estimated as ni/N.

where: ni = The number of individuals represented by the i^{th} species.

N = The total number of individuals recorded.

The value of the index is usually between 1.5 and 3.5, and only rarely surpasses 4.5 (Magurran, 1988).

2. Evenness (J) (Pielou, 1975)

For any given number of species (i. e. a given species-richness), the highest value of H' will be obtained if all the species present are equally abundant. There is, consequently, a maximum value of H' for any given species-richness: H max. The ratio of observed diversity (H') to maximum diversity (H max.) can therefore be taken as a measure of evenness (J).

$J = H' / H\ max. = H' / \ln (S)$

where S = no. species observed.

The maximum value of evenness is 1.0.

4.4 Sample site description

The vegetation of the National Park of Brasília has a mosaic-like pattern. Plant communities with similar physiognomic and floristic characteristics can be found repeated in the landscape, at sites with similar geomorphologic and edaphic characteristics. Consequently, distinct plant associations were recognised, from which sampling was carried out.

A varied landscape is produced by the terrain of the Contagem plateau and its slopes, the dissected erosion levels, and stream valleys.

These geomorphic features and geological attributes give rise to an edaphic distinction which seems to be the principal determinant of the present distribution of the vegetation. These associated factors were also observed in other areas of savannas by Frost et al. (1986), and related to the plant available moisture (PAM), and the plant available nutrients (PAN), which indicates that the vegetation communities are distributed either in a fertility gradient or in a moisture gradient, or by the interaction of both gradients.

Fire and herbivory certainly have influence in the present plant distribution (Solbrig, 1990), being selective, either favouring or being detrimental to the establishment of certain species. Nevertheless, their effects are unknown in the National Park of Brasília.

The vegetation communities of the National Park of Brasília can be described as follows:

4.4.1 Cerrado *sensu stricto*

This vegetation type can be observed over the Contagem plateau and on its gently sloping flanks, on very deep and well-drained Dark-Red Latosols and Red-Yellow Latosols, particularly the former.

The cerrado *sensu stricto* is dominated by a woody vegetation, consisting of trees and shrubs. The ground layer is formed mainly by grasses, sub-shrubs and sedges (Goodland, 1971; Ratter,1980, 1991). This layer can be dense or sparse, and in many places the soil is exposed. Shrubs, small trees and palms of less than 3m tall are abundant, and taller trees, most lower than 12m, but sometimes reaching 18m tall are sparser than the shrubs. The scrub formation and the trees together have a cover ranging between 10 and 60% (Eiten, 1990).

4.4.2 Cerrado scrub (Campo cerrado)

This vegetation type is dominated by cerrado shrubs and small trees, and larger trees are infrequent. It is not dense enough to suppress the ground cover consisting of grasses and sedges, with many sub-shrubs and forbs, which is generally denser than that found in the cerrado sensu stricto.

It is a typical shrubby community which in the National Park of Brasília is found at sites on gentle slopes, with deep, well-drained Red-Yellow Latosols. These distinct plant associations have been distinguished within this physiognomic scrub category.

1. Typical cerrado scrub can be observed just downslope in the catena, below the cerrado areas of the plateau. It shows the same shrubby structure as in the cerrado areas, but trees are rare.
2. The scrub community denominated as Vellozietum is found located downslope in the same catena as the previous scrub community. This community is also found on deep and well-drained Red-Yellow Latosols. The vegetation is dominated by the monocotyledonous shrub *Vellozia flavicans*, which characterises the community.
3. Another typical cerrado scrub community is found in some sites over the plateau borders, where the well-drained Red-Yellow Latosols include an ironstone layer, about 70cm deep. Here the soil becomes water-saturated during the rains. These areas

are distinguished by the dominance of the shrub *Rapanea guianensis* associated with *Vellozia flavicans,* which gives the name RAPVELL to the sample site.

4.4.3 Cerrado scrub with emergents

These communities are easily recognised by the presence of tall trees of *Vochysia thyrsoidea*, emerging from a typical cerrado scrub (Vochysietum). They can be found in the borders of the Contagem plateau, over concretionary Red-Yellow Latosols.

4.4.4 Cerrado open scrub (Campo sujo)

This physiognomic category is known in Brazilian vernacular as campo sujo (dirty field), and consists of a dense grass layer with sparse scattered woody plants, shrubs or very small trees. The herbaceous layer consists of grasses and sedges with many forbs and sub-shrubs, the same as those found in cerrado scrub sites. Many of the shrubby species are dwarf individuals of the cerrado trees. This vegetation category can be found in sites where the water-table is near the soil surface during the rainy season, and the Red-Yellow Latosols become water-saturated.

4.4.5 Cerrado rupestre (Rocky cerrado)

This is found on sandstone outcrops on top of the hills, or on narrow terraces on the sloping flanks of the interfluves of the Tortinho stream basin. Sandy Cambic soils develop between the cracks of the rocks. In terms of physiognomy this category could be classified as cerrado *sensu stricto*, but the geomorphic distinctness of its sites, and also the presence of some characteristic species such as *Terminalia argentea* and *Miconia ferruginata* indicate that it is better considered apart.

4.4.6 Campo rupestre (Rocky field)

The physiognomy of this community could be considered as cerrado scrub, but the presence of species such as *Lychnophora ericoides* and *Vellozia swallenii* make it floristically different. This association is found on shallow Cambic soils along the hillsides of the interfluve between the Tortinho and Tres Barras streams. The soils are very dry during the dry season and saturated during the rains.

4.4.7 Murundu fields

Murundus are rounded earth mounds originating in this area mainly by differential water erosion processes (Araújo Neto et al., 1986; Furley, 1986) . In the National Park of Brasília they can be found scattered on slopes and on field catchments, surrounding gallery forest heads. They represent vestiges of past Latosol surfaces which suffered dissection processes. Their tops are formed of the Red-Yellow Latosols, and at their bases, Hydromorphic gleyed soils develop as a result of the oscillation of the water-table level.

The vegetation of the murundus consists mainly of cerrado shrub species, but tree species also commonly occur.

4.4.8 Thicket of *Trembleya parviflora*

Shrubs of *Trembleya parviflora* (Trembleyetum) occur as a monodominant community commonly forming dense thickets with individuals to 2-3m tall and 40cm basal girth in the drainage lines on the sloping flanks of some stream valleys, and particularly in field catchment over gallery forest heads. In these places the plinthic and sandy soils are water-saturated throughout the year. Vegetation data were not collected in this vegetation type but one soil profile was studied.

4.4.9 Gallery forests

Gallery forests develop along the streams in valley bottoms and show distinct species associations according to terrain configuration. Thus, some gallery forest patches are situated on well-drained soils, displaying some deciduous species. Such sites generally occupy the higher parts of the slopes, extending above the wetter parts of the forest near the streams margins. These drier sites are generally found on Cambic soils, but also on Latosols.

There are other characteristic associations, some on sites with a mesic water regime on Latosols, and others on moist or flooded areas on Hydromorphic soils.

The geomorphological variation of the terrain of the National Park causes great changes in the gallery forests. Distinct patches with differing soil characteristics and water regimes, replace each other in a gradual or abrupt succession along the course of gallery forest .

In the National Park of Brasília most of the gallery forests have a continuous canopy formed by trees varying from 15 to 25 meters tall. Natural or anthropogenic gaps occur, some in process of recovering naturally through normal succession processes, others dominated by weeds such as *Pteridium aquilinum* and the alien grass *Melinis minutiflora.*

Understorey trees and shrubs are abundant, but in general it is possible to walk relatively easily through the forest. Lianas are also common.

The humid or flooded gallery forest patches are easily recognised at a distance by the presence of dense groups of characteristic species such as the tall, slender, Annonaceous *Xylopia emarginata.* Many of the tree species of the humid gallery have buttress roots, while others have breathing roots such as the bizarre 'knee' roots of the Magnoliaceous *Talauma ovata.*

4.5 Anthropogenic alterations

Before the establishment of the National Park, settlers had made small farms in some non-flooded gallery forest edges where better soils provided conditions for subsistence crops and for planting orchards (Brasil, 1979).

Although these farms do not exist any more, their sites are nowadays occupied by weeds and some relict cultivated trees. The latter are mainly mango, orange and avocado, which cover in total a very small area and seem to cause no problems for the plant population dynamics of the Park. However, these altered sites have become a source of weeds, among which the African grass *Melinis minutiflora*, introduced to Brazil in the past to improve cattle pasture, has become a serious problem, competing with native species of cerrado grass layer, and dominating large areas (personal observations).

The Public-use Zones of the Park, with their residential and administrative buildings and facilities for the public have also become sources of weed invasion, as have some old *Eucalyptus* plantations.

A large dam built in the past to provide water for the city of Brasília caused enormous changes in the vegetation on its periphery. This dam with an area of about 825 ha is entirely situated in the interior of the National Park (Fig. 6 - p.33). The huge land movement using heavy machinery during the dam building devastated the surrounding areas, which are now occupied mainly by *Melinis minutiflora.*

4.6 Study sites

In order to study the vegetation, eight sample sites were established in gallery forests and 18 in cerrado areas (Fig. 6). The names used for these sample sites follows either traditional names used by local people, or refer to the stream basins or the vegetation in which they occur. Soil classification is based on EMBRAPA (1978).

4.6.1 Gallery forests

Two study sites were established on gallery forest heads (BARRIGUDA and TRES BARRAS); three on middle slopes, characterised by the presence of deciduous tree species (PISCINA1 , CEMAVE and PALMAS); one in a transition cerrado-cerradão-gallery forest (CRISTAL); one in a flooded site (BANANAL); and one in the valley bottom about halfway along the length of the Capão Comprido stream (CAPÃO COMPRIDO).

4.6.1.1 BARRIGUDA

This gallery forest covers the fanlike catchment of the Barriguda stream. It is situated in the south-west corner of the National Park, and is enclosed by the borders of the plateau (Chapada da Contagem).

The site is underlain by Red-Yellow Latosols, which are deep and well-drained, and covered by a thin litter layer.

The canopy is at about 20 to 25m and trees of *Copaifera langsdorffii* can be observed even at a distance, their flat crowns give a characteristic appearance to the site. *Callisthene major*, *Tapirira guianensis*, *Vochysia pyramidalis*, *Ficus* sp. and *Terminalia fagifolia* are also important canopy trees. *Cheiloclinium cognatum* and *Alibertia edulis* are common understorey tree species.

4.6.1.2 TRES BARRAS

This site is also within the plateau area. It is situated in the north corner of the National Park, in the headwaters of the Tres Barras stream, and like the previous site, displays a characteristic fanlike form.

At the sampling point the Tres Barras valley has a V shape, with the right side on well drained Red-Yellow Latosol, and the left on Hydromorphic soils.

The well drained slope supports groups of *Callisthene major* up to 15m tall, at the edge of the forest, while *Copaifera langsdorffii* and *Pseudolmedia laevigata* reaching about 20m are common species in the inner parts of the forest. *Cheiloclinium cognatum* is common as an understorey tree.

On the wetter hydromorphic side, tufts of the toboca grass, *Olyra taquara*, groups of the tree fern *Cyathea* sp., and the palm trees *Euterpe edulis* and *Geonoma schottiana* create a distinct community along the valley bottom. Moving upwards from this point to the forest edge, large trees form a canopy between 20 and 25m, where *Tapirira guianensis*, *Protium heptaphyllum* and *Hieronyma alchorneoides* dominate the community. Species of characteristic tall trees such as *Richeria obovata*, and *Tapirira guianensis* are found on the abrupt forest edge bordering wet grassland (campo limpo). They, together with understorey trees such as *Hedyosmum brasiliense*, *Ferdinandusa speciosa* and shrubs of *Miconia chamissois,* form an impressive wall of vegetation.

4.6.1.3 PISCINA 1

This sample site is on a well-drained area sloping down to the Acampamento stream. It occurs on the upper parts of the slope, forming a distinctive vegetation due to the presence of deciduous trees.

This tract of forest is on dystrophic Cambic soils, with a dark-brown colour and thick A horizon. The soil is concretionary, with ironstones and quartzite gravel lying over weathered slate.

The vegetation is typical of the semideciduous forest widespread on the Central Plateau, where *Anadenanthera colubrina* var. *cebil* and *Copaifera langsdorffii* are most important in the crown cover, at heights about 20 to 25m, and *Guettarda viburnoides*, *Cupania vernalis* and *Alibertia edulis* are frequent understorey trees.

The forest forms an abrupt edge with cerrado vegetation in which *Myrcia tomentosa*, *Myrcia rostrata*, *Lithraea molleoides* and *Pseudobombax tomentosum* are common trees.

4.6.1.4 CEMAVE

This site is located near the residential area of the National Park of Brasília, on a drier patch sloping down to the Acampamento stream.

This part of the gallery forest is on mesotrophic Cambic soils, where *Anadenanthera colubrina* var. *cebil* and *Piptadenia gonoacantha* are the main semideciduous tree species; the former reaches 25m, as an emergent. *Aspidosperma subincanum*, *Bauhinia rufa*, *Maytenus alaternoides* and *Campomanesia velutina* are the most frequent understorey trees.

Forest gaps caused by past human activities in the area, are dominated by a *Bromelia balansae*, forming dense clumps which prevent the sprouting of other species. These gaps are scattered within this area, showing that important disturbance happened in the past. Information from old employees of the National Park confirmed this: the disturbance was caused by a plant nursery which operated in this site before the establishment of the National Park.

4.6.1.5 CRISTAL

This sample site stands on the upper part of a slope, at the head of the Rego stream. It lies in a transitional area of cerrado-cerradão-gallery forest.

Cerrado species were found within this forest, which suggests a recent succession from cerrado to forest. The absence of large trees along the edges of the forest can also be taken as further evidence of such a succession.

The area is on Dark-Red Latosols, which is a soil group often covered by cerrado vegetation.

Tree species such as *Copaifera langsdorffii*, *Siphoneugena densiflora* and *Astronium fraxinifolium*, which are found in this area, are consistent with succession from cerrado to cerradão and gallery forest.

The 20m tall *Copaifera langsdorffii* emerges from a canopy between 12 and 15m, formed mainly by trees such as *Matayba guianensis*, *Siphoneugena densiflora*, and *Diospyros hispida*. The understorey trees are *Alibertia edulis*, *Myrcia rostrata*, *Bauhinia rufa*, *Cupania vernalis* and *Guettarda viburnoides*.

4.6.1.6 CAPÃO COMPRIDO

This site is situated in the gallery forest of the Capão Comprido stream, along the watercourse in the valley bottom. It lies partly on well drained Red-Yellow to Dark Red Latosols, and partly on Hydromorphic soils.

It is a typical Federal District gallery forest. In the drier parts large trees of *Copaifera langsdorffii* and *Hymenaea courbaril* var. *stilbocarpa*, to 20 and 25m, emerge from the canopy of the forest on the freely drained soils. *Cheiloclinium cognatum* and *Alibertia edulis* are commonly found as understorey trees of the same area.

In the wetter parts, tall trees of *Calophyllum brasiliense*, *Protium heptaphyllum*, *Hieronyma alchorneoides*, *Xylopia emarginata*, *Talauma ovata* and the palm *Euterpe edulis* are important. These trees may attain heights between 15 to 25m, forming an irregular crown cover.

4.6.1.7 BANANAL

This site is on a flooded part of the Bananal stream.

Peat-like Hydromorphic soils accumulate in these flooded areas, where *Xylopia emarginata* occurs in dense groups, and *Calophyllum brasiliense*, *Talauma* *ovata*, and *Protium heptaphyllum* are also common. These trees reach heights between 20 to 25m. *Polypodium fraxinifolium* is widespread in the ground layer.

A very dense thicket of slender shrubs and little trees forms the forest margin. *Gaylussacia brasiliensis*, *Euplassa inaequalis* and *Ferdinandusa speciosa*, all species associated with very damp conditions, are abundant in this marginal thicket.

Outside the thicket, along its edge with open wet grasslands, a thin strip of the tall palm tree *Mauritia flexuosa* forms a narrow grove or "vereda".

4.6.1.8 PALMAS

This site is characterised by great numbers of individuals of the palm tree *Attalea phalerata* forming an evergreen understorey. *Anadenanthera colubrina* var. *cebil*, which is a strikingly deciduous tree, *Emmotum nitens*, and *Hymenaea courbaril* var. *stilbocarpa* are found in the forest canopy, reaching heights up to 15 to 20m tall. *Matayba guianensis, Aspidosperma subincanum* and *Terminalia fagifolia* are common tree species mainly in the understorey.

The forest is situated on a well-drained middle slope on the margins of the Tortinho stream. Occasional sandstone outcrops protrude from the sandy Cambic soil which underlies this site.

This forest type is the least common in the National Park of Brasília area, and is found in only two small patches along the Tortinho stream.

4.6.2 The cerrado community sites

4.6.2.1 Cerrado *sensu stricto*

These study areas are sited to provide a thorough sampling of cerrado *sensu stricto*, the most widespread vegetation of the National Park of Brasília.

This vegetation, referred to simply as cerrado from now on, is represented in this study by six sample sites in different regions of the Park.

The sample site BARRAGEM is on deep and well-drained Red-Yellow Latosol. The other five sites are on Dark-Red Latosols.

Although these areas exhibit floristic and physiognomic similarities, they show clear phytosociological differences.

Most of the large trees are about 7m tall, with the tallest attaining heights of 18m. The most common tree species overall are *Qualea parviflora*, *Q. grandiflora*, *Caryocar brasiliense*, *Styrax ferrugineus* and *Sclerolobium paniculatum*. However, shrubs to 3m tall are more abundant than trees. *Kielmeyera coriacea, Erythroxylum suberosum, Roupala montana, Ouratea hexasperma, Connarus suberosus*, and the palms *Syagrus comosa, S. flexuosa*, and *Butia leiospatha* are commonly found in the shrub layer.

4.6.2.2 Cerrado scrub (campo cerrado)

Three sample sites were established in this community. All occurred on Red-Yellow Latosols, the sand content of which varies from one to another.

The first sample site (CERRADO TRES BURACOS 1) is located at the top of the Tres Buracos catena. Here, the soil is deep and well-drained with a variable texture ranging in the profile from clay loam to clay. It is a typical cerrado scrub community where shrub species of *Erythroxylum suberosum, Connarus suberosum, Eremanthus glomerulatus* and *Kielmeyera coriacea* are common.

The second site in the catena (CERRADO TRES BURACOS 2) is also on deep and well-drained soil. In this case, the texture in the profile varies from sandy clay loam to sandy clay. The vegetation community is characterised by the widespread shrubby monocotyledonous *Vellozia flavicans* which is associated with

Erythroxylum suberosum, Kielmeyera coriacea, and *Aspidosperma tomentosum*. This association (Vellozietum) constitutes a distinct plant community in the area.

The third site (RAPVELL), located far from the other two, is near the Park watchtower. It is situated on shallower soil with an ironstone layer. The texture in the profile varies from sandy loam to loamy clay. This area which is on the border of the plateau (Chapada da Contagem), is distinguished by dense clumps of the shrubby species association of *Rapanea guianensis* with *Vellozia flavicans*, from which the sample site name was derived.

4.6.2.3 Cerrado scrub with emergents

There are two sample sites in this type of vegetation. One at the Tres Buracos catena (VOCHYSIA 1), and another (VOCHYSIA 2) at the border of the plateau near the seismographic station.

These sites are easily recognised. They are characterised by sparse groves of the tall tree *Vochysia thyrsoidea* emerging on the shrubby layer. The latter is formed mainly by *Vellozia flavicans, Rapanea guianensis, Qualea parviflora* and *Roupala montana*. Both sites are underlain by well-drained, sandy Red-Yellow Latosols, with an ironstone concretionary layer.

4.6.2.4 Cerrado open scrub (campo sujo)

This type of cerrado vegetation was sampled in three places. Two sites were established on the middle slopes of the Acampamento stream, and the third was located on top of the plateau, beside the watchtower.

All these areas are on Red-Yellow Latosols, with variable texture. The site CAMPO SUJO NOVO SETOR has a deep clay soil. CAMPO SUJO MATO

GROSSO is on a deep soil, where the texture in the profile varies from clay loam to clay. Both sites are similar floristically and physiognomically. They carry populations of *Connarus suberosus*, *Kielmeyera coriacea*, *Neea theeifera*, and *Aspidosperma tomentosum* which attain heights of about 1 m.

Table 9 - Floristic characteristics of Brasília National Park sample sites

sample sites	o. familie	no. genera	o. specie	diversity	evenness
GALLERY FOREST					
TRES BARRAS	50	80	98	4,17	0,91
PALMAS	43	72	85	4,05	0,91
BARRIGUDA	50	70	84	4,09	0,93
CAPAO COMPRIDO	41	61	76	3,53	0,82
BANANAL	38	46	57	3,56	0,88
CEMAVE	34	46	54	3,63	0,91
PISCINA1	36	44	47	3,44	0,89
CRISTAL	27	35	40	3,22	0,87
CERRADO "sensu stricto"					
BARRAGEM ***	38	55	65	3,64	0,87
CERRADO CAPAO COMPRIDO ***	32	51	61	3,37	0,82
CERRADO TORTINHO ***	31	43	61	3,49	0,85
BARRAGEM *	35	43	52	3,45	0,87
CERRADO TORTINHO *	28	35	51	3,35	0,85
CERRADO CAPAO COMPRIDO *	29	40	49	3,33	0,85
CERRADO MATO GROSSO ***	26	35	43	3,11	0,83
CERRADO TORRE ***	28	37	42	3,08	0,82
CERRADO NOVO SETOR ***	28	34	42	3,34	0,89
BARRAGEM **	26	36	41	3,18	0,86
CERRADO MATO GROSSO *	26	31	39	2,99	0,82
CERRADO NOVO SETOR *	24	30	36	3,17	0,89
CERRADO TORTINHO **	21	28	34	2,91	0,82
CERRADO CAPAO COMPRIDO **	20	28	31	2,47	0,72
CERRADO TORRE *	22	26	30	3,13	0,92
CERRADO TORRE **	21	26	27	2,52	0,76
CERRADO NOVO SETOR **	19	21	26	2,76	0,85
CERRADO MATO GROSSO **	18	20	24	2,59	0,81
CERRADO RUPESTRE					
INVERNADA ***	25	29	38	2,94	0,81
CERRADO PALMAS ***	21	31	37	2,98	0,83
INVERNADA *	25	29	36	2,87	0,80
CERRADO PALMAS *	19	27	33	3,22	0,92
INVERNADA **	16	17	21	2,46	0,80
CERRADO PALMAS **	11	14	18	2,12	0,73
CERRADO SCRUB WITH EMERGENTS					
VOCHYSIA 1	23	29	30	2,80	0,82
VOCHYSIA 2	20	22	26	2,71	0,83
CERRADO SCRUB					
TRES BURACOS 1	25	33	35	3,03	0,85
TRES BURACOS 2	21	24	27	2,13	0,65
MURUNDU	18	19	23	2,45	0,78
RAPVELL	11	11	11	1,69	0,70
CERRADO OPEN SCRUB					
ARNICAS (campo rupestre)	18	22	29	2,79	0,83
CAMPO SUJO MATO GROSSO	18	21	25	2,52	0,78
CAMPO SUJO NOVO SETOR	17	18	19	2,03	0,69
TORRE 1	8	9	11	1,87	0,78

* only individual plants with less than 30cm circumference at the stem base registered

** only individual plants with more than 30cm circumference at the stem base (large plants) registered

*** individuals of both circumference size classes together

Table 10 - Gallery forest woody species of Brasília National Park

Anacardiaceae
Astronium fraxinifolium Schott.
Lithraea molleoides (Vell.) Engler
Tapirira guianensis Aublet

Annonaceae
Duguetia lanceolata A. St. - Hil.
Cardiopetalum calophyllum Schltdl.
Guatteria sellowiana Schltdl.
Guatteria sp.
Rollinia sericea R. E. Fries
Xylopia aromatica Lam.
Xylopia brasiliensis Sprengel
Xylopia emarginata Mart.
Xylopia sericea A. St. - Hil.

Apocynaceae
Aspidosperma discolor A. DC.
Aspidosperma spruceanum Benth.
Aspidosperma subincanum Mart.
Aspidosperma sp.

Aquifoliaceae
Ilex affinis Gardner
Ilex conocarpa Reisseck
Ilex integrifolia (Vell.) Reisseck
Ilex pseudotheezans Reisseck

Araliaceae
Schefflera morototoni (Aublet) D. Frodin

Bignoniaceae
Lundia nitidula DC.
Tabebuia aurea (Manso) Benth. & Hook
Tabebuia impetiginosa (Mart.) Standl.
Tabebuia roseo-alba (Ridl.) Sandw.
Bignoniaceae (366-2)

Bombacaceae
Eriotheca candolleana (K. Schum.) A. Robyns
Eriotheca gracilipes (K. Schum.) A. Robyns
Pseudobombax longiflorum (Mart. & Zucc.) A. Robyns
Pseudobombax tomentosum (Mart. & Zucc.) A. Robyns

Boraginaceae
Cordia rufescens A. DC.
Cordia sellowiana Cham.
Cordia trichotoma (Vell.) Arnab.
Cordia sp.

Burseraceae
Protium almecega Marchand
Protium heptaphyllum (Aublet) Marchand

Caesalpinaceae
Apuleia leiocarpa (Vogel) Macbr.
Copaifera langsdorffii Desf.
Hymenaea courbaril L. var. stilbocarpa (Hayne) Lee & Langenheim
Sclerolobium aureum (Tul.) Benth.
Sclerolobium paniculatum Vog. var. subvelutinum (Tul.) Benth.
Leg. (319-2)

Cecropiaceae
Cecropia pachystachya Trécul

Celastraceae
Maytenus alaternoides Reisseck
Maytenus salicifolia Reisseck
Celastraceae (921-3)

Chloranthaceae
Hedyosmum brasiliense Mart.

Chrysobalanaceae
Couepia grandiflora (Mart. & Zucc.) Benth.
Licania apetala (E. Meyer) Fritsch
Licania octandra (Hoffm.) Kuntze

Chrysobalanaceae (cont.)
Licania sp.

Combretaceae
Terminalia fagifolia Mart. & Zucc.
Terminalia glabrescens Mart.
Terminalia phaeocarpa Eichler

Compositae
Dasyphyllum brasiliense (Spr.) Cabr.
Mikania psilostachya DC.
Vernonia ferruginea Less.
Compositae (361-3)
Compositae 2 (1060-2)

Connaraceae
Connarus regnellii Schelemberg

Cunoniaceae
Lamanonia ternata Vell.

Cyatheaceae
Cyathea sp.

Dichapetalaceae
Tapura amazonica Poepp. & Engler

Ebenaceae
Diospyros hispida A. DC.

Ericaceae
Gaylussacia brasiliensis (Spr.) Mart.

Erythroxylaceae
Erythroxylum englerii O. E. Schultz
Erythroxylum sp.
Erythroxylum daphnites Mart.

Euphorbiaceae
Alchornea glandulosa Poepp. & Endl.
Hieronyma alchorneoides Fr. Allem
Maprounea guianensis Aublet
Margaritaria nobilis L. f.
Pera obovata Baillon
Richeria obovata (M. Arg.) Pax & K. Hoffm.
Sapium obovatum Klotzsch ex M. Arg.

Fabaceae
Andira sp.
Indigofera suffruticosa Mill.
Machaerium aculeatum Raddi
Machaerium acutifolium Vogel
Pterodon pubescens Benth.
Swartzia apetala A. DC.
Vatairea macrocarpa (Benth.) Ducke
Fabaceae (1018-1)

Flacourtiaceae
Casearia sylvestris Swartz
Xylosma benthamii (Tul.)Triana & Planchon
Xylosma pseudosalzmanii Sleumer

Guttiferae
Calophyllum brasiliense Cambess.
Kielmeyera variabilis Mart.

Hippocrateaceae
Cheiloclinium cognatum (Miers.) A. C. Smith
Salacia elliptica (Mart.) E. Don.

Humiriaceae
Sacoglottis mattogrossensis Malme

Icacinaceae
Emmotum nitens (Benth.) Miers

Table 10 - Gallery forest woody species of Brasília National Park (cont.)

Lacistemaceae
Lacistema hasslerianum Chodat

Lauraceae
Cryptocarya aschersoniana Mez
Cinnamomum sp.
Endlicheria paniculata (Sprengel) Macbr.
Licaria cf armeniaca (Nees) Kosterm
Nectandra cissiflora Nees
Nectandra gardneri Meisner
Nectandra sp.
Nectandra sp1
Nectandra sp2
Ocotea aciphylla (Nees) Mez
Ocotea corymbosa (Meisner) Mez
Ocotea spixiana (Nees) Mez
Ocotea sp1
Ocotea sp2

Lecythidaceae
Cariniana estrellensis (Raddi) Kuntze

Lythraceae
Diplusodon virgatus Gardn. ex Koehne

Magnoliaceae
Talauma ovata A. St. - Hil.

Malpighiaceae
Banisteriopsis anisandra (Adr. Juss.) Gates
Banisteriopsis malifolia (Nees & Martius) B. Gates
Banisteriopsis pubipetala (Adr. Juss.) Cuatrec.
Banisteriopsis sp.
Banisteriopsis sp1
Banisteriopsis sp2
Banisteriopsis sp3
Heteropteris acutifolia Adr. Juss.
Malpighiaceae (1021-4)

Melastomataceae
Macairea sp.
Miconia bergei
Miconia burchellii Triana
Miconia chamissois Naud.
Miconia chartacea Triana var. miqueliana Cogn
Miconia cuspidata Naudin
Miconia sellowiana Naudin
Miconia sp. 1
Miconia sp. 2
Miconia sp. 3
Miconia sp. 4
Miconia sp. 5
Miconia sp. 6
Miconia sp. 7
Miconia sp. 8
Miconia sp. 9
Tibouchina candolleana (DC.) Cogn.
Trembleya parviflora (Don.) Cogn. subs. triflora Cogn

Meliaceae
Cabralea canjerana (Vell.) Mart.
Guarea kunthiana A. Juss.
Guarea macrophylla Vahl
Trichilia catigua A. Juss.
Trichilia elegans A. Juss.

Mimosaceae
Anadenanthera colubrina (Vell.) Brenan var. cebil (Griseb.) Altschul
Enterolobium gummiferum (Vell.) Benth.
Inga affinis DC.
Inga alba (Sw.) Willd.
Inga cylindrica (Vell.) Mart.
Inga marginata Willd.
Piptadenia gonoacantha (Mart.) Macbr.

Monimiaceae
Mollinedia oligantha Perkins
Siparuna guianensis Aublet

Moraceae
Ficus eximia Schott.
Ficus sp.
Ficus sp1
Pseudolmedia laevigata Trécul
Sorocea ilicifolia Miq.
Sorocea sp.

Myristicaceae
Virola sebifera Aublet
Virola urbaniana Warb.

Myrsinaceae
Cybianthus detergens Mart.
Cybianthus glaber A. DC.
Cybianthus gardneri (A. DC.) Agostini
Myrsine coriacea R. Br.
Myrsine guianensis (Aublet) Kuntze
Myrsine umbellata Mart.
Stylogyne ambigua (Mart.) Mez

Myrtaceae
Calyptranthes lucida Mart.
Calyptranthes sp.
Campomanesia velutina (Cambess.) Berg
Eugenia florida DC.
Gomidesia brunea (Cambess.) Berg
Myrcia laruotteana Cambess.
Myrcia pubipetala Miq.
Myrcia rostrata DC.
Myrcia tomentosa (Aublet) DC.
Myrcia venulosa DC.
Myrcia sp.
Psidium sartorianumNiedenzu
Psidium warmingianum Kiaersk
Siphoneugena densiflora Berg

Nyctaginaceae
Guapira sp.

Ochnaceae
Ouratea castaneaefolia Engler

Oleaceae
Chionanthus arboreus (Eichler) P. S. Green

Opiliaceae
Agonandra englerii Hoehne

Palmae
Attalea phalerata (Mart.) Burret
Euterpe edulis Mart.
Geonoma schottiana Mart.
Syagrus flexuosa (Mart.) Becc.
Syagrus oleracea (Mart.) Becc.

Piperaceae
Piper arboreum Aublet
Piper sp.

Polygalaceae
Moutabea excoriata Mart. ex Miq.

Polygonaceae
Coccoloba cf. ochreolata Wedd.
Coccoloba sp.

Polypodiaceae
Polypodium fraxinifolium Jacq.

Table 10 - Gallery forest woody species of Brasília National Park (cont.)

Proteaceae
Euplassa inaequalis (Pohl) Engler
Roupala montana Aublet

Rhamnaceae
Rhamnidium elaeocarpum Reiss.

Rosaceae
Prunus chamissoana Koehne ex Cham.
Prunus sellowii Koehne

Rubiaceae
Alibertia edulis (L. Rich.) A. Rich.
Alibertia macrophylla Schum.
Amaioua guianensis Aubl.
Coussarea hydrangeaefolia Benth. ex Muell. Arg.
Coutarea hexandra (Jacq.) Schum.
Faramea cyanea Muell. Arg.
Ferdinandusa speciosa Pohl
Guettarda viburnioides C. S.
Ixora warmingii Muell. Arg.
Malanea macrophylla Bartl.
Posoqueria latifolia (Rudge) R. & S.
Psychotria carthagenensis Jacq.
Sabicea brasiliensis Wirnh.
Rubiaceae sp.

Rutaceae
Zanthoxylum rhoifolium Lam.

Sapindaceae
Cupania vernalis Camb.
Matayba guianensis Aubl.
Serjania cf. caracasana (Jacq.) Willd.
Serjania sp.

Sapotaceae
Chrysophyllum marginatum Radlk
Micropholis venulosa (Mart. & Eich.) Pierre

Simaroubaceae
Simarouba versicolor St. Hil.

Solanaceae
Brunfelsia brasiliensis (Spreng.) Smith & Downs
Cestrum cf. baenitzii
Cestrum cf. pedicellatum Sandtm.
Solanum crinitum Lam.

Sterculiaceae
Guazuma ulmifolia L.
Helicteres cf. brevispira St. Hil.

Styracaceae
Styrax guianensis A. DC.

Symplocaceae
Symplocos lanceolata Mart.
Symplocos mosenii Brand
Symplocos nitens (Pohl) Benth.
Symplocos rhamnifolia A. DC.
Symplocos sp.

Thymelaeaceae
Daphnopsis fasciculata (Meisner) Nevl.

Tiliaceae
Luehea paniculata Mart.

Ulmaceae
Celtis iguanaea (Jacquin) Sargent

Verbenaceae
Aegiphila sellowiana Cham.
Lippia sp.
Vitex polygama Cham.

Vochysiaceae
Callisthene major Mart.
Callisthene fasciculata (Spr.) Mart.
Qualea dichotoma (Mart.) Warm.
Qualea glauca Warm.
Vochysia pyramidalis (Mart.)

Indetermined species
Indet 1 (369-1)
Indet 2 (168-3)
Indet 3 (337-4)
Indet 4 (23-4)
Indet 5 (295-1)
Indet 6 (408-4)
Indet 7 (324-1)
Indet 8 (396-2)
Indet 9 (203-2)
Indet 10 (405-1)
Indet 11 (266-1)
Indet 12 (414-3)
Indet 13 (226-13)
Indet 14 (240-4)
Indet 15 (137-2)
Indet 16 (137-3)
Indet 17 (339-1)
Indet 18 (311-1)
Indet 19 (31-1)
Indet 20 (292-4)
Indet 21 (32-2)
Indet 22 (392-4)
Indet 23 (134-3)
Indet 24 (187-3)
Indet 25 (266-3)
Indet 26 (274-1)

Table 11 - Cerrado "sensu lato" woody species of Brasília National Park

Anacardiaceae
Anacardium humile St. Hil.

Annonaceae
Annona crassiflora Mart.
Annona monticola Mart.
Annona tomentosa R. E. Fr.

Apocynaceae
Aspidosperma macrocarpum Mart.
Aspidosperma tomentosum Mart.

Araliaceae
Didymopanax macrocarpum (C. & S.) Seem.

Bignoniaceae
Arrabidaea florida DC.
Jacaranda caroba (Vell.) DC.
Tabebuia aurea (Mart.) Bur.
Tabebuia ochracea Cham.
Zeyheria montana Mart.

Bombacaceae
Eriotheca pubescens (Mart. & Zucc.) Schott. & Endl.
Pseudobombax longiflorum (Mart. & Zucc.) A. Robyns
Pseudobombax tomentosum (Mart. & Zucc.) A. Robyns

Caesalpinaceae
Bauhinia rufa (Bong.) Steud.
Bauhinia sp.
Cassia claussenii Benth.
Cassia orbiculata Benth.
Copaifera langsdorffii Desf.
Hymenaea stigonocarpa (Mart. ex) Hayne var. pubescens Benth.
Sclerolobium aureum (Tul.) Benth.
Sclerolobium paniculatum Vog. var. subvelutinum (Tul.) Benth.

Caryocaraceae
Caryocar brasiliense Cambess.

Celastraceae
Austroplenkia populnea (Reiss.) Lund

Combretaceae
Terminalia argentea Mart. & Zucc.

Compositae
Eremanthus glomerulatus Less.
Eremanthus goyazensis Sch. Bip.
Lychnophora ericoides Mart.
Piptocarpha rotundifolia (Less.) Baker
Piptocarpha macropoda Baker

Connaraceae
Connarus suberosus Planch. var. fulvus (Planch.) Forero

Dilleniaceae
Davilla elliptica St. Hil.

Ebenaceae
Diospyros burchellii Hiern

Erythroxylaceae
Erythroxylum campestre St. Hil.
Erythroxylum daphnites Mart.
Erythroxylum deciduum St. Hil.
Erythroxylum suberosum St. Hil.
Erythroxilum tortuosum Mart.

Fabaceae
Acosmium dasycarpum (Vog.) Yakovl.
Andira paniculata Benth.
Indigofera suffruticosa Mill.
Machaerium acutifolium Vog.
Machaerium opacum Vog.
Pterodon pubescens Benth.
Vatairea macrocarpa (Benth) Ducke

Flacourtiaceae
Casearia sylvestris Sw.

Guttiferae
Kielmeyera coriacea (Spr.) Mart.
Kielmeyera variabilis Mart.

Hippocrateaceae
Salacia crassifolia (Mart.) Peyr.

Labiateae
Hyptis saxatilis St. Hil. ex Benth.

Loganiaceae
Strychnos pseudoquina St. Hil.

Lythraceae
Lafoensia densiflora Pohl
Lafoensia pacari St. Hil.

Malpighiaceae
Banisteriopsis argyrophylla (Adr. Juss.) B. Gates
Banisteriopsis gardneriana
Banisteriopsis latifolia (Adr. Juss.) Cuatrec.
Banisteriopsis schizoptera (Adr. Juss.) B. Gates
Banisteriopsis stellaris (Griseb.) B. Gates
Banisteriopsis variabilis B. Gates
Banisteriopsis sp4
Byrsonima coccolobifolia (Spr.) Kunth
Byrsonima crassa Nied
Byrsonima guilleminiana Adr. Juss.
Byrsonima laxiflora Griseb.
Byrsonima subterranea Brade & Markgraf
Byrsonima verbascifolia L. Rich. ex Adr. Juss.
Byrsonima sp.
Heteropteris byrsonimifolia Adr. Juss.
Heteropteris cf procoriacea Niedenzu

Melastomataceae
Miconia albicans (Sw.) Triana
Miconia fallax DC.
Miconia ferruginata (DC.) Cogn.
Miconia ligustroides Naud.
Miconia pohliana Cogn.
Miconia rubiginosa (Bonpl.) DC.
Miconia sp10
Miconia sp11
Trembleya parviflora Cogn.

Mimosaceae
Dimorphandra mollis Benth.
Enterolobium gummiferum (Vell.) Benth.
Mimosa claussenii Benth.
Plathymenia reticulata Benth.
Stryphnodendron adstringens (Mart.) Coville

Moraceae
Brosimum gaudichaudii Trécul

Myrsinaceae
Myrsine guianensis Aubl.

Myrtaceae
Blepharocalyx salicifolia Berg
Eugenia bimarginata DC.
Psidium australe Cambess.
Psidium myrsinoides Berg
Psidium sartorianum Niedenzu
Psidium warmingianum Kiaersk
Siphoneugena densiflora Berg

Nyctaginaceae
Guapira noxia Netto
Guapira sp.
Neea theifera Oerst.

Table 11 - Cerrado "sensu lato" woody species of Brasília National Park (cont.)

Ochnaceae
Ouratea hexasperma (St. Hil.) Baill.
Ouratea parviflora Baill.

Palmae
Butia leiospatha (Mart.) Becc.
Syagrus comosa (Mart.) Mart.
Syagrus flexuosa Mart. Becc.
Syagrus oleracea Becc.

Polygalaceae
Moutabea excoriata Mart. ex Miq.

Proteaceae
Roupala montana Aubl.

Rubiaceae
Chomelia ribesioides Benth.
Palicourea rigida Kunth
Tocoyena formosa (C. & S.) K. Sch.

Sapotaceae
Pouteria ramiflora (Mart.) Radlk.
Pouteria torta (Mart.) Radlk.

Styracaceae
Styrax ferrugineus Nees & Mart.

Velloziaceae
Vellozia flavicans Mart.
Vellozia swallenii L. B. Smith

Vochysiaceae
Qualea grandiflora Mart.
Qualea multiflora Mart.
Qualea parviflora Mart.
Vochysia elliptica (Spr.) Mart.
Vochysia thyrsoidea Pohl.

Indetermined species
Indet 27 (539-1)

TORRE 1 differs somewhat. It is situated on a shallow soil with ironstone concretions, and the soil profile varies in texture from sandy clay to silt clay. Here the common species are *Erythroxylum tortuosum, Neea theeifera* and *Salacia crassifolia.* The shrubs are sparser and smaller than in the other two campo sujo sites.

4.6.2.5 Cerrado rupestre

Two areas of cerrado rupestre were selected for sampling. One is on the interfluves of the Invernada stream (INVERNADA). The other is located near the PALMAS gallery forest site (CERRADO PALMAS) on a middle slope which runs between the plateau and the Tortinho stream.

In these areas, *Sclerolobium paniculatum* and *Terminalia argentea* are common larger trees, reaching a height of 10 m. They emerge from a community of smaller trees, dominated by *Qualea parviflora* and *Miconia ferruginata,* reaching 5m and having a layer of shrubby vegetation below. The latter is formed mainly by *Kielmeyera coriacea, Eremanthus glomerulatus, E. goyazensis, Palicourea rigida* and *Byrsonima coccolobifolia.*

4.6.2.6 Campo rupestre

This community has limited distribution in the National Park of Brasília. It is restricted to areas of shallow and rocky soils, at the interfluve of the Tortinho and Tres Barras streams.

The soils are mainly derived from quartzite and sandstone. Being sandy and shallow, they are almost entirely devoid of moisture during the dry season.

In this site, the campo rupestre contains an association of *Vellozia swallenii*, *Vellozia* sp. and *Lychnophora ericoides*, which are considered characteristic species. *Miconia ferruginata* and *Palicourea rigida* are other common species.

4.6.2.7 Campos de murundus

These occur extensively in the National Park on the catchment campos outside the gallery forests . They are also found on some slopes with shallow soils which flood seasonally.

Two different sites of *campo de murundus* were studied in seasonally flooded areas. One is located in the catchment of the Acampamento stream and the other lies in the Capão Comprido catchment.

The murundus (earth-mounds) have clay Red-Yellow Latosols above and Hydromorphic, generally gleyed soils, below in the part where the water- table fluctuates.

The most commonly found species on the murundus in these sites, are *Psidium warmingianun*, *Eremanthus glomerulatus*, *Kielmeyera coriacea*, *Miconia rubiginosa* and *Acosmium dasycarpum*.

4.7 Results

4.7.1 Floristics and diversity

In total 5304 plants were recorded from 1290 sampling points using the Point Center Quarter method and from 10 sampling areas that were surveyed by quadrat. The study covered a total of 26 different vegetation sample sites, eight of which were in gallery forests, and 18 in the cerrado communities.

The number of species, genera and families, and diversity indices of the sample are given in Table 9. In all, 76 families, 194 genera, and 380 species were registered. Of these, 300 were identified to the species, 46 to the genus, seven to the family and the remaining 27 (all of which were represented by vegetative material only) were undetermined.

The gallery forests contained 284 species belonging to 71 families, and 140 genera, with 26 species undetermined. The cerrado plant communities had 121 species belonging to 39 families, and 68 genera, with one remaining undetermined. Since some species occur in both habitats, the total number of species recorded is less than the sum of the gallery forest and cerrado totals. The list of the gallery forest species registered in the National Park are shown in Table 10, and the list of cerrado species are given in Table 11.

4.7.1.1 Gallery forests

According to the number of species, the most important families were: Leguminosae (17 species), Melastomataceae (16), Lauraceae (14), Rubiaceae (14), Myrtaceae (11), Annonaceae (9), Malpighiaceae (8), Euphorbiaceae (7), Moraceae (6), Myrsinaceae (6), Symplocaceae (5), Vochysiaceae (5), Apocynaceae (4), Bombacaceae (4), Sapindaceae (4), Anacardiaceae (3), Aquifoliaceae (3), Boraginaceae (3), Chrysobalanaceae (3), Combretaceae (3), Meliaceae (3), Solanaceae (3), and Verbenaceae (3).

These 23 families comprise 54% of the total number of species found within the eight gallery forest sample sites. 27 families were represented by only a single species.

Among the 194 genera, *Miconia* (14 species), *Myrcia* (7), *Banisteriopsis* (6), *Ocotea* (5), *Symplocos* (5), *Aspidosperma* (4), *Inga* (4), *Myrsine* (4), *Nectandra* (4), and *Xylopia* (4) were the most important.

The gallery forest sample site with highest species-richness was TRES BARRAS with 98 species (n = 60 points, totals 240 individuals registered), while CRISTAL was the poorest with 40 species (n = 40, totals 160 individuals registered).

Leguminosae were the richest family in five sample sites, but not in the water-logged BANANAL site. Lauraceae were species-rich only in the

BARRIGUDA and TRES BARRAS sites. Melastomataceae were represented in higher species number in BARRIGUDA, TRES BARRAS and PALMAS sample sites.

Myrcia, Banisteriopsis, and *Miconia* were represented by many species, while 100 genera were represented by a single species each.

The sample site TRES BARRAS had the highest Shannon's diversity index with H' = 4.17 and the sample site CRISTAL had the lowest diversity with H' = 3.22. The gallery forest sites TRES BARRAS, BARRIGUDA and PALMAS were the richest in species and also had the highest diversity.

4.7.1.2 Cerrado communities

According to the number of species the most important woody cerrado families were: Leguminosae (21), Malpighiaceae (16), Melastomataceae (9), Compositae (6), Myrtaceae (6), Vochysiaceae (6), Bignoniaceae (5), Erythroxylaceae (5), Annonaceae (4), Apocynaceae (3), Bombacaceae (3), Nyctaginaceae (3), Palmae (3), and Rubiaceae (3). 77% percent of the woody cerrado species of the National Park belong to these families, while 16 families were represented by a single species .

The genera *Miconia* (9), *Banisteriopsis* (6), *Erythroxylum* (5), *Annona* (4), and *Qualea* (4), were the richest in species.

The Shannon's diversity indices of the cerrado communities varied from 1.69 in a cerrado scrub area to 3.64 in a cerrado *sensu stricto* site.

Table 12 - Phytosociological parameters - sample site PISCINA 1

no. of points = 40
no. of ind. = 160
Shannon - Wiener H' = 3.44, evenness = 0.89

density = 5221.43ind./ha
basal area = 63.591m2/ha

aver. point-plant dist. = 1.38
circ > = 5cm

species	n	abs. dens.	abs. freq.	abs. dom.	rel. dens.	rel. dom.	rel. freq.	I V I
Anadenanthera colubrina var. cebil	11	359,00	22,50	30,42	6,88	47,84	7,26	61,98
Matayba guianensis	17	554,80	35,00	2,02	10,63	3,18	11,29	25,10
Bauhinia rufa	13	424,20	22,50	4,42	8,13	6,96	7,26	22,33
Myrcia tomentosa	14	456,90	22,50	3,38	8,75	5,32	7,26	21,33
Chrysophyllum marginatum	5	163,20	12,50	3,95	3,13	6,21	4,03	13,36
Lithraea molleoides	6	195,80	15,00	2,18	3,75	3,43	4,84	12,01
Aspidosperma subincanum	6	195,80	12,50	1,51	3,75	2,37	4,03	10,16
Copaifera langsdorffii	2	65,30	5,00	3,30	1,25	5,19	1,61	8,06
Emmotum nitens	5	163,20	7,50	1,42	3,13	2,23	2,42	7,78
Tapirira guianensis	6	195,80	10,00	0,40	3,75	0,63	3,23	7,60
Myrcia rostrata	5	163,20	10,00	0,75	3,13	1,18	3,23	7,53
Alibertia edulis	5	163,20	12,50	0,09	3,13	0,14	4,03	7,30
Guettarda viburnioides	4	130,50	7,50	0,92	2,50	1,44	2,42	6,36
Cardiopetalum calophyllum	4	130,50	7,50	0,74	2,50	1,17	2,42	6,09
Guapira sp.	3	97,90	5,00	1,61	1,88	2,54	1,61	6,02
Cupania vernalis	4	130,50	7,50	0,06	2,50	0,09	2,42	5,01
Cecropia pachystachya	3	97,90	5,00	0,76	1,88	1,19	1,61	4,68
Xylosma benthamii	3	97,90	7,50	0,08	1,88	0,13	2,42	4,42
Banisteriopsis anisandra	4	130,50	5,00	0,14	2,50	0,22	1,61	4,33
Indet 19 (31-1)	4	130,50	5,00	0,08	2,50	0,13	1,61	4,24
Celtis iguanaea	2	65,30	5,00	0,61	1,25	0,96	1,61	3,82
Myrsine umbellata	2	65,30	5,00	0,36	1,25	0,54	1,61	3,41
Maytenus alaternoides	3	97,90	2,50	0,27	1,88	0,42	0,81	3,10
Eriotheca candolleana	1	32,60	2,50	0,97	0,63	1,52	0,81	2,95
Lafoensia pacari	1	32,60	2,50	0,84	0,63	1,33	0,81	2,76
Sclerolobium paniculatum var. subvelutinum	1	32,60	2,50	0,68	0,63	1,06	0,81	2,49
Miconia chamissois	2	65,30	2,50	0,11	1,25	0,18	0,81	2,23
Banisteriopsis pubipetala	2	65,30	2,50	0,11	1,25	0,17	0,81	2,23
Talauma ovata	2	65,30	2,50	0,06	1,25	0,10	0,81	2,16
Inga alba	2	65,30	2,50	0,03	1,25	0,05	0,81	2,11
Piper sp.	2	65,30	2,50	0,03	1,25	0,04	0,81	2,10
Campomanesia velutina	1	32,60	2,50	0,20	0,63	0,32	0,81	1,76
Machaerium aculeatum	1	32,60	2,50	0,19	0,63	0,30	0,81	1,73
Tapura amazonica	1	32,60	2,50	0,18	0,63	0,28	0,81	1,71
Styrax guianensis	1	32,60	2,50	0,16	0,63	0,26	0,81	1,69
Pseudobombax tomentosum	1	32,60	2,50	0,15	0,63	0,24	0,81	1,67
Ficus eximia	1	32,60	2,50	0,08	0,63	0,13	0,81	1,56
Terminalia phaeocarpa	1	32,60	2,50	0,07	0,63	0,11	0,81	1,54
Ficus sp.	1	32,60	2,50	0,07	0,63	0,10	0,81	1,53
Vitex polygama	1	32,60	2,50	0,04	0,63	0,07	0,80	1,50
Cordia trichotoma	1	32,60	2,50	0,04	0,63	0,07	0,80	1,50
Pera obovata	1	32,60	2,50	0,04	0,63	0,07	0,80	1,50
Tabebuia roseo-alba	1	32,60	2,50	0,03	0,63	0,04	0,80	1,46
Dasyphyllum brasiliense	1	32,60	2,50	0,02	0,63	0,03	0,80	1,46
Indet 4 (23-4)	1	32,60	2,50	0,01	0,63	0,01	0,80	1,45
Guazuma ulmifolia	1	32,60	2,50	0,01	0,63	0,01	0,80	1,45
Zanthoxylum rhoifolium	1	32,60	2,50	0,01	0,63	0,01	0,80	1,45

Note: 36 families, 44 genera and 47 species present. Seven families account for 40% of the species: Leguminosae (8), Myrtaceae (3), Anacardiaceae (2), Malpighiaceae (2), Moraceae (2), Rubiaceae (2), and Sapindaceae (2). Three genera, *Banisteriopsis*, *Ficus* and *Myrcia* ,have two species all others are represented by a single species.

Table 13 - Phytosociological parameters - sample site CEMAVE

no. of points = 40
no. of ind. = 160
Shannon - Wiener H' = 3.63, evenness = 0.91

density = 5907.19
basal area = 35.747m2/ha

aver. point-plant dist. = 1.301m
circ > = 5cm

species	n	abs. dens.	abs. freq.	abs. dom	rel. dens.	rel. dom.	rel. freq.	I V I
Aspidosperma subincanum	6	221,50	15,00	7,89	3,75	22,08	4,41	30,24
Maytenus alaternoides	14	516,90	22,50	2,73	8,75	7,63	6,62	22,99
Bauhinia rufa	7	258,40	17,50	4,46	4,38	12,49	5,15	22,01
Anadenanthera colubrina var. cebil	5	184,60	10,00	3,94	3,13	11,02	2,94	17,09
Campomanesia velutina	8	295,40	17,50	1,17	5,00	3,28	5,15	13,43
Matayba guianensis	10	369,20	20,00	0,36	6,25	1,01	5,88	13,14
Piptadenia gonoacantha	10	369,20	15,00	0,34	6,25	0,96	4,41	11,62
Cardiopetalum calophyllum	6	221,50	12,50	1,23	3,75	3,44	3,68	10,87
Cupania vernalis	7	258,40	15,00	0,55	4,38	1,54	4,41	10,33
Casearia sylvestris	7	258,40	10,00	0,51	4,38	1,42	2,94	8,74

Table 13 - Phytosociological parameters - sample site CEMAVE - (cont.)

species	n	abs. dens.	abs. freq.	abs. dom	rel. dens.	rel. dom.	rel. freq.	IVI
Cariniana estrellensis	4	147,70	10,00	1,14	2,50	3,18	2,94	8,62
Diospyros hispida	5	184,60	10,00	0,82	3,13	2,30	2,94	8,37
Tapirira guianensis	5	184,60	12,50	0,07	3,13	0,21	3,68	7,01
Alibertia edulis	4	147,70	7,50	0,65	2,50	1,80	2,21	6,51
Margaritaria nobilis	2	73,80	5,00	1,25	1,25	3,49	1,47	6,21
Zanthoxylum rhoifolium	3	110,80	7,50	0,57	1,88	1,61	2,21	5,69
Emmotum nitens	3	110,80	2,50	0,84	1,88	2,36	0,74	4,97
Indet 22 (392-4)	1	36,90	2,50	1,24	0,63	3,47	0,74	4,83
Myrsine umbellata	3	110,80	5,00	0,34	1,88	0,96	1,47	4,31
Xylosma benthamii	3	110,80	7,50	0,05	1,88	0,13	2,21	4,21
Myrcia rostrata	3	110,80	7,50	0,03	1,88	0,09	2,21	4,17
Myrcia sp.	2	73,80	5,00	0,47	1,25	1,31	1,47	4,03
Guettarda viburnioides	2	73,80	5,00	0,45	1,25	1,26	1,47	3,97
Copaifera langsdorffii	2	73,80	5,00	0,39	1,25	1,09	1,47	3,81
Erythroxylum sp.	1	36,90	2,50	0,87	0,63	2,44	0,74	3,80
Pera obovata	3	110,80	5,00	0,09	1,88	0,26	1,47	3,59
Indet 21 (32-2)	2	73,80	5,00	0,27	1,25	0,77	1,47	3,49
Coutarea hexandra	2	73,80	5,00	0,12	1,25	0,32	1,47	3,04
Rhamnidium elaeocarpum	2	73,80	5,00	0,11	1,25	0,32	1,47	3,04
Chrysophyllum marginatum	2	73,80	5,00	0,06	1,25	0,16	1,47	2,88
Indigofera suffruticosa	2	73,80	5,00	0,04	1,25	0,10	1,47	2,82
Indet 19 (31-1)	2	73,80	5,00	0,02	1,25	0,05	1,47	2,77
Psidium warmingianum	1	36,90	2,50	0,47	0,63	1,31	0,74	2,67
Platypodium elegans	1	36,90	2,50	0,34	0,63	0,96	0,74	2,31
Tabebuia roseo-alba	1	36,90	2,50	0,26	0,63	0,74	0,74	2,10
Myrcia tomentosa	1	36,90	2,50	0,24	0,63	0,67	0,74	2,03
Terminalia glabrescens	1	36,90	2,50	0,23	0,63	0,64	0,74	2,00
Lithraea molleoides	1	36,90	2,50	0,20	0,63	0,55	0,74	1,92
Vitex polygama	1	36,90	2,50	0,14	0,63	0,40	0,74	1,76
Cordia trichotoma	1	36,90	2,50	0,12	0,63	0,33	0,74	1,69
Roupala montana	1	36,90	2,50	0,12	0,63	0,33	0,74	1,69
Serjania cf. caracasana	1	36,90	2,50	0,11	0,63	0,30	0,74	1,66
Lafoensia densiflora	1	36,90	2,50	0,10	0,63	0,27	0,74	1,63
Linociera arborea	1	36,90	2,50	0,08	0,63	0,24	0,74	1,60
Psidium sartorianum	1	36,90	2,50	0,06	0,63	0,17	0,74	1,53
Inga cylindrica	1	36,90	2,50	0,05	0,63	0,15	0,74	1,51
Nectandra sp.	1	36,90	2,50	0,04	0,63	0,11	0,74	1,47
Indet 4 (23-4)	1	36,90	2,50	0,02	0,63	0,07	0,74	1,43
Calophyllum brasiliense	1	36,90	2,50	0,02	0,63	0,05	0,74	1,41
Terminalia phaeocarpa	1	36,90	2,50	0,02	0,63	0,05	0,74	1,41
Dasyphyllum brasiliense	1	36,90	2,50	0,02	0,63	0,05	0,74	1,41
Arrabidaea florida	1	36,90	2,50	0,01	0,63	0,03	0,74	1,40
Erythroxylum englerii	1	36,90	2,50	0,01	0,63	0,03	0,74	1,39
Sclerolobium paniculatum var. subvelutinum	1	36,90	2,50	0,01	0,63	0,03	0,74	1,39

Note: 34 families, 46 genera and 54 species present. Four families account for 43% of the species: Leguminosae (11), Myrtaceae (6), Rubiaceae (3) and Sapindaceae (3). Four genera, *Myrcia* (3), *Erythroxylum* (2), *Psidium* (2) and *Terminalia* (2) had more than one species.

Table 14 - Phytosociological parameters - sample site CRISTAL

no. of points = 40 density = 17784.56ind./ha aver. point-plant dist. = 0.750m
no. of ind. = 160 basal area = 69.339m2/ha circ > = 5cm
Shannon - Wiener H' = 3.22, evenness = 0.87

species	n	abs. dens.	abs. freq.	abs. dom.	rel. dens.	rel. dom.	rel. freq.	IVI
Matayba guianensis	27	3001,10	55,00	12,16	16,88	17,52	15,71	50,11
Copaifera langsdorffii	15	1667,30	32,50	15,68	9,38	22,62	9,29	41,28
Siphoneugena densiflora	4	444,60	7,50	8,99	2,50	12,97	2,14	17,62
Cupania vernalis	9	1000,40	20,00	2,47	5,63	3,57	5,71	14,91
Cheiloclinium cognatum	9	1000,40	22,50	1,91	5,63	2,76	6,43	14,81
Myrcia rostrata	6	666,90	15,00	2,86	3,75	4,12	4,29	12,16
Alibertia edulis	5	555,80	12,50	2,97	3,13	4,28	3,57	10,98
Terminalia glabrescens	2	222,30	5,00	5,61	1,25	8,09	1,43	10,77
Piptadenia gonoacantha	5	555,80	12,50	2,16	3,13	3,12	3,57	9,81
Maytenus alaternoides	6	666,90	15,00	1,08	3,75	1,56	4,29	9,60
Erythroxylum englerii	7	778,10	12,50	0,79	4,38	1,13	3,57	9,08
Diospyros hispida	4	444,60	7,50	2,46	2,50	3,54	2,14	8,18
Aspidosperma subincanum	6	666,90	12,50	0,53	3,75	0,76	3,57	8,08
Tapura amazonica	6	666,90	12,50	0,52	3,75	0,74	3,57	8,06
Guettarda viburnioides	5	555,80	12,50	0,73	3,13	1,06	3,57	7,76
Trichilia elegans	6	666,90	10,00	0,56	3,75	0,81	2,86	7,42
Bauhinia rufa	5	555,80	5,00	0,27	3,13	0,38	1,43	4,94
Aspidosperma spruceanum	3	333,50	7,50	0,51	1,88	0,74	2,14	4,76

Table 14 - Phytosociological parameters - sample site CRISTAL - (cont.)

species	n	abs. dens.	abs. freq.	abs. dom.	rel. dens.	rel. dom.	rel. freq.	IVI
Ixora warmingii	3	333,50	7,50	0,19	1,88	0,27	2,14	4,29
Hymenaea courbaril var. stilbocarpa	3	333,50	7,50	0,15	1,88	0,22	2,14	4,24
Symplocos mosenii	1	111,20	2,50	1,52	0,63	2,20	0,71	3,54
Cardiopetalum calophyllum	2	222,30	5,00	0,54	1,26	0,77	1,43	3,46
Astronium fraxinifolium	1	111,20	2,50	1,38	0,63	1,99	0,71	3,33
Banisteriopsis sp1	2	222,30	5,00	0,18	1,26	0,26	1,43	2,94
Aspidosperma discolor	2	222,30	5,00	0,07	1,26	0,09	1,43	2,77
Serjania cf. caracasana	1	111,20	2,50	0,60	0,63	0,86	0,71	2,20
Indet 22 (392-4)	1	111,20	2,50	0,53	0,63	0,77	0,71	2,11
Virola sebifera	2	222,30	2,50	0,08	1,26	0,12	0,71	2,08
Syagrus flexuosa	1	111,20	2,50	0,51	0,63	0,73	0,71	2,07
Aspidosperma sp.	1	111,20	2,50	0,29	0,63	0,41	0,71	1,76
Ficus eximia	1	111,20	2,50	0,26	0,63	0,37	0,71	1,71
Tapirira guianensis	1	111,20	2,50	0,26	0,63	0,37	0,71	1,71
Banisteriopsis anisandra	1	111,20	2,50	0,17	0,63	0,25	0,71	1,59
Faramea cyanea	1	111,20	2,50	0,14	0,63	0,20	0,71	1,54
Cariniana estrellensis	1	111,20	2,50	0,09	0,63	0,13	0,71	1,47
Ouratea parviflora	1	111,20	2,50	0,06	0,63	0,08	0,71	1,42
Indet 23 (134-3)	1	111,20	2,50	0,02	0,63	0,03	0,71	1,37
Serjania sp.	1	111,20	2,50	0,02	0,63	0,03	0,71	1,37
Lacistema hasslerianum	1	111,20	2,50	0,02	0,63	0,03	0,71	1,37
Lundia nitidula	1	111,20	2,50	0,02	0,63	0,03	0,71	1,37

Note: 27 families, 35 genera and 40 species present. Four families account for 40% of the species: Apocynaceae (4), Leguminosae (4), Rubiaceae (4) and Sapindaceae (4). *Aspidospermae* (4), *Banisteriopsis* (2) and *Serjania* (2) have more than one species.

Table 15 - Phytosociological parameters - sample site CAPÃO COMPRIDO

no. of points = 60	density = 7271.61ind./ha	aver. point-plant dist. = 1.173m
no. of ind. = 240	basal area = 167.277m2/ha	circ >= 5cm
Shannon - Wiener H' = 3.53, evenness = 0.82		

species	n	abs. dens.	abs. freq.	abs. dom.	rel. dens.	rel. dom.	rel. freq.	IVI
Euterpe edulis	56	1694,7	46,76	18,36	23,31	10,97	14,29	48,56
Xylopia emarginata	11	338,9	16,26	34,56	4,66	20,66	4,76	30,08
Cheiloclinium cognatum	22	677,9	20,34	13,06	9,32	7,81	6,35	23,48
Tabebuia impetiginosa	3	92,4	5,08	28,83	1,27	17,24	1,59	20,09
Alibertia edulis	12	369,7	18,64	1,89	5,08	1,13	5,82	12,03
Terminalia fagifolia	1	30,8	1,69	14,12	0,42	8,44	0,53	9,39
Tapirira guianensis	6	184,9	10,17	5,04	2,54	3,01	3,17	8,73
Matayba guianensis	8	246,5	11,86	0,56	3,39	0,33	3,70	7,43
Siphoneugena densiflora	3	92,4	3,39	7,10	1,27	4,24	1,06	6,57
Copaifera langsdorffii	1	30,8	1,69	8,67	0,42	5,18	0,53	6,13
Calophyllum brasiliense	4	123,2	6,78	3,88	1,69	2,32	2,12	6,13
Maytenus alaternoides	5	164,1	8,47	0,68	2,12	0,41	2,65	5,17
Trichilia elegans	5	164,1	8,47	0,16	2,12	0,09	2,65	4,86
Inga alba	1	30,8	1,69	5,82	0,42	3,48	0,53	4,43
Syagrus oleracea	4	123,2	6,78	0,74	1,69	0,44	2,12	4,26
Hymenaea courbaril var. stilbocarpa	2	61,6	3,39	3,84	0,86	2,30	1,06	4,20
Talauma ovata	2	61,6	3,39	3,59	0,86	2,15	1,06	4,05
Linociera arborea	4	123,2	5,08	0,49	1,69	0,29	1,59	3,57
Lamanonia ternata	3	92,4	5,08	1,14	1,27	0,68	1,59	3,54
Calyptranthes lucida	3	92,4	5,08	0,82	1,27	0,49	1,59	3,36
Protium heptaphyllum	2	61,6	3,39	2,27	0,86	1,35	1,06	3,28
Trichilia catigua	3	92,4	5,08	0,50	1,27	0,30	1,59	3,16
Myrcia rostrata	3	92,4	5,08	0,24	1,27	0,14	1,59	3,00
Symplocos sp.	2	61,6	3,39	1,83	0,86	1,09	1,06	3,00
Symplocos nitens	2	61,6	3,39	1,79	0,86	1,07	1,06	2,98
Indet 15 (137-2)	2	61,6	3,39	0,81	0,86	0,49	1,06	2,39
Indet 16 (137-3)	3	92,4	3,39	0,04	1,27	0,02	1,06	2,35
Banisteriopsis pubipetala	2	61,6	3,39	0,46	0,86	0,27	1,06	2,17
Cupania vernalis	2	61,6	3,39	0,36	0,86	0,22	1,06	2,12
Roupala montana	2	61,6	3,39	0,30	0,86	0,18	1,06	2,09
Miconia chamissois	2	61,6	3,39	0,10	0,86	0,06	1,06	1,97
Calyptranthes sp.	2	61,6	3,39	0,07	0,86	0,04	1,06	1,94
Sorocea ilicifolia	2	61,6	3,39	0,06	0,86	0,04	1,06	1,94
Guarea kunthiana	2	61,6	3,39	0,06	0,86	0,03	1,06	1,94
Ilex pseudotheezans	2	61,6	3,39	0,06	0,86	0,03	1,06	1,94
Cybianthus glaber	2	61,6	3,39	0,05	0,86	0,03	1,06	1,93
Alchornea glandulosa	2	61,6	3,39	0,04	0,86	0,02	1,06	1,93
Indet 2 (168-3)	2	61,6	3,39	0,03	0,86	0,02	1,06	1,92
Guarea macrophyla	2	61,6	3,39	0,02	0,86	0,01	1,06	1,92
Malanea macrophylla	2	61,6	3,39	0,02	0,86	0,01	1,06	1,92

Table 15 - Phytosociological parameters - sample site CAPÃO COMPRIDO - (cont.)

species	n	abs. dens.	abs. freq.	abs. dom.	rel. dens.	rel. dom.	rel. freq.	IVI
Ficus eximia	2	61,6	1,69	0,45	0,85	0,27	0,53	1,64
Indet 22 (392-4)	1	30,8	1,69	0,88	0,42	0,53	0,53	1,48
Ilex integrifolius	2	61,6	1,69	0,14	0,85	0,08	0,53	1,46
Cyathea sp.	1	30,8	1,69	0,76	0,42	0,45	0,53	1,40
Hieronyma alchorneoides	1	30,8	1,69	0,51	0,42	0,30	0,53	1,26
Ficus sp.	1	30,8	1,69	0,45	0,42	0,27	0,53	1,22
Lithraea molleoides	1	30,8	1,69	0,44	0,42	0,26	0,53	1,22
Myrcia tomentosa	1	30,8	1,69	0,35	0,42	0,21	0,53	1,16
Licaria cf. armeniaca	1	30,8	1,69	0,20	0,42	0,12	0,53	1,07
Hedyosmum brasiliense	1	30,8	1,69	0,15	0,42	0,09	0,53	1,04
Posoqueria latifolia	1	30,8	1,69	0,07	0,42	0,04	0,53	1,00
Myrsine umbellata	1	30,8	1,69	0,07	0,42	0,04	0,53	0,99
Serjania sp.	1	30,8	1,69	0,06	0,42	0,04	0,53	0,99
Terminalia phaeocarpa	1	30,8	1,69	0,05	0,42	0,03	0,53	0,98
Plathymenia reticulata	1	30,8	1,69	0,04	0,42	0,02	0,53	0,98
Cryptocarya aschersoniana	1	30,8	1,69	0,03	0,42	0,02	0,53	0,97
Symplocos mosenii	1	30,8	1,69	0,02	0,42	0,01	0,53	0,96
Maytenus salicifola	1	30,8	1,69	0,02	0,42	0,01	0,53	0,96
Blepharocalyx salicifolius	1	30,8	1,69	0,01	0,42	0,01	0,53	0,96
Aspidosperma subincanum	1	30,8	1,69	0,01	0,42	0,01	0,53	0,96
Tapura amazonica	1	30,8	1,69	0,01	0,42	0,01	0,53	0,96
Banisteriopsis sp.	1	30,8	1,69	0,01	0,42	0,01	0,53	0,96
Schefflera morototoni	1	30,8	1,69	0,01	0,42	0,01	0,53	0,96
Platypodium elegans	1	30,8	1,69	0,01	0,42	0,01	0,53	0,96
Bauhinia rufa	1	30,8	1,69	0,01	0,42	0,01	0,53	0,96
Sorocea sp.	1	30,8	1,69	0,01	0,42	0,01	0,53	0,96
Pseudolmedia laevigata	1	30,8	1,69	0,01	0,42	0,01	0,53	0,96
Ouratea castaneifolia	1	30,8	1,69	0,01	0,42	0,01	0,53	0,96
Serjania cf. caracasana	1	30,8	1,69	0,01	0,42	0,01	0,53	0,96
Indet 6 (408-4)	1	30,8	1,69	0,01	0,42	0,01	0,53	0,96
Cybianthus detergens	1	30,8	1,69	0,01	0,42	0,00	0,53	0,96
Protium almecega	1	30,8	1,69	0,01	0,42	0,00	0,53	0,96
Chrysophyllum marginatum	1	30,8	1,69	0,01	0,42	0,00	0,53	0,96
Cardiopetalum calophyllum	1	30,8	1,69	0,01	0,42	0,00	0,53	0,96
Erythroxylum englerii	1	30,8	1,69	0,01	0,42	0,00	0,53	0,96
Banisteriopsis sp1	1	30,8	1,69	0,01	0,42	0,00	0,53	0,96

Note: 41 families, 81 genera and 76 species present. Nine families account for 49% of the species: Leguminosae (6), Myrtaceae (8), Moraceae (5), Meliaceae (4), Sapindaceae (4), Rubiaceae (3), Symplocaceae (3), Malpighiaceae (3) and Myrsinaceae (3). Eleven genera, *Banisteriopsis* (3), *Symplocos* (3), *Ficus* (2), *Guarea* (2), *Myrcia* (2), *Protium* (2), *Terminalia* (2) and *Trichilia* (2), had more than one species.

Table 16 - Phytosociological parameters - sample site BARRIGUDA

No. of points = 60
No. of ind. = 240
Shannon - Wiener H' = 4.09, evenness = 0.93

density = 9024.34ind./ha
basal area = 131.261m2/ha

aver. point-plant dist. = 1.053m
circ > = 5cm

species	n	abs. dens.	abs. freq.	abs. dom.	rel. dens.	rel. dom.	rel. freq.	IVI
Copaifera langsdorffii	7	263,20	10,00	21,62	2,92	16,47	2,86	22,25
Micropholis venulosa	2	75,20	3,33	22,65	0,83	17,26	0,95	19,04
Cheiloclinium cognatum	15	564,00	20,00	8,73	6,25	6,66	5,71	18,62
Tapirira guianensis	10	376,00	15,00	11,53	4,17	8,78	4,29	17,23
Vochysia pyramidalis	2	75,20	3,33	14,14	0,83	10,77	0,95	12,56
Alibertia edulis	11	413,60	15,00	1,19	4,58	0,90	4,29	9,77
Lacistema hasslerianum	10	376,00	16,67	0,14	4,17	0,10	4,76	9,03
Callisthene major	6	225,60	6,67	5,97	2,50	4,54	1,90	8,95
Ficus sp1	1	37,60	1,67	9,91	0,42	7,55	0,48	8,44
Vitex polygama	3	112,80	1,67	7,00	1,25	5,33	0,48	7,06
Rollinia sericea	6	225,60	10,00	2,00	2,50	1,53	2,86	6,88
Terminalia fagifolia	1	37,60	1,67	7,66	0,42	5,84	0,48	6,73
Nectandra gardneri	7	263,20	11,67	0,59	2,92	0,45	3,33	6,70
Guapira sp.	7	263,20	10,00	0,09	2,92	0,07	2,86	5,84
Ixora warmingii	6	225,60	10,00	0,26	2,50	0,20	2,86	5,56
Roupala montana	7	263,20	8,33	0,22	2,92	0,17	2,38	5,47
Licania sp.	3	112,80	3,33	3,84	1,25	2,93	0,95	5,13
Pera obovata	6	225,60	8,33	0,14	2,50	0,11	2,38	4,99
Sorocea sp.	6	225,60	8,33	0,11	2,50	0,09	2,38	4,97
Aspidosperma spruceanum	5	188,00	8,33	0,23	2,08	0,18	2,38	4,64
Diospyros hispida	5	188,00	6,67	0,69	2,08	0,52	1,90	4,51
Matayba guianensis	4	150,40	6,67	0,69	1,67	0,53	1,90	4,10
Myrcia rostrata	5	188,00	6,67	0,11	2,08	0,09	1,90	4,07
Indet 1 (369-1)	4	150,40	6,67	0,11	1,67	0,08	1,90	3,65

Table 16 - Phytosociological parameters - sample site BARRIGUDA - (cont.)

species	n	abs. dens.	abs. freq.	abs. dom.	rel. dens.	rel. dom.	rel. freq.	IVI
Myrsine umbellata	4	150,40	6,67	0,08	1,67	0,06	1,90	3,63
Aspidosperma subincanum	4	150,40	5,00	0,33	1,67	0,26	1,43	3,34
Piptocarpha macropoda	3	112,80	5,00	0,69	1,26	0,53	1,43	3,20
Cupania vernalis	5	188,00	3,33	0,11	2,08	0,09	0,95	3,12
Salacia elliptica	3	112,80	5,00	0,30	1,26	0,23	1,43	2,90
Banisteriopsis sp.3	3	112,80	5,00	0,28	1,26	0,22	1,43	2,89
Inga cylindrica	3	112,80	5,00	0,18	1,26	0,14	1,43	2,82
Siphoneugena densiflora	3	112,80	5,00	0,08	1,26	0,06	1,43	2,74
Miconia sp.5	3	112,80	5,00	0,06	1,26	0,04	1,43	2,72
Guettarda viburnoides	2	75,20	3,33	1,18	0,83	0,90	0,95	2,69
Inga alba	2	75,20	3,33	0,84	0,83	0,64	0,95	2,42
Cordia sellowiana	2	75,20	3,33	0,79	0,83	0,60	0,95	2,39
Myrsine guianensis	3	112,80	1,67	0,69	1,26	0,53	0,48	2,26
Eriotheca pubescens	1	37,60	1,67	1,73	0,42	1,32	0,48	2,21
Cryptocarya aschersoniana	2	75,20	3,33	0,44	0,83	0,34	0,95	2,12
Swartzia apetala	2	75,20	3,33	0,29	0,83	0,22	0,95	2,01
Miconia chamissois	2	75,20	3,33	0,19	0,83	0,14	0,95	1,93
Licania apetala	2	75,20	3,33	0,09	0,83	0,07	0,95	1,86
Cardiopetalum calophyllum	2	75,20	3,33	0,08	0,83	0,06	0,95	1,85
Indet 22 (392-4)	2	75,20	3,33	0,06	0,83	0,05	0,95	1,83
Prunus sellowii	2	75,20	3,33	0,03	0,83	0,02	0,95	1,81
Trichilia elegans	2	75,20	3,33	0,03	0,83	0,02	0,95	1,81
Miconia sp.1	2	75,20	3,33	0,02	0,83	0,02	0,95	1,80
Indet 9 (203-2)	1	37,60	1,67	1,08	0,42	0,82	0,48	1,71
Amaioua guianensis	2	75,20	1,67	0,07	0,83	0,05	0,48	1,36
Cestrum cf. baeritzii	2	75,20	1,67	0,06	0,83	0,04	0,48	1,35
Erythroxylum engleri	2	75,20	1,67	0,04	0,83	0,03	0,48	1,34
Xylosma benthamii	2	75,20	1,67	0,02	0,83	0,02	0,48	1,32
Qualea multiflora	1	37,60	1,67	0,43	0,42	0,33	0,48	1,22
Miconia sellowiana	1	37,60	1,67	0,14	0,42	0,11	0,48	1,00
Austroplenkia populnea	1	37,60	1,67	0,12	0,42	0,09	0,48	0,98
Syagrus oleracea	1	37,60	1,67	0,11	0,42	0,08	0,48	0,98
Myrcia pubipetala	1	37,60	1,67	0,10	0,42	0,07	0,48	0,97
Endlicheria paniculata	1	37,60	1,67	0,08	0,42	0,06	0,48	0,95
Serjania sp.	1	37,60	1,67	0,08	0,42	0,06	0,48	0,95
Indet 4 (23-4)	1	37,60	1,67	0,07	0,42	0,05	0,48	0,94
Banisteriopsis malifolia	1	37,60	1,67	0,06	0,42	0,05	0,48	0,94
Miconia sp.7	1	37,60	1,67	0,06	0,42	0,04	0,48	0,94
Jacaranda copaia	1	37,60	1,67	0,05	0,42	0,04	0,48	0,93
Emmotum nitens	1	37,60	1,67	0,05	0,42	0,04	0,48	0,93
Maytenus alaternoides	1	37,60	1,67	0,05	0,42	0,04	0,48	0,93
Tapura amazonica	1	37,60	1,67	0,05	0,42	0,04	0,48	0,93
Trembleya parviflora	1	37,60	1,67	0,04	0,42	0,03	0,48	0,92
Hedyosmum brasiliense	1	37,60	1,67	0,03	0,42	0,03	0,48	0,92
Xylosma pseudosalzmanii	1	37,60	1,67	0,03	0,42	0,03	0,48	0,92
Indet 2 (168-3)	1	37,60	1,67	0,03	0,42	0,03	0,48	0,92
Heteropteris acutifolia	1	37,60	1,67	0,02	0,42	0,02	0,48	0,91
Sacoglottis mattogrossensis	1	37,60	1,67	0,02	0,42	0,01	0,48	0,91
Miconia sp.2	1	37,60	1,67	0,02	0,42	0,01	0,48	0,91
Banisteriopsis sp.	1	37,60	1,67	0,02	0,42	0,01	0,48	0,91
Coussarea hydrangeaefolia	1	37,60	1,67	0,02	0,42	0,01	0,48	0,91
Byrsonima laxiflora	1	37,60	1,67	0,02	0,42	0,01	0,48	0,91
Piper sp.	1	37,60	1,67	0,01	0,42	0,01	0,48	0,90
Ouratea parviflora	1	37,60	1,67	0,01	0,42	0,01	0,48	0,90
Banisteriopsis sp.2	1	37,60	1,67	0,01	0,42	0,01	0,48	0,90
Indet 13 (226-13)	1	37,60	1,67	0,01	0,42	0,01	0,48	0,90
Rubiaceae sp.	1	37,60	1,67	0,01	0,42	0,01	0,48	0,90
Xylopia sericea	1	37,60	1,67	0,01	0,42	0,01	0,48	0,90
Coccoloba cf. ochreolata	1	37,60	1,67	0,01	0,42	0,01	0,48	0,90

Note: 50 families, 70 genera and 84 species present. Nine families account for 45% of the species: Melastomataceae (7), Malpighiaceae (6), Rubiaceae (6), Leguminosae (4), Annonaceae (3), Lauraceae (3), Myrtaceae (3), Sapindaceae (3) and Vochysiaceae (3). Seven genera, *Miconia* (5), *Banisteriopsis* (4), *Aspidosperma* (2), *Inga* (2), *Licania* (2), *Myrcia* (2) and *Xylosma* (2) have more than one species.

Table 17 - Phytosociological parameters - sample site TRES BARRAS

no. of points = 64　　density = 7743.06ind./ha　　aver. point-plant dist. = 1.136m
no. of ind. = 256　　basal area = 94.888m2/ha　　circ. > = 5cm
Shannon - Wiener H' = 4.17, evenness = 0.91

species	n	abs. dens.	abs. freq.	abs. dom.	rel. dens.	rel. dom.	rel. freq.	IVI
Tapirira guianensis	14	423,40	20,31	16,49	5,47	16,33	5,94	27,73
Cyathea sp.	12	363,00	12,50	6,84	4,69	7,21	3,65	16,56
Cheiloclinium cognatum	9	272,20	14,06	6,66	3,52	7,01	4,11	14,64
Pseudolmedia laevigata	10	302,50	12,50	6,67	3,91	7,03	3,65	14,59
Miconia chartacea	17	514,20	18,75	1,35	6,64	1,42	5,48	13,54
Euterpe edulis	8	242,00	6,25	5,46	3,13	5,75	1,83	10,70
Protium heptaphyllum	4	121,00	6,25	4,18	1,56	4,40	1,83	7,79
Matayba guianensis	9	272,20	12,50	0,28	3,52	0,30	3,65	7,47
Callisthene major	7	211,70	6,25	2,40	2,73	2,53	1,83	7,09
Copaifera langsdorffii	5	151,20	7,81	2,63	1,95	2,77	2,28	7,01
Hieronyma alchorneoides	1	30,20	1,56	5,71	0,39	6,02	0,46	6,86
Miconia cuspidata	7	211,70	10,94	0,77	2,73	0,81	3,20	6,74
Indet 22 (392-4)	1	30,20	1,56	5,42	0,39	5,71	0,46	6,56
Symplocos nitens	1	30,20	1,56	4,66	0,39	4,90	0,46	5,76
Siphoneugena densiflora	5	151,20	6,25	1,44	1,95	1,51	1,83	5,29
Miconia chamissois	6	181,50	7,81	0,22	2,34	0,23	2,28	4,86
Rapanea umbellata	5	151,20	7,81	0,13	1,95	0,13	2,28	4,37
Xylopia sericea	6	181,50	4,69	0,60	2,34	0,63	1,37	4,35
Sacoglottis mattogrossensis	5	151,20	4,69	0,64	1,95	0,68	1,37	4,00
Siparuna guianensis	2	60,50	3,13	2,12	0,78	2,24	0,91	3,93
Licania apetala	5	151,20	6,25	0,07	1,95	0,07	1,83	3,85
Indet 11 (266-1)	2	60,50	1,56	2,43	0,78	2,56	0,46	3,80
Virola sebifera	3	90,70	4,69	1,14	1,17	1,20	1,37	3,74
Faramea cyanea	3	90,70	4,69	0,60	1,17	0,63	1,37	3,17
Nectandra sp.2	1	30,20	1,56	2,13	0,39	2,24	0,46	3,09
Protium sp.	1	30,20	1,56	2,10	0,39	2,22.	0,46	3,06
Ferdinandusa speciosa	1	30,20	1,56	2,08	0,39	2,19	0,46	3,04
Tapura amazonica	4	121,00	4,69	0,10	1,56	0,10	1,37	3,04
Richeria obovata	2	60,50	3,13	1,21	0,78	1,27	0,91	2,97
Ilex integrifolius	3	90,70	4,69	0,32	1,17	0,33	1,37	2,88
Gomidesia brunea	3	90,70	4,69	0,12	1,17	0,13	1,37	2,67
Guatteria sp.	3	90,70	4,69	0,09	1,17	0,09	1,37	2,64
Miconia sp.8	3	90,70	3,13	0,49	1,17	0,52	0,91	2,60
Geonoma schottiana	3	90,70	4,69	0,04	1,17	0,04	1,37	2,58
Cecropia pachystachya	2	60,50	3,13	0,84	0,78	0,89	0,91	2,58
Symplocos mosenii	2	60,50	3,13	0,67	0,78	0,71	0,91	2,40
Sclerolobium paniculatum var. subvelutinum	3	90,70	3,13	0,09	1,17	0,10	0,91	2,18
Cordia sp.	3	90,70	3,13	0,08	1,17	0,08	0,91	2,17
Protium almecega	2	60,50	3,13	0,41	0,78	0,43	0,91	2,12
Duguetia lanceolata	3	90,70	3,13	0,03	1,17	0,03	0,91	2,11
Sorocea sp.	2	60,50	3,13	0,34	0,78	0,36	0,91	2,05
Cryptocarya aschersoniana	2	60,50	3,13	0,29	0,78	0,31	0,91	2,00
Pera obovata	2	60,50	3,13	0,22	0,78	0,23	0,91	1,92
Hedyosmum brasiliense	2	60,50	3,13	0,19	0,78	0,21	0,91	1,90
Maprounea guianensis	2	60,50	1,56	0,62	0,78	0,65	0,46	1,89
Salacia elliptica	1	30,20	1,56	0,88	0,39	0,93	0,46	1,78
Cybianthus glaber	2	60,50	3,13	0,07	0,78	0,08	0,91	1,77
Cupania vernalis	2	60,50	3,13	0,07	0,78	0,07	0,91	1,77
Cabralea canjerana	2	60,50	3,13	0,03	0,78	0,03	0,91	1,72
Prunus chamissoana	2	60,50	3,13	0,02	0,78	0,03	0,91	1,72
Lacistema hasslerianum	2	60,50	3,13	0,02	0,78	0,02	0,91	1,72
Ilex pseudotheezans	1	30,20	1,56	0,58	0,39	0,61	0,46	1,46
Daphnopsis fasciculata	1	30,20	1,56	0,46	0,39	0,48	0,46	1,33
Nectandra sp.1	2	60,50	1,56	0,03	0,78	0,03	0,46	1,27
Vernonia ferruginea	2	60,50	1,56	0,02	0,78	0,02	0,46	1,26
Indet 26 (274-1)	1	30,20	1,56	0,39	0,39	0,41	0,46	1,26
Licania octandra	1	30,20	1,56	0,38	0,39	0,40	0,46	1,24
Guatteria sellowiana	1	30,20	1,56	0,23	0,39	0,24	0,46	1,09
Miconia sellowiana	1	30,20	1,56	0,18	0,39	0,19	0,46	1,04
Tibouchina candolleana	1	30,20	1,56	0,13	0,39	0,14	0,46	0,99
Kielmeyera variabilis	1	30,20	1,56	0,13	0,39	0,13	0,46	0,98
Miconia sp.3	1	30,20	1,56	0,12	0,39	0,12	0,46	0,97
Ficus sp.	1	30,20	1,56	0,10	0,39	0,10	0,46	0,95
Banisteriopsis sp.	1	30,20	1,56	0,10	0,39	0,10	0,46	0,95
Callisthene fasciculata	1	30,20	1,56	0,09	0,39	0,09	0,46	0,94
Ocotea sp.1	1	30,20	1,56	0,05	0,39	0,05	0,46	0,90
Nectandra gardneri	1	30,20	1,56	0,04	0,39	0,04	0,46	0,89
Mollinedia oligantha	1	30,20	1,56	0,03	0,39	0,04	0,46	0,88
Indet 1 (369-1)	1	30,20	1,56	0,03	0,39	0,04	0,46	0,88
Ocotea corymbosa	1	30,20	1,56	0,03	0,39	0,04	0,46	0,88
Bauhinia sp.	1	30,20	1,56	0,03	0,39	0,03	0,46	0,88

Table 17 - Phytosociological parameters - sample site TRES BARRAS - (cont.)

species	n	abs. dens.	abs. freq.	abs. dom.	rel. dens.	rel. dom.	rel. freq.	IVI
Ocotea spixiana	1	30,20	1,56	0,02	0,39	0,03	0,46	0,87
Qualea dichotoma	1	30,20	1,56	0,02	0,39	0,02	0,46	0,87
Cestrum cf. pedicellatum	1	30,20	1,56	0,02	0,39	0,02	0,46	0,87
Piper sp.	1	30,20	1,56	0,02	0,39	0,02	0,46	0,87
Indet 21 (32-2)	1	30,20	1,56	0,02	0,39	0,02	0,46	0,86
Guettarda viburnioides	1	30,20	1,56	0,02	0,39	0,02	0,46	0,86
Nectandra cissiflora	1	30,20	1,56	0,01	0,39	0,01	0,46	0,86
Amaioua guianensis	1	30,20	1,56	0,01	0,39	0,01	0,46	0,86
Xylopia brasiliensis	1	30,20	1,56	0,01	0,39	0,01	0,46	0,86
Alchornea glandulosa	1	30,20	1,56	0,01	0,39	0,01	0,46	0,86
Indet 13 (226-13)	1	30,20	1,56	0,01	0,39	0,01	0,46	0,86
Mikania psilostachya	1	30,20	1,56	0,01	0,39	0,01	0,46	0,86
Indet 5 (285-1)	1	30,20	1,56	0,01	0,39	0,01	0,46	0,86
Xylosma pseudosalzmanii	1	30,20	1,56	0,01	0,39	0,01	0,46	0,86
Agonandra englerii	1	30,20	1,56	0,01	0,39	0,01	0,46	0,86
Ocotea sp.2	1	30,20	1,56	0,01	0,39	0,01	0,46	0,86
Myrsine coriacea	1	30,20	1,56	0,01	0,39	0,01	0,46	0,86
Cardiopetalum calophyllum	1	30,20	1,56	0,01	0,39	0,01	0,46	0,86
Indet 14 (240-4)	1	30,20	1,56	0,01	0,39	0,01	0,46	0,86
Celtis iguanaea	1	30,20	1,56	0,01	0,39	0,01	0,46	0,86
Maytenus alaternoides	1	30,20	1,56	0,01	0,39	0,01	0,46	0,86
Rollinia sericea	1	30,20	1,56	0,01	0,39	0,01	0,46	0,85
Terminalia phaeocarpa	1	30,20	1,56	0,01	0,39	0,01	0,46	0,85
Coussarea hydrangeaefolia	1	30,20	1,56	0,01	0,39	0,01	0,46	0,85
Miconia sp.4	1	30,20	1,56	0,01	0,39	0,01	0,46	0,85
Indet 20 (282-4)	1	30,20	1,56	0,01	0,39	0,01	0,46	0,85
Psychotria carthagenensis	1	30,20	1,56	0,01	0,39	0,01	0,46	0,85

Note: 50 families, 80 genera and 98 species present. 10 families account for 51% of the species: Lauraceae (9), Melastomataceae (8), Annonaceae (7), Rubiaceae (6), Euphorbiaceae (5), Burseraceae (3), Leguminosae (3), Moraceae (3), Myrsinaceae (3) and Vochysiaceae (3). Three genera, Miconia (8), Myrsine (2) and Protium (2), have more than a single species.

Table 18 - Phytosociological parameters - sample site PALMAS

no. of points = 60
no. of ind. = 240
Shannon - Wiener H' = 4.06, evenness = 0.91

density = 10699.10ind./ha
basal area = 94.348m2/ha

aver. point-plant dist. = 0.967m
circ. > = 5cm

species	n	abs. dens.	abs. freq.	abs. dom.	rel. dens.	rel. dom.	rel. freq.	IVI
Attalea phalerata	14	624,10	18,33	33,56	5,83	35,57	5,31	46,72
Anadenanthera colubrina var. cebil	3	133,70	5,00	16,30	1,25	17,28	1,46	19,98
Matayba guianensis	13	579,60	20,00	1,16	5,42	1,23	5,80	12,44
Cupania vernalis	12	535,00	20,00	1,06	5,00	1,11	5,80	11,91
Swartzia apetala	15	668,70	16,67	0,41	6,25	0,44	4,83	11,52
Aspidosperma subincanum	11	490,40	16,67	0,80	4,58	0,85	4,83	10,26
Emmotum nitens	4	178,30	6,67	5,03	1,67	5,34	1,93	8,94
Banisteriopsis sp.	8	356,60	11,67	0,47	3,33	0,50	3,38	7,22
Terminalia fagifolia	5	222,90	6,67	1,67	2,08	1,77	1,93	5,78
Myrcia rostrata	6	267,50	8,33	0,76	2,50	0,81	2,42	5,72
Cheiloclinium cognatum	6	267,50	10,00	0,27	2,50	0,28	2,90	5,68
Guettarda viburnioides	4	178,30	6,67	1,79	1,67	1,89	1,93	5,49
Coussarea hydrangeaefolia	5	222,90	3,33	1,78	2,08	1,89	0,97	4,94
Tapura amazonica	6	267,50	6,67	0,28	2,50	0,29	1,93	4,73
Siphoneugena densiflora	5	222,90	6,67	0,15	2,08	0,16	1,93	4,18
Bauhinia rufa	3	133,70	5,00	1,38	1,25	1,47	1,46	4,18
Palmae (328-1)	1	44,60	1,67	3,07	0,42	3,26	0,48	4,16
Enterolobium ellipticum	1	44,60	1,67	3,07	0,42	3,26	0,48	4,16
Connarus regnellii	5	222,90	6,67	0,09	2,08	0,10	1,93	4,11
Ficus sp.	3	133,70	5,00	1,25	1,25	1,32	1,46	4,02
Alibertia edulis	4	178,30	6,67	0,34	1,67	0,36	1,93	3,96
Tapirira guianensis	4	178,30	6,67	0,24	1,67	0,26	1,93	3,86
Roupala montana	5	222,90	5,00	0,15	2,08	0,16	1,46	3,69
Hymenaea courbaril var. stilbocarpa	1	44,60	1,67	2,56	0,42	2,72	0,48	3,62
Inga alba	3	133,70	3,33	0,92	1,25	0,97	0,97	3,19
Licania apetala	5	222,90	3,33	0,10	2,08	0,11	0,97	3,16
Tibouchina candolleana	1	44,60	1,67	2,10	0,42	2,23	0,48	3,13
Campomanesia velutina	2	89,20	3,33	1,25	0,83	1,33	0,97	3,13
Diospyros hispida	3	133,70	5,00	0,28	1,25	0,30	1,46	3,00
Salacia elliptica	3	133,70	5,00	0,19	1,25	0,20	1,46	2,90
Solanum paniculatum	3	133,70	5,00	0,14	1,25	0,15	1,46	2,86
Simarouba versicolor	2	89,20	3,33	0,98	0,83	1,04	0,97	2,84
Terminalia glabrescens	1	44,60	1,67	1,79	0,42	1,90	0,48	2,80

Table 18 - Phytosociological parameters - sample site PALMAS (cont.)

species	n	abs. dens.	abs. freq.	abs. dom.	rel. dens.	rel. dom.	rel. freq.	IVI
Copaifera langsdorffii	3	133,70	5,00	0,04	1,26	0,04	1,46	2,74
Leg (319-2)	3	133,70	3,33	0,49	1,26	0,51	0,97	2,73
Sclerolobium paniculatum var. subvelutinum	3	133,70	3,33	0,44	1,26	0,46	0,97	2,68
Moutabea excoriata	1	44,60	1,67	1,56	0,42	1,64	0,48	2,54
Luehea grandiflora	3	133,70	1,67	0,76	1,26	0,80	0,48	2,54
Piptocarpha macropoda	3	133,70	3,33	0,11	1,26	0,12	0,97	2,34
Bignoniaceae (356-2)	3	133,70	3,33	0,05	1,26	0,05	0,97	2,27
Myrsine umbellata	2	89,20	3,33	0,32	0,83	0,34	0,97	2,14
Macairea sp.	2	89,20	3,33	0,27	0,83	0,28	0,97	2,08
Indet 22 (392-4)	1	44,60	1,67	1,11	0,42	1,18	0,48	2,08
Andira sp.	1	44,60	1,67	0,96	0,42	1,02	0,48	1,92
Tabebuia impetiginosa	2	89,20	3,33	0,11	0,83	0,11	0,97	1,91
Indet 3 (337-4)	2	89,20	3,33	0,08	0,83	0,08	0,97	1,88
Indet 18 (311-1)	2	89,20	3,33	0,04	0,83	0,04	0,97	1,84
Indet 7 (324-1)	2	89,20	3,33	0,03	0,83	0,03	0,97	1,83
Calyptranthes lucida	2	89,20	3,33	0,03	0,83	0,03	0,97	1,83
Xylopia emarginata	2	89,20	3,33	0,02	0,83	0,02	0,97	1,82
Myrsine coriacea	1	44,60	1,67	0,86	0,42	0,90	0,48	1,80
Xylopia brasiliensis	2	89,20	1,67	0,13	0,83	0,14	0,48	1,46
Miconia sp.8	1	44,60	1,67	0,30	0,42	0,32	0,48	1,22
Ouratea castaneifolia	1	44,60	1,67	0,16	0,42	0,17	0,48	1,07
Ocotea spixiana	1	44,60	1,67	0,12	0,42	0,12	0,48	1,02
Cybianthus detergens	1	44,60	1,67	0,12	0,42	0,12	0,48	1,02
Virola sebifera	1	44,60	1,67	0,10	0,42	0,11	0,48	1,01
Eugenia florida	1	44,60	1,67	0,09	0,42	0,10	0,48	1,00
Inga marginata	1	44,60	1,67	0,09	0,42	0,09	0,48	0,99
Apuleia leiocarpa	1	44,60	1,67	0,07	0,42	0,07	0,48	0,97
Cinnamomum sp.	1	44,60	1,67	0,06	0,42	0,06	0,48	0,96
Faramea cyanea	1	44,60	1,67	0,05	0,42	0,05	0,48	0,95
Miconia albicans	1	44,60	1,67	0,04	0,42	0,05	0,48	0,95
Indet 15 (137-2)	1	44,60	1,67	0,04	0,42	0,04	0,48	0,94
Machaerium aculeatum	1	44,60	1,67	0,04	0,42	0,04	0,48	0,94
Ouratea hexasperma	1	44,60	1,67	0,03	0,42	0,03	0,48	0,93
Callisthene major	1	44,60	1,67	0,03	0,42	0,03	0,48	0,93
Mikania psilostachya	1	44,60	1,67	0,02	0,42	0,02	0,48	0,92
Myrcia tomentosa	1	44,60	1,67	0,02	0,42	0,02	0,48	0,92
Lacistema hasslerianum	1	44,60	1,67	0,02	0,42	0,02	0,48	0,92
Xylosma pseudosalzmanii	1	44,60	1,67	0,02	0,42	0,02	0,48	0,92
Indet 17 (339-1)	1	44,60	1,67	0,02	0,42	0,02	0,48	0,92
Chrysophyllum marginatum	1	44,60	1,67	0,02	0,42	0,02	0,48	0,92
Miconia bergei	1	44,60	1,67	0,02	0,42	0,02	0,48	0,92
Rubiaceae sp.	1	44,60	1,67	0,02	0,42	0,02	0,48	0,92
Myrsine gardneriana	1	44,60	1,67	0,02	0,42	0,02	0,48	0,92
Alibertia macrophylla	1	44,60	1,67	0,01	0,42	0,01	0,48	0,91
Trembleya parviflora	1	44,60	1,67	0,01	0,42	0,01	0,48	0,91
Miconia sp.9	1	44,60	1,67	0,01	0,42	0,01	0,48	0,91
Celtis iguanaea	1	44,60	1,67	0,01	0,42	0,01	0,48	0,91
Helicteres cf. brevispira	1	44,60	1,67	0,01	0,42	0,01	0,48	0,91
Licania octandra	1	44,60	1,67	0,01	0,42	0,01	0,48	0,91
Compositae (361-3)	1	44,60	1,67	0,01	0,42	0,01	0,48	0,91
Brunfelsia brasiliensis	1	44,60	1,67	0,01	0,42	0,01	0,48	0,91
Miconia chartacea	1	44,60	1,67	0,01	0,42	0,01	0,48	0,91

Note: 43 families, 72 genera and 85 species present. Six families account for 47% of the species: Leguminosae (13), Melastomataceae (8), Myrtaceae (6), Rubiaceae (6), Myrsinaceae (4) and Compositae (3). Six genera, Miconia (5), Myrsine (3), Licania (2), Myrcia (2), Terminalia (2) and Xylopia (2), have more than one species.

Table 19 - Phytosociological parameters - sample site BANANAL

no. of points = 60 density = 25944.70ind./ha aver. point-plant dist. = 0.621m
no. of ind. = 240 basal area = 249.149m2/ha circ > = 6cm
Shannon - Wiener H' = 3.53, evenness = 0.82

species	n	abs. dens.	abs. freq.	abs. dom.	rel. dens.	rel. dom.	rel. freq.	IVI
Calophyllum brasiliense	19	2088,80	28,81	98,82	8,06	39,66	8,21	55,93
Xylopia emarginata	22	2418,60	32,20	19,56	9,32	7,85	9,18	26,36
Talauma ovata	16	1759,00	27,12	16,89	6,78	6,78	7,73	21,29
Myrcia sp.	19	2088,80	25,42	3,06	8,06	1,23	7,25	16,52
Polypodium fraxinifolium	6	659,60	10,17	19,16	2,54	7,69	2,90	13,13
Geonoma schottiana	16	1539,10	20,34	1,39	5,93	0,56	5,80	12,29
Tapirira guianensis	6	659,60	10,17	15,92	2,54	6,39	2,90	11,83
Faramea cyanea	5	549,70	3,39	19,96	2,12	8,01	0,97	11,09
Protium heptaphyllum	5	549,70	8,47	13,71	2,12	5,50	2,42	10,04

Table 19 - Phytosociological parameters - sample site BANANAL - (cont.)

species	n	abs. dens.	abs. freq.	abs. dom.	rel. dens.	rel. dom.	rel. freq.	IVI
Myrsine umbellata	10	1099,40	13,56	4,39	4,24	1,76	3,86	9,86
Malanea macrophylla	9	989,40	16,25	0,53	3,81	0,21	4,36	8,37
Protium almecega	6	659,60	10,16	6,86	2,54	2,76	2,90	8,20
Hedyosmum brasiliense	5	549,70	8,47	0,72	2,12	0,29	2,42	4,82
Prunus chamissoana	5	549,70	8,47	0,67	2,12	0,27	2,42	4,80
Indet 22 (392-4)	2	219,90	3,39	6,44	0,85	2,58	0,97	4,40
Myrcia laruotteana	5	549,70	6,78	0,69	2,12	0,28	1,93	4,33
Erythroxylum daphnites	4	439,70	6,78	1,16	1,69	0,46	1,93	4,09
Styrax guianensis	3	329,80	5,08	3,31	1,27	1,33	1,46	4,06
Pera obovata	4	439,70	5,08	1,86	1,69	0,74	1,46	3,89
Myrsine guianensis	4	439,70	6,78	0,60	1,69	0,24	1,93	3,87
Erythroxylum anglerii	5	549,70	5,08	0,55	2,12	0,22	1,46	3,79
Prunus sellowii	4	439,70	5,08	1,41	1,69	0,57	1,46	3,71
Psychotria carthagenensis	5	439,70	6,78	0,20	1,69	0,08	1,93	3,71
Trichilia catigua	4	439,70	5,08	0,27	1,69	0,11	1,46	3,26
Gaylussacia brasiliensis	5	439,70	5,08	0,26	1,69	0,10	1,46	3,25
Cyathea sp.	2	219,90	3,39	3,06	0,85	1,23	0,97	3,04
Banisteriopsis sp.	2	219,90	3,39	2,70	0,85	1,09	0,97	2,90
Euplassa inaequalis	3	329,80	5,08	0,26	1,27	0,10	1,46	2,82
Ferdinandusa speciosa	4	439,70	3,39	0,40	1,69	0,16	0,97	2,82
Cybianthus glaber	3	329,80	5,08	0,12	1,27	0,05	1,46	2,77
Emmotum nitens	2	219,90	3,39	0,26	0,85	0,10	0,97	1,92
Indet 12 (414-3)	2	219,90	3,39	0,10	0,85	0,04	0,97	1,86
Myrcia pubipetala	2	219,90	1,69	1,16	0,85	0,46	0,48	1,79
Ilex affinis	2	219,9	1,69	0,3664	0,85	0,15	0,48	1,48
Indet 8 (396-2)	2	219.9	1,69	0,1123	0,85	0,05	0,48	1,38
Siphoneugena densiflora	1	219,90	1,69	0,07	0,85	0,03	0,48	1,36
Licania apetala	1	109,90	1,69	0,69	0,42	0,28	0,48	1,18
Tabebuia impetiginosa	1	109,90	1,69	0,50	0,42	0,20	0,48	1,11
Ocotea aciphylla	1	109,90	1,69	0,25	0,42	0,10	0,48	1,01
Coccoloba sp.	1	109,90	1,69	0,08	0,42	0,03	0,48	0,94
Ilex integrifolius	1	109,90	1,69	0,08	0,42	0,03	0,48	0,94
Symplocos mosenii	1	109,90	1,69	0,07	0,42	0,03	0,48	0,94
Miconia chamissois	1	109,90	1,69	0,06	0,42	0,02	0,48	0,93
Linociera arborea	1	109,90	1,69	0,06	0,42	0,02	0,48	0,93
Indet 10 (405-1)	1	109,90	1,69	0,05	0,42	0,02	0,48	0,93
Stylogyne ambigua	1	109,90	1,69	0,04	0,42	0,02	0,48	0,92
Guatteria sp.	1	109,90	1,69	0,04	0,42	0,02	0,48	0,92
Cabralea canjerana	1	109,90	1,69	0,04	0,42	0,01	0,48	0,92
Piper arboreum	1	109,90	1,69	0,04	0,42	0,01	0,48	0,92
Sapium obovatum	1	109,90	1,69	0,03	0,42	0,01	0,48	0,92
Inga affinis	1	109,90	1,69	0,03	0,42	0,01	0,48	0,92
Indet 6 (408-4)	1	109,90	1,69	0,03	0,42-	0,01	0,48	0,92
Banisteriopsis malifolia	1	109,90	1,69	0,03	0,42	0,01	0,48	0,92
Myrcia venulosa	1	109,90	1,69	0,02	0,42	0,01	0,48	0,92
Indet 1 (369-1)	1	109,90	1,69	0,02	0,42	0,01	0,48	0,92
Miconia sp.6	1	109.90	1,69	0,02	0,42	0,01	0,48	0,92

Note: 38 families, 46 genera and 57 species present. Three families account for 22 % of the species: Myrtaceae (5), Burseraceae (4) and Rubiaceae (4). Seven genera, Myrcia (4), Banisteriopsis (2), Erythroxylum (2), Ilex (2), Miconia (2), Myrsine (2) and Protium (2), have more than one species.

Table 20 - Phytosociological parameters - sample site CERRADO NOVO SETOR

no. of points = 60 | density = 514.72ind./ha | aver. point-plant dist. = 4.408m
no. of ind. = 240 | basal area = 11.948m2/ha | circ. > = 5cm
Shannon - Wiener H' = 3.34, evenness = 0.89

species	n	abs. dens.	abs. freq.	abs. dom.	rel. dens.	rel. dom.	rel. freq.	I V I
Qualea parviflora	21	45,00	28,67	2,94	8,75	24,84	7,62	41,00
Caryocar brasiliense	16	34,30	25,00	1,27	6,67	10,66	7,14	24,46
Dalbergia miscolobium	13	27,90	20,00	1,12	5,42	9,36	5,71	20,48
Syagrus comosa	17	36,60	23,33	0,72	7,08	6,01	6,67	19,76
Qualea grandiflora	12	25,70	18,33	1,09	5,00	9,10	5,24	19,33
Kielmeyera coriacea	24	51,50	28,33	0,08	10,00	0,66	8,10	18,74
Pouteria ramiflora	11	23,60	16,67	0,62	4,58	5,18	4,76	14,53
Pterodon pubescens	6	12,90	8,33	1,05	2,50	8,81	2,38	13,69
Salacia crassifolia	10	21,40	16,67	0,25	4,17	2,08	4,76	11,01
Eriotheca pubescens	10	21,40	13,33	0,16	4,17	1,31	3,81	9,28
Pouteria torta	5	10,70	6,67	0,52	2,08	4,36	1,90	8,35
Styrax ferrugineus	6	12,90	10,00	0,34	2,50	2,87	2,86	8,23
Piptocarpha rotundifolia	7	15,00	11,67	0,15	2,92	1,29	3,33	7,54
Aspidosperma tomentosum	8	17,20	13,33	0,03	3,33	0,23	3,81	7,38
Connarus suberosus var. fulvus	7	15,00	11,67	0,05	2,92	0,44	3,33	6,69
Byrsonima verbascifolia	6	12,90	8,33	0,10	2,50	0,83	2,38	5,71
Butia leiospatha	4	8,60	6,67	0,22	1,67	1,88	1,90	5,45
Ouratea hexasperma	6	12,90	5,00	0,13	2,50	1,11	1,43	5,03
Byrsonima crassa	4	8,60	6,67	0,11	1,67	0,89	1,90	4,46
Annona crassiflora	3	6,40	5,00	0,21	1,25	1,75	1,43	4,43
Guapira noxia	4	8,60	6,67	0,10	1,67	0,80	1,90	4,37
Acosmium dasycarpum	4	8,60	6,67	0,06	1,67	0,51	1,90	4,08
Erythroxylum suberosum	4	8,60	6,67	0,01	1,67	0,09	1,90	3,66
Syagrus flexuosa	4	8,60	5,00	0,05	1,67	0,38	1,43	3,48
Eremanthus glomerulatus	3	6,40	5,00	0,02	1,25	0,15	1,43	2,83
Qualea multiflora	1	2,10	1,67	0,17	0,42	1,46	0,48	2,36
Dimorphandra mollis	2	4,30	1,67	0,12	0,83	1,01	0,48	2,32
Lafoensia pacari	2	4,30	3,33	0,05	0,83	0,43	0,95	2,21
Erythroxylum tortuosum	2	4,30	3,33	0,01	0,83	0,12	0,95	1,90
Mimosa claussenii	2	4,30	3,33	0,01	0,83	0,07	0,95	1,86
Byrsonima coccolobifolia	2	4,30	3,33	0,00	0,83	0,04	0,95	1,82
Davilla elliptica	2	4,30	3,33	0,00	0,83	0,03	0,95	1,82
Tabebuia ochracea	2	4,30	3,33	0,00	0,83	0,03	0,95	1,82
Indet. (dead by fire)	1	2,10	1,67	0,07	0,42	0,62	0,48	1,52
Roupala montana	2	4,30	1,67	0,01	0,83	0,06	0,48	1,37
Hymenaea stigonocarpa var. pubescens	1	2,10	1,67	0,04	0,42	0,36	0,48	1,26
Strychnos pseudoquina	1	2,10	1,67	0,03	0,42	0,29	0,48	1,18
Machaerium opacum	1	2,10	1,67	0,01	0,42	0,06	0,48	0,95
Diospyros burchellii	1	2,10	1,67	0,00	0,42	0,02	0,48	0,92
Palicourea rigida	1	2,10	1,67	0,00	0,42	0,02	0,48	0,91
Neea theifera	1	2,10	1,67	0,00	0,42	0,02	0,48	0,91
Casearia sylvestris	1	2,10	1,67	0,00	0,42	0,01	0,48	0,90

Note: 28 families, 35 genera and 42 species present. Four familiesaccount for 38% of the species: Leguminosae (7), Malpighiaceae (3), Palmae (3) and Vochysiaceae (3). Four genera, Byrsonima (3), Qualea (3), Erythroxylum (2) and Pouteria (2), have more than one species.

Table 21 - Phytosociological parameters - sample site CERRADO MATO GROSSO

no. of points = 60 | density = 573.07ind./ha | aver. point-plant dist. = 4.177m
no. of ind. = 240 | basal area = 10.672m2/ha | circ. > = 5cm
Shannon - Wiener H' = 3.08, evenness = 0.82

species	n	abs. dens.	abs. freq.	abs. dom.	rel. dens.	rel. dom.	rel. freq.	I V I
Ouratea hexasperma	34	81,2	41,67	1,1136	14,17	10,43	11,96	36,56
Caryocar brasiliense	22	52,5	30	1,9323	9,17	18,11	8,61	35,88
Qualea parviflora	20	47,8	28,33	2,0622	8,33	19,23	8,13	35,7
Dalbergia miscolobium	20	47,8	25	1,5793	8,33	14,8	7,18	30,31
Qualea grandiflora	19	45,4	30	0,733	7,92	6,87	8,61	23,4
Kielmeyera coriacea	21	50,1	26,67	0,084	8,75	0,79	7,66	17,19
Qualea multiflora	13	31	20	0,4334	5,42	4,06	5,74	15,22
Piptocarpha rotundifolia	11	26,3	18,33	0,0819	4,58	0,77	5,26	10,61
Didymopanax macrocarpum	8	19,1	13,33	0,2212	3,33	2,07	3,83	9,23
Salacia crassifolia	7	16,7	11,67	0,2878	2,92	2,7	3,35	8,96
Miconia rubiginosa	6	14,3	10	0,2789	2,5	2,61	2,87	7,98
Sclerolobium paniculatum var. subvelutinum	6	14,3	10	0,1898	2,5	1,78	2,87	7,15
Annona crassiflora	2	4,8	3,33	0,2999	0,83	2,81	0,96	4,6
Enterolobium ellipticum	2	4,8	3,33	0,2832	0,83	2,66	0,96	4,44

Table 21 - Phytosociological parameters - sample site CERRADO MATO GROSSO - (cont.)

species	n	abs. dens.	abs. freq.	abs. dom.	rel. dens.	rel. dom.	rel. freq.	I V I
Styrax ferrugineus	3	7,2	5	0,1779	1,25	1,67	1,44	4,36
Davilla elliptica	4	9,6	6,67	0,0213	1,67	0,2	1,91	3,78
Erythroxylum suberosum	4	9,6	6,67	0,0106	1,67	0,1	1,91	3,68
Stryphnodendron adstringens	3	7,2	5	0,0426	1,25	0,4	1,44	3,08
Miconia fallax	2	4,8	3,33	0,1216	0,83	1,14	0,96	2,93
Aspidosperma tomentosum	3	7,2	5	0,0167	1,25	0,16	1,44	2,84
Machaerium opacum	2	4,8	3,33	0,0913	0,83	0,86	0,96	2,65
Pouteria torta	2	4,8	3,33	0,0668	0,83	0,62	0,96	2,41
Strychnos pseudo-quina	2	4,8	3,33	0,056	0,83	0,52	0,96	2,31
Blepharocalyx salicifolius	1	2,4	1,67	0,1293	0,42	1,21	0,48	2,11
Byrsonima crassa	2	4,8	3,33	0,0238	0,83	0,22	0,96	2,01
Erythroxilum tortuosum	3	7,2	1,67	0,0126	1,25	0,12	0,48	1,85
Tabebuia ochracea	2	4,8	3,33	0,0014	0,83	0,01	0,96	1,8
Guapira noxia	1	2,4	1,67	0,079	0,42	0,74	0,48	1,64
Byrsonima verbascifolia	2	4,8	1,67	0,0195	0,83	0,18	0,48	1,49
Hymenaea stigonocarpa var. pubescens	1	2,4	1,67	0,0598	0,42	0,56	0,48	1,46
Syagrus comosa	1	2,4	1,67	0,0438	0,42	0,41	0,48	1,31
Tabebuia aurea	1	2,4	1,67	0,0393	0,42	0,37	0,48	1,26
Eriotheca pubescens	1	2,4	1,67	0,0171	0,42	0,16	0,48	1,06
Piptocarpha macropoda	1	2,4	1,67	0,0129	0,42	0,12	0,48	1,02
Eremanthus glomerulatus	1	2,4	1,67	0,0129	0,42	0,12	0,48	1,02
Syagrus flexuosa	1	2,4	1,67	0,0129	0,42	0,12	0,48	1,02
Pouteria ramiflora	1	2,4	1,67	0,0124	0,42	0,12	0,48	1,01
Annona coriacea	1	2,4	1,67	0,0084	0,42	0,08	0,48	0,97
Mimosa claussenii	1	2,4	1,67	0,0043	0,42	0,04	0,48	0,94
Roupala montana	1	2,4	1,67	0,0043	0,42	0,04	0,48	0,94
Erythroxylum deciduum	1	2,4	1,67	0,0032	0,42	0,03	0,48	0,93
Byrsonima coccolobifolia	1	2,4	1,67	0,0015	0,42	0,01	0,48	0,91

Note: 25 families, 33 genera and 42 species present. Ten families account for 59% of the species: Leguminosae (7), Erythroxylaceae (3), Malpighiaceae (3), Vochysiaceae (3), Annonaceae (2), Bignoniaceae (2), Melastomataceae (2), Palmae (2) and Sapotaceae (2). Eight genera, *Byrsonima* (3), *Erythroxylum* (3), *Qualea* (3), *Miconia* (2), *Piptocarpha* (2), *Pouteria* (2), *Tabebuia* (2) and *Syagrus* (2), have more than one species.

Table 22 - Phytosociological parameters - sample site CERRADO CAPÃO COMPRIDO

no. of points = 60 | density = 811.38ind./ha | average point-plant distance = 3.511m
no. of ind. = 240 | basal area = 12.682m2/ha | circ. > = 5cm
Shannon - Wiener H' = 3.22, evenness = 0.80

species	n	abs. dens.	abs. freq.	abs. dom.	rel. dens.	rel. dom.	rel. freq.	I V I
Qualea grandiflora	52	175,80	55,00	5,5161	21,67	43,49	17,37	82,52
Qualea parviflora	15	50,70	21,67	1,385	6,25	10,92	6,84	24,01
Kielmeyera coriacea	28	94,70	26,67	0,0967	11,67	0,76	8,42	20,85
Eriotheca pubescens	13	43,90	18,33	0,8356	5,42	6,59	5,79	17,79
Syagrus flexuosa	15	50,70	20,00	0,336	6,25	2,66	6,32	15,21
Tabebuia ochracea	10	33,80	15,00	0,2672	4,17	2,11	4,74	11,01
Pseudobombax longiflorum	8	27,00	11,67	0,3305	3,33	2,61	3,68	9,62
Qualea glauca	4	13,50	5,00	0,651	1,67	5,13	1,58	8,38
Strychnos pseudoquina	3	10,10	5,00	0,5332	1,25	4,20	1,58	7,03
Dalbergia miscolobium	5	16,90	6,67	0,3084	2,08	2,43	2,11	6,62
Acosmium dasycarpum	5	16,90	8,33	0,092	2,08	0,73	2,63	5,44
Piptocarpha rotundifolia	5	16,90	8,33	0,0197	2,08	0,16	2,63	4,87
Guapira noxia	4	13,50	6,67	0,1015	1,67	0,80	2,11	4,57
Connarus suberosus var. fulvus	4	13,50	6,67	0,0158	1,67	0,12	2,11	3,90
Platypodium elegans	2	6,80	1,67	0,2716	0,83	2,14	0,53	3,50
Roupala montana	3	10,10	5,00	0,0747	1,25	0,59	1,58	3,42
Lafoensia pacari	3	10,10	5,00	0,0639	1,25	0,50	1,58	3,33
Terminalia fagifolia	4	13,50	3,33	0,0708	1,67	0,56	1,05	3,28
Machaerium acutifolium	4	13,50	5,00	0,0031	1,67	0,02	1,58	3,27
Plathymenia reticulata	2	6,80	3,33	0,1708	0,83	1,35	1,05	3,23
Copaifera langsdorffii	2	6,80	3,33	0,1332	0,83	1,05	1,05	2,94
Matayba guianensis	3	10,10	5,00	0,0031	1,25	0,02	1,58	2,85
Guettarda viburnioides	3	10,10	5,00	0,0022	1,25	0,02	1,58	2,85
Luehea paniculata	2	6,80	3,33	0,1105	0,83	0,87	1,05	2,75
Aspidosperma tomentosum	3	10,10	3,33	0,0118	1,25	0,09	1,05	2,40

Table 22 - Phytosociological parameters - sample site CERRADO CAPÃO COMPRIDO - (cont.)

species	n	abs. dens.	abs. freq.	abs. dom.	rel. dens.	rel. dom.	rel. freq.	I V I
Machaerium opacum	3	10,10	3,33	0,0096	1,26	0,08	1,06	2,38
Didymopanax macrocarpum	2	6,80	3,33	0,0663	0,83	0,44	1,06	2,33
Tabebuia aurea .	3	10,10	3,33	0,0026	1,26	0,02	1,06	2,32
Butia leiospatha	2	6,80	1,67	0,1176	0,83	0,93	0,53	2,29
Enterolobium gummiferum	1	3,40	1,67	0,1637	0,42	1,29	0,53	2,23
Qualea multiflora	1	3,40	1,67	0,1633	0,42	1,21	0,53	2,16
Diospyros burchellii	2	6,80	3,33	0,0272	0,83	0,21	1,06	2,10
Pseudobombax tomentosum	2	6,80	3,33	0,0212	0,83	0,17	1,06	2,06
Alibertia edulis	1	3,40	1,67	0,106	0,42	0,83	0,53	1,77
Sclerolobium aureum	1	3,40	1,67	0,0921	0,42	0,73	0,53	1,67
Bowdichia virgilioides	1	3,40	1,67	0,0814	0,42	0,64	0,53	1,58
Lithraea molleoides	1	3,40	1,67	0,077	0,42	0,61	0,53	1,56
Leg (319-2)	1	3,40	1,67	0,0713	0,42	0,56	0,53	1,51
Styrax ferrugineus	1	3,40	1,67	0,062	0,42	0,49	0,53	1,43
Annona crassiflora	1	3,40	1,67	0,0607	0,42	0,48	0,53	1,42
Myrcia rostrata	1	3,40	1,67	0,0594	0,42	0,47	0,53	1,41
Pouteria ramiflora	1	3,40	1,67	0,0569	0,42	0,45	0,53	1,39
Erythroxylum daphnites	1	3,40	1,67	0,0168	0,42	0,13	0,53	1,08
Banisteriopsis pubipetala	1	3,40	1,67	0,0108	0,42	0,08	0,53	1,03
Mimosa claussenii	1	3,40	1,67	0,0108	0,42	0,08	0,53	1,03
Myrcia tomentosa	1	3,40	1,67	0,0067	0,42	0,04	0,53	0,99
Aegiphila sellowiana	1	3,40	1,67	0,0063	0,42	0,04	0,53	0,98
Austroplenkia populnea	1	3,40	1,67	0,0039	0,42	0,03	0,53	0,97
Didymopanax morototoni	1	3,40	1,67	0,003	0,42	0,02	0,53	0,97
Blepharocalyx salicifolius	1	3,40	1,67	0,0022	0,42	0,02	0,53	0,96
Salacia crassifolia	1	3,40	1,67	0,0007	0,42	0,01	0,53	0,96
Zeyheria montana	1	3,40	1,67	0,0007	0,42	0,01	0,53	0,96
Hymenaea stigonocarpa	1	3,40	1,67	0,0007	0,42	0,01	0,53	0,96
Andira paniculata	1	3,40	1,67	0,0007	0,42	0,01	0,53	0,96
Neea theifera	1	3,40	1,67	0,0007	0,42	0,01	0,53	0,96

Note: 31 families, 45 genera and 55 species present. Six families account for 54.5% of the species: Leguminosae (14), Vochysiaceae (4), Bignoniaceae (3), Bombacaceae (3), Myrtaceae (3), and Rubiaceae (3). Six genera, *Qualea* (4), *Erythroxylum* (2), *Machaerium* (2), *Myrcia* (2), *Pseudobombax* (2) and *Tabebuia* (2) have more than one species.

Table 23 - Phytosociological parameters - sample site BARRAGEM

no. of points = 100 density = 1676.97ind./ha aver. point-plant dist. = 2.442m
no. of ind. = 400 basal area = 15.728m2/ha circ. > = 5cm
Shannon - Wiener H' = 3.64, evenness = 0.87

species	n	abs. dens.	abs. freq.	abs. dom.	rel. dens.	rel. dom.	rel. freq.	I V I
Qualea parviflora	32	134,20	23,00	2,61	8,00	16,63	6,55	31,18
Vellozia flavicans	22	92,20	18,00	1,45	5,50	9,21	5,13	19,84
Qualea grandiflora	21	88,00	18,00	1,49	5,25	9,46	5,13	19,84
Cassia claussenii	26	109,00	22,00	1,07	6,50	6,78	6,27	19,55
Kielmeyera coriacea	34	142,50	26,00	0,25	8,50	1,58	7,12	17,20
Ouratea hexasperma	27	113,20	24,00	0,45	6,75	2,85	6,84	16,43
Mimosa claussenii	15	62,90	15,00	0,58	3,75	3,66	4,27	11,68
Eriotheca pubescens	10	41,90	8,00	1,01	2,50	6,45	2,28	11,23
Butia leiospatha	10	41,90	10,00	0,81	2,50	5,14	2,85	10,49
Caryocar brasiliense	12	50,30	11,00	0,52	3,00	3,32	3,13	9,45
Roupala montana	14	58,70	11,00	0,10	3,50	0,66	3,13	7,29
Didymopanax macrocarpum	7	29,30	7,00	0,51	1,75	3,24	1,99	6,99
Annona crassiflora	8	33,50	8,00	0,41	2,00	2,60	2,28	6,88
Salacia crassifolia	11	46,10	11,00	0,14	2,75	0,87	3,13	6,75
Sclerolobium paniculatum var. subvelutinum	5	21,00	5,00	0,60	1,25	3,84	1,42	6,52
Aspidosperma tomentosum	9	37,70	9,00	0,18	2,25	1,14	2,56	5,96
Pouteria torta	7	29,30	7,00	0,28	1,75	1,78	1,99	5,52
Erythroxylum tortuosum	7	29,30	7,00	0,12	1,75	0,75	1,99	4,49
Dimorphandra mollis	4	16,80	4,00	0,35	1,00	2,24	1,14	4,38
Dalbergia miscolobium	6	25,20	6,00	0,16	1,50	1,02	1,71	4,23
Syagrus comosa	5	21,00	4,00	0,27	1,25	1,71	1,14	4,10
Connarus suberosus var. fulvus	6	25,20	6,00	0,04	1,50	0,28	1,71	3,49
Byrsonima verbascifolia	5	21,00	5,00	0,13	1,25	0,80	1,42	3,47
Eremanthus glomerulatus	6	25,20	5,00	0,08	1,50	0,53	1,42	3,45
Lafoensia pacari	6	25,20	6,00	0,03	1,50	0,18	1,71	3,38
Davilla elliptica	4	16,80	2,00	0,28	1,00	1,76	0,57	3,32
Piptocarpha rotundifolia	5	21,00	3,00	0,16	1,25	0,99	0,85	3,09
Machaerium opacum	4	16,80	3,00	0,18	1,00	1,16	0,85	3,01
Styrax ferrugineus	4	16,80	4,00	0,11	1,00	0,68	1,14	2,82
Byrsonima coccolobifolia	3	12,60	3,00	0,11	0,75	0,72	0,85	2,33
Erythroxylum suberosum	4	16,80	4,00	0,02	1,00	0,15	1,14	2,29

Table 23 - Phytosociological parameters - sample site BARRAGEM - (cont.)

species	n	abs. dens.	abs. freq.	abs. dom.	rel. dens.	rel. dom.	rel. freq.	IVI
Brosimum gaudichaudii	4	16,80	4,00	0,01	1,00	0,04	1,14	2,18
Enterolobium gummiferum	3	12,60	3,00	0,08	0,75	0,49	0,85	2,09
Pouteria ramiflora	3	12,60	3,00	0,08	0,75	0,48	0,85	2,09
Stryphnodendron adstringens	2	8,40	2,00	0,15	0,50	0,98	0,57	2,05
Strychnos pseudoquina	2	8,40	2,00	0,14	0,50	0,86	0,57	1,93
Diospyros burchellii	3	12,60	2,00	0,06	0,75	0,39	0,57	1,71
Austroplenkia populnea	2	8,40	2,00	0,10	0,50	0,62	0,57	1,69
Protium ovatum	3	12,60	3,00	0,00	0,75	0,02	0,85	1,62
Symplocos rhamnifolia	2	8,40	2,00	0,09	0,50	0,54	0,57	1,61
Tabebuia aurea	2	8,40	1,00	0,10	0,50	0,62	0,28	1,40
Acosmium dasycarpum	2	8,40	2,00	0,05	0,50	0,33	0,57	1,40
Psidium australe	2	8,40	2,00	0,05	0,50	0,31	0,57	1,38
Hymenaea stigonocarpa var. pubescens	3	12.60	2,00	0,01	0,75	0,04	0,57	1,36
Casearia sylvestris	3	12,60	2,00	0,01	0,75	0,03	0,57	1,35
Tocoyena formosa	2	8,40	2,00	0,01	0,50	0,07	0,57	1,14
Erythroxylum englerii	2	8,40	2,00	0,00	0,50	0,02	0,57	1,09
Neea theifera	2	8,40	2,00	0,00	0,50	0,02	0,57	1,09
Tabebuia ochracea	2	8,40	2,00	0,00	0,50	0,02	0,57	1,09
Anacardium humile	2	8,40	2,00	0,00	0,50	0,01	0,57	1,08
Heteropteris byrsonimifolia	1	4,20	1,00	0,06	0,25	0,39	0,28	0,93
Hancornia pubescens	1	4,20	1,00	0,06	0,25	0,39	0,28	0,93
Plathymenia reticulata	1	4,20	1,00	0,04	0,25	0,25	0,28	0,79
Sclerolobium aureum	1	4,20	1,00	0,04	0,25	0,23	0,28	0,77
Vochysia elliptica	1	4,20	1,00	0,04	0,25	0,22	0,28	0,76
Byrsonima crassa	1	4,20	1,00	0,03	0,25	0,19	0,28	0,73
Schefflera morototoni	1	4,20	1,00	0,01	0,25	0,09	0,28	0,62
Cybianthus detergens	1	4,20	1,00	0,01	0,25	0,06	0,28	0,60
Eremanthus goyazensis	1	4,20	1,00	0,01	0,25	0,05	0,28	0,59
Psidium myrsinoides	1	4,20	1,00	0,00	0,25	0,02	0,28	0,55
Miconia albicans	1	4,20	1,00	0,00	0,25	0,02	0,28	0,55
Machaerium acutifolium	1	4,20	1,00	0,00	0,25	0,01	0,28	0,55
Banisteriopsis argyrophylla	1	4,20	1,00	0,00	0,25	0,01	0,28	0,54
Hyptis saxatilis	1	4,20	1,00	0,00	0,25	0,01	0,28	0,54
Zeyheria montana	1	4,20	1,00	0,00	0,25	0,01	0,28	0,54

Note: 38 families, 55 genera and 65 species present. Six families account for 49% of the species: Leguminosae (13), Malpighiaceae (5), Bignoniaceae (3), Compositae (3), Erythroxylaceae (3) and Vochysiaceae (3). Six genera, Byrsonima (3), Erythroxylum (3), Eremanthus (2), Pouteria (2), Qualea (2) and Tabebuia (2), have more than one species.

Table 24 - Phytosociological parameters - sample site CERRADO TORTINHO

no. of points = 100
density = 563.61ind./ha
aver. point-plant dist. = 4.212m
no. of ind. = 400
basal area = 7.150m2/ha
circ. > = 5cm
Shannon - Weaner H' = 3.46, evenness = 0.86

species	n	abs. dens.	abs. freq.	abs. dom.	rel. dens.	rel. dom.	rel. freq.	IVI
Sclerolobium paniculatum var. subvelutinum	39	55	26	1,3841	9,75	19,36	7,6	36,71
Qualea parviflora	24	33,8	19	1,1225	6	15,7	5,56	27,26
Caryocar brasiliense	20	28,2	19	0,5741	5	8,03	5,56	18,59
Styrax ferrugineus	27	38	20	0,386	6,75	5,4	5,85	18
Miconia ligustroides	25	35,2	21	0,1735	6,25	2,43	6,14	14,82
Kielmeyera coriacea	22	31	20	0,2097	5,5	2,93	5,85	14,28
Miconia pohliana	17	24	14	0,3176	4,25	4,44	4,09	12,79
Byrsonima coccolobifolia	17	24	15	0,1916	4,25	2,68	4,39	11,32
Erythroxylum suberosum	21	29,6	18	0,0572	5,25	0,8	5,26	11,31
Roupala montana	22	31	16	0,027	5,5	0,38	4,68	10,56
Vochysia thyrsoidea	4	5,6	4	0,5673	1	7,93	1,17	10,1
Byrsonima verbascifolia	12	16,9	12	0,1517	3	2,12	3,51	8,63
Qualea multiflora	7	9,9	7	0,3333	1,75	4,66	2,05	8,46
Dalbergia miscolobium	11	15,5	10	0,1438	2,75	2,01	2,92	7,69
Vellozia flavicans	8	11,3	7	0,2097	2	2,93	2,05	6,98
Eremanthus glomerulatus	11	15,5	11	0,0437	2,75	0,61	3,22	6,58
Pouteria ramiflora	5	7	5	0,1941	1,25	2,71	1,46	5,43
Connarus suberosus	9	12,7	8	0,038	2,25	0,53	2,34	5,12
Ouratea hexasperma	9	12,7	8	0,0373	2,25	0,52	2,34	5,11
Qualea grandiflora	5	7	5	0,1568	1,25	2,19	1,46	4,91
Austroplenkia populnea	7	9,9	7	0,0563	1,75	0,79	2,05	4,58
Blepharocalyx salicifolius	2	2,8	2	0,2291	0,5	3,2	0,58	4,29
Vochysia elliptica	5	7	5	0,078	1,25	1,09	1,46	3,8
Aspidosperma tomentosum	7	9,9	6	0,0094	1,75	0,13	1,75	3,64
Stryphnodendron adstringens	5	7	5	0,066	1,25	0,92	1,46	3,63

Table 24 - Phytosociological parameters - sample site CERRADO TORTINHO - (cont.)

species	n	abs. dens.	abs. freq.	abs. dom.	rel. dens.	rel. dom.	rel. freq.	IVI
Mimosa claussenii	6	8,5	5	0,0236	1,5	0,33	1,46	3,29
Acosmium dasycarpum	5	7	4	0,0083	1,25	0,12	1,17	2,54
Diospyros burchellii	4	5,6	4	0,0033	1	0,05	1,17	2,22
Psidium myrsinoides	4	5,6	4	0,002	1	0,03	1,17	2,2
Salacia crassifolia	4	5,6	3	0,0196	1	0,27	0,88	2,15
Symplocos lanceolata	2	2,8	2	0,072	0,5	1,01	0,58	2,09
Syagrus comosa	2	2,8	2	0,0646	0,5	0,9	0,58	1,99
Tocoyena formosa	3	4,2	3	0,0012	0,75	0,02	0,88	1,64
Pouteria torta	3	4,2	2	0,0142	0,75	0,2	0,58	1,53
Miconia sp.10	2	2,8	2	0,013	0,5	0,18	0,58	1,27
Pterodon pubescens	1	1,4	1	0,0503	0,25	0,7	0,29	1,25
Butia leiospatha	1	1,4	1	0,0431	0,25	0,6	0,29	1,15
Didymopanax macrocarpum	2	2,8	1	0,0031	0,5	0,04	0,29	0,84
Eriotheca pubescens	1	1,4	1	0,0207	0,25	0,29	0,29	0,83
Miconia sp.11	1	1,4	1	0,0198	0,25	0,28	0,29	0,82
Banisteriopsis sp.3	2	2,8	1	0,0009	0,5	0,01	0,29	0,81
Clethra scabra	2	2.8	1	0,0006	0,5	0,01	0,29	0,8
Miconia rubiginosa	1	1,4	1	0,007	0,25	0,1	0,29	0,64
Eremanthus goyazensis	1	1,4	1	0,0065	0,25	0,09	0,29	0,63
Enterolobium gummiferum	1	1,4	1	0,0045	0,25	0,06	0 29	0,61
Erythroxylum campestre	1	1,4	1	0,0031	0,25	0,04	0,29	0,59
Erythroxylum tortuosum	1	1,4	1	0,0029	0,25	0,04	0,29	0,58
Xylopia aromatica	1	1,4	1	0,0027	0,25	0,04	0,29	0,58
Banisteriopsis schizoptera	1	1,4	1	0,0014	0,25	0,02	0.29	0,56
Miconia albicans	1	1,4	1	0,001	0,25	0,01	0,29	0,56
Miconia burchellii	1	1,4	1	0,0006	0,25	0,01	0,29	0,55
Psidium warmingianum	1	1,4	1	0,0006	0,25	0,01	0,29	0,55
Davilla elliptica	1	1,4	1	0,0006	0,25	0,01	0,29	0,55
Siphoneugena densiflora	1	1,4	1	0,0004	0,25	0,01	0,29	0,55
Neea theifera	1	1,4	1	0,0003	0,25	0	0,29	0,55
Protium ovatum	1	1,4	1	0,0003	0,25	0	0,29	0,55

Note: 31 families, 42 genera and 56 species present. Six families account for 62.5% of the species: Leguminosae (9), Melastomataceae (7), Myrtaceae (6), Malpighiaceae (5), Vochysiaceae (5) and Erythroxylaceae (3). Eight genera, *Miconia* (7), *Erythroxylum* (3), *Qualea* (3), *Banisteriopsis* (2), *Byrsonima* (2), *Eremanthus* (2), *Pouteria* (2) and *Vochysia* (2), have more than one species.

Table 25 - Phytosociological parameters - sample site CERRADO TORRE

no. of points = 30
no. of ind. = 120
Shannon - Wiener H' = 3.14, evenness = 0.82

density = 5,630 ind./ha
basal area = 8.562m2/ha

aver. point-plant dist. = 1.33m
circ. > = 5cm

species	n	abs. dens.	abs. freq.	abs. dom.	rel. dens.	rel. dom.	rel. freq.	IVI
Ouratea hexasperma	14	656,9	30	1,6254	11,67	18,98	9,74	39,39
Eremanthus glomerulatus	8	375,4	20	0,9047	6,67	10,57	5,83	23,06
Roupala montana	10	469,2	33,33	0,2549	8,33	2,98	9,71	21,02
Connarus suberosus var. fulvus	5	234,6	16,67	0,9814	4,17	11,46	4,85	20,48
Salacia crassifolia	7	328,5	20	0,5129	5,83	5,99	5,83	17,65
Caryocar brasiliense	6	281,5	16,67	0,4906	5	5,73	4,85	15,58
Vellozia flavicans	5	234,6	13,33	0,5616	4,17	6,56	3,88	14,61
Machaerium opacum	7	328,5	23,33	0,148	5,83	1,73	6,8	14,36
Kielmeyera coriacea	7	328,5	16,67	0,293	5,83	3,42	4,85	14,11
Pouteria torta	6	281,5	13,33	0,2508	5	2,93	3,88	11,81
Aspidosperma tomentosum	5	234,6	16,67	0,234	4,17	2,73	4,85	11,75
Qualea parviflora	5	234,6	13,33	0,2287	4,17	2,67	3,88	10,72
Austroplenkia populnea	4	187,7	13,33	0,1868	3,33	2,18	3,88	9,4
Neea theifera	4	187,7	13,33	0,0894	3,33	1,04	3,88	8,26
Erythroxylum suberosum	3	140,8	10	0,1983	2,5	2,32	2,91	7,73
Sclerolobium paniculatum var. subvelutinum	2	93,8	6,67	0,2949	1,67	3,44	1,94	7,05
Palicourea rigida	2	93,8	6,67	0,1851	1,67	2,16	1,94	5,77
Dalbergia miscolobium	2	93,8	6,67	0,1688	1,67	1,97	1,94	5,58
Enterolobium ellipticum	2	93,8	6,67	0,1289	1,67	1,51	1,94	5,11
Diospyros burchellii	2	93,8	6,67	0,0682	1,67	0,8	1,94	4,4
Erythroxylum tortuosum	2	93,8	3,33	0,1415	1,67	1,65	0,97	4,29
Erythroxylum deciduum	2	93,8	6,67	0,0466	1,67	0,54	1,94	4,15
Lafoensia pacari	2	93,8	3,33	0,1199	1,67	1.4	0,97	4,04
Byrsonima verbascifolia	2	93,8	6,67	0,0247	1,67	0,29	1,94	3,9
Qualea grandiflora	1	46,9	3,33	0,1495	0,83	1,76	0,97	3,55

Table 26 - Phytosociological parameters - sample site CERRADO TORRE - (cont.)

species	n	abs. dens.	abs. freq.	abs. dom.	rel. dens.	rel. dom.	rel. freq.	IVI
Acosmium dasycarpum	1	46,9	3,33	0,121	0,83	1,41	0,97	3,22
Mimosa claussenii	1	46,9	3,33	0,1016	0,83	1,19	0,97	2,99
Aegiphila sellowiana	1	46,9	3,33	0,0301	0,83	0,36	0,97	2,16
Byrsonima coccolobifolia	1	46,9	3,33	0,0113	0,83	0,13	0,97	1,94
Heteropteris cf. procoriacea	1	46,9	3,33	0,0093	0,83	0,11	0,97	1,91

Note: 22 families, 25 genera and 30 species present. Four families account for 36% of the species: Leguminosae (3), Malpighiaceae (3), Erythroxylaceae (3) and Vochysiaceae (2). Three genera, Erythroxylum (3), Qualea (3) and Byrsonima (3), have more than one species.

Table 26 - Phytosociological parameters - sample site TRES BURACOS 1

no. of points = 60 density = 3677.36ind./ha aver. point-plant dist. = 1.672m
no. of ind. = 240 basal area = 8.214m2/ha circ. > = 5cm
Shannon - Wiener H' = 3.03, evenness = 0.86

species	n	abs. dens.	abs. freq.	abs. dom.	rel. dens.	rel. dom.	rel. freq.	IVI
Erythroxylum suberosum	41	611,10	60,00	1,09	17,08	13,26	16,31	46,66
Vellozia flavicans	12	178,90	20,00	2,14	5,00	26,01	6,12	37,13
Connarus suberosus var. fulvus	26	387,50	31,67	0,64	10,83	6,56	9,69	27,08
Cassia orbiculata	10	149,10	13,33	1,13	4,17	13,71	4,08	21,96
Eremanthus glomerulatus	19	283,20	21,67	0,36	7,92	4,40	6,63	18,94
Kielmeyera coriacea	14	208,70	16,67	0,60	5,83	7,32	5,10	18,25
Byrsonima verbascifolia	13	193,80	18,33	0,39	5,42	4,70	5,61	15,73
Neea theifera	12	178,90	18,33	0,18	5,00	2,21	5,61	12,82
Mimosa claussenii	8	119,20	8,33	0,47	3,33	5,68	2,55	11,56
Aspidosperma tomentosum	9	134,20	15,00	0,08	3,75	0,97	4,59	9,31
Salacia crassifolia	9	134,20	13,33	0,10	3,75	1,18	4,08	9,01
Roupala montana	8	119,20	10,00	0,14	3,33	1,73	3,06	8,13
Davilla elliptica	7	104,30	10,00	0,18	2,92	2,13	3,06	8,11
Tabebuia ochracea	7	104,30	10,00	0,05	2,92	0,66	3,06	6,63
Tocoyena formosa	5	74,50	8,33	0,09	2,08	1,08	2,55	5,72
Erythroxylum tortuosum	4	59,60	6,67	0,09	1,67	1,13	2,04	4,84
Erythroxylum deciduum	4	59,60	6,67	0,06	1,67	0,76	2,04	4,46
Zeyheria montana	4	59,60	6,67	0,02	1,67	0,24	2,04	3,95
Brosimum gaudichaudii	4	59,60	5,00	0,02	1,67	0,26	1,53	3,45
Acosmium dasycarpum	3	44,70	5,00	0,03	1,25	0,37	1,53	3,15
Butia leiospatha	2	29,80	1,67	0,14	0,83	1,71	0,51	3,06
Diospyros burchellii	3	44,70	3,33	0,05	1,25	0,56	1,02	2,83
Eremanthus goyazensis	2	29,80	3,33	0,05	0,83	0,61	1,02	2,47
Pouteria torta	2	29,80	3,33	0,02	0,83	0,29	1,02	2,14
Byrsonima coccolobifolia	2	29,80	3,33	0,02	0,83	0,27	1,02	2,13
Qualea multiflora	1	14,90	1,67	0,08	0,42	0,94	0,51	1,87
Symplocos rhamnifolia	1	14,90	1,67	0,04	0,42	0,47	0,51	1,39
Ouratea hexasperma	1	14,90	1,67	0,02	0,42	0,23	0,51	1,16
Palicourea rigida	1	14,90	1,67	0,01	0,42	0,17	0,51	1,10
Dalbergia miscolobium	1	14,90	1,67	0,01	0,42	0,14	0,51	1,07
Eriotheca pubescens	1	14,90	1,67	0,01	0,42	0,10	0,51	1,03
Psidium warmingianum	1	14,90	1,67	0,01	0,42	0,06	0,51	0,99
Bauhinia rufa	1	14,90	1,67	0,00	0,42	0,04	0,51	0,96
Sabicea brasiliensis	1	14,90	1,67	0,00	0,42	0,04	0,51	0,96
Tabebuia aurea	1	14,90	1,67	0,00	0,42	0,04	0,51	0,96

Note: 25 families, 33 genera and 35 species present. Four families account for 40% of the species: Leguminosae (5), Bignoniaceae (3), Erythroxylaceae (3) and Rubiaceae (3). Three genera, *Erythroxylum* (3), *Byrsonima* (2) and *Eremanthus* (2), have more than one species.

Table 27 - Phytosociological parameters - sample site TRES BURACOS 2

no. of points = 60 density = 990.32ind./ha aver. point-plant dist. = 3.178m
no. of ind. = 240 basal area = 8.828m2/ha circ. > = 5cm
Shannon - Wiener H' = 2.13, evenness = 0.66

species	n	abs. dens.	abs. freq.	abs. dom.	rel. dens.	rel. dom.	rel. freq.	IVI
Vellozia flavicans	121	499,30	80,00	7,30	50,42	82,71	30,19	163,31
Erythroxylum suberosum	18	74,30	28,33	0,14	7,50	1,58	10,69	19,77
Cassia orbiculata	10	41,30	15,00	0,51	4,17	5,82	5,66	15,65
Kielmeyera coriacea	13	53,60	20,00	0,06	5,42	0,73	7,55	13,70
Tabebuia ochracea	8	33,00	13,33	0,23	3,33	2,57	5,03	10,93
Aspidosperma tomentosum	11	45,40	15,00	0,02	4,58	0,21	5,66	10,46
Palicourea rigida	6	24,80	10,00	0,04	2,50	0,42	3,77	6,70
Davilla elliptica	6	24,80	10,00	0,04	2,50	0,40	3,77	6,67

Table 27 - Phytosociological parameters - sample site TRES BURACOS 2 - (cont.)

species	n	abs. dens.	abs. freq.	abs. dom.	rel. dens.	rel. dom.	rel. freq.	IVI
Eugenia bimarginata	6	24,80	10,00	0,02	2,50	0,22	3,77	6,49
Butia leiospatha	3	12,40	5,00	0,24	1,25	2,75	1,89	5,89
Eremanthus glomerulatus	5	20,60	6,67	0,02	2,08	0,17	2,52	4,77
Stryphnodendron adstringens	5	20,60	5,00	0,06	2,08	0,63	1,89	4,60
Tocoyena formosa	4	16,50	6,67	0,02	1,67	0,18	2,52	4,36
Erythroxylum tortuosum	3	12,40	5,00	0,03	1,25	0,36	1,89	3,50
Byrsonima verbascifolia	3	12,40	5,00	0,02	1,25	0,19	1,89	3,32
Dalbergia miscolobium	3	12,40	5,00	0,02	1,25	0,18	1,89	3,32
Tabebuia aurea	3	12,40	5,00	0,01	1,25	0,13	1,89	3,27
Enterolobium gummiferum	2	8,30	3,33	0,02	0,83	0,19	1,26	2,28
Neea theifera	2	8,30	3,33	0,00	0,83	0,05	1,26	2,14
Indet 27 (639-1)	1	4,10	1,67	0,02	0,42	0,18	0,63	1,23
Solanum crinitum	1	4,10	1,67	0,01	0,42	0,08	0,63	1,13
Ouratea hexasperma	1	4,10	1,67	0,01	0,42	0,07	0,63	1,12
Eremanthus goyazensis	1	4,10	1,67	0,01	0,42	0,06	0,63	1,10
Pouteria ramiflora	1	4,10	1,67	0,00	0,42	0,04	0,63	1,09
Eriotheca pubescens	1	4,10	1,67	0,00	0,42	0,03	0,6[illegible]	1,08
Psidium myrsinoides	1	4,10	1,67	0,00	0,42	0,02	0,63	1,06
Salacia crassifolia	1	4,10	1,67	0,00	0,42	0,01	0,63	1,06

Note: 21 families, 24 genera and 27 species present. Six families account for 59% of the species: Leguminosae (4), Bignoniaceae (2), Erythroxylaceae (2), Malpighiaceae (2), Myrtaceae (2) and Rubiaceae (2). Three genera, Eremanthus, Erythroxylum and Tabebuia, have two species, all others are represented by a single species.

Table 28 - Phytosociological parameters - sample site RAPVELL

no. of points = 20   density = 3768.68ind./ha   aver. point-plant dist. = 1.629m

no. of ind. = 80   basal area = 6.195m2/ha   circ. >= 5cm

Shannon - Wiener H' = 1.68, evenness = 0.70

species	n	abs. dens.	abs. freq.	abs. dom.	rel. dens.	rel. dom.	rel. freq.	IVI
Roupala montana	23	1083,60	70,00	1,36	28,75	21,72	29,79	80,26
Myrsine guianensis	32	1507,40	55,00	0,73	40,00	11,78	23,40	75,18
Vellozia flavicans	5	235,50	25,00	1,61	6,25	25,94	10,64	42,83
Erythroxylum tortuosum	7	329,80	30,00	0,62	8,75	10,04	12,77	31,56
Butia leiospatha	1	47,10	5,00	1,24	1,25	20,00	2,13	23,38
Connarus suberosus var. fulvus	5	235,50	15,00	0,36	6,25	5,59	6,38	18,23
Diospyros burchellii	2	94,20	10,00	0,06	2,50	0,88	4,26	7,63
Tabebuia ochracea	2	94,20	10,00	0,03	2,50	0,54	4,26	7,29
Vochysia elliptica	1	47,10	5,00	0,12	1,25	1,96	2,13	5,34
Styrax ferrugineus	1	47,10	5,00	0,06	1,25	0,95	2,13	4,32
Salacia crassifolia	1	47,10	5,00	0,04	1,25	0,60	2,13	3,98

Note: 11 families, 11 genera and 11 species present.

Cerrado scrub with emergents - Phytosociological parameters

Table 29 - Phytosociological parameters - sample site VOCHYSIA 1

no. of points = 60 density = 4798.39ind./ha aver. point-plant dist. = 1.444m
no. of ind. = 240 basal area = 29.067m2/ha circ. > = 5cm
Shannon - Wiener H' = 2.80, evenness = 0.82

species	n	abs. dens.	abs. freq.	abs. dom.	rel. dens.	rel. dom.	rel. freq.	IVI
Vellozia flavicans	48	910,00	66,17	7,47	18,97	25,68	16,58	61,23
Mimosa claussenii	17	351,80	24,14	12,06	7,33	41,49	7,25	56,07
Qualea parviflora	21	413,70	22,41	3,74	8,62	12,86	6,74	28,21
Banisteriopsis latifolia	25	475,70	32,76	0,33	9,91	1,12	9,84	20,88
Syagrus comosa	10	206,80	17,24	2,07	4,31	7,12	5,18	16,61
Myrsine guianensis	21	413,70	24,14	0,18	8,62	0,62	7,25	16,49
Cassia orbiculata	10	206,80	17,24	1,31	4,31	4,50	5,18	13,99
Roupala montana	14	289,60	22,41	0,33	6,03	1,14	6,74	13,91
Diospyros burchellii	13	268,90	17,24	0,35	5,60	1,20	5,18	11,98
Ouratea hexasperma	12	248,20	18,97	0,25	5,17	0,86	5,70	11,73
Vochysia elliptica	8	165,60	13,79	0,33	3,46	1,15	4,15	8,74
Acosmium dasycarpum	8	165,60	12,07	0,16	3,46	0,52	3,63	7,60
Byrsonima coccolobifolia	5	103,40	8,62	0,04	2,16	0,13	2,59	4,87
Erythroxylum suberosum	5	103,40	6,90	0,15	2,16	0,50	2,07	4,73
Byrsonima crassa	3	62,00	5,17	0,06	1,29	0,20	1,56	3,05
Tocoyena formosa	3	62,00	5,17	0,05	1,29	0,16	1,56	3,00
Neea theifera	3	62,00	5,17	0,03	1,29	0,12	1,56	2,97
Caryocar brasiliense	2	41,40	3,45	0,03	0,86	0,10	1,04	1,99
Pouteria ramiflora	1	20,70	1,72	0,03	0,43	0,10	0,52	1,04
Kielmeyera coriacea	1	20,70	1,72	0,02	0,43	0,08	0,52	1,03
Psidium myrsinoides	1	20,70	1,72	0,02	0,43	0,07	0,52	1,02
Guapira noxia	1	20,70	1,72	0,02	0,43	0,07	0,52	1,02
Hymenaea stigonocarpa var. pubescens	1	20,70	1,72	0,01	0,43	0,04	0,52	0,99
Eremanthus glomerulatus	1	20,70	1,72	0,01	0,43	0,04	0,52	0,99
Schefflera macrocarpum	1	20,70	1,72	0,01	0,43	0,04	0,52	0,99
Tabebuia ochracea	1	20,70	1,72	0,01	0,43	0,03	0,52	0,98
Psidium warmingianum	1	20,70	1,72	0,01	0,43	0,03	0,52	0,98
Salacia crassifolia	1	20,70	1,72	0,01	0,43	0,02	0,52	0,97
Connarus suberosus var. fulvus	1	20,70	1,72	0,01	0,43	0,02	0,52	0,97
Stryphnodendron adstringens	1	20,70	1,72	0,00	0,43	0,01	0,52	0,96

Note:23 families, 29 genera and 30 species present. Two families account for 27% of the species: Leguminosae (5) and Malpighiaceae (3). Two genera, *Byrsonima* and *Psidium* have two species, all others are represented by a single species.

Table 30 - Phytosociological parameters - sample site VOCHYSIA 2

no. of points = 30 density = 6259.06ind./ha aver. point-plant dist. = 1.264m
no. of ind. = 120 basal area = 14.702m2/ha circ. > = 5cm
Shannon - Wiener H' = 2.71, evenness = 0.83

species	n	abs. dens.	abs. freq.	abs. dom.	rel. dens.	rel. dom.	rel. freq.	IVI
Vellozia flavicans	16	868,10	35,48	4,46	13,71	30,30	12,22	56,23
Psidium myrsinoides	16	958,10	32,26	1,67	13,71	11,38	11,11	36,20
Myrsine guianensis	23	1261,90	32,26	0,45	20,16	3,06	11,11	34,34
Vochysia thyrsoidea	2	101,00	6,45	3,54	1,61	24,09	2,22	27,92
Roupala montana	13	656,20	32,26	0,35	10,48	2,41	11,11	24,00
Couepia grandiflora	6	302,90	16,13	0,25	4,84	1,68	5,56	12,08
Miconia albicans	2	101,00	6,45	1,19	1,61	8,07	2,22	11,90
Ouratea hexasperma	6	302,90	16,13	0,14	4,84	0,93	5,56	11,33
Miconia pohliana	3	151,40	9,68	0,42	2,42	2,89	3,33	8,64
Vochysia elliptica	2	101,00	6,45	0,64	1,61	4,34	2,22	8,17
Tabebuia ochracea	3	151,40	9,68	0,25	2,42	1,72	3,33	7,48
Diospyros burchellii	4	201,90	9,68	0,11	3,23	0,72	3,33	7,28
Palicourea rigida	3	151,40	9,68	0,22	2,42	1,53	3,33	7,28
Kielmeyera coriacea	2	101,00	6,45	0,23	1,61	1,58	2,22	5,41
Mimosa claussenii	2	101,00	6,45	0,15	1,61	1,00	2,22	4,84
Acosmium dasycarpum	2	101,00	6,45	0,08	1,61	0,56	2,22	4,38
Connarus suberosus var. fulvus	2	101,00	6,45	0,08	1,61	0,54	2,22	4,37
Styrax ferrugineus	2	101,00	6,45	0,08	1,61	0,52	2,22	4,35
Eremanthus glomerulatus	2	101,00	6,45	0,06	1,61	0,36	2,22	4,19
Malpighiaceae (1021-4)	2	101,00	6,45	0,04	1,61	0,24	2,22	4,08
Vernonia ferruginea	2	101,00	6,45	0,02	1,61	0,14	2,22	3,97
Austroplenkia populnea	1	50,50	3,23	0,10	0,81	0,70	1,11	2,62
Byrsonima coccolobifolia	1	50,50	3,23	0,08	0,81	0,58	1,11	2,49
Eremanthus goyazensis	1	50,50	3,23	0,07	0,81	0,50	1,11	2,42
Annona crassiflora	1	50,50	3,23	0,01	0,81	0,10	1,11	2,02
Fabaceae (1018-1)	1	50,50	3,23	0,01	0,81	0,08	1,11	2,00

Note: 20 families, 22 genera and 26 species present. Two families account for 23% of the species: Compositae (3) and Leguminosae (3). Three genera, *Eremanthus*, *Miconia* and *Vochysia* have two species, all others are represented by a single species.

Table 31 - Phytosociological parameters - sample site TORRE 1

no. of points = 20 | density = 1046.42ind./ha | aver. point-plant dist. = 3.091m
no. of ind. = 80 | basal area = 1.399m2/ha | circ. >= 5cm
Shannon - Wiener H' = 1.87, evenness = 0.78

species	n	abs. dens.	abs. freq.	abs. dom.	rel. dens.	rel. dom.	rel. freq.	I V I
Erythroxylum tortuosum	18	235,4	70	0,6616	22,5	47,3	24,14	93,94
Neea theifera	29	379,3	80	0,1856	36,25	13,27	27,59	77,11
Salacia crassifolia	10	130,8	35	0,1763	12,5	12,61	12,07	37,17
Erythroxylum suberosum	5	65,4	20	0,0986	6,25	7,05	6,9	20,19
Palicourea rigida	6	78,5	25	0,04	7,5	2,86	8,62	18,98
Kielmeyera coriacea	4	52,3	20	0,045	5	3,22	6,9	15,12
Eriotheca pubescens	1	13,1	5	0,1203	1,25	8,6	1,72	11,57
Byrsonima subterranea	2	26,2	10	0,0409	2,5	2,92	3,45	8,87
Byrsonima verbascifolia	2	26,2	10	0,017	2,5	1,21	3,45	7,16
Davilla elliptica	2	26,2	10	0,0083	2,5	0,59	3,45	6,54
Sabicea brasiliensis	1	13,1	5	0,0051	1,25	0,37	1,72	3,34

Note: 8 families, 9 genera and 11 species present. Two genera, *Erythroxylum* and *Byrsonima*, have two species, all others are represented by a single species.

Table 32 - Phytosociological parameters - sample site CAMPO SUJO NOVO SETOR

no. of points = 30 | density = 800.47ind./ha | aver. point-plant dist. = 3.534m
no. of ind. = 120 | basal area = 1.326m2/ha | circ. >= 5cm
Shannon - Wiener H' = 2.03, evenness = 0.69

species	n	abs. dens.	abs. freq.	abs. dom.	rel. dens.	rel. dom.	rel. freq.	I V I
Kielmeyera coriacea	34	226,80	70,00	0,45	28,33	34,10	26,58	89,01
Connarus suberosus var. fulvus	41	273,50	66,67	0,29	34,17	21,66	25,32	81,14
Aspidosperma tomentosum	12	80,00	23,33	0,07	10,00	5,29	8,86	24,15
Butia leiospatha	3	20,00	10,00	0,20	2,50	14,81	3,80	21,11
Byrsonima verbascifolia	3	20,00	10,00	0,14	2,50	10,21	3,80	16,51
Dalbergia miscolobium	4	26,70	13,33	0,04	3,33	2,91	5,06	11,30
Tabebuia ochracea	4	26,70	13,33	0,02	3,33	1,82	5,06	10,22
Pouteria torta	3	20,00	10,00	0,01	2,50	0,83	3,80	7,12
Annona crassiflora	2	13,30	6,67	0,03	1,67	2,26	2,53	6,46
Diospyros burchellii	3	20,00	6,67	0,01	2,50	0,39	2,53	5,42
Acosmium dasycarpum	3	20,00	6,67	0,00	2,50	0,34	2,53	5,37
Roupala montana	1	6,70	3,33	0,02	0,83	1,85	1,27	3,95
Davilla elliptica	1	6,70	3,33	0,01	0,83	1,02	1,27	3,12
Erythroxylum suberosum	1	6,70	3,33	0,01	0,83	0,79	1,27	2,88
Dimorphandra mollis	1	6,70	3,33	0,01	0,83	0,79	1,27	2,88
Salacia crassifolia	1	6,70	3,33	0,01	0,83	0,58	1,27	2,68
Styrax ferrugineus	1	6,70	3,33	0,00	0,83	0,14	1,27	2,24
Pouteria ramiflora	1	6,70	3,33	0,00	0,83	0,12	1,27	2,22
Tocoyena formosa	1	6,70	3,33	0,00	0,83	0,10	1,27	2,20

Note: 17 families, 18 genera and 19 species present. Two families account for 26% of the species: Leguminosae (3) and Sapotaceae (2). Only one genus, *Pouteria*, has two species, all others are represented by a single species.

Table 33 - Phytosociological parameters - sample site CAMPO SUJO MATOGROSSO

no. of points = 30 | density = 1069.62ind./ha | aver. point-plant dist. = 3.058m
no. of ind. = 120 | basal area = 2.018m2/ha | circ. >= 5cm
Shannon - Wiener H' = 2.52, evenness = 0.78

species	n	abs. dens.	abs. freq.	abs. dom.	rel. dens.	rel. dom.	rel. freq.	I V I
Connarus suberosus var. fulvus	33	294,10	60,00	0,57	27,50	28,24	20,22	75,96
Kielmeyera coriacea	19	169,40	43,33	0,30	15,83	14,81	14,61	45,25
Erythroxylum tortuosum	9	80,20	26,67	0,27	7,50	13,58	8,99	30,07
Neea theifera	13	115,90	33,33	0,07	10,83	3,71	11,24	25,78
Tabebuia ochracea	7	62,40	20,00	0,12	5,83	6,07	6,74	18,65
Stryphnodendron adstringens	5	44,60	13,33	0,11	4,17	5,28	4,49	13,94
Ouratea hexasperma	3	26,70	10,00	0,10	2,50	5,13	3,37	11,00
Aspidosperma tomentosum	5	44,60	13,33	0,02	4,17	1,16	4,49	9,81
Pouteria ramiflora	4	35,70	10,00	0,04	3,33	2,08	3,37	8,78
Eremanthus glomerulatus	3	26,70	10,00	0,02	2,50	0,94	3,37	6,81
Syagrus flexuosa	2	17,80	6,67	0,05	1,67	2,28	2,25	6,20
Pouteria torta	2	17,80	6,67	0,03	1,67	1,55	2,25	5,47
Qualea parviflora	1	8,90	3,33	0,06	0,83	2,76	1,12	4,71
Qualea grandiflora	1	8,90	3,33	0,05	0,83	2,38	1,12	4,34

Table 33 - Phytosociological parameters - sample site CAMPO SUJO MATOGROSSO - (cont.)

species	n	abs. dens.	abs. freq.	abs. dom.	rel. dens.	rel. dom.	rel. freq.	I V I
Erythroxylum deciduum	2	17,80	3,33	0,03	1,67	1,62	1,12	4,31
Annona tomentosa	2	17,80	3,33	0,02	1,67	0,86	1,12	3,65
Dalbergia miscolobium	1	8,90	3,33	0,03	0,83	1,41	1,12	3,36
Acosmium dasycarpum	1	8,90	3,33	0,03	0,83	1,41	1,12	3,36
Annona crassiflora	1	8,90	3,33	0,03	0,83	1,34	1,12	3,29
Eriotheca pubescens	1	8,90	3,33	0,02	0,83	1,14	1,12	3,10
Enterolobium ellipticum	1	8,90	3,33	0,02	0,83	1,02	1,12	2,97
Davilla elliptica	1	8,90	3,33	0,01	0,83	0,43	1,12	2,38
Salacia crassifolia	1	8,90	3,33	0,01	0,83	0,35	1,12	2,31
Tabebuia aurea	1	8,90	3,33	0,01	0,83	0,35	1,12	2,31
Casearia sylvestris	1	8,90	3,33	0,00	0,83	0,23	1,12	2,18

Note: 18 families, 21 genera and 25 species present. Six families account for 56% of the species: Leguminosae (4), Annonaceae (2), Bignoniaceae (2), Erythroxylaceae (2), Sapotaceae (2) and Vochysiaceae (2). Five genera, *Annona*, *Erythroxylum*, *Pouteria*, *Qualea* and *Tabebuia*, have two species, all others are represented by a single species.

Table 34 - Phytosociological parameters - sample site INVERNADA

no. of points = 60 | density = 1702.24ind./ha | aver. point-plant dist. = 2.424m
no. of ind. = 240 | basal area = 17.782m2/ha | circ. > = 5cm
Shannon - Wiener H' = 3.22, evenness = 0.80

species	n	abs. dens.	abs. freq.	abs. dom.	rel. dens.	rel. dom.	rel. freq.	IVI
Terminalia argentea	16	113,5	20	6,2089	6,67	34,96	6,28	47,91
Kielmeyera coriacea	52	368,8	53,33	1,3854	21,67	7,8	16,75	46,22
Sclerolobium paniculatum var. subvelutinum	27	191,5	31,67	3,2258	11,25	18,16	9,95	39,36
Miconia ferruginata	30	212,8	38,33	1,7397	12,5	9,79	12,04	34,34
Miconia pohliana	10	70,9	16,67	1,0401	4,17	5,86	5,24	15,26
Psidium myrsinoides	11	78	16,67	0,4567	4,58	2,57	5,24	12,39
Eremanthus glomerulatus	12	85,1	15	0,1972	5	1,11	4,71	10,82
Qualea parviflora	7	49,6	11,67	0,6954	2,92	3,92	3,66	10,5
Byrsonima coccolobifolia	9	63,8	15	0,3347	3,75	1,88	4,71	10,35
Aspidosperma tomentosum	11	78	15	0,1257	4,58	0,71	4,71	10
Ouratea hexasperma	7	49,6	10	0,4457	2,92	2,51	3,14	8,57
Mimosa claussenii	8	56,7	11,67	0,1041	3,33	0,59	3,66	7,58
Palicourea rigida	6	42,6	10	0,164	2,5	0,92	3,14	6,56
Salacia crassifolia	4	28,4	6,67	0,3051	1,67	1,72	2,09	5,48
Byrsonima verbascifolia	4	28,4	6,67	0,143	1,67	0,81	2,09	4,57
Guapira noxia	3	21,3	5	0,217	1,25	1,22	1,57	4,04
Vochysia elliptica	3	21,3	5	0,1543	1,25	0,87	1,57	3,69
Styrax ferrugineus	2	14,2	3,33	0,2	0,83	1,13	1,05	3.01
Scheflera macrocarpum	2	14,2	3,33	0,0966	0,83	0,54	1,05	2,42
Qualea grandiflora	1	7,1	1,67	0,2573	0,42	1,46	0,52	2,39
Syagrus comosa	2	14,2	3,33	0,0715	0,83	0,4	1,05	2,28
Erythroxylum tortuosum	2	14,2	3,33	0,0356	0,83	0,2	1,05	2,08
Erythroxylum suberosum	2	14,2	3,33	0,0048	0,83	0,03	1,05	1,91
Stryphnodendron adstringens	2	14,2	1,67	0,015	0,83	0,08	0,52	1,44
Heteropteris byrsonimifolia	2	14,2	1,67	0,012	0,83	0,07	0,52	1,42
Miconia albicans	1	7,1	1,67	0,056	0,42	0,32	0,52	1,26
Lippia sp.	1	7,1	1,67	0,0543	0,42	0,31	0,52	1,25
Roupala montana	1	7,1	1,67	0,0081	0,42	0,05	0,52	0,99
Casearia sylvestris	1	7,1	1,67	0,0056	0,42	0,03	0,52	0,97
Celastraceae (921-3)	1	7,1	1,67	0,002	0,42	0,01	0,52	0,96

Note: 22 families, 25 genera and 30 species present. Three families account for 53.3% of the species: Malpighiaceae (4), Leguminosae (3), Melastomataceae (3), Nyctaginaceae (3) and Vochysiaceae (3). Four genera, *Miconia* (3), *Byrsonima* (2), *Eremanthus* (2) and *Qualea* (2), have more than one species.

Table 35 - Phytosociological parameters - sample site CERRADO PALMAS

no. of points = 60 | density = 630.91ind./ha | aver. point-plant dist. = 3.981m
no. of ind. = 240 | basal area = 5.191m2/ha | circ. > = 5cm
Shannon - Wiener H' = 2.98, evenness = 0.83

species	n	abs. dens.	abs. freq.	abs. dom.	rel. dens.	rel. dom.	rel. freq.	IVI
Sclerolobium paniculatum var. subvelutinum	39	104,30	40,68	1,86	16,53	35,88	12,24	64,65
Qualea parviflora	31	80,20	38,98	0,83	12,71	16,06	11,73	40,50
Syagrus comosa	25	66,80	33,90	0,95	10,59	18,36	10,20	39,15
Miconia burchellii	16	42,80	25,42	0,40	6,78	7,74	7,65	22,18
Miconia ferruginata	10	26,70	15,25	0,23	4,24	4,42	4,59	13,25
Eremanthus goyazensis	13	34,80	20,34	0,06	5,51	1,18	6,12	12,81
Vochysia elliptica	11	29,40	16,95	0,13	4,66	2,48	5,10	12,24
Salacia crassifolia	9	24,10	11,86	0,14	3,81	2,63	3,57	10,01
Psidium myrsinoides	9	24,10	10,17	0,09	3,81	1,75	3,06	8,63
Neea theifera	9	24,10	11,86	0,01	3,81	0,15	3,57	7,53
Byrsonima coccolobifolia	7	18,70	11,86	0,04	2,97	0,78	3,57	7,31
Piptocarpha rotundifolia	6	16,00	10,17	0,06	2,54	1,17	3,06	6,78
Compositae2 (1050-2)	7	18,70	11,86	0,00	2,97	0,08	3,57	6,62
Byrsonima guilleminiana	5	13,40	6,78	0,00	2,12	0,06	2,04	4,22
Malpighiaceae (1021-4)	4	10,70	6,78	0,02	1,69	0,48	2,04	4,21
Palicourea rigida	4	10,70	6,78	0,02	1,69	0,42	2,04	4,16
Guapira noxia	3	8,00	5,08	0,07	1,27	1,27	1,53	4,07
Byrsonima verbascifolia	4	10,70	5,08	0,01	1,69	0,13	1,53	3,36
Mimosa claussenii	3	8,00	5,08	0,02	1,27	0,30	1,53	3,10
Miconia albicans	1	2,70	1,69	0,09	0,42	1,79	0,51	2,72
Eremanthus glomerulatus	2	5,30	3,39	0,03	0,85	0,60	1,02	2,46
Roupala montana	2	5,30	3,39	0,01	0,85	0,14	1,02	2,01
Erythroxylum tortuosum	2	5,30	3,39	0,00	0,85	0,07	1,02	1,94
Erythroxylum suberosum	2	5,30	3,39	0,00	0,85	0,04	1,02	1,90
Banisteriopsis sp.	1	2,70	1,69	0,04	0,42	0,69	0,51	1,62
Ouratea hexasperma	1	2,70	1,69	0,02	0,42	0,42	0,51	1,35
Ilex integrifolius	1	2,70	1,69	0,02	0,42	0,39	0,51	1,33

Table 35 - Phytosociological parameters - sample site CERRADO PALMAS - (Cont.)

species	n	abs. dens.	abs. freq.	abs. dom.	rel. dens.	rel. dom.	rel. freq.	IVI
Kielmeyera coriacea	1	2,70	1,69	0,01	0,42	0,13	0,51	1,07
Stryphnodendron adstringens	1	2,70	1,69	0,01	0,42	0,13	0,51	1,07
Tabebuia ochracea	1	2,70	1,69	0,01	0,42	0,13	0,51	1,06
Aspidosperma tomentosum	1	2,70	1,69	0,00	0,42	0,08	0,51	1,01
Zeyheria montana	1	2,70	1,69	0,00	0,42	0,02	0,51	0,95
Styrax ferrugineus	1	2,70	1,69	0,00	0,42	0,01	0,51	0,95
Bauhinia rufa	1	2,70	1,69	0,00	0,42	0,01	0,51	0,94
Schefflera macrocarpum	1	2,70	1,69	0,00	0,42	0,01	0,51	0,94
Qualea grandiflora	1	2,70	1,69	0,00	0,42	0,01	0,51	0,94
Banisteriopsis sp.3	1	2,70	1,69	0,00	0,42	0,01	0,51	0,94

Note: 21 families, 31 genera and 37 species present. Four families account for 46% of the species: Malpighiaceae (6), Compositae (4), Leguminosae (4) and Melastomataceae (3). Six genera, *Byrsonima* (3), *Miconia* (3), *Banisteriopsis* (2), *Eremanthus* (2) and *Qualea* (2), have more than one species.

Table 36 - Phytosociological parameters - sample site ARNICAS

no. of points = 60 | density = 4986.93ind./ha | aver. point-plant dist. = 1.416m
no. of ind. = 240 | basal area = 10.921m2/ha | circ > = 5cm
Shannon - Wiener H' = 2.79, evenness = 0.83

species	n	abs. dens.	abs. freq.	abs. dom.	rel. dens.	rel. dom.	rel. freq.	I V I
Vellozia swallenii	48	988,80	39,66	3,87	19,83	35,43	13,37	68,63
Miconia ferruginata	26	516,90	32,76	1,88	10,34	17,26	11,05	38,65
Lychnophora ericoides	25	537,40	29,31	0,68	10,78	6,20	9,88	26,86
Qualea parviflora	23	461,40	25,86	0,73	9,05	6,67	8,72	24,44
Palicourea rigida	18	343,90	24,14	0,56	6,90	5,14	8,14	20,18
Miconia pohliana	13	279,40	20,69	0,43	5,60	3,90	6,98	16,48
Banisteriopsis variabilis	13	279,40	10,34	0,46	5,60	4,23	3,49	13,32
Byrsonima guilleminiana	8	172,00	13,79	0,18	3,46	1,62	4,65	9,72
Byrsonima coccolobifolia	6	129,00	10,34	0,39	2,59	3,61	3,49	9,68
Psidium myrsinoides	8	172,00	10,34	0,16	3,46	1,43	3,49	8,37
Miconia albicans	8	172,00	10,34	0,10	3,45	0,94	3,49	7,88
Sclerolobium paniculatum var. subvelutinum	3	64,50	5,17	0,43	1,29	3,97	1,74	7,00
Erythroxylum suberosum	6	129,00	10,34	0,10	2,59	0,92	3,49	7,00
Eremanthus goyazensis	5	107,50	6,90	0,14	2,16	1,29	2,33	5,77
Byrsonima verbascifolia	5	107,50	6,90	0,11	2,16	0,98	2,33	5,46
Terminalia argentea	5	107,50	6,90	0,04	2,16	0,37	2,33	4,86
Pouteria torta	3	64,50	5,17	0,04	1,29	0,40	1,74	3,44
Mimosa claussenii	2	43,00	3,45	0,10	0,86	0,93	1,16	2,96
Chomelia ribesioides	3	64,50	3,45	0,04	1,29	0,38	1,16	2,83
Schefflera macrocarpum	1	21,50	1,72	0,19	0,43	1,76	0,58	2,77
Banisteriopsis malifolia	2	43,00	3,45	0,08	0,86	0,69	1,16	2,72
Banisteriopsis sp.4	2	43,00	3,45	0,03	0,86	0,29	1,16	2,32
Banisteriopsis gardneriana	1	21,50	1,72	0,09	0,43	0,83	0,58	1,84
Vellozia flavicans	1	21,50	1,72	0,03	0,43	0,29	0,58	1,30
Neea theifera	1	21,50	1,72	0,03	0,43	0,26	0,58	1,28
Acosmium dasycarpum	1	21,50	1,72	0.01	0,43	0,06	0,58	1,07
Protium ovatum	1	21,50	1,72	0,01	0,43	0,06	0,58	1,07
Emmotum nitens	1	21,50	1,72	0,01	0,43	0,05	0,58	1,06
Kielmeyera coriacea	1	21,50	1,72	0,01	0,43	0.05	0,58	1,06

Note: 18 families, 22 genera and 29 species present. Six families account for 65.5% of the species species: Malpighiaceae (7), Leguminosae (3), Compositae (2), Rubiaceae (2) and Velloziaceae (2). Four genera, Banisteriopsis(3), Byrsonima (3), Miconia (3) and Vellozia, have more than one species

Table 37 - Phytosociological parameters - sample site MURUNDU

no. of samples = 10 density = 2016.74ind./ha circ. >= 5cm
no. of ind. = 144 basal area = 5.948m2/ha
Shannon - Wiener H' = 2,45, evenness = 0.78

species	n	abs. dens.	abs. freq.	abs. dom.	rel. dens.	rel. dom.	rel. freq.	IVI
Psidium warmingianum	31	434,20	90,00	1,25	21,53	21,00	14,52	57,05
Eremanthus glomerulatus	20	280,10	50,00	1,04	13,89	17,56	8,06	39,52
Kielmeyera coriacea	18	252,10	70,00	0,80	12,50	13,41	11,29	37,20
Miconia rubiginosa	18	252,10	70,00	0,49	12,50	8,20	11,29	31,99
Miconia albicans	3	42,00	30,00	1,01	2,08	16,99	4,84	23,91
Acosmium dasycarpum	15	210,10	40,00	0,15	10,42	2,48	6,45	19,35
Erythroxylum tortuosum	7	98,00	60,00	0,21	4,86	3,46	9,68	17,99
Styrax ferrugineus	9	126,00	30,00	0,14	6,25	2,40	4,84	13,49
Symplocos lanceolata	6	84,00	20,00	0,17	4,17	2,84	3,23	10,23
Byrsonima sp.	1	14,00	10,00	0,34	0,69	5,67	1,61	7,98
Aegiphilla lanata	2	28,00	20,00	0,01	1,39	0,12	3,23	4,74
Annona monticola	2	28,00	20,00	0,01	1,39	0,09	3,23	4,71
Lafoensia pacari	1	14,00	10,00	0,11	0,69	1,80	1,61	4,11
Caryocar brasiliense	1	14,00	10,00	0,09	0,69	1,47	1,61	3,78
Erythroxylum suberosum	2	28,00	10,00	0,02	1,39	0,36	1,61	3,36
Aspidosperma macrocarpum	1	14,00	10,00	0,06	0,69	0,99	1,61	3,30
Salacia crassifolia	1	14,00	10,00	0,03	0,69	0,48	1,61	2,79
Byrsonima verbascifolia	1	14,00	10,00	0,01	0,69	0,23	1,61	2,53
Davilla elliptica	1	14,00	10,00	0,01	0,69	0,19	1,61	2,49
Piptocarpha rotundifolia	1	14,00	10,00	0,01	0,69	0,09	1,61	2,40
Tocoyena formosa	1	14,00	10,00	0,00	0,69	0,08	1,61	2,39
Protium ovatum	1	14,00	10,00	0,00	0,69	0,06	1,61	2,36
Eremanthus goyazensis	1	14,00	10,00	0,00	0,69	0,05	1,61	2,35

Note: 18 families, 19 genera and 23 species present. Four families account for 39% of the species: Compositae (3), Erythroxylaceae (2), Malpighiaceae (2) and Melastomataceae (2). Four genera, *Byrsonima*, *Eremanthus*, *Erythroxylum* and *Miconia*, have two species, all others are represented by a single species.

In the National Park the physiognomic gradient from cerrado *sensu stricto* to cerrado open scrub is accompanied by a gradient of descending species-richness and diversity .

The cerrado sample site BARRAGEM was the richest in species (65) and presented the highest Shannon's diversity with H' = 3.64, while CERRADO NOVO SETOR, CERRADO MATO GROSSO and CERRADO TORRE had the same figure for species-richness (42 spp.), and of them CERRADO NOVO SETOR had the highest diversity (H' = 3.34).

Differences in richness and diversity were observed among the Brasília National Park cerrado *sensu stricto* sample sites, when considering both the large (girth ≥ 30cm) and the small (≥ 5cm) trees and shrubs. It was observed that the populations of small trees and shrubs were richer in species and more diverse than the populations of large trees and shrubs.

Of the cerrado rupestre sample sites, PALMAS was richer in species (37 spp.) and had higher diversity (H' = 2.98) than INVERNADA (30 spp. ; H' = 2.78).

The cerrado scrub with emergents sample site VOCHYSIA 1 was species-richer (30 spp.) and also had higher Shannon's diversity (H' = 2.80) than the site VOCHYSIA 2 (26 spp. ; H' = 2.71).

Sample site TRES BURACOS 1 was the species-richest (35 spp.) and had the highest Shannon's diversity (H' = 3.03) of the cerrado scrub sites.

Sample site CAMPO SUJO MATO GROSSO was the richest in species (25 spp.) and had the highest diversity (H' = 2.52) of the cerrado open scrub sites.

4.7.1.3 Cerrado x gallery forest

Leguminosae, Malpighiaceae, Melastomataceae, Rubiaceae, and Annonaceae were important families in both the cerrado and gallery forests sites in the National

Park, while Caryocaraceae, Celastraceae, Dilleniaceae, Loganiaceae and Velloziaceae were confined to the cerrado communities.

In general the cerrado communities had lower diversity indices than the gallery forests, except for the gallery forests sample sites PISCINA1, CEMAVE, and CRISTAL, which had similar diversity indices to some cerrado communities.

Some species were common to the gallery forests and cerrado sample sites such as *Pseudobombax longiflorum* and *P. tomentosum* (Bombacaceae); *Bauhinia rufa, Copaifera langsdorffii* and *Sclerolobium paniculatum* var. *subvelutinum* (Caesalpiniaceae); *Pterodon pubescens* (Fabaceae); *Enterolobium gummiferum* (Mimosaceae); *Myrsine guianensis* (Myrsinaceae); *Siphoneugena densiflora* (Myrtaceae); and *Roupala montana* (Proteaceae).

4.7.2 Phytosociology

The results giving absolute and relative values of density, frequency and dominance, and importance value index (IVI), of the species in each sample site, are presented in Tables 12 to 37. The number of surveyed points, number of plant individuals, absolute density, absolute basal area, Shannon's diversity indices and evenness of each sample site, are summarised in the heads of these Tables. The most important families in each sample site are listed in the foot notes of these Tables. Girth and height ranges are shown in Table 38, and the girth and height frequency class distribution, is shown in Figs 25 to 34.

Table 38 - Circumference and height ranges in plant communities of Brasília National Park

Circumference and height ranges of the gallery forest sample sites

	circumference (cm)			height (m)		
sample site	min.	med.	max.	min.	med.	max.
PISCINA1	5	26.96	152	0.57	5.25	25
CEMAVE	5	19.46	150	0.6	4.72	25
CRISTAL	5	16.48	94	0.8	4.95	20
CAPAO COMPRIDO	5	33.08	340	0.5	5.39	30
BARRIGUDA	5	21.81	275	0.7	4.7	30
TRES BARRAS	5	26.2	154	0.5	6.09	25
PALMAS	5	19.73	220	0.5	4.58	20
BANANAL	5	21.1	225	0.5	5.1	25

Circumference and height ranges of the cerrado "sensu stricto" sample sites

	circumference (cm)			height (m)		
sample site	min.	med.	max.	min.	med.	max.
CERRADO NOVO SETOR	5	42.49	156.5	0.5	3.2	12
CERRADO MATO GROSSO	5	41.18	157	0.55	3.55	12
CERRADO CAPAO COMPRIDO	5	38.99	154	0.5	3.59	9.6
BARRAGEM	5	28.03	139	0.5	2.44	18
CERRADO TORRE	5	27.42	88	0.5	1.81	6.8
CERRADO TORTINHO	5	30.92	164	0.5	2.56	18

Circumference and height ranges of the cerrado rupestre sample sites

	circumference (cm)			height (m)		
sample site	min.	med.	max.	min.	med.	max.
INVERNADA	5	28.46	249	0.5	2.64	10
CERRADO PALMAS	5	26.79	80.5	0.5	2.32	7.6

Circumference and height ranges of the cerrado scrub sample sites

	circumference (cm)			height (m)		
sample site	min.	med.	max.	min.	med.	max.
TRES BURACOS 1	5	14.36	57.5	0.5	1.05	2.9
TRES BURACOS 2	5	26.02	225	0.5	1.32	2.6
RAPVELL	5	11.83	57.5	0.5	0.81	2
MURUNDU	5	15.56	90	0.5	1.18	3.95

Circumference and height ranges of the cerrado open scrub sample sites

	circumference (cm)			height (m)		
sample site	min.	med.	max.	min.	med.	max.
CAMPO SUJO NOVO SETOR	5	12.3	44.5	0.5	0.82	3.5
CAMPO SUJO MATO GROSSO	5	14.22	37.5	0.55	1.79	3.5
TORRE	5	11.29	34	0.5	0.8	3.5
ARNICAS	5	14.8	54	0.5	1.2	4.8

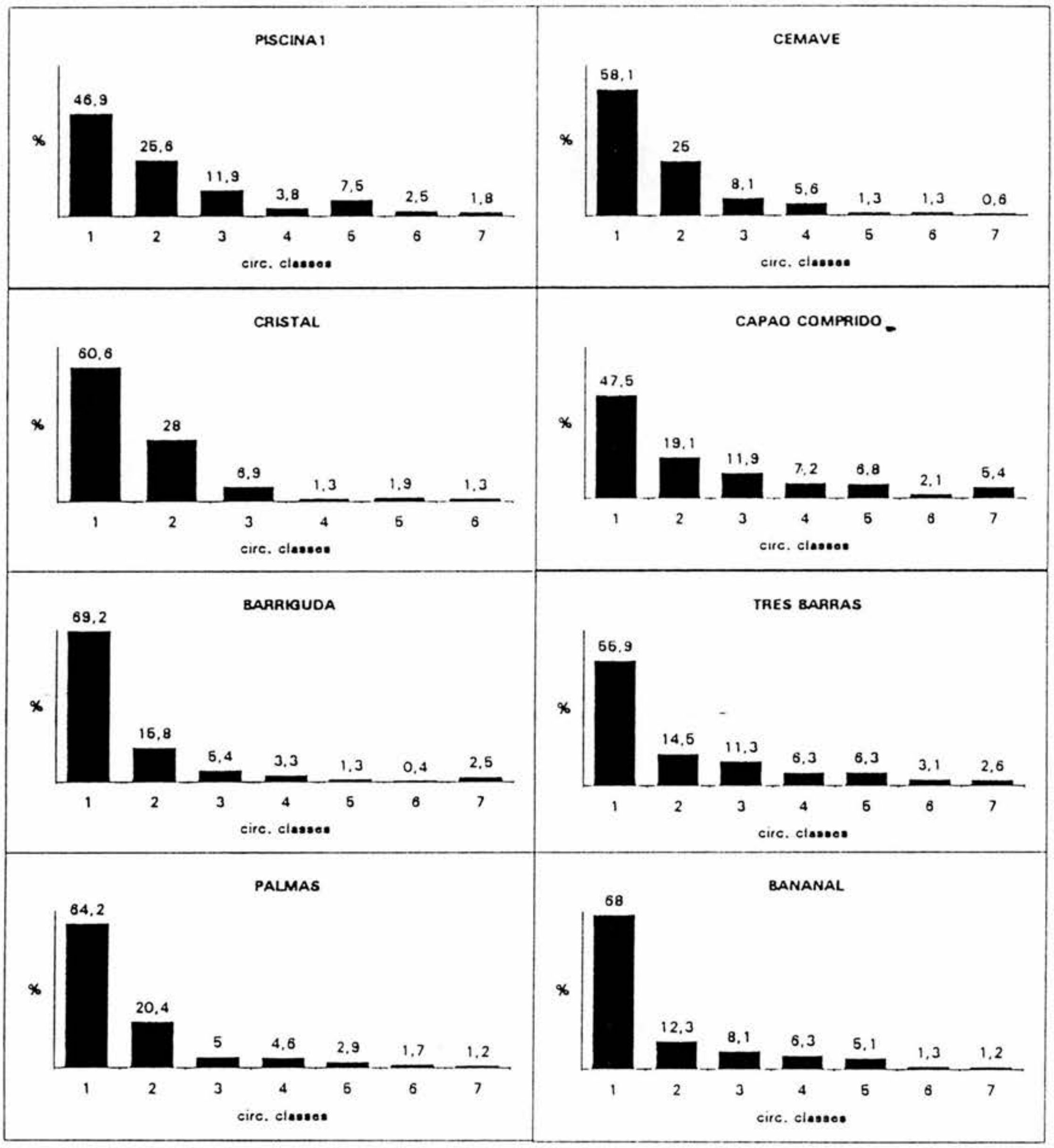


Figure 25 - Circumference class distribution in gallery forests of Brasília National Park

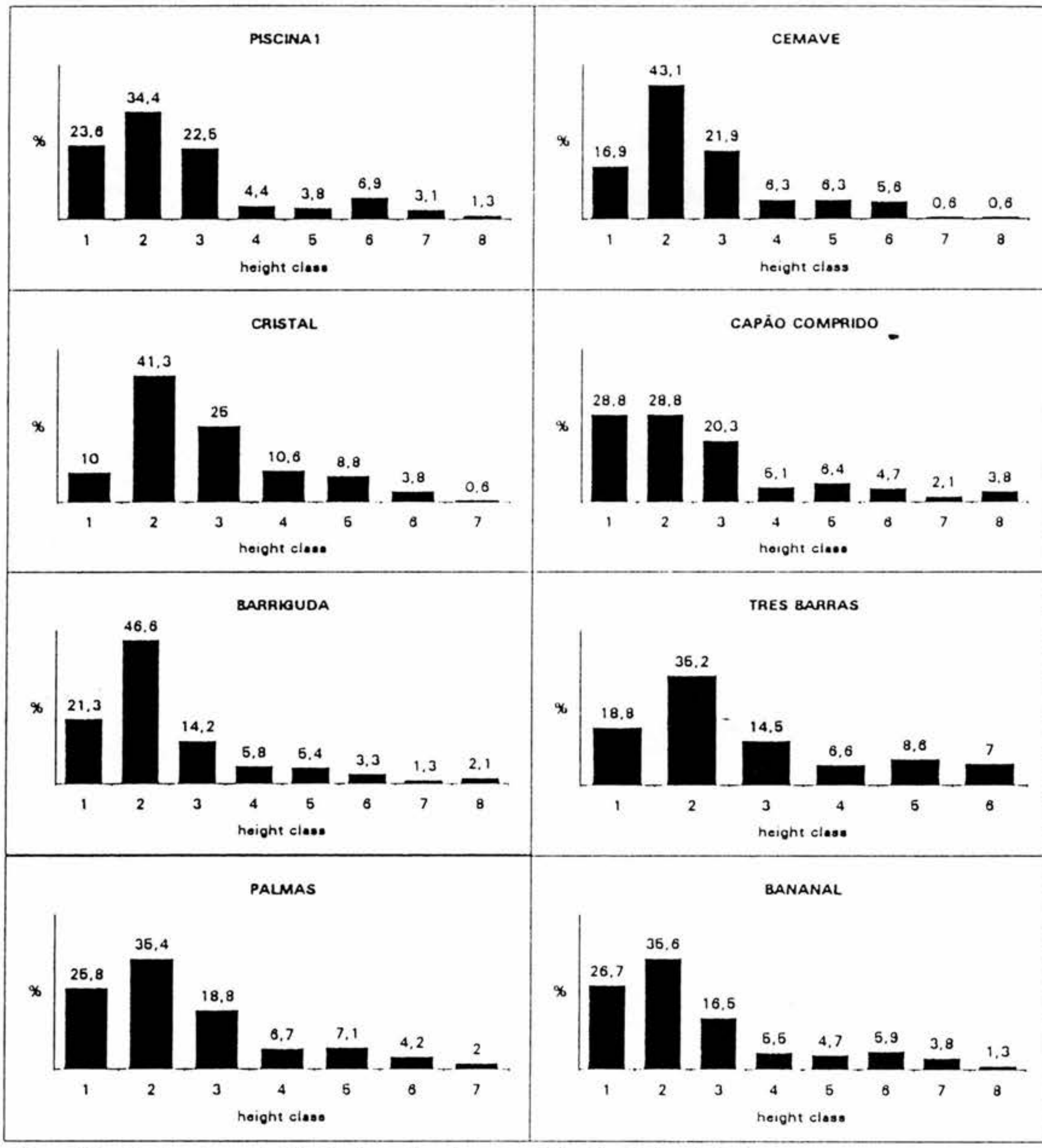


Figure 26 - Height class distribution in gallery forests of Brasília National Park

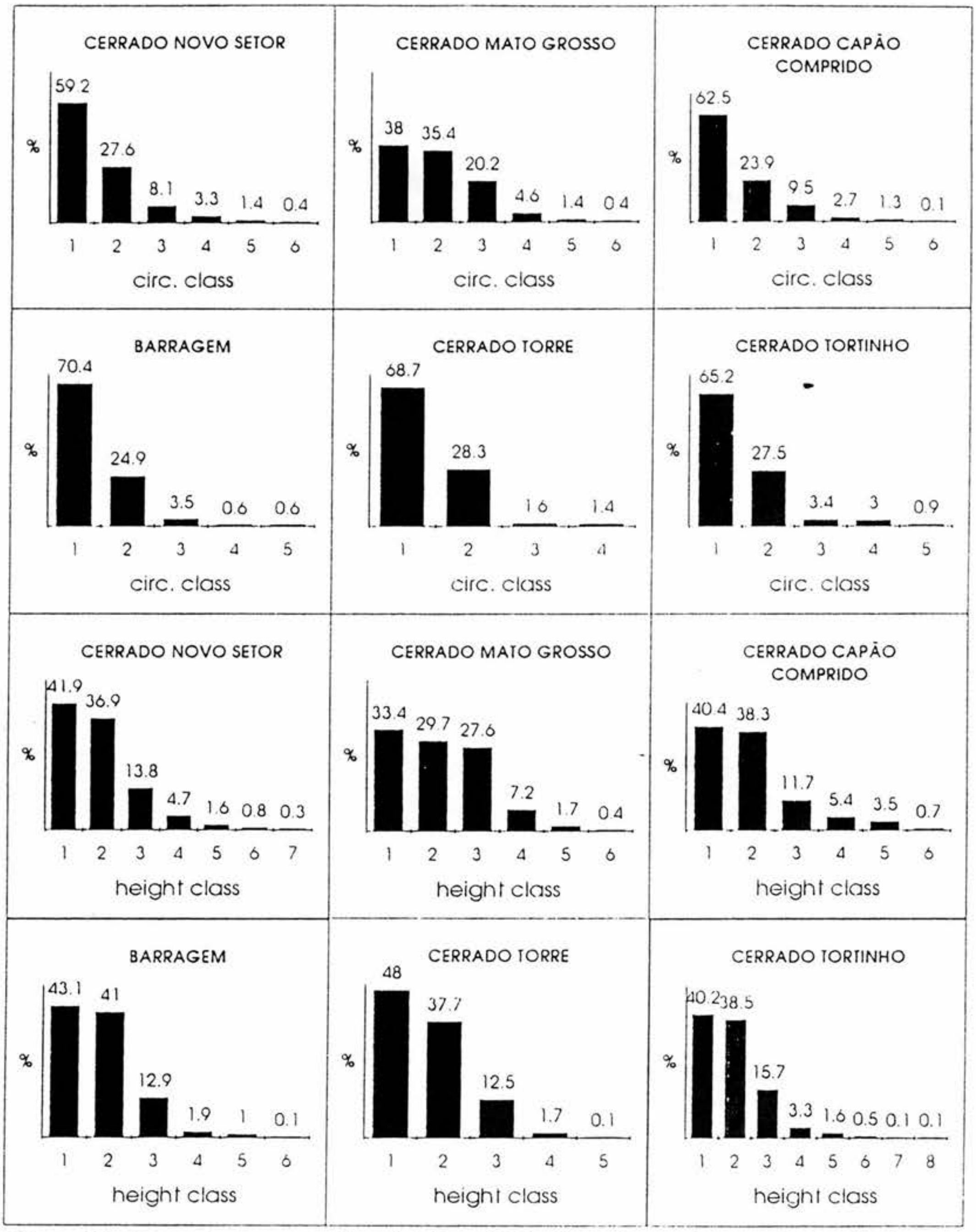


Figure 27 - Circumference and height class distribution of cerrado woody plants of Brasilia National Park

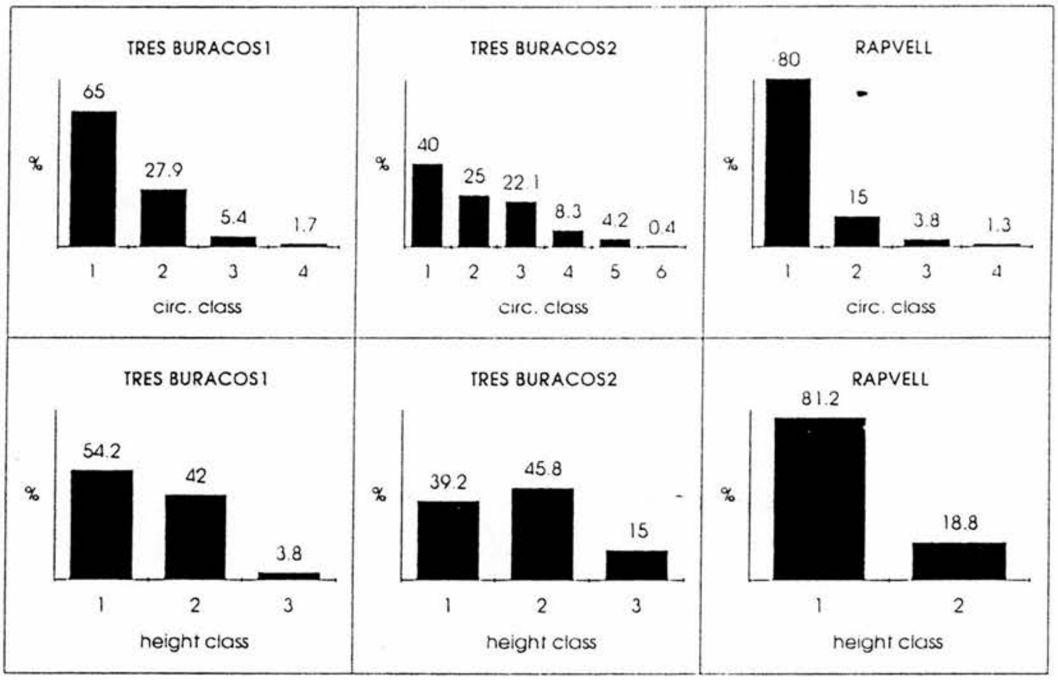


Figure 28 - Circumference and height class distribution of cerrado scrub woody plants of Brasilia National Park

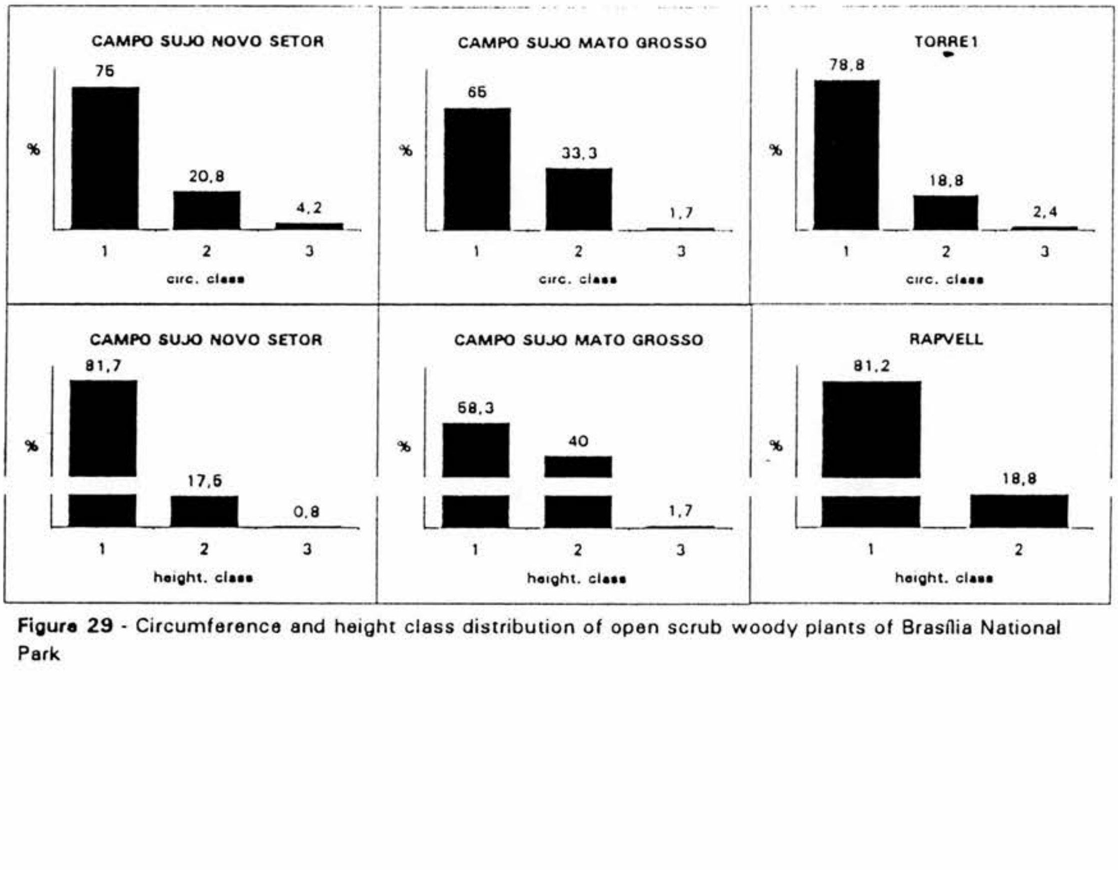


Figure 29 - Circumference and height class distribution of open scrub woody plants of Brasília National Park

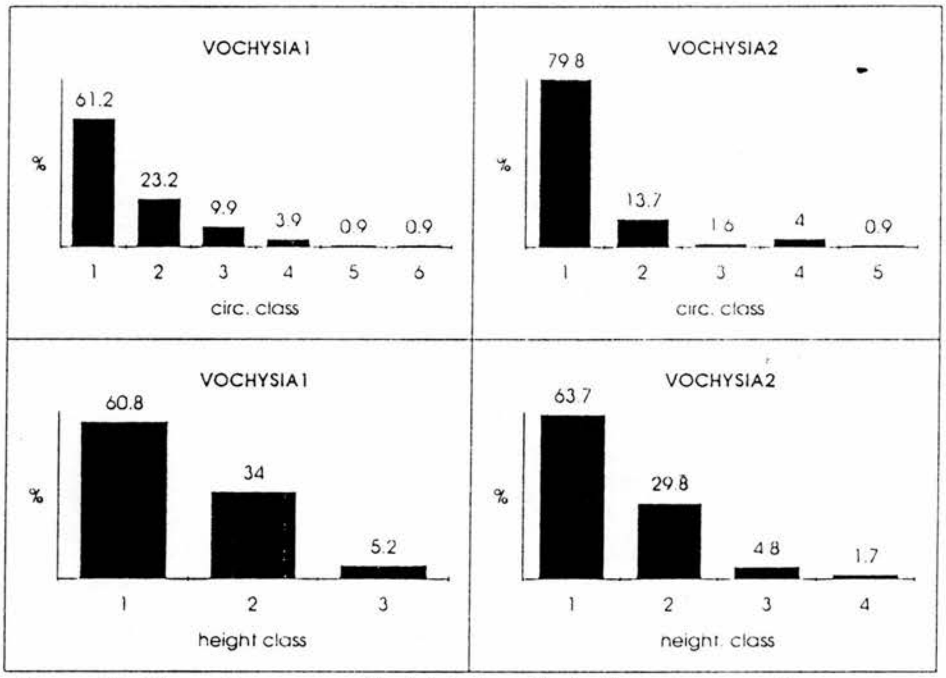


Figure 30 - Circumference and height class distribution of scrub with emergents woody plants of Brasilia National Park

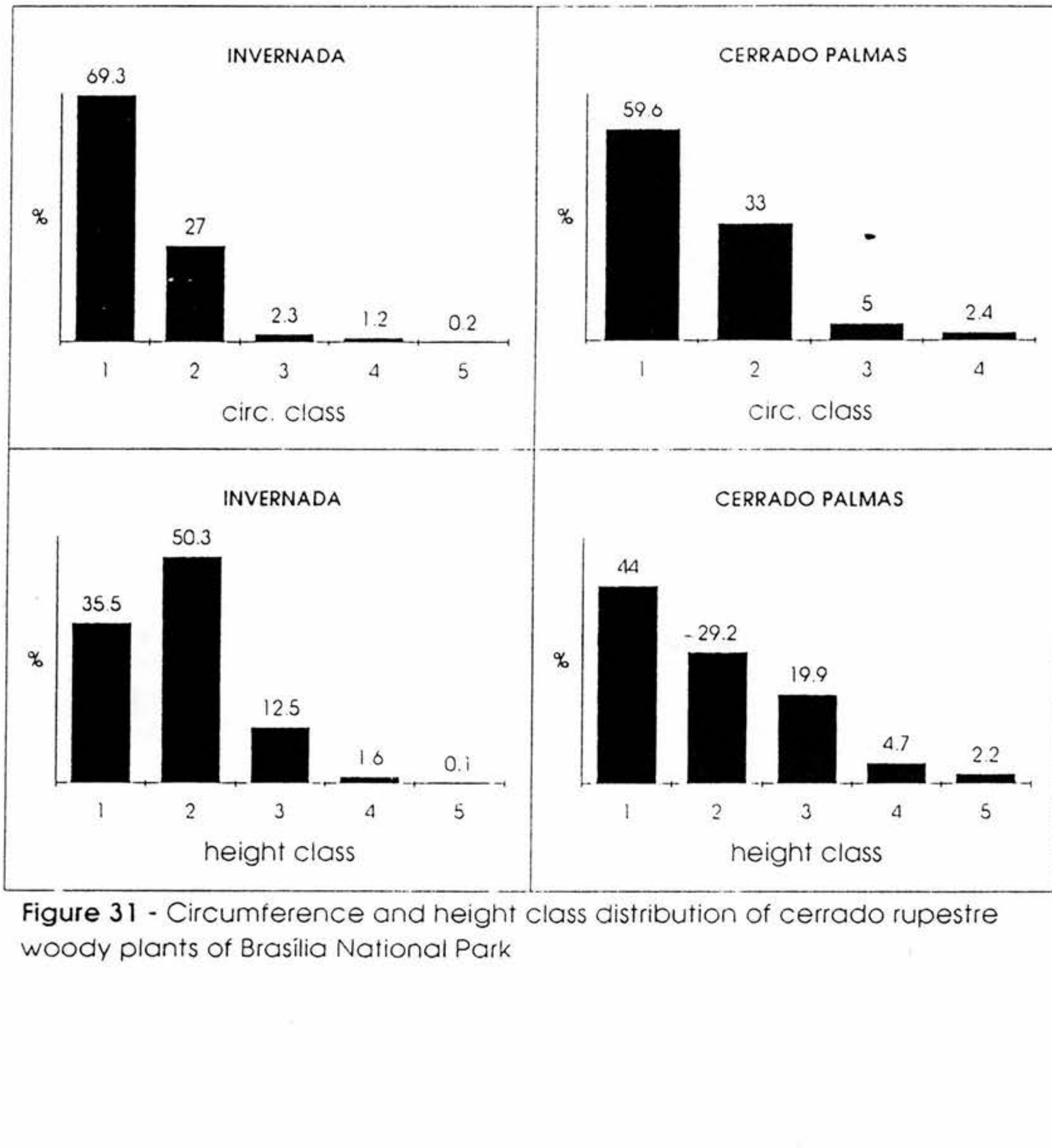


Figure 31 - Circumference and height class distribution of cerrado rupestre woody plants of Brasília National Park

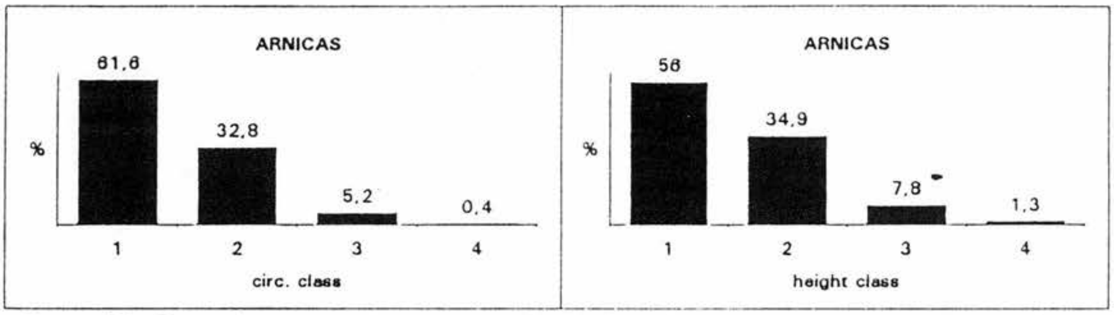


Figure 32 - Circumference and height class distribution of campo rupestre woody plants of Brasília National Park

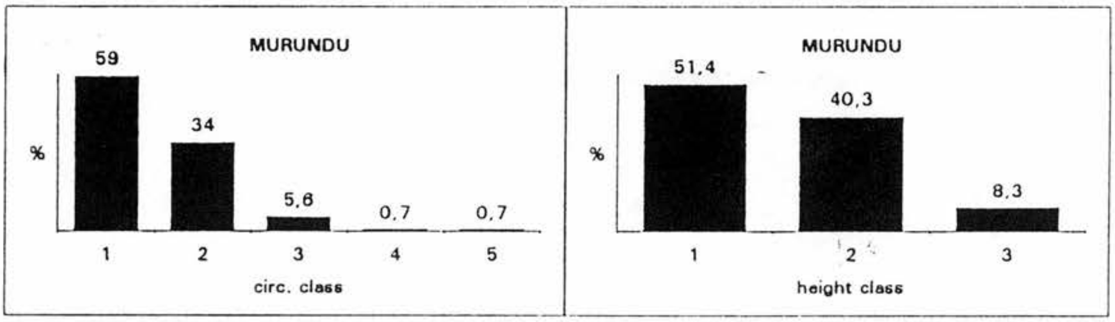


Figure 33 - Circumference and height class distribution of murundu woody plants of Brasília National Park

4.7.2.1 Gallery forests

The total density of the gallery forests ranged from 5221.43ind./ha in PISCINA 1 sample site to 25944.70ind./ha in the flooded BANANAL site. The basal area ranged from 35.747m²/ha in the semideciduous site CEMAVE to 249.149m²/ha in the water-logged forest site BANANAL.

In all the gallery forest samplings together, from 46.9% to 69.2% of the recorded plants were distributed in the first girth class (5 to 15cm), and from 68.5% to 81.9% of the individuals were distributed in the three first height classes, up to 4m tall. Only from 0.6% to 3.8% of the plants registered in the gallery forests were large trees ≥ 20m high (Fig. 25).

Anadenanthera colubrina var. *cebil, Aspidosperma subincanum, Calophyllum brasiliense, Cariniana estrelensis, Chrysophyllum marginatum, Copaifera langsdorffii, Hieronyma alchorneoides, Hymenaea courbaril* var. *stilbocarpa, Micropholis venulosa, Pseudolmedia laevigata, Qualea dichotoma, Richeria obovata, Tabebuia impetiginosa, Vochysia pyramidalis* and *Xylopia emarginata* are the most abundant and have the highest IVIs among the large trees in the gallery forests of the National Park of Brasília (Table 12 to 19).

Alibertia edulis, Aspidosperma discolor, Attalea phalerata (palm), *Bauhinia rufa, Campomanesia velutina, Cheiloclinium cognatum, Cupania vernalis, Diospyros hispida, Euterpe edulis* (palm), *Ferdinandusa speciosa, Geonoma schottiana* (palm), *Guettarda viburnoides, Hedyosmum brasiliense, Maytenus alaeternoides, Miconia chartacea, Myrcia rostrata, M. tomentosa, Tibouchina candolleana* and *Trichilia catigua*, all had high IVIs as understorey, shade tolerant trees of the gallery forests.

In the gallery forest sites, Leguminosae, Myrtaceae, Rubiaceae, Palmae, Anacardiaceae, Annonaceae, Hippocrateaceae, Apocynaceae, Guttiferae, Celastraceae, Melastomataceae, Vochysiaceae, Magnoliaceae, and Bignoniaceae had the highest Importance Value Indices - IVI.

Leguminosae were important in almost all gallery forest sites in the National Park, except in the water-logged BANANAL sample site.

Palmae were important in the flooded patches of the gallery forest sites and in the dry gallery forest site PALMAS, but the species present in the two habitats were completely different.

Annonaceae, Guttiferae and Magnoliaceae were important in the flooded site BANANAL and also in damp parts of the gallery forest sites CAPÃO COMPRIDO and BARRIGUDA.

4.7.2.2 Cerrado categories

The density of the cerrado communities ranged from 514.72ind./ha in the cerrado *sensu stricto* sample site CERRADO NOVO SETOR to 6259.06ind./ha in the cerrado scrub with emergents site VOCHYSIA 2. The basal areas varied from 1.326m²/ha in the open scrub site CAMPO SUJO NOVO SETOR to 29.067m²/ha in the scrub with emergents site VOCHYSIA 1. From 38.0% to 81.2% of the recorded individuals were distributed in the first girth class (5-15cm). The first height class (0.5m -1.0m) included from 33.4% to 81.7% of the surveyed individuals. Only 3% of surveyed individuals in the cerrado were ≥ 8m tall (Figs. 26 and 27).

Dalbergia miscolobium, Pterodon pubescens, Sclerolobium paniculatum and *Vochysia thyrsoidea* were the commonest large trees of the cerrado in the National Park of Brasília.

Caryocar brasiliense, Dalbergia miscolobium, Eriotheca pubescens, Qualea parviflora, Q. grandiflora, Sclerolobium paniculatum and *Styrax ferrugineus* were the most important cerrado tree species and the most important shrubs species were *Cassia orbiculata, Kielmeyera coriacea, Miconia ligustroides, Ouratea hexasperma, Salacia crassifolia, Syagrus comosa* (palm), *S. flexuosa* and *Vellozia flavicans* (see Table 20 to 25).

In the cerrado rupestre category, *Qualea parviflora, Sclerolobium paniculatum* and *Terminalia argentea* were important tree species (Tables 35 and 36) while *Kielmeyera coriacea, Miconia burchellii, M. ferruginata, M. pohliana and Syagrus comosa* (palm), were important shrub species with the IVI range from 13.25% to 64.65%.

Aspidosperma tomentosum, Banisteriopsis latifolia, Butia leiospatha, Byrsonima verbascifolia, Cassia orbiculata, Connarus suberosus, Eremanthus glomerulatus, Erythroxylum suberosum, E. tortuosum, Kielmeyera coriacea, Mimosa claussenii, Neea theifera, Palicourea rigida, Psidium myrsinoides, Myrsine guianensis, Roupala montana, Salacia crassifolia, Syagrus comosa, Tabebuia ochracea and *Vellozia flavicans* were the species with the highest IVIs within the shrubby cerrado categories. Most of these species were also important in the cerrado *sensu stricto* and cerrado rupestre shrub layer.

Vellozia flavicans was especially important in the cerrado scrub with emergents (Vochysietum) (Tables 29 and 30), and in the cerrado scrub sample sites (Tables 26, 27 and 28). In the CERRADO TRES BURACOS 2 (Vellozietum) this species had the highest IVI recorded in any area of the National Park of Brasília, with 163.31 (Table 27).

In the Vochysietum the trees of *Vochysia thyrsoidea* which characterised the site, were sparsely distributed, and were scarcely detected by the sampling points.

Although the arboreal element is either absent or infrequent in the cerrado scrub sites, dwarf plants of *Caryocar brasiliense, Dalbergia miscolobium, Hymenaea stigonocarpa, Pouteria ramiflora* and *Stryphnodendron adstringens* are often found.

Vellozia swallenii, Miconia ferruginata and *Lychnophora ericoides* were the most important species in the campo rupestre ARNICAS sample site (Table 36) and *Psidium warmingianum, Eremanthus glomerulatus* and *Kielmeyera coriacea* for the MURUNDU site (Table 37).

In general, in the cerrado communities, the species with high IVI had also high density, frequency and dominance.

4.8 Discussion

4.8.1 Floristics and diversity

4.8.1.1 Gallery forests

The major gallery forest families represented in this study have also been identified as species-rich families in other gallery forests of the Distrito Federal (Ratter, 1980, 1991; Felfili & Silva Jr., 1992; Felfili, 1993).

The pattern encountered in the gallery forests of the National Park of Brasília shows that a few genera had many species, some had a few species, but the vast majority were represented by a single species, i. e. most of the taxa represented are not closely related.

The same pattern of species-genus relationships found in the gallery forests of the National Park of Brasília was observed in a mesophytic forest in the Distrito Federal (Ramos, 1989), in the gallery forests of the research station of the University of Brasília, Fazenda Água Limpa (Ratter, 1980, 1991) and in Gama gallery forest (Felfili, 1993a), all of them situated in the Distrito Federal. Comparing the results found in the Gama gallery forest with different tropical forest communities, Felfili (1993a) recognised that the Central Brasil gallery forests, have lower numbers of congeneric species than the species-rich tropical forests.

The tropical forests experienced a contraction of area during the Pleistocene Glacial periods (van der Hammen, 1983). At these times drier conditions obtained in the tropics and the forests were reduced in area to form disjunct islands (refugia) which constitute distinct centres of diversity and endemism (Prance 1973). After the Glacial periods, a wetter climate provided favourable conditions for the tropical forests to expand again from their refuges (van der Hammen, 1983). But, in Central

Brazil the forest expansion was restricted to younger lower situated relief of Quaternary age, shaped by fluvial morphodynamics (Emmerich, 1990). In any case most of the region is characterised by a climate which belongs to Köppen's Aw-subtype of the tropical rain climate (A), so establishment of evergreen rainforest would not be expected. The limitation of area and the distance from the forest refuges, associated with the seasonal climate and periodic burning, affords one explanation for the lower species-richness of the Central Brazilian gallery forests, when compared with the Amazonian and Atlantic forests.

The observation of forest fragmentation studies casts light on the relationships of area and species diversity. Terborgh (1992) demonstrates the following in his analysis of the maintenance of diversity in tropical forests:

1. Species loss accompanies or quickly follows habitat fragmentation.

2. A fragment of a given size may provide perfectly well for one species and be wholly insufficient for another.

3. Reduction in the area of a habitat has the immediate consequence of drastically reducing the effective population sizes of many species, including those with the lowest intrinsic population densities.

4. Intrusion of the edges is an inevitable consequence of fragmentation. Where the forest interior is exposed to opening up, wind and light will penetrate the understorey. The changes in the physical environment lead in turn to changes in species composition and structure of the vegetation.

Although these studies relate to fragmentation of large areas covered by tropical forests, they can help in the understanding of the differences in species-richness between the central Brazilian and the Amazonian and Atlantic forests.

It seems to be clear that many species dependent upon large areas with specific environmental conditions cannot exist in the narrow corridors formed by the gallery forests, which are submitted to the strong edge effects of wind, light and fire.

Despite all this, the gallery forests of Central Brazil have a surprisingly great species diversity when their relatively small area is taken into account. It is also interesting to note that characteristic species such as *Callisthene major, Myrcia tomentosa, Myrcia rostrata, Lithraea molleoides* and *Pseudobombax tomentosum* form populations on the margins of the gallery forests and can be considered species adapted to edge effects, including fire.

Some interesting points should be emphasised about the diversity of the National Park gallery forests:

The CEMAVE, PISCINA1, CRISTAL and BANANAL sample sites constitute a distinct group with lower species-richness and diversity than the other gallery forests in the National Park.

The areas studied at PISCINA 1 and CEMAVE sample sites were situated on drier and well-drained soils. The presence of characteristic semideciduous species such as *Anadenanthera colubrina* var. *cebil*, considered an indicator of mesotrophic forests (Ratter et al., 1978; Ramos, 1989), made these two sites distinct from others in the National Park. CEMAVE showed the highest levels of soil nutrients amongst the gallery forests studied, and together with the CRISTAL sample site carried mesophytic forest, but PISCINA 1 unexpectedly showed low nutrient levels, suggesting that *Anadenanthera colubrina* var. *cebil* can also occur on dystrophic soils or on the other hand that errors were made in the soil analysis of this site.

Table 39 - Phytosociological parameters of different communities in Brazil

site	source	circ./diam. (cm)	sample size	density ind./ha	basal area m^2/ha	Shannon's diversity
Forest						
National Park	present study	basal cir. = 5	PCQ **	5221.43 - 25944.70	35.75 - 249.15	3.22 - 4.17
Gama gallery forest (DF)	Felfili, 1993	gbh = 31	10 x 20m	649	30,4	3,84
Taquara gallery forest (DF)	Silva, 1991	dbh = 10	40 PCQ	1590	35,4	-
Olho d'agua da onça gallery forest (DF)	"	dbh = 10	40 PCQ	980	24,2	-
Monjolo gallery forest (DF)	"	dbh = 10	40 PCQ	654	23,2	-
Gama gallery forest (DF)	"	dbh = 10	40 PCQ	654	27,6	-
Faz. Barreiro Rico mesophytic semideciduous forest (SP)	Cesar & Leitão F., 1990	dbh = 3	300 PCQ	3955,54	17,29	3,56
Maracá (Amazon) terra firme forest	Milliken & Ratter, 1989	dbh = 10	50 PCQ	504,61	36,28	3,57
"	"	dbh = 30	50 PCQ	112,94	24,1	3,21
"	"	dbh = 10	20 PCQ	622,23	30,06	2,45
"	"	dbh = 30	20 PCQ	115,78	18,85	1,89
"	"	dbh = 10	10 PCQ	348,74	61,19	2,78
Cerrado						
National Park	present study	basal cir. = 5	PCQ	514.72 - 6259.06	1.33 - 29.07	1.69 - 3.64
National Park	Felfili et al, 1993	dbh = 5cm	20 x 50m	1036	8,32	3,34
Águas Emendadas (DF)	"	"	"	1396	10,76	3,62
Paracatu (MG)	"	"	"	664	5,89	3,11
Angatuba (Mato Grosso) cerrado	Ratter et al, 1988	basal d. = 3	25 x10m	4040	12	-
" campo cerrado	"	"	"	2360	7,54	-
" cerradão	"	"	"	7840	33	-
Southern Mato Grosso murundu	Oliveira-Filho & Martins, 1991	basal cir. = 9	80 *	2713,7	31,96	2,35
" pebble cerrado	"	"	140 PCQ	1049,9	15,03	3,39
" phyllite cerrado	"	"	60 PCQ	1546,4	16,12	3,36
" sandstone cerrado	"	"	50 PCQ	1187	13,6	2,81
" interfluvial cerrado	"	"	10x10m	1888	21,04	3,23

* 80 sample areas on murundus (each earth mound was an sample area)

** variable sampling size

PCQ - number of sampling points applying the Point Quarter Center method

The composition of mesophytic forests tend towards the dominance of relatively few species rather than high diversity (Ratter, personal communication). This lower diversity of forests on mesotrophic soils corroborates the predictions of Tilman (1982) as cited in Moreira (1992) that plant communities should have maximum diversity in moderately resource-poor habitats.

The lower diversity of PISCINA 1 can be explained by its position in the Public-Use zone, where it suffers the impact of visitors walking in the vegetation and especially the grazing and trampling of horses.

CRISTAL, as indicated earlier, is a site where gallery forest species have expanded into the cerrado area. It occurs as a small patch on mesotrophic soil, in a pre-existing ecotonal cerrado-cerradão-gallery forest tract, where the cerrado species have already been shaded out by the gallery forest trees during the succession process. Some cerrado species such as *Kielmeyera coriacea* and *Qualea parviflora* were observed in this part of the gallery forest. However, only *Syagrus flexuosa*, a characteristic cerrado palm, was actually recorded in the PCQ samples. The presence of *Siphoneugena densiflora* and *Cardiopetalum calophyllum* (Table 14) which are widely considered to be indicative of dystrophic facies cerradão (Ratter et al., 1973, 1977; Ratter, 1971) and also the presence of *Astronium fraxinifolium* which is an indicator species of mesotrophic cerradão (Ratter et al., 1977; Furley & Ratter, 1988), reinforce the idea of gallery forest expansion into a pre-existing cerradão.

Other species such as *Copaifera langsdorffii, Hymenaea courbaril* var. *stilbocarpa, Guettarda viburnoides*, and *Alibertia edulis* which are commonly found in the CRISTAL sample site, are also common species in cerradão sites in Mato Grosso (Ratter et al., 1989).

This succession from cerrado to cerradão and the gradual expansion of the gallery forests in the Distrito Federal is discussed in Ratter (1980, 1992) and in Ratter et al. (1973, 1978a).

The gallery forest site CAPÃO COMPRIDO had a lower diversity index than CEMAVE and BANANAL (Tables 15, 13 and 19, respectively), although it was richer in species than the two latter sites. The reason for this is that CAPÃO COMPRIDO had lower evenness than the two other sites. The great abundance of individuals of *Euterpe edulis,* and *Xylopia emarginata* occurring on a damp area on the site and of clumped populations of *Cheiloclinium cognatum* and *Alibertia edulis* occurring on mesic soils within the area produced this unevenness.

It was anticipated that the water-logged site BANANAL would show intermediate richness and diversity, as indeed was the case. The high soil water content limited the establishment of many species and provided an open niche which was occupied mainly by water-loving species such as *Xylopia emarginata* and *Calophyllum brasiliense.* These two species showed a great number of individuals, giving the BANANAL sample site an uneven distribution of species abundance.

Compared with other phytosociological studies in different regions of Brazil (Table 39), Brasília National Park gallery forest sample sites CEMAVE, BANANAL, CAPÃO COMPRIDO, PISCINA 1 and CRISTAL can be considered as having median diversity and TRES BARRAS, BARRIGUDA and PALMAS as having high diversity.

4.8.1.2 Cerrado communities

The species-rich families found in the cerrado communities of the National Park of Brasília are largely the same as those described in the works of Rizzini (1979) ,Goodland (1979) and Ratter (1980), who identified the most important cerrado families as Leguminosae, Malpighiaceae, Rubiaceae, Myrtaceae, Apocynaceae, Annonaceae, Melastomataceae, Bignoniaceae, Vochysiaceae, Palmae, Sapindaceae, and Anacardiaceae.

In the present work a gradient of species-richness and diversity was observed paralleling a physiognomic gradient from the cerrado *sensu stricto* to the cerrado open scrub (campo sujo). An exception to this was the cerrado scrub TRES BURACOS 1 which had a high species-richness and diversity, similar to cerrado sensu stricto sites

The pattern observed in these cerrado categories seems to be mainly related to the edaphic characteristics which are responsible for the distribution of the cerrado vegetation (Furley, 1985; Ratter, 1980; Frost et al., 1986; Oliveira-Filho et al., 1989). Fire can also be important, since the establishment of sensitive species is impeded in some cerrado areas subject to periodic fire regimes (Moreira, 1992).

Since Shannon's diversity indices are influenced by species abundance (Pielou, 1975, and see discussion on forest sites), some sample sites gave higher diversity figures as a result of their evenness. for example, the sample sites CERRADO NOVO SETOR and CERRADO MATO GROSSO both had 42 species, but the former presented higher Shannon's diversity (H' = 3.34) than the latter (H' = 3.08). However, the evenness of CERRADO NOVO SETOR was higher (J = 0.89) than the evenness of CERRADO MATO GROSSO (J = 0.82).

The cerrado *sensu stricto* sample sites presented high diversity when compared with other published work (Table 39). Some cerrado sensu stricto sites in the Brasília National Park had diversity indices even higher than some forest sites.

In the National Park of Brasília the cerrado diversity ranged from 3.08 to 3.64, which is similar to a cerrado area in the research station of Brasília University (Felfili, 1993), where the diversity was 3.46. In various cerrado sites surveyed in the Chapada da Pratinha in Central Brasil, Felfili et al. (1993) found a diversity ranging from 3.11 to 3.56. Thus, the diversity indices calculated for the cerrado vegetation communities in the National Park of Brasília are typically in the range of those found in several Brazilian cerrado areas. However, the differences in sampling methods, particularly those relating to sampling intensity (Magurran, 1988) and the minimum girth sizes used prevent straightforward comparisons between the different studies.

4.8.2Phytosociology

4.8.2.1 Gallery forests

The present study shows considerable heterogeneity in species composition of the gallery forests of the National Park of Brasília. This agrees with the data of the Projeto Biogeografia (Biogeography Project) (SEPLAN, 1990), which surveyed five different gallery forests in the Chapada Pratinha region (Pratinha plateau), a large plateau including much of the States of Minas Gerais, Goiás and the whole of the Distrito Federal.

The Chapada Pratinha is considered a homogeneous physiographic region in Central Brazil (Cochrane et al. , 1985). However the *Projeto Biogeografia* showed that the gallery forests of the region were floristicaly extremely heterogeneous. Only a *Protium* sp., *Tapirira guianensis* and *Cheiloclinum cognatum* were amongst the 10 most important tree species in all five sampled areas, while *Ixora warmingii*, *Virola sebifera, Licania apetala* and *Maprounea guianensis,* the next most widespread species, were important tree species in only two of the areas studied. The great majority of species were of rare occurrence even if they were present in a number of areas.

Of the 316 species recorded in the gallery forests of the Chapada da Pratinha, Central Brazil, only 62.66% were found in the Ecological Reserves of the Distrito Federal (SEPLAN, 1990), including Brasília National Park.

This heterogeneity in species composition of the gallery forests is also striking when comparing the data recorded in different studies in the Distrito Federal (Ratter, 1980; Azevedo et al., 1990; da Silva, 1991; Felfili, 1993). A few species such as *Amaioua guianensis, Calophyllum brasiliense, Licania apetala, Maprounea guianensis, Pseudolmedia laevigata, Protium heptaphyllum, Richeria obovata, Talauma ovata, Tapirira guianensis* and *Xylopia emarginata* were important in most of the gallery forests studied in the Distrito Federal, but these represent only a very small percentage of the total species recorded. The water-logged sites show a much more homogeneous species composition and contain widespread species such as *Xylopia emarginata, Calophyllum brasiliense, Mauritia flexuosa, Virola urbaniana,* etc.

A number of habitat associations can be identified in the National Park galleries. *Copaifera langsdorffii, Hymenaea courbaril var. stilbocarpa, Micropholis venulosa, Cheiloclinum cognatum* and *Alibertia edulis* are important tree species in mesic to dry well-drained gallery forest patches; They are also important in some gallery forest heads (cabeceiras) such as the BARRIGUDA gallery head site. *Myrcia tomentosa* and *Callisthene major* are important trees in the dry marginal areas of the gallery forests abutting on cerrado vegetation, while *Ferdinandusa speciosa, Richeria obovata* and *Byrsonima umbellata* are important tree species in the damp gallery forest margins. Ratter (1980) found the same distribution of characteristic species in the Fazenda Água Limpa gallery forests in the Distrito Federal.

The community of some dry stretches of gallery forests and particularly some cabeceiras (gallery forest heads) in the National Park of Brasília resemble the "cerradão das cabeceiras" observed in Mato Grosso (Oliveira-Filho and Martins, 1986), which is similar to the dystrophic facies cerradão described by Ratter et al., (1973), where *Copaifera langsdorffii, Emmotum nitens, Protium heptaphyllum* and *Callisthene major* were important species.

In general the gallery forests of the National Park are dominated by only a few species which have high IVIs. This concentration of IVI in a few species was observed in several other undisturbed Brazilian forest communities (Oliveira Filho, 1989; Cesar & Leitão Filho, 1990; Felfili, 1993).

In general, dominance appears to be the most important characteristic determining IVIs for large trees in gallery forests. For smaller trees which are more abundant, IVIs tend to more closely reflect density.

Differences in sample sizes, minimum qualifying size and methods make it difficult to compare the basal area (dominance) and density of the gallery forest tree species of the Brasília National Park with those reported in other works. However, the physiognomic descriptions of undisturbed gallery forest sites in different studies (Ratter, 1980; Oliveira-Filho, 1989) have shown that they have some similarities.

In the National Park the girth distribution of all gallery forest trees combined showed a reversed-J shape (Fig. 25, p.135). The height distribution of trees (Fig. 26) from 50cm high was a bell shaped curve characteristic of natural distribution. These structural patterns are characteristic of self-regenerating communities (Harper, 1977), where there is a dynamic equilibrium between recruitment and mortality of trees, and the populations are represented mostly by young trees. Felfili (1993) studying the Gama gallery forest in the Distrito Federal found the same pattern of size class distribution.

In the National Park saplings from 5 to 15cm of girth were present in great numbers, followed by poles from 15 to 30cm of trunk girth. Trees from 30 to 90cm girth and large trees > 90cm girth were present in lower numbers, but are responsible for much of the gallery forests appearance, due their great dominance.

Apart from the gallery forest edges or in some gaps caused by tree falls, where there is enough light, the gallery forest floor is in deep shade provided by the cover of the dominant trees. Thus, the best conditions for the regeneration of most of large trees which seem to be light demanding (Felfili, 1993) are present in few places in these forests. This seems to be the cause for the low numbers of saplings and poles of dominant species found. The saplings and poles which do occur are mainly young individuals of shade tolerant understorey tree species, such as *Alibertia edulis, Bauhinia rufa, Cheiloclinum cognatum, Cupania vernalis, Guettarda viburnoides, etc.* in dry sites, and *Euterpe edulis, Talauma ovata, and Cyathea* sp. in humid places.

4.8.2.2 Cerrado communities

The importance (IVI) of the species of the cerrado community sample sites varied along the physiognomic gradient from cerrado open scrub to cerrado *sensu stricto*.

In this study the number of species present increased along the physiognomic gradient from cerrado open scrub (campo sujo) to cerrado *sensu stricto.* The same pattern was observed by Goodland (1971) in the cerrado of Minas Gerais. This seems to be related to the edaphic characteristics of the sites studied. Some authors have correlated the cerrado physiognomic gradient from campo sujo to cerradão (Goodland & Pollard, 1973; Lopes & Cox, 1977) to an ascending gradient of soil fertility which is also correlated with declining aluminium saturation. However, other studies have failed to show this, e. g. Ribeiro et al. (1985), who found tall dense cerradão on some of the poorest soils they encountered. Some researchers have also shown that the cerrado gradient of physiognomy is mainly related to the ground water regime (Oliveira-Filho, 1989; Oliveira-Filho et al., 1990; Furley, 1992), indicating that the depth of the water-table determines the vegetation type along a cerrado topo-sequence in Mato Grosso.

Leguminosae and Vochysiaceae are the most important families in the communities of cerrado *sensu stricto* in the National Park; the same families are also recorded as most important in various studies of the cerrados of Central Brazil (Ratter, 1980; Nascimento & Saddi, 1992; Felfili & Silva Jr., 1993).

Qualea parviflora (Vochysiaceae) which is the most important species of the cerrado of the National Park is certainly one of the most important species in the cerrado of Central Brazil, showing high IVI values in many studies. The results of Goodland (1979), Ribeiro et al. (1985), Oliveira-Filho et al.(1989) and Nascimento & Saddi (1992) indicated that it is the most important tree in the cerrado *sensu stricto* of Central Brazil. Another important Vochysiad in the National Park, *Qualea grandiflora,* was found to be the most widespread cerrado tree species in the analysis of 26 areas situated throughout the vast cerrado region of Brazil (Ratter & Dargie, 1992). In the same study other important species of the National Park such as *Aspidosperma tomentosum, Caryocar brasiliense, Connarus suberosus, Erythroxylum suberosum, E. tortuosum* and *Kielmeyera coriacea* were recorded amongst the most widespread cerrado species of the Brazilian cerrados.

It is known that the Vochysiaceae are aluminium accumulators (Haridasan & Araujo, 1988; Medeiros & Haridasan, 1985). These aluminium-accumulating species are not absolutely confined to acidic or dystrophic soils, but they seem to have a competitive advantage on them, and this seems to be especially the case for *Qualea* spp. (Haridasan & Araujo, 1988).

Qualea grandiflora and *Q. parviflora* were the most important tree species in the cerrado *sensu stricto* sample site CERRADO CAPÃO COMPRIDO, which is a cerrado marginal to the gallery forest of the Capão Comprido stream. The location of this site marginal to a dry and well-drained patch of the gallery forest and its floristic composition shows evidence of expansion of the gallery forest species into the cerrado area. The floristic composition also resembles the dystrophic facies cerradão described by Ratter et al. (1973), the expansion of gallery forest into fringing cerrados in Fazenda Água Limpa (Ratter, 1980) and the "cerradão das cabeceiras" (Oliveira-Filho & Martins, 1986) observed in Mato Grosso, which is a characteristic vegetation type often found marginal to dry and well-drained gallery forest patches. This characteristic form of vegetation is also found in the fringe of mesophytic forests in Central Brazil (Ratter et al., 1978a).

The fact that shrubby species became more important along the cerrado gradient of physiognomy from cerrado *sensu stricto* to cerrado open scrub (campo sujo) might be related to the depth of the water-table, since it is well known that the cerrado *sensu stricto* only occurs in deep and well-drained soils in Central Brazil (Eiten, 1972; Furley & Ratter, 1988).

The cerrado communities identified in this study as cerrado scrub and cerrado open scrub, in which *Vellozia flavicans, Erythroxylum suberosum, Connarus suberosus, Roupala montana* and *Kielmeyera coriacea* are the most important species, might have their distribution in the landscape mainly determined by the water-table depth. The cerrado scrub with emergents (Vochysietum) in the National Park of Brasília is related to geomorphic sites in the disruptions of the relief at the plateau borders, associated with the presence of an ironstone layer, and the cerrado scrub site (Vellozietum) is associated with shallow soils in the plateau, where the water-table is near the surface. These cerrado categories were described by Veloso (1948) in his studies in the cerrado of Mato Grosso and Goiás. He considered them as seral stages of the cerrado continuum. They were found occupying the same topographic situation and with similar edaphic conditions to those of the equivalent communities in the National Park.

The most important species found in the cerrado rupestre and campo rupestre sample sites in the National Park of Brasília were also considered important species in the vegetation studies of Fazenda Água Limpa (Ratter, 1980) in the "cerrados and campos dos montes" (cerrado and campos of the hills). The cerrado rupestre community was also described in the vegetation studies of the Chapada dos Guimarães in Mato Grosso (Oliveira-Filho & Martins, 1986). As in the National Park of Brasília, the soil of the cerrado rupestre sites develops in the cracks between the rocks, where the soil and water accumulate. *Sclerolobium paniculatum* was an important tree species in these rocky cerrado sites.

The frequency distribution of girth and height size classes of the cerrado woody species communities had a reversed-J shape (Figs. 27 to 33, p.137 to 142), with most of the individuals concentrated in the lower sizes of girth and height.

As a whole, girths from 5 to 15cm included 38% - 80% of the individuals and the height classes up to 2m contained 63.1% - 85.7% of the individuals. Only 0.1% of the surveyed plants of the cerrado were large trees > 12m tall. However, trees of that size do exist scattered throughout the cerrado, except in the cerrado scrub and open scrub areas. Small trees and shrubs are largely responsible for the appearance of the cerrado *sensu stricto*.

The same physiognomic pattern observed in the cerrado communities of the National Park were found in the cerrado of Fazenda Água Limpa, within the Distrito Federal (Ratter, 1980; Felfili & Silva Jr., 1988; Silva Jr. & Silva, 1988) and in a cerrado area in Mato Grosso (Nascimento & Saddi, 1992), where most of the individuals are under 10cm diameter with very few trees reaching 45cm diameter.

The reason for the small stature and low density of cerrado trees in the National Park of Brasília might be related to frequent fires, which prevent tree recruitment, eliminate sensitive species (Ratter, 1980; Moreira, 1992), and also promote leaf fall and damage in the trunks and branches, thus much reducing growth and in the long term causing mortality (Nascimento & Saddi, 1992; Moreira, 1992).

Dwarf trees of *Caryocar brasiliense, Dalbergia miscolobium, Hymenaea stigonocarpa, Pouteria ramiflora* and *Stryphnodendron adstringens* were found in cerrado scrub areas in the National Park. The causes for the abnormal forms of these cerrado trees were not studied but the observed elongation of the trunk bases, with successive scars caused by periodic fires suggests that fire might be an important factor. However, the tendency to dwarfing in cerrado physiognomy with increasing limiting soil factors has been observed by Eiten (1972) for cerrados covering Lithosols, by Askew et al. (1971) and Eiten (1975) for interfluvial cerrados at their poorly drained margins and by Goodland & Pollard (1973) for cerrados with lower soil fertility and toxic Aluminium levels.

4.9 Conclusions

Typical vegetation communities of the cerrado gradient in the National Park, from cerrado *sensu stricto* to campo sujo and other cerrado categories which are also part of the cerrado continuum, such as cerrado scrub with emergents (Vochysietum), cerrado rupestre, campo rupestre and campos de murundus were all represented in the present study. Besides the cerrado communities, this study also considered the gallery forests sites which clearly show much physiognomic and floristic variation. Thus, a complete range of flooded, dry semideciduous, head-water ('cabeceira') and other distinct types of gallery forests were surveyed and are represented by their floristic and phytosociological parameters.

In this survey 26 samples sites were studied, eight in gallery forests and 18 in cerrado areas. In total 5304 plants were recorded from 1290 sampling points using the PCQ method and one cerrado category was surveyed by quadrats (MURUNDU sample site). In all 76 families, 194 genera and 380 species, from which 71 families, 140 genera and 284 species belonged to the gallery forest and 39 families, 68 genera and 121 species were found in the cerrado communities.

The study demonstrates that the diversity of the gallery forest is generally higher than for the cerrado sites, but cerrado *sensu stricto* sites present Shannon's diversity indices similar to some of the dry gallery forest sites and the flooded BANANAL. However, in general the diversity decreases in the cerrado gradient from cerrado *sensu stricto* to cerrado open scrub (campo sujo).

The gallery forests and the cerrado *sensu stricto* communities of the National Park had high diversity (3.08 - 4.17) for basal girth ≥ 5cm, when compared with that found in Atlantic and Amazonian rain forests, from 3.7 - 4.3 for trees ≥10cm DBH (Silva & Leitão Filho, 1982), and for other cerrado areas in Central Brazil, from 3.11 - 3.56 for individuals ≥5cm at 30cm from the ground (Felfili et al., 1993).

The heterogeneity of species distribution in the different sample sites in the National Park of Brasília and in other areas of central Brazil shows that a biogeographically based conservation strategy must be applied, selecting representative conservation areas to assure maintenance of the maximum possible level of the biodiversity of the cerrado biome .

The high diversity of the vegetation communities of the National Park reinforces the importance of the area for the conservation of cerrado biodiversity. The gallery forest PALMAS and the campo rupestre ARNICAS vegetation communities are considered the most important in terms of conservation priority in the National Park of Brasília, because of the rarity of these habitats.

The phytosociological data analysed in this research provide information which make possible future observations and comparisons to understand better the dynamics of the National Park of Brasília plant populations. They also contribute to the search for the determinant factors responsible for the distribution and maintenance of the vegetation communities of central Brazil.

Chapter 5

Gradient analysis of the soils and vegetation communities of the Brasília National Park

5.1 Introduction

In the preceding chapter the vegetation sample sites were compared and classified according to their species composition and abundance. Here the sample sites, species abundance and soil environmental factors are ordinated. The purpose of these analyses is to detect the existing relationships between vegetation communities, soil properties and associated land forms.

The phytosociological gradients of cerrado vegetation have been a theme of discussion since the pioneer ecological studies of Warming in 1892, in Minas Gerais state, Brazil (Warming & Ferri, 1973). However, Veloso (1946, 1948a, 1948b) was the first to present a phytosociological classification of the cerrado species associations through a qualitative direct analysis of gradient. Veloso classified the plant associations through their visually dominant species and made a representation of the cerrado vegetation continuum in Mato Grosso and Goiás states.

Goodland (1971a, 1971b) carried out the first quantitative phytosociological study, analysing the cerrado gradient of the Triângulo Mineiro (Goodland & Ferri, 1979). Direct gradient analysis was applied in this study, using a graphic distribution of species importance along the physiognomic gradient of the cerrado vegetation: cerradão, cerrado, campo cerrado and campo sujo. Principal Component Analysis (PCA) was also used in order to ordinate the vegetation. Through these studies the physiognomic gradient of the cerrado vegetation was associated with a fertility gradient in the soils.

Lopes & Cox (1977) found the same relationship between vegetation type and soil fertility in the gradient analysis of the cerrado vegetation of the Distrito

Federal, Brasília, although no ordination method was applied in the study. Ribeiro et al. (1982) and Ribeiro & Haridasan (1990) failed to find a fertility gradient when comparing areas of dense cerradão and cerrado in the Distrito Federal; again without the use of ordination techniques.

Ratter (1971) and Ratter et al. (1973, 1978a) made an important contribution to the knowledge and interpretation of the physiognomic and floristic gradients of the cerrado vegetation of Mato Grosso and Goiás. Developing a direct gradient analysis relating the species distribution with soil properties, two types of cerradão (dystrophic and mesotrophic) and the forests on mesotrophic soils were analysed. In these studies, indicator species of the distinct vegetation types were identified. All the results of these studies were obtained without the application of ordination methods.

The assessment and interpretation of vegetation and soil data of Central Brazil through the application of multivariate analysis computer programs is recent, but is becoming a common procedure. They are useful tools in the search for pattern in the ecological parameters associated with the distribution of the vegetation communities.

In this context, Oliveira-Filho (1984) and Oliveira-Filho et al. (1989) studying the cerrado vegetation of the Chapada dos Guimarães in Mato Grosso, applied the Reciprocal Averaging (RA) and Principal Component Analysis (PCA) (Gauch, 1982) as classification and ordination methods. In these studies the most important physiognomic and structural gradients of cerrado vegetation in the area were associated with periodic soil saturation by the rising of the water table, nature of the slopes and rockiness of the soils.

Oliveira-Filho et al. (1991) compared five areas of cerrado using three dissimilarity measures: the Coefficient of Community (CC), the Percentage Difference (PD) and the Euclidean Distance (ED), according to Gauch (1982).

Ratter & Dargie (1992) used TWINSPAN and DECORANA to study the floristic distribution of 26 areas situated more or less throughout the total extension of the cerrado biome. They found that the latitude, longitude and, most strongly, soil type (mesotrophic or dystrophic) were the three major gradients in the variation.

Felfili & Silva Jr. (1993) described the preferential group of species (dominant species), comparing and classifying six samples of cerrado *sensu stricto* in Central Brazil. They used the computer program Two-Way Indicator Species Analysis - TWINSPAN (Hill, 1979a) in their analysis.

5.2 Material and methods

A gradient analysis strategy was carried out in order to determine the similarity between the vegetation sites sampled in the National Park of Brasília and to elucidate their relationships to soil properties .

5.2.1 Variance analysis of soil properties

Initially the existence of a gradient of fertility paralleling the gradient of vegetation was tested. The soil properties were correlated with the averaged soil properties of the gallery forests, cerrado *sensu stricto,* cerrado scrub and cerrado open scrub. A variance analysis was promoted to test the significance of the observed differences amongst the averaged soil properties of the vegetation categories. Spearman's correlation and ANOVA variance analysis method were applied using the computer program EXCEL.

5.2.2 Multivariate analysis

The ordination and classification techniques were used to organise the vegetation community data based on species abundance and soil properties.

The result of an ordination is the arrangement of species and samples in a low dimensional space so that similar entities are close and dissimilar ones far apart. The ordination axes define gradients in vegetation which should reflect environmental gradients. The result of classification is the assignment of species and samples to classes (Gauch, 1982; Greig-Smith, 1983).

In order to ordinate and classify the vegetation sample sites in the National Park, the vegetation and soil data were organised in matrices of floristics (presence-absence of species), species absolute density and soil properties.

5.2.2.1 Detrended Correspondence Analysis - DECORANA

The values of 17 soil properties of the A horizon recorded in 26 soil profiles in the vegetation sites in the National Park were used by running the computer program DECORANA, a detrended correspondence analysis (DCA) (Hill, 1979b; Hill & Gauch, 1980).

DECORANA is a FORTRAN computer program devised to perform a detrended form of reciprocal averaging (RA). For running this program the soil variables were standardised for zero mean and unit variance. This transformation was carried out using the program FITOPAC 2 written and developed by George Shepherd of the University of Campinas (São Paulo state, Brazil). The soil properties included in this analysis were pH, Al, H + AL, OM, N, Ca + Mg, P, K, C, C/N, Al Saturation, V, S, CEC, clay, silt and sand.

5.2.2.2 Classification of the sample sites - cluster analysis

A floristic and phytosociological classification of the sample sites in the National Park was carried out by the Cluster option of FITOPAC 2. In this program a numerical hierarchical method was applied to classify the surveyed areas. This method uses agglomerative techniques (Kent & Coker, 1992). A sorting strategy is applied by which the set of sampling is progressively allocated to groups on the basis of the information in the matrix. Similar pairs are fused into the same groups. The process of fusion selected in the FITOPAC 2 was the average-linkage or group average, which is based on the minimum average distance between individuals and groups. It used the unweighted pair-groups method with arithmetic averages (UPGMA).

5.2.2.2.1 Sϕrensen's similarity index

Sϕrensen's similarity indices were used as row data matrices for the floristic classification and Morisita's (modified by Horn (1966)) similarity indices were used as data row matrices for the phytosociological classification.

The calculations of the similarity indices were made as follows:

Sϕrensen index (qualitative)

$$S = 2c / a + b$$

a = number of species in sample 1

b = number of species in sample 2

c = number of species common to both samples

This index is designed to equal 1 in cases of complete similarity (that is where the two sets of species are identical) and 0 if the sites are dissimilar and have no species in common.

5.2.2.2.2 Morisita's similarity index

Morisita index (Horn, 1966)

The Morisita index measure of community similarity is based on the probability that two randomly selected individuals from a community will be of the same species:

$$L_1 = \sum Xi\,(Xi - 1) / N_1\,(N_1 - 1)$$

Where Xi is the number of individuals in species i in community L, and N_1 is the total number of individuals in community L ($N_1 = \sum Xi$); likewise:

$$L_2 = \sum Yi\,(Yi - 1) / N_2\,(N_2 - 1)$$

Where, for community 2, L_2 is Simpson's dominance index. Yi is the abundance of species i, and $N_2 = \sum Yi$, the total number of individuals in community 2.

The Morisita index of community similarity (also called Morisita's index of overlap, Horn, 1966) is:

$$I_M = 2 \sum XiYi / (L_1 + L_2)\,N_1\,N_2$$

It may range from 0 (no similarity) to approximately 1 (identical). It has the desirable characteristic of being very little affected by the sizes of the samples. This index of community refers to the probability that individuals randomly drawn from each of the two communities will belong to the same species, relative to the probability of randomly selecting a pair of specimens of the same species from one of the communities.

5.2.2.3 Detrended Correspondence Analysis - DCCA (CANOCO)

Detrended canonical correspondence analysis (DCCA) was used in order to study the relationships between species abundances and the quantitative and qualitative soil properties. DCCA is an ordination technique that incorporates multiple regressions, with the ordination axes constrained as linear combinations of environmental variables. DCCA

Table 40 - Averaged soil properties of the Brasília National Park

Vegetation Communities	pH	Al Sat %	Al cmol/kg	CEC cmol/kg	H + Al cmol/kg	Ca + Mg cmol/kg	P (ppm)	K (ppm)	N %	clay %	silt %	sand %
Gallery forest	5,2	34,3	1	18,2	12,4	6,7	2,6	84	0,5	42,5	19,8	37,7
Cerrado	4,9	43,8	0,6	10,9	8,4	2,3	1,6	42,8	0,3	54,7	15,3	30
Cerrado scrub	4,8	51,7	0,7	5,9	5,2	0,4	1	30,5	0,2	39,7	11	49
Cerrado open scrub	4,7	62,8	1	8	7,5	0,3	0,9	38	0,2	26	9	65,5
Campo limpo	5	65,3	1,3	11,8	11,1	0,5	2	69	0,3	43	21	36
Cerrado scrub with emergents	5	65,8	0,9	5,6	5,2	4	1,5	27	0,1	39	12	49
Cerrado rupestre	5,2	38,2	0,6	5,2	7,3	1,3	2,1	57,5	0,1	15,5	8	76,5
Campo rupestre	5,2	29,3	0,6	7,2	5,8	1,3	2,6	70	0,3	55	18	27
Trembleytetum	4,8	68,8	0,8	7,7	7,3	0,3	0,9	34	0,2	24	7	69

The linear correlation coefficients (r) between the soil properties and the physiognomic gradient gallery forest-cerrado-cerrado scrub-cerrado open scrub were: pH = 0.53, Al sat = 0.40, Al = 0.51, CEC = 0.83, H + Al = 0.67, Ca + Mg = 0.94, P = 0.60, K = 0.67, N = 0.75, clay = 0.00, silt = 0.53, sand = 0.12.

Obs: The coefficients were obtained by correlating the averaged basal area/ha of the distinct vegetation physiognomic categories with the soil properties.

Table 41 - Sorensen's similarity indices of Brasília National Park sample sites

1	PISC1																									
2	0.57	CEMA																								
3	0.33	0.39	CRIST																							
4	0.35	0.32	0.36	BARRIG																						
5	0.34	0.33	0.39	0.34	CAPÃO																					
6	0.25	0.18	0.22	0.35	0.34	TBAR																				
7	0.31	0.28	0.31	0.35	0.33	0.32	PALM																			
8	0.14	0.17	0.13	0.20	0.35	0.30	0.14	BANAN																		
9	0.02	0.07	0.03	0.05	0.04	0.00	0.05	0.00	CETB1																	
10	0.00	0.00	0.00	0.02	0.00	0.02	0.04	0.00	0.62	CETB2																
11	0.00	0.05	0.00	0.04	0.02	0.00	0.04	0.00	0.53	0.46	VOCH1															
12	0.02	0.04	0.02	0.06	0.03	0.03	0.08	0.00	0.47	0.43	0.53	CEMG														
13	0.00	0.03	0.03	0.02	0.00	0.00	0.04	0.00	0.54	0.58	0.40	0.60	CSMT													
14	0.02	0.04	0.02	0.05	0.02	0.01	0.03	0.00	0.58	0.46	0.56	0.76	0.60	CENS												
15	0.00	0.03	0.00	0.02	0.02	0.02	0.02	0.00	0.53	0.48	0.41	0.46	0.50	0.59	CSNS											
16	0.21	0.14	0.11	0.17	0.15	0.05	0.09	0.04	0.43	0.26	0.41	0.48	0.41	0.51	0.32	CECCO										
17	0.04	0.07	0.02	0.05	0.07	0.05	0.08	0.02	0.53	0.46	0.51	0.60	0.47	0.65	0.43	0.46	BARAG									
18	0.05	0.07	0.00	0.07	0.02	0.03	0.07	0.00	0.42	0.46	0.47	0.53	0.41	0.55	0.28	0.30	0.50	INV								
19	0.00	0.00	0.00	0.02	0.00	0.02	0.00	0.00	0.40	0.47	0.20	0.26	0.33	0.34	0.33	0.13	0.18	0.37	TOR1							
20	0.00	0.03	0.00	0.04	0.02	0.00	0.02	0.00	0.32	0.22	0.35	0.19	0.17	0.27	0.41	0.20	0.24	0.21	0.19	RAPVEL						
21	0.04	0.04	0.00	0.05	0.02	0.03	0.06	0.00	0.55	0.49	0.56	0.67	0.57	0.71	0.49	0.48	0.64	0.53	0.30	0.31	CETOR					
22	0.00	0.03	0.00	0.06	0.02	0.02	0.06	0.00	0.43	0.30	0.50	0.29	0.27	0.38	0.38	0.29	0.37	0.41	0.11	0.39	0.47	VOCH2				
23	0.05	0.07	0.03	0.05	0.07	0.06	0.10	0.04	0.45	0.44	0.51	0.53	0.35	0.51	0.29	0.35	0.49	0.72	0.29	0.21	0.53	0.44	CEPAL			
24	0.04	0.07	0.02	0.10	0.04	0.06	0.08	0.02	0.52	0.47	0.54	0.60	0.44	0.58	0.42	0.43	0.65	0.54	0.22	0.25	0.60	0.43	0.53	CETORT		
25	0.05	0.05	0.00	0.02	0.02	0.05	0.05	0.02	0.33	0.27	0.35	0.30	0.21	0.32	0.24	0.20	0.37	0.51	0.28	0.10	0.38	0.31	0.46	0.38	ARNI	
26	0.03	0.03	0.00	0.00	0.00	0.03	0.02	0.00	0.35	0.36	0.30	0.34	0.25	0.40	0.38	0.22	0.34	0.36	0.35	0.18	0.31	0.24	0.33	0.40	0.29	MURU
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26

Sample sites abbreviations: PISC1 - PISCINA 1; CEMA - CEMAVE; CRIST - CRISTAL; BARRIG - BARRIGUDA; CAPÃO - CAPÃO COMPRIDO, TBAR - TRES BARRAS, PALM - PALMAS, BANAN - BANANAL; CETB1 - CERRADO TRES BURACOS 1, CETB2 - CERRADO TRES BURACOS 2; VOCH1 - VOCHYSIA 1; CEMG - CERRADO MATO GROSSO; CSMT - CAMPO SUJO MATO GROSSO; CENS - CERRADO NOVO SETOR, CSNS - CAMPO SUJO NOVO SETOR, CECCO - CERRADO CAPÃO COMPRIDO, BARAG - BARRAGEM; INV - INVERNADA; TOR1 - TORRE 1; RAPVEL - RAPVELL; CETOR - CERRADO TORRE; VOCH2 - VOCHYSIA 2, CEPAL - CERRADO PALMAS, CETORT - CERRADO TORTINHO, ARNI - ARNICAS, MURU - MURUNDU

Obs. numbers in bold show similarity greater than 50% or more

Table 42 - Morisita's similarity indices of Brasília National Park sample sites

1	PISC1																									
2	**0,81**	CEMA																								
3	**0,56**	**0,57**	CRIST																							
4	0,29	0,31	0,42	BARRIG																						
5	0,15	0,15	0,25	0,25	CAPÃO																					
6	0,24	0,20	0,30	0,40	0,31	TBAR																				
7	0,44	0,41	**0,53**	0,44	0,17	0,29	PALM																			
8	0,07	0,10	0,03	0,10	0,15	0,17	0,08	BANAN																		
9	0,01	0,01	0,00	0,02	0,00	0,00	0,02	0,00	CETB1																	
10	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,30	CETB2																
11	0,00	0,01	0,00	0,06	0,01	0,00	0,03	0,00	0,31	**0,56**	VOCH1															
12	0,00	0,00	0,00	0,01	0,00	0,02	0,03	0,00	0,32	0,10	0,17	CEMG														
13	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	**0,54**	0,08	0,06	0,44	CSMT													
14	0,00	0,01	0,00	0,02	0,00	0,02	0,01	0,00	0,48	0,11	0,16	**0,79**	**0,54**	CENS												
15	0,00	0,00	0,00	0,00	0,00	0,01	0,00	0,00	0,46	0,10	0,04	0,46	**0,86**	**0,58**	CSNS											
16	0,09	0,04	0,08	0,05	0,02	0,02	0,07	0,00	0,27	0,07	0,13	**0,64**	0,42	**0,76**	0,43	CECCO										
17	0,00	0,03	0,01	0,06	0,01	0,03	0,05	0,00	0,31	0,10	0,28	0,35	0,19	0,34	0,12	0,21	BARAG									
18	0,00	0,01	0,00	0,01	0,00	0,02	0,01	0,00	0,35	0,11	0,13	**0,68**	0,40	0,71	0,47	**0,56**	0,14	INV								
19	0,00	0,00	0,00	0,00	0,00	0,01	0,00	0,00	0,30	0,07	0,05	0,14	0,38	0,18	0,08	0,09	0,13	0,17	TOR1							
20	0,00	0,01	0,00	0,10	0,02	0,00	0,05	0,00	0,14	0,12	0,38	0,04	0,12	0,06	0,11	0,07	0,14	0,02	0,09	RAPVEL						
21	0,00	0,01	0,00	0,07	0,01	0,02	0,07	0,00	0,49	0,25	0,45	**0,61**	0,36	**0,54**	0,27	0,36	**0,56**	0,37	0,20	0,19	CETOR					
22	0,00	0,01	0,00	0,10	0,01	0,00	0,04	0,00	0,19	0,39	**0,63**	0,13	0,08	0,11	0,08	0,09	0,21	0,17	0,02	**0,69**	0,34	VOCH2				
23	0,02	0,02	0,00	0,01	0,00	0,05	0,04	0,00	0,21	0,04	0,25	0,21	0,17	0,23	0,05	0,22	0,18	0,30	0,23	0,04	0,30	0,14	CEPAL			
24	0,01	0,02	0,00	0,10	0,02	0,03	0,09	0,00	**0,56**	0,10	0,29	0,48	0,28	**0,53**	0,29	0,36	0,37	0,45	0,10	0,22	**0,59**	0,30	0,32	CETORT		
25	0,01	0,01	0,00	0,00	0,00	0,02	0,01	0,00	0,08	0,03	0,16	0,09	0,02	0,09	0,02	0,10	0,06	0,25	0,06	0,00	0,15	0,05	0,35	0,18	ARNI	
26	0,00	0,02	0,00	0,00	0,00	0,00	0,00	0,00	0,27	0,06	0,08	0,35	0,23	0,35	0,24	0,27	0,10	0,41	0,12	0,03	0,21	0,07	0,05	0,29	0,02	MURU
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26

Sample sites abbreviations: PISC1 = PISCINA 1; CEMA = CEMAVE; CRIST = CRISTAL; BARRIG = BARRIGUDA; CAPÃO = CAPÃO COMPRIDO; TBAR = TRES BARRAS; PALM = PALMAS; BANAN = BANANAL; CETB1 = CERRADO TRES BURACOS 1; CETB2 = CERRADO TRES BURACOS 2; VOCH1 = VOCHYSIA 1; CEMG = CERRADO MATO GROSSO; CSMT = CAMPO SUJO MATO GROSSO; CENS = CERRADO NOVO SETOR; CSNS = CAMPO SUJO NOVO SETOR; CECCO = CERRADO CAPÃO COMPRIDO; BARAG = BARRAGEM; INV = INVERNADA; TOR1 = TORRE 1; RAPVEL = RAPVELL; CETOR = CERRADO TORRE; VOCH2 = VOCHYSIA 2; CEPAL = CERRADO PALMAS; CETORT = CERRADO TORTINHO; ARNI = ARNICAS; MURU = MURUNDU

Obs: numbers in bold show similarity greater than 50% or more

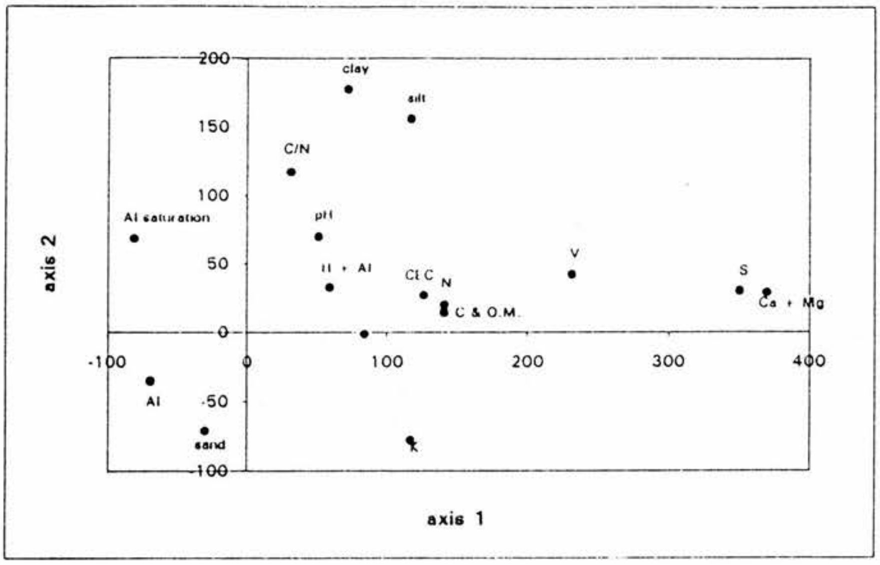


Figure 34 - Ordination of the soil properties of Brasília National Park using a Detrended Correspondence Analysis - DECORANA

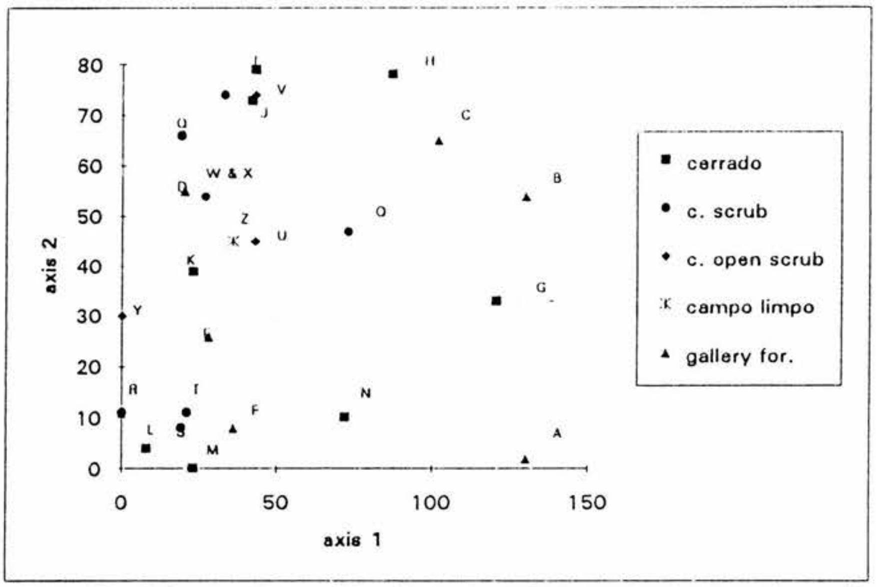


Figure 35 - Ordination biplot of Brasília National Park sample sites based on soil properties.

Sample site identification: Gallery forest sites, A - CEMAVE, B - CRISTAL, C - BARRIGUDA, D - PISCINA 1, E - PALMAS, F - TRES BARRAS; Cerrado *sensu strictu* sites, G - CER. CAPÃO COMPRIDO, H - CER. MAT GROSSO, I - CER. NOVO SETOR, J - CER. TORTINHO, K - BARRAGEM, L - INVERNADA, M - CER. TORRE, N -CER. PALMAS; Cerrado scrub sites, O - ARNICAS, P - VOCHYSIA 2, Q - CER. TRES BURACOS 2, R - VOCHYSIA 1, S - RAPVELL, T - TREMBEYETUM; Cerrado open scrub sites, U - CAMPO SUJO MATO GROSSO, V - MURUNDU, W - CAMPO SUJO NOVO SETOR, X - CER. TRES BURACOS 1, Y - TORRE 1 and Z - CAMPO LIMPO.

Figure 36 - Sørensen Coefficient

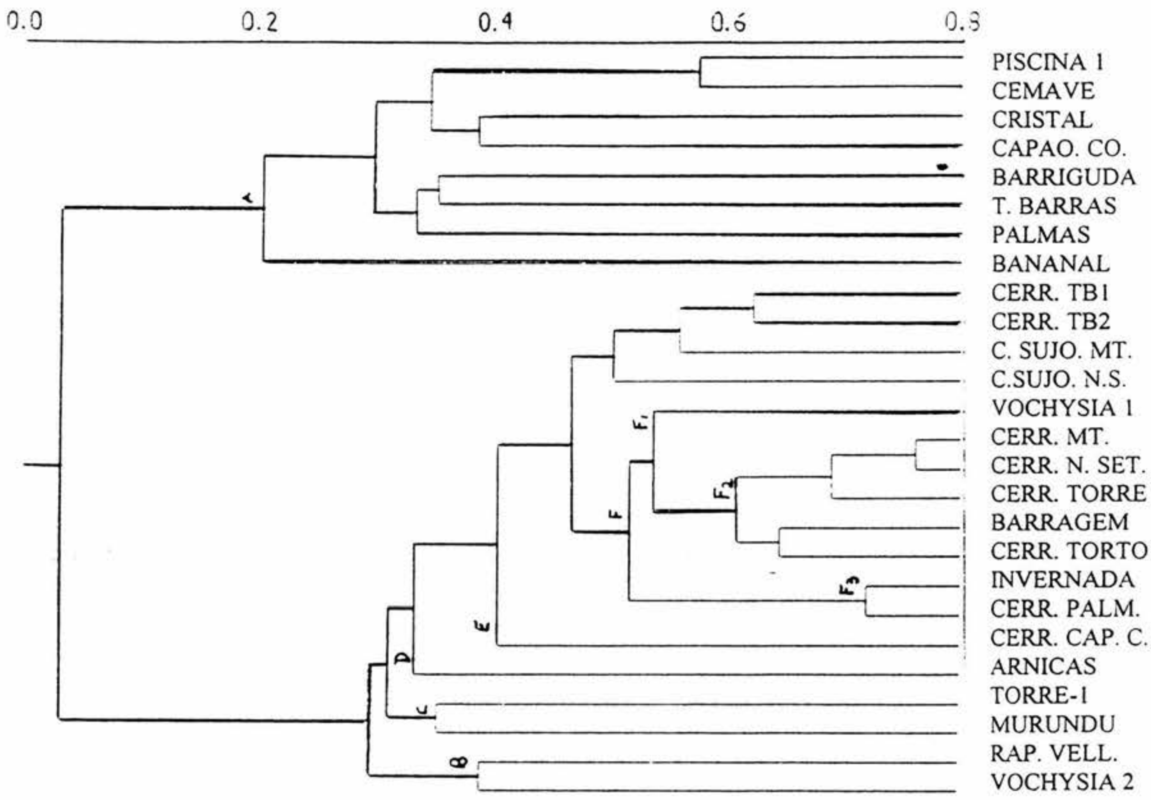
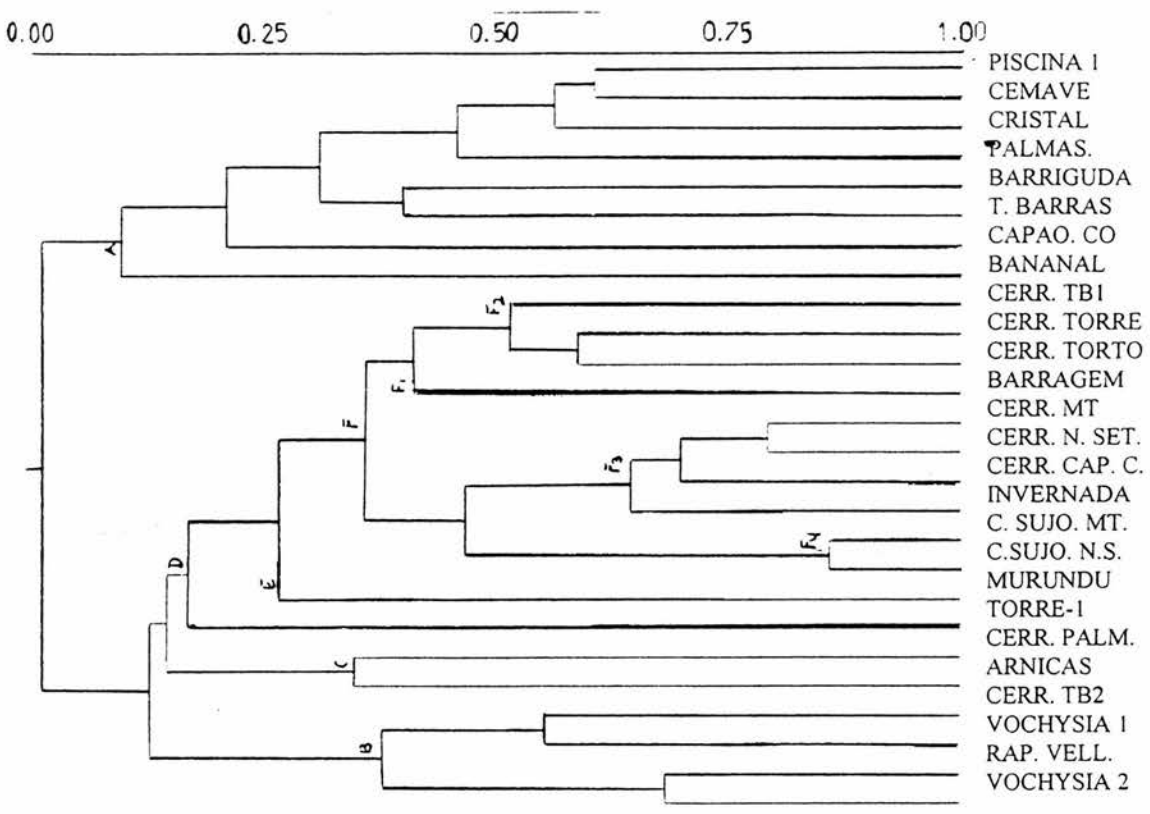


Figure 37 - Morisita Index



	SPEC AX1	SPEC AX2	SPEC AX3	SPEC AX4	ENVI AX1	ENVI AX2	ENVI AX3	ENVI AX4	Ca + Mg	Al.sat.	Wt.deep	Mesic
SPEC AX1	1											
SPEC AX2	0,31	1										
SPEC AX3	0,54	0,58	1									
SPEC AX4	-0,52	-0,58	-0,96	1								
ENVI AX1	0,91	0,21	0,34	-0,33	1							
ENVI AX2	0,22	0,85	0,30	-0,30	0,24	1						
ENVI AX3	0,63	0,52	0,50	-0,45	0,69	0,61	1					
ENVI AX4	-0,66	-0,56	-0,49	0,45	-0,72	-0,65	-0,99	1				
Ca + Mg	-0,52	-0,70	-0,41	0,40	-0,57	-0,83	-0,83	0,88	1			
Al. sat.	0,27	0,49	0,16	-0,19	0,30	0,58	0,33	-0,41	-0,78	1		
Deep w.t.	-0,66	-0,23	-0,11	0,12	-0,72	-0,27	-0,22	0,28	0,22	-0,07	1	
Mesic soil	-0,67	0,27	-0,13	0,13	-0,74	0,32	-0,27	0,30	0,21	-0,29	0,31	1
Seas. wet	0,67	-0,27	0,13	-0,13	0,74	-0,32	0,27	-0,30	-0,21	0,29	-0,31	-1,00

Table 43 - Detrended canonical correspondence analysis - DCCA: matrix of weighted correlations between the species (SPEC) axis, environmental (ENVI) axis and the environmental variables. Ca + Mg, Calcium plus Magnesium; Al. sat., Aluminium saturation; Deep w. t., Deep water-table; Mesic soil; Seas. wet, Seasonal wet soil.

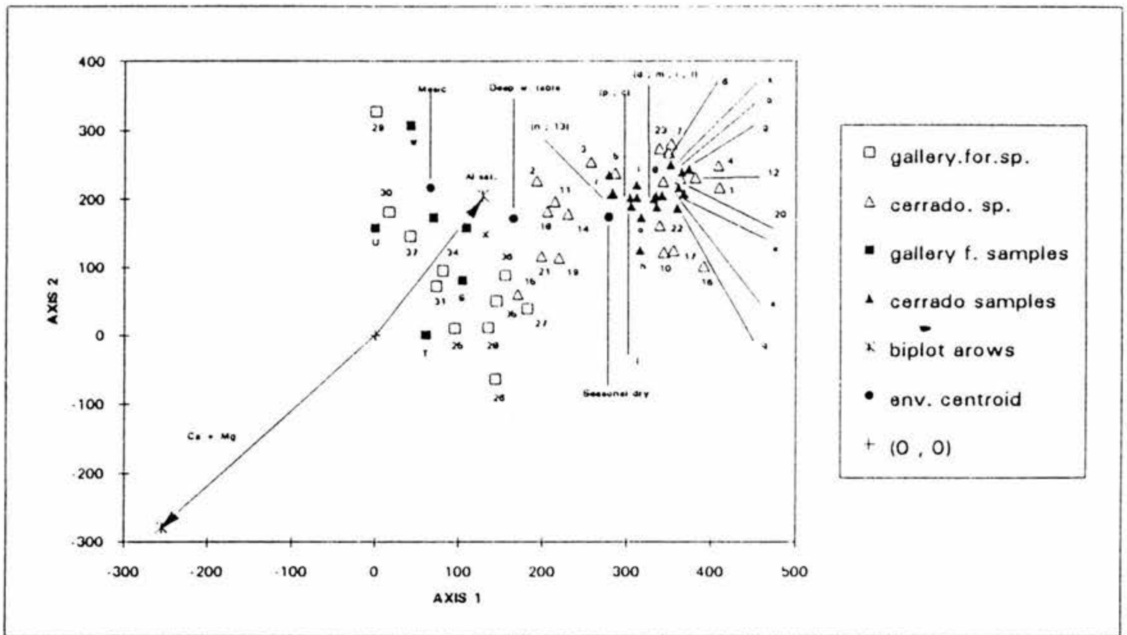


Figure 38 - Canonical analysis ordination biplot of Brasília National Park sample sites, woody plant species and soil properties.

The sample sites are identified as follows: a, CER. TRES BURACOS 1; b, CER. TRES BURACOS 2; c, VOCHYSIA 1; d, CER. MATO GROSSO; e,CAMPO SUJO MATO GROSSO; f, CER. NOVO SETOR; g, CAMPO SUJO NOVO SETOR; h, CER. CAPÃO COMPRIDO; i, BARRAGEM; j, INVERNADA; k, TORRE 1; l, RAPVELL; m, CER. TORRE; n, VOCHYSIA 2; o, CER. PALMAS; p, CER. TORTINHO; q, ARNICAS; r, MURUNDU; S, PISCINA 1; T, CEMAVE; U, CRISTAL; V, BARRIGUDA; W, TRES BARRAS; X, PALMAS.

The species are indicated by: 1, *Aspidosperma tomentosum*; 2, *Banisteriopsis latifolia*; 3, *Caryocar brasiliense*; 4, *Connarus suberosus* var. *fulvus*; 5, *Eremanthus glomerulatus*; 6, *Erythroxylum suberosum*; 7, *E. tortuosum*; 8, *Kielmeyera coriacea*; 9, *Lychnofora ericoides*; 10, *Miconia ferruginata*; 11, *Miconia ligustroides*; 12, *Neea theifera*; 13, *Ouratea hexasperma*; 14, *Psidium myrsinoides*; 15, *P. warmingianum*; 16, *Qualea grandiflora*; 17, *Qualea parviflora*; 18, *Myrsine guianensis*; 19, *Roupala montana*; 20, *Salacia crassifolia*; 21, *Sclerolobium paniculatum* var. *subvelutinum*; 22, *Syagrus comosa*; 23, *Vellozia flavicans*; 24, *V. swallenii*; 25, *Alibertia edulis*; 26, *Anadenanthera colubrina* var. *cebil*; 27, *Attalea phalerata*; 28, *Bauhinia rufa*; 29, *Cheiloclinum cognatum*; 30, *Copaifera langsdorffii*; 31, *Cupania vernalis*; 32, *Cyathea* sp.; 33, *Euterpe edulis*; 34, *Matayba guianensis*; 35, *Myrcia tomentosa*; 36, *Swartzia apetala*; 37, *Tapirira guianensis*.

is used to avoid a Guttman effect or arch effect in the ordination results. DCCA also allows a statistical significance test on the correlations between species abundance and the environmental variables supplied, which is the Monte Carlo permutation test. For carrying out these analyses and the Monte Carlo test the program CANOCO version 3.1 (ter Braak, 1988) was used.

The data of species and environmental variables were organised in two distinct matrices, as required by DCCA. The species matrix consisted of the values for the number of individual plants of the species per hectare. Species with less than 100 individuals per hectare in all the samples were eliminated, resulting in a 248 species x 24 sample sites matrix. Rare species have little or no influence on the results of ordination techniques and their elimination reduces the amount both of calculation and meaningless results (Causton, 1988). Besides the elimination of rare species, the downweighting technique was also applied by the program to avoid the influence of the least abundant species. However, only the most abundant species are represented in the ordination biplot, as indicators of the distinct sample sites.

The matrix of environmental variables included per sample site all the chemical and textural fraction figures provided by soil analysis, as well as a matrix of qualitative variables provided by the soil profile descriptions. These included depth of the soil profiles, depth of the water table, water regime (mesic, seasonal wet, and flooded) presence of mottles, presence of ironstone layer and outcrops, topographical position of the soil profile (ridge top, middle slope, lower slope and valley bottom, plateau shoulders, and gallery head), and the soil textural classes (clay, clay loam, silty clay, sand clay loam, sand loam, loam sand and organic). As indicated by the program (ter Braak, 1988), the environmental variables were gradually eliminated from the analysis according to their correlation coefficients with the ordination axes. Between the variables found covarying, those having weaker correlation with the ordination axes were also eliminated. The best results were given by the variables Ca

+ Mg, aluminium saturation, deep water-table, mesic water regime and seasonal wet (seasonal soil water saturation).

CANOCO yields an ordination biplot in which the distribution of samples and species scores are represented by points (approximated position of weighted averages) and the environmental variables by arrows pointing in the direction of maximum change, the arrow length being proportional to the correlations between the variables and the axes.

5.3 Results

5.3.1 Testing the vegetation gradient x fertility gradient

Differences in the averaged soil properties were observed in the gradient of vegetation of the National Park, from the gallery forest to cerrado open scrub (Table 40). Thus, the averaged values of pH, Ca + Mg and P decreased along the vegetation gradient, while the averaged contents of Al, H + Al, K, N and CEC showed descending values from the gallery forest to cerrado scrub,but increasing again for cerrado open scrub. The Al saturation presented increasing values along the vegetation gradient.

Spearman's correlation coefficient (r) between averaged soil properties (Table 40) and averaged absolute dominance of the distinct vegetation categories, were strong for Ca + Mg, CEC and N, although Ca + Mg had the strongest correlation ($r = 0.935$).

Despite the differences among the averaged soil properties and the strong correlations of some of these properties with the physiognomic gradient of vegetation, the variance analysis ANOVA (Appendix - 3) shows that most of the soil properties are not significantly different amongst the vegetation categories. Nevertheless, the gallery forest sites were significantly different from the cerrado categories in terms of their contents of P and CEC. For H + Al the difference was significant between the gallery forests and the cerrado scrub (campo cerrado) sites, while for K contents the difference was significant only between the gallery forests and the cerrado *sensu sticto*.

5.3.2 Ordination of soil properties

The arrangement of the sample sites according to the soil properties was based on the results of the detrended correspondence analysis DECORANA. They are summarised by Figs. 34 and 35 showing the ordination samples and soil properties in the first two eigenvectors, represented by AXES I and II. The third and fourth eigenvectors (AXES III and IV) are not shown because they were responsible for a lesser amounts of variation and tended to repeat patterns that were already shown by AXES I and II. The eigenvalues corresponding to AXES I to IV were 0.166, 0.150, 0.018 and 0.010, respectively.

The ordination promoted by the program DECORANA with basis in the soil properties did not sort out the sites sampled in the National Park into similar physiognomic groups. Thus, the gallery forest areas were not grouped apart from the cerrado sites, which in turn were not distributed in their different physiognomic categories by the groups of the ordination diagram.

Nevertheless, AXIS I which is responsible for much of the soil property variance shows that Ca + Mg and aluminium saturation were the most important soil factors in the ordination of the sample sites. Potassium, clay, silt and sand were responsible for much of the remaining soil property variance, being represented by AXIS II.

The ordination concurs with the idea that the physiognomic gradient of the cerrado vegetation cannot be explained solely by the soil fertility, even when associated with the textural fractions clay, silt and sand.

5.3.3 Phytosociological and floristic classification of the vegetation sample sites

The results of the classification of the vegetation sites of the National Park of Brasília using the Cluster option of the program FITOPAC 2 are given in two similarity coefficients diagrams (Tables 41 and 42) and in two hierarchical cluster dendrograms (Figs. 36 and 37).

The similarity diagrams show that Sϕrensen indices (presence-absence of species) were generally higher than Morisita's indices which also consider the abundance of species. The lower values found for Morisita's indices indicates that the vegetation communities are more dissimilar in terms of species abundance than floristically. The similarities between gallery forest sample sites are in general lower than those amongst cerrado sites, revealing, as is well known, that the gallery forests are floristically richer and more heterogeneous in species abundance than the cerrado.

PISCINA 1 and CEMAVE are the most similar gallery forest sites with 0.6066 and 0.5743 of Morisita and Sϕrensen indices respectively. Amongst the forest sites, BANANAL (flooded) is the most dissimilar, with the lowest similarity indices.

CAMPO SUJO NOVO SETOR and CAMPO SUJO MATO GROSSO are the closest sites in terms of species abundance. They have the highest Morisita index (0.8593) of all sample sites in the National Park. However, CERRADO NOVO SETOR and CERRADO MATO GROSSO showed the highest floristic similarity in the National Park, with a Sϕrensen index of 0.7619.

TORRE 1 (cerrado open scrub) and MURUNDU (earth-mound fields) have the overall lowest similarity indices in this classification analysis.

The drier sites of the gallery forests show some floristic similarities with the cerrado sites. CERRADO CAPÃO COMPRIDO was the cerrado site closest to those of the gallery forest. This proximity is more evident when considering floristic similarity. The gallery forest site closest to CERRADO CAPÃO COMPRIDO was PISCINA 1 with a similarity of Sϕrensen = 0.2083 and Morisita = 0.0874. The high similarity observed between these two sample sites agrees with the phytosociological data in Chapter 4 which describes the expansion of the gallery forest species in this marginal cerrado site.

Based on the distances between the sample sites, both clustering procedures used by FITOPAC 2 (Sϕrensen and Morisita indices) were able to separate the gallery forest from the cerrado sites. But, Morisita indices made a more effective classification of the gallery forests, giving a hierarchical organisation which is apparently related to an intrinsic humidity gradient. The water-logged gallery forest site BANANAL is plotted apart from the other forests in the diagram. The other gallery forest sample sites seem to be clustered according to the abundance of characteristic species of damp sites.

Xylopia emarginata, Calophyllum brasiliense, Talauma ovata, Euterpe edulis appear and rise to their modes on wet areas, and are substituted by *Tapirira guianensis, Cheiloclinum cognatum, Copaifera langsdorffii, Callisthene major, Anadenanthera colubrina* var. *cebil* and other tree species on drier ground.

In general Morisita similarity indices were also stronger than Sϕrensen coefficients for clustering the cerrado sites. However, in some cases the opposite occurred. Thus, the cerrado *sensu stricto* sites were better grouped by the application of Sϕrensen indices which clustered together five of the six sites. The cerrado rupestre areas were also grouped together by Sϕrensen indices, but were plotted apart by Morisita indices. So, sometimes the floristic similarities were effective for grouping the sites studied, but as a whole the abundance of species gave a better result.

High densities of shrub species such as *Myrsine guianensis, Roupala montana* and *Vellozia flavicans* were responsible for grouping together the sites VOCHYSIA 1, VOCHYSIA 2 (cerrado scrub with emergents sites), RAPVELL and TRES BURACOS 2 (cerrado scrub sites). They are localised in very similar topographical and edaphic conditions, all covering areas on the border of the plateau of the *Chapada da Contagem*, on sandy soils and all except TRES BURACOS 2 have an ironstone layer in the profile (see profile descriptions in Appendix - 2).

CERRADO PALMAS (cerrado rupestre) and ARNICAS (campo rupestre) appear together in the Morisita cluster diagram, but INVERNADA (cerrado rupestre) was divided apart from them. However, these two cerrado rupestre areas were grouped together when using Sϕrensen's indices. These three sample sites occupy similar geomorphic and edaphic sites, with *cerrado rupestre* on the hill tops and *campo rupestre* at the hill flanks, on sand and rocky soils. *Miconia ferruginata, Qualea parviflora, Sclerolobium paniculatum* var. *subvelutinum, Psidium myrsinoides* and *Palicourea rigida* were the common species responsible for the similarities of these sites.

The cerrado open scrub sites CAMPO SUJO NOVO SETOR and CAMPO SUJO MATO GROSSO with the highest Morisita similarity indices were grouped together in both dendrograms. These samples occur on very similar topographic and edaphic conditions on Red-Yellow Latosols which have a shallow water-table during the rainy season. High densities of shrubs of *Connarus suberosus* and *Kielmeyera coriacea* characterise these sites floristically and structurally.

Given the ideas about distinct clusters formed by FITOPAC 2, it is possible to determine groups in the dendrograms.

5.3.3.1 Morisita dendrogram (Fig. 37, p. 174)

Six groups from A to F were identified:

Group A - In this group the gallery forest sites were clustered according to the abundance of tree species, found on soils with distinct moisture conditions. Thus, the flooded BANANAL is plotted apart the other forest sites.

Group B - Is represented by the clustering of two cerrado scrub sites (TRES BURACOS 2 and RAPVELL) and two sites of cerrado scrub with emergents (VOCHYSIA 1 and 2). These sites present similar topographical situations in their catenas. They develop on sites near the borders of the plateau where the water-table approaches the soil surface in the rainy season. Besides that, RAPVELL, VOCHYSIA 1 and VOCHYSIA 2 have sandy soils with the presence of an ironstone layer.

Group C - One cerrado rupestre area (CERRADO PALMAS) and the campo rupestre (ARNICAS) form this group. The abundance of *Qualea parviflora, Miconia ferruginata, Eremanthus goyazensis, Psidium myrsinoides* and *Byrsonima coccolobifolia* were responsible for the similarity of these sites.

Group D - This group was formed as a result of the dissimilarities of MURUNDU (earth mound field) with the other cerrado sites. *Psidium warmingianum* is an abundant shrub species which gives to the site the observed low similarity.

Group E - Is represented by the open scrub sample site TORRE 1. This site is in a shallow and concretionary soil which is water-saturated during the rainy season. Limiting soil environmental conditions impede the establishment of sensitive species, this gives the area a low diversity and a low similarity to other areas.

Group F - This includes the cerrado *sensu stricto* sites, one area of cerrado scrub (TRES BURACOS 1), one cerrado rupestre (INVERNADA) and two samples in cerrado open scrub sites (CAMPO SUJO NOVO SETOR and CAMPO SUJO MATO GROSSO). This cluster can be sub-divided into five sub-groups each with strong similarity:

F1 - This is represented by one site alone, the cerrado *sensu stricto* BARRAGEM. It has the highest diversity, density and dominance amongst the cerrado sites, and even higher diversity than some gallery forest sites.

F2 - The cerrado *sensu stricto* sites CERRADO TORTO, CERRADO TORRE and the cerrado scrub TRES BURACOS 1 represent this sub-group. The abundance of *Sclerolobium paniculatum* var. *subvelutinum, Qualea parviflora* and *Caryocar brasiliense* brings about the similarity of these sites of cerrado *sensu stricto* and the common presence of *Vellozia flavicans*, an abundant shrub species in CERRADO TORRE and the most abundant species in CERRADO TRES BURACOS 1, places the cerrado scrub in the same cluster.

F3 - This is formed by the clustering of three cerrado *sensu stricto* sites and one cerrado rupestre. CERRADO MATO GROSSO and CERRADO NOVO SETOR were the most similar sites in the group and the second most similar amongst all sites studied. The similarity between INVERNADA and CERRADO CAPÃO COMPRIDO was strongly influenced by the abundance of *Kielmeyera coriacea* which was also mainly responsible for the similarity between the sub-groups F3 and F4.

F4 - This sub-group is formed by two cerrado open scrub areas which were the most similar sites amongst all those studied.

5.3.3.2 Sϕrensen dendrogram (Fig. 36, p. 173)

Seven groups from A to E were identified:

Group A - This is represented by the gallery forest sample sites. The arrangement of the forest sites by their floristic characteristics (presence-absence of species) grouped the gallery forest site PALMAS, which is a characteristically dry site near the flooded BANANAL, and the mesic TRES BARRAS. This was caused by the presence of a few individuals of *Xylopia emarginata* (tree species characteristic of damp soils), found in the stream margin of PALMAS gallery forest.

Group B - Formed by the cerrado scrub site RAPVELL and the scrub with emergents VOCHYSIA 2. *Roupala montana, Rapanea guianensis* and *Vellozia flavicans* gave the similarity between these sites.

Group C - Represented by MURUNDU and TORRE 1 sample sites. The low indices of similarity of these sites grouped them in this position.

Group D - This group consists of the campo rupestre site ARNICAS alone. It is a distinct site both floristically and structurally.

Group E - This is represented by cerrado CAPÃO COMPRIDO alone. This cerrado site was the most similar to the gallery forest sites, because of the presence of forest species found expanding into this cerrado site.

Group F - This cluster can be sub-divided in three similarity sub-groups:

F1 - This is represented by the cerrado scrub with emergents VOCHYSIA 1.

F2 - This cluster grouped all the cerrado *sensu stricto* sites except CERRADO CAPÃO COMPRIDO already mentioned.

F3 - This is formed by the cerrado rupestre sites.

Group G - This cluster is arranged by two areas of cerrado scrub and two areas of cerrado open scrub. They are united by the presence of various shrub species common to them.

Most of the cerrado sites were grouped together in both dendrograms. The union of distinct physiognomic categories of cerrado in the same group might be caused by the fact that the distinct categories of cerrado carry various shrub species in common. Both dendrograms grouped the sample sites MURUNDU and TORRE 1 together. They are the most distinct among the cerrado sites, being poorer floristically.

5.3.4 Detrended Canonical Correspondence Analysis - DCCA

The results of the DCCA are shown in the ordination diagram (Fig. 38), while Table 43 presents the weighted correlations among the first two environment and species axes and the environmental variables.

The eigenvalues for the DCCA axes were 0.630, 0.164, 0.0015, and 0.006, respectively. The cumulative percentage variance accounted by these axes were 50.5%, 67.5%, 0% and 0%. These results indicate that the environmental variables supplied were apparently sufficient to explain most of the floristic variance among the sample sites, and that the AXIS 1 was very important.

The Monte Carlo test carried out for the analysis indicated that the species were significantly related to the environmental variables supplied ($P< 0.01$).

From these results it can be inferred that the AXIS 1 was mainly a hydrological gradient while the AXIS 2 was mainly a gradient of Ca + Mg contents in the soils and, at a lower level, aluminium saturation. The highest negative correlations with AXIS 1 were mesic soils and deep water-table. A positive correlation was found with seasonal wet soil.

AXIS 2 was highly and negatively correlated with Ca + Mg and positively correlated with Al saturation, but this was not a strong correlation. The correlations obtained between the environmental variables show that only Ca + Mg and Al saturation were correlated (negatively), the other environmental variables were uncorrelated.

The qualitative variables, seasonal wet soils, deep water-table and mesic water regime represented by AXIS 1 characterise a humidity gradient of the soils in the National Park. They seem to be the most important factors controlling the distribution of vegetation from gallery forests to cerrado open scrub (campo sujo), covering 50.5% of the variance of the species distribution.

The gradient of Ca + Mg and aluminium saturation was shown to be the second most important factor, responsible for 27% of the variance of the species distribution in the National Park communities.

The gallery forests and cerrado sample sites are situated in distinct regions of the ordination biplot. *Euterpe edulis* and *Cyathea* sp., which occur in dense populations in damp places in the gallery forests, and *Connarus suberosus* var. *fulvus*, *Neea theifera, Vellozia flavicans, Erythroxylum suberosum* and *E. tortuosum* all important species in the shrubby categories of cerrado (scrub) sample sites, are plotted at the opposite sides of the ordination biplot.

The gallery forest sites are generally associated with mesic water regimes, deep water-table is related to cerrado *sensu stricto* sites, whilst the sites which relate to seasonal influences of the water-table (seasonally wet) are represented by cerrado scrub (campo cerrado) and cerrado open scrub (campo sujo).

The ordination of the sample sites by AXIS 2 was much less discriminating and the separation of the gallery sites in the biplot was stronger than for the cerrado sites. The gallery forest site PISCINA 1 which was found on a dystrophic soil is plotted near CEMAVE which is an eutrophic site. Cerrado sites such as RAPVELL, VOCHYSIA 1 and 2 plotted between the gallery forests and the cerrado *sensu stricto* sites were expected to appear positioned near the cerrado scrub sites. These unexpected site positions was caused by the existence of sites similar in species composition and abundance occurring in different environmental soil conditions, giving rise to noise in the analysis.

The most important result shown in this DCCA is that the vegetation gradient from gallery forests to cerrado open scrub is strongly correlated by the soil moisture gradient.

5.4 Discussion

Despite the strong correlations found between the structural gradient of vegetation and the soil properties in the National Park, it cannot be claimed that soil fertility is necessarily the most important factor determining the distribution of distinct vegetation communities. The variance analysis of the soil parameters in the area shows that significant differences in soil properties were detected only between the gallery forests and the cerrado sites; no important variation was revealed amongst the cerrado categories. Besides this, the ordination of the sample sites by their chemical and textural soil properties failed to cluster similar structural vegetation types together, although the nutrient rich sites were separated from the majority of nutrient-poorer ones in the ordination biplot.

All these facts emphasise the assertion that the physiognomic vegetation gradient in the cerrado region cannot be explained by soil fertility alone (Furley & Ratter, 1988; Haridasan, 1992).

In the literature, specific studies have often been quoted when the gradient of fertility of the cerrado is discussed. Some authors considered soil fertility to be a major determinant of the wide and diverse physiognomic gradient encountered in the cerrado vegetation (Eiten, 1972; Queiroz Neto, 1982). Goodland & Pollard (1973) worked with cerrado vegetation and soils in Minas Gerais, ranging from campo sujo (cerrado open scrub) to cerradão, and found a significant correlation between the increased production of woody vegetation and level of phosphorus, nitrogen and potassium in the surface soil horizons, while Lopes & Cox (1977), who studied 500 sites covering much of the cerrado of central Brazil encountered the same relationship. However, Ribeiro (1983) registered no significant differences in soil fertility between a well developed cerradão and sparser cerrado forms nearby.

Furley & Ratter (1988) suggested that the explanation of these contradictory results lies at least partly in the occurrence of two floristically and pedologically different forms of cerradão, the mesotrophic and dystrophic facies. Ribeiro (1983) compared a site of dystrophic cerradão with an area of cerrado *sensu stricto*, which are vegetation types which occurs on similar soil conditions, as was first demonstrated by detailed studies in Mato Grosso (Ratter, 1971; Ratter et al., 1973).

Although the evidence obtained from the variance analysis (ANOVA) of the soil properties among the vegetation categories in the National Park indicates the absence of a fertility gradient, some richer soils were observed either in gallery forest sites such as CEMAVE and CRISTAL or in some cerrado *sensu stricto* sites such as CERRADO MATO GROSSO and CERRADO CAPÃO COMPRIDO. However, as expected none of the scrub categories had high levels of nutrients.

Ratter (1980) and Furley (1985) studying the vegetation and soils of Fazenda Água Limpa in the Distrito Federal also found patches of cerrado vegetation, characterised by the presence of semideciduous trees of *Luehea paniculata,* on soils rich in Ca and Mg within more typically dystrophic surrounding cerrado areas.

Deciduous or semideciduous forests occur as climax vegetation of better soils (Ratter et al., 1978a; Furley & Ratter, 1988; Ramos, 1989). The mesotrophic cerradão generally occurs at the margins of the deciduous forests with intermediate levels of soil fertility between that of the more dystrophic forms of cerrado and that of the deciduous forest (see Table 7). The dystrophic facies cerradão is found on more dystrophic soils with the similar soil characteristics of those occupied by the cerrado, as described by Ribeiro (1983).

Apparently, the distribution of the dystrophic cerradão seems to be limited to the same topographical position occupied by cerrado *sensu stricto* over old geomorphic surfaces, on well-drained, deep and poorer Latosols. Dystrophic cerradão is very widespread in central Brazil, and it seems probable that in the past, before the advent of frequent man-made fires, the dense arboreal forms of cerrado were more common and covered a much larger area than they do today (Warming, 1892; Furley & Ratter, 1988).

Considering the mesotrophic cerradão as a component of the cerrado vegetation continuum, we can agree with the idea that the distribution of cerrado communities are in part determined by the fertility gradient. It is therefore possible to concur with the hypothesis of the existence of two main axes (gradients) which determine most of the variation in the distribution of the savannas. These are represented by the available plant nutrient (PAN) and the available plant moisture (PAM) (Frost et al., 1986; Goldstein & Sarmiento, 1987; Solbrig, 1990).

In the National Park of Brasília the gallery forest sites CEMAVE, CRISTAL and BARRIGUDA, and the cerrado *sensu stricto* sites CERRADO MATO GROSSO and CERRADO CAPÃO COMPRIDO revealed higher contents of nutrients. Accordingly, these sample sites were located in the ordination biplot regions of richer soils. So, for these sites the distribution of species and the physiognomy might be influenced by the fertility gradient.

Thus, CEMAVE and CRISTAL showed indicator species of better soils such as *Anadenanthera colubrina* var. *cebil* and *Astronium fraxinifolium*. BARRIGUDA has a species distribution which resembles the "cerradão das cabeceiras" (cerradão of the head waters) described by Oliveira-Filho & Martins (1986). *Pseudobombax tomentosum* is a characteristic species of Ca rich soils in the cerrado, while *Guettarda viburnoides* is found in mesotrophic semideciduous forest (Ramos, 1989). Both species were registered in CERRADO CAPÃO COMPRIDO. However, *Sclerolobium paniculatum* var. *subvelutinum* and *Blepharocalyx salicifolius* which are indicator species of dystrophic facies cerradão were registered in CERRADO MATO GROSSO.

A gradient of Ca + Mg and aluminium saturation was detected by the detrended canonical correspondence analysis CANOCO, showing that 27% of the variance of the species-environmental relations was explained by this parameter.

The core area of cerrado is in a tropical semi-humid climate with 1300 - 2200mm precipitation per year and 2 - 5 months drought (Köppen Aw - type). Such a climate favours the expansion of forests and, according to Emmerich (1990), a semideciduous forest would be expected as the zonal vegetation. In fact this agrees well with observations: in central Brazil semideciduous forests are the climax vegetation of better soils, while cerrado is confined to the great extensions of poorer soils (Furley & Ratter, 1988).

A dynamic process of expansion and retreat of the forest margins in contact with cerrado vegetation caused by fires has been observed in the National Park. Characteristic species of cerradão such as *Callisthene major, Copaifera langsdorffii, Blepharocalyx salicifolius, Plathymenia reticulata, Eriotheca pubescens* and *Pseudobombax tomentosum* are commonly found in cerrado *sensu stricto* sites on the margins of gallery forests. These observations suggest that succession processes are operating in these sites but are being inhibited by fire (Ratter, 1980, 1991, 1992).

The interplay of dry, fire-prone years, and wet fireless years determines changes in the composition and structure of these vegetation communities. Fire has been indicated as an important factor responsible for physiognomic and floristic gradients. It is well known that regular dry season fires tend to suppress woody vegetation, particularly young plants, in many savanna areas around the world (Coutinho, 1982; Sarmiento, 1984; Trollope, 1984).

Based on the effects of fire protection on different cerrado physiognomies, Moreira (1992) concluded that fire is a major determinant affecting composition and structure of cerrado vegetation. In fact fire protection induces gradual changes in density of tree species leading to denser arboreal communities (Menaut, 1977; San José & Fariñas, 1983; Frost & Robertson, 1987; Moreira, 1992).

Succession from cerrado to cerradão has been reported. Coutinho (1982, 1990) related that 43 years of fire and cattle grazing protection of a campo sujo (open scrub) in Pirassununga, São Paulo State brought about a gradual and progressive increase in the woody vegetation. The original campo sujo gradually became denser, transforming into cerradão. Ratter (1980) discussed a succession from cerrado to cerradão in the Distrito Federal and in N. E. Mato Grosso in Ratter et al. (1973, 1978b), and in the discussion on forest-savanna boundaries (Ratter, 1992).

Distinctive communities were observed in the margins of gallery forests in the areas of contact with cerrado vegetation. The evidence from the high frequency of fire in the area suggests that the composition and structure of such communities is mainly determined by fire. *Callisthene major, Plathymenia reticulata, Copaifera langsdorffii,* and *Myrcia tomentosa* are common species of the communities. Once established, these species seems to be fire tolerant, surviving the periodic burns, and providing shade for the re-establishment of fire sensitive forest species.

The Detrended Canonical Correspondence Analysis (DCCA) indicated a moisture gradient as the most important factor in the distribution of the vegetation communities in the National Park. This gradient is described by other authors as one of the determinants of the savannas. It is represented by the axis of available plant moisture - PAM (Frost et al., 1986; Goldstein & Sarmiento, 1987; Solbrig, 1991). Soil moisture controls many of the most clear differences in vegetation in the cerrado landscape. In general cerrado trees only occur on soils which are well- drained throughout the year. Swampy gallery forest is found where the water-table is permanently high. The cerrado scrub and cerrado open scrub are believed to represent catenas of gradual changes in the soil moisture. The former are found at higher positions in the catena and the latter are found where the water table oscillates near the surface during the rainy season (Macedo & Bryant, 1987). The pattern is well represented by the DCCA ordination data of the sample sites and species of the National Park (Fig. 38).

Ratter & Dargie (1992) did not consider the moisture gradient in their multivariate analysis of 26 cerrado areas in Brazil. Their analysis revealed latitude, longitude and, most strongly, soil type (mesotrophic or dystrophic) as major gradients. However, detailed soil information was computed in the analysis but little habitat information was available for many sites.

Furley & Ratter (1988) describing the soil resources and plant communities of central Brazilian cerrados, associated the distribution of the communities in part with the soil properties (mesotrophic or dystrophic). They associated many of the most obvious distinct cerrado categories to the moisture gradient, such as cerrado of *Curatella americana*/*Byrsonima crassifolia* and campos de murundus.

The ordination analysis of the National Park sample sites was highly significant, representing 67.5% of the species-environment relations variance. The remaining non-explained species-environment relations might be attributed to "noise" in the data.

Replicate community samples are rarely identical, depending on the sample size, the precision of measurements or estimates, the number of species, and so on. The variation in species composition of the samples of a data set is due, in part, to interesting variation in environmental factors and, additionally, to uninteresting noise. The data is "noisy" in that samples from identical environmental conditions are not identical in species composition and vice-versa. Consequently, the data reflect partly interesting structure and partly noise. The biological causes of noise are complex and include chance distribution and establishment of individuals, animal activity, local disturbances, and environmental heterogeneity at scales below that of the sample area. Noise also results from statistical limitations of finite samples and from limitations in measuring or estimating species abundance (Gauch, 1982).

PICINA 1 gallery forest site contained indicator tree species of mesotrophic soils, although the analysis shows the contrary, that the soils are in fact dystrophic. However, the sample site was ordinated near CEMAVE which is a semideciduous forest on mesotrophic soil. It would certainly be of value to carry out a re-analysis of the PISCINA 1 soils to try to elucidate the situation.

The cerrado rupestre and cerrado scrub with emergents (Vochysietum) sites were located near the cerrado *sensu stricto* sites in the analysis because of similarities in species abundances. However, these communities have important differences in soil environmental conditions, which are determined by the presence of sandstone outcrops (cerrado rupestre) and an ironstone layer (cerrado scrub with emergent). Besides these soil differences they are found on very peculiar topographic features which also characterise the communities. The cerrado rupestre areas are found on rocky hill tops and the cerrado scrub with emergents develops on ironstone outcrops, on relief fault at the tableland borders. In both cases, sites similar in species abundances, occurring on distinct soil environment conditions, caused noise in data analysis, as can be seen by their positions in the ordination biplot.

5.5 Conclusions

The multivariate analysis of the species abundance and soil properties of the National Park of Brasília was able to explain most of the pattern of the vegetation communities in the landscape.

The ordination of the species and sample sites shows that the moisture and fertility gradients were regarded as the primary determinants of the vegetation distribution of the National Park. This conclusion concurs with the concept of a

PAM-PAN plane intended "to produce a classification of the world's savannas based upon an ordination of actual sites in relation to these indices" (Frost et al., 1986).

The available plant moisture gradient (PAM) which is associated with geomorphological characteristics of the landscape was shown to be the first determinant of most of the obvious differences in the vegetation gradient. The available plant nutrient (PAN) was the second axis in the vegetation distribution.

Fire might be considered the third factor related to the gradient of vegetation, either preventing sensitive species of cerradão or gallery forest from expanding into the cerrado areas or changing dense arboreal forms of cerrado into more open treeless cerrado types.

Finally, lithologic and edaphic features associated with the topographic situation, such as presence of ironstones at the borders of the plateau (Chapada da Contagem) and existence of sandstone outcrops on hill watersheds in some interfluves of the National Park, were indicated by the classification analysis of the sample sites as complementary factors to the gradients of moisture and fertility in the distribution of cerrado scrub with emergents, cerrado rupestre and campo rupestre sites.

Chapter 6

Conclusions

Cerrado originally covered 2 million km^2, representing about 23 % of the total area of Brazil. It is an ancient vegetation with a rich flora, consisting of at least 1000 species of trees and shrubs, and many times that number of herbs and sub-shrubs. According to a report for the WWF (Ratter, 1991) relating to the conservation situation of the Brazilian cerrado vegetation, the cerrado vegetation has suffered greatly during the last two decades from the impact on a massive scale of intensive agriculture and charcoal burning . It has been estimated that approximately 50% of the cerrado is now destroyed. This represents about 1 million km^2. Only 20,000 km^2 representing 1.2% of the cerrado biome is protected in Parks (Dias, 1992). An increase of protected areas is necessary to preserve the biodiversity of the cerrado (Ratter, 1991), but it is also urgent to understand better how to conserve the biodiversity represented by the established reserves.

The protected areas are suffering various types of stress such as fire and pollution, generally originating from surrounding man-made habitats. In the absence of appropriate management techniques, many reserves in the cerrado region are becoming smothered by the invasive African grasses, *Melinis minutiflora* (capim gordura) and *Brachiaria* sp. and by the giant fern *Pteridium aquilinum* (bracken) (Ratter, 1991).

Fire is a seasonal event affecting the cerrado vegetation in the National Park. No evaluation of its significance in the area has been carried out up to the present. *Melinis minutiflora* and *Brachiaria sp.,* which were introduced into the region to improve cattle production, are now competing with the cerrado species. *Melinis minutiflora* is now dominating many cerrado areas in the National Park, forming a dense blanket of vegetation which smothers and eliminates the natural ground layer of native species. The giant fern *Pteridium aquilinum* dominates some forest gaps impeding natural regeneration. These facts were also mentioned by Ratter (1991) for the cerrado region of central Brazil and by Ratter et al. (1988) for the southernmost area of cerrado still in existence at Angatuba, São Paulo State.

The basic question formulated in the introductory chapter arose from a necessity to understand relationships between vegetation communities and the environmental and ecological factors determining their distribution and maintenance. Chapter 4 provides the first part of this information through analysis of the floristics and phytosociological parameters of the vegetation communities; while Chapter 3 characterises the soils on which they occur. The working hypothesis answering the question is provided by the gradient analysis in Chapter 5 which detects the most important environmental factors determining the distribution of the vegetation communities. The ordination of species abundance with soil properties reveals that soil moisture is the most important gradient, explaining most of the variance of the species distribution and soil factors. Soil contents of Ca + Mg and Al saturation characterise another gradient, represented by the second ordination AXIS, which corresponds to 27% of the variance of species distribution.

Other soil properties were less important, and covaried with the more significant ones discussed above. However, the topography, the rockiness of the terrain and the presence of an ironstone layer in the soil profiles were indirectly indicated as important factors in the distribution of some vegetation communities such as cerrado rupestre, campo rupestre and cerrado scrub with emergents (Vochysietum). The topography was also associated with the moisture gradient in catenary associations, producing typical toposequences of cerrado vegetation communities. Cerrado *sensu stricto* occurs on well-drained soils at the upper parts of the table-land. Cerrado scrub and cerrado open scrub are found on the slopes of the catena, according to the depth of the water-table. Gallery forests generally occur in the valley bottom, but sometimes extend to higher sites over the valley slopes. In these conditions floristics and structure of the forest change according to the moisture gradient, from damp to dry semideciduous forest. The clarification of the importance of water status will depend upon detailed instrumentation and monitoring, and represent an important future direction of research.

The structure and floristic composition of the gallery forests also vary along the watercourses, according to soil conditions. Thus, drier patches on Cambic soils, carry some deciduous tree species. Other sites occur on deep and well-drained Latosols, such as in the head-water gallery forests and other distinct patches, where forest is expanding into the cerrado areas. Finally, the flooded gallery forests on organic, hydromorphic soils have distinctive plant populations with a few characteristic dominant species.

Based on the results of this work, some practical applications for the management of the National Park can be suggested:

6.1 Priority vegetation communities for protection.

1. A number of sites contain semideciduous forest with a characteristic flora occurring over more fertile soils. Although these forest types are widespread in central Brazil, they are extremely vulnerable since the soils are valuable for cultivation. There are certainly extremely few conserved areas of this vegetation so their protection in the Park is of great importance.
2. The cerrado rupestre and campo rupestre occur in limited areas, carrying characteristic species such as *Lychnophora ericoides* and the rare *Vellozia swallenii,* an endemic species of the rupestre vegetation.

6.2 Fire management

As a consequence of the high frequency of fire in the National Park, a prevention and management program has been practised since 1986. However, it is based mainly on rule-of-thumb experience without scientific guidance. As a result of the present research, some relationships between fire and vegetation communities can be inferred. Based on the following inferences, some fire management guidelines can be suggested:

1. Some cerrado *sensu stricto* sites revealed soil properties similar to those of mesotrophic facies cerradão (Ratter et al., 1973). The high frequency of fire in these areas is likely to be an important determinant of the physiognomy and species distribution. It can be deduced here that fire is impeding these vegetation communities from establishing cerradão, or at least a denser arboreal cerrado.

2. At the fringes of gallery forest abutting on cerrado vegetation there are characteristic vegetation communities, similar to dystrophic facies cerradão (Ratter, 1973) or the cerradão das cabeceiras, described by Oliveira-Filho & Martins (1986) in Mato Grosso State. The dynamics of these communities seem to be strongly affected by periodic burning. Some tree species such as *Callisthene major* and *Myrcia tomentosa,* once established, are able to survive the seasonal fires (personal observation). They become dominant trees at the margins of the forests. On the other hand, sensitive species such as *Siphoneugena densiflora* require much greater periods without fire to establish successfully.

3. Mortality of campo rupestre species such as *Lychnophora ericoides* and *Vellozia* sp. was observed after fires. This indicates that fire is changing the vegetation structure in this endangered community.

The vegetation communities mentioned above might be considered as priorities in the fire management plan, and specific efforts need to be applied to suppress the burning in these areas. As a consequence of fire control it is expected that the cerrado sites on mesotrophic soils would gradually change to a cerradão, or a denser cerrado, while the gallery forests would expand into adjacent cerrado areas.

Nevertheless, control and reduction of fires must be monitored carefully to increase our knowledge of the dynamics of the plant populations. This will help to determine the correct role of fire in the maintenance of the National Park vegetation communities.

6.3 Permanent monitoring of the vegetation communities.

One of the main purposes of this research was to provide the National Park with a permanent set of vegetation and soil plots, to furnish basic information through continuous monitoring.

To this end floristic, phytosociological and soil parameters of the most important woody plant communities of the National Park were established. Continuity of these studies is paramount for an understanding of the dynamics of the plant populations to be protected.

6.4 Further suggestions

1. The soil studies revealed the inadequacy of the EMBRAPA soil survey map to represent the soil units in the National Park, and thus provide the necessary detail for management purposes. As a consequence, it is very important to provide the area with a complete systematic soil survey, compatible with management necessities.

2. Since the hydrological gradient was demonstrated as the most important determinant factor of the distribution of most of the vegetation communities, permanent stations to register water-table depth and soil moisture need to be established in different vegetation communities. The data provided by such stations

will help to improve the understanding of the relationships between drainage, soil water, seasonal changes in ground water, and the vegetation communities.

3. As indicated in this study, fire is an important ecological factor determining the structure of the vegetation. Management priorities might be considered to evaluate the impact of fire. Initially, emphasis needs to be given to rare vegetation communities, such as the rupestre areas. Cerrado *sensu stricto* on mesotrophic soils, and characteristic communities found at the fringes of cerrado - gallery forests are also priority areas for this purpose.

4. The dymamics of the population of indicator species of distinct communities, including the reproductive biology of such species, are also of great importance for a better understanding of their ecology. These species are responsible for much of the structure of the vegetation communities. Understanding their dynamics will provide guidelines for conservation strategy in the management of the National Park.

5. Nowadays, researchers discuss the effects of past climates on natural communities, with emphasis on refugia during the Pleistocene climatic fluctuations. Ecological reserves such as the National Park of Brasília will probably be the refugia of the modern "anthropogenic period", and in the future they may act as centres of diversity and species dispersion. Hopefully records will be sufficient to allow mapping with less difficulty and disagreement than has been the case of the Pleistocene refugia.

The present research set out to provide a platform for the scientific management of the National Park. It has succeeded in giving a framework for a better understanding of woody plant communities, soils and geomorphology, whilst highlighting those areas of study which remain to be undertaken. There have been many difficulties in performing the task: it was hard, but now it is done.

References

Ab' Saber, A. N., 1963. Contribuição à geomorfologia da área dos cerrados. In: Ferri, M. G. (coordenador) *Simpósio sobre o cerrado*, S. Paulo, EDUSP, pp.117-124.

Ab' Saber, A. N., 1970. *Províncias geológicas e domínios morfoclimáticos no Brasil*. University of S. Paulo, Instituto de Geografia, Geomorfologia, 20: 1-26.

Ab' Saber, A. N., 1971. A organização da paisagem inter e subtropicais brasileiras. In: *III Simpósio sobre o cerrado*, EDUSP & Ed. Blucher Ltda., São Paulo, pp. 1-14.

Ab' Saber, A. N., 1977. Espaços ocupados pela expansão dos climas secos na América do Sul, por ocasião dos períodos glaciais quaternários. *Paleoclimas* no. 3 IGEDG - USP.

Ab' Saber, A. N., 1981. Domínios morfoclimáticos atuais e quaternários na região dos cerrados. Universidade Estadual paulista "Júlio de Mesquita Filho", S.Paulo, *Craton e Intracraton*. 14.

Adamoli, J., J. Macedo, L. G. Azevedo & J. Madeira Neto, 1986. In: Goedert, W. J. (Ed.), *Solos dos cerrados*, EMBRAPA. NOBEL. Caracterização da região dos cerrados, pp. 33-74.

Alvim, P. de T. & W. A. Araújo, 1952. Soil as an ecological factor in the development of vegetation in the Central plateau of Brazil. *Turrialba* 2: 153-160.

Anderson, A. B. & D. A. Posey, 1985. Cerrado management by the Kayapó Indians. *Boletim do Museu paraense Emílio Goeldi, Série Botânica* 2 (1).

Araújo, G. M., 1984. *Comparação do estado nutricional de dois cerrados em solos distrófico e mesotrófico no planalto Central do Brasil*, Master's thesis, Departamento de Biologia Vegetal, Universidade de Brasília.

Araújo Neto, M. D., P. A., Furley, M., Haridasan, & C. E., Johnson, 1986. The murundus of the cerrado region of Central Brasil, *Journal of Tropical Ecology* 2: 17-35.

Arens, K., 1958a. Considerações sobre a causa do xeromorfismo foliar. *Botânica, USP* 15: 25-56.

Arens, K., 1958b. O cerrado como vegetação oligotrófica. *Botânica, USP* 15: 59-77.

Arens, K., 1963. As plantas lenhosas dos campos cerrados como flora adaptada às deficiências minerais do solo. In: Ferri, M. G., (ed.) *Simpósio sobre o cerrado.* SP, EDUSP, pp. 285-303.

Arens, K., M. G. Ferri & L. M. Coutinho, 1958. papel do fator nutricional na economia d'agua de plantas do cerrado. *Revista de Biologia de Lisboa* 1: 313-324.

Askew, G. P., D. J. Moffat, R. F. Montgomery & P. L. Searl, 1971. Soils and soil moisture as factors influencing the distribution of the vegetation formations of the Serra do Roncador, Mato Grosso. In: *III Simpósio sobre o cerrado,* coordenador M. G. Ferri, USP & Ed. Blücher, São Paulo.

Azevedo, L. G. & R. L., Caser, 1979. Regionalização do cerrado. In: *Simpósio sobre o cerrado 5: uso e manejo*, EMBRAPA-CPAC, CNPq and EDITER, Brasília, pp. 213-229.

Azevedo, L. G., J. F. Ribeiro, I. Schiavini & P. E. A. M. Oliveira, 1990. *Levantamento da vegetação do Jardim Botânico de Brasília - DF.* Fundação Zoobotânica, Jardim Botânico de Brasília, DF.

Batmanian, G. J. 1983. *Efeitos do fogo sobre a produção primária e a acumulação de nutrientes do estrato rasteiro de um cerrado.* Master's thesis, Departamento de Ecologia, Universidade de Brasília.

Benema, J., 1963. Características químicas e físicas de latossolos sob vegetação de cerrado. In: *Reunião brasileira do cerrado 1,* Sete Lagoas, Ministério da Agricultura, Serviço de Informação Agrícola, pp. 137-144.

Bigarella, J. J., D. de Andrade Lima & P. J. Riehs, 1975. Considerações a respeito das mudanças paleoambientais na distribuição de algumas espécies vegetais e animais no Brasil. *Anais da Academia Brasileira de Ciências* 47, (suplemento): 411-464.

Bourlière, F., (Ed.), 1983. *Tropical Savannas.* Amsterdam, Elsevier.

Brady, N.C., 1984. *The nature and properties of soils.* Ninth edition, McMillan publishing Co., New York, Collier Macmillan publishers, London.

Brasil, 1979. *Plano de manejo do parque Nacional de Brasília.* Ministério da Agricultura, Instituto Brasileiro de Desenvolvimento Florestal, Fundação Brasileira para Conservação da Natureza, Documento Técnico no.2, Brasília, pp. 9.

Brasil, 1982. Fitogeografia brasileira: classificação fisionômico-ecológica da vegetação Neotropical, *Boletim técnico do programa RADAM Brasil*, série vegetação no.1, Salvador, Brasil, pp. 85.

Brasil, 1982. *Levantamento de recursos naturais, Folha SD. 23 - Brasília,* projeto RADAMBRASIL, Ministério das Minas e Energias, Rio de Janeiro, pp. 494-519.

Brasil, 1990. P*rojeto biogeografia do bioma cerrado: zoneamento visando manejo e conservação. Relatório final*, SEPLAN - FUB, Brasília - DF, pp. 203.

Camargo, M. N., E. Klant, J. H. Kauffman, 1986. Classificação de solos usada em levantamentos pedológicos no Brasil, *Annual Report, International Soil Reference and Information Center, ISRIC*, Wageningen, Holland, pp. 24.

Causton, D. R. 1988. *An introduction to vegetation analysis, principles, practices and interpretation*. Unwin Hyman, London.

Cavalcanti, L. H., 1978. Efeito das cinzas resultantes da queima sobre a profundidade do estrato herbáceo-subarbustivo do cerrado de Emas (SP). *Tese de Doutoramento*, Universidade de São Paulo.

Cavedon, A. D. & S. Sommer, 1990. *Levantamento semidetalhado dos solos*. Fundação Zoobotânica do Distrito Federal, Jardim Botânico de Brasília, Brasília, pp. 95.

Cesar, O. & H. F. Leitão Filho, 1990. Estudo florístico quantitativo de mata mesófila semidecídua na fazenda Barreiro Rico, município de Anhembí, SP. *Revista Brasileira de Biologia*. 50 (1): 133-147.

Cochrane, T. T., L. G.Sanchez, L. G. Azevedo, J. A. Porras, & C. L. Garver, 1985, *Land in Tropical America*, CIAT, EMBRAPA-CPAC, Brasília, vols. 1 to 3.

CODEPLAN, 1976. *Diagnóstico do espaço natural do Distrito Federal*. Governo do Distrito Federal, Brasília, pp. 269.

Cole, M. M., 1958. A savanna brasileira. *Boletim Carioca de Geografia* 11: 5-52.

Connor, E. F. & E. D. McCoy., 1979. The statistics and biology of the species - area relationship. *The American Naturalist* 113 (6): 791 - 833.

Coutinho, L. M., 1986. *Contribuição ao conhecimento do papel ecológico das queimadas na floração das espécies do cerrado*. Departamento de Botânica do Instituto de Biociências da Universidade de São Paulo. Tese de Livre-docência em Ecologia Vegetal. pp. 173

Coutinho, L. M., 1977. Aspectos ecológicos do fogo no cerrado II. As queimadas e a dispersão de sementes de algumas espécies anemocóricas do estrato herbáceo-subarbustivo. *Boletim de Botânica, USP* 5: 57-64.

Coutinho, L. M., 1978. Aspectos ecológicos do fogo no cerrado I - temperatura do solo durante as queimadas. *Revista Brasileira de Botânica* 1 (2): 93-96.

Coutinho, L. M., 1978a. O conceito de cerrado. *Revista Brasileira de Botânica* 1: 17-23.

Coutinho, L. M., 1979. Aspectos ecológicos do fogo no cerrado. III A precipitação atmosférica de nutrientes minerais. *Revista Brasileira de Botânica* 2: 97-101.

Coutinho, L. M., 1980. As queimadas e seu papel ecológico. *Revista Brasil Florestal* 44: 7-23.

Coutinho, L. M., 1981. Aspectos ecológicos do fogo no cerrado: Nota sobre a ocorrência e datação de carvões encontrados no interior de solo sob cerrado. *Revista Brasileira de Botânica* 4: 115-117.

Coutinho, L. M., 1982. Ecological effects of fire in Brazilian cerrado. In: Huntley, B. J. & Walker, B. H. (eds.). *Ecology of Tropical Savannas*, Springer-Verlag, Berlin, pp. 273-291.

Coutinho, L. M., 1990. Fire in ecology of the Brazilian cerrado. In: J. G. Goldammer, *Fire in the tropical biota.* Springer-Verlag, Berlin, pp. 82-105.

da Silva, P. E. N., 1991. *Estado nutricional de comunidades arbóreas em quatro matas de galeria na região dos cerrados do Brasil Central.* Master's thesis, Departamento de Ecologia, Universidade de Brasília.

Dias, B. F. S., 1992. A conservação da natureza. In: Pinto, M. N. (organizadora), *Cerrado, caracterização, ocupação e perspectivas*. Editora Universidade de Brasília, pp. 583 - 640.

Eiten, G., 1963. Habitat flora of fazenda Campininha, São Paulo, Brasil In: *Simpósio sobre o cerrado*, Editora da Universidade de S. Paulo, pp. 181-231.

Eiten, G., 1972. The cerrado vegetation of Brasil. *Botanical Review* 38: 201-341.

Eiten, G., 1975. The vegetation of Serra do Roncador. *Biotropica* 7(2): 112-135.

Eiten, G., 1978. Delimitation of cerrado concept. *Vegetatio* 36 (3): 169-178.

Eiten, G., 1978. A sketch of vegetation of Central Brasil. In: *Congresso Nacional de Botânica* 29, pp. 1-37.

Eiten, G., 1984. Vegetation of Brasília, Brazil. *Phytocoenologia* 12(2/3): 271-292.

Eiten, G., 1986. The use of the term savanna. *Tropical Ecology* 27: 10-23.

Eiten, G., 1990. Vegetação do cerrado. In: *Cerrado, caracterização, ocupação e perspectivas*, Pinto, M. N. (organizadora), Fundação Universidade de Brasília, pp. 9-65.

EMBRAPA, 1978. Levantamento de reconhecimento dos solos do Distrito Federal, *Boletim Técnico, Serviço Nacional de Levantamento e Conservação dos Solos* 53, pp. 455.

Emmerich, K. H., 1990. Influence of land form, landscape development and soil moisture balance on forest and savanna ecosystem patterns in Brazil. *Pedologie* 40(1): 5-17.

Felfili, J. M., 1993. *Structure and dynamics of a gallery forest in Central Brazil.* D. Phil. thesis, Oxford Forest Institute, Department of Plant Sciences, University of Oxford.

Felfili, J. M. & M. C. Silva Jr., 1988. Distribuição dos diâmetros numa faixa de cerrado na Fazenda Água Limpa (FAL), em Brasília-DF. *Acta Botânica Brasílica* 2(1-2): 85-104.

Felfili, J. M. & M. C. Silva Jr., 1992. Floristic composition, phytosociology and comparison of cerrado and gallery forests at Fazenda Água Limpa, Federal

District, Brazil. In: Furley, P. A., J. A. Proctor & Ratter J. A. *Nature and dynamic of forest savanna boundaries.* Chapman & Hall, London, pp. 393-415.

Felfili, J. M. & M. C. Silva Jr., 1993. A comparative study of cerrado (*sensu stricto*) vegetation in Central Brazil. *Journal of Tropical Ecology* 9: 277-289.

Felfili, J. M., M. C. Silva Jr., A. V. Rezende, J. W. B. Machado, B. M. T. Walter, P. E. N. da Silva & J. D. Hay, 1993. Análise comparativa da florística e fitossociologia da vegetação arbórea do cerrado *sensu stricto* na Chapada da Pratinha, DF - Brasil. *Acta Botânica Brasílica* 6 (2): 27-46.

Ferri, M. G., 1943. Observações sobre Lagoa Santa. *Ceres* 4(12): 1-16.

Ferri, M. G., 1955. Contribuição ao conhecimento da ecologia do cerrado e da caatinga. Estudo comparativo do balanço d'água de sua vegetação. *Boletim da Faculdade de Filosofia, Ciências e Letras, USP 195 Botânica* 12: 1-70.

Ferri, M. G., 1977. Ecologia do cerrado. In: Ferri, M. G. (ed.), *IV Simpósio sobre o cerrado.* Editora Itatiaia, Belo Horizonte, Brasil.

Ferri, M. G. & L. M. Coutinho, 1958. Contribuição ao conhecimento da ecologia do cerrado. Estudo comparativo da economia d'água de sua vegetação em Emas (Estado de São Paulo), Campo Grande (Estado de Mato Grosso) e Goiânia (Estado de Goiás). *Boletim da Faculdade de Filosofia, Ciências e Letras, USP, 224 Botânica* 15: 103-150.

Feuer, R., 1956. *An exploratory investigation of the soils and agricultural potential of the soils of the future Federal District in the central plateau of Brazil.* Ithaca, New York, Cornell University, Ph. D. thesis pp. 432.

Flenley, J. R., 1979. *The equatorial rain forest: a geological history.* Butterworth & Co., London. pp. 162.

Frost, P., E. Medina, J. C. Menault, O. Solbrig, M. Swift, & B. Walker, 1986. Responses of savannas to stress and disturbance. *Biology International, Special Issue* 10: 1-82.

Frost, P. G. H. & F. Robertsons, 1987. The ecological effects of fire in savannas. In: B. H. Walker (ed.). *Determinants of tropical savannas.* Oxford, IRL Press. pp. 93 - 140.

FUNATURA, 1992. *Vegetação e flora do parque Nacional de Brasília, Anexo 4. Revisão do plano de manejo do Parque Nacional de Brasília.* pp. 46.

Furley, P. A., 1985. Notes on the soils and plant communities of Fazenda Água Limpa, Brasília, DF. *Occasional Publications* 5, Dept. of Geography, University of Edinburgh.

Furley, P. A., 1986. Classification and distribution of murundus within cerrado of central Brazil. *Journal of Biogeography* 13: 265-268.

Furley, P. A., 1992. Edaphic changes at the forest-savanna boundary with particular reference to the Neotropics. In: *Nature and dynamics of forest-savanna boundaries,* Furley, P. A., J. Proctor & J. A. Ratter (eds.), Chapman & Hall, London.

Furley, P. A. & A. T. Oliveira, 1990. Monchão, cocurutu, murundu. *Ciência Hoje* 11 (61): 30-37.

Furley, P. A. & J. A. Ratter, 1988. Soil resources and plant communities of the central Brazilian cerrado and their development. *Journal of Biogeography* 15: 97-108.

Furley, P. A., J. A. Ratter & D. R. Gifford, 1988. Observations on the vegetation of eastern Mato Grosso, Brazil. III The woody vegetation and soils of the Morro da Fumaça, Torixoréu. *Proceedings of the Royal Society of London, B* 235: 259-280.

Gauch, H. G. Jr., 1982. *Multivariate analysis in community ecology*. Cambridge, New York, Sydney.

Goldstein, G. & G. Sarmiento, 1987. Water relations of trees and grasses and their consequences for the structure of savanna vegetation. In: B. H. Walker (ed.), *Determinants of tropical savannas.* Oxford, IRL Press. pp.13-38.

Goodland, R., 1971a. A physiognomic analysis of the cerrado vegetation of central Brasil. *Journal of Ecology* 59: 411-419.

Goodland, R., 1971b. Oligotrofismo e alumínio no cerrado. In: *III Simpósio sobre o cerrado.* EDUSP e Ed. Edgard Blucher, pp. 44-60.

Goodland, R., 1979. Análise ecológica da vegetação do cerrado. In: Goodland, R. & Ferri, M. G., *Ecologia do Cerrado.* Belo Horizonte, Itatiaia, pp. 61-171.

Goodland, R. & M. G. Ferri, 1979. *Ecologia do Cerrado.* Editora Itatiaia, Belo Horizonte, Brasil.

Goodland, R. & R. Pollard, 1973. The Brazilian cerrado vegetation: a fertility gradient. *Journal of Ecology* 61: 219-224.

Goedert, W. J., 1985. *Solos do cerrado: tecnologias e estratégias de manejo*. Goedert, W. J. (ed.), S. Paulo, Nobel, Brasília, EMBRAPA, CPAC, pp. 422.

Haridasan, M., 1982. Aluminium accumulation by some cerrado native species of central Brazil. *Plant and Soil* 65: 265-273.

Haridasan, M., 1990. Solos. In: Pinto, M. N. (organizadora),*Cerrado, caracterização, ocupação e perspectivas.* Editora Universidade de Brasília, pp. 309-330.

Haridasan, M., 1992. Impactos de processos ecológicos: estresse nutricional. In: *Alternativas de desenvolvimento dos cerrados: manejo e conservação dos recursos naturais renováveis.* FUNATURA, IBAMA, Brasília, DF, pp. 27-30.

Haridasan, M. & G. M. Araujo, 1988. Aluminium accumulating species in two forest communities in the cerrado region of central Brazil. *Forest Ecology Management* 24: 15-26.

Harper, J. L., 1977. *Population biology of plants*. Academic Press, London.

Heringer, E. P., G. M. Barroso, J. A. Rizzo & C. T. Rizzini, 1977. A flora do cerrado. In: *4° Simpósio sobre o cerrado. Brasília.* Belo Horizonte, Ed. Itatiaia/ São Paulo, EDUSP. pp. 211-232.

Hill, M. O., 1979a. *TWINSPAN - A FORTRAN program for arranging multivariate data in an ordered two-way table by classification of individuals and attributes.* Ithaca, NY. Cornell University.

Hill, M. O., 1979b. *DECORANA a FORTRAN program for detrended correspondence analysis and reciprocal averaging.* Ithaca, NY. Cornell University.

Hill, M. O. & H. G. Gauch, 1980. Detrended correspondence analysis, an improved ordination technique. *Vegetatio* 42: 47 - 58.

Horn, H. S., 1966. Measurement of "overlap" in comparative ecological studies. *American Naturalist* 100: 419 - 424.

Huntley, B. J. & B. H. Walker (eds.), 1982. *Ecology of tropical savannas*. Springer-Verlag,Berlin.

Hutchinson, G. E., 1945. Aluminum in soils, plants, and animals. *Soil Science* 60: 29-40.

Kämpf, W., & U. Schwertmann, 1983. Goethite and hematite in a clinosequence in Southern Brazil and their application in classification of caulinitic soils, *Geoderma* 29: 27-39.

Kellman, M., K. Mysnishi & P. Hiebert, 1985. Nutrient retention by savanna ecosystems. *Journal of Ecology* 73: 953-962.

Kent, M. & P. Coker, 1992. *Vegetation description and analysis - a practical approach.* London.

Kiehl, E. J., 1979. *Manual de Edafologia - relações solo-planta,* Editora Agronômica CERES, São Paulo.

Kruger, F. J., 1984. Effects of fire on vegetation structure and dynamics. In: Booysen, P. V. & Taiton, N. (eds.), *Ecological Studies.* Springer-Verlag, N. York, 48:219-244.

Labouriau, L. G., 1966. Revisão da situação da ecologia vegetal nos cerrados. *Anais da Academia Brasileira de Ciências* 38 (supl.): 5-38.

Lemos, R. C. & R. D. Santos, 1984. *Manual de descrição de coleta de solo no campo.* Sociedade Brasileira de Ciência do Solo, Serviço Nacional de Levantamento e Conservação de Solos. Campinas. SP.

Lopes, A. S. & F. R. Cox, 1977. Cerrado vegetation in Brazil: an edaphic gradient. *Agronomy Journal* 69: 828-831.

Macedo, J. & R. B. Bryant, 1987. Morphology, mineralogy, and genesis of a hydrosequence of Oxisols in Brazil. *Soil Science Society American Journal* 51(3): 690-698.

Macedo, J. & R. B. Bryant, 1989. preferential microbial reduction of Hematite over Goethite in a Brazilian Oxisol. *Soil Science Society American Journal* 53(4) 1114-1118.

Magurran, A. E., 1988. *Ecological diversity and its measurement.* University Press, Cambridge.

Malavolta, E., 1976. *Manual de química agrícola - nutrição de plantas e fertilidade do solo.* Editora Agronômica CERES, São Paulo.

Martins, F. R., 1989. Fitossociologia de florestas do Brasil: um histórico bibliográfico. *Pesquisas, série Botânica* 40: 103-164.

Matteucci, S. D. & A. Colma, 1982. Metodologia para el estudio de la vegetacion. *Serie de Biologia*, Monografia no.22, OEA, Washington D.C..

Medeiros, R. A. & M. Haridasan, 1988. Seasonal variations in the foliar concentrations of nutrients in some aluminium accumulating and non accumulating species of the cerrado region of central Brazil, *Plant and Soil* short communication.

Menault, J. C., 1977. Evolution of plots protected from fire since 13 years in a Guinea savanna of Ivory Coast. *4th International Symposium in Tropical Ecology,* Panama.

Montgomery, R. F. & G. P. Askew, 1983. Soils of tropical savannas. In: F. Bourlière (ed.) *Ecosystems of the World, vol. 13. Tropical savannas.* Elsevier, Amsterdam, Oxford & New York, pp. 19-36.

Moreira, A. G. 1992. *Fire protection and vegetation dynamics in the Brazilian cerrado.* Ph. D..thesis, Harvard University.

Mori, S. A., 1989. Eastern, Extra-Amazon Brazil. In: *Floristic inventory of tropical countries.* Campbell, D. G. & Hammond H. D.(eds.), New York Botanic Garden, New York, USA.

Mueller-Dombois, D. & H. Ellenberg, 1974. *Aims and methods of vegetation ecology.* J. Wiley & Sons. London, Sydney & Toronto.

Nascimento, M. T. & C. N. Cunha, 1989. Estrutura e composição florística de um cambarazal no Pantanal de Poconé-MT. *Acta Botânica Brasílica* 3(1): 3-23.

Nascimento, M. T. & N. Saddi, 1992. Structure and floristic composition in an area of cerrado in Cuiabá-MT, Brazil. *Revista Brasileira de Botânica* 15(1): 47-55.

Novaes Pinto, M., 1990. Caracterização geomorfológica do Distrito Federal. In: *Cerrado: caracterização, ocupação e perspectivas.* SEMATEC, Universidade de Brasília, Brasília.

Oliveira, P. E. A. M., L. A. Pereira, V. L. G. F. Lima, A. C. Franco, A. A. Barbosa, G. Batmanian & L. C. Moura, 1982. Levantamento preliminar de um cerrado no parque Nacional de Brasília. *Revista Brasil Florestal* 7: 25-33.

Oliveira-Filho, A. T., 1984. *Estudo florístico e fitossociológico em um cerrado na Chapada dos Guimarães, Mato Grosso-Uma análise de gradientes.* Master's thesis. Universidade Estadual de Campinas.

Oliveira-Filho, A. T., 1989. Composição florística e estrutura comunitária da floresta de galeria do córrego da Paciência, Cuiabá (MT). *Acta Botânica Brasílica* 3(1): 91-112.

Oliveira-Filho, A. T. & F. R. Martins, 1986. Distribuição, caracterização e composição florística das formações vegetais da região da Salgadeira, na Chapada dos Guimarães (MT). *Revista Brasileira de Botânica* 9: 207-223.

Oliveira-Filho, A. T. & F. R. Martins, 1991. A comparative study of five cerrado areas in southern Mato Grosso, Brazil. *Edinburgh Journal of Botany* 48 (3): 307 - 332.

Oliveira-Filho, A. T., J. A. Ratter & G. J. Shepherd, 1990. Floristic composition and community structure of a central Brazilian gallery forest. *Flora* 184: 103-117.

Oliveira-Filho, A. T., G. J. Shepherd, F. R. Martins & W. H. Stubblebine, 1989. Environmental factors affecting physiognomic and floristic variation in an area of cerrado in central Brazil. *Journal of Tropical Ecology* 5: 413-431.

Pavageau, M., 1952. Estudo comparativo de alguns solos típicos do planalto Central brasileiro. *Revista Brasileira de Geografia.* 14 (2): 127-180.

Pielou, E. C., 1975. *Ecological diversity.* John Wiley & Sons, New York, London, Sydney, Toronto.

Pielou, E. C., 1984. *The interpretation of ecological data - a primer on classification and ordination.* John Wiley & Sons, New York.

Prance, G. T., 1973. phytogeographic support for the theory of pleistocene forest refuges in the Amazon basin, based on evidence from distribution patterns in Caryocaraceae and Lecythidaceae. *Acta Amazonica* 3(3): 5-28.

Queiroz Neto, J. P., 1982. Os solos da região dos cerrados e suas interpretações. *Revista Brasileira de Ciência do Solo* 6: 1-12.

Rachid-Edwards, M., 1956. Alguns dispositivos para proteção de plantas contra seca e fogo. *Boletim de Botânica, USP* 13: 35-68.

Ramos, A. E., 1990. *Efeito da queimada sobre a vegetação lenhosa do cerrado.* Master's thesis, Departamento de Ecologia, Universidade de Brasília.

Ramos, P. C. M., 1989. *Estudos fitossociológicos em uma floresta semidecídua, na FERCAL, Brasília-DF.* Master's thesis, Departamento de Ecologia, Universidade de Brasília.

Ratter, J. A., 1971. Some notes on two types of cerradão occurring in north-eastern Mato Grosso. In: *III Simpósipo sobre o cerrado* (ed. M. G. Ferri), Universidade de São Paulo, Brazil, pp. 100-102.

Ratter, J. A., 1980. *Notes on the vegetation of Fazenda Água Limpa* (Brasília, DF, Brazil), Edinburgh Royal Botanic Garden.

Ratter, J. A., 1987. Notes on the vegetation of the parque Nacional do Araguaia (Brazil). *Notes from the Royal Botanic Garden of Edinburgh* 44 (2): 311-342.

Ratter, J. A., 1991. *Guia para vegetação da Fazenda Água Limpa (Brasília, DF).* Brasília, Editora Universidade de Brasília, pp.137.

Ratter, J. A., 1991a. *The conservation situation of the Brazilian cerrado vegetation.* Report for WWF.

Ratter, J. A., 1992. Transitions between cerrado and forest vegetation in Brazil. In: *Nature and dynamics of forest-savanna boundaries,* Furley, P. A., J. Proctor & J. A. Ratter (eds.), Chapman & Hall, London, pp. 417-429.

Ratter, J. A., G. P. Askew, R. F. Montgomery & D. R. Gifford, 1977. Observações adicionais sobre o cerradão de solos mesotróficos no Brasil Central. *IV Simpósio sobre o cerrado*, USP, pp. 306-316.

Ratter, J. A., G. P. Askew, R. F. Montgomery & D. R. Gifford, 1978a. Observations on forests of some mesotrophic soils in Central Brasil. *Revista Brasileira de Botânica* 1: 47-58.

Ratter, J. A., G. P. Askew, R. F. Montgomery & D. R. Gifford, 1978b. Observations on the vegetation of north-eastern Mato Grosso. II Forests and soils of the Rio Suiá-Missu area. *Proceedings of the Royal Society of London* B 203: 191-208.

Ratter, J. A. & T. C. D. Dargie, 1992. An analysis of the floristic composition of 26 cerrado areas in Brazil. *Edinburgh Journal of Botany* 49 (2): 235 - 250.

Ratter, J. A., H. F. Leitão Filho, G. Argent, P. E. Gibbs, J.Semir, G. Shepherd & J. Tamashiro, 1988. Floristic composition and community structure of a southern cerrado area in Brazil. *Notes from the Royal Botanic Garden of Edinburgh* 45 (1): 137-151.

Ratter, J. A., A. Pott, V. Pott, C. N. Cunha & M. Haridasan, 1989. Observations on forests of some mesotrophic soils in the Pantanal and at Corumbá, Brazil. *Notes from the Royal Botanic Garden of Edinburgh* 45: 503-525.

Ratter, J. A., P. W. Richards, G. Argent & D. R. Gifford, 1973. Observations on the vegetation of north-eastern Mato Grosso, I. The woody vegetation types of the

Xavantina-Cachimbo Expedition area. *Philosophical Transactions of the Royal Society of London* (B) 226: 449-492.

Rawitscher, F. K., 1942a. Problemas de fitoecologia com considerações especiais sobre o Brasil meridional. *Boletim de Botânica, USP* 3: 3-111.

Rawitscher, F. K., 1942b. Algumas noções sobre a transpiração e o balanço d'agua de plantas brasileiras. *Anais da Academia Brasileira de Ciências* 14: 7-36.

Rawitscher, F. K., M. G. Ferri & M. Rachid, 1943. Profundidade dos solos e vegetação em campos cerrados do Brasil meridional. *Anais da Academia Brasileira de Ciências* 15: 267-294.

Ribeiro, J. F., 1983. *Comparação da concentração de nutrientes na vegetação arbórea e nos solos de um cerrado e um cerradão no Distrito Federal- Brasília.* Master's thesis, Departamento de Ecologia, Universidade de Brasília.

Ribeiro J. F. & M. Haridasan, 1990. Comparação fitossociológica de um cerrado denso e um cerradão em solos distróficos no Distrito Federal. In: *Anais do 35° Congresso Nacional de Botânica.*

Ribeiro, J. F., S. M. Sano & J. A. da Silva, 1982a. Chave preliminar de identificação dos tipos fisionômicos da vegetação dos cerrados. *Anais do XXXII Congresso Nacional de Botânica,* Terezina-PI, pp. 124-133.

Ribeiro, J. F., J. C. S. Silva, L. G. Azevedo, 1982. Estrutura e composição florística em tipologias vegetais dos cerrados e sua interação com os parâmetros do solo. *Anais do XXXII Congresso Nacional de Botânica,* Terezina-PI, pp. 141-156.

Ribeiro, J. F., J. C. S. Silva & G. J. Batmanian, 1985. Fitossociologia de tipos fisionômicos de cerrado em planaltina-DF. *Revista Brasileira de Botânica* 8: 131-142.

Richter, D. D. & L. I. Babbar, 1991. *Advances in ecological research* 21: 315-389.

Rizzini, C. T., 1963. A flora do cerrado, análise florística das savanas centrais. In: *Simpósio sobre o cerrado.* M. G. Ferri (coordenador), EDUSP, São Paulo, pp. 125-177.

Rizzini, C. T. 1965. Estudos experimentais sobre o xilopódio e outros órgãos tuberosos de plantas do cerrado. *Anais da Academia Brasileira de Ciências* 37 (1): 87-113.

Rizzini, C. T., 1979. *Tratado de fitogeografia do Brasil*, vol. 2. HUCITEC - EDUSP, São Paulo.

Rizzini, C. T. & E. P. Heringer, 1962. Studies on the underground organs of trees and shrubs from some southern Brazilian savannas. *Anais da Academia Brasileira de Ciências* 34(2): 235-247.

Rizzini, C. T. & E. P. Heringer, 1966. Estudo sobre os sistemas subterrâneos difusos de plantas campestres. *Anais da Academia Brasileira de Ciência* 38: 85-112.

Rodrigues, T. E., 1977. *Mineralogia e gênesis de uma sequência de solos dos cerrados, no Distrito Federal.* Master's thesis, Departamento de Solos da UFRGS, Porto Alegre.

Rodrigues, T. E. & E. Klant, 1978. Comissão V - gênese, morfologia e classificação do solo: mineralogia e gênese de uma sequência de solos do Distrito Federal. *Revista Brasileira de Ciência do Solo* 2: 132-139.

Sanches, P. A., 1976. *Properties and management of soils in the Tropics.* John Wiley & Sons, New York.

San José, J. J. & M. R. Fariñas, 1983. Changes in tree density and species composition in a protected Trachypogon savanna, Venezuela. *Ecology* 64: 447-453.

San José, J. J. & M. R. Fariñas, 1991. Temporal changes in the structure of a Trachypogon savanna protected for 25 years. *Acta Oecologica* 12: 237 - 247.

Sarmiento, G. & M. Monasterio, 1985. A critical consideration of the ecological conditions associated with the occurrence of savanna ecosystems in tropical America. In: F. B. Golley & E. Medina (eds.), *Tropical Ecological Systems*, Springer-Verlag, Berlin, pp. 223-250.

Sarmiento, G., 1984. *The ecology of Neotropical savannas.* Cambridge, Mass., Harvard University Press.

Sarmiento, G. 1983. The savannas of tropical America. In: F. Bourlière (ed.), *Ecosystems of the World, vol. 13 Tropical Savannas*, Elsevier, Amsterdam, Oxford & New York, pp. 245-288.

Sarmiento, G., G., Goldstein & F. Meinzer, 1985. Adaptive strategies of wood species in Neotropical savannas. *Biological Review* 60: 315-355.

Sarmiento, G. & M. Monasterio, 1985. A critical consideration of the environmental conditions associated with the occurrence of savanna ecosystems in tropical America. In: F. B. Golley & E. Medina (eds.), *Tropical Ecological Systems*, Springer-Verlag,Berlin, pp. 223-250.

Schubart, O. & F. Rawitscher, 1950. Nota sobre o movimento de água subterrânea de Emas-Pirassununga. *Boletim da Faculdade de Filosofia, Ciências e Letras, Universidade de São Paulo, 109 Botânica* 8: 69-73.

Schwertman, U., 1971. Transformation of hematite to goethite in soils. *Nature* 232: 624-625.

Silva Jr., M. C. & A. F. Silva, 1988. Distribuição dos diâmetros dos troncos das espécies mais importantes do cerrado na estação florestal de experimentação de Paraopeba (EFLEX) - MG. *Acta Botânica Brasílica* 2: 107-126.

Soil Survey Staff, 1975. *Soil Taxonomy, a basic system of soil classification for making and interpreting soil surveys, Agric. Handbook no. 436*, US. Government printing Office, Washington D.C., pp. 754.

Solbrig, O. T., 1990. Savanna modelling for global change. *Biology International, Special Issue* 24: 1-47.

Terborgh, J., 1992. Maintenance of diversity in tropical forests. *Biotropica* 24: 283-292.

Ter Braak, C. J. F. 1988. CANOCO - A FORTRAN program for canonical community ordination by partial detrended canonical correspondence analysis and redundancy analysis (version 2.1). *Technical report: LWA-88-02*. Netherlands.

Tothill, J. C. & J. J. Mott, 1985. *Ecology and management of the world's savannas.* Canberra, Australian Academy of Sciences.

Trollope, W. S. W., 1984. Fire in savanna. In: P. V. Booysen & N. M. Taiton (eds.), *Ecological effects of fire in south African ecosystems.* Springer-Verlag, Berlin, pp. 149 - 175.

van der Hammen, T., 1983. The palaeoecology and palaeogeography of savannas. In: Bourlière, F. (ed.), *Ecosystems of the World* vol. 13, *Tropical Savannas,* Elsevier, Amsterdam, Oxford & New York, pp. 19-36.

Veloso, H. P. 1946. Considerações gerais sobre a vegetação do estado de Mato Grosso. I - Notas preliminares sobre o cerrado. *Memórias do Instituto Oswaldo Cruz* 44 (4): 579-602.

Veloso, H. P., 1948a. Considerações gerais sobre a vegetação do estado de Goiás, *Memórias do Instituto Oswaldo Cruz* 46(1): 89-124.

Veloso, H. P., 1948b. Fitofisionomia e algumas considerações sobre a vegetação do centro-oeste brasileiro. *Memórias do Instituto Oswaldo Cruz* 46(4): 813-852.

Veloso, H. P., 1963. Os grandes clímaces do Brasil III. Considerações gerais sobre a vegetação da região Centro Oeste. *Memórias do Instituto Oswaldo Cruz* 61 (2): 357-370.

Veloso, H. P., A. L. Rangel Filho, J. C. A. Lima, 1991. *Classificação da vegetação brasileira, adaptada a um sistema universal.* Rio de Janeiro, Brasil, pp. 123.

Viro, P. J., 1974. Effects of forest fire on soil. physiological Ecology. In: Kozlowsk, T. T. & C. E. Ahlgren (eds.), *Fire and Ecosystems*, Academic Press, New York, pp. 7-45.

Volkoff, B., 1978. Comissão V - gênese, morfologia, e classificação do solo: os produtos ferruginosos que determinam a cor dos latossolos da Bahia. *Revista Brasileira de Ciência do Solo* 2: 55-59.

Waibel, L., 1948. Vegetation and land use in the planalto central of Brazil. *Geographical Review* 38: 529-554.

Walker, B. H., 1987. *Determinants of tropical savannas*. Oxford, IRL Press Limited.

Warming, E., 1892. Lagoa Santa: Et bidrag til den biologiska plantegeografi. *K.danske Vidensk. Selsk. Skr*. 6: 153-488.

Warming, E. & M. G. Ferri, 1973. *Lagoa Santa e a vegetação de cerrados brasileiros*. Livraria Itatiaia, Ed. Belo Horizonte e EDUSP, São Paulo, pp. 362.

Wells, C. G. 1971. Effects of prescribed burning on soil chemical properties and nutrient availability. *Prescribed Burning Symposium*. USDA, Forest Service, Asheville, North Carolina, USA, pp. 86-97.

Wilding, L. P., N. E. Smeck & G. F. Hall, 1983. *pedogenesis and soil Taxonomy*, vols. I and II, Elsevier, Amsterdam, Netherlands.

Appendix 1

EMBRAPA Soil Map Units in the National Park

Dark-Red Latosols

LEd1 - Dark-Red Latosol Allic or Dystrophic, moderate (ochric) A epipedon or proeminent (umbric) A epipedon, clay texture, semideciduous forest phase, level and gently undulated relief.

LEd2 - Dark-Red Latosol Allic or Dystrophic, moderate A, clay texture, semideciduous cerradão phase, level and gently undulated relief.

LEd3 - Dark-Red Latosol Allic or Dystrophic, moderate A, clay texture semideciduous cerrado phase, level and gently undulated relief.

LEd6 - Dark-Red Latosol Allic or Dystrophic, moderate A, medium texture, semideciduous cerrado phase, level and gently undulated relief.

Red-Yellow Latosols

LVd1 - Red-Yellow Latosol Allic, moderate A, clay texture, semideciduous cerrado phase, level and gently undulated relief.

LVd4 - Red-Yellow Latosol Allic, moderate A, clay texture, campo cerrado phase, level and gently undulated relief.

LVd6 - Red-Yellow Latosol Allic, moderate A, medium texture, semideciduous cerrado phase, level and gently undulating relief.

LVd9 - Red-Yellow Latosol Allic, moderate A, medium texture, campo cerrado phase, level and gently undulated relief.

LVd10 - Red-Yellow Latosol Allic, moderate A, medium texture, campo cerrado phase, level and gently undulated relief, concretionary substratum.

LVd11 - Red-Yellow Latosol Allic, concretionary moderate A, clay texture very gravelly, semideciduous cerrado phase, level and gently undulating relief.

LVd13 - Red-Yellow Latosol Allic, concretionary moderate A, clay texture very gravelly, campo cerrado and campestre phase, level and gently undulating relief.

LVd14 - Red-Yellow Latosol Allic, slightly drained, moderate A, clay texture, campo cerrado phase, level and gently undulated relief.

Cambic soils

Cd3 - Cambic soil Allic, low activity clay, moderate A, clay texture gravelly, semideciduous forest phase, relief gently undulating, phyllite, schist, metasiltite and slate substratum.

Cd4 - Cambic soil Allic, low activity clay, moderate A, clay texture gravelly, semideciduous forest phase, undulate relief, phyllite, schist, metasiltite and slate substratum.

Cd12 - Cambic soil Allic, low activity clay, moderate A, clay texture gravelly concretionary, campo cerrado and campestre phase, level and gently undulated relief, phyllite, schist, metasiltite, and slate substratum.

Cd14 - Cambic soil Allic, clay of low activity, moderate A, clay texture gravelly concretionary, campo cerrado and campestre (grassland) phase, strongly undulating and mountainous relief, phyllite, schist, metasiltite and slate substratum.

Cd18 - Cambic soil Allic, shallow low activity clay, moderate A, medium texture gravelly, campo cerrado and campestre phase, strongly undulating and mountainous relief, quartzite substratum.

Cd19 - Cambic soil Allic, shallow low activity clay, moderate A, medium texture gravelly, campo cerrado and campestre phase, strongly undulating and montainous.

Hydromorphic soils

Hi3 - Indiscriminated Hydromorphic soil, campo higrófilo de surgente (seepage hydromorphic grassland), level and gently undulating relief.

HLd - Dystrophic Hydromorphic Laterite, moderate A, clay texture, campo higrófilo de surgente, level relief, concretionary substratum.

Hil - Indiscriminated Hydromorphic soil, evergreen (várzea) forest phase, level relief.

Appendix 2
Soil profile description

Parque Nacional de Brasília soil profiles: PN 1
Date: 19/09/90; clear, sunny
Location: 20m from track in dense cerrado in a place called Novo Setor
Soil class: LEd3
Vegetation: cerrado
Slope: 1° 5'
Drainage: very good

(A00): 3-0cm; litter on/within grass

(A1): 0-10cm; red to dark red, dry (2.5YR 4/6-3/6); silty clay; granular, rounded, very variable predominantly very small, moderate structure, including a few very hard clay nodules; many very small pores; pressure surfaces; slightly hard consistency with very hard nodules; medium and fine root mat; abundant termite activity; gradual, horizontal boundary

(A2): 11-27cm; red to reddish brown, damp (2.5YR 4/4-4/6); silty clay; blocky, sub-angular, large moderate structure; many very small pores; damp firm consistency; medium, fine, and some larger (to 1 5cm diam) roots, abundant termite activity; gradual, horizontal boundary

(B1): 28-78cm; red, damp (2.5YR 4/6); clay, with strong clay nodules; blocky, sub-angular large, moderate structure; many very small pores; damp firm consistency; many fine and medium roots, with some larger (to 2cm diam); diffuse, horizontal boundary

(B2): 79-140+cm; red, damp (2.5YR 4/8); clay; blocky, sub-angular, large, weak structure; many very small pores; damp, very friable consistency; frequent medium and some fine roots

Parque Nacional de Brasília soil profile: PN 2
Date: 19/09/90; clear, sunny
Location: 30m from track, around 1km further along the track and sloping down from PN 1, in the Novo Setor, over a gentle slope. Cerrado merging sloping down to campo sujo
Soil class: LVd4
Vegetation: campo sujo
Slope: 2°
Drainage: good

(A00): 5-0cm, incorporated in grass (compacts to < 1cm)

(A1): 0-10cm; strong brown, damp (7.5YR 4/6); clay loam; granular, sub-angular, very large, weak structure; many very small pores; damp friable consistency; many small and medium and frequent large (>2cm) roots; numerous termites; clear, horizontal boundary

(A2): 11-20cm; yellowish red, damp (5YR 4/6); clayey loam, few clay nodules; granular, sub-rounded, medium, weak structure; many very small pores; damp, friable consistency; many small and few larger (to 1cm) roots; gradual, horizontal boundary

(B1): 21-38cm; yellowish red, damp (5YR 4/6); silty clay with small strong clay nodules; blocky, sub-angular, medium, moderate structure; many very small pores; damp, friable consistency; many small, some medium and a few larger (1cm diam.) roots; gradual, horizontal boundary

(B2): 39-150+cm; red, damp (2.5YR 4/8); clay with small strong clay nodules; blocky, sub-angular, large, weak structure; many very small pores; damp, very friable consistency; many medium and a few larger (1cm diam.) roots

Parque Nacional de Brasília soil profiles: PN 3
Date:19/09/90 (clear, sunny)
Location: top of earth mound (murundu), lower end of topographical sequence (PN1-PN3); draining S-SE to a gallery forest head of the Acampamento stream
Soil class: HLd
Vegetation: campo de murundus; cerrado vegetation on top of the murundus (earth mounds)
Slope: 0° (flat top); overall gentle slope S-SE
Drainage: good to the bottom of profile (c. 160cm), where a seasonal water-table is found

(A00): 3-0cm; tussock trapping grass debris and a few leaves; compacts to <1cm

(A1): 0-7cm; brown, dry (10YR 5/3); clay, with small hard clay nodules; granular, sub-rounded, large breaking to predominantly medium, moderate structure; many very fine pores; damp, friable consistency; few fine, many medium and isolated larger (<1cm) roots; evidence of ants and termites but no galleries visible; gradual, horizontal boundary

(A2): 7-25cm; brown to dark brown, humid (10YR 4/3); silt clay, with a few fine sand grains and casts evident with a hand lens; blocky, sub-rounded, large, moderate structure; many fine pores; humid friable consistency; many medium and a few larger (<1cm) roots; numerous ants; clear, horizontal boundary

(A3): 26-57cm; brown, damp (10YR 5/3); silt clay, with fine sand grains and casts evident with a lens; blocky, sub-angular, large, moderate structure; many small medium and large pores (faunal channels); damp, firm consistency; many medium and occasional larger roots; clear, horizontal boundary

(B1): 58-88cm; yellowish brown, (10YR 5/4-5/6); clay; blocky, angular, large, weak to moderate structure; many small and very small pores; damp firm consistency; many medium roots and a few larger (to 2cm diam.); diffuse, horizontal boundary

(B2): 89-160cm, (water-table); yellowish brown, very damp (10YR 5/6); slightly sandy clay; blocky, angular, large, weak structure; many very small pores; damp, plastic, sticky consistency; frequent medium roots

Parque Nacional de Brasília soil profiles: PN 4
Date: 20/09/90 (clear sunny)
Location: 30m into the forest from paved track, above the swimming pool (Piscina 1)
Soil class: Cd4
Vegetation: Mesophytic Semideciduous Forest
Slope: 2° (upslope 5° and sharper drop downslope)
Drainage: good

(A00); 5-1cm leaf litter
(A0): 1-0cm advanced stage of decomposition of litter

(A1): 0-22cm; black, damp (10YR 2/1); silt clay, with gravel; granular, sub-angular, large, moderate structure; many very small pores; damp, friable consistency; fine root mat, many medium and a few larger roots (to 4cm diam.); clear, horinzontal boundary

(A2); 23-40cm; very dark brown, damp (10YR 2/2); silt clay, with much small gravel; blocky, sub-angular, large, moderate structure, , breaking to granular, sub-angular, medium, moderate; many very small pores; damp friable consistency; a few weak pressure surfaces; many fine, common, medium and a few larger (to 1cm diam.) roots; gradual, horizontal boundary

(A3): 41-51cm; very dark greyish brown, damp (10YR 3/2); silt clay with some loose sand and much gravel; blocky, sub-angular, large, weak structure, breaking to granular, sub-rounded, small, weak; a few weak pressure surfaces; many small pores and larger voids between stones; damp, very friable consistency; many fine, common medium and few larger roots; clear, horizontal boundary

(IIC): 52-108cm; reddish yellow, damp (5YR 6/6), matrix patches of rock colour, weak red (5R 5/2) with patches of oxidised clay, yellowish red (5YR 5/5); massive; rare medium roots; clear horizontal boundary

(IIIC): 109-125cm; rock, weak red (5YR 5/2); massive

Parque Nacional de Brasília soil profiles: PN 5
Date: 20/09/90
Location: forest margin a track to Cristal Água, by the side of a pipe
Soil class: LEd1
Vegetation: Ecotone (gallery forest - cerrado)
Slope: 5° facing NE
Drainage: good

(A00): 7-3cm; leaf litter
(AO): 3-0cm; F layer (no H)

(A1): 0-11cm; reddish brown, damp (2.5YR 4/4); clay, with small hard clay nodules; granular, sub-rounded, medium to large, strong structure; damp, firm consistency; many very small pores; many fine, medium and larger roots; clear, horizontal boundary

(A2): 12-36cm; red, damp (2.5YR 4/6); clay, with small hard clay nodules; granular to sub-blocky, sub-angular, large, moderate; damp, friable consistency; many small pores; frequent medium and large roots; gradual, horizontal boundary

(B1/2): 37-140+cm; red, damp (2.5YR 4/8); clay; blocky, angular, large, moderate structure (notably weaker structure below 90cm); many very small pores; damp, friable consistency; frequent medium and occasional large roots

Parque Nacional de Brasília soil profiles: PN 6
Date: 16/09/91; clear, sunny
Location: cerrado area, 20m from track at Novo Setor
Soil class: LEd3
Vegetation: cerrado
Slope: locally at the top of a gentle interfluve; 1°10'
Drainage: very good

(A00): 2-0cm; grass and leaf litter

(A1): 0-10cm; dark reddish brown, damp (2.5YR 3/4); silt clay; granular, sub-rounded, small to very small, moderate structure; many very small pores; damp friable consistency; many fine and medium roots and a few larger (to 1cm diam.); evident termite activity; gradual, horizontal boundary

(A2): 11-29cm; dark red, damp (2.5YR 3/6); silt clay; granular, sub-rounded, medium, moderate structure; many very small pores; damp friable consistency; frequent fine and medium roots, with a few larger (to 1cm diam.); frequent termite activity; diffuse horizontal boundary

(B1): 30-70cm; red, damp (2.5YR 4/6-4/8); silt clay; blocky, sub-angular, medium, moderate structure; many very small pores; damp, firm consistency; frequent medium and occasionally larger (to 1cm diam.) roots; diffuse, horizontal boundary

(B2): 71-160+cm; red, damp(2.5YR 4/6-8); clay, with some hard clay nodules; blocky, sub-angular, large, weak structure; many very small pores; damp very friable consistency; few medium and occasionally larger (to 1cm diam.) roots

Parque Nacional de Brasília soil profiles: PN 7
Date:21/01/90; clear, sunny between heavy storms
Location: campo sujo with sub-shrubs very sparse, on the shoulders of the Chapada da Contagem, downslope, near the watchtower no 1
Soil class: LVd13
Vegetation: campo sujo
Slope: top of steep slope facing SW; 1°
Drainage: good, but floods at surface during intense storms

(A00): <1cm grass and light woody litter

(A1): 0-28cm; brown, damp (10YR 5/3); sandy clayey loam; granular, sub-rounded, small and very small, weak structure; many very small pores; damp very friable consistency; concentration of lateritic nodules and some cementation; many fine, a few medium and larger roots; clear horizontal boundary

(A2): 29-53cm; yellowish brown, damp (10YR 5/6); predominantly gravel with sandy clayey loam matrix; granular, sub-rounded, small, weak structure; many small pores; damp, friable consistency; many fine and a few medium and large roots; clear, horizontal boundary

(B1): 54-62cm; yellowish brown, damp (10YR 5/6-5/8); gravel with sandy clayey loam matrix (fewer stones than in the A horizons); granular, sub-rounded, small, weak structure; many small pores; damp, very friable consistency; frequent fine and medium roots; clear, horizontal boundary

(B2): 63-100cm; strong brown, damp (7.5YR 5/6-5/8); gravel plus silt clay; granular, sub-rounded, small, weak structure; many small pores; damp very friable consistency; few fine and medium roots; gradual, horizontal boundary

(C): 101-130+cm; brownish yellow, damp (10YR 6/8); matrix with red, damp, weathered gravel (2 5YR 4/8), silt clay plus gravel; structure of weathered rock laminar to granular, sub-rounded, small, weak; many small pores; damp very friable consistency; transition downwards to weathered rock strata capped by a thin impermeable band of clay impeding downward percolation; few medium roots

Parque Nacional de Brasília soil profiles: PN 8
Date: 22/09/90: clear, sunny
Location: cerrado on the Chapada da Contagem plateau, 1km further PN7, along track parallel to the perimeter fence, along the shoulders of the plateau
Soil class: LEd6
Vegetation: cerrado (medium density)
Slope: top of steep slope, facing S; 1°
Drainage: very good

(A00): 2-0cm; grass litter

(A1): 0-12cm; dark brown, dry (10YR 3/3); sandy loam; granular, sub-rounded, small, weak structure; many very small pores; slightly damp, very friable consistency; many fine and medium roots, frequent larger roots (to 1/2cm diam.); clear, horizontal boundary

(A2): 13-34cm; dark brown to brown, damp (7.5YR 4/4); sandy loam; granular, sub-rounded, small, weak structure; many small pores; damp very friable consistency; frequent fine with a few medium roots; gradual, horizontal boundary

(B1/2): 35-102cm; strong brown, damp (7.5YR 4/6); sandy loam; blocky, sub-angular, large, weak structure; many very small pores; some large pores with clay film around clay walls; damp very friable consistency; frequent medium roots; sharp, horizontal boundary

(IIC): 103-140+; yellowish red, damp (5YR 4/6); predominantly fine gravel with some infiltrated sandy loam; friable stones and gravels, some granular, sub-rounded, very small weak structure to the sandy loam matrix; frequent medium and occasional larger (to 1cm diam) roots

Parque Nacional de Brasília soil profiles: PN 9
Date: 21/09/90; clear, sunny
Location: foot slope, near the end of the track at Tres Buracos, by the side of a sink hole
Soil class: HLd
Vegetation: campo limpo (grassland)
Slope: foot of undulating slope with murundus and sink holes; 4° facing NW
Drainage: good

(A00): 1-0cm; slight grass and leaves blown from woody plants growing in the large sink hole

(A1): 0-20cm; dark brown, damp (10YR 3/3); silt clay; blocky, sub-angular, large, moderate structure; many very small pores; damp friable consistency; pressure surfaces; many fine and medium roots and some larger (to 1/2cm); clear, uniform, inclined boundary

(A2): 21-34cm; dark yellowish brown, damp (10YR 4/4); silt clay; blocky, angular, large, moderate structure; many very small pores; damp friable consistency; pressure surfaces; frequent faunal holes of 1cm diam ; many fine and frequent medium roots; clear, undulating, inclined boundary

(B1): 35-63cm; yellowish brown, damp (10YR 5/8); scattered (5%) dark red, damp mottles (2.5YR 3/6); blocky, sub-angular, large, moderate structure; many very small and some small pores; damp very friable consistency; few fine and frequent medium roots; gradual, uniform, inclined boundary

(B2): 64-127cm; yellowish brown, damp (10YR 5/8) matrix red damp mottles (2.5YR 4/8) 30-40%, small and medium; silt clay; blocky, sub-angular, large, moderate structure; many very small pores; damp friable consistency; few medium and occasionally large roots (to 2cm diam); gradual, uniform, slightly inclined boundary

(B3g): 128-150+cm; strong brown, damp (7.5YR 5/6) matrix; red, damp mottles (2.5YR 4/8), 50% medium and large; blocky, sub-angular, large, moderate structure; many very small and small pores; pressure surfaces; frequent faunal holes infilled with organic matter; few medium and occasional large roots (to 2cm diam.)

Parque Nacional de Brasília soil profiles: PN 10
Date: 21/09/90; clear, sunny
Location: *Vellozia flavicans* dominated shrub grassland, in the mid slope to Tres Buracos
Soil class: LVd9
Vegetation: campo sujo (*Vellozia flavicans)*
Slope: linear section, facing N; 2°
Drainage: good

(A00): less than 1cm, grass and scattered leaves

(A1): 0-8cm; brown to dark brown, nearly dry (7.5YR 4/4); sandy clayey loam; granular, sug-angular, sub-rounded, small to medium, moderate structure; many very small pores damp friable consistency; many small and medium, and frequent large roots (to 2cm diam.); gradual, horizontal boundary

(A2): 9-21cm; brown to dark brown, damp (7.5YR 4/4); clayey loam; blocky, sub-angular, medium, moderate structure, breaking to granular, moderate; many small pores; damp friable consistency; few fine and frequent medium roots; gradual, horizontal boundary

(B1): 22-47cm; yellowish red, damp (5YR 4/6); clayey loam; blocky, angular, large, moderate structure; many small pores; damp friable consistency; few medium roots; gradual, horizontal boundary

(B2): 48-148+cm; yellowish red, damp (5YR 5/8); sandy clay; blocky, sub-angular, large, moderate; many very small pores; damp friable consistency; few medium and large (to 2cm diam.) roots

Parque Nacional de Brasília soil profiles: PN 11
Date: 21/09/90; sunny, clear
Location: Tres Buracos, top of the catenary sequence
Soil class: LVd9
Vegetation: cerrado (shrubby)
Slope: gentle convexity, interfluve facing NE; 2°
Drainage: good

(A00): less than 1cm, grass and scattered leaves

(A1): 0-5cm; brown to dark brown, damp (7.5YR 4/4); clayey loam (including sand sized charcoal); granular, sub-rounded, small, moderate structure; many very small pores; damp, friable consistency; many fine, frequent medium roots; clear, horizontal boundary

(A2): 6-15cm; yellowish red, damp (5YR 4/6); silt clay; blocky, sub-angular, large, moderate structure; many small pores; damp friable consistency; many fine, frequent medium, occasional large (to 2cm diam.) roots; gradual, horizontal boundary

(B1): 16-36cm; yellowish red, damp (5YR 4/6); silt clay; blocky, sub-angular, large, moderate structure; many small pores; damp very friable consistency; many fine, frequent medium, occasional larger (to 2cm diam.) roots; diffuse, horizontal boundary

(B2): 37-144+cm; yellowish red, damp (5YR 5/7-5/8); clay with frequent small, hard clay nodules; blocky, sub-angular, large, weak structure; many small pores; damp very friable consistency; few medium and occasional larger (to 2cm diam.)roots

Parque Nacional de Brasília soil profiles: PN 12
Date: 27/07/92; clear, sunny
Location: 20m from track in campo sujo, in a gentle slope near the Acampamento stream gallery forest head
Soil class: LVd4
Vegetation: campo sujo
Slope: 1°
Drainage: good but floods at surface during intense storms

(A00): sparse material from dead leaves and branches

(A1): 0-7cm; brownish yellow, dry (10YR 6/6), dark yellowish brown, damp (10YR 4/4); clay; blocky, sub-angular, very small to medium, moderate structure; many very small, many small, and common medium pores; damp friable consistency; many fine and some medium and larger roots; termite activity; gradual, horizontal boundary

(B1): 7-27cm; brownish yellow, dry (10YR 6/8), yellowish brown, damp (10YR 5/8); clay; blocky, sub-angular, very small to medium, moderate structure; many very small and common medium pores; damp, friable consistency; some fine and medium roots; termite activity; gradual, horizontal boundary

(B2): 27-150cm+; reddish yellow, dry (7.5YR 6/8), reddish yellow, damp (7.5YR 6/8); clay; blocky, sub-angular, many very small, weak structure; many very small pores; damp, friable consistency; some fine and medium roots; termite activity

Parque Nacional de Brasília soil profiles: PN 13
Date: 28/07/92; clear, sunny
Location: 20m from track in the gallery forest head of the Mata da Barriguda
Soil class: LVd1
Vegetation: gallery forest (head)
Slope: 1°
Drainage: good

(A00): 3-1cm; dead leaves and branches forming a layer
(A0): 1-0; advanced decomposed organic matter forming a layer, entangled by superficial roots

(A1): 0-5cm; reddish yellow, damp (7.5YR 6/8); mottled, many small, brown to dark brown, damp (7.5YR 4/4); clay; blocky, sub-angular and angular, many very small, granular, moderate structure; many small pores; damp, slight hard consistency; many fine, common medium and large roots; gradual, horizontal boundary

(B1): 5-44cm; reddish yellow, damp (7.5YR 6/8), mottled, common small brown to dark brown, damp (7.5YR 4/4); clay; blocky, sub-angular and angular, many small, moderate structure; many small pores; damp friable consistency; many fine, common medium, and a few larger roots; gradual, horizontal boundary

(B2): 44-79cm; yellowish red, damp (5YR 5/8); clay; strong, very small, granular structure; many very small pores; damp, very friable consistency; many fine, common medium and a few larger roots; gradual, horizontal boundary

(B21): 79-150+cm; red, damp (10R 5/8); clay; strong, very small, granular structure; many very small pores; damp, very friable consistency; some fine and medium, and a few large roots

Parque Nacional de Brasília soil profiles: PN 14
Date: 28/07/92; clear, sunny
Location: *Vochysia thyrsoidea* association on the shoulders of the Chapada da Contagem, by the side of the track (20m apart) to Tres Buracos
Soil class: LVd11
Vegetation: cerrado (open)
Slope: 4°
Drainage: good

(A00): sparse material from dead leaves and branches, irregular layer

(A1): 0-14cm; brown to dark brown, dry (7.5YR 4/4); sandy loam; blocky, sub-angular, small granular, moderate structure; many very small pores; damp, very friable consistency; concretionary, with many ironstones, extremely hard, variable in size, sub-round, irregular and angular yellow-ferruginous; many fine and medium, and some larger roots; clear, horizontal boundary

(B1): 14-40cm; brownish yellow, dry (10YR 6/8); clay; blocky, sub-angular, small, granular, strong structure; many very small and medium pores, damp, soft consistency; concretionary, ironstones, extremely hard, variable in size, sub-round, irregular and angular; yellow-ferruginous ; many fine, common medium, and a few larger roots; gradual, horizontal boundary

(B2): 40-150+cm; reddish yellow, dry (7.5YR 6/8); loamy clayey sand; strong small granular structure; many fine pores; very friable consistency; concretionary, ironstones, extremely hard, variable in size, sub-round, and angular; yellow-ferruginous; some fine and medium, and a few larger roots

Parque Nacional de Brasília soil profiles: PN 15
Date: 28/07/92; clear, sunny
Location: 20m from track in cerrado, near the Santa Maria reservoir, in the interfluve between the lake and the Bananal river
Soil class: LVd6
Vegetation: cerrado
Slope: 4°
Drainage: good

(A00): sparse material from dead leaves and branches, irregular layer

(A1): 0-8cm; yellowish red, dry (5YR 5/8); clay; blocky, sub-angular, small and large, moderate structure; many small and some medium pores; damp, slightly hard consistency; many fine, common medium, and few larger roots; clear, horizontal boundary

(B1): 8-50cm; yellowish red, dry (5YR 4/8); clay; very small granular strong structure; many very small pores; damp, very friable consistency; common fine and medium, and a few larger roots; gradual, horizontal boundary

(B2): 50-150+cm; red, dry (2.5YR 4/8); clay; very small granular strong structure; many very small pores; damp, very friable consistency; common medium and a few larger roots

Parque Nacional de Brasília soil profiles: PN 16
Date: 30/07/92; clear, sunny
Location: 20m from track in a cerrado area at the margin of Capão Comprido gallery forest
Soil class: LEd3
Vegetation: cerrado
Slope: 0°
Drainage: good

(A00): sparse material from dead leaves and branches, irregular layer

(A1): 0-3cm; reddish brown, dry (2.5YR 5/4); clay; blocky, sub-angular, moderate structure; many very small and common medium pores; damp, friable consistency; many fine, common medium and a few larger roots; clear, horizontal boundary

(B1): 3-20cm; red, dry (2.5YR 4/6); clay, very small granular, strong structure; many very small pores, damp, friable consistency; many fine, common medium and a few larger roots; diffuse, horizontal boundary

(B2): 20-150+cm; red, dry (2.5YR 4/8); clay; very small granular, strong structure; many very small pores; damp very friable consistency; common fine and medium, and a few larger roots

Parque Nacional de Brasília soil profiles: PN 17
Date: 30/07/92; clear, sunny
Location: 10m from track in a mountainous interfluve named Invernada (along Invernada stream). Outcrops are an important feature
Soil class: Cd14
Vegetation: cerrado
Slope: 6°
Drainage: good

(A00): sparse material from dead leaves and branches

(A1): 0-8cm; pale red, dry (2.5YR 6/2); loamy sand; granular, weak structure; many very small and small pores; damp,loose consistency; many concretions of many sizes and forms, ironstones, and sandstones covered by Fe and Al oxides; many fine and a few medium roots; clear, horizontal boundary

(B1): 8-23cm; light red, dry (2.5YR 6/6); loamy sand; granular, weak structure; many very small pores; damp, loose consistency; concretionary, ironstones, and sandstones covered by FE and Al oxides; many fine and common medium roots; diffuse, horizontal boundary

(B2): 23-40cm; light brown, dry (7.5YR 6/4); loamy clay; very small, granular, strong structure; many very small pores; damp, soft consistency; concretionary, ironstones, and sandstones covered by Fe and Al oxides; common fine and medium roots; diffuse, horizontal boundary

(C): 40-150+cm; pink, dry (7.5YR 7/4), very weathered, mottled sandstones, reddish yellow (5YR 7/8), light grey (7.5YR 7/2), light red (10R 6/8); loamy clayey sand; most part structureless, and some very small, granular, strong structure; damp, loose consistency; many very small pores, some fine and medium roots

Parque Nacional de Brasília soil profiles: PN 18
Date: 30/07/92; clear, sunny
Location: 20m from track, the second profile after the watchtower no 1 at the shoulder of the Chapada da Contagem in a *Myrsine guianensis* association
Soil class: LVd10
Vegetation: campo sujo
Slope: 5°
Drainage: good but floods at surface during intense rainfall

(A00): sparse material from dead leaves and branches, irregular layer

(A1): 0-15cm; brown, dry (7.5YR 5/4); sandy loam; small, granular, moderate structure; many very small and small pores; damp, loose consistency; many fine, common medium, and a few larger roots; clear, horizontal boundary

(B1): 15-70cm; reddish yellow, damp (7.5YR 7/8); sandy loam; small, granular moderate structure; many very small pores; damp, loose consistency; many fine, common medium, and a few larger roots; diffuse, horizontal boundary

(B2): 70-150+cm; reddish brown, damp (5YR 6/8); loamy clay; very small, granular strong structure; many very small pores; damp, loose consistency; concretionary, ironstones and weathered sandstones; a few fine and larger, and some medium roots

Parque Nacional de Brasília soil profiles: PN 19
Date: 30/07/92; clear, sunny
Location: By the side of the track that follows the shoulders of the Chapada da Contagem , after the crossing track from P6 (gate 6 - seismological station), in a *Trembleya latifolia* community
Soil class: Plinthic
Vegetation: closed scrub (thicket) of *Trembleya latifolia*
Slope: 3°

(A00): sparse material from leaves, irregular layer

(A1): 0-15cm; light yellow brown, dry (10YR 6/4); loamy clayey sand; blocky, sub-angular, small, weak structure; many very small and small pores; damp loose consistency; many fine, common medium and a few larger roots; termite activity; gradual, horizontal boundary

(B2): 15-115cm; yellow, damp (10YR 7/8), mottled, 10%, damp (10R 4/8); loamy clayey sand; small, granular, weak structure; many small pores; damp, very friable; few fine, common medium, and a few larger roots; clear horizontal boundary

(C): 115-150+cm; weathered rocks, yellow-red colours

Parque Nacional de Brasília soil profiles: PN 20
Date: 30/07/92; clear, sunny
Location: 20m from the track that follows the shoulders of Chapada da Contagem, after PN 19, in a *Vochysia thyrsoidea* association
Soil class: Cd18
Vegetation: cerrado
Slope: 4°
Drainage: good

(A00): sparse material from leaves and branches, irregular layer

(A1): 0-19cm; pale brown, dry (10YR 6/3); clay; small, granular, strong structure; many small pores; damp, loose consistency; concretionary, ironstones; clear, horizontal boundary

(B2): 19-110cm; brownish yellow, dry (10YR 6/8); sandy loam; small, granular, weak structure; many small pores; damp, loose consistency; concretionary, ironstones; common fine and medium, and a few larger roots; clear, horizontal boundary

(C): 110+cm; sand; coloured by Fe and Al oxides, structureless, damp, loose consistency; mottled, large, white and red

Parque Nacional de Brasília soil profiles: PN 21
Date: 30/07/92; clear, sunny
Location: cerrado on outcrops at the downslope from the Chapada da Contagem towards to Tortinho river
Soil class: Cd18
Vegetation: cerrado
Slope: 6°
Drainage: good

(A00): sparse material from leaves and branches

(A1): 0-5cm; light yellowish brown, dry (10YR 6/4); loamy sand; granular, weak structure; many small pores; damp, very friable; concretionary, ironstones; many fine, common medium and a few larger roots; clear, horizontal boundary

(B2): 5-28cm; brownish yellow, dry (10YR 6/6); loamy sand; granular, weak structure; many small pores; damp, very friable; concretionary, ironstones; common fine and medium roots, and a few larger roots; gradual, horizontal boundary

(C): 28-75cm; yellow, dry (10YR 7/6); loamy sand; granular, weak structure; many small pores; weathered sandstones, covered by Fe and Al oxides; a few fine, medium and larger roots; clear, irregular slope boundary

(R): 75-150+cm; slate; reddish

Parque Nacional de Brasília soil profiles: PN 22
Date: 30/07/92; clear, sunny
Location: forest with palm trees at the bottom slope, interfluve, in the Torto river margin
Soil class: Cd4
Vegetation: interfluve forest, with palm trees
Slope: 4°
Drainage: good

(A00): 7-3cm; dead leaves from palm trees, and from other plants

(A0): 3-0cm organic material entangled by root surface layer

(A1): 0-10cm; brown to dark brown, dry (7.5YR 4/4); loamy sand, with sandstones blocks of different sizes, common larger; blocky, sub-angular, and granular, single grain, moderate to weak structure; many small and common medium pores; damp, loose consistency; many fine, common medium and a few larger roots; clear, horizontal boundary

(B1): 10-40cm; yellowish red, dry (5YR 4/6); loamy sand, sandstones large rocks; granular, single grain, structureless; many small pores; damp, loose consistency; common fine, and a few medium and large roots; irregular, diffuse boundary

(C): 40+cm; large sandstones rocks, with sand between the cracks, where a few larger roots can be established

Parque Nacional de Brasília soil profiles: PN 23
Date: 30/07/92; clear, sunny
Location: 20m form track at the Chapada da Contagem, near the head of the Torto stream
Soil class: LEd2
Vegetation: cerrado
Slope: 0°
Drainage: good

(A00): sparse material, from dead leaves and branches

(A1): 0-5cm; yellowish red, dry (5YR 4/8); clay; blocky, sub-angular to angular, moderate structure; many very small pores; damp, friable consistency; many fine, common medium, and a few larger roots; clear, horizontal boundary

(B1): 5-15cm; red, dry (2.5YR 4/8); clay, very small, granular, strong structure; many very small pores; damp, friable consistency; many fine, common medium, and a few larger roots; diffuse, horizontal boundary

(B2)15-150+cm; red, dry (2.5YR 5/8); clay; very small, granular, strong structure; many very small pores, damp, friable consistency; some fine and medium, and a few larger roots

Parque Nacional de Brasília soil profiles: PN 24
Date: 30/07/92; clear, sunny
Location: Tres Barras stream; gallery forest head
Soil class: LVd1
Vegetation: gallery forest (head)
Slope: 10°
Drainage: good

(A0): 10-7cm; dead leaves and branches
(A00): 7-0cm; layer of organic material entangled by surface roots

(A1): 0-11cm; yellowish brown, damp (10YR 5/6); clay; blocky, sub-angular, small, medium, and large, moderate structure; many very small, common medium and few large pores; damp, very firm consistency; many fine, common medium and large roots; clear, horizontal boundary

(B1): 11-25cm; yellowish brown, damp (10yr 5/8); clay; blocky, sub-angular and angular, medium and large, moderate structure; many very small pores; damp, very firm consistency; many fine, common medium and large roots; gradual, horizontal boundary

(B2): 25-70cm; reddish yellow, damp (7.5YR 6/8); clay; blocky, sub-angular and angular, medium and large, moderate structure; many very small pores; damp, very firm consistency; common fine , medium and larger roots; clear, horizontal boundary

(C): 70-150+cm; reddish yellow, damp (7.5YR 6/8), mottled (10R 5/6); weathered slate, reddish yellow

Parque Nacional de Brasília soil profiles: PN 25
Date: 30/07/92; clear, sunny
Location: interfluve at the confluence between Torto river and Tres Barras stream, at Arnicas
Soil class: Cd19
Vegetation: campo rupestre
Slope: at the base of a slope about 15°

(A00): sparse material from dead leaves and branches

(A1): 0-3cm; light grey, dry (10YR 7/2); clay; concretionary ironstones and sandstones; blocky, sub-angular, small, granular, strong structure; many very small pores; damp, very friable consistency; many fine, and some medium roots; clear, horizontal boundary

(B2): 3-10cm; very pale brown, dry (10YR 7/4); loamy clay; concretionary, ironstones and sandstones; very small, granular, strong structure; many very small pores; damp very friable consistency; many fine and a few medium roots; clear, irregular boundary

(C): 10-150cm+; weathered reddish slate

Parque Nacional de Brasília soil profiles: PN 26
Date: 11/08/92; clear, sunny
Location: interfluve forest, near CEMAVE building, in a track bank
Soil class: Cd4
Vegetation: semideciduous forest
Slope: 6°
Drainage: good

(A00): 10-4cm; leaves and other dead plant materials
(A0): 4-0cm; organic material entangled by surface roots

(A1): 0-10cm; light brown, dry (7.5YR 6/4); clay, concretionary, ironstones and quartzites; blocky, sub-angular, small moderate structure; many fine, common medium and some larger pores; damp, friable consistency; many fine, common medium and a few larger roots; clear, horizontal boundary

(B1): 10-40cm; reddish yellow, dry (7.5YR 7/6); loamy clay; concretionary, ironstones and quartzites; blocky, sub-angular, small, moderate structure; many small pores; damp, firm consistency; common medium and a few larger roots; clear, horizontal boundary

(C):weathered slate