Tree communities of the gallery forests of the IBGE Ecological Reserve, Federal District, Brazil.

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Ph.D. in Geography

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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.

Manoel Cláudio da Silva Júnior.

Acknowledgements

It has been a great satisfaction to study the Central Brazilian Cerrado biome and I am most grateful to my colleague Dr. Jeanine Maria Felfili, with whom I have worked for the last 10 years. Together we have accomplished many studies and this has made us realize just how much there is still to be understood.

I wish to thank many friends for their help in my work, amongst whom I should particularly mention Benedito Pereira, Roberta Mendonça, and the field assistants Chiquinho and Diacis from the IBGE Ecological Reserve and Felipe Ribeiro from EMBRAPA-CPAC. Prof. Alba Rezende was my representative in the University of Brasília during my absence from Brazil and also gave me great help in the field work. Dr. M. Haridasan kindly guided me in the description of the soil profiles. Prof. Paulo Ernane, Denise Borgato and Angélica Garcia also helped in the fieldwork. Newton Rodrigues, (field assistant) of the Forestry Department of the University of Brasília, helped me with his impressive knowledge of trees. Prof. Carolyn Proença identified the Myrtaceae, an abundant and taxonomically extremely difficult family. Prof. Ary Oliveira-Filho (Federal University of Lavras) helped me with the identifications in the herbarium of Edinburgh (E) and was always available for interesting discussions on multivariate analysis. Many thanks also to my cousin Maria Cecilia, always ready to help me in any background logistics in Brazil.

I am very grateful to Dr. James A. Ratter and Dr. Peter A. Furley who as my friends provided me a comfortable time in Edinburgh and as my supervisors gave me the support to develop my ideas.

I want to express my gratitude to Christopher Fagg (University of Oxford), Samuel Bridgewater, Dr. Toby Pennington and Ruth Atkinson (all of the Royal Botanic Garden Edinburgh) for reading and criticizing the draft of my thesis.

In Scotland I shared great moments with many friends who became my Scottish family, especially Chris, Freda and Jessica Minty (the last, the friendiest labrador in Scotland), Mônica (morena), Marcelo (my flatmate), Mônica (loira), Kwiton, Nancy, Lyria and Ary, Marcela, Luis, Rose, Mel, David, Paulo Cesar, Paulo and Helô (Pedro, Gabriel, Mariana, Aninha e Leandro), Marcelo (Paulista), Teresa and Juan Luis, Rogério and Maristerra (Pedro and Daniel), Vicenta and Juan Claudio, Sheila, Marianne, Gavin, Ray, Abdul, Marcelo and Dora, Maria Alice, Audrey and Marcos, Cristoph and Delia, Sam, Gordon, William Milliken, Armando and Cláudia, and Tânia.

I wish to thank CAPES for sponsoring my study and especially Sandra and Marta who competently dealt with all sorts of administrative problems during this period. The Forestry Department of the University of Brasília provided me the chance to pursue my studies.

Many thanks indeed to my father Manoel, my mother Cleonice and my sister Rita who always gave me all the support needed.

"Eu hoje encontrei em ruas, separadamente, dois amigos meus que se haviam zangado um com o outro. Cada um me contou a narrativa de porque se haviam zangado. Cada um disse a verdade. Cada um me contou as suas razões. Ambos tinham razão. Não era que um via uma coisa e outro outra, ou que um via um lado das coisas e outro um lado diferente. Não: cada um via as coisas exatamente como se haviam passado, cada um as via com um critério idêntico ao do outro, mas cada um via uma coisa diferente, e cada um, portanto, tinha razão. Fiquei confuso desta dupla existência da verdade."

Fernando Pessoa

"Today I met separately in the street two of my friends who had argued with each other. Each of them related the story of why they had argued. Each of them told me the truth. Each told me their reasons. Both were right. It wasn't that one saw one thing and the other another, or that one saw one side of things and the other another side. No: each saw things exactly as they had happened; each saw them from an identical viewpoint; but each saw a different thing, and each therefore was right. I was confused by this twofold existence of truth."

Fernando Pessoa

Glossary of vegetation types of Central Brazil

Caatinga. The native vegetation of the arid northeast of Brazil. It ranges from low cactus /thorn scrub to quite tall deciduous forests (mata acatingada) and has a rich endemic flora. The name caatinga means white forest in Tupi-guarani and refers to the bleached appearance of the vegetation when it is leafless during the long dry season.

Campo cerrado. The stage in the physiognomic continuum of cerrado (*sensu lato*) lying between Campo sujo and cerrado (*sensu stricto*). It is characterised by the presence of trees producing up to c. 20% cover with usually exuberant ground vegetation between. The name means 'closed field' in Portuguese.

Campo de murundus. Areas of hydrologic campo 'grassland' (rich in sedges, grasses and xyrids) bearing fairly evenly spaced earthmounds. Larger earthmounds carry shrubs and trees and usually a termitarium. The position of earthmounds often follows a very regular spatial pattern over the catenary form of the slopes.

Campo limpo. A treeless 'grassland' (actually with a vegetation usually consisting of grasses, forbs, subshrubs and sedges). It represents the treeless form of cerrado vegetation (*sensu lato*). The name means 'clean field' in Portuguese.

Campo rupestre. A low montane savanna vegetation found on rocky ground. It has many characteristic species and at higher altitudes an interesting endemic flora.

Campo sujo. 'Grassland' with a scattering of shrubs and small trees. This is another form of cerrado vegetation (*sensu lato*). The name means 'dirty field' in Portuguese.

Cerrado (*sensu lato*). The Brazilian savanna vegetation which covers one area of 2 million km^2 and has a rich native flora of probably approximately 6,000 species of vascular plants. It ranges in physiognomies from open grasslands to closed savanna woodlands. The following vernacular names running from the most open to the most closed forms, are given to recognisable points in this vegetation series: campo limpo, campo sujo, campo cerrado, cerrado (*sensu stricto)* and cerradão; they are all defined in this glossary.

Cerrado (*sensu stricto*). At this stage the cerrado woodland has became so dense that a horsemen can not ride through it . Tree cover is approximately 20-60% but the ground layer is still well-developed. Trees in cerrado (*sensu stricto*) often tend to be taller but heights to 13 m are uncommon.

Cerradão. This is the augmentative of cerrado and indicates the densest and tallest forms of cerrado (*sensu lato*). Tree cover varies from 60% to sometimes a completely closed canopy. The trees also are usually taller than in the more open forms of the vegetation and are often 12-15 m (or exceptionally even more). The shade of the denser canopy suppresses the ground vegetation which in the most closed Cerradão is very sparse.

Chaco. The native open woodland vegetation of parts of N Argentina and Paraguay. It is characterised by a high water table during part of the year and has a rich endemic flora. In Brazil Chaco is only found in some very small areas of S Mato Grosso but the name has been misapplied to the disjunct areas of the Caatinga vegetation found near Corumbá, MS.

Chapadas. High flat plains and tablelands which in Central Brazil are normally covered with continuous extensions of cerrado vegetation. The soils are usually extremely leached and very dystrophic but despite this chapadas are much threatened , since the long flat expanses are ideal for mechanised agriculture.

Gallery forest. The enormously variable riverine forest following watercourses. It is usually evergreen and is floristically extremely heterogeneous. Smaller seasonal watercourses with steep bands often have a form of gallery Cerradão, known as Cerradão ciliar (= eyelash Cerradão)

Mesophytic forest. Deciduous or semideciduous forest found on richer soils in the cerrado biome. The canopy height is generally 15-25 m and the community has a very characteristic flora.

Veredas. Areas of hydrologic campo carrying groves of the 'Buriti' fan-palm (*Mauritia flexuosa* L. F.). The palms normally run in files following drainage lines.

Abstract

This study was designed to discover whether there are patterns in tree communities and to examine their possible links with environment in undisturbed gallery forests. The study focused on the Pitoco, Monjolo and Taquara streams, within the Ecological Reserve of the ' Instituto Brasileiro de Geografia e Estatística' in the Federal District, in Central Brazil. The three gallery forests are representative of an endangered and extremely important vegetation formation, which is closely related to the maintenance of environmental health and to the volume and quality of the water supply in the region.

The conspicuous flora, including species which reflect characteristic environmental features, guided the choice of sites. An intensive study focused on the vegetation and soils of each gallery. Tree species were recorded using the Point Centred-Quarter (PCQ) method from the stream margins to the forest-cerrado border. Soil samples were taken to reflect environmental changes within each catchment.

Analysis of the galleries' phytosociology and diameter distribution highlighted their considerable heterogeneity. Only *Copaifera langsdorffii* and *Tapirira guianensis* occurred as important species in all three sites. This probably reflects environmental differences between the three areas. Classification by TWINSPAN distinguished forest communities at each locality, referred to as 'wet' and 'dry' according to their position in relation to the stream margins and site topography. The floristic links between the galleries and communities were investigated by cluster analysis (UPGMA), which reinforced the model of a strong association between communities and soil moisture. In fact there was a stronger relationship between communities from areas of similar soil moisture at different stream locations, than between 'wet' and 'dry' communities within the same stream. The soil properties were also found to follow a consistent spatial patterning at all three sites. The wet community soils had significantly higher Al, H + Al, Al saturation, Cu, Fe and Zn levels, and the dry

community soils had significantly higher values for pH, Ca, Mg, K, Mn, TEB and total exchangeable cations. Principal Component Analysis (PCA) summarised the seventeen soil variables into a few components and demonstrated that Al and Al-saturation had the highest correlation with the wet communities soil samples, and that Ca, Mg, Mn and pH were strongly correlated with the dry community soils. Both wet and dry communities were found over a range of soil textures from those dominated by sand to those by high clay fractions. Detrended Correspondence Canonical Analysis (DCCA) analysed species dominance and environmental relationships. The main gradient (axis I) ranges from the wettest site (Monjolo wet community) to the dry and richest site at Taquara. Axis II placed the communities on a gradient ranging from the Al-richer to the Ca-richer soils. The results are to be taken as hypothesis generators and further experimentation is required to confirm and reinforce the patterns indicated.

The study shows that species spatial patterning results in identifiable floristic communities within the gallery forests, which are related to particular environmental features. The analysis suggests that detailed experimentation is required to produce the strategic technology necessary for the recuperation of the already vastly depleted gallery forests of Central Brazil.

Resumo

Este estudo tem como objetivo investigar se há padrões em comunidades de árvores, bem como examinar as possíveis relações de tais padrões com o ambiente, em matas de galeria não degradadas. Foram focos do estudo os riachos do Pitoco, Monjolo e Taquara, localizados na Reserva Ecológica do Instituto Brasileiro de Geografia e Estatística, no Distrito Federal. As três matas de galeria em questão são representativas da extremamente importante e ameaçada formação vegetal, intimamente relacionada com a saúde ambiental e com o suprimento do volume e qualidade de água na região.

A escolha dos locais de estudo foi então guiada pela presença de uma flora distinta, caracterizada por espécies que refletem características particulares de cada mata. A vegetação arbórea foi amostrada intensivamente, usando-se o método de quadrantes, ao longo do gradiente que se extende desde as margens dos riachos até os limites entre a mata e o cerrado. Amostras de solo e medidas de elevação foram tomadas considerando-se que ambas refletem as mudanças ambientais em cada sítio.

A análise da fitossociologia e da distribuição dos diâmetros mostrou a considerável heterogeneidade entre as matas. Somente *Copaifera langsdorffii* e *Tapirira guianensis* occorreram como espécies importantes, o que provavelmente indica diferenças ambientais entre as três áreas. Usou-se classificação por meio de TWINSPAN, para distinguir as comunidades florísticas, que receberam os nomes úmida e seca de acordo com suas posições em relação aos riachos e à topografia. As relações florísticas entre as galerias e suas comunidades foram investigadas através de análise de agrupamento (UPGMA), a qual reafirmou a forte associação entre a vegetação e a umidade dos solos. Verificou-se haver mais relação entre as comunidades de solos úmidos das três matas - o que permitiu o agrupamemto das mesmas - do que entre as comunidades de solos úmido e seco dentro da mesma mata.

Os solos mostraram um padrão espacial bastante consistente nos três locais de estudo. Os solos das comunidades úmidas tiveram sempre níveis significativamente maiores de Al, H + Al, saturação de alumínio, Cu, Fe e Zn, enquanto os solos da comunidade seca mostraram níveis mais elevados para o pH, Ca, Mg, K, Mn e total de bases trocáveis. A análise de componentes principais sumarizou as 17 variáveis do solo em poucos componentes e demostrou que o Al e a saturação de Al tiveram as correlações mais fortes com os solos das comunidades úmidas e que o Ca, Mg, Mn e o pH estavam fortemente correlacionados com os solos das comunidades úmidas. Ambas as comunidades, úmida e seca, foram encontrdas sobre uma grande amplitude de classes texturais de solo, desde aqueles dominados por areia até aqueles dominados por argila. A Análise de Correspondência Canônica por Segmentos (DCCA) mostrou as relações entre a área basal das espécies e o ambiente. O gradiente principal (eixo I) representou a variação entre os sítios mais úmidos (comunidade úmida do Monjolo) até os solos mais secos e ricos do Taquara. O eixo II posicionou as comunidades ao longo do gradiente dos solos ricos em alumínio até aqueles ricos em cálcio. Os resultados devem ser tomados como geradores de hipóteses e experimentação subsequente faz-se necessária para reafirmar os padrões encontrados.

Em suma, o estudo mostra que o padrão espacial das espécies nas matas de galleria resulta em comunidades florísticas identificáveis, as quais estão relacionadas com características ambientais locais. As análises apontam ainda para a necessidade de experimentação detalhada no sentido de produzir as técnicas apropriadas para a recuperação das grandes áreas de matas de galeria devastadas no Brasil Central.

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Chapter 1 - Introduction.

Evidence supports the occurrence of cycles of expansion and contraction of forests versus open vegetation formations, linked to the occurrence of alternating warmer/wetter and colder/drier periods during the Pleistocene and Holocene (Prance, 1987). Narrow strips in a dendritic pattern following streams and rivers in the cerrado area might have been the sites (refugia) maintaining forest species during the drier/colder periods of the glacial maxima in the Pleistocene (Pires 1984). During this time most of the present tropical forest region probably resembled today's savannas landscape (Meave et al. 1994).

Recent palynological data (Ledru 1993) have provided evidence suggesting that, in fact, the cerrado area from 17,000 to 13,000 B.P. was not as dry as previously regarded, and was covered by seasonal forests. Consequently, its current flora and fauna show links with the Amazon, Atlantic and Paranense provinces (Warming 1908, Ab'sáber 1971, Bezerra dos Santos 1975, Pires & Prance, 1977, Rizzini 1979, Pires & Prance 1985, Oliveira-Filho & Ratter in press).

The outstanding floristic and phytosociological feature of the gallery forests is the great richness of tree species, most of which occur at very low densities, whilst a few species account for the majority of individuals and basal area (Camargo et al. 1971, Ratter 1980, 1986, Oliveira-Filho et al. 1990, Felfili & Silva Júnior 1992, Felfili 1993, Ramos 1994).

The list of tree species of the gallery forests of the Federal District is continually being updated and a figure above 500 will probably be reached. The few floristic surveys (Ratter 1986, FZDF 1990, Silva 1991, Felfili & Silva Júnior 1992, Felfili 1993, Ramos 1994) carried out in the gallery forests in the area recorded 63 families among which only five were in every site: Anacardiaceae, Annonaceae, Leguminosae, Myrtaceae and Rubiaceae. Among 226 species (DBH≥ 5cm) 27.4% were exclusive to single sites. Only four species: *Copaifera langsdorffii, Matayba* *guianensis, Sclerolobium paniculatum* var. *rubiginosum* and *Tapirira guianensis* were recorded in every site (Silva Júnior et al. in prep.). Thus because of their great floristic heterogeneity, the Federal District gallery forests represent an extraordinary natural experiment where vegetation-environment relationships can be assessed.

The present investigation is a detailed and comparative study of three communities: the Pitoco, Monjolo and Taquara gallery forests in the IBGE ecological reserve (RECOR). The three sites were selected because of their distinct floristic composition and their having been protected from major disturbance for at least 20 years.

The approach in this study is conceived as a sequence of complementary analyses to investigate the association of particular floristic communities with differing environmental conditions.

1.1.- The problem.

The few studies that have already been carried out demonstrate that gallery communities of distinctive floristic composition are related mainly to differences in water availability and soil nutrient status (Silva Júnior & Felfili 1986, Oliveira-Filho et al. 1989, Schiavini 1992, Felfili 1993, Ramos 1994, Oliveira-Filho et al. 1994)

To continue and amplify such studies, I visited the Pitoco, Monjolo and Taquara gallery forests many times previous to this study and noted the floristic differences related to wet and dry conditions along the streamside and the forest-cerrado border. In order to seek patterns in these poorly studied ecosystems, I formulated the following questions which I intend to examine in the next chapters:

1) - What is the floristic composition, phytosociology and diameter structure of each of the gallery forests?

2) - Is there any pattern of spatial distribution of species which would indicate the presence of different communities within these galleries?

3) - Do these three galleries show similarities in floristic composition, density and basal area?

4) - What are the soil characteristics of these gallery forests?

5) - Is there any pattern of soil distribution related to different communities within these gallery forests?

6) - Are the structure and communities of the gallery forest related to the environmental variables studied?

1.2. - Tackling the problem.

There have been a large number of studies on the ecology of vegetation communities where the approach has been to try and extract clear information on their distributional patterns. The following paragraphs show step by step, how the analysis is carried in order to emphasise the spatial patterns in the tree communities and their relationships with the environment in the galleries studied.

The point-centred quarter method (PCQ) is applied to measure floristic composition and phytosociology. A total of 250 sampling points in each gallery forest provided 1000 individual trees (DBH ≥ 5cm) to measure the floristic composition, phytosociology and diameter distribution and forms the evidence to answer question 1 (**see Chapter 4**).

TWINSPAN (Two way indicator species analysis) (Hill 1979) based on presence and absence of species, provides groups of sampling points which are separately resubmitted to phytosociological analysis. Identifiable communities derived from species occurrence, density and basal area are thus found objectively to answer question 2 (**see Chapter 5**).

A hierarchical agglomerative classification by UPGMA (Unweighted Pair Groups method Using Arithmetical averages) using Sørensen and Morisita similarity indices provides a comparison of the gallery forests based on floristic composition, density and basal area, and addresses question 3 (**see Chapter 6**).

Soil profiles and samples of the superficial layer (0-10 cm) are collected in accordance with the vegetation sampling procedure and analysed to assess the fertility status and physical characteristics of each gallery soil, the subject of question 4 (see **Chapter 7**).

In **Chapter 8** soil parameters are ordinated by Principal Component Analysis (PCA) emphasising a strong marked soil gradients closely related to the tree communities spatial distribution, to answer question 5.

The relationships between species and environmental variables are emphasised by ordination carried out using Detrended Canonical Correspondence Analysis (DCCA) answering question 6 (**see Chapter 9**).

Figure 1 displays step by step, the sequence of analyses carried out in order to analyse relationships between vegetation and the environmental variables.

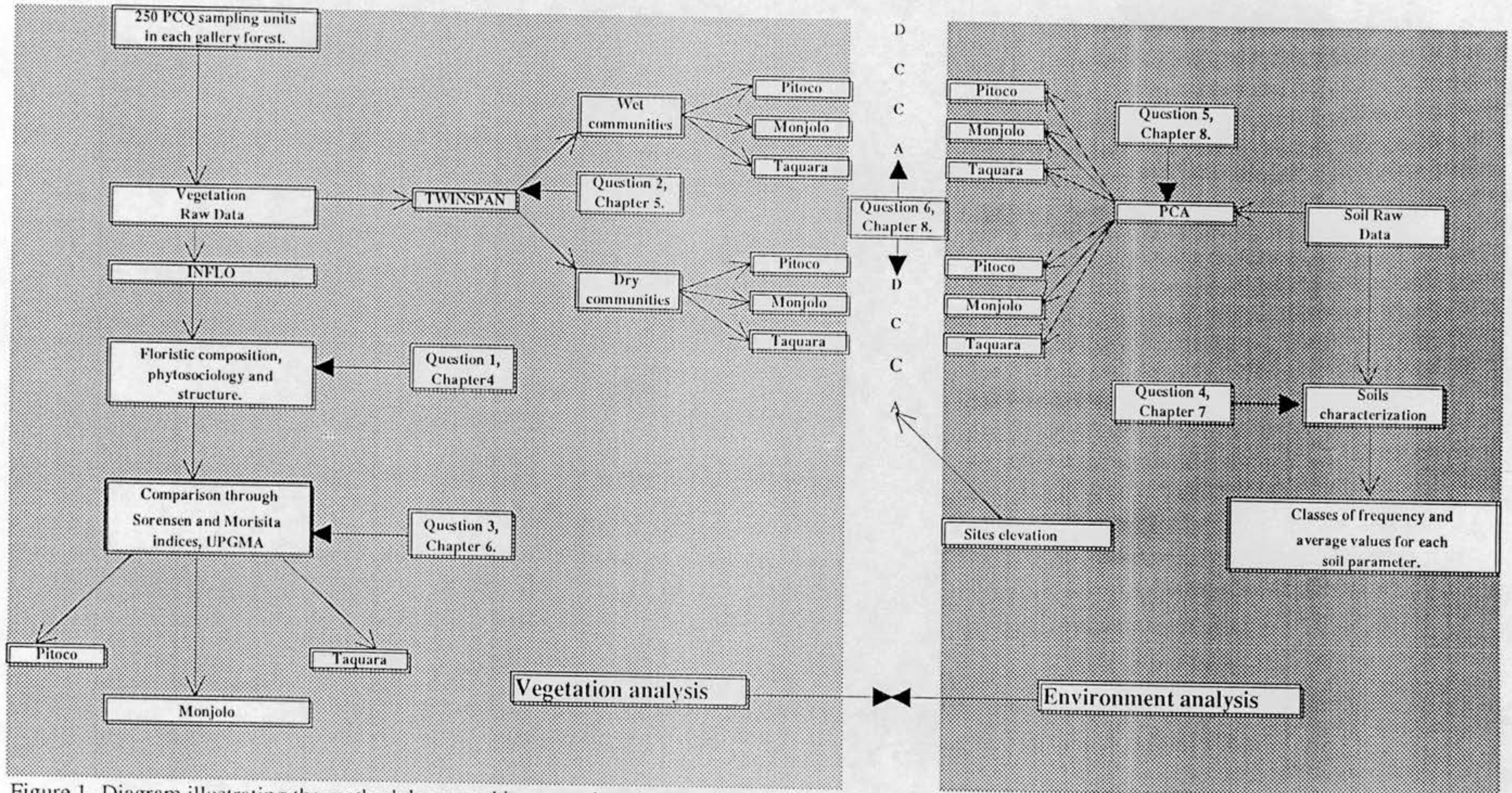


Figure 1- Diagram illustrating the methodology used in answering the questions posed in chapter 1. INFLO refers to to a microcomputer package for phytosociological analysis.

Chapter 2.- General background: The gallery forests of the the Brazilian cerrados.

2.1.- Tropical Savannas.

According to Cole (1986), tropical savannas exist within a belt across the Equator extending to approximately 20° latitude in both hemispheres, and at present cover almost 20% of the Earth's surface. A continuous ground layer dominated by grasses and sedges is their prevailing feature, while trees and shrubs may occur at variable spacing and heights thus producing a landscape of variable plant physiognomy (Eiten 1972, Frost et al. 1986).

A climate with well defined wet and dry seasons associated with characteristic soil properties, notably variable soil moisture, acidity, and poor nutrient availability, are recognised as the main determinants (Montgomery & Askew 1983, Lamote 1990). Secondary determinants, such as fire, herbivory and landscape management, play a varying role in each area (Medina 1987). Geology, geomorphology, climatic changes and environmental history are also very important (Cole 1986).

Summarising studies on savanna-environment relationships, Frost et al. (1986) aggregated the main controlling factors along two axes: PAM, referring to plant available moisture and PAN to plant available nutrients.

Differences in the occurrence, intensity and frequency of the above factors have resulted in a particular set of attributes for each of the current main tropical savanna regions of the world.

2.2.- The Brazilian Cerrados.

The Brazilian savanna vegetation is called *cerrado* a word with two meanings: cerrado (*sensu lato*) covers the whole range of this vegetation, while cerrado (*sensu stricto)* denotes one specific physiognomic unit within it.

Much of the discussion on current South American vegetation distribution relates to climatic fluctuations in the late Quaternary (Prance, 1987). Studies of land forms, soil formation, palynology and present day plant and animal distributions provide evidence of greater areas of open formations and concomitant contraction of forests under a former drier and cooler environment (Brown & Ab'Saber 1979, Van der Hammen 1983).

As pointed out by Prado & Gibbs (1993), most of the attention is focused on the ongoing issue of the Amazonian forest refugia theory and little has been discussed regarding the drier formations. These are recognised by Vanzolini (1963) as the so-called 'diagonal of open formations' from the northeast of Brazil, including the 'Caatinga', to northern Argentina, including the 'Chaco' vegetation. In broad perspective, as demonstrated by Eiten (1972), the cerrado formation occupies a site of intermediate humidity in South America. It is bordered by the drier Caatinga and Chaco, in the northeast and southwest and by the more humid Amazonian and 'Atlantic complex' tropical forests in the north and southeast (Figure 2).

The importance of the cerrados is not only due to their huge area, (2 million km^2) covering more than 20% of the Brazilian territory, but also to their high biodiversity, since they harbour a large number of endemic plant and animal species. Unfortunately, their woody vegetation has been used extensively for charcoal production and, since the seventies, the government's agricultural policy has stimulated large scale cultivation which has already resulted in destruction of around 40% of the original area (Dias 1990). Moreover, the Amazonian forest has been the main focus for concern in conservation which, although necessary and justified, has

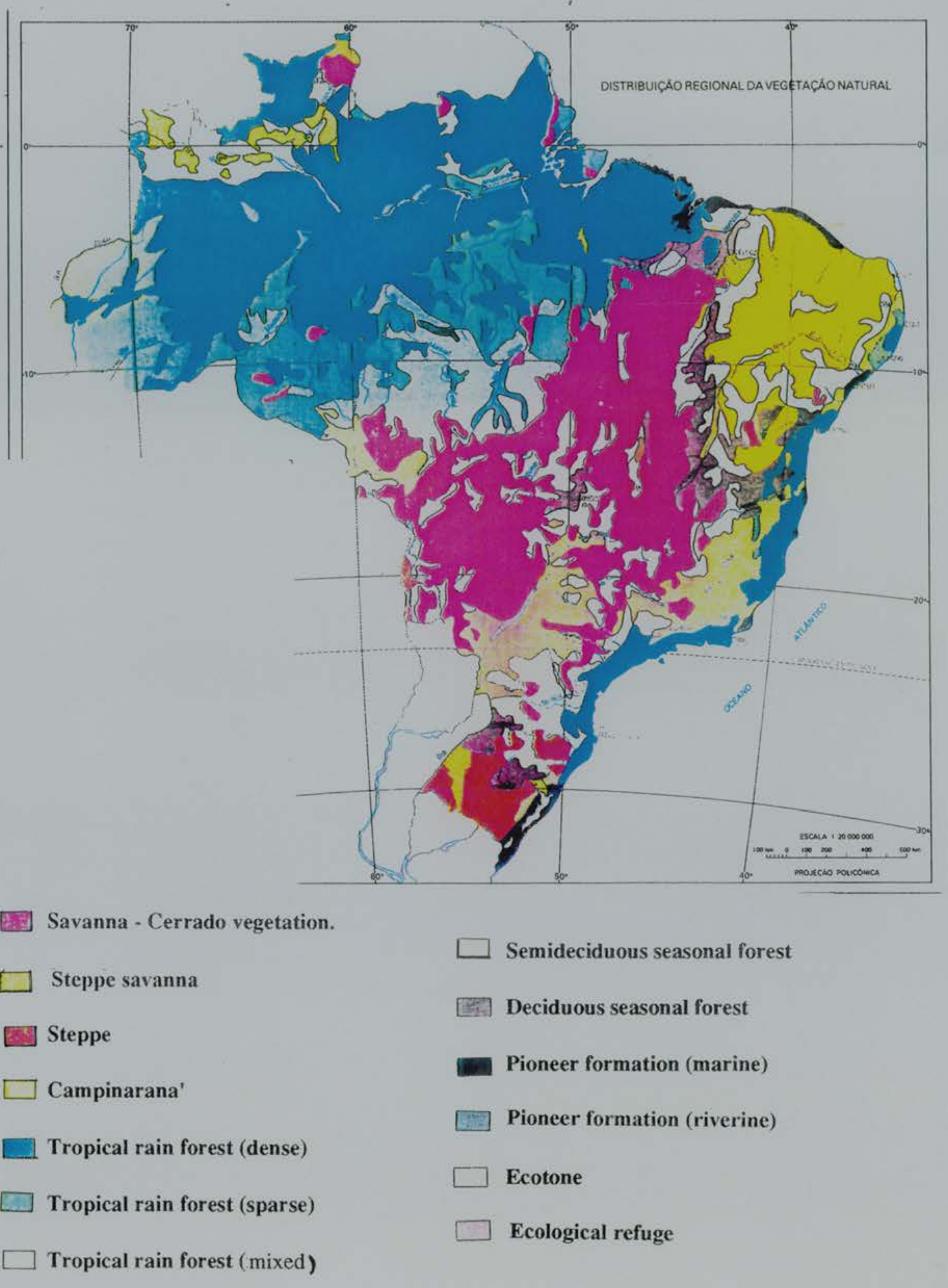


Figure 2 - Map showing the distribution of the Cerrado Biome in relation to other Brazilian's vegetation provinces according to IBGE (1994).

stimulated a new wave of pressure on the cerrado area where many 'development' projects have been undertaken, endangering its rich flora and fauna.

The environment studied in the present research is representative of a large area of the cerrados and has been the focus of many recent investigations. The succeeding section examines the characteristics of the cerrado environment of the Federal District.

2.2.1.- Climate.

The occurrence of a rainy warm season and a dry fresher season in the Federal District characterises the regional climate, which is Aw following Köppen's classification, i.e. the savanna subtype of the tropical rain climate. Precipitation is about 1600mm, most of which (c. 75%) falls between October to May. The length of the dry season (usually April to September) can vary from five to six months (Ferri & Goodland 1977).

Isothermy is a common characteristic of every tropical environment and average temperatures of the hottest and coldest months are only slightly different. The daily range particularly in the dry season can be greater than the seasonal variation and plays an important role in the life of plants and animals (Goldstein & Sarmiento 1987). Average annual temperatures range from 18 to 20°C. September-October is the warmest period (average 20-22°C) and July is the coldest month when the average drops to 16 to 18° C.

Clear skies and high solar radiation favour plant growth. Day length varies little but clouds can provide a marked seasonal rhythm (Menaut & Cesar 1982). Monthly insulation is consistently higher than 120 hours, reaching more than 200 hours in the dry period (Pereira et al. 1989).

Air humidity may vary from region to region but is generally high in the wet season (>70-85%) and drops to an average of 50-65% during the dry season, when values lower than 20% have been recorded (Adamoli et al. 1985).

These atmospheric conditions produce a high evapotranspiration potential (1700-1800mm per year), and a resulting water deficit which may vary depending on the precipitation and soil water supply in each region (Eiten 1972). Dew and condensation may assume an important role in the drier months (Cole 1986).

Frosts are not common but act as a selective factor in determining floristic composition, as reported closer to the southern cerrado limit (Silberbauer-Gottsberger et al. 1977). They are, however, very rare in the Federal District.

Under these climatic conditions, water availability is one of the most important regulators of the balance between a continuous shallow-rooted ground layer, which experiences water shortage in the dry season, and a discontinuous deep-rooted layer of woody plants well supplied during the whole year (Goldstein & Sarmiento 1987, Medina 1987).

The seasonal variation in water supply is associated with a xeromorphic vegetation as pointed out as long ago as 1908 by Warming. Later Rawitscher and co-workers (1942, 1943) and also Ferri (1944) and Rachid (1947), demonstrated that water was not a limiting factor for deep-rooted woody vegetation. The presence of big leaves, absence of wilting even in the dry period, and the occurrence of flowering and sprouting before the onset of the wet season were factors contradictory to the hypothesis that the xeromorphy of cerrado vegetation was an adaptation to economise water. These authors found that during the dry period cerrado soils, with exception of the surface layer (2m), contain sufficient water to maintain the vegetation. Because of this, during the dry periods the shallow-rooted ground layer shows a completely different behaviour to the deep-rooted trees and shrubs.

2.2.2.- Soils.

Much evidence supports the theory that during the hot and wet climate of the Cretaceous and early Tertiary presence of widespread tropical forest over the disintegrating Gondwanaland provided conditions for deep weathering, producing ferralitic or plinthitic soil profiles. A subsequent drier environment resulted in more open vegetation, accelerating surface erosion and exposure and led to induration (Cole 1986).

The Federal District occupies the high lands of the ancient central plateau, a relict Gondwananaland block. Its surface is characterised by three geomorphological macro-units: 1) the region of 'chapadas' (plateau level), 2) the areas of intermediate hillslopes and, 3) the dissected valleys.

The first two of these macro-units are above 1000m. They occupy respectively 34% and 31% of the area and are regarded as residues of a Tertiary planation surface over quartzites, slates, phyllites and mica-schist rocks. Both show flat to gently undulating topography (< 8% slope) associated with Latosols (OXISOLS) (Haridasan 1990) which are very deep old soils, strongly leached, poor in weatherable material (Sanchez 1976), and of dystrophic status, where the 1:1 low activity clay fraction is dominated by kaolinite, gibbsite, amorphous material, quartz and iron oxides and hydroxides (Sanchez 1976, Wilding et al. 1983). Texture varies widely but is mostly of sandy-clay and generally weakly structured, with a loose consistency which gives the soils good drainage characteristics in most areas (Adamoli et al. 1985). Ironstone and plinthitic gravel layers are revealed in many profiles (Furley 1985, Furley & Ratter 1988).

The third macro-unit, the dissected area of valleys, occupies 35% of the Federal District and is characterised by incised drainage systems cutting into rocks of varying resistance (Pinto 1990). Here due to the slope (> 8%) continuous erosion provides natural renewal of weathered material (Haridasan 1990).

Cambic soils (INCEPTISOLS) are characterised as shallow soils with thin ochric and A horizons. Weatherable material is still present in B horizons which lie over a C horizon with gravel, pebbles and fragments of rock. Higher CEC values are generally prevalent when compared with Latosols. Nutrient status can be dystrophic to eutrophic depending on the associated bedrock and topography. Most of the area of this soil class is over metamorphic acid rocks giving poor allic soils which cover more than 30% of the area in the Federal District (Adamoli et al. 1985, Haridasan 1990).

Podzolic soils (ULTISOLS, ALFISOLS) account for less than 3% of the area and are associated with slope and characterised by an illuvial clayey B horizon.

'Terra roxa estruturada' soils (ALFISOL) which cover over 1.3% of the area originate from calcareous parent material, and are associated with valleys, characterised by low acidity and high nutrient status of Ca, Mg and K but not necessarily of P.

'Areias quartzosas' (ENTISOLS) do not show development of eluvial / illuvial horizons. They form 2m thick A-C profiles where sand represents ≥ 80% of the textural fraction. They are deprived of primary minerals and show very low nutrient availability, OM, and moisture holding capacity with high acidity and Al contents.

Hydromorphic soils (mostly INCEPTISOLS or ENTISOLS) are found under conditions of seasonal or permanent saturation due to the water table being at or near the surface. A range of soil types, covering 4.2% of the Federal District surface, can be distinguished:

-'Laterita hidromórfica' soils (INCEPTISOLS) occur in flat areas at the valley bottoms. They are subject to periods of inundation, resulting in a latosolic or podzolic B horizon forming a greyish and mottled layer due to reduction processes with the seasonal saturation. During long dry periods, oxidation may occur resulting in a plinthic horizon. Most soils are dystrophic.

Gley soils (INCEPTISOLS, ENTISOLS), originating mainly from alluvial and colluvial deposits, are conditioned by an alternating wetting and drying regime which results in a dark A horizon of variable organic matter content (Humic, Slightly humic, Organic). The presence of iron in its reduced forms gives greyish colours. During dry periods, iron oxidation results in a mottled horizon with yellowish and reddish spots. The soils are mostly dystrophic, allic and badly drained.

Each soil type is generally found associated with one or more vegetation communities which compose the typical local landscape patterns repeatedly observed throughout the cerrado area. They are described in section 2.2.4.

2.2.3.- Fire.

Although savannas were at one time considered purely as a man-made vegetation resulting from frequent burning, their world-wide distribution, endemisms, and palynological history are now used as testimony to their long-term presence on Earth as a natural climax vegetation (Sarmiento et al. 1985, Frost et al. 1986). Nevertheless, human activity has been the major cause of fires in Brazil for at least the last 10,000 years and some cerrado areas can be considered as fire climax (Coutinho 1982).

The cerrado vegetation in its natural condition suffers periodic fires caused by lightning. After normal seasonal fires, as a result of organic matter mineralization and mineral cycling, the soil surface layer possesses higher nutrient availability and a near zero level of aluminium for at least the first three months (Coutinho 1976, 1982, 1985). In fact, fire causes a nutrient transfer from the woody to the herbaceous stratum and allows fast recovery of the latter (Eiten & Goodland 1979).

In the main, the arboreal and ground layers of the cerrado show contrasting adaptive strategies to fire. Trees have thick, corky, insulating bark and the ability to sprout adventitious buds from deeper lying tissue (such as the wood cambium), while the aerial shoots of the herbaceous layer are of short duration and are simply 'sacrificed' to the fire and rapidly replaced by new growth from the almost universal large xylopodia. The ground species are extremely fire-resistant and markedly more so than the shrubs and trees, in fact some are even fire-dependent pyrophytes (Coutinho 1982).

In contrast, fire is pernicious and very dangerous for forest communities, particularly gallery forest, which show low resilience after destruction by fire.

2.2.4.--Vegetation communities.

Climate, topography, nutrient levels and soil-water regime were indicated as the major determinants of the regional, sub-regional and local boundaries of the distribution of vegetation and communities in Neotropic savannas (Furley 1992). Land forms and their related water status and soil properties were regarded as determining the presence of the main cerrado physiognomic types (Furley 1985, Oliveira-Filho et al. 1989, Emmerich 1990). This section describes the typical vegetation communities of the landscape of the cerrado biome.

Cerrado (*sensu stricto*) (savanna woodland) is characterised by presence of trees and large shrubs generally 3-7m tall with a variable (10-50%) cover. It is associated with Latosols (OXISOLS) over the 'chapadas' plateau level (Haridasan 1990).

Where root growth is limited by a hardened plinthitic layer, which might result from the compacting of iron-rich gravels on the convex interfluves or occur where plinthite is hardened to ironstone at seepage points over the lower segments of slopes, cerrado is replaced by more open communities dominated by a continuous well developed 0.5 to 0.7 m tall grass-field layer (Eiten 1972, 1990, Adamoli 1985). These are: *Campo Cerrado* (dry grassland) with numerous shrubs and trees which may reach 10% canopy cover; *Campo Sujo* (dry grassland) with even sparser and usually smaller shrubs and trees; and *Campo Limpo* (dry or grassland) which lacks shrubs or trees. *Campo rupestre* (rocky field) exhibiting small trees, scrub woodland or grass fields is another open savanna vegetation type found above 1000 m altitude over outcrops of quartzite and sandstone (Eiten 1978); it has a distinct endemic flora.

Dystrophic Cerradão (Closed cerrado woodland) occurs over soils which apparently have better water availability and possibly a better nutrient status than those of cerrado, probably related to texture and structure, and shows a flora of non-exclusive species in both trees and ground layers suggesting a better grown cerrado where some gallery forest species may also be found (Ratter 1971, Ratter et al. 1973, Brasil 1991). It is represented only by small patches mainly over Dark-Red Latosols. A *Mesotrophic Cerradão* is an equivalent but floristically distinct vegetation found on more calcareous soils (Ratter 1971, 1992; Ratter et al. 1973). Both forms of cerradão display 8-15 m tall trees giving 70 to 100% canopy cover resulting in a poorly developed ground layer, and commonly show sharp boundaries with neighbouring communities.

Where soils exhibit higher nutrient and/or water content, mostly in dissected lands over basic bedrock, forest often replaces cerrado (Eiten 1972, 1990, Ratter et al. 1973, Adamoli 1985, Furley & Ratter 1988, Furley et al. 1988). Mesophytic upland deciduous forest (Limestone outcrops), semideciduous (Podzols) and evergreen forests (Latosols) all occur with 15-25 m trees and canopy cover from 70-100%. All types are sparsely represented in Central Brazil and are postulated as vestiges of a once extensive and continuous seasonal woodland of richer soils (18,000 to 12,000 BP.) (Prado & Gibbs 1993).

Further downslope, *Campo Limpo Úmido* (wet grassland), without shrubs or trees, is found on Cambic and litholic seasonally saturated soils, It often carries earthmounds to form the so-called *Campo de Murundus* (campo with scattered earth hummocks). These earth-mounds are of variable size and have been suggested as termite-formed material made up of Latosols (Oliveira-Filho 1992, Diniz et al. 1986).

They are high enough to stand above the water-table during the wet season and carry typical ground-layer and small trees of cerrado species (Furley 1985, Haridasan 1990, Oliveira-Filho 1992). In the area around Brasília, they are likely to be of geomorphic origin although the mounds are frequently occupied by termitaria (Diniz et al. 1986, Furley 1986). Strips of these campos, varying from a few to several hundred metres, separate well-drained communities lying upslope from gallery forests in the valley-bottoms.

Gallery forests occur along the watercourses and are associated with hydromorphic, Cambic or Latosol soils of variable depth and water content. Such forests are usually evergreen with the canopy trees 15-25m tall, and have considerable species diversity.

Flat permanently flooded areas around spring sources exhibit *Veredas* (Marsh palm groves) over hydromorphic soils, where *Mauritia flexuosa* L., a tall fan-palm, dominates the landscape.

This ensemble of communities and physiognomies coexists, merges and is changed by fire, herbivory and human activities which produce noticeable variations in the landscape.

Figure 3 shows the characteristic toposequences of plant communities and soils found on sloping topography in the Federal District (Furley 1985).

2.2.5.- Plant communities and their relation with soils.

Coexistence of different communities under the same climate in Central Brazil was first discussed by Warming (1908). Further research suggested cerrado was associated with poor soils and water availability, gallery forests with poor soils of sufficient water supply and mesophytic forests with richer soils (Waibel 1948, Alvin & Araújo 1952, Alvin 1954).

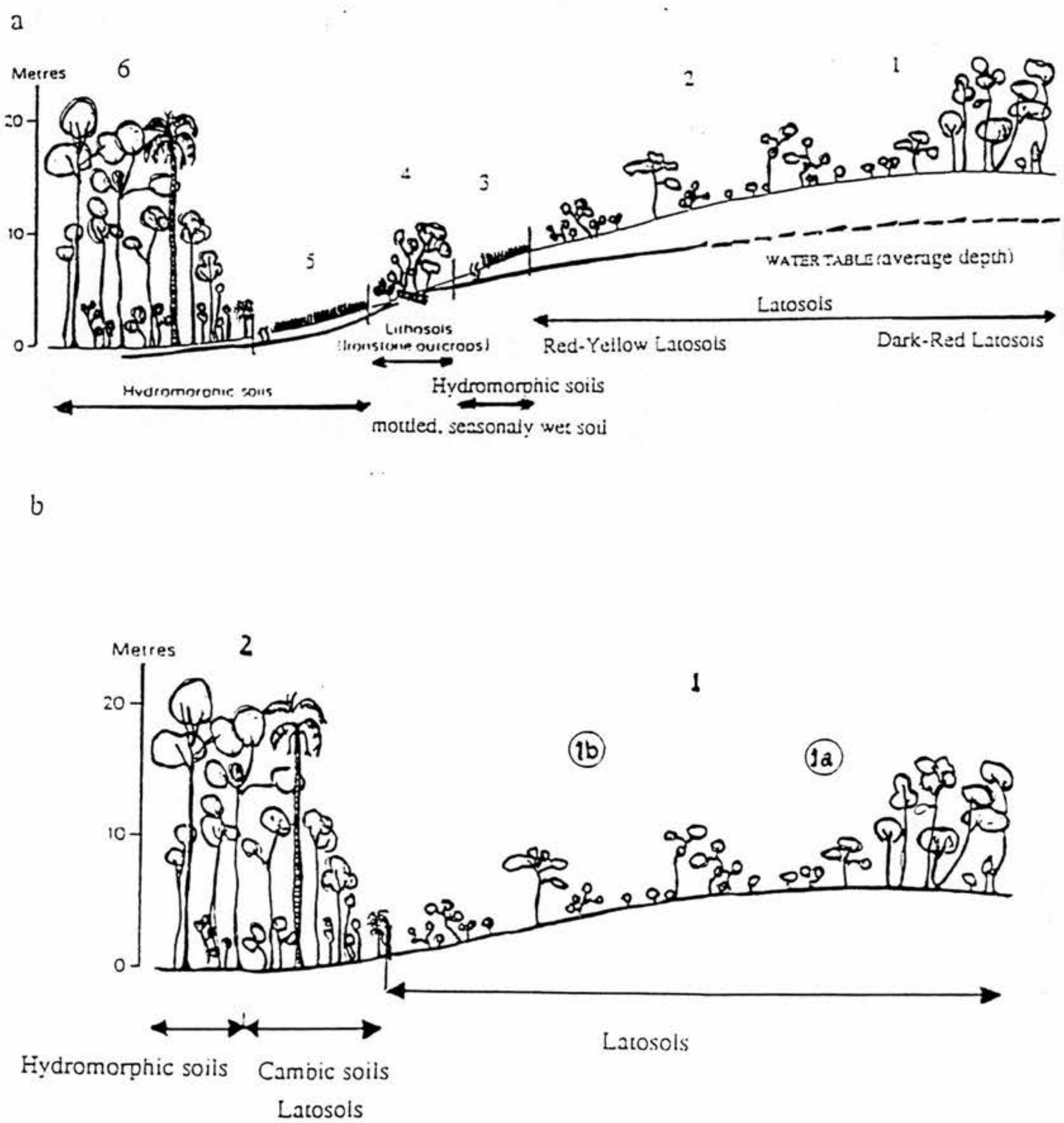


Figure 3 - Characteristic toposequences of communities and soils found over sloping topography in the cerrados of central Brazil.

a) **1-** Cerrado (sensu stricto) (Savanna woodland); **2-** Campo cerrado (dry grassland with numerous shrubs and trees; **3-** Campo sujo (dry grassland with sparse shrubs and trees); **4-** Campo cerrado (dry grassland with emergents) on Lithosols; **5-** Campo limpo (wet grassland without shrubs or trees) and/or Campo de murundus (grass communities with patches of woody cerrado on raised earth-mounds) and **6-** Gallery forests.

b) **1**- Cerrado (sensu lato) on latosols; **1a**- Cerrado (sensu stricto); **1b-** Campo cerrado; **2-** Gallery forests on Cambic soils or on Latosols in the margins abutting on cerrado vegetation, and on Hydromorphic soils in the lower parts of the catena, near the watercourses. (source: Furley 1985).

Cole (1986) regarded cerrado as the edaphic climax associated with older plateau surfaces, and forests as the climatic climax over dissected younger slopes. Subsequent debate (Askew et al. 1971, Ratter et al. 1973, Lopes & Cox 1977, Montgomery & Askew 1982) indicated that Cole's hypothesis was not always applicable, but adequate for many situations within the region.

The first quantitative study on communities and their associated soils was carried out by Goodland (1969) who indicated a close correlation between vegetation biomass and a soil fertility gradient, and also emphasised the importance of aluminium in the cerrado biome.

Recent controversial data on communities and soil relationships have shown poorer nutrient status and higher aluminium saturation in certain forest communities than in cerrado (Ratter et al 1973, Haridasan 1985, 1990, Ribeiro 1983, Furley 1985, Batmanian & Haridasan 1985, Silva Júnior 1984, Araújo & Haridasan 1988, Ramos 1994).

Under the generally dystrophic environment of the Federal District, differences in soil fertility do not suffice to explain the distribution of vegetation communities. However, within communities, species populations have shown reliable correlation with aluminium and other soil characteristics indicating their distinctive competitive potential (Ratter 1971, Silva Júnior 1987, Oliveira- Filho 1989, Silva 1991, Felfili 1993, Ramos 1994). For instance, low nutrient requirements and high re-absorption rates are adaptive strategies to overcome nutrient stress (Sarmiento et al 1985, Medina 1987). In this connection, native species show higher foliar nutrient contents than would be expected from the soil nutrient levels, thus indicating high uptake efficiency (Haridasan 1982, Ribeiro 1983, Araújo 1985, Machado 1986, Silva 1991).

Soil aluminium levels, regarded as the main constraint for establishment and growth of cultivated plants in the cerrado landscape where they suffer from aluminium toxicity, have been studied in detail since the work of Haridasan (1982), who demonstrated similar levels of most nutrients in foliar analysis of aluminium accumulator and non-accumulator species. Machado (1985) demonstrated the inability of *Vochysia thyrsoidea* (a cerrado aluminium accumulator species) to grow in environments where calcium was present (soil and nutrient solution) and showed high concentrations of aluminium in physiologically active tissues such as meristem and phloem.

In a specific study on gallery forest in the Federal District (Silva 1991) found 51% of the tree species to be aluminium accumulators, some of them at levels higher than ever reported in cerrado species, as in *Symplocos nitens* which showed 51,000 ppm of aluminium in its leaves.

This short assessment is intended to show the current level of knowledge about cerrado species and soil relationships and to stress that much remains to be studied in order to understand how native species deal with what seems to be an adverse soil environment.

2.3.- Gallery Forests.

Gallery forests are conspicuous in the cerrado landscape. They are in general evergreen, with a continuous canopy ranging from 20-30m in height which provides 80-100% cover resulting in a weakly developed ground layer. Due to the presence of water in the streams and valley bottom, high air humidity is maintained even during the dry season, allowing the growth of epiphytes and lianas (Ribeiro et al. 1983, Mantovani et al. 1989, Eiten 1990).

As a consequence of drainage into the valley bottoms, the water table remains close to the surface almost all year round and in some situations areas of flat valley floors may be seasonally inundated. The water-table level can define the outside boundary of gallery forests (Furley 1985, 1992, Oliveira-Filho et al. 1990). Within the forest the water table influences physiognomy, floristic and community composition, species richness, and density of larger trees (Metzler & Donnaman 1985, Powell 1984, Dunham 1989, Huges 1990).

Waterlogging may result in low soil O_2 levels and consequent accumulation of phytotoxic products due to anaerobic metabolism, regarded as the main impediments to be withstood by trees colonising such wet areas (Kozlowski 1982, Joly & Crawford 1982).

Soils of differing chemical and physical characteristics may occur in gallery forests (Dematté 1989) because of their position at the bottom of a toposequence, where different terraces of distinct ages and formations may contribute material (Catharino 1989). Sediments from long distances can also be added, depending on the size of the catchment basin, topography and flooding surface. However, small rivers and streams, such as are commonly found in the Federal District, only have limited catchment basins. Consequently, the alluvial + colluvial soils are derived from the local region and are similar to adjacent cerrado areas. Under such conditions the nature of alluvial and colluvial material (Bertoni & Martins 1987), the soil type, its mineral composition and texture (Gouvea 1974) were regarded as secondary determinants of the vegetation.

2.3.1- Environmental role.

Gallery forests are very important in the maintenance of the environment. Their presence reduces erosion on steep slopes, acts as a buffer filtering agrochemicals from adjoining cultivated lands thus preventing contamination of water, stops silting of streams and provides food and cover for the local fauna (Karr & Schlosser 1978, Schlosser & Karr 1981, Lawrance et al. 1984, Gay 1985, Paula Lima 1989).

Because of their environmental role, gallery forests have been protected by law in many countries. Brazilian legislation (Law 7511 of 07/07/1986) provides for the preservation of a 30m strip of forest at each side of streams up to 10m wide and a 50m strip on wider streams. The strict implementation of this law and constant monitoring would substantially reduce damage to gallery forests which too often have been exploited to produce timber and crops, particularly for local use.

In the Federal District, preservation of gallery forests is extremely important since the river basins, characterised mostly by abundant narrow streams, are responsible for the maintenance of the volume and quality of the region's water supply. This is of critical importance since population growth has already surpassed the estimate for the year 2000 and has boosted the water demand to an alarming level.

2.4.- Quantitative methods for forest phytosociological studies.

The methods used for phytosociological studies form a controversial subject giving rise to infinite, usually sterile polemics - often expanded by those far more interested in arcane aspects of theory than the practical study of vegetation. The next paragraphs are intended to give some background to the methods chosen for this study and the reason for selecting them.

In Europe, the development of phytosociology concentrated on the detailed study of small areas of herbaceous vegetation and forestry understorey strata, as a consequence of the paucity of tree species and the large extensions of planted forests, while in the USA it focused on understanding natural distribution in high diversity forests. As a result, many sampling techniques were developed for the analysis of forests over large areas (see Braun-Blanquet 1966, Mueller-Dombois & Ellenberg 1974). In Brazil, phytosociology has become a flourishing science because of the extensive forested areas, most of which have still not been accurately described.

The aims of studies of forest phytosociology include the accurate estimation of density, dominance and frequency. Density is the number of individuals of a species per unit of area. Dominance is an expression of size, volume or cover of each species in relation to space or volume of the community (usually expressed as basal area) and frequency is the number of sampling units where a species occurs in relation to the total number of sampling units.

A synthetic parameter, the Importance Value Index (IVI) is produced by adding the relative density, relative dominance and relative frequency and is used to compare species in a stand. It is regarded as representative of their current competitive potential for exploiting the resources of a site. Despite much debate and criticism, IVI has been successfully used to differentiate types of forests, correlate them with environmental features, and to establish species structure (Curtis & McIntosh 1951, Cain & Castro 1971).

A variety of sampling methods have been developed for estimation of phytosociological parameters, which fall into two groups: *i* - plot sampling or methods of fixed area, and *ii* - plotless, or distance, or methods of variable area (Daubenmire 1968, Cottam & Curtis 1956).

2.4.1.- The Point-Centred-Quarter method (PCQ).

The fundamental concept on which plotless sampling methods are based was named 'average area' by Klyn (1926) (see Curtis & McIntosh 1951) and by Braun-Blanquet in 1932 as 'average distance' (Braun-Blanquet 1966). It was formulated assuming an ideal forest where regularly spaced trees, say 2m apart, occupy the centres of contiguous squares so that the area occupied by each tree is 2x2m (=4m^2). Cottam (1947) established the basis of all plotless methods:- that the 'average distance' (**d**), assessed through recording distances between trees squaring 'average distance' gives 'average area' occupied by each tree in a forest.

In 1833/1834 a method based on distances between sampling points and the nearest tree was used for forest surveys by the US Land Survey Service . This can be considered the first plotless sampling method and its application is even earlier than the first use of plot sampling methods in 1848 (Daubenmire 1968). In the next century, Cottam (1947) developed the 'random pair' method to assess changes in the vegetation compared with data generated by the Land Survey Service. Many other methods were developed for forest surveys and they were named in accordance with the way in which distances were measured. Amongst others, 'nearest individual' and 'nearest neighbour' are illustrative. Many criticisms have been levelled at these methods and Cottam & Curtis (1956) as a result of reviewing them and considering the method used by the US Land Survey Service more than a century previously, introduced the Point-centred-quarter method (PCQ). In this method each sampling point is the centre of four imaginary quarters in each of which where the nearest tree is recorded. Variations, including the nearest neighbour and/or classes of size in each quarter have also been used (e.g. Milliken & Ratter 1989).

Cottam & Curtis (1956) recommended use of the PCQ method basing their advice on Morisita's mathematical development proving its scientific validity (Morisita 1954). They compared four plotless sampling methods and a multiple plot method to study three forest stands and one artificial population of known floristic composition and random spatial distribution. They found that plot sampling showed the least deviation from the known composition and PCQ represented the second best match. Deviations of both methods were below theoretical limits and supported their recommendation. Gibbs et al. (1980) carried out a similar exercise on an area of 1.5 ha of gallery forest in Mogi-Guaçu, São Paulo state, Brazil, where a complete floristic and phytosociological mapping of the vegetation had been made. They compared a survey of this known area using both plots and PCQ and discovered that the latter provided a more accurate estimate than the former.

Both plot and plotless methods are limited by requiring the uncommon random spatial distribution of individuals in natural populations, on which the mathematical treatment is totally dependent (Blackman 1935 quoted in Martins 1979). Consequently they assume forests with the presence of infinite populations of random spatial distribution from which samples are taken. Statistical treatment of plot sampling assumes a continuous distribution of probability obeying Gauss' law (normal distribution) with a small number of plots and a large number of individuals sampled in each one. PCQ assumes a discrete distribution of probability following Poisson's law, with a large number of sampling units and few individuals sampled in each (Martins 1979). Mueller-Dombois & Ellenberg (1974) also recommended this method for studies of tree populations in forests which tend to show a random spatial distribution.

Silva Júnior et al. (1986) compared plots and PCQ on the measurement of the floristic composition and phytosociological parameters in the tree cerrado vegetation in the Federal District. The 2,014 trees measured in 2.1 ha sampled by 21 plots (20 x 50 m), gave the same number of species and statistically similar density and basal area estimations when compared with the estimations given by 210 sampling points (840 trees) applied within the plots.

Based on an extensive literature review and field experience, Martins (1979) produced a list of advantages for using the PCQ method to study forest phytosociology, some of which were decisive for its choice in the present study: 1) easy allocation and localisation of sampling points which can follow sampling lines; 2) possibility of extending the sample over a much larger area than plots would allow; 3) much faster execution than plot sampling. Additionally it has the advantage of considerable economy of field-work effort.

Chapter 3 - Description of the area of study.

3.1 - Location

The Ecological Reserve of the Brazilian Institute of Geography and Statistics (RECOR-IBGE) covers an area of 1300 ha with the headquarters buildings located at 15° 56' 41" S and 47° 56' 07" W in Federal District, Brazil. The area was donated to IBGE in 1960 and transformed in 1975 into a conservation unit designated for preservation and study of the local environment. It has been protected against fire for almost 20 years and other disturbances have been kept at very low levels.

RECOR has its northern boundary with the Brasília Botanic Garden and its southern with Fazenda Água Limpa (the University of Brasília experimental station). Together these three areas total more than 9000 ha and constitute a green arc that skirts the southeastern portion of the city of Brasília forming part of the Environmental Protective Area (APA) Gama-Cabeça do Veado (Figure 4).

3.2 - Geology and Geomorphology

RECOR (at 1048 to 1160m altitude) lies on the Chapada Brasília where a flat to slightly rolling plateau shows differences in level only where cut by the drainage system (Pinto 1986). The Chapada is of Tertiary origin with a surface formed of plinthitic residues. There are also small-scale outcrops of Pre-Cambrian terrain with the occurrence of quartzite and shists. Strips of Quaternary alluvial sediments are also present over the gallery floors (CODEPLAN 1984, Pereira et al 1989, 1993).

Figure 4 - A section of the Federal District environmental map indicating the location of RECOR-IBGE, Brasília Botanic Garden, Fazenda Água Limpa and the National Park, which are conservation units around Brasília. (source: CODEPLAN 1992)

- Roncador Ecological Reserve (RECOR-IBGE)
- Brasília Botanic Garden (JBB)
- Água Limpa Farm (FAL)
- Brasília National Park (PNB)

3.3 - Soils

RECOR lies on Dark-red Latosols and Red-Yellow Latosols that cover almost 70% of the plateau surface. Cambisols and Hydromorphic soils are also identified by EMBRAPA (1978, 1980) and are associated with dissected areas. These soils are, in general, dystrophic and very acid with high levels of exchangeable Al (EMBRAPA 1980).

3.4 -Climate

The climatic data were collected at the RECOR meteorological station and presented by Pereira et al. (1989, 1993) who summarised them in the climatograph presented in Figure 5.

The rainfall over the period 1980 to 1992 was 1436 mm. The dry season comprises the months of June to September. Temperatures are high in the wet season and mild in the dry season, showing averages of maximum and minimum temperatures of 26.3° C and 15.8° C respectively. Absolute maximum and minimum values can be higher than 30° C in September which is generally the warmest month, and lower than 10° C in July which is the coldest month. The average annual temperature is 20.8° C.

The atmospheric humidity is higher during the wet season (summer) and parts of spring and autumn. In these periods values vary from 72 to 83%. Between June and September (dry season, winter) values drop to 58 to 67%, with some days with values below 20%. The average annual value is 73%.

The annual insolation is 2352 hours, and the monthly figure always exceeds 120 hours. Within the period April-September the sun shines for more than 200 hours per month.

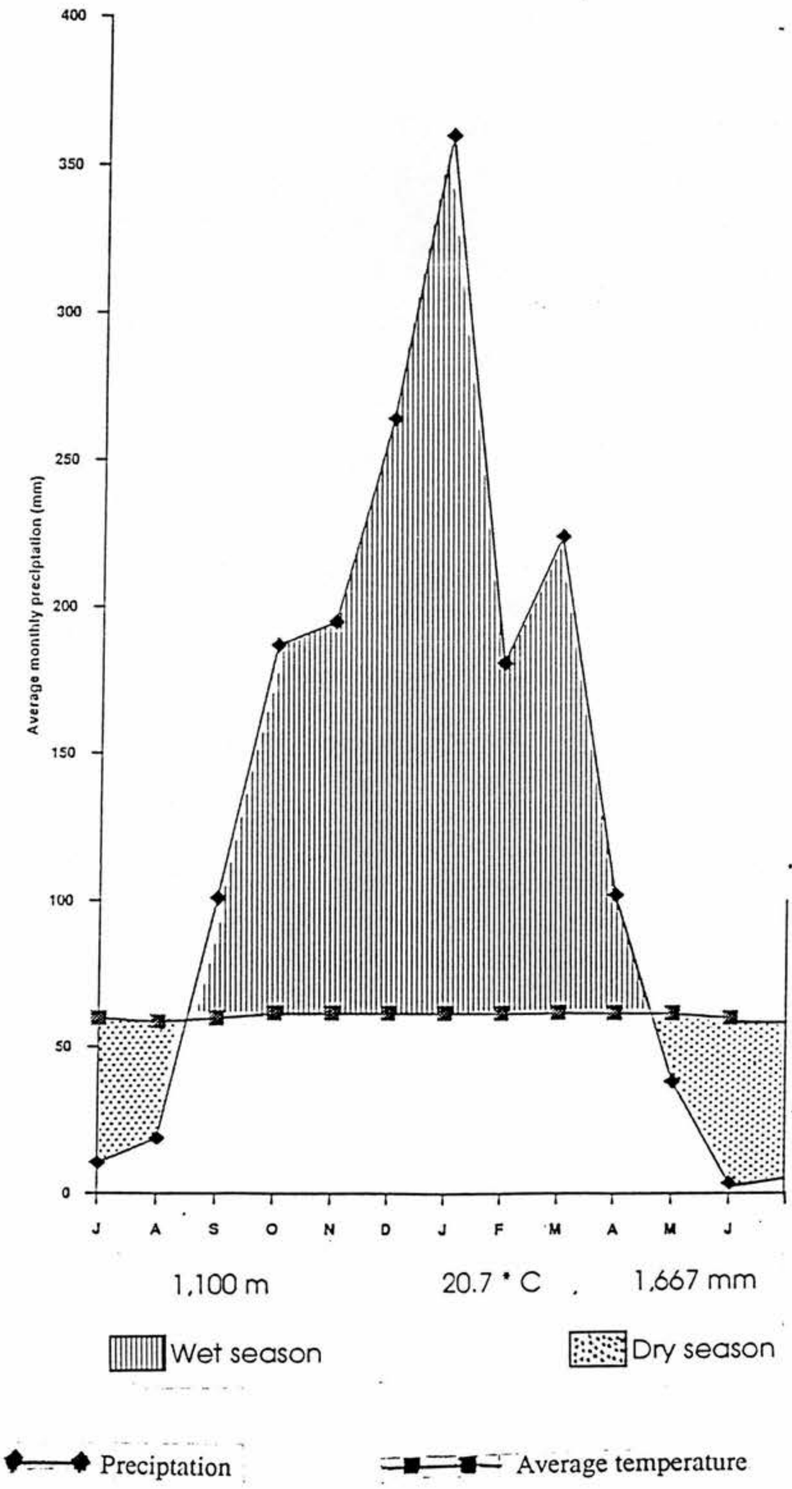


Figure 5 - Diagram showing the climate of the IBGE Ecological Reserve. (Source: Pereira et al. 1989).

The average annual evaporation is 1771 mm with values never lower than 100 mm per month. Highest values are recorded for the period between June and October and the lowest in December to March.

The wind regime is characterised as weak to moderate with an average speed of 2.1 m/sec. Months of weaker winds show speeds of 1.6 m/sec and May shows the strongest with 2.9 m/sec. East winds are predominant but during the rainy season northeast and northwest winds are important too.

3.5 - Vegetation

The RECOR-IBGE area shows several physiognomies typical of the Cerrado domain. Grasslands (campo limpo and campo sujo) total 467 ha and 34.3% of the area. Cerrado (sensu stricto) (savanna woodland) with 657 ha (48.3%) and cerradão (dense savanna woodland) with 15 ha (1.1%) are associated with the interfluvial plateau terrain. Wet grasslands, occupying 85 ha (6.25%), are found downslope, surrounding the gallery forests (Pereira et al. 1989, 1993).

There are five streams sustaining 104 ha (8%) of gallery forests within the RECOR area, viz.: Taquara, Roncador, Escondido, Pitoco and Monjolo. Pitoco, Monjolo and Escondido are tributaries of the Roncador which in turn runs into the Taquara. This in turn, after leaving the reserve, flows into the Gama stream, one of the most important affluents of Lake Paranoá which skirts the city of Brasília (CODEPLAN 1992) (Figure 4). The gallery forests of these streams present a very diverse flora related principally to variations in soil moisture associated with topographic features. None of the areas studied is prone to flooding.

Although most of the gallery forests are shown simply as lying on hydromorphic soils according to EMBRAPA (1980), recent detailed studies have shown that in fact they occur over a variety of soil types (Cavedon & Soomer 1991, Silva 1991, Felfili 1993, Ramos 1994). Eiten (pers. comm.) suggested that 90% of the gallery forests are not on hydromorphic soils.

The Pitoco, Monjolo and Taquara gallery forests (Figure 6) are selected as the subjects for the present research because of their state of preservation, their distinct physical character and the fact that their flora requires study.

3.5.1 - Pitoco gallery forest (P).

The Pitoco gallery forest lies in the northeast portion of RECOR-IBGE, and most of its area occurs over well-drained Cambisols. It is wider at the stream head (160m), and narrows downstream (120m and less) where the forest is concentrated in a short toposequence. The slope of the valley sides of Pitoco is the steepest of the three galleries.

3.5.2 - Monjolo gallery forest (M).

The Monjolo stream has a gallery forest almost 160 m broad along most of its course. The stream bed is well defined with no boggy areas. Topography is flatter along most of the area studied and becomes steeper further downstream. The soils are predominantly Cambisols with some patches of plinthitic gravel. The Monjolo and Pitoco streams unite before flowing into the Roncador stream (Figure 6).

3.5.3 - Taquara gallery forest (T).

The Taquara stream is located at the southeastern limit of RECOR. Its headwater area is characterised by the presence of small cliff-like banks descending into a deep riverbed (3 m). Downstream the area flattens and the riverbed becomes broad and shallow. This area is prone to seasonal flooding and is colonised mainly by

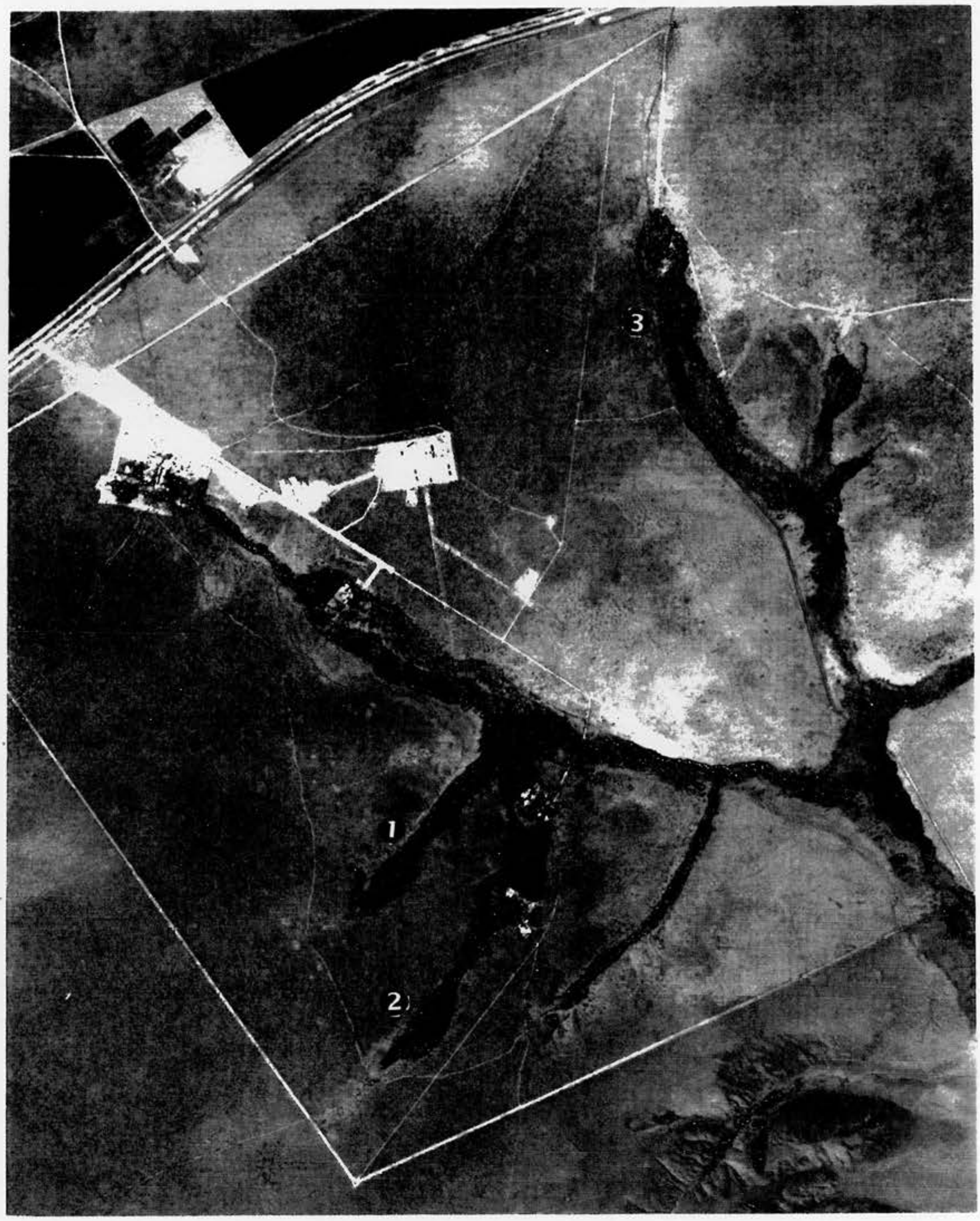


Figure 6 - RECOR-IBGE aerial photograph showing the Pitoco (1), Monjolo (2) and Taquara (3) gallery forests.

Olyra taquara and tree ferns of *Cyathea* sp. It was not sampled since it contains few trees. The sampled area lies on Cambisols where patches of calcium-rich and plintithic gravel soils are also found. The Taquara site has the flattest relief of all the three studied.

Chapter 4 - Floristic composition, phytosociology and diameter structure of the Pitoco (P), Monjolo (M) and Taquara (T) gallery forests.

4.1.- Introduction.

Studies on vegetation ecology have focused attention on how to describe, measure and interpret data on plant communities. In Brazil basic studies on floristic composition are yet to be carried out over vast extensions of the country's forested territory. However, present rates of devastation urgently require intensification of studies to generate basic information to support projects on vegetation recuperation.

Comparatively few studies have been carried out in protected conservation units. The IBGE Ecological Reserve (RECOR) is currently been inventoried to provide data on which to base the implementation of its first plan of management. The area is regarded as an extremely important and rich centre of biodiversity (Dias 1990) where flora and fauna have been recorded since the seventies. Its own herbarium (RECOR) already totals almost 10,000 specimens and recently (Pereira et al. 1993) published a list of its vascular plants which reached 1378 species.

The phytosociology of most of the savanna type formations of the reserve has already been studied to provide basic information for a project on effects of fire in the cerrado vegetation. However, the gallery forests have not been satisfactorily studied and are still the least known communities in Central Brazil. The present study aims to rectify this to some extent.

This chapter presents the results of the first attempt to study the floristic composition, phytosociology and diameter structure of areas of the Pitoco (P), Monjolo (M) and Taquara (T) gallery forests in RECOR, addressing **question 1.** (What is the floristic composition, phytosociology and diameter structure of each of the gallery forests?)

4.2. -Material and Methods.

4.2.1.- Species - number of sampling points curve.

Leps & Stursa (1989) pointed out that species richness during the successional process may increase and decrease simultaneously in different parts of an area. This may be further complicated by the presence of environmental gradients. They therefore suggested that the species richness of a plant community would be better described by the species/area relationship rather than by a total species number.

The curve for species versus number of sampling points is plotted for each area to discover whether the sample size is sufficient to evaluate the floristic composition (Mueller-Dombois & Ellenberg 1974). The minimum sample size has found to be related to the vegetation heterogeneity at each site, and in theory, a curve that represents an adequate sample flattens with the increasing number of sampling points (Kershaw 1975).

4.2.2.- Floristic composition and phytosociology.

The Point-Centred-Quarter (PCQ) method (Cottam & Curtis 1956) was used to survey trees with DBH $\geq$ 5 cm. Grids of 250 sampling points, spaced at 10 m intervals from the river bank to the forest edge along sampling lines 10 m apart were sited in each study area. Figure 7 shows the disposition of sampling points in each of the three streams.

Every sampling point and tree was marked with an aluminium label to facilitate permanent monitoring. Identifications were made using the herbaria of the University of Brasília (UB), the IBGE Ecological Reserve (RECOR) and the Royal Botanic Garden, Edinburgh (E), where collections are also deposited. In some cases reference to specialists was required.

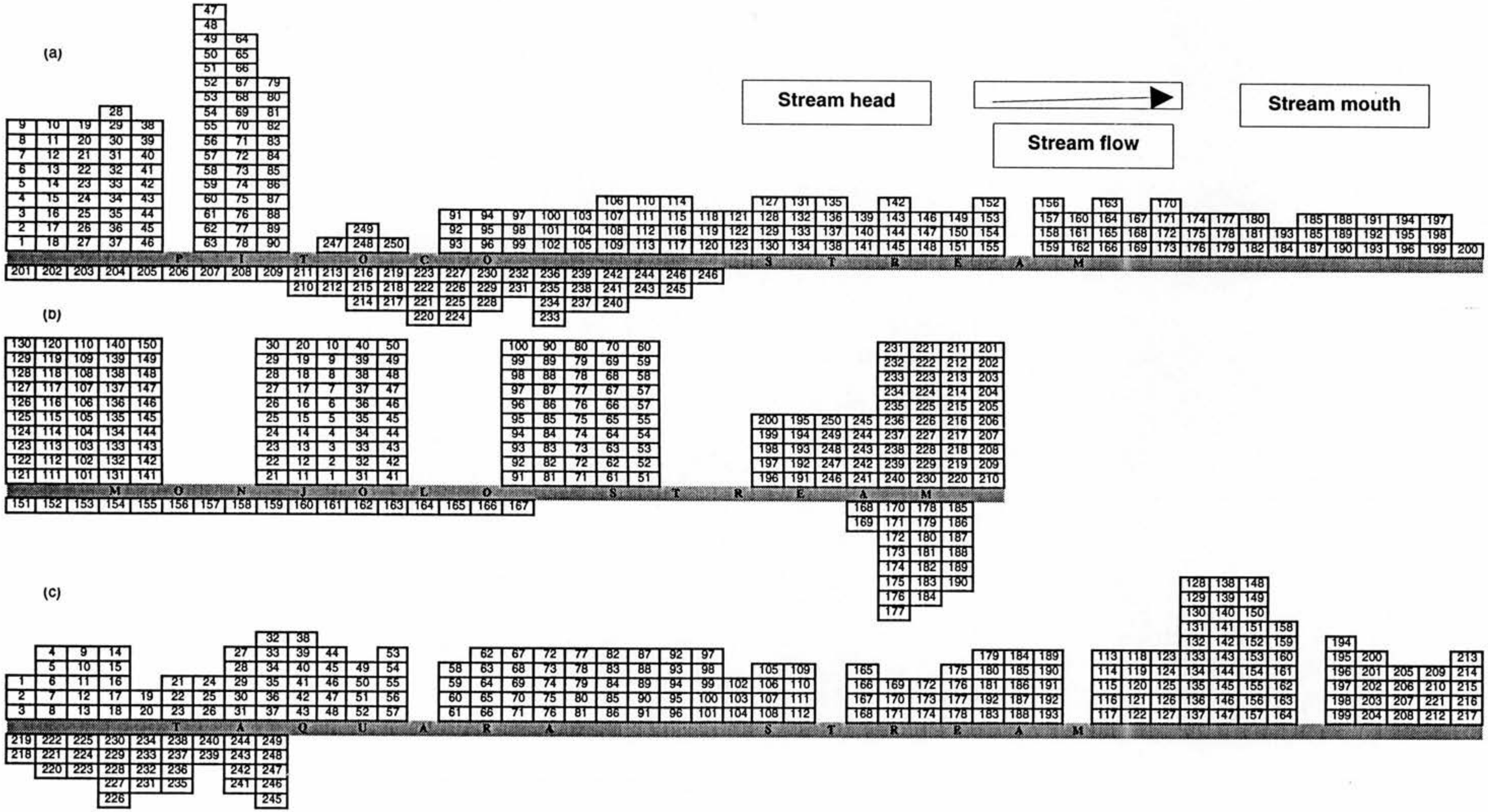


Figure 7 - Positions of sampling points in the Pitoco (a), Monjolo (b) and Taquara (c) gallery forests in RECOR -IBGE, Brasilia, Federal District.

Field data were loaded into the microcomputer package INFLO (microcomputer package for vegetation analysis, developed at the Forest Department of the University of Brasília) to process the phytosociological and diameter distribution analysis. The formulae used follow Mueller-Dombois & Ellenberg (1974):

- Absolute density **(n/ha)** = number of individuals of a species per hectare.
- Relative density **(%)**= (number of individuals of a species (ni) / total number of individuals of all species (N)) x 100.

  Total density per hectare **(DTA)** = squared average distance (m^2) / 10,000 m^2 (=1 ha).

  Density per hectare **(DA)** = relative density (n_i / N) x DTA.
- Absolute dominance (**basal area - cm^2/ha**) = total basal area of a species per hectare.
- Relative dominance **(%)**= (Total basal area of a species (ABi) / total basal area of all species (ABT)) x 100.

  Total basal area per hectare = relative dominance (ABi / ABT) x DA
- Absolute frequency **(FA)** = percentage of sampling points at which a species occurs.
- Relative frequency **(%)** = (Frequency of the species / sum frequency of all species) x 100.
- Importance value index of a species **(IVI)** = Relative density + Relative dominance + Relative frequency.

Despite the opinion that frequency should be deleted from the IVI because of over-representation of the number of individuals when added to density (Förster 1973), I agree with Silberbauer-Gottsberger & Eiten's (1983) opinion that frequency is important in that it indicates how a species is dispersed through an area, and therefore should be included. For this reason it is used in this study rather than Cover Value Index (CVI) (= relative dominance + relative density).

4.2.3.- Floristic diversity.

As pointed out by Marguran (1988) it is often useful and informative to measure diversity, which is frequently seen as an indicator of the well-being of ecological systems. However, the huge range of indices and models available for the evaluation leads to different perceptions of what is involved.

Diversity involves two basic concepts: species richness (number of species) and evenness or equitability (species density). Its measurement can be based either on richness alone or on indices which seek to unite the two concepts into a single figure (Marguran 1988).

Diversity is assessed using the Shannon & Wiener Index (H') taking into account species richness and species abundance distribution, and Pielou's evenness Index (J'), which is a ratio between H' and H' maximum (when all the species are perfectly even) indicating the percentage of maximum diversity that the samples achieved. The Shannon & Wiener Index is calculated as follows, Pielou (1975):

$$H' = - \sum_{i=1}^{s} = [(n_i / n) \ln (n_i / n)]$$

$$J' = H' / \ln (s)$$

Where n_i is the number of individuals belonging to the i $_{th}$ of s species and n is the total number of species in the sample. The maximum value of evenness is 1.0.

4.2.4.- Classes of diameter.

When plotting tree frequency in classes of size for a stand made up of trees of all ages, an inverted 'J' shaped curve is indicative of a balanced diameter distribution (Meyer 1952). A complete sequence of classes, where mortality proportionally decreases with increasing tree size was theorised for climax communities (Daubenmire 1968). Meyer (1952) suggested this balanced distribution could be found when studying a forest over an extensive area but, as commented by Harper (1977), most natural forests do not show this distribution exactly but only approximate to it.

This structure is in fact a picture of past events within the forest as recognised by Liocourt (1898), who proposed his 'q' quotient calculated by dividing the number of individuals in a class by the number in the previous class to assess recruitment ('q') and mortality (1-'q') through successive classes of diameter (Meyer 1952). Quotient 'q' for classes of smaller diameter is expected to be closer to an average value due to the larger number of trees there represented and more variable in the larger classes because of their lower numbers (Leak 1964).

Monitoring the radial growth of trees may predict whether or not environmental conditions are favourable to the establishment of a population and its further success as a community (Johnson & Bell 1975).

Trees per hectare are analysed by INFLO using the formulae suggested by Spiegel (1976) which minimise the number of classes that would have no members as follows:

$$\mathbf{IC = A / NC}$$

$$\mathbf{NC = 1 + 3.3 \log (n)}$$

where: **IC** - is the classes interval;

A - is the amplitude (maximum - minimum diameter recorded);

NC - number of classes;

n = number of individuals.

The lowest limit of the classes distribution, (I) is given by:

$$I = IC / 2$$

To allow comparisons with other studies the class interval is approximated to the nearest entire value, here every 5 cm of diameter.

4.2.5 - Structural classification.

The layer position of each tree was observed and classified using the CENARGEN-EMBRAPA guidelines for the implementation of *in situ* genetic reserves (Silva et al. 1987) into the following groups:

- - **Emergent:** large trees emerging from the upper canopy.
- - **Canopy:** large and medium size trees forming the canopy immediately below the emergent.
- - **Lower storey trees:** small trees adapted to lower light conditions.

Information is given regarding the class in which individuals of each species were observed in the field work and also according to the records of other workers.

4.3.- Results.

4.3.1.- Sampling.

The curves for species versus number of sampling points for all the three galleries (Figure 8) tend to flatten, indicating that the number of points is enough to record their floristic composition (Mueller-Dumbois & Ellenberg 1974). Observation of the curves indicates that half the number of points (125) would be sufficient to cover respectively 84, 74 and 83% of the species recorded at Pitoco, Monjolo and

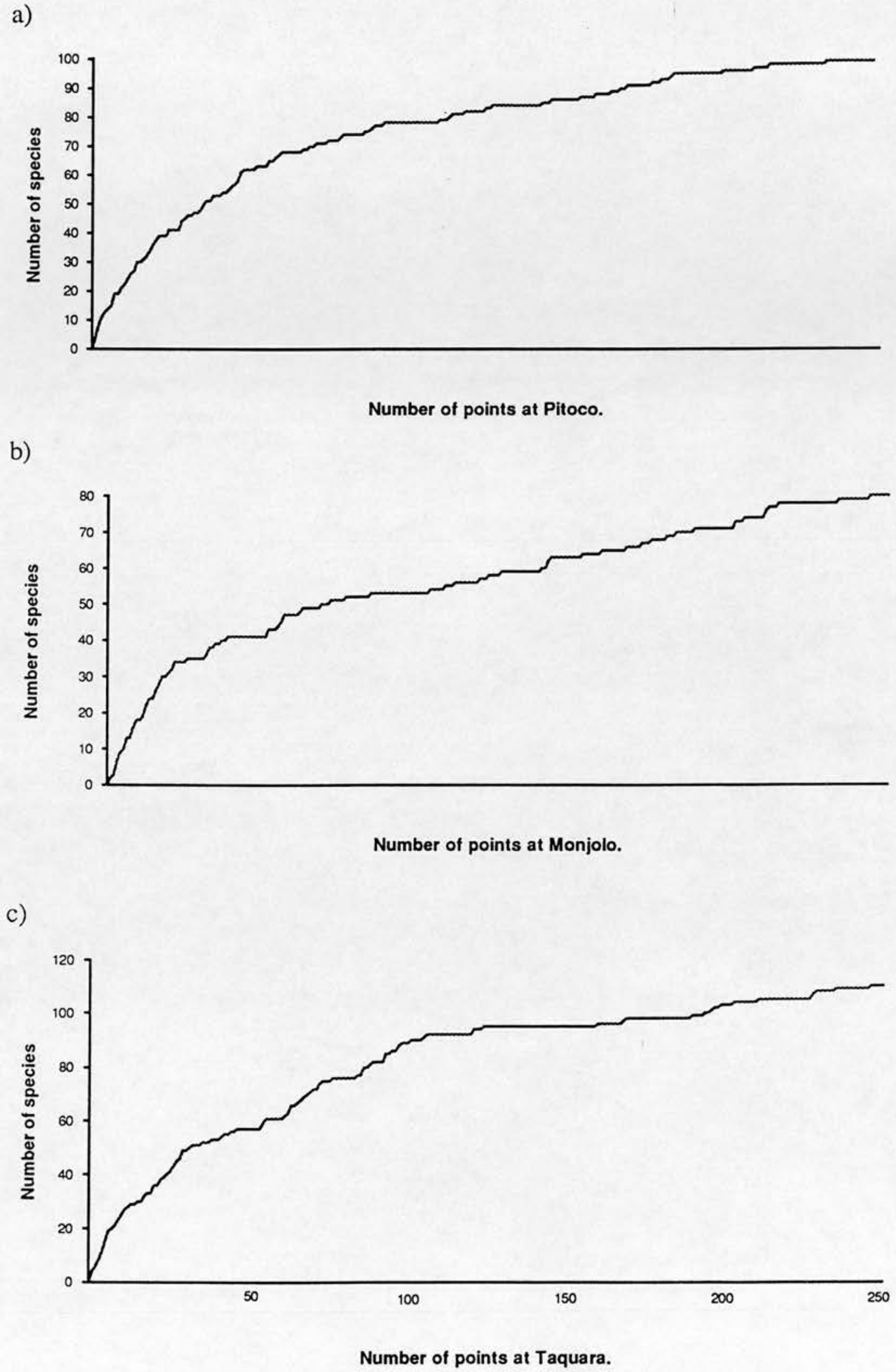


Figure 8 - Species versus number of points curve for Pitoco (a), Monjolo (b) and Taquara (c) Gallery forests.

Taquara. The inclusion of a further 125 sampling points, representing a further 500 individuals, added 16 (16%), 21 (26%) and 19 (17%) new species respectively to these sites. Only at Monjolo did the 21 species added indicate a continuously increasing number of species and this is related to the presence of a steep slope in the final portion of the sampled area, as opposed to the predominant flatter terrain elsewhere.

According to Yodzis (1978) in Leps & Stursa (1989), communities at the earlier successional stages showing low niche differentiation would present a curve increasing steadily, while late successional communities, showing high niche differentiation, would present a curve levelling off earlier. The curves of the three communities studied flatten early in agreement with their suggested maturity related to their low disturbance levels.

In the present study, it is concluded that 250 sampling points in each gallery forest are sufficient to provide a representative floristic survey and also give adequate data for estimating density and basal area of the more important species.

4.3.2.- Floristic composition and phytosociology.

A total of 52 families, 108 genera, and 137 species are recorded at Pitoco (P), Monjolo (M) and Taquara (T). They are listed in Table 1. Two species of Myrtaceae, *Eugenia uruguaiensis* at Pitoco and *Myrciaria glanduliflora* at Taquara, are new additions to the flora of the Federal District.

4.3.2.1.- Families.

The Annonaceae, Euphorbiaceae, Lauraceae, Leguminosae, Melastomataceae, Moraceae, Myrtaceae, Rubiaceae and Vochysiaceae are the predominant families in

Table 1- List of species in alphabetical order of families recorded at Pitoco (P), Monjolo (M)and Taquara (T) gallery forests at RECOR-IBGE, Brasília, Federal District.

1- Anacardiaceae (P,M,T)

Astronium gracile Engl. (M)
Tapirira guianensis Aublet (P,M,T)

2- Annonaceae (P,M,T)

Cardiopetalum calophyllum Schlecht.(P,T)
Guatteria sellowiana Schlecht. (P,M,T)
Xylopia emarginata Mart. (P,T)
Xylopia sericea A. St. Hil. (P,M,T)

3- Apocynaceae (P,M,T)

Aspidosperma cylindrocarpon Muell. Arg. (M)
A. discolor A. DC.(T)
A. spruceanum Benth. ex Muell. Arg. (P,T)
A. subincanum Mart. (M,T)

4- Aquifoliaceae (P)

Ilex integrifolia Mart. (P)

5- Araliaceae (P,M,T)

Schefflera morototoni (Aublet) D. Frodin (P,M,T)

6- Bignoniaceae (P,M,T)

Jacaranda puberula Cham.(P,M,T)
Tabebuia impetiginosa (Mart.) Standley (T)
T. serratifolia Rolfe (M, T)
T. umbellata (Sond.) Sandw. (T)

7-Bombacaceae (P,M,T)

Eriotheca gracilipes (K. Schum.) A. Robyns (T)
E. pubescens Schott. & Endl. (P,T)
Pseudobombax longiflorum (A. Robyns) A. Robyns (T)
P. tomentosum (Mart. & Zucc.) A.Robyns (T)

8- Boraginaceae (P,M,T)

Cordia sellowiana Cham. (P,M,T)
Cordia trichotoma Vell. ex Steud. (T)

9- Burseraceae (P,M,T)

Protium almecega Marchand (P,M,T)
Tetragastris balsamifera Kuntze (T)

10- Celastraceae (T)

Maytenus salicifolia Reiss. (T)

11- Chloranthaceae (T)

Hedyosmum brasiliense Mart.(T)

12- Chrysobalanaceae (P,M,T)

Hirtella glandulosa Spreng. (P,M,T)
H. gracilipes (Hook. f.) Prance (T)
Licania apetala (E.Mey.)Fritsch (P,M,T)

13- Combretaceae (P,M,T)

Terminalia argentea Mart. & Zucc. (M)
T. glabrescens Mart.(P,M,T)

14- Compositae (P,M,T)

Piptocarpha macropoda Baker. (P,M,T)

15- Cunoniaceae (P,M,T)
Lamanonia ternata Vell. (P,M,T)

16- Dichapetalaceae (P,M,T)

Tapura amazonica Poepp. & Endl.

17- Ebenaceae (P,M,T)

Diospyros hispida A. DC. (P,M,T)

18- Elaeocarpaceae (T)

Sloanea guianensis Benth. (T)

19- Erythroxylaceae (P,T)

Erythroxylum sp. (P,T)

20- Euphorbiaceae (P,M,T)

Alchornea iricurana Casar. (M)
Hieronyma ferruginea Tul. (P,T)

Table - 1 cont...

Euphorbiaceae cont...

Maprounea guianensis Aublet (P,M,T)
Margaritaria nobilis Linn. f. (T)
Pera glabrata Poepp. ex Baill. (P,T)
Richeria obovata Pax & K. Hoffm. (P,T)

21- Flacourtiaceae (P,M,T)

Casearia gossypiosperma Briq. (T)
C. sylvestris Sw. (P,M)

22- Guttiferae (P,M,T)

Calophyllum brasiliense Cambess. (P,T)
Kielmeyera coriacea Mart. (P,T)
Vismia guianensis (Aubl.) Choisy(M)

23- Hippocrateaceae (P,M,T)

Cheiloclinium cognatum (Miers) A. C. Smith (P,M,T)
Salacia elliptica G. Don.(P,M,)

24- Humiriaceae (P,M,T)

Sacoglottis guianensis Benth. (P,M,T)

25- Icacinaceae (P,M,T)

Emmotum nitens Miers (P,M,T)

26- Lacistemataceae (P)
Lacistema hasslerianum Chod.(P)

27- Lauraceae(P,M,T)

Aniba heringerii Vattimo(P)
Cryptocarya aschersoniana Mez (P,M,T)
Nectandra cissiflora Nees(M,T)
Nectandra mollis Nees (M)
Ocotea aciphylla Mez (P,M,T)
O. corymbosa Mez(P,M,T)
O. pomaderroides (Meissner) Mez(P)
O. spixiana Mez (P,T)

28- Leguminosae (P,M,T)

Caesalpinioideae (P,M,T)
Apuleia leiocarpa Macbr. (M)
Bauhinia rufa Steud.(P,T)
Copaifera langsdorffii Desf. (P,M,T)
Hymenaea coubaril L. (P,M,T)
Sclerolobium aureum Baill. (M)
S. paniculatum Benth. var *rubiginosum* (P,M,T)

Faboideae
Andira vermifuga Mart. ex Benth. (P,M)
Dalbergia foliolosa Benth.(P,T)
Machaerium aculeatum Raddi (P,M)
M. acutifolium Vog.(M,T)
Ormosia stipularis Ducke (P,M)
Platypodium elegans Vog.(P,M,T)

Mimosoideae
Anadenanthera colubrina (Vell.) Brenan var. *cebil* (T)
Dimorphandra mollis Benth. (P)
Inga alba Willd. (P,M,T)
Inga alba Willd. (P,M,T)
Piptadenia gonoacantha Macbr.(T)

29- Lythraceae

Lafoensia pacari St. Hil. (P,T)

30- Malpighiaceae

Byrsonima laxiflora Griseb. (P,M,T)

31- Melastomataceae

Miconia chartacea Triana (P,M,T)
M. cuspidata Naudin (P,M,T)
M. pepericarpa DC.(P)
M. sellowiana Naud (P,M)
Mouriri glazioviana Cogn. (P,M)
Tibouchina candolleana (DC.) Cogn. (P)

32- Meliaceae

Guarea guidonia (L.) Sleumer(P,T)

33- Monimiaceae

Mollinedia oligantha Perkins. (P,T)
Siparuna guianensis Aublet (P,M,T)

34- Moraceae

Cecropia lyratiloba Miq.(P,M,T)
C. pachystachya Tréc.(P,T)
Ficus citrifolia P. Miller (P,T)
Pseudolmedia guaranitica Hassl. (P,M,T)

Table 1 - cont...

Moraceae cont...

Sorocea guilleminiana Gaud. (P,M,T)

35- Myristicaceae

Virola sebifera Aublet (P,M,T)
V. urbaniana Warb. (P,T)

36- Myrsinaceae (P,M,T)

Cybianthus gardnerii (A. DC.) Agostini (P,M,T)
Myrsine coriacea R.Br.(P,M,T)
M. umbellata Mart.(P,T)

37- Myrtaceae (P,M,T)

Blepharocalyx salicifolius (Kunth) Berg (M,T)
Eugenia uruguaiensis Camb.(P)
Gomidesia bruneia (Camb.) Legrand (P,M,T)
Myrcia rostrata DC. (P,M,T)
M. tomentosa (Aublet) DC. (P,M,T)
Myrciaria glanduliflora (Kiaresk.) Mattos & Legrand (T)
Psidium longipetiolatum Legrand (P)
Siphoneugena densiflora Berg (P,M,T)

38- Nyctaginaceae (P,M,T)

Guapira graciliflora (Mart. ex Schmidt) Lundell (P,M,T)

39- Ochnaceae (P,M,T)

Ouratea castaneaefolia Engler (P,M,T)

40- Proteaceae (P,M,T)

Euplassa inaequalis (Pohl) Engler (P,T)
Roupala brasiliensis Klotzch (M,T)

41- Rosaceae (M,T)

Prunus brasiliensis (Spreng.) Schott. (M,T)

42- Rubiaceae (P,M,T)

Alibertia edulis (L.C. Rich) A. Rich.. (T)
A.macrophylla Schum. (P,M,T)
Amaioua guianensis Aublet (P,M,T)
Chomelia pohliana Muell. Arg.(T)
Coussarea hydrangeifolia Benth. & Hook. (P,T)
Faramea cyanea Muell. Arg. (P,M,T)
Ferdinandusa speciosa Pohl (P)
Guettarda viburnioides Cham. & Schlecht. (P,T)
Ixora warmingii Muell. Arg. (T)

43- Rutaceae (T)

Zanthoxylum rhoifolium Lam. (T)

44- Sapindaceae (P,M,T)

Cupania vernalis Camb.(P,M,T)
Matayba guianensis Aublet (P,M,T)

45- Sapotaceae (P,M,T)

Micropholis rigida Pierre (P,M,T)
Pouteria ramiflora Radlk. (P,M,T)

46- Simaroubaceae (P,M)

Simarouba amara Aubl. (P,M)

47- Styracaceae (P,M,T)

Styrax guianensis A.DC. (P,M,T)

48- Symplocaceae (P,M,T)

Symplocos mosenii Brand.(P,M,T)
S. nitens (Pohl) Benth. (P,T)

49- Theaceae (P,M,T)

Laplacea fruticosa (Schrad.) Kobuski (P,M,T)

50 - **Tiliaceae** (T)

Luehea grandiflora Mart. & Zucc. (T)

51- Verbenaceae (P,M,T)

Aegiphila sellowiana Cham. (M)
Vitex polygama Cham. (P,M,T)

52- Vochysiaceae (P,M,T)

Callisthene major Mart. (P,M,T)
Qualea dichotoma (Mart.) Warm. (P,M,T))
Q.multiflora Mart. (P,M,T)
Vochysia tucanorum Mart.(P,T)

terms of number of species. These nine families accounted for 52.5, 42.5 and 42.3% respectively of the total number of species in Pitoco, Monjolo and Taquara.

Regarding the number of individuals, Anacardiaceae, Euphorbiaceae, Lauraceae, Leguminosae, Moraceae and Rubiaceae are well represented in all three sites, while other families are important in this respect at only one site; examples of the latter are Annonaceae, Burseraceae and Vochysiaceae in Pitoco, Chrysobalanaceae, Hippocrateaceae and Melastomataceae in Monjolo, and Myrtaceae and Sapindaceae in Taquara. These families together accounted for 50, 52 and 50% of the total number of individuals recorded respectively in each site.

The families Anacardiaceae, Cunoniaceae, Euphorbiaceae, Lauraceae, Leguminosae and Vochysiaceae showed high basal area scores in all three sites. Additionally, Burseraceae, Icacinaceae and Symplocaceae are important at Pitoco, Apocynaceae and Chrysobalanaceae at Monjolo, and Rubiaceae and Sapindaceae at Taquara. These families represented respectively 60, 61 and 54% of the total basal area in each site.

Anacardiaceae, Burseraceae, Euphorbiaceae, Lauraceae, Leguminosae, Rubiaceae and Vochysiaceae are ranked amongst the important families in terms of IVI at Pitoco, Monjolo and Taquara. Of these Anacardiaceae, Annonaceae, Leguminosae, Myrtaceae and Rubiaceae are very important families throughout the Federal District, being recorded in 12 out of 15 gallery forest sites so far surveyed (Silva Júnior et al. in prep.)

Families recorded with only one individual in each area are considered rare and are: Erythroxylaceae, Lythraceae, Meliaceae, Simaroubaceae and Verbenaceae in Pitoco; Monimiaceae, Nyctaginaceae, Rosaceae, Styracaceae, Theaceae and Verbenaceae in Monjolo; and Chloranthaceae, Flacourtiaceae, Humiriaceae, Rutaceae, Theaceae and Tiliaceae in Taquara. Table 2 indicates the families and their phytosociological parameters in each site.

Table 2 - Families recorded at Pitoco (P), Monjolo (M) and Taquara (T) Gallery Forests with number of genera, number of species, number of individuals (N), density (n/ha), dominance (cm /ha), IVI and IVI rank at each site.

	Families	Genera				Species				N				Density n/ha			Dominance cm /ha			IVI			IVI rank		
		P	M	T	Tot.	P	M	T	Tot.	P	M	T	Tot.	P	M	T	P	M	T	P	M	T	P	M	T
1	Anacardiaceae	1	2	1	2	1	2	1	2	64	68	70	202	122.5	117	110.1	20798	27196	16748	17.5	19.4	17.1	4	3	3
2	Annonaceae	3	2	3	3	4	2	4	4	40	19	21	80	76.6	32.7	33	8758	7739	8087	10.5	5.55	6.46	9	17	14
3	Apocynaceae	1	1	1	1	1	2	3	4	2	24	23	49	3.8	41.3	36.2	77	29112	14750	0.44	11.4	8.61	38	8	9
4	Aquifoliaceae	1	*	*	1	1	*	*	1	1	*	*	1	1.9	*	8	54	*	*	0.23	*	*	41	*	*
5	Araliaceae	1	1	1	1	1	1	1	1	16	7	14	37	30.6	12	22	4020	1917	3323	4.34	1.92	3.66	23	29	26
6	Bignoniaceae	1	2	2	2	1	2	4	4	24	28	23	75	45.9	48.2	36.2	7536	6188	5820	6.63	6.33	5.97	16	15	16
7	Bombacaceae	1	*	2	2	1	*	4	4	11	*	17	28	21	*	26.7	3006	*	13964	3.01	*	7.16	24	*	12
8	Boraginaceae	1	1	1	1	1	1	2	2	4	5	7	16	7.7	8.6	11	682	833	577	1.03	1.25	1.6	32	30	34
9	Burseraceae	1	1	2	2	1	1	2	2	54	33	23	109	103.3	56.8	36.2	18690	4640	10807	15.5	7.83	0.88	7	13	13
10	Celastraceae	*	*	1	1	*	*	1	1	*	*	3	3	*	*	4.8	*	*	287	*	*	0.7	*	*	38
11	Chloranthaceae	*	*	1	1	*	*	1	1	*	*	1	1	*	*	1.6	*	*	40	*	*	0.22	*	*	43
12	Chrysobalanaceae	2	2	2	2	2	2	3	3	19	47	17	82	36.4	80.8	25.2	10864	33648	4646	6.69	16.8	4.53	15	4	21
13	Combretaceae	1	1	1	1	1	2	1	2	7	8	8	23	13.4	13.8	12.6	2450	2150	3591	2.02	2.19	2.6	26	28	30
14	Compositae	1	1	1	1	1	1	1	1	5	15	36	56	9.6	25.8	56.6	797	4294	12038	1.27	4.15	9.85	30	22	7
15	Cunoniaceae	1	1	1	1	1	1	1	1	16	6	16	38	30.6	10.3	25.2	20845	14419	17435	8.81	4.38	7.64	13	21	10
16	Dichapetalaceae	1	1	1	1	1	1	1	1	25	18	18	61	47.8	31	28.3	4152	4627	6025	6.17	4.86	5.2	14	18	18
17	Ebenaceae	1	1	1	1	1	1	1	1	9	4	17	30	17.2	6.9	26.7	1336	362	4854	2.04	0.93	4.69	28	31	20
18	Elaeocarpaceae	*	*	1	1	*	*	1	1	*	*	1	2	*	*	1.6	*	*	112	*	*	0.51	*	*	40
19	Erythroxylaceae	1	*	1	1	1	*	1	1	1	*	3	4	1.9	*	4.7	339	*	793	0.3	*	0.83	40	*	37
20	Euphorbiaceae	4	2	5	6	4	2	5	6	50	35	47	132	95.7	60.2	73.9	25057	23973	20598	16.5	12.4	15	5	7	4
21	Flacourtiaceae	1	1	1	1	1	1	1	2	2	3	2	7	3.83	5.2	3.1	191	460	130	0.47	0.74	0.45	37	33	41
22	Guttiferae	2	1	3	3	2	1	3	3	4	4	5	13	7.66	6.9	7.9	397	423	695	0.84	0.95	1.22	34	31	35
24	Hippocrateaceae	2	2	1	2	2	2	1	2	14	52	16	82	26.79	89.4	25.2	2497	14340	2209	3.52	13.8	3.79	22	6	24
23	Humiriaceae	1	1	1	1	1	1	1	1	6	13	1	20	11.48	22.4	1.6	3007	8079	71	1.96	4.57	0.23	27	20	43
25	Icacinaceae	1	1	1	1	1	1	1	1	23	20	13	56	44.02	34.4	20.4	18166	16605	8612	9.47	7.96	4.83	11	12	19
26	Lacistemataceae	1	*	*	1	1	*	*	1	6	*	*	6	11.48	*	*	637	*	*	1.33	8	*	29	*	*

Table 2 - cont...

	Families	Genera				Species				N				Density n/ha			Dominance cm /ha			IVI			IVI rank		
	P	P	M	T	Tot.	P	M	T	Tot.	P	M	T	Tot.	P	M	T	P	M	T	P	M	T	P	M	T
27	Lauraceae	3	3	3	4	6	5	5	8	55	72	32	159	105.3	123.8	50.3	17176	38881	11158	16	23.1	9.55	6	2	8
28	Leguminosae	11	9	10	14	11	11	10	16	107	134	125	366	204.8	230.5	196.7	68668	85900	75288	40	45.2	44.9	1	1	1
29	Lythraceae	1	*	1	1	1	*	1	1	1	*	6	7	1.9	*	9.4	498	*	2696	0.34	*	1.95	39	*	33
30	Malpighiaceae	1	1	1	1	1	1	1	1	20	11	15	46	38.3	18.9	23.6	4449	1242	3576	5.08	2.39	3.99	19	27	23
31	Melastomataceae	3	2	1	3	6	4	2	6	9	70	8	89	17.2	120.4	12.6	830	11250	4709	2.12	16.2	2.78	25	5	29
32	Meliaceae	1	*	1	1	1	*	1	1	1	*	5	6	1.9	*	7.9	47	*	3875	0.22	*	2.05	41	*	32
33	Monimiaceae	2	1	2	2	2	1	2	2	14	15	3	32	26.8	25.8	4.7	3207	1529	180	3.71	3.42	0.67	21	35	39
34	Moraceae	4	3	4	4	5	3	5	5	59	41	21	121	107.2	70.5	33	10517	6264	3831	14.3	9.11	5.36	8	10	17
35	Myristicaceae	1	1	1	1	2	1	2	2	19	23	9	51	36.4	39.9	14.2	6273	7514	1853	5.47	6.35	2.35	18	15	31
36	Myrsinaceae	2	2	2	2	3	2	3	3	8	16	13	35	15.3	27.5	20.4	585	11241	2558	1.85	5.68	3.26	29	16	27
37	Myrtaceae	5	4	5	7	6	5	6	8	37	17	42	96	70.8	29.2	66.1	5703	4513	10088	9.13	4.62	11.1	12	19	6
38	Nyctaginaceae	1	1	1	1	1	1	1	1	5	1	15	21	9.6	1.7	23.6	488	42	2888	1.19	0.22	3.76	31	38	25
39	Ochnaceae	1	1	1	1	1	1	1	1	4	10	5	19	7.7	17.2	7.9	468	1544	400	0.97	2.47	1.14	33	25	36
40	Proteaceae	1	1	2	2	1	1	2	2	2	3	12	7	3.8	5.2	18.9	150	1261	6988	0.46	0.92	4.2	37	32	22
41	Rosaceae	*	1	1	1	*	1	1	1	*	1	3	4	*	1.7	4.7	*	55	154	*	0.23	0.66	*	38	39
42	Rubiaceae	6	3	8	8	6	3	8	9	73	42	115	230	139.7	72.4	180.9	10219	9686	32928	17.8	10.7	31.2	3	9	2
43	Rutaceae	*	*	1	1	*	*	1	1	*	*	1	1	*	*	1.6	*	*	107	*	*	0.24	*	*	42
44	Sapindaceae	2	2	2	2	2	2	2	2	24	17	48	89	45.9	29.2	75.5	3618	2410	19709	5.82	3.82	14.6	17	23	5
45	Sapotaceae	2	2	2	2	2	2	2	2	13	22	9	44	24.9	37.8	14.2	5747	11522	709	4.28	7.13	2.05	20	14	32
46	Simaroubaceae	1	1	*	1	1	1	*	1	1	10	*	11	1.9	17.2	*	460	3905	*	0.33	2.77	*	39	24	*
47	Styracaceae	1	1	1	1	1	1	1	1	3	3	12	18	5.7	5.2	18.9	320	271	1756	0.72	0.59	2.95	35	36	28
48	Symplocaceae	1	1	1	1	2	1	2	2	23	6	26	55	44	10.3	40.9	18838	5147	3275	9.53	2.43	6.15	10	26	15
49	Theaceae	1	1	1	1	1	1	1	1	2	1	1	4	3.8	1.7	1.6	233	181	51	0.49	0.25	0.22	36	37	43
50	Tiliaceae	*	*	1	1	*	*	1	1	*	*	2	2	*	*	3.1	*	*	152	*	*	0.46	*	*	41
51	Verbenaceae	1	2	1	2	1	2	1	2	1	3	3	8	1.9	5.2	4.7	520	307	330	0.35	0.71	0.71	39	34	38
52	Vochysiaceae	3	2	3	3	4	3	4	4	74	19	20	113	141.6	32.7	31.5	38826	19437	13055	24.3	8.27	7.54	2	11	11
	Dead trees									42	54	48	144	80.4	92.9	75.5	24783	22772	26382	15.1	16.1	16.6	5	2	2
	Totals	88	70	91	108	99	80	111	137	1000	1000	1000	3000	1914	1720	1573	376998	447879	384909	300	300	300			

Leguminosae is the family that reaches the highest value of importance by far in most areas. This is because of its great number of species, some of them showing high density and/or dominance figures. This result corroborates the observations of Heinsdijk (1965) and Richards (1976) who found Leguminosae to be the dominant family in many and different types of forests in South America. Goodland (1979) also indicated the Leguminosae as one of the most important families of the tree strata in the neighbouring cerrado vegetation. It has been suggested that the success of this family could be due to its nitrogen fixation capability which might be very important for the colonisation of the poor soils found in Central Brazil (Lopes 1980). These results agree with those of many authors worldwide which indicate that Leguminosae and other vascular plants capable of symbiotic nitrogen fixation reach the highest densities in habitats with nitrogen-poor soils, as an expression of high competitiveness (Tilman 1986).

The high importance figure of the Anacardiaceae is mainly due to the high density of *Tapirira guianensis*, always recorded in gallery forests in the Federal District (Ratter 1982, Brasil 1990, Felfili & Silva Júnior 1992, Felfili 1993, 1994, Ramos 1994). For instance Oliveira-Filho & Ratter (in press) indicate this species as one of the most widespread in the gallery forests in Central Brazil.

4.3.2.2.- Species.

The numbers of species recorded at Pitoco, Monjolo and Taquara are 99, 80 and 110 respectively. The average inter tree distances are 2.28, 2.41 and 2.51m , giving areas of survey estimated as 5.2, 5.8 and 6.3 ha respectively; while the estimated densities are 1914, 1720 and 1573 trees/ha and basal areas 37.7, 44.8 and 38.5 m^2/ha.

Tables 3, 4 and 5 present the phytosociological parameters for species plus the group of dead trees at each site. Species are ranked by IVI and generally the most

Table 3- Phytosociological parameters for trees recorded at Pitoco (P) Gallery Forest in RECOR-IBGE, Brasilia, Federal District.

	Species	Families	N	Density		Dominance		Frequency	IVI	Vertical
				n/ha	%	cm2/ha	%	%		Stratification
1	*Callisthene major*	Vochysiaceae	62	122.2	6.20	35458	9.13	5.25	20.58	emergent
2	*Tapirira guianensis*	Anacardiaceae	64	126.1	6.40	21417	5.52	5.59	17.50	emergent
3	*Protium almecega*	Burseraceae	54	106.4	5.40	19246	4.96	5.14	15.50	canopy
4	*Copaifera langsdorffii*	Leg.-Caesalpinioideae	28	55.2	2.80	37125	9.56	2.79	15.16	emergent
5	Dead Trees		42	82.8	4.20	25521	6.57	4.36	15.13	**********
6	*Sclerolobium paniculatum var. rubiginosum*	Leg.-Caesalpinioideae	36	71.0	3.60	25284	6.51	3.69	13.80	canopy
7	*Pseudolmedia guaranitica*	Moraceae	51	100.5	5.10	10058	2.59	4.69	12.38	canopy
8	*Faramea cyanea*	Rubiaceae	46	90.7	4.60	6501	1.67	4.92	11.19	lower storey
9	*Emmotum nitens*	Icacinaceae	23	45.3	2.30	18707	4.82	2.35	9.47	canopy
10	*Lamanonia ternata*	Cunoniaceae	16	31.5	1.60	21466	5.53	1.68	8.81	canopy
11	*Maprounea guianensis*	Euphorbiaceae	24	47.3	2.40	13156	3.39	2.46	8.25	canopy
12	*Symplocos mosenii*	Symplocaceae	20	39.4	2.00	15603	4.02	1.90	7.92	canopy
13	*Jacaranda puberula*	Bignoniaceae	24	47.3	2.40	7761	2.00	2.23	6.63	lower storey
14	*Tapura amazonica*	Dichapetalaceae	25	49.3	2.50	4276	1.10	2.57	6.17	canopy
15	*Byrsonima laxiflora*	Malpighiaceae	20	39.4	2.00	4581	1.18	1.90	5.08	lower storey
16	*Licania apetala*	Chrysobalanaceae	14	27.6	1.40	7976	2.05	1.34	4.80	canopy
17	*Ocotea aciphylla*	Lauraceae	16	31.5	1.60	4508	1.16	1.79	4.55	canopy
18	*Xylopia emarginata*	Annonaceae	17	33.5	1.70	4355	1.12	1.68	4.50	canopy
19	*Virola sebifera*	Myristicaceae	18	35.5	1.80	3026	0.78	1.79	4.37	canopy
20	*Schefflera morototoni*	Araliaceae	16	31.5	1.60	4140	1.07	1.68	4.34	canopy
21	*Ocotea spixiana*	Lauraceae	12	23.7	1.20	6043	1.56	1.34	4.10	canopy
22	*Pera glabrata*	Euphorbiaceae	16	31.5	1.60	3186	0.82	1.34	3.76	lower storey
23	*Myrcia rostrata*	Myrtaceae	15	29.6	1.50	2181	0.56	1.56	3.63	lower storey
24	*Richeria obovata*	Euphorbiaceae	6	11.8	0.60	8644	2.23	0.67	3.50	canopy
25	*Matayba guianensis*	Sapindaceae	14	27.6	1.40	2233	0.58	1.34	3.32	canopy
26	*Cryptocarya aschersoniana*	Lauraceae	13	25.6	1.30	1756	0.45	1.34	3.09	emergent
27	*Xylopia sericea*	Annonaceae	12	23.7	1.20	2574	0.66	1.23	3.09	canopy
28	*Platypodium elegans*	Leg.-Caesalpinioideae	12	23.7	1.20	2830	0.73	1.12	3.05	canopy
29	*Eriotheca pubescens*	Bombacaceae	11	21.7	1.10	3095	0.80	1.12	3.01	lower storey
30	*Guettarda viburnioides*	Rubiaceae	12	23.7	1.20	1887	0.49	1.23	2.92	lower storey
31	*Bauhinia rufa*	Leg.-Caesalpinioideae	11	21.7	1.10	2100	0.54	1.23	2.87	lower storey
32	*Inga alba*	Leg.-Mimosoideae	11	21.7	1.10	1943	0.50	1.23	2.83	canopy
33	*Cheiloclinium cognatum*	Hippocrateaceae	11	21.7	1.10	2285	0.59	1.12	2.81	lower storey
34	*Siphoneugena densiflora*	Myrtaceae	10	19.7	1.00	2026	0.52	1.12	2.64	canopy

Table 3- cont.

	Species	Families	N	Density		Dominance		Frequency	IVI	Vertical Stratification
				n/ha	%	cm2/ha	%	%		
35	*Mollinedia oligantha*	Monimiaceae	9	17.7	0.90	3005	0.77	0.89	2.57	lower storey
36	*Cupania vernalis*	Sapindaceae	10	19.7	1.00	1494	0.38	1.12	2.50	canopy
37	*Ocotea corymbosa*	Lauraceae	9	17.7	0.90	2647	0.68	0.89	2.48	lower storey
38	*Guatteria sellowiana*	Annonaceae	9	17.7	0.90	1967	0.51	1.01	2.41	canopy
39	*Pouteria ramiflora*	Sapotaceae	7	13.8	0.70	3322	0.86	0.78	2.34	lower storey
40	*Gomidesia brunea*	Myrtaceae	9	17.7	0.90	1130	0.29	0.89	2.08	canopy
41	*Diospyros hispida*	Ebenaceae	9	17.7	0.90	1396	0.36	0.78	2.04	lower storey
42	*Terminalia glabrescens*	Combretaceae	7	13.8	0.70	2523	0.65	0.67	2.02	emergent
43	*Sacoglottis guianensis*	Humiriaceae	6	11.8	0.60	3097	0.80	0.56	1.96	canopy
44	*Micropholis rigida*	Sapotaceae	6	11.8	0.60	2596	0.67	0.67	1.94	canopy
45	*Alibertia macrophylla*	Rubiaceae	8	15.8	0.80	826	0.21	0.89	1.91	lower storey
46	*Hirtella glandulosa*	Chrysobalanaceae	5	9.9	0.50	3212	0.83	0.56	1.89	canopy
47	*Vochysia tucanorum*	Vochysiaceae	7	13.8	0.70	1091	0.28	0.78	1.76	canopy
48	*Symplocos nitens*	Symplocaceae	3	5.9	0.30	3795	0.98	0.34	1.61	canopy
49	*Lacistema hassleriana*	Lacistemataceae	6	11.8	0.60	656	0.17	0.56	1.33	lower storey
50	*Piptocarpha macropoda*	Compositae	5	9.9	0.50	821	0.21	0.56	1.27	canopy
51	*Cecropia lyratiloba*	Moraceae	5	9.9	0.50	542	0.14	0.56	1.20	canopy
52	*Guapira graciliflora*	Nyctaginaceae	5	9.9	0.50	503	0.13	0.56	1.19	canopy
53	*Siparuna guianensis*	Monimiaceae	5	9.9	0.50	299	0.08	0.56	1.14	lower storey
54	*Amaioua guianensis*	Rubiaceae	4	7.9	0.40	1108	0.29	0.45	1.13	canopy
55	*Virola urbaniana*	Myristicaceae	1	2.0	0.10	3434	0.88	0.11	1.10	canopy
56	*Qualea dichotoma*	Vochysiaceae	3	5.9	0.30	1781	0.46	0.34	1.09	emergent
57	*Cordia sellowiana*	Boraginaceae	4	7.9	0.40	702	0.18	0.45	1.03	canopy
58	*Ouratea castaneaefolia*	Ochnaceae	4	7.9	0.40	482	0.12	0.45	0.97	canopy
59	*Ocotea pomaderroides*	Lauraceae	3	5.9	0.30	1275	0.33	0.34	0.96	
60	*Hieronyma ferruginea*	Euphorbiaceae	4	7.9	0.40	813	0.21	0.34	0.94	canopy
61	*Cybianthus gardnerii*	Myrsinaceae	4	7.9	0.40	279	0.07	0.45	0.92	lower storey
62	*Qualea multiflora*	Vochysiaceae	2	3.9	0.20	1655	0.43	0.22	0.85	emergent
63	*Hymenaea coubaril var. stilbocarpa*	Leg.-Caesalpinioideae	3	5.9	0.30	825	0.21	0.34	0.85	canopy
64	*Aniba herringerii*	Lauraceae	2	3.9	0.20	1458	0.38	0.22	0.80	lower storey
65	*Styrax guianensis*	Styracaceae	3	5.9	0.30	329	0.08	0.34	0.72	lower storey
66	*Salacia elliptica*	Hippocrateaceae	3	5.9	0.30	286	0.07	0.34	0.71	lower storey
67	*Miconia sellowiana*	Melastomataceae	3	5.9	0.30	170	0.04	0.34	0.68	canopy
68	*Kielmeyera coriacea*	Guttiferae	3	5.9	0.30	347	0.09	0.22	0.61	lower storey

Table 3 - cont...

	Species	Families	N	Density n/ha	Density %	Dominance cm2/ha	Dominance %	Frequency %	IVI	Vertical Stratification
69	*Dalbergia densiflora*	Leg.-Faboideae	2	3.9	0.20	394	0.10	0.22	0.52	lower storey
70	*Laplacea fruticosa*	Theaceae	2	3.9	0.20	239	0.06	0.22	0.49	lower storey
71	*Myrsine coriacea*	Myrsinaceae	2	3.9	0.20	229	0.06	0.22	0.48	canopy
72	*Casearia sylvestris*	Flacourtiaceae	2	3.9	0.20	197	0.05	0.22	0.47	lower storey
73	*Euplassa inaequalis*	Proteaceae	2	3.9	0.20	155	0.04	0.22	0.46	canopy
74	*Ferdinandusa speciosa*	Rubiaceae	2	3.9	0.20	154	0.04	0.22	0.46	lower storey
75	*Cardiopetalum calophyllum*	Annonaceae	2	3.9	0.20	123	0.03	0.22	0.46	lower storey
76	*Miconia pepericarpa*	Melastomataceae	2	3.9	0.20	112	0.03	0.22	0.45	lower storey
77	*Myrsine umbellata*	Myrsinaceae	2	3.9	0.20	94	0.02	0.22	0.45	lower storey
78	*Aspidosperma spruceanum*	Apocynaceae	2	3.9	0.20	79	0.02	0.22	0.44	canopy
79	*Vitex polygama*	Verbenaceae	1	2.0	0.10	535	0.14	0.11	0.35	lower storey
80	*Lafoensia pacari*	Lythraceae	1	2.0	0.10	513	0.13	0.11	0.34	lowr storey
81	*Simarouba versicolor*	Simaroubaceae	1	2.0	0.10	474	0.12	0.11	0.33	canopy
82	*Erythroxylum sp.*	Erythroxylaceae	1	2.0	0.10	348	0.09	0.11	0.30	lower storey
83	*Psidium longipetiolatum*	Myrtaceae	1	2.0	0.10	299	0.08	0.11	0.29	lower strata
84	*Tibouchina candolleana*	Melastomataceae	1	2.0	0.10	250	0.06	0.11	0.28	canopy
85	*Eugenia uruguaiensis*	Myrtaceae	1	2.0	0.10	181	0.05	0.11	0.26	lower storey
86	*Miconia cuspidata*	Melastomataceae	1	2.0	0.10	125	0.03	0.11	0.24	emergent
87	*Sorocea guilleminiana*	Moraceae	1	2.0	0.10	120	0.03	0.11	0.24	lower storey
88	*Mouriri glaziovii*	Melastomataceae	1	2.0	0.10	112	0.03	0.11	0.24	lower storey
89	*Machaerium aculeatum*	Leg.-Faboideae	1	2.0	0.10	94	0.02	0.11	0.24	canopy
90	*Miconia chartacea*	Melastomataceae	1	2.0	0.10	87	0.02	0.11	0.23	lower storey
91	*Ficus citrifolia*	Moraceae	1	2.0	0.10	69	0.02	0.11	0.23	lower storey
92	*Calophyllum brasiliense*	Guttiferae	1	2.0	0.10	59	0.02	0.11	0.23	canopy
93	*Myrcia tomentosa*	Myrtaceae	1	2.0	0.10	58	0.01	0.11	0.23	lower storey
94	*Ilex integrifolia*	Aquifoliaceae	1	2.0	0.10	56	0.01	0.11	0.23	lower storey
95	*Coussarea hydrangeaefolia*	Rubiaceae	1	2.0	0.10	49	0.01	0.11	0.22	lower storey
96	*Guarea guidonia*	Meliaceae	1	2.0	0.10	49	0.01	0.11	0.22	lower storey
97	*Cecropia pachystachya*	Moraceae	1	2.0	0.10	42	0.01	0.11	0.22	canopy
98	*Andira vermifuga*	Leg.-Faboideae	1	2.0	0.10	40	0.01	0.11	0.22	lower storey
99	*Dimorphandra mollis*	Leg.-Mimosoideae	1	2.0	0.10	40	0.01	0.11	0.22	lower storey
100	*Ormosia sp.*	Leg.-Faboideae	1	2.0	0.10	39	0.01	0.11	0.22	canopy
Totals	99 species	46 families	1000	1971	100%	388 227	100%	100%	300%	

Table 4 - Phytosociological parameters for trees recorded at Monjolo (M) Gallery Forest in RECOR-IBGE, Brasilia, Federal District.

	Species	Families	N	Density		Dominance		Frequency	IVI	Vertical
				n/ha	%	cm/ha	%	%		stratification
1	*Tapirira guianensis*	Anacardiaceae	58	99.8	5.80	23869	5.33	5.64	16.77	emergent
2	Dead trees		54	92.9	5.40	22772	5.08	5.64	16.12	**********
3	*Cryptocarya aschersoniana*	Lauraceae	50	86.0	5.00	23257	5.19	4.85	15.04	emergent
4	*Licania apetala*	Chrysobalanaceae	37	63.6	3.70	29406	6.57	3.49	13.76	canopy
5	*Miconia cuspidata*	Melastomataceae	57	98.0	5.70	9308	2.08	5.19	12.96	canopy
6	*Copaifera langsdorffii*	Leg.-Caesalpinioideae	22	37.8	2.20	37138	8.29	2.14	12.63	emergent
7	*Inga alba*	Leg.-Mimosoideae	54	92.9	5.40	8842	1.97	5.19	12.56	canopy
8	*Maprounea guianensis*	Euphorbiaceae	26	44.7	2.60	22656	5.06	2.59	10.25	canopy
9	*Aspidosperma subincanun*	Apocynaceae	20	34.4	2.00	27336	6.10	2.03	10.13	canopy
10	*Sclerolobium paniculatum var. rubiginosum*	Leg.-Caesalpinioideae	30	51.6	3.00	14227	3.18	2.71	8.88	canopy
11	*Cheiloclinium cognatum*	Hippocrateaceae	32	55.0	3.20	9802	2.19	3.38	8.77	lower storey
12	*Emmotum nitens*	Icacinaceae	20	34.4	2.00	16605	3.71	2.25	7.96	canopy
13	*Protium almecega*	Burseraceae	33	56.8	3.30	4640	1.04	3.49	7.83	emergent
14	*Amaioua guianensis*	Rubiaceae	30	51.6	3.00	7772	1.74	2.93	7.67	canopy
15	*Virola sebifera*	Myristicaceae	23	39.6	2.30	7515	1.68	2.37	6.35	canopy
16	*Pouteria ramiflora*	Sapotaceae	18	31.0	1.80	11056	2.47	1.92	6.18	lower storey
17	*Jacaranda puberula*	Bignoniaceae	27	46.4	2.70	6077	1.36	2.03	6.09	lower storey
18	*Pseudolmedia guaranitica*	Moraceae	26	44.7	2.60	4873	1.09	2.25	5.94	lower storey
19	*Myrsine coriacea*	Myrsinaceae	15	25.8	1.50	11142	2.49	1.47	5.45	canopy
20	*Salacia elliptica*	Hippocrateaceae	20	34.4	2.00	4538	1.01	2.03	5.04	canopy
21	*Tapura amazonica*	Dichapetalaceae	18	31.0	1.80	4627	1.03	2.03	4.86	canopy
22	*Sacoglottis guianensis*	Humiriaceae	13	22.4	1.30	8079	1.80	1.47	4.57	canopy
23	*Lamanonia ternata*	Cunoniaceae	6	10.3	0.60	14419	3.22	0.56	4.38	canopy
24	*Piptocarpha macropoda*	Compositae	15	25.8	1.50	4294	0.96	1.69	4.15	canopy
25	*Nectandra mollis*	Lauraceae	8	13.8	0.80	8905	1.99	0.90	3.69	canopy
26	*Callisthene major*	Vochysiaceae	9	15.5	0.90	7430	1.66	0.90	3.46	canopy
27	*Siparuna guianensis*	Monimiaceae	15	25.8	1.50	1529	0.34	1.58	3.42	lower storey
28	*Qualea dichotoma*	Vochysiaceae	5	8.6	0.50	9502	2.12	0.56	3.19	emergent

Table 4- cont.

	Species	Families	N	Density		Dominance		Frequency	IVI	Vertical
				n/ha	%	cm/ha	%	%		stratification
29	*Hirtella glandulosa*	Chrysobalanaceae	10	17.2	1.00	4242	0.95	1.13	3.07	lower storey
30	*Guatteria sellowiana*	Annonaceae	13	22.4	1.30	2136	0.48	1.24	3.02	canopy
31	*Platypodium elegans*	Leg.-Caesalpinioideae	4	6.9	0.40	10422	2.33	0.23	2.95	canopy
32	*Simarouba versicolor*	Simaroubaceae	10	17.2	1.00	3905	0.87	0.90	2.77	canopy
33	*Faramea cyanea*	Rubiaceae	11	18.9	1.10	1819	0.41	1.24	2.75	lower storey
34	*Matayba guianensis*	Sapindaceae	12	20.6	1.20	1102	0.25	1.24	2.69	canopy
35	*Astronium fraxinifolium*	Anacardiaceae	10	17.2	1.00	3327	0.74	0.90	2.64	canopy
36	*Hymenaea coubaril var. stilbocarpa*	Leg.-Caesalpinioideae	6	10.3	0.60	6244	1.39	0.56	2.56	canopy
37	*Xylopia sericea*	Annonaceae	6	10.3	0.60	5603	1.25	0.68	2.53	canopy
38	*Ouratea castaneaefolia*	Ochnaceae	10	17.2	1.00	1544	0.34	1.13	2.47	lower storey
39	*Ocotea aciphylla*	Lauraceae	9	15.5	0.90	2489	0.56	1.01	2.47	canopy
40	*Symplocos mosenii*	Symplocaceae	6	10.3	0.60	5147	1.15	0.68	2.43	canopy
41	*Byrsonima laxiflora*	Malpighiaceae	11	18.9	1.10	1242	0.28	1.01	2.39	canopy
42	*Cecropia lyratiloba*	Moraceae	11	18.9	1.10	1137	0.25	0.90	2.26	canopy
43	*Alchornea ferruginea*	Euphorbiaceae	9	15.5	0.90	1317	0.29	0.90	2.10	canopy
44	*Machaerium acutifolium*	Leg.-Faboideae	6	10.3	0.60	2887	0.64	0.68	1.92	canopy
45	*Schefflera morototoni*	Araliaceae	7	12.0	0.70	1917	0.43	0.79	1.92	canopy
46	*Apuleia leiocarpa*	Leg.-Caesalpinioideae	5	8.6	0.50	4664	1.04	0.34	1.88	canopy
47	*Qualea multiflora*	Vochysiaceae	5	8.6	0.50	2505	0.56	0.56	1.62	canopy
48	*Miconia chartacea*	Melastomataceae	7	12.0	0.70	479	0.11	0.79	1.60	lower storey
49	*Gomidesia brunea*	Myrtaceae	6	10.3	0.60	1080	0.24	0.68	1.52	canopy
50	*Terminalia glabrescens*	Combretaceae	5	8.6	0.50	1940	0.43	0.56	1.50	canopy
51	*Myrcia rostrata*	Myrtaceae	6	10.3	0.60	557	0.12	0.68	1.40	lower storey
52	*Miconia sellowiana*	Melastomataceae	5	8.6	0.50	1370	0.31	0.56	1.37	canopy
53	*Nectandra cissiflora*	Lauraceae	2	3.4	0.20	4015	0.90	0.23	1.32	canopy
54	*Cordia sellowiana*	Boraginaceae	5	8.6	0.50	833	0.19	0.56	1.25	canopy
55	*Aspidosperma cylindrocarpon*	Apocynaceae	4	6.9	0.40	1776	0.40	0.45	1.25	canopy
56	*Cupania vernalis*	Sapindaceae	5	8.6	0.50	1308	0.29	0.34	1.13	canopy

Table 4- cont.

	Species	Families	N	Density		Dominance		Frequency	IVI	Vertical
				n/ha	%	cm/ha	%	%		stratification
57	*Micropholis rigida*	Sapotaceae	4	6.9	0.40	466	0.10	0.45	0.95	canopy
58	*Vismia guianensis*	Guttiferae	4	6.9	0.40	423	0.09	0.45	0.95	lower storey
59	*Diospyros hispida*	Ebenaceae	4	6.9	0.40	362	0.08	0.45	0.93	lower storey
60	*Roupala brasiliensis*	Proteaceae	3	5.2	0.30	1261	0.28	0.34	0.92	lower storey
61	*Sorocea guilleminiana*	Moraceae	4	6.9	0.40	254	0.06	0.45	0.91	lower storey
62	*Siphoneugena densiflora*	Myrtaceae	2	3.4	0.20	2131	0.48	0.23	0.90	canopy
63	*Sclerolobium aureum*	Leg.-Caesalpinioideae	3	5.2	0.30	676	0.15	0.34	0.79	canopy
64	*Casearia sylvestris*	Flacourtiaceae	3	5.2	0.30	460	0.10	0.34	0.74	lower storey
65	*Terminalia argentea*	Combretaceae	3	5.2	0.30	211	0.05	0.34	0.69	canopy
66	*Styrax guianensis*	Styracaceae	3	5.2	0.30	271	0.06	0.23	0.59	lower storey
67	*Blepharocalyx salicifolius*	Myrtaceae	2	3.4	0.20	707	0.16	0.23	0.58	lower storey
68	*Ocotea corymbosa*	Lauraceae	3	5.2	0.30	216	0.05	0.23	0.57	canopy
69	*Machaerium aculeatum*	Leg.-Faboideae	2	3.4	0.20	349	0.08	0.23	0.50	lower storey
70	*Aegiphilla sellowiana*	Verbenaceae	2	3.4	0.20	272	0.06	0.23	0.49	lower storey
71	*Andira vermifuga*	Leg.-Faboideae	1	1.7	0.10	355	0.08	0.11	0.29	lower storey
72	*Laplacea fruticosa*	Theaceae	1	1.7	0.10	182	0.04	0.11	0.25	lower storey
73	*Tabebuia serratifolia*	Bignoniaceae	1	1.7	0.10	112	0.03	0.11	0.24	lower storey
74	*Cybianthus gardnerii*	Myrsinaceae	1	1.7	0.10	100	0.02	0.11	0.23	lower storey
75	*Alibertia macrophylla*	Rubiaceae	1	1.7	0.10	95	0.02	0.11	0.23	lower storey
76	*Ormosia stipularis*	Leg.-Faboideae	1	1.7	0.10	93	0.02	0.11	0.23	lower storey
77	*Mouriri glaziovii*	Melastomataceae	1	1.7	0.10	93	0.02	0.11	0.23	lower storey
78	*Prunus brasiliensis*	Rosaceae	1	1.7	0.10	55	0.01	0.11	0.23	lower storey
79	*Guapira graciliflora*	Nyctaginaceae	1	1.7	0.10	42	0.01	0.11	0.22	canopy
80	*Myrcia tomentosa*	Myrtaceae	1	1.7	0.10	39	0.01	0.11	0.22	lower storey
81	*Vitex polygama*	Verbenaceae	1	1.7	0.10	37	0.01	0.11	0.22	lower storey
Totals	80 species	41 families	1000	1720	100%	448 765	100%	100%	300%	

Table 5- Phytosociological parameters for trees recorded at Taquara (T) Gallery Forest in RECOR-IBGE, Brasilia, Federal District.

	Species	Families	N	Density		Dominance		Frequency	IVI	Vertical
				n/ha	%	cm/ha	%	%		stratification
1	*Tapirira guianensis*	Anacardiaceae	70	111.7	7.00	20099	4.35	5.72	17.07	emergent
2	Dead Trees		48	73.9	4.80	31572	6.85	4.96	16.62	**********
3	*Copaifera langsdorffii*	Leg.-Caesalpinioideae	30	47.2	3.00	33170	7.28	3.13	13.41	emergent
4	*Lamanonia ternata*	Cunoniaceae	33	25.2	3.30	28623	4.45	3.24	10.98	emergent
5	*Anadenanthera colubrina var. cebil*	Leg.-Mimosoideae	42	33.0	4.20	22110	2.76	3.78	10.74	emergent
6	*Piptocarpha macropoda*	Compositae	36	55.1	3.60	12936	3.13	3.13	9.85	canopy
7	*Alibertia macrophylla*	Rubiaceae	23	64.5	2.30	4872	3.31	2.37	7.98	lower storey
8	*Matayba guianensis*	Sapindaceae	19	51.9	1.90	6018	3.84	1.94	7.68	canopy
9	*Pera glabrata*	Euphorbiaceae	16	31.5	1.60	12373	4.53	1.51	7.64	lower storey
10	*Guettarda viburnioides*	Rubiaceae	20	47.2	2.00	4604	3.21	2.16	7.37	lower storey
11	*Ixora warmingii*	Rubiaceae	30	36.2	3.00	7324	1.20	2.91	7.11	lower storey
12	*Platypodium elegans*	Leg.-Caesalpinioideae	22	28.3	2.20	9972	2.74	1.94	6.88	canopy
13	*Protium almecega*	Burseraceae	19	34.6	1.90	7996	2.10	1.83	5.83	emergent
14	*Sclerolobium paniculatum var. rubiginosum*	Leg.-Caesalpinioideae	18	29.9	1.80	8132	2.02	1.83	5.66	canopy
15	*Tapura amazonica*	Dichapetalaceae	18	28.3	1.80	5870	1.57	1.83	5.20	canopy
16	*Emmotum nitens*	Icacinaceae	13	20.5	1.30	8425	2.24	1.29	4.83	canopy
17	*Diospyros hispida*	Ebenaceae	17	26.7	1.70	4858	1.26	1.73	4.69	lower storey
18	*Hymenaea coubaril var. stilbocarpa*	Leg.-Caesalpinioideae	19	9.4	1.90	12842	0.40	1.83	4.13	canopy
19	*Pseudobombax tomentosum*	Bombacaceae	15	11.0	1.50	11243	0.93	1.51	3.94	emergent
20	*Myrcia rostrata*	Myrtaceae	6	29.9	0.60	1367	2.68	0.65	3.92	lower storey
21	*Byrsonima laxiflora*	Malpighiaceae	7	22.0	0.70	4305	2.44	0.76	3.90	lower storey
22	*Cheiloclinium cognatum*	Hippocrateaceae	16	25.2	1.60	2209	0.57	1.62	3.79	lower storey
23	*Guapira graciliflora*	Nyctaginaceae	15	23.6	1.50	2818	0.75	1.51	3.76	canopy
24	*Maprounea guianensis*	Euphorbiaceae	15	23.6	1.50	2610	0.69	1.51	3.70	canopy
25	*Ocotea corymbosa*	Lauraceae	14	18.9	1.40	4292	0.86	1.40	3.67	domonant
26	*Cupania vernalis*	Sapindaceae	12	23.6	1.20	2591	1.14	1.29	3.64	canopy
27	*Myrcia tomentosa*	Myrtaceae	15	20.5	1.50	3487	0.67	1.40	3.58	lower storey

Table 5- cont.

	Species	Families	N	Density		Dominance		Frequency	IVI	Vertical
				n/ha	%	cm/ha	%	%		stratification
28	*Symplocos nitens*	Symplocaceae	13	23.6	1.30	1729	0.91	1.29	3.50	canopy
29	*Inga alba*	Leg.-Mimosoideae	13	20.5	1.30	2813	0.77	1.40	3.47	canopy
30	*Aspidosperma spruceanum*	Apocynaceae	15	11.0	1.50	7522	0.45	1.51	3.46	canopy
31	*Schefflera morototoni*	Araliaceae	7	22.0	0.70	1617	1.95	0.76	3.41	canopy
32	*Cousarea hydrangeifolia*	Rubiaceae	12	22.0	1.20	1151	0.73	1.19	3.12	lower storey
33	*Qualea dichotoma*	Vochysiaceae	14	9.4	1.40	6670	0.30	1.40	3.10	canopy
34	*Jacaranda puberula*	Bignoniaceae	12	20.5	1.20	1447	0.46	1.29	2.95	lower storey
35	*Ocotea spixiana*	Lauraceae	10	15.7	1.00	3370	0.87	1.08	2.95	canopy
36	*Styrax guianensis*	Styracaceae	9	18.9	0.90	1756	1.04	0.97	2.91	lower storey
37	*Aspidosperma subincanum*	Apocynaceae	11	14.2	1.10	4044	0.40	1.19	2.69	canopy
38	*Symplocos mosenii*	Symplocaceae	5	17.3	0.50	2138	1.58	0.54	2.62	canopy
39	*Aspidosperma discolor*	Apocynaceae	8	12.6	0.80	3280	0.93	0.86	2.60	canopy
40	*Callisthene major*	Vochysiaceae	7	7.9	0.70	5666	1.21	0.65	2.56	canopy
41	*Terminalia glabrescens*	Combretaceae	5	12.6	0.50	3098	1.47	0.54	2.51	canopy
42	*Machaerium acutifolium*	Leg.-Faboideae	9	14.2	0.90	2300	0.57	0.86	2.33	canopy
43	*Xylopia sericea*	Annonaceae	8	14.2	0.80	1673	0.63	0.86	2.30	canopy
44	*Hirtella glandulosa*	Chrysobalanaceae	7	12.6	0.70	2442	0.84	0.76	2.29	lower storey
45	*Miconia cuspidata*	Melastomataceae	10	11.0	1.00	3629	0.27	0.97	2.25	emergent
46	*Roupala brasiliensis*	Proteaceae	8	15.7	0.80	1058	0.42	0.86	2.08	lower storey
47	*Virola sebifera*	Myristicaceae	8	12.6	0.80	1604	0.42	0.86	2.08	canopy
48	*Licania apetala*	Chrysobalanaceae	5	11.0	0.50	2068	1.01	0.54	2.05	canopy
49	*Lafoensia densiflora*	Lythraceae	7	9.4	0.70	2696	0.54	0.76	1.99	lower storey
50	*Cecropia lyratiloba*	Moraceae	2	11.0	0.20	1892	1.54	0.22	1.96	canopy
51	*Hieronyma ferruginea*	Euphorbiaceae	6	9.4	0.60	2465	0.70	0.65	1.95	lower storey
52	*Margaritaria nobilis*	Lauraceae	7	7.9	0.70	3088	0.47	0.76	1.92	canopy
53	*Siphoneugena densiflora*	Myrtaceae	6	6.3	0.60	3617	0.64	0.65	1.89	canopy
54	*Vochysia tucanorum*	Vochysiaceae	5	11.0	0.50	1142	0.80	0.54	1.84	canopy

Table 5- cont.

	Species	Families	N	Density		Dominance		Frequency	IVI	Vertical
				n/ha	%	cm/ha	%	%		stratification
55	*Nectandra cissiflora*	Lauraceae	4	9.4	0.40	1747	0.94	0.43	1.77	canopy
56	*Cecropia pachystachya*	Moraceae	7	11.0	0.70	745	0.30	0.76	1.75	canopy
57	*Piptadenia gonoacantha*	Leg.-Mimosoideae	6	7.9	0.60	2292	0.45	0.65	1.70	canopy
58	*Eriotheca gracilipes*	Bombacaceae	5	6.3	0.50	2948	0.61	0.54	1.65	lower storey
59	*Myrsine coriacea*	Myrsinaceae	3	11.0	0.30	429	1.01	0.32	1.63	canopy
60	*Tabebuia impetiginosa*	Bignoniaceae	4	7.9	0.40	1484	0.77	0.43	1.60	lower storey
61	*Micropholis rigida*	Sapotaceae	7	9.4	0.70	557	0.13	0.76	1.58	canopy
62	*Guatteria sellowiana*	Annonaceae	3	9.4	0.30	331	0.85	0.32	1.47	canopy
63	*Bauhinia rufa*	Leg.-Caesalpinioideae	7	9.4	0.70	316	0.11	0.65	1.46	lower storey
64	*Guarea guidonia*	Meliaceae	5	7.9	0.50	681	0.39	0.54	1.42	lower storey
65	*Ouratea castaneaefolia*	Ochnaceae	5	7.9	0.50	400	0.38	0.54	1.42	lower storey
66	*Cordia sellowiana*	Boraginaceae	6	7.9	0.60	313	0.14	0.65	1.39	canopy
67	*Tabebuia umbellata*	Bignoniaceae	6	7.9	0.60	1129	0.09	0.65	1.33	lower storey
68	*Eriotheca pubescens*	Bombacaceae	6	6.3	0.60	1071	0.07	0.65	1.31	lower storey
69	*Euplassa inaequalis*	Proteaceae	5	1.6	0.50	3201	0.11	0.54	1.15	canopy
70	*Myrsine umbellata*	Myrsinaceae	5	6.3	0.50	527	0.10	0.54	1.14	lower storey
71	*Pseudolmedia guaranitica*	Moraceae	5	6.3	0.50	501	0.29	0.32	1.12	lower storey
72	*Cardiopetalum calophyllum*	Annonaceae	4	6.3	0.40	467	0.26	0.43	1.09	lower storey
73	*Qualea multiflora*	Vochysiaceae	4	3.2	0.40	1815	0.22	0.43	1.05	emergent
74	*Cryptocarya aschersoniana*	Lauraceae	4	4.7	0.40	933	0.14	0.43	0.97	emergent
75	*Gomidesia brunea*	Myrtaceae	3	4.7	0.30	849	0.24	0.32	0.87	canopy
76	*Erythroxylum sp.*	Erythroxylaceae	3	4.7	0.30	793	0.22	0.32	0.84	lower storey
77	*Faramea cyanea*	Rubiaceae	2	4.7	0.20	727	0.42	0.22	0.83	lower storey
78	*Kielmeyera coriacea*	Guttiferae	3	4.7	0.30	589	0.21	0.32	0.83	lower storey
79	*Vitex polygama*	Verbenaceae	3	4.7	0.30	330	0.15	0.32	0.78	lower storey
80	*Maytenus salicifolia*	Celastraceae	3	4.7	0.30	287	0.09	0.32	0.71	lower storey
81	*Prunus brasiliensis*	Rosaceae	3	4.7	0.30	154	0.07	0.32	0.70	lower storey

Table 5- cont.

	Species	Families	N	Density		Dominance		Frequency	IVI	Vertical
				n/ha	%	cm2/ha	%	%		stratification
82	*Pouteria ramiflora*	Sapotaceae	3	4.7	0.30	152	0.04	0.32	0.66	lower storey
83	*Calophyllum brasiliense*	Guttiferae	3	1.6	0.30	1445	0.04	0.32	0.66	canopy
84	*Pseudobombax longiflorum*	Bombacaceae	2	3.2	0.20	605	0.16	0.22	0.57	canopy
85	*Myrciaria glanduliflora*	Myrtaceae	2	3.2	0.20	268	0.07	0.22	0.49	lower storey
86	*Alibertia edulis*	Rubiaceae	2	3.2	0.20	194	0.05	0.22	0.47	lower storey
87	*Luehea grandiflora*	Tiliaceae	2	3.2	0.20	152	0.04	0.22	0.46	lower storey
88	*Cordia trichotoma*	Boraginaceae	2	3.2	0.20	136	0.04	0.22	0.45	lower storey
89	*Casearia grandiflora*	Flacourtiaceae	2	3.2	0.20	130	0.03	0.22	0.45	lower storey
90	*Siparuna guianensis*	Monimiaceae	2	3.2	0.20	95	0.02	0.22	0.44	lower storey
91	*Cybianthus gardnerii*	Myrsinaceae	2	3.2	0.20	81	0.02	0.22	0.43	lower storey
92	*Xylopia emarginata*	Annonaceae	1	3.2	0.10	64	0.19	0.11	0.40	canopy
93	*Ocotea aciphylla*	Lauraceae	1	1.6	0.10	730	0.10	0.11	0.31	canopy
94	*Tabebuia serratifolia*	Bignoniaceae	1	1.6	0.10	396	0.09	0.11	0.30	lower storey
95	*Chomelia pohliana*	Rubiaceae	1	1.6	0.10	336	0.09	0.11	0.30	lower storey
96	*Blepharocalyx salicifolius*	Myrtaceae	1	1.6	0.10	336	0.06	0.11	0.27	lower storey
97	*Sacoglottis guianensis*	Humiriaceae	1	1.6	0.10	256	0.06	0.11	0.27	canopy
98	*Tetragastris balsamifera*	Burseraceae	1	1.6	0.10	249	0.04	0.11	0.24	lower storey
99	*Virola urbaniana*	Myristicaceae	1	1.6	0.10	242	0.03	0.11	0.24	canopy
100	*Hirtella gracilipes*	Chrysobalanaceae	1	1.6	0.10	136	0.03	0.11	0.24	lower storey
101	*Sloanea guianensis*	Elaeocarpaceae	1	1.6	0.10	112	0.02	0.11	0.23	lower storey
102	*Zanthoxylum rhoifolium*	Rurtaceae	1	1.6	0.10	107	0.02	0.11	0.23	lower storey
103	*Mollinedia oligantha*	Monimiaceae	1	1.6	0.10	85	0.02	0.11	0.22	lower storey
104	*Vismia guianesis*	Guttiferae	1	1.6	0.10	66	0.01	0.11	0.22	lower storey
105	*Laplacea fruticosa*	Theaceae	1	1.6	0.10	51	0.01	0.11	0.22	lower storey
106	*Sorocea guilleminiana*	Moraceae	1	1.6	0.10	51	0.01	0.11	0.22	lower storey
107	*Dalbergia densiflora*	Leg.-Faboideae	1	1.6	0.10	51	0.01	0.11	0.22	lower storey
108	*Hedyosmum brasiliense*	Chloranthaceae	1	1.6	0.10	40	0.01	0.11	0.22	lower storey

Table 5- cont.

	Species	Families	N	Density		Dominance		Frequency	IVI	Vertical
				n/ha	%	cm2/ha	%	%		stratification
109	*Ficus citrifolia*	Moraceae	1	1.6	0.10	37	0.01	0.11	0.22	lower storey
110	*Miconia chartacea*	Melastomataceae	1	1.6	0.10	36	0.01	0.11	0.22	lower storey
111	*Richeria obovata*	Euphorbiaceae	1	1.6	0.10	32	0.01	0.11	0.22	canopy
Totals	110 species	48 families	1000	1573	100%	384980	100%	100%	300%	

important component of this is density, but in some species presence of very large individuals means high dominance is the most important factor. The latter situation occurs in *Copaifera langsdorffii, Emmotum nitens, Lamanonia ternata,* and also locally for *Sclerolobium paniculatum* var. *rubiginosum, Licania apetala* and *Richeria obovata* at Pitoco, for *Licania apetala, Maprounea guianensis* and *Aspidosperma cylindrocarpon* at Monjolo, and for *Anadenanthera colubrina* var. *cebil, Hymenaea courbaril* var. *stilbocarpa* and *Pseudobombax tomentosum* at Taquara.

Frequency tends in general to follow density, unless populations show uneven distribution. No species showed values in this parameter that suggested any unusual spatial distribution.

Rare species, recorded by just one individual, accounted for 21.2, 12.5 and 18% of the total number of species in Pitoco, Monjolo and Taquara respectively. In terms of vegetation structure and ecosystem maintenance, rare species are widely regarded as having little significance. They have often been considered merely as unsuccessful species but in fact their careful study may hold a key to dynamic changes in vegetation.

Despite being close to each other, each site had also its own exclusive species, accounting for nine (9.1%), 10 (12.5%) and 21 (21.6%) at Pitoco, Monjolo and Taquara respectively.

The results illustrate the presence of a few common generalist species, such as *Tapirira guianensis, Copaifera langsdorffii, Emmotum nitens, Sclerolobium paniculatum* var. *rubiginosum, Maprounea guianensis,* and a large number of rare species. The floristic individuality of sites is brought about by high percentages of exclusive species.

A similar very heterogeneous pattern was also found in a comparison of the woody vegetation of 26 areas scattered through the cerrado biome. Nearly half of the 485 species recorded occurred at only one site and only 27 species occurred at 15 or more (Ratter & Dargie 1992).

4.3.3.- Floristic diversity.

The 1000 trees recorded in each gallery forest consisted of 99, 80 and 110 species in Pitoco, Monjolo and Taquara respectively (exclusive of dead trees).

The Shannon & Weiner diversity index is calculated as 3.86 for Pitoco, 3.83 for Monjolo and 4.25 for the Taquara gallery forest. Generally the values for gallery forests are higher than those for cerrado (*sensu stricto*) (3.11 to 3.62, Felfili & Silva Júnior 1993) or cerradão (3.42, Felfili & Silva Júnior 1992), the neighbouring communities in the cerrado biome. The present gallery indices are comparable with those for Amazonian and Atlantic rain forest which range from 3.7 to 4.3 (Silva Júnior 1984).

Pielou's evenness index calculated for the three galleries gives figures of 84, 87 and 90% respectively of the maximum diversity possible in view of the sampling size.

Diversity measuring is influenced by methodological differences, mainly sampling technique, sampling effort and minimum diameter. Differences in the methods used make the results of different workers difficult to compare (Marguram 1988).

4.3.4.- Diameter distribution.

The diameter distribution of scored individuals in each gallery showed a general tendency to an inverted 'J' pattern, suggesting a dynamic equilibrium between growth and mortality as expected in self-regenerating forest communities (Harper 1977).

At Pitoco (Figure 9 a) 50.6% of the total number of individuals are in the first class (5-9.9 cm) and almost 92% had DBH ≤ 30 cm. The largest diameter recorded is 77 cm for a dead tree, followed by 68.4 cm for a specimen of *Copaifera langsdorffii*. This is an expected figure where smaller trees comprise the greater majority of individuals (Meyer et al. 1961, Harper 1977). Only a few species such as *Copaifera langsdorffii, Lamanonia ternata* and *Richeria obovata* reached diameters as large as 50 cm.

The average 'q' was calculated as 0.55 and each class quotient indicated recruitment higher than the average for 30 to 50 cm classes and lower for the larger classes. This may represent a natural potential of growth of most of the species or the results of selective felling. The latter, however, has not occurred at RECOR for at least the last 20 years.

At Monjolo, the estimated 1720 individuals/ha are distributed in 16 classes of diameter (Figure 9 b). More than 50% of the trees belong to the 5 - 9.9 cm class and about 92% of the trees have DBH ≤ 30 cm. The largest tree recorded is a specimen of *Copaifera langsdorffii* of 84.3 cm DBH. Excluding dead trees, only 12 species, *Amaioua guianensis, Aspidosperma subincanum, Copaifera langsdorffii, Cryptocarya aschersoniana, Emmotum nitens, Hymenaea coubaril* var. *stilbocarpa, Lamanonia ternata, Licania apetala, Maprounea guianensis, Platypodium elegans, Pouteria ramiflora* and *Qualea dichotoma* are recorded with diameters larger than 50 cm.

The average percentage of recruitment is calculated as 0.61 (average 'q' value) and recruitment for the smaller classes is below the average ('qs' = 0.40, 0.51 and 0.52) (Figure 9 b) indicating high mortality which may result in a lower population density in the future

Almost 52% of the 1573 trees scored on the Taquara site are in the first diameter class (5-9.9 cm) and 91% are ≤ 30 cm DBH (Figure 9 c). An individual of *Lamanonia ternata* is the largest tree recorded with 88.9 cm DBH. Only eight species a)

b)

c)

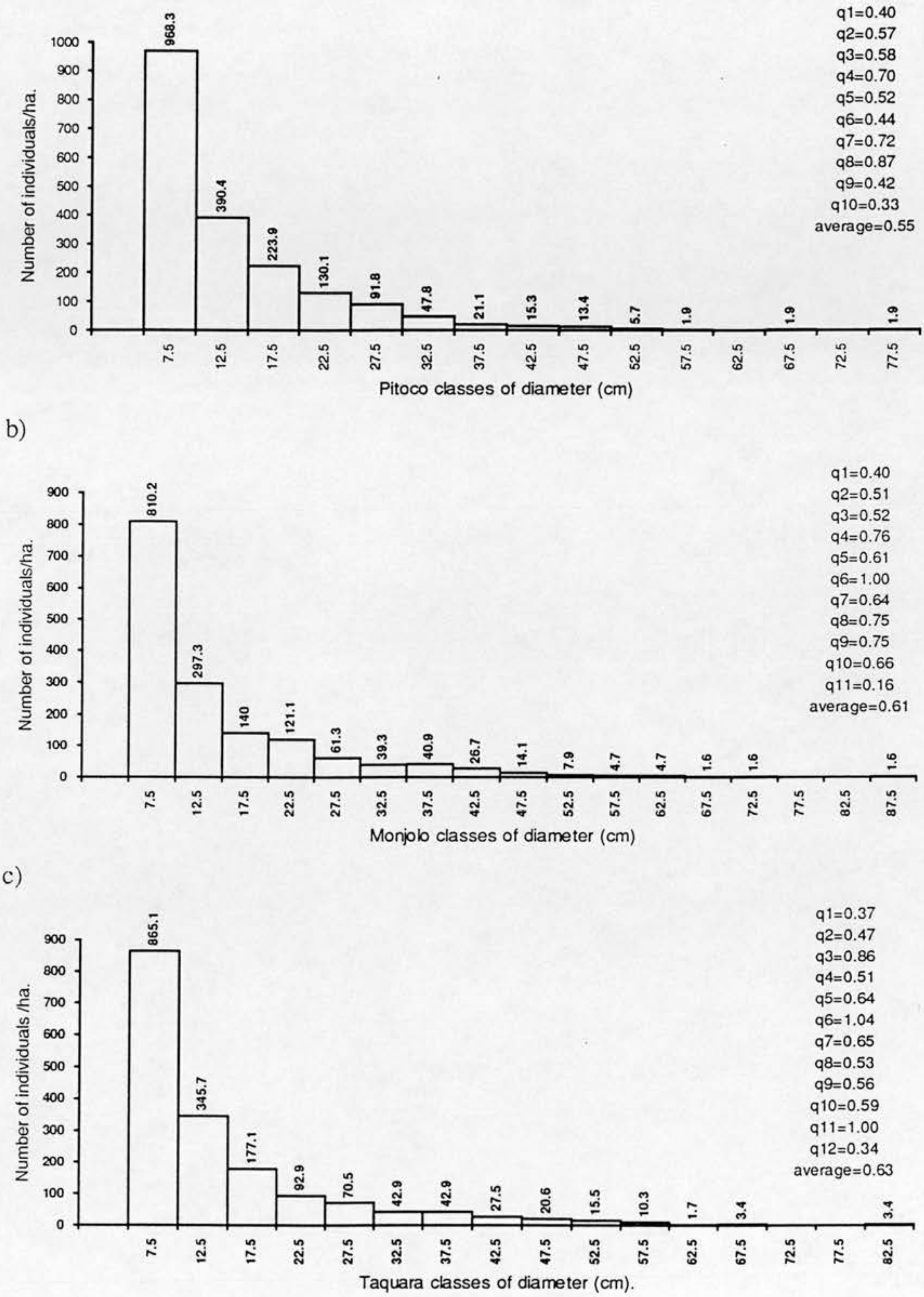


Figure 9-Diameter distribution and Liocourt's "q" quotient for the total sampling at Pitoco (a), Monjolo (b) and Taquara (c) gallery forests.

are recorded with diameters larger than 50 cm: *Anadenanthera colubrina* var. *cebil, Copaifera langsdorffii, Euplassa inaequalis, Hymenaea coubaril* var. *stilbocarpa, Lamanonia ternata, Miconia cuspidata, Protium almecega* and *Pseudobombax tomentosum*.

Liocourt's 'q' quotient is quite variable around the average of 0.63, indicating a low tree recruitment amongst classes. Since the structure of the forest populations is sensitive to the environment, these values could indicate the occurrence of disturbance. Further observations are needed for the assessment of the causes.

The analysis of the diameter distributions at Pitoco, Monjolo and Taquara shows that all communities are composed mainly of small trees with large individuals belonging to only few species. Felfili (1993) observed a similar structure at the Gama gallery forest at Fazenda Água-Limpa (FAL), a neighbouring area to RECOR-IBGE. She found 90% of the trees had DBH smaller than 45 cm, with the maximum diameter reaching around 100 cm. Almost exactly the same species are recorded with larger individuals by Felfili as in the present study.

The inverted 'J' pattern, where a greater number of trees in the first diameter class (5-9.9 cm) and a low representation in the larger classes, is clearly shown in all three sites, indicating self-regenerating forests. Variations on the Liocourt's 'q' quotient suggest communities that tend towards a balanced diameter distribution, as pointed out by Harper (1977), and indicate unbalance between recruitment and mortality. This is probably the result of past events, however the little information on growth rates and dynamics of gallery forests which exists suggests that long periods are necessary for the complete recovery of damaged forest. Thus present day diameter structure is likely to reflect disturbance older than RECOR records which do not show any occurrence of major disturbance for at least the last 20 years.

These results represent the first observations on the RECOR gallery forests. Periodic future measurements must be made to generate data on their dynamics as a basic requirement for conservation management or any other rational use of the area.

Chapter 5 - Communities and related species in Pitoco (P), Monjolo (M) and Taquara (T) gallery forests.

5.1.- Introduction.

The existence of a variety of habitats allows different species to express their innate abilities to exploit local resources thus making possible their coexistence. The result is the mosaic of plant communities to which ecologists have devoted so much energy whilst trying to define the biotic /abiotic environment (Crawley 1986).

The recognition of plants associated with habitats representing the end points of a gradient is usually simple, however separating vegetation in differing but adjacent communities is always rather difficult (Miller & Johnson 1986).

Classification is based on the spatial distribution of the different species in the vegetation which, in turn, is controlled by ecological factors and the response of the different species to gradients in these factors, competition, etc. (van Groenewoud 1992) or in some cases may have a strong stochastic element. If the distribution of species forms a continuum along a gradient, as suggested by many authors (Curtis & McIntosh 1951, Whittaker 1978, Austin & Smith 1989), discrete natural groups may not exist (Belbin & McDonald 1993).

TWINSPAN (Hill 1979) provides a two-way classification of both samples and species; it can be used to construct vegetation groups that may be used to decide to which segment of the vegetation continuum a particular community belongs (van Groenewoud 1992).

The gallery forests of Central Brazil have been poorly studied, but the works which do exist indicate great floristic and phytosociological heterogeneity. The relationship of some species and communities to distinct subhabitats has already been suggested but quantitative analysis of this has been attempted in very few studies (Schiavini 1992, Felfili 1993, Oliveira-Filho et al. in press). Detecting and understanding the constituent plant communities of the galleries and their associated environments would provide vital information for projects on their recuperation.

The aim of this study is to use a hierarchical classification (TWINSPAN) to investigate whether or not the differing species distribution can define 'communities' meaningfully related to the environmental features of the galleries. This is to answer question 2: Is there any pattern of spatial distribution of species which would indicate the presence of different communities within these galleries?

5.2.- Material and methods.

Each gallery forest was sampled as described in Chapter 4 with a total of 250 sampling points recording 1000 trees. The elevation for each gallery was measured (Figures 10, 15 and 20), giving an indirect assessment of the level of the water table. The heights were measured using a 12m long transparent, plastic pipe filled with water as a level. This had slightly upturned tips and was extended between two subsequent sampling points 10m apart, each of which had vertical scales.

The approach adopted in this survey consisted of the use of PCQ surveys to generate the raw vegetation data. The data were then classified into communities using TWINSPAN giving an objective distinction between vegetation units, the intermediate groups of which were not visually obvious in the field. The groups thus yielded (hereafter referred to as communities) are first examined within each site to assess their relation to any evident environmental factor. This TWINSPAN analysis provides lists of species which occur preferentially in each community, and in addition a separate phytosociological analysis by INFLO (microcomputer package for vegetation analysis) is carried out to characterise the community floristic composition and species density and basal area.

The phytosociological parameters of the communities are compared with those from the total sampling analysis (Chapter 4). Only species with more than 10 trees (1% of the 1000 recorded) in the total sampling are compared. Those showing increases within the community of more than 50% in density and basal area of that scored in the total sampling are indicated as 'related' to it. Other species showing increases from 20-50% are regarded as with a 'tendency' to occur in the community. Finally species showing scores around 80% - 120% of these in the total sampling are considered as indifferent.

When necessary the TWINSPAN second division is used to investigate whether any other consistent pattern becomes clear within the communities indicated in the first analysis. In fact this technique is applied to seek patterns in the vegetation data that could be corroborated by field observations.

Species occurring in similar communities in different sites are compared to check whether their status is consistent. Species density and basal area scores in each community are used as the basis for this comparison.

5.3.- Results.

5.3.1.- Pitoco gallery forest.

Figure 10 shows the communities and elevation profiles along the Pitoco stream. Close to the stream head the bed is 0.5 to 1.0 m deep and supports a wide forest containing sampling lines up to 170 m long. Downstream the river bed becomes shallower and the gallery has little inclination and is much narrower, only permitting sampling lines up to 40m long. The topography of the river valley is quite steep and because of this the dry community occurs as near as 30 m from the stream margins.

Irrespective of forest width, the positions of sampling points of the two groups yielded by TWINSPAN first division revealed a major pattern related to the elevation

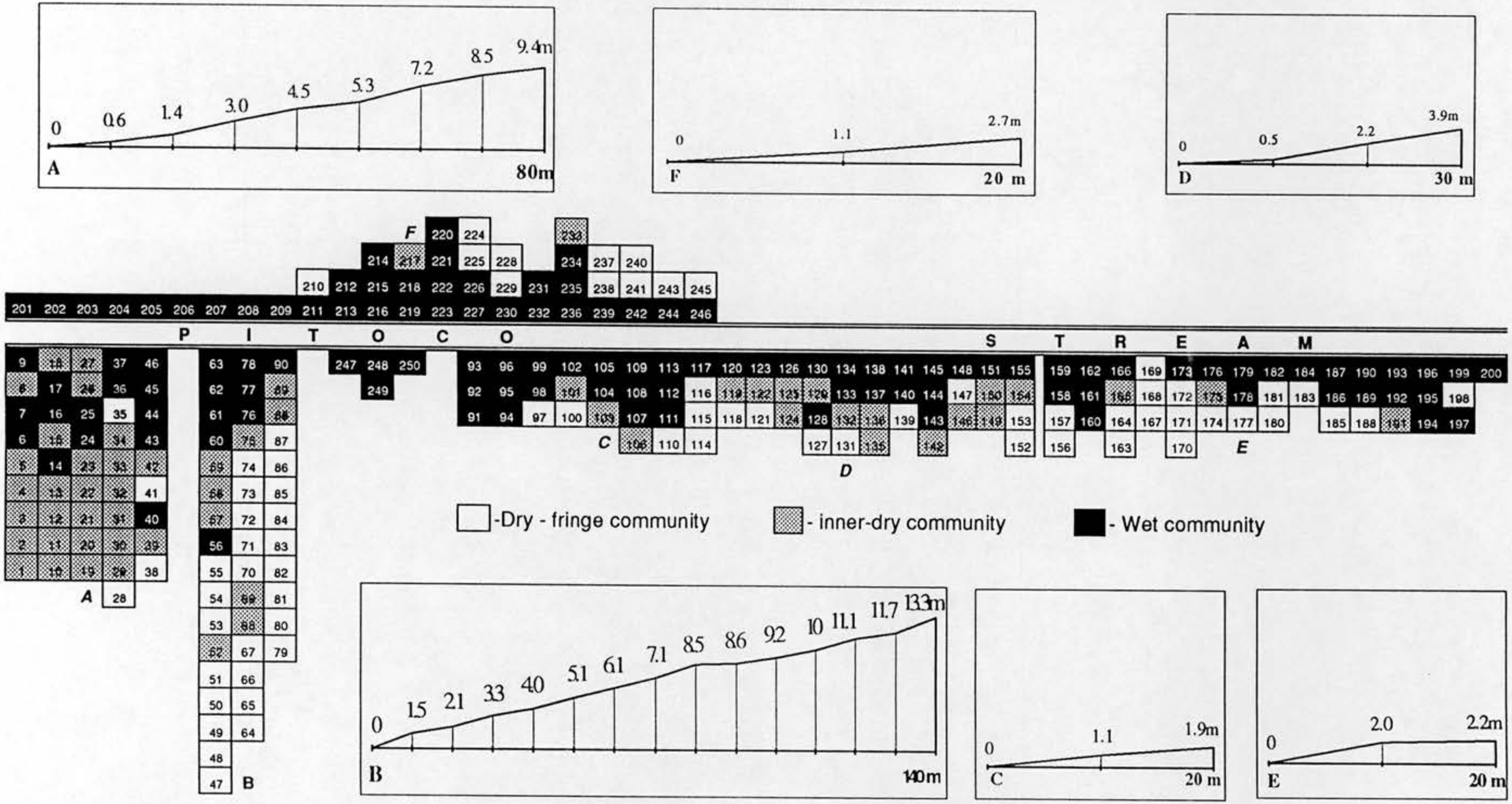


Figure 10 - Tree communities of the Pitoco gallery forest and inclination profiles for each of the sampling areas.

of sites. The division separated 'wet' communities occurring close to the stream bank and 'dry' further upslope.

The dry and wet communities showed a very dissimilar floristic composition, and therefore a further TWINSPAN division was run to try to discover other vegetation groups that could be associated with site features. This division fails to reveal any subgroups in the wet communities, but yields two usable classes in the dry community. These sub-communities are related to slope and distance from the stream bank and are designated as inner-dry and dry-fringe. Details of these communities are given in Tables 6, 7 and 8.

5.3.1.1.- Species related to the dry community.

Callisthene major holds the first position in IVI rank both in the total sampling (see Chapter 4) and in the dry-fringe community. This species has its density and basal area scores tripled in the dry community and reduced to 95 and 98% in the wet community. *Copaifera langsdorffii* is related to the inner-dry community where it has a high density and basal area, but is not recorded in the wet community.

Figures 11 and 12, display density and basal area scores for the following other species: *Lamanonia ternata, Pera glabrata, Platypodium elegans, Guettarda viburnioides* (dry-fringe community) and *Bauhinia rufa, Jacaranda puberula and Matayba guianensis* (inner-dry community).

Eriotheca pubescens, Siphoneugena densiflora and *Xylopia sericea* show a tendency to colonise the dry-fringe community. *Cryptocarya aschersoniana, Cupania vernalis, Maprounea guianensis, Myrcia rostrata* and *Tapura amazonica* have rather lower scores indicating a tendency to occur in the inner-dry community.

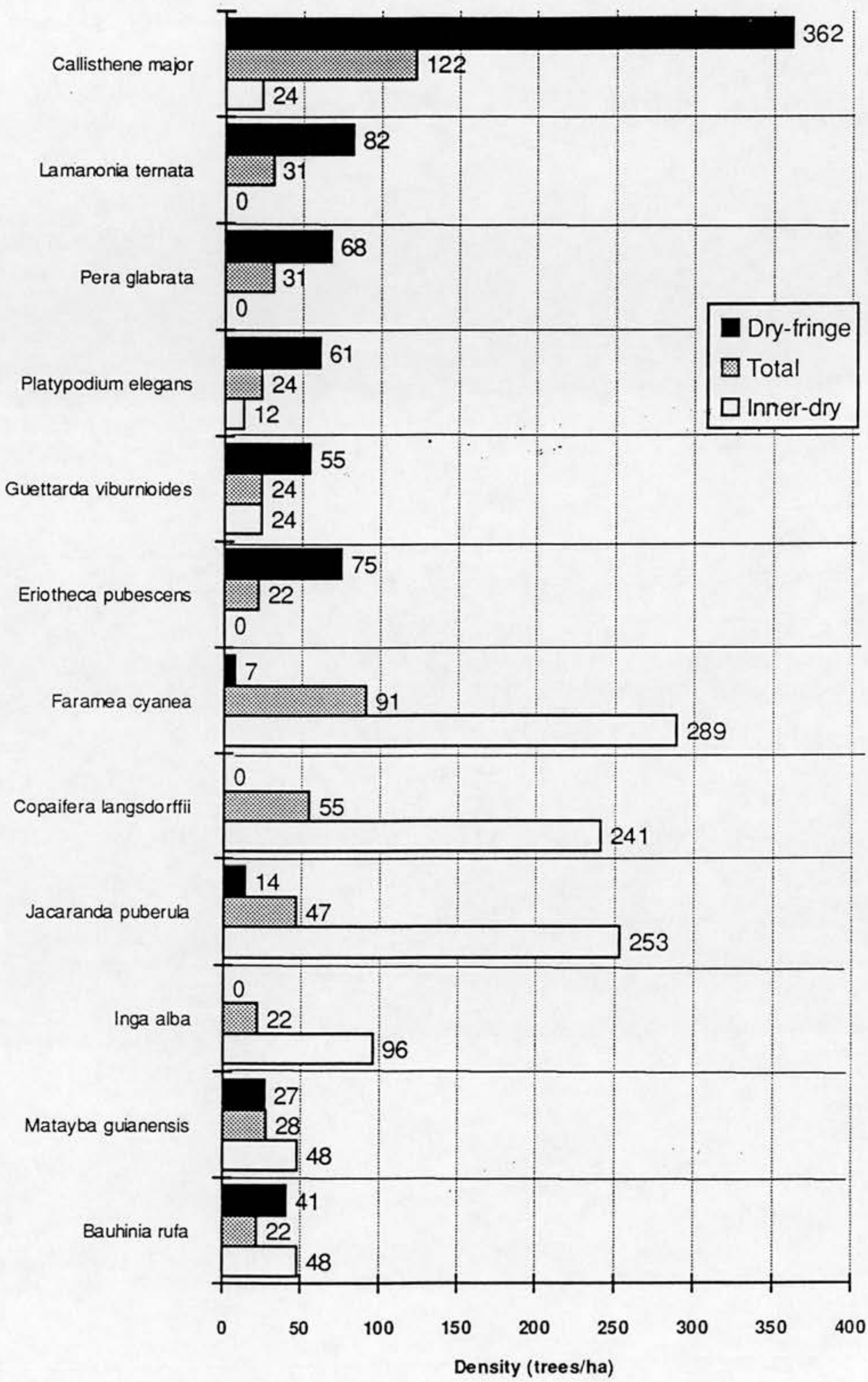


Figure 11- Density values for species of the communities dry-fringe and inner-dry of the Pitoco gallery forest. Scores for total sampling are also displayed for comparison.

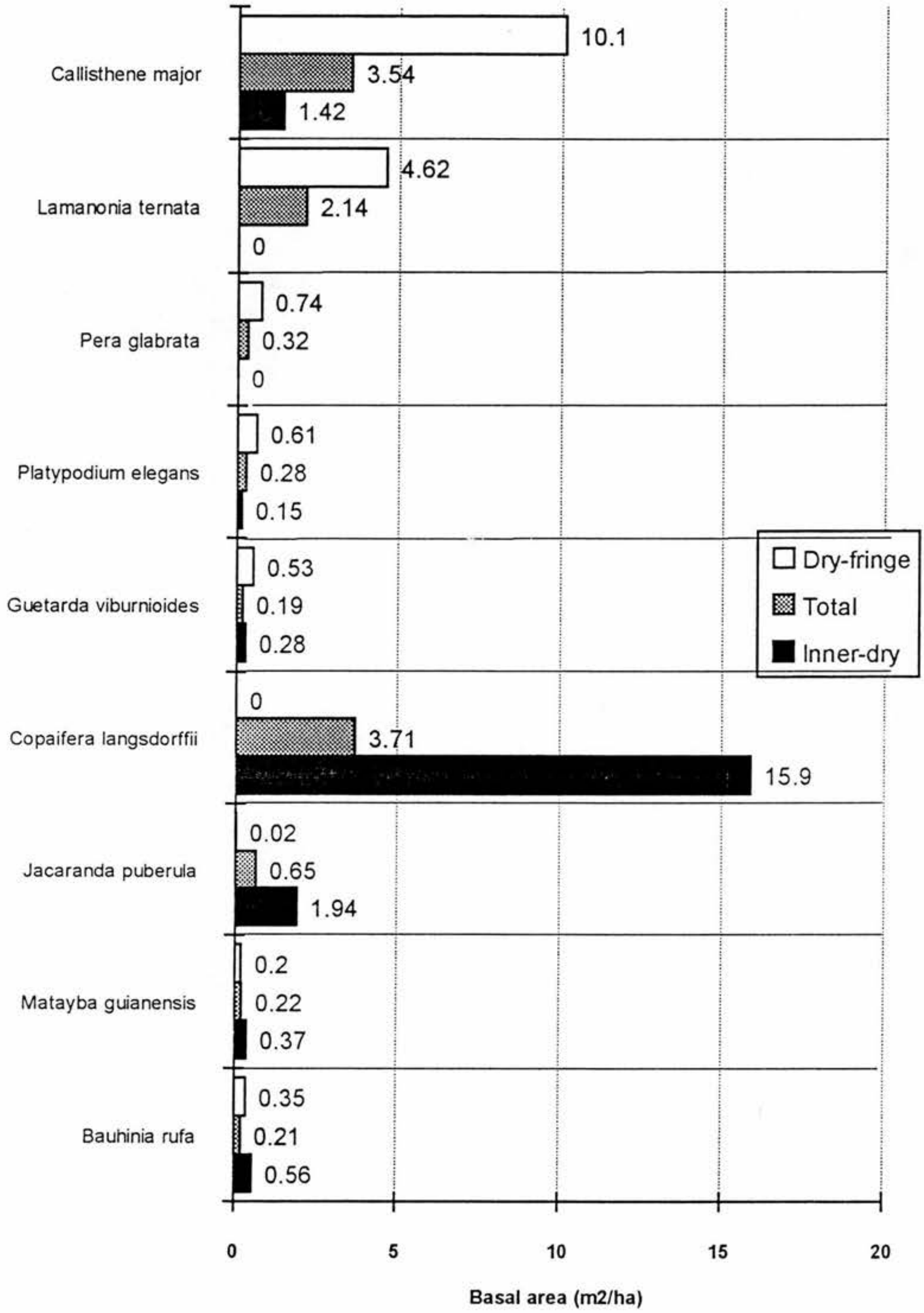


Figure 12- Basal area values for species of the communities dry-fringe and inner-dry within Pitoco gallery forest. Scores for total sampling are also displayed for comparison.

Table 6- Phytosociological parameters for trees recorded in Pitoco dry-fringe community.

	Species	Family	Density		Dominance		Frequency	IVI
			n/ha	%	cm2/ha	%	%	
1	*Callisthene major*	Vochysiaceae	362	20.08	100652	29.46	17.17	66.70
2	Dead Trees		95.62	5.3	43393	12.7	5.15	23.15
3	*Lamanonia ternata*	Cunoniaceae	81.96	4.55	46232	13.53	4.72	22.80
4	*Sclerolobium paniculatum var. rubiginosum*	Leg.-Caesalpinioideae	95.62	5.3	27961	8.18	5.15	18.64
5	*Eriotheca pubescens*	Bombacaceae	75.13	4.17	10728	3.14	4.29	11.60
6	*Tapirira guianensis*	Anacardiaceae	61.47	3.41	11526	3.37	3.86	10.65
7	*Pera glabrata*	Euphorbiaceae	68.3	3.79	7380	2.16	3.43	9.38
8	*Symplocos mosenii*	Symplocaceae	54.64	3.03	9848	2.88	3	8.92
9	*Platypodium elegans*	Leg.-Caesalpinioideae	61.47	3.41	6079	1.78	3	8.19
10	*Guettarda viburnioides*	Rubiaceae	61.47	3.41	3290	0.96	3.43	7.81
11	*Byrsonima laxiflora*	Malpighiaceae	54.64	3.03	5360	1.57	3	7.60
12	*Xylopia emarginata*	Annonaceae	47.81	2.65	6589	1.93	2.15	6.73
13	*Siphoneugena densiflora*	Myrtaceae	40.98	2.27	5858	1.71	2.58	6.56
14	*Copaifera langsdorffii*	Leg.-Caesalpinioideae	27.32	1.52	10596	3.1	1.72	6.33
15	*Bauhinia rufa*	Leg.-Caesalpinioideae	40.98	2.27	3553	1.04	2.58	5.89
16	*Alibertia macrophylla*	Rubiaceae	40.98	2.27	1225	0.36	2.58	5.21
17	*Xylopia sericea*	Annonaceae	40.98	2.27	1796	0.53	2.15	4.94
18	*Matayba guianensis*	Sapindaceae	27.32	1.52	1976	0.58	1.72	3.81
19	*Cupania vernalis*	Sapindaceae	27.32	1.52	1927	0.56	1.72	3.80
20	*Guapira graciliflora*	Nyctaginaceae	27.32	1.52	1516	0.44	1.72	3.68
21	*Jacaranda puberula*	Bignoniaceae	13.66	0.76	5751	1.68	0.86	3.30
22	*Lacistema hassleriana*	Lacistemataceae	27.32	1.52	1350	0.4	1.29	3.20
23	*Virola sebifera*	Myristicaceae	20.49	1.14	2430	0.71	1.29	3.14
24	*Mollinedia oligantha*	Monimiaceae	20.49	1.14	1928	0.56	1.29	2.99
25	*Vochysia tucanorum*	Vochysiaceae	20.49	1.14	1918	0.56	1.29	2.99
26	*Guatteria sellowiana*	Annonaceae	20.49	1.14	1536	0.45	1.29	2.87
27	*Tapura amazonica*	Dichapetalaceae	20.49	1.14	1033	0.3	1.29	2.73
28	*Kielmeyera coriacea*	Guttiferae	20.49	1.14	1201	0.35	0.86	2.35
29	*Terminalia glabrescens*	Combretaceae	13.66	0.76	2233	0.65	0.86	2.27
30	*Symplocos nitens*	Symplocaceae	13.66	0.76	1702	0.5	0.86	2.11
31	*Piptocarpha macropoda*	Compositae	13.66	0.76	1024	0.3	0.86	1.92

Table 6 - cont....

	Species	Family	Density		Dominance		Frequency	IVI
			n/ha	%	cm2/ha	%	%	
32	*Laplacea fruticosa*	Theaceae	13.66	0.76	830	0.24	0.86	1.86
33	*Gomidesia brunea*	Myrtaceae	13.66	0.76	670	0.2	0.86	1.81
34	*Styrax guianensis*	Styracaceae	13.66	0.76	657	0.19	0.86	1.81
35	*Salacia elliptica*	Hippocrateaceae	13.66	0.76	649	0.19	0.86	1.81
36	*Cordia sellowiana*	Boraginaceae	13.66	0.76	580	0.17	0.86	1.79
37	*Schefflera morototoni*	Araliaceae	13.66	0.76	495	0.14	0.86	1.76
38	*Cybianthus gardinerii*	Myrsinaceae	13.66	0.76	331	0.1	0.86	1.71
39	*Myrsine umbellata*	Myrsinaceae	13.66	0.76	327	0.1	0.86	1.71
40	*Qualea dichotoma*	Vochysiaceae	6.83	0.38	2040	0.6	0.43	1.41
41	*Lafoensia pacari*	Lythraceae	6.83	0.38	1777	0.52	0.43	1.33
42	*Emmotum nitens*	Icacinaceae	6.83	0.38	1097	0.32	0.43	1.13
43	*Richeria obovata*	Euphorbiaceae	6.83	0.38	454	0.13	0.43	0.94
44	*Sorocea guilleminiana*	Moraceae	6.83	0.38	415	0.12	0.43	0.93
45	*Ocotea pomaderoides*	Lauraceae	6.83	0.38	302	0.09	0.43	0.9
46	*Ouratea cataneaefolia*	Ochnaceae	6.83	0.38	278	0.08	0.43	0.89
47	*Miconia pepericarpa*	Melatomataceae	6.83	0.38	213	0.06	0.43	0.87
48	*Faramea cyanea*	Rubiaceae	6.83	0.38	193	0.06	0.43	0.86
49	*Ilex integrifolia*	Aquifoliaceae	6.83	0.38	193	0.06	0.43	0.86
50	*Coussarea hydrangeaefolia*	Rubiaceae	6.83	0.38	168	0.05	0.43	0.86
51	*Ocotea spixiana*	Lauraceae	6.83	0.38	140	0.04	0.43	0.85
52	*Dimorphandra mollis*	Leg- Mimosoideae	6.83	0.38	140	0.04	0.43	0.85
53	*Myrcia rostrata*	Myrtaceae	6.83	0.38	134	0.04	0.43	0.85
	Totals		1803 ind/ha	100%	341,674 cm2/ha	100%	100%	300%

Table 7- Phytosociological parameters for trees recorded in the Pitoco inner-dry community.

	Species	Family	Density n/ha	%	Dominance cm2/ha	%	Frequency %	IVI
1	*Copaifera langsdorffii*	Leg.-Caesalpinioideae	240.63	10.64	159046	38.07	10.29	59
2	*Faramea cyanea*	Rubiaceae	288.76	12.77	19358	4.63	12.57	29.97
3	*Jacaranda puberula*	Bignoniaceae	252.66	11.17	36305	8.69	9.71	29.58
4	Dead Trees		84.22	3.72	18096	4.33	4	12.06
5	*Maprounea guianensis*	Euphorbiaceae	72.19	3.19	19317	4.62	3.43	11.24
6	*Sclerolobium paniculatum var. rubiginosum*	Leg.-Caesalpinioideae	84.22	3.72	14798	3.54	3.43	10.69
7	*Inga alba*	Leg- Mimosoideae	96.25	4.26	5768	1.38	4.57	10.21
8	*Tapirira guianensis*	Anacardiaceae	60.16	2.66	8439	2.02	2.29	6.97
9	*Myrcia rostrata*	Myrtaceae	60.16	2.66	5534	1.32	2.86	6.84
10	*Ocotea corymbosa*	Lauraceae	48.13	2.13	9986	2.39	1.71	6.23
11	*Tapura amazonica*	Dichapetalaceae	60.16	2.66	4487	1.07	2.29	6.02
12	*Bauhinia rufa*	Leg.-Caesalpinioideae	48.13	2.13	5654	1.35	2.29	5.77
13	*Callisthene major*	Vochysiaceae	24.06	1.06	14163	3.39	1.14	5.6
14	*Cryptocarya aschersoniana*	Lauraceae	48.13	2.13	2817	0.67	2.29	5.09
15	*Matayba guianensis*	Sapindaceae	48.13	2.13	3695	0.88	1.71	4.73
16	*Qualea multiflora*	Vochysiaceae	24.06	1.06	10103	2.42	1.14	4.63
17	*Hymenaea coubaril*	Leg.-Caesalpinioideae	36.1	1.6	5036	1.21	1.71	4.52
18	*Schefflera morototoni*	Araliaceae	36.1	1.6	4550	1.09	1.71	4.4
19	*Terminalia glabrescens*	Combretaceae	36.1	1.6	3630	0.87	1.71	4.18
20	*Piptocarpha macropoda*	Compositae	36.1	1.6	3207	0.77	1.71	4.08
21	*Ocotea pommaderoides*	Lauraceae	24.06	1.06	7252	1.74	1.14	3.94
22	*Cupania vernalis*	Sapindaceae	36.1	1.6	2062	0.49	1.71	3.8
23	*Guatteria sellowiana*	Annonaceae	36.1	1.6	1446	0.35	1.71	3.66
24	*Licania apetala*	Chrysobalanaceae	24.06	1.06	5683	1.36	1.14	3.57
25	*Guettarda viburnioides*	Rubiaceae	24.06	1.06	5328	1.28	1.14	3.48
26	*Diospyros hispida*	Ebenaceae	24.06	1.06	1770	0.42	1.14	2.63
27	*Lacistema hassleriana*	Lacistemataceae	24.06	1.06	1629	0.39	1.14	2.6
28	*Cheiloclinium cognatum*	Hippocrateaceae	24.06	1.06	1290	0.31	1.14	2.52
29	*Casearia sylvestris*	Flacourtiaceae	24.06	1.06	1200	0.29	1.14	2.49
30	*Cardiopetalum calophyllum*	Annonaceae	24.06	1.06	752	0.18	1.14	2.39
31	*Amaioua guianensis*	Rubiaceae	12.03	0.53	4784	1.15	0.57	2.25

Table 7 - cont....

	Species	Family	Density n/ha	%	Dominance cm2/ha	%	Frequency %	IVI
32	*Sacoglottis guianensis*	Humiriaceae	12.03	0.53	4287	1.03	0.57	2.13
33	*Protium almecega*	Burseraceae	12.03	0.53	3780	0.9	0.57	2.01
34	*Vitex polygama*	Verbenaceae	12.03	0.53	3269	0.78	0.57	1.89
35	*Erythroxylum sp.*	Erythroxylaceae	12.03	0.53	2126	0.51	0.57	1.61
36	*Dalbergia densiflora*	Leg.-Caesalpinioideae	12.03	0.53	2042	0.49	0.57	1.59
37	*Ocotea spixiana*	Lauraceae	12.03	0.53	1697	0.41	0.57	1.51
38	*Tibouchina candolleana*	Melastomataceae	12.03	0.53	1524	0.36	0.57	1.47
39	*Lamanonia ternata*	Cunoniaceae	12.03	0.53	1477	0.35	0.57	1.46
40	*Platypodium elegans*	Leg- Faboideae	12.03	0.53	1477	0.35	0.57	1.46
41	*Eugenia uruguaiensis*	Myrtaceae	12.03	0.53	1102	0.26	0.57	1.37
42	*Styrax guianensis*	Styracaceae	12.03	0.53	853	0.2	0.57	1.31
43	*Vochysia tucanorum*	Vochysiaceae	12.03	0.53	853	0.2	0.57	1.31
44	*Cyibianthus gardinerri*	Myrsinaceae	12.03	0.53	853	0.2	0.57	1.31
45	*Ocotea aciphylla*	Lauraceae	12.03	0.53	765	0.18	0.57	1.29
46	*Cecropia lyratiloba*	Moraceae	12.03	0.53	699	0.17	0.57	1.27
47	*Salacia elliptica*	Hippocrateaceae	12.03	0.53	605	0.14	0.57	1.25
48	*Pouteria ramiflora*	Sapotaceae	12.03	0.53	590	0.14	0.57	1.24
49	*Siphoneugena densiflora*	Myrtaceae	12.03	0.53	463	0.11	0.57	1.21
50	*Siparuna guianensis*	Monimiaceae	12.03	0.53	399	0.1	0.57	1.2
51	*Calophyllum brasiliensis*	Guttiferae	12.03	0.53	363	0.09	0.57	1.19
52	*Xylopia sericea*	Annonaceae	12.03	0.53	363	0.09	0.57	1.19
53	*Aspidosperma spruceanum*	Apocynaceae	12.03	0.53	246	0.06	0.57	1.16
54	*Myrsine coriacea*	Myrsinaceae	12.03	0.53	236	0.06	0.57	1.16
55	*Miconia sellowiana*	Melastomataceae	12.03	0.53	236	0.06	0.57	1.16
56	*Cordia sellowiana*	Boraginaceae	12.03	0.53	236	0.06	0.57	1.16
	Totals		2262 ind/ha	100%	417727 cm2/ha	100%	100%	300%

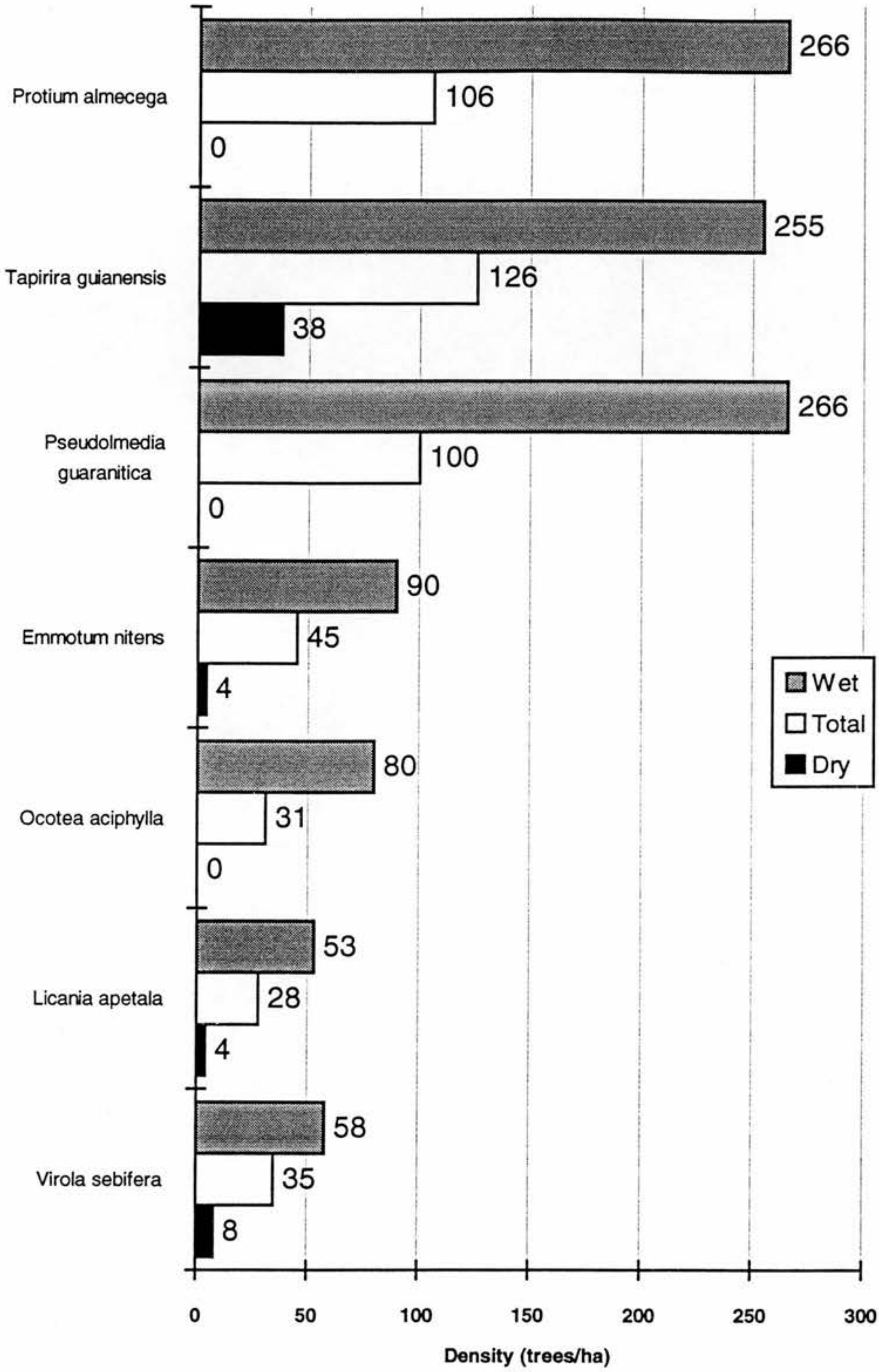


Figure 13- Density values for species of the wet community of the Pitoco gallery forest. Scores for total sampling and the dry community are also displayed for comparison.

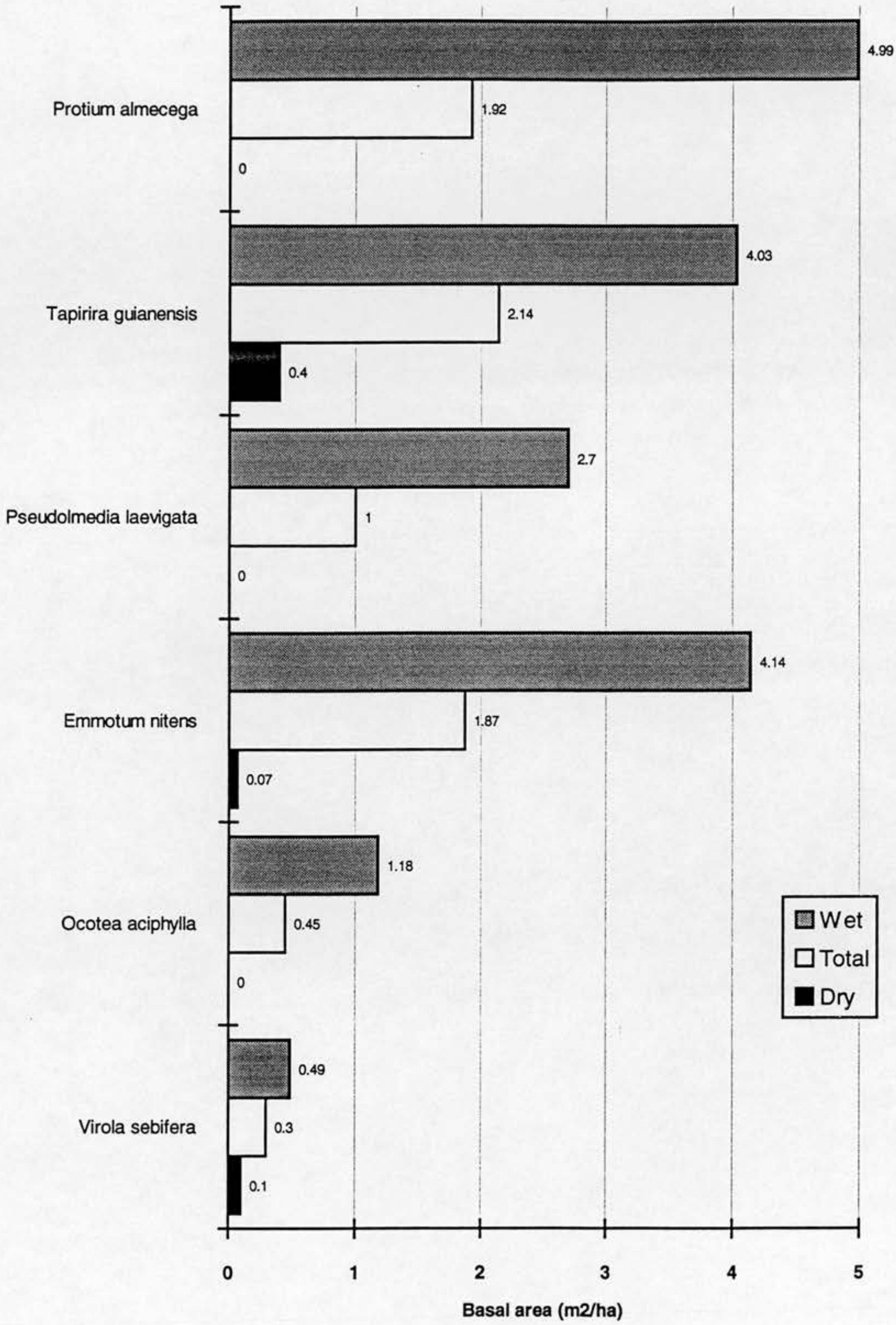


Figure 14- Basal area values for species of the wet community of Pitoco gallery forest. Scores for total sampling and the dry community are also displayed for comparison.

	Species	Family	Density		Dominance		Frequency	IVI
			n/ha	%	cm2/ha	%	%	
1	*Protium almecega*	Burseraceae	266.11	13.44	49894	13.12	12.8	39.36
2	*Tapirira guianensis*	Anacardiaceae	255.46	12.9	40318	10.6	10.67	34.17
3	*Pseudolmedia guaranitica*	Moraceae	266.11	13.44	26963	7.09	12.5	33.03
4	*Emmotum nitens*	Icacinaceae	90.48	4.57	41379	10.88	4.57	20.02
5	Dead Trees		79.83	4.03	14599	3.84	4.27	12.14
6	*Ocotea aciphylla*	Lauraceae	79.83	4.03	11837	3.11	4.57	11.72
7	*Maprounea guianensis*	Euphorbiaceae	42.58	2.15	18508	4.87	2.13	9.15
8	*Richeria obovata*	Euphorbiaceae	26.61	1.34	22990	6.05	1.52	8.91
9	*Licania apetala*	Chrysobalanaceae	53.22	2.69	11708	3.08	2.44	8.21
10	*Sclerolobium paniculatum var. rubiginosum*	Leg.-Caesalpinioideae	37.26	1.88	15318	4.03	2.13	8.04
11	*Faramea cyanea*	Rubiaceae	58.54	2.96	5119	1.35	3.35	7.66
12	*Virola sebifera*	Myristicaceae	58.54	2.96	4924	1.29	3.05	7.3
13	*Ocotea spixiana*	Lauraceae	31.93	1.61	11247	2.96	1.83	6.4
14	*Byrsonima laxiflora*	Malpighiaceae	47.9	2.42	5452	1.43	2.13	5.99
15	*Schefflera morototoni*	Araliaceae	42.58	2.15	6291	1.65	2.13	5.94
16	*Xylopia emarginata*	Annonaceae	42.58	2.15	4529	1.19	2.44	5.78
17	*Tapura amazonica*	Dichapetalaceae	42.58	2.15	4161	1.09	2.44	5.68
18	*Hirtella glandulosa*	Chrysobalanaceae	26.61	1.34	8675	2.28	1.52	5.15
19	*Symplocos mosenii*	Symplocaceae	21.29	1.08	10619	2.79	1.22	5.09
20	*Cheiloclinium cognatum*	Hippocrateaceae	37.26	1.88	5225	1.37	1.83	5.08
21	*Xylopia sericea*	Annonaceae	26.61	1.34	5392	1.42	1.52	4.29
22	*Sacoglottis guianensis*	Humiriaceae	21.29	1.08	5738	1.51	0.91	3.5
23	*Micropholis rigida*	Sapotaceae	21.29	1.08	2955	0.78	1.22	3.07
24	*Virola urbaniana*	Myristicaceae	5.32	0.27	9273	2.44	0.3	3.01
25	*Myrcia rostrata*	Myrtaceae	21.29	1.08	1940	0.51	1.22	2.8
26	*Cryptocarya aschersoniana*	Lauraceae	21.29	1.08	1687	0.44	1.22	2.74
27	*Guatteria sellowiana*	Annonaceae	15.97	0.81	3475	0.91	0.91	2.63
28	*Cecropia lyratiloba*	Moraceae	21.29	1.08	1154	0.3	1.22	2.6
29	*Cybianthus gardnerii*	Myrsinaceae	21.29	1.08	2196	0.58	0.91	2.57
30	*Mollinedia oligantha*	Monimiaceae	15.97	0.81	3013	0.79	0.91	2.51
31	*Gomidesia brunea*	Myrtaceae	21.29	1.08	1889	0.5	0.91	2.49

Table 8- cont.

	Species	Family	Density		Dominance		Frequency	IVI
			n/ha	%	cm2/ha	%	%	
32	*Siphoneugena densiflora*	Myrtaceae	15.97	0.81	701	0.18	0.91	1.91
33	*Ocotea corymbosa*	Lauraceae	10.64	0.54	1872	0.49	0.61	1.64
34	*Inga alba*	Leg.-Mimosoideae	10.64	0.54	1666	0.44	0.61	1.59
35	*Lamanonia ternata*	Cunoniaceae	5.32	0.27	3207	0.84	0.3	1.42
36	*Ferdinandusa speciosa*	Rubiaceae	10.64	0.54	415	0.11	0.61	1.26
37	*Siparuna guianensis*	Monimiaceae	10.64	0.54	400	0.11	0.61	1.25
38	*Qualea dichotoma*	Vochysiaceae	5.32	0.27	2328	0.61	0.3	1.19
39	*Pouteria ramiflora*	Sapotaceae	5.32	0.27	2308	0.61	0.3	1.18
40	*Aniba herringerii*	Lauraceae	5.32	0.27	2060	0.54	0.3	1.12
41	*Simarouba versicolor*	Simaroubaceae	5.32	0.27	1280	0.34	0.3	0.91
42	*Matayba guianensis*	Sapindaceae	5.32	0.27	1070	0.28	0.3	0.86
43	*Psidium longipetiolatum*	Myrtaceae	5.32	0.27	808	0.21	0.3	0.79
44	*Callisthene major*	Vochysiaceae	5.32	0.27	751	0.2	0.3	0.77
45	*Vochysia tucanorum*	Vochysiaceae	5.32	0.27	612	0.16	0.3	0.73
46	*Diospyros hispida*	Ebenaceae	5.32	0.27	470	0.12	0.3	0.7
47	*Amaioua guianensis*	Rubiaceae	5.32	0.27	443	0.12	0.3	0.69
48	*Miconia cuspidata*	Melastomataceae	5.32	0.27	339	0.09	0.3	0.66
49	*Miconia chartacea*	Melastomataceae	5.32	0.27	235	0.06	0.3	0.64
50	*Miconia sellowiana*	Melastomataceae	5.32	0.27	193	0.05	0.3	0.62
51	*Dalbergia densiflora*	Leg.-Faboideae	5.32	0.27	161	0.04	0.3	0.62
52	*Myrcia tomentosa*	Myrtaceae	5.32	0.27	156	0.04	0.3	0.61
53	*Miconia pepericarpa*	Melastomataceae	5.32	0.27	136	0.04	0.3	0.61
54	*Guarea guidonia*	Meliaceae	5.32	0.27	131	0.03	0.3	0.61
55	*Andira vermifuga*	Leg.-Faboideae	5.32	0.27	109	0.03	0.3	0.6
	Totals		1980 ind/ha	100%	380,316 cm2/ha	100%	100%	300%

5.3.1.2.- Species related to the wet community.

Protium almecega is ranked as the third most important species in the total sampling (see Chapter 4), and reaches the highest IVI in the wet community. Its density and basal area score is 2.5 times higher in the wet community than in the total sampling, with no records in the dry community. Other species related to the community are: *Tapirira guianensis, Pseudolmedia guaranitica, Emmotum nitens, Ocotea aciphylla, Licania apetala* and *Virola sebifera.*

Species with lower increases, but still showing a tendency to occur in the wet community are: *Richeria obovata, Ocotea spixiana* and *Cheiloclinium cognatum* (see Figures 13 and 14).

5.3.1.3.- Indifferent species.

Species with approximately similar density and basal area scores in all communities are classified as indifferent. Within Pitoco *Byrsonima laxiflora* and *Symplocos mosenii* fall into this category.

The differences in species density and basal area within the Pitoco gallery are considered as indicative of significant environmental preferences characterising distinct plant communities. Topography and consequent soil moisture differences seem to be the most important factors in floristic and structural variation. A complementary study on the soil physicochemical characteristics of the communities is considered to offer valuable evidence. This is addressed in Chapters 7, 8 and 9.

5.3.2.- Monjolo gallery forest.

Figure 15 shows the sampling points, their community classification and elevation profiles on the Monjolo stream. A flat stream head area is cut by a stream

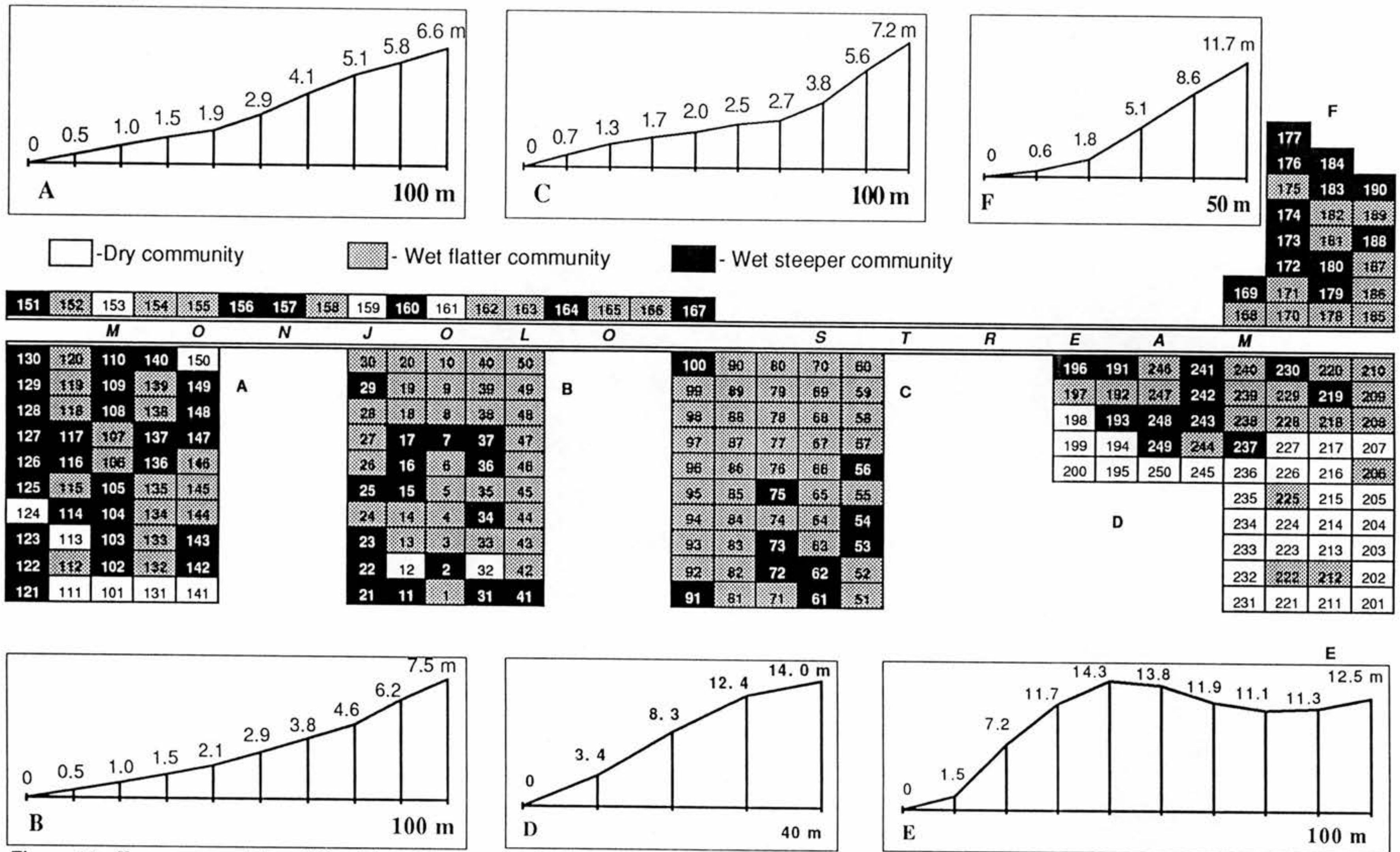


Figure 15 - Tree communities of Monjolo gallery forest and inclination profiles for each of the sampling areas.

bed approximately 1.5m deep. As one goes downstream the sides of the valley become somewhat steeper. The gallery forest is of fairly constant breadth and was sampled along lines up to 100m long. In contrast to the Pitoco site, the Monjolo gallery is under strong high water-table influence and the great majority of sampling points are classified as wet communities. The dry community is found almost exclusively on a steep slope separating the upper sites from the stream bank area. In flatter sites it only occurs on the forest-cerrado border.

Undoubtedly the principal cause of the very strong TWINSPAN first division is the contrast of the much 'wetter' community of the flatter topography with the drier community. As in the other galleries, 'dry' and 'wet' are used to designate the two communities.

The phytosociological analysis of the dry community (Table 9) resulted in the identification of a distinct floristic group where species show density and basal area increases up to nine times higher than in the total sampling. Such species show low values for moist sites. The number of sampling points classified in this group (43) is insufficient to consider further TWINSPAN divisions.

Species classified as preferring the wet community do not show any significant increases or decreases in their density and basal area scores when compared with the figures for the total sampling. Because of the lack of significance of this result a further TWINSPAN division was made. This demonstrates occurrence of communities showing differences when compared with the total sampling (Chapter 4). They are recognised as related to steeper sites around the stream head area, referred to as the wet-steeper community, and at the intermediate flatter portion of the sampling area, named the wet-flatter community, (Figure 15). Again site elevation and the inferred differential soil moisture regime seem to be the main environmental determinants of the different three communities. The phytosociological characteristics of the wet-flatter and wet-steeper communities are shown in Tables 10 and 11 respectively.

5.3.2.1.- Species related to the dry community.

The phytosociological analysis includes 43 sampling points (172 trees). *Copaifera langsdorffii*, which is ranked as the sixth most important species in the total sampling, assumed the first importance showing seven-fold increases for its density and five-fold for its basal area scores over those of the total sampling. Even more impressive, *Callisthene major* and *Platypodium elegans* show over nine-fold increases. Results for other community-related species, *Jacaranda puberula, Matayba guianensis* and *Myrsine coriacea,* together with their poor representation and low growth within the wet community (Figures 16 and 17) support the presence of a conspicuous community associated with the drier upper sites within Monjolo.

Another group of species, showing lower increases in their phytosociological parameters, is recognised with the 'tendency' to colonise the dry community and included *Byrsonima laxiflora* and *Sacoglottis guianensis*.

5.3.2.2.- Species related to the wet communities.

Differences in the density and basal area of the most important species between the steeper and flatter wet communities occur and are displayed in Figures 18 and 19.

Licania apetala is the most important species within the wet-flatter community and reached the fourth position in the total sampling (see Chapter 4). Other species characteristic of this community are *Cryptocarya aschersoniana, Miconia cuspidata, Aspidosperma subincanum, Cheiloclinium cognatum, Amaioua guianensis, Pouteria ramiflora, Pseudolmedia guaranitica* and *Salacia elliptica.*

A tendency to colonise the wet-flatter community is displayed by *Guatteria sellowiana, Maprounea guianensis, Piptocarpha macropoda* and *Protium almecega.*

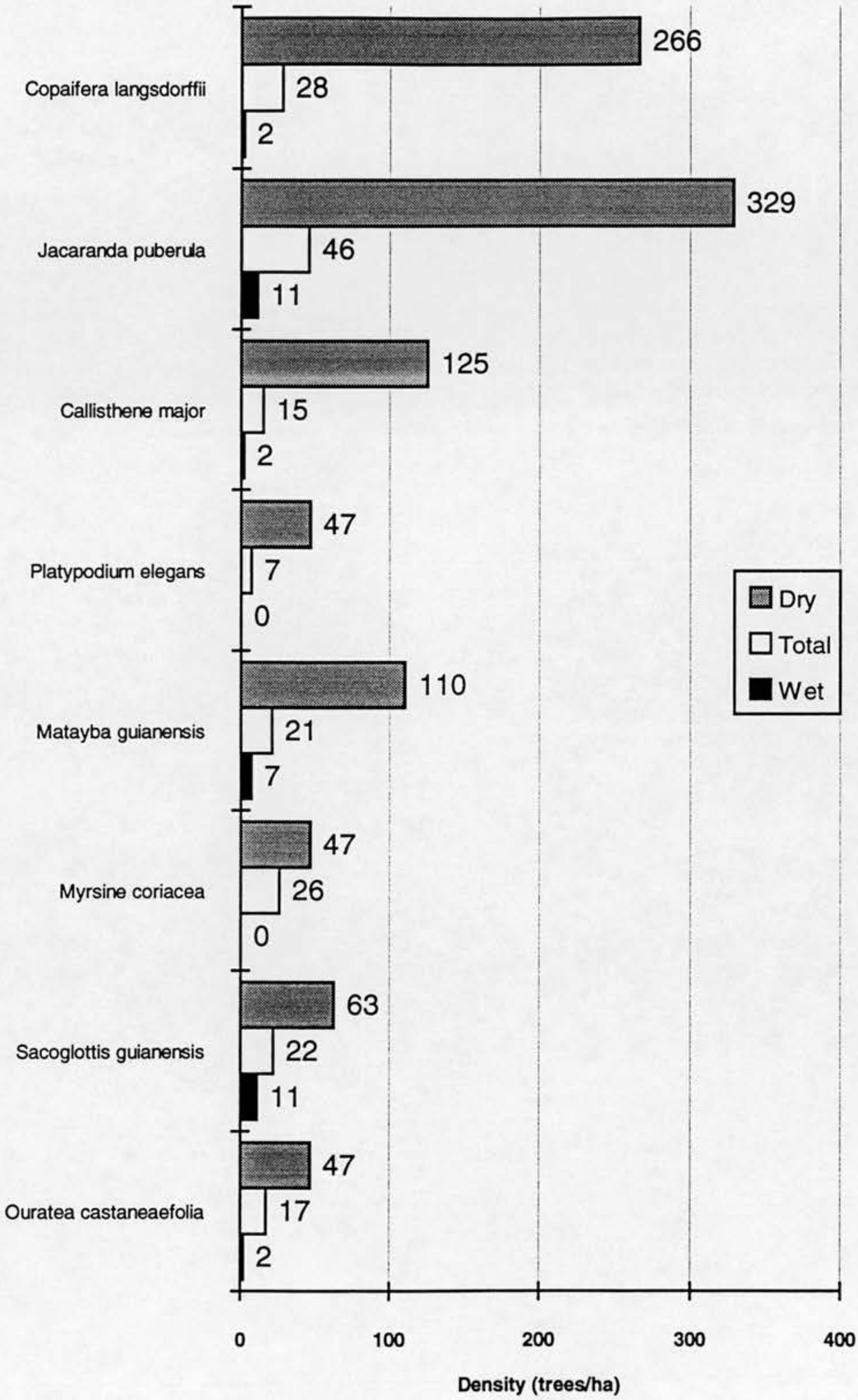


Figure 16- Density values for species of the dry community within the Monjolo gallery forest. Scores for the total sampling and the wet community are also displayed for comparison.

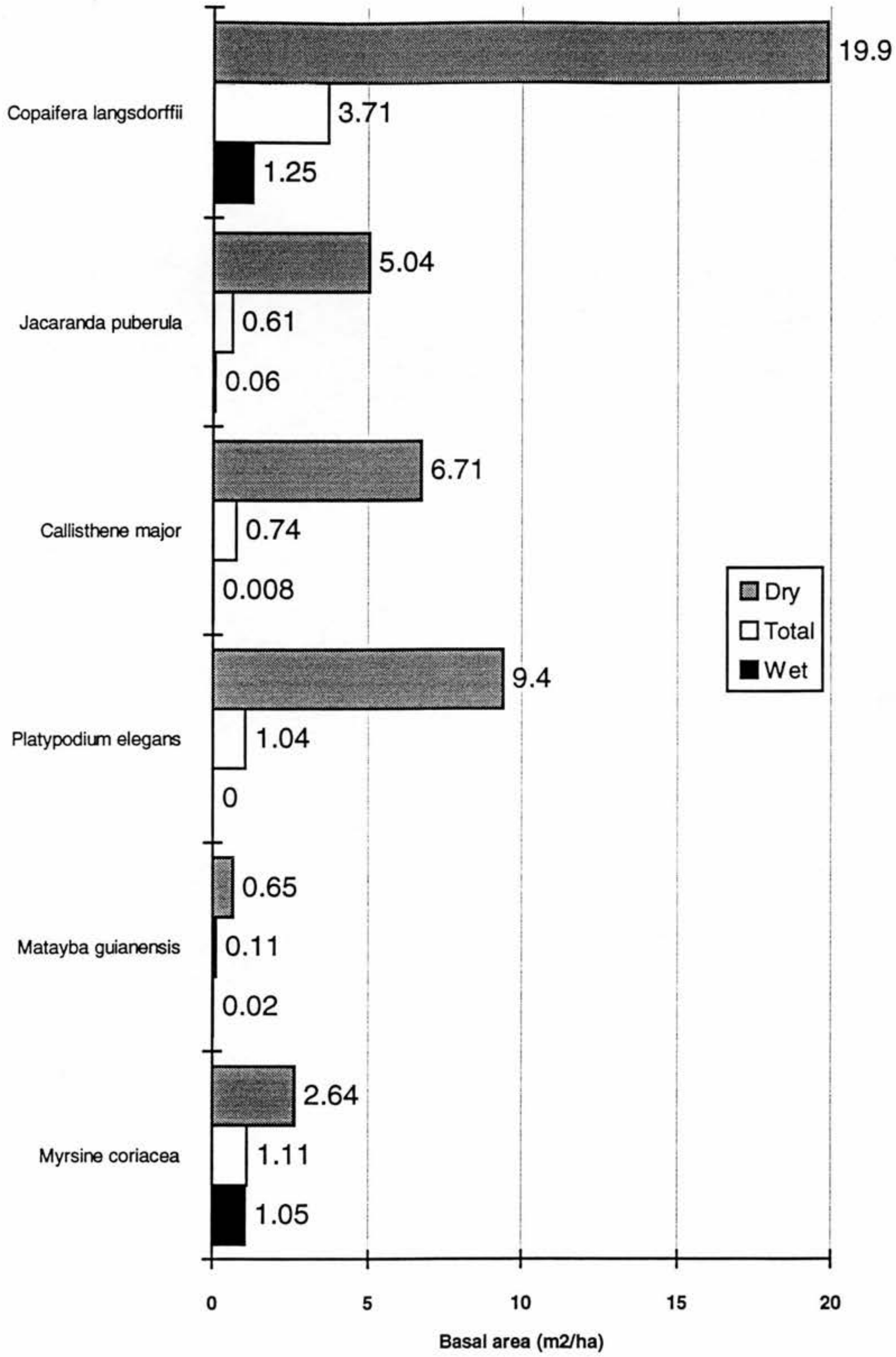


Figure 17- Basal area values for species of the dry community of the Monjolo gallery forest. Scores for the total sampling and the wet community are also displayed for comparison.

Table 9 - Phytosociological parameters for trees recorded in the Monjolo dry community.

	Species	Family	Density		Dominance		Frequency	IVI
			n/ha	%	cm/ha	%	%	
1	*Copaifera langsdorffii*	Leg.-Caesalpinioideae	266.51	14.66	198557	35.38	14.00	64.04
2	*Jacaranda puberula*	Bignoniaceae	329.21	18.1	50364	8.98	13.00	40.08
3	*Callisthene major*	Vochysiaceae	125.41	6.9	67117	11.96	7.00	25.86
4	*Platypodium elegans*	Leg.-Caesalpinioideae	47.03	2.59	94015	16.75	1.00	20.34
5	*Matayba guianensis*	Sapindaceae	109.74	6.03	6473	1.15	6.00	13.19
6	*Myrsine coriacea*	Myrsinaceae	47.03	2.59	26381	4.7	2.00	9.29
7	*Sacoglottis guianensis*	Humiriaceae	62.71	3.45	9971	1.78	4.00	9.23
8	*Machaerium acutifolium*	Leg.-Faboideae	62.71	3.45	4324	0.77	4.00	8.22
9	*Tapirira guianensis*	Anacardiaceae	47.03	2.59	13037	2.32	3.00	7.91
10	Dead trees		47.03	2.59	5040	0.9	3.00	6.48
11	*Lamanonia ternata*	Cunoniaceae	15.68	0.86	25827	4.6	1.00	6.46
12	*Ouratea castaneaefolia*	Ochnaceae	47.03	2.59	4487	0.8	3.00	6.39
13	*Terminalia argentea*	Combretaceae	47.03	2.59	1923	0.34	3.00	5.93
14	*Machaerium aculeatum*	Leg.-Faboideae	31.35	1.72	3177	0.57	2.00	4.29
15	*Cordia sellowiana*	Boraginaceae	31.35	1.72	2564	0.46	2.00	4.18
16	*Byrsonima laxiflora*	Malpighiaceae	31.35	1.72	2488	0.44	2.00	4.17
17	*Diospyros hispida*	Ebenaceae	31.35	1.72	2117	0.38	2.00	4.1
18	*Cheiloclinium cognatum*	Hippocrateaceae	31.35	1.72	1419	0.25	2.00	3.98
19	*Myrcia rostrata*	Myrtaceae	31.35	1.72	828	0.15	2.00	3.87
20	*Qualea dichotoma*	Vochysiaceae	15.68	0.86	10570	1.88	1.00	3.75
21	*Symplocos mosenii*	Symplocaceae	15.68	0.86	5276	0.94	1.00	2.8
22	*Nectandra mollis*	Lauraceae	15.68	0.86	4214	0.75	1.00	2.61
23	*Andira vermifuga*	Leg.-Faboideae	15.68	0.86	3231	0.58	1.00	2.44
24	*Gomidesia brunea*	Myrtaceae	15.68	0.86	2413	0.43	1.00	2.29
25	*Casearia sylvestris*	Flacourtiaceae	15.68	0.86	1803	0.32	1.00	2.18
26	*Blepharocalyx salicifolius*	Myrtaceae	15.68	0.86	1714	0.31	1.00	2.17

Table 9 - cont...

	Species	Family	Density		Dominance		Frequency	IVI
			n/ha	%	cm/ha	%	%	
27	*Astronium fraxinifolium*	Anacardiaceae	15.68	0.86	1714	0.31	1.00	2.17
28	*Faramea cyanea*	Rubiaceae	15.68	0.86	1281	0.23	1.00	2.09
29	*Aspidosperma cylindrocarpon*	Apocynaceae	15.68	0.86	1281	0.23	1.00	2.09
30	*Tabebuia serratifolia*	Bignoniaceae	15.68	0.86	1020	0.18	1.00	2.04
31	*Schefflera morototoni*	Araliaceae	15.68	0.86	711	0.13	1.00	1.99
32	*Ocotea aciphylla*	Lauraceae	15.68	0.86	656	0.12	1.00	1.98
33	*Siphoneugena densiflora*	Myrtaceae	15.68	0.86	603	0.11	1.00	1.97
34	*Terminalia glabrescens*	Combretaceae	15.68	0.86	603	0.11	1.00	1.97
35	*Guatteria sellowiana*	Annonaceae	15.68	0.86	569	0.1	1.00	1.96
36	*Salacia elliptica*	Hippocrateaceae	15.68	0.86	553	0.1	1.00	1.96
37	*Sclerolobium paniculatum var. rubiginosum*	Leg.-Caesalpinioideae	15.68	0.86	504	0.09	1.00	1.95
38	*Virola sebifera*	Myristicaceae	15.68	0.86	443	0.08	1.00	1.94
39	*Sclerolobium aureum*	Leg.-Caesalpinioideae	15.68	0.86	429	0.08	1.00	1.94
40	*Tapura amazonica*	Dichapetalaceae	15.68	0.86	400	0.07	1.00	1.93
41	*Piptocarpha macropoda*	Compositae	15.68	0.86	359	0.06	1.00	1.93
42	*Myrcia tomentosa*	Myrtaceae	15.68	0.86	359	0.06	1.00	1.93
43	*Amaioua guianensis*	Rubiaceae	15.68	0.86	320	0.06	1.00	1.92
	Totals		1818 ind/ha	100%	561,137 cm2/ha	100%	100%	300%

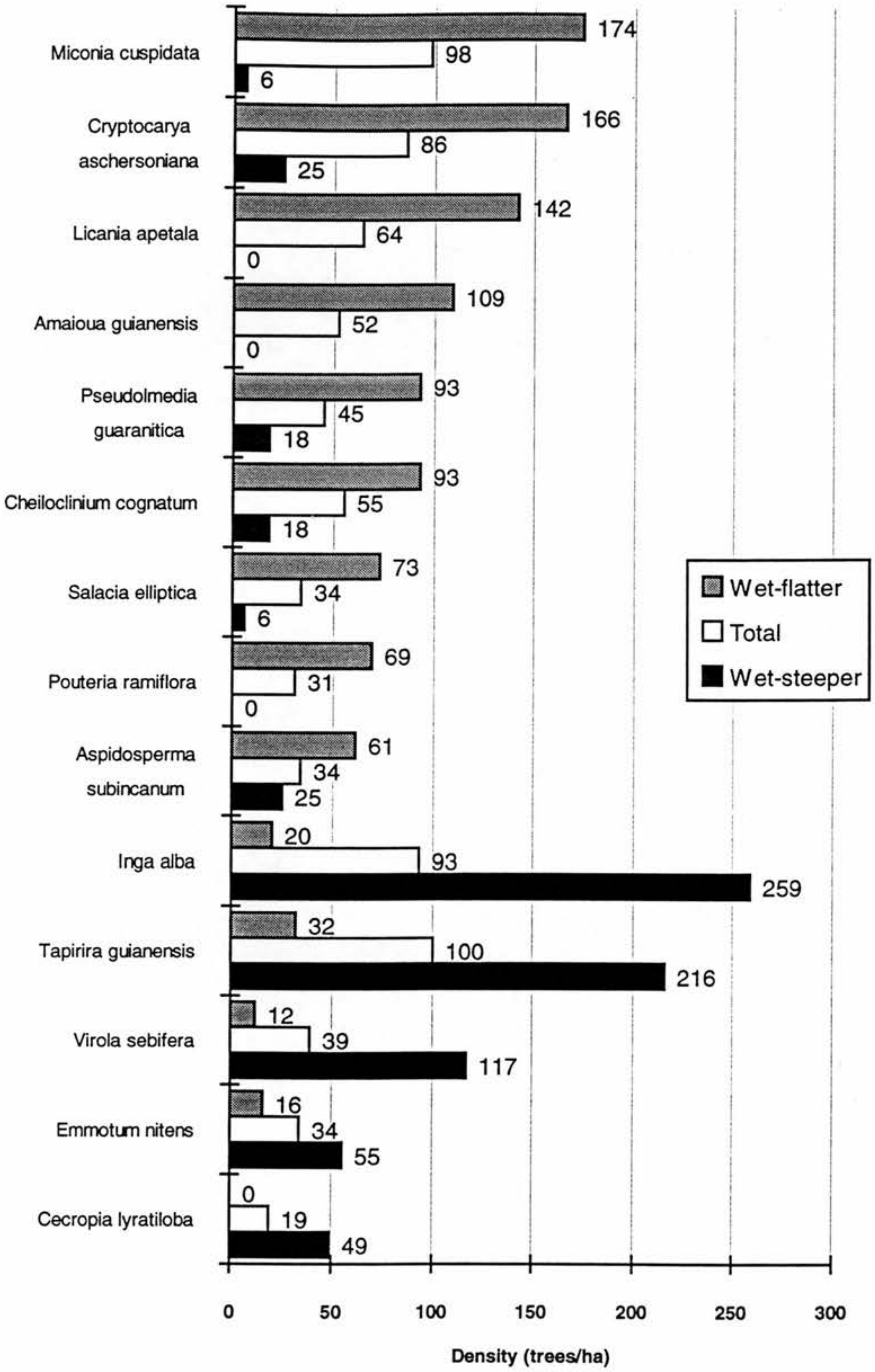


Figure 18- Density values for species of the communities wet-steeper and wet-flatter of the Monjolo gallery forest. Scores for the total sampling are also displayed for comparison.

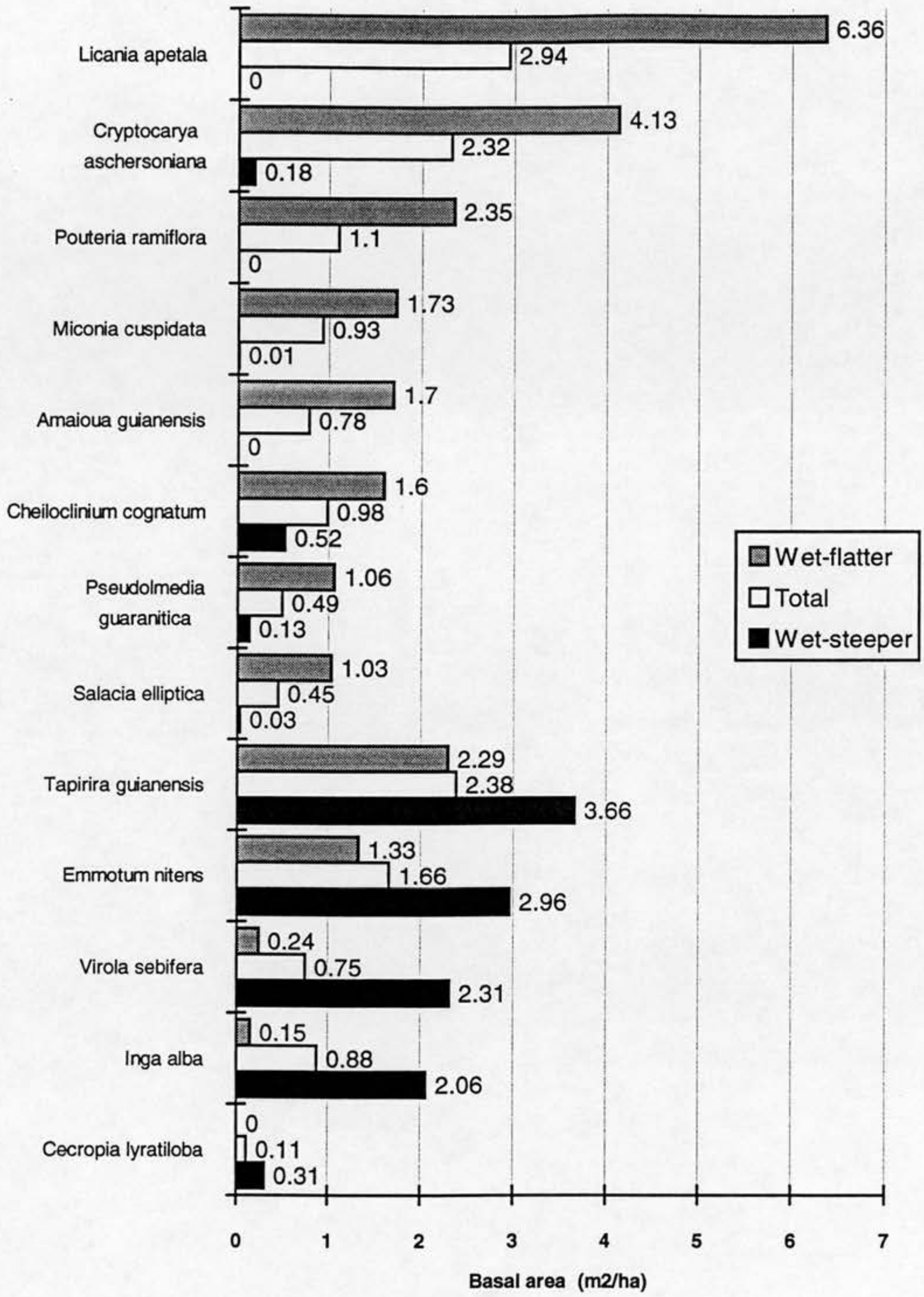


Figure 19- Basal area values for species of the communities wet-steeper and wet-flatter of the Monjolo gallery forest. Scores for the total sampling are also displayed for comparison.

Table 10 - Phytosociological parameters for trees recorded in the Monjolo wet-flatter community.

	Species	Family	Density		Dominance		Frequency	IVI
			n/ha	%	cm/ha	%	%	
1	*Licania apetala*	Chrysobalanaceae	141.71	7.95	63601	13.21	7.61	28.77
2	*Cryptocarya aschersoniana*	Lauraceae	166	9.32	41333	8.58	8.88	26.78
3	*Miconia cuspidata*	Melastomataceae	174.1	9.77	17338	3.6	8.88	22.26
4	*Aspidosperma subincanum*	Apocynaceae	60.73	3.41	49448	10.27	3.55	17.23
5	Dead trees		93.12	5.23	30844	6.4	5.08	16.71
6	*Amaioua guianensis*	Rubiaceae	109.32	6.14	17061	3.54	6.09	15.77
7	*Cheiloclinium cognatum*	Hippocrateaceae	93.12	5.23	16018	3.33	5.33	13.88
8	*Pouteria ramiflora*	Sapotaceae	68.83	3.86	25882	5.37	4.06	13.3
9	*Maprounea guianensis*	Euphorbiaceae	64.78	3.64	29104	6.04	3.55	13.23
10	*Pseudolmedia guaranitica*	Moraceae	93.12	5.23	10626	2.21	4.31	11.75
11	*Salacia elliptica*	Hippocrateaceae	72.88	4.09	10287	2.14	4.06	10.29
12	*Protium almecega*	Burseraceae	72.88	4.09	6230	1.29	4.06	9.45
13	*Tapirira guianensis*	Anacardiaceae	32.39	1.82	22880	4.75	2.03	8.6
14	*Sacoglottis guianensis*	Humiriaceae	28.34	1.59	12226	2.54	1.78	5.91
15	*Piptocarpha macropoda*	Compositae	36.44	2.05	6742	1.4	2.28	5.73
16	*Copaifera langsdorffii*	Leg.-Caesalpinioideae	4.05	0.23	22598	4.69	0.25	5.17
17	*Emmotum nitens*	Icacinaceae	16.19	0.91	13334	2.77	1.02	4.69
18	*Sclerolobium paniculatum var. rubiginosum*	Leg.-Caesalpinioideae	24.29	1.36	9652	2	1.27	4.64
19	*Simarouba versicolor*	Simaroubaceae	20.24	1.14	6393	1.33	1.27	3.73
20	*Miconia chartacea*	Melastomataceae	28.34	1.59	1126	0.23	1.78	3.6
21	*Siparuna guianensis*	Monimiaceae	24.29	1.36	2745	0.57	1.52	3.46
22	*Qualea multiflora*	Vochysiaceae	16.19	0.91	5506	1.14	1.02	3.07
23	*Guatteria sellowiana*	Annonaceae	20.24	1.14	2984	0.62	1.27	3.02
24	*Apuleia leiocarpa*	Leg.-Caesalpinioideae	12.15	0.68	8527	1.77	0.51	2.96
25	*Xylopia sericea*	Annonaceae	8.1	0.45	8948	1.86	0.51	2.82
26	*Inga alba*	Leg.-Mimosoideae	20.24	1.14	1508	0.31	1.27	2.72
27	*Faramea cyanea*	Rubiaceae	20.24	1.14	894	0.19	1.27	2.59
28	*Hirtella glandulosa*	Chrysobalanaceae	16.19	0.91	2807	0.58	1.02	2.51
29	*Nectandra mollis*	Lauraceae	8.1	0.45	7309	1.52	0.51	2.48
30	*Ouratea castaneaefolia*	Ochnaceae	16.19	0.91	1770	0.37	1.02	2.29

Table 10 - Cont...

	Species	Family	Density		Dominance		Frequency	IVI
			n/ha	%	cm/ha	%	%	
31	*Sorocea guilleminiana*	Moraceae	16.19	0.91	597	0.12	1.02	2.05
32	*Virola sebifera*	Myristicaceae	12.15	0.68	2396	0.5	0.76	1.94
33	*Tapura amazonica*	Dichapetalaceae	12.15	0.68	1856	0.39	0.76	1.83
34	*Cupania vernalis*	Sapindaceae	12.15	0.68	2843	0.59	0.51	1.78
35	*Aspidosperma cylindrocarpon*	Apocynaceae	8.1	0.45	3750	0.78	0.51	1.74
36	*Gomidesia brunea*	Myrtaceae	12.15	0.68	957	0.2	0.76	1.64
37	*Matayba guianensis*	Sapindaceae	12.15	0.68	408	0.08	0.76	1.53
38	*Miconia sellowiana*	Melastomataceae	8.1	0.45	2687	0.56	0.51	1.52
39	*Alchornea ferruginea*	Euphorbiaceae	12.15	0.68	319	0.07	0.76	1.51
40	*Ocotea corymbosa*	Lauraceae	12.15	0.68	507	0.11	0.51	1.29
41	*Ocotea aciphylla*	Lauraceae	8.1	0.45	1077	0.22	0.51	1.19
42	*Astronium fraxinifolium*	Anacardiaceae	8.1	0.45	764	0.16	0.51	1.12
43	*Byrsonima laxiflora*	Malpighiaceae	8.1	0.45	748	0.16	0.51	1.12
44	*Nectandra cissiflora*	Lauraceae	4.05	0.23	2003	0.42	0.25	0.9
45	*Styrax guianensis*	Styracaceae	8.1	0.45	454	0.09	0.25	0.8
46	*Blepharocalyx salicifolius*	Myrtaceae	4.05	0.23	1222	0.25	0.25	0.73
47	*Roupala brasiliensis*	Proteaceae	4.05	0.23	669	0.14	0.25	0.62
48	*Laplacea fruticosa*	Theaceae	4.05	0.23	428	0.09	0.25	0.57
49	*Schefflera morototoni*	Araliaceae	4.05	0.23	312	0.06	0.25	0.55
50	*Alibertia macrophylla*	Rubiaceae	4.05	0.23	224	0.05	0.25	0.53
51	*Myrsine coriacea*	Myrsinaceae	4.05	0.23	224	0.05	0.25	0.53
52	*Ormosia stipularis*	Leg.-Faboideae	4.05	0.23	219	0.05	0.25	0.53
53	*Mouriri glaziovii*	Melastomataceae	4.05	0.23	219	0.05	0.25	0.53
54	*Diospyros hispida*	Ebenaceae	4.05	0.23	193	0.04	0.25	0.52
55	*Myrcia rostrata*	Myrtaceae	4.05	0.23	156	0.03	0.25	0.51
56	*Vismia guianensis*	Guttiferae	4.05	0.23	143	0.03	0.25	0.51
57	*Prunus brasiliensis*	Rosaceae	4.05	0.23	130	0.03	0.25	0.51
58	*Callisthene major*	Vochysiaceae	4.05	0.23	122	0.03	0.25	0.51
59	*Guapira graciliflora*	Nyctaginaceae	4.05	0.23	100	0.02	0.25	0.5
60	*Jacaranda puberula*	Bignoniaceae	4.05	0.23	100	0.02	0.25	0.5
61	*Vitex polygama*	Verbenaceae	4.05	0.23	86	0.02	0.25	0.5
	Totals		1781 ind/ha	100%	481,636 cm2/ha	100%	100%	300%

Table 11 - Phytosociological parameters for trees recorded in the Monjolo wet-steeper community.

	Species	Family	Density		Dominance		Frequency	IVI
			n/ha	%	cm/ha	%	%	
1	*Inga alba*	Leg.-Mimosoideae	258.77	15.91	20601	5.84	14.53	36.28
2	*Tapirira guianensis*	Anacardiaceae	215.64	13.26	36651	10.39	12.39	36.04
3	*Virola sebifera*	Myristicaceae	117.06	7.2	23100	6.55	7.26	21.01
4	*Emmotum nitens*	Icacinaceae	55.45	3.41	29634	8.4	3.85	15.65
5	Dead trees		92.42	5.68	12666	3.59	5.98	15.25
6	*Sclerolobium paniculatum var. rubiginosum*	Leg.-Caesalpinioideae	80.1	4.92	14010	3.97	4.7	13.6
7	*Myrsine coriacea*	Myrsinaceae	36.97	2.27	17925	5.08	2.14	9.49
8	*Aspidosperma subincanun*	Apocynaceae	24.65	1.52	22311	6.32	1.28	9.12
9	*Tapura amazonica*	Dichapetalaceae	43.13	2.65	9806	2.78	2.99	8.42
10	*Protium almecega*	Burseraceae	49.29	3.03	4236	1.2	3.42	7.65
11	*Hymenaea coubaril var. stilbocarpa*	Leg.-Caesalpinioideae	12.32	0.76	19011	5.39	0.85	7
12	*Cecropia lyratiloba*	Moraceae	49.29	3.03	3129	0.89	2.56	6.48
13	*Hirtella glandulosa*	Chrysobalanaceae	30.81	1.89	6598	1.87	2.14	5.9
14	*Maprounea guianensis*	Euphorbiaceae	30.81	1.89	6356	1.8	2.14	5.83
15	*Faramea cyanea*	Rubiaceae	30.81	1.89	4653	1.32	2.14	5.35
16	*Lamanonia ternata*	Cunoniaceae	6.16	0.38	15888	4.5	0.43	5.31
17	*Nectandra mollis*	Lauraceae	18.48	1.14	10176	2.88	1.28	5.3
18	*Copaifera langsdorffii*	Leg.-Caesalpinioideae	18.48	1.14	9415	2.67	1.28	5.09
19	*Ocotea aciphylla*	Lauraceae	24.65	1.52	6150	1.74	1.71	4.97
20	*Alchornea ferruginea*	Euphorbiaceae	30.81	1.89	4028	1.14	1.71	4.74
21	*Simarouba versicolor*	Simaroubaceae	30.81	1.89	4261	1.21	1.28	4.38
22	*Terminalia glabrescens*	Combretaceae	18.48	1.14	6433	1.82	1.28	4.24
23	*Siparuna guianensis*	Monimiaceae	30.81	1.89	708	0.2	2.14	4.23
24	*Xylopia sericea*	Annonaceae	18.48	1.14	5980	1.69	1.28	4.11
25	*Cheiloclinium cognatum*	Hippocrateaceae	18.48	1.14	5227	1.48	1.28	3.9
26	*Astronium fraxinifolium*	Anacardiaceae	12.32	0.76	6333	1.79	0.85	3.41
27	*Cryptocarya aschersoniana*	Lauraceae	24.65	1.52	1833	0.52	1.28	3.32
28	*Byrsonima laxiflora*	Malpighiaceae	24.65	1.52	1728	0.49	1.28	3.29
29	*Siphoneugena densiflora*	Myrtaceae	6.16	0.38	7398	2.1	0.43	2.9
30	*Qualea dichotoma*	Vochysiaceae	12.32	0.76	4227	1.2	0.85	2.81

Table 11 - cont...

	Species	Family	Density		Dominance		Frequency	IVI
			n/ha	%	cm/ha	%	%	
31	*Vismia guianensis*	Guttiferae	18.48	1.14	1297	0.37	1.28	2.79
32	*Pseudolmedia guaranitica*	Moraceae	18.48	1.14	1287	0.36	1.28	2.78
33	*Symplocos mosenii*	Symplocaceae	6.16	0.38	6271	1.78	0.43	2.58
34	*Sacoglottis guianensis*	Humiriaceae	6.16	0.38	5561	1.58	0.43	2.38
35	*Piptocarpha macropoda*	Compositae	12.32	0.76	2471	0.7	0.85	2.31
36	*Jacaranda puberula*	Bignoniaceae	18.48	1.14	1018	0.29	0.85	2.28
37	*Apuleia leiocarpa*	Leg.-Caesalpinioideae	12.32	0.76	3731	1.06	0.43	2.24
38	*Schefflera morototoni*	Araliaceae	12.32	0.76	1405	0.4	0.85	2.01
39	*Aegiphila sellowiana*	Verbenaceae	12.32	0.76	974	0.28	0.85	1.89
40	*Casearia sylvestris*	Flacourtiaceae	12.32	0.76	938	0.27	0.85	1.88
41	*Roupala brasiliensis*	Proteaceae	6.16	0.38	3373	0.96	0.43	1.76
42	*Guatteria sellowiana*	Annonaceae	6.16	0.38	720	0.2	0.43	1.01
43	*Gomidesia brunea*	Myrtaceae	6.16	0.38	596	0.17	0.43	0.98
44	*Qualea multiflora*	Vochysiaceae	6.16	0.38	596	0.17	0.43	0.98
45	*Matayba guianensis*	Sapindaceae	6.16	0.38	564	0.16	0.43	0.97
46	*Salacia elliptica*	Hippocrateaceae	6.16	0.38	383	0.11	0.43	0.91
47	*Cybianthus gardnerii*	Myrsinaceae	6.16	0.38	358	0.1	0.43	0.91
48	*Callisthene major*	Vochysiaceae	6.16	0.38	237	0.07	0.43	0.87
49	*Miconia sellowiana*	Melastomataceae	6.16	0.38	204	0.06	0.43	0.86
50	*Diospyros hispida*	Ebenaceae	6.16	0.38	168	0.05	0.43	0.85
51	*Micropholis rigida*	Sapotaceae	6.16	0.38	141	0.04	0.43	0.85
52	*Miconia cuspidata*	Melastomataceae	6.16	0.38	121	0.03	0.43	0.84
	Totals		1626 ind/ha	100%	352,886 cm2/ha	100%	100%	300%

The wet-steeper community is led by *Tapirira guianensis* which is ranked sixth in the total sampling (Chapter 4). Other species related to the community are: *Cercropia lyratiloba, Emmotum nitens, Inga alba* and *Virola sebifera*. Species recognised with a tendency to colonise this community are *Sclerolobium paniculatum* var. *rubiginosum, Faramea cyanea* and *Hirtella glandulosa*.

5.3.2.3.- Indifferent species.

Simarouba amara and *Siparuna guianensis* show similar figures for density and basal area in both dry and wet communities, demonstrating apparent indifference to the prevailing environmental conditions of the two habitats.

5.3.3.- Taquara gallery forest.

The Taquara has the flattest topography of the three galleries (Figure 20). The stream bed at the river head area is 2.0-3.0m deep becoming shallower downstream where some patches are under a seasonal flooding regime. These flooded patches are dominated by *Olyra taquara* and a *Cyathea* sp. tree fern with only a few trees present. The gallery width varies along the stream and sampling lines from 20 up to 100m long were established.

The grouping of sampling points generated by TWINSPAN indicates the presence of two communities related to site elevation and consequently position. The community in the river bank area is classified as wet in contrast to the dry community of the slight slope in the area of the forest-cerrado border. Patches of mesotrophic soils are found in the area of the dry community.

The communities are strongly separated on species composition and phytosociology. Further classification failed to provide any breakdown into consistent subcommunities.

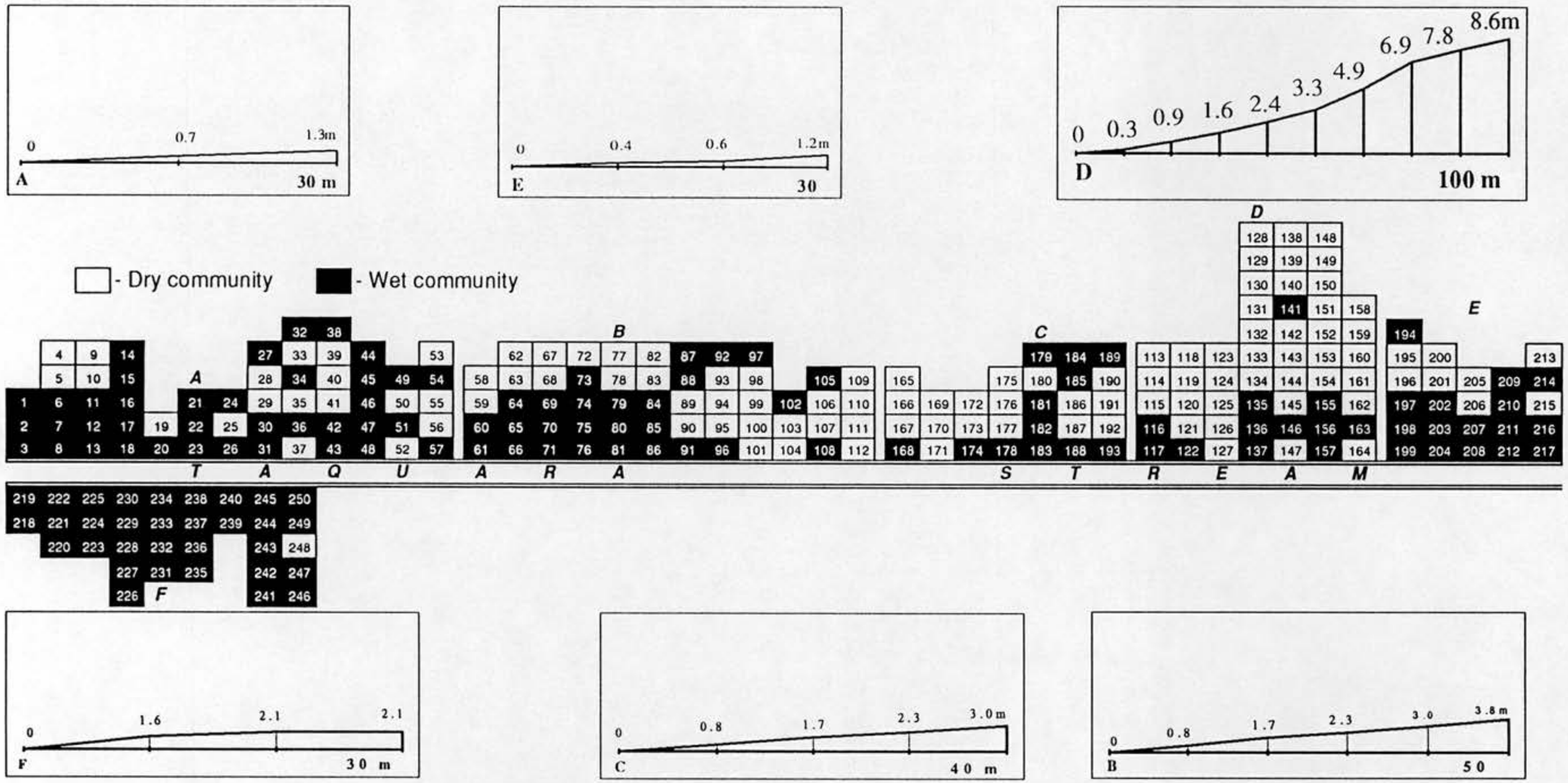


Figure 20 - Tree communities of the Taquara gallery forest and inclination profiles for each of the sampling areas.

Tables 12 and 13 show the phytosociological characteristics of the dry and wet communities respectively.

5.3.3.1.- Species related to the dry community.

Copaifera langsdorffii lies in the leading position in the dry community with a score twice as high as in the total sampling where it is in second place. The other species of the community are: *Anadenanthera colubrina* var. *cebil, Alibertia macrophylla, Guettarda viburnioides, Pera glabrata, Platypodium elegans, Diospyros hispida* and *Myrcia tomentosa. Matayba guianensis* and *Roupala brasiliensis* are prominent within the community only for their basal area and density respectively. Their paucity and small stature within the wet community also support their preference for the dry community (Figure 21 and 22).

Species with a tendency to occur in the community are *Byrsonima laxiflora, Coussarea hydrangeifolia, Styrax guianensis* and *Symplocos nitens,* all with scores increased from 20 to up to 50% as compared to those of the total sampling.

5.3.3.2.- Species related to the wet community.

Tapirira guianensis is the most important species both in the total sampling and the wet community, however its density and basal area scores almost doubled within the latter. Other important species are *Lamanonia ternata, Maprounea guianensis, Piptocarpha macropoda, Sclerolobium paniculatum* var. *rubiginosum* and *Tapura amazonica* of which scores are shown in Figures 23 and 24.

Species with a tendency to occur in the wet community are: *Inga alba, Ixora warmingii, Ocotea corymbosa, Ocotea spixiana* and *Symplocos mosenii.*

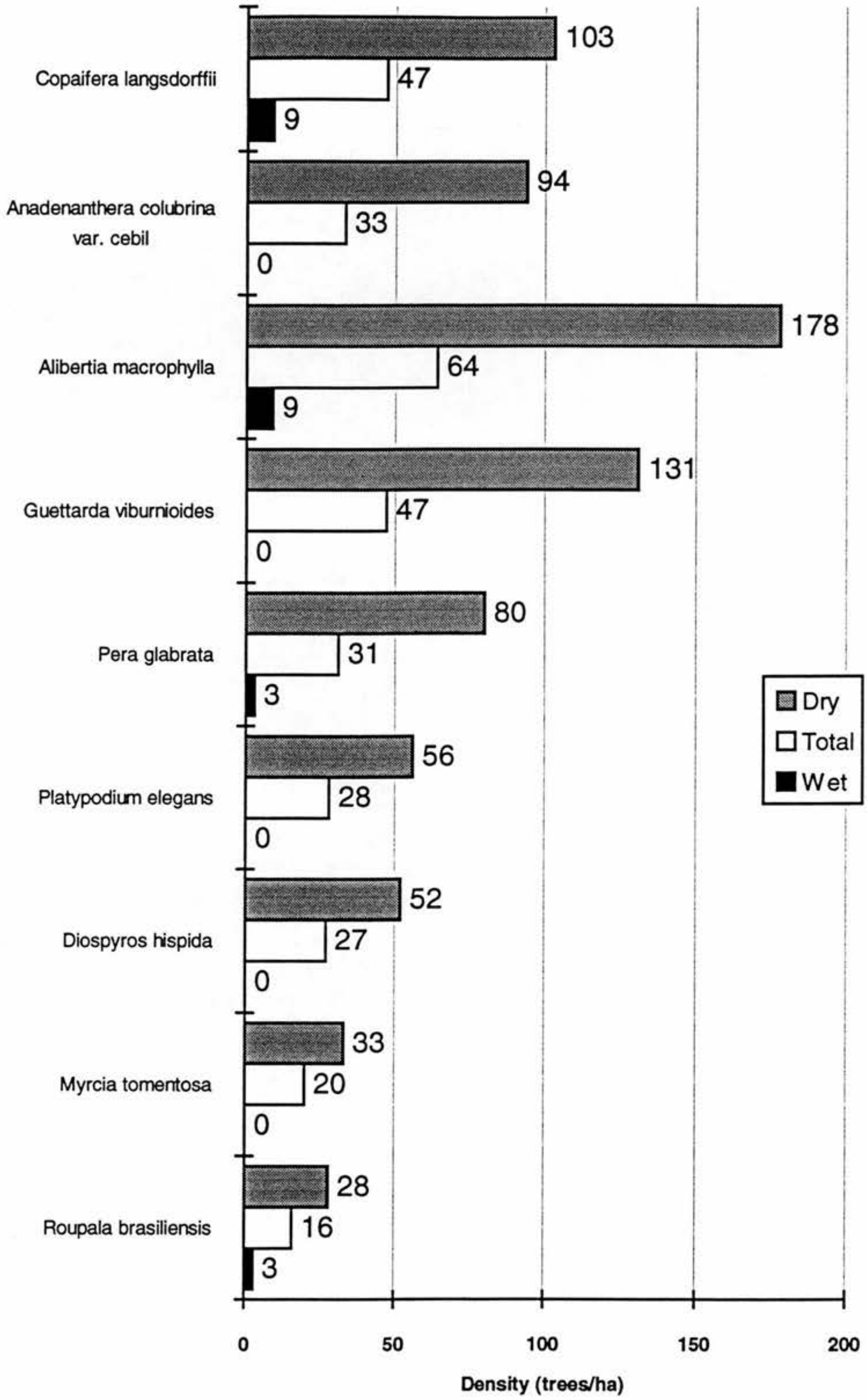


Figure 21 - Density values for species of the dry community of the Taquara gallery forest. Scores for total sampling and the wet community are also displayed for comparison.

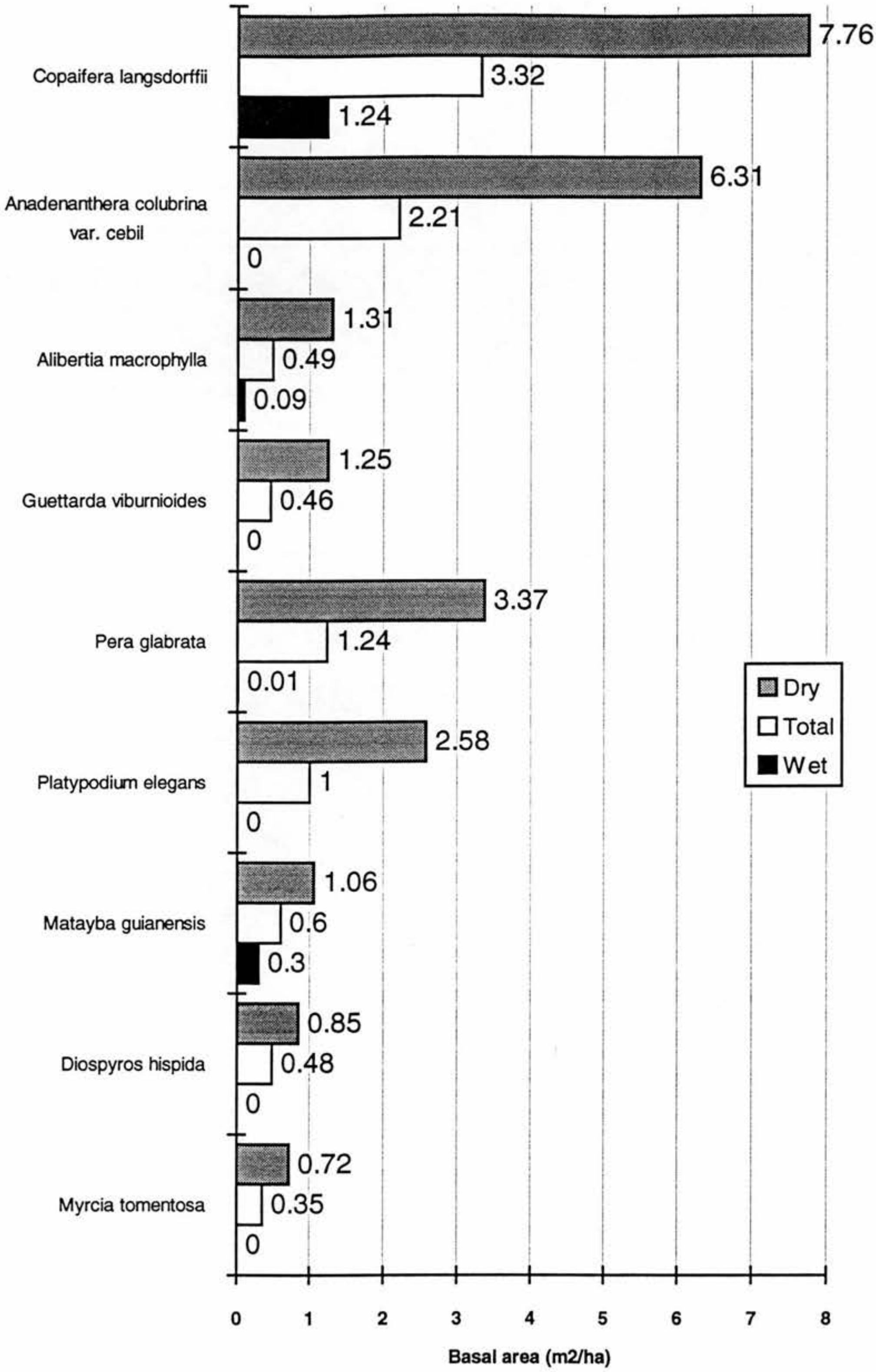


Figure 22 - Basal area values for species of the dry community of the Taquara gallery forest. Scores for total sampling and the wet community are also displayed for comparison.

Table 12- Phytosociological parameters for trees recorded in the Taquara dry community.

	Species	Family	Density		Dominance		Frequency	IVI
			n/ha	%	cm/ha	%	%	
1	*Copaifera langsdorffii*	Leg.-Caesalpinioideae	103.12	6.63	77579	18.91	6.73	32.27
2	*Anadenanthera colubrina var. cebil*	Leg.-Mimosoideae	93.75	6.02	63130	15.39	6.09	27.5
3	*Alibertia macrophylla*	Rubiaceae	178.12	11.45	13089	3.19	10.26	24.89
4	*Guettarda viburnioides*	Rubiaceae	131.24	8.43	12485	3.04	8.01	19.49
5	*Pera glabrata*	Euphorbiaceae	79.68	5.12	33748	8.23	5.45	18.8
6	*Platypodium elegans*	Leg.-Caesalpinioideae	56.25	3.61	25822	6.3	3.85	13.76
7	Dead Trees		60.93	3.92	22046	5.37	3.85	13.14
8	*Matayba guianensis*	Sapindaceae	65.62	4.22	10576	2.58	4.49	11.28
9	*Diospyros hispida*	Ebenaceae	51.56	3.31	8520	2.08	3.21	8.6
10	*Aspidosperma spruceanum*	Apocynaceae	18.75	1.2	16742	4.08	1.28	6.57
11	*Ixora warmingii*	Rubiaceae	42.19	2.71	5244	1.28	2.56	6.55
12	*Myrcia rostrata*	Myrtaceae	32.81	2.11	7224	1.76	1.92	5.79
13	*Byrsonima laxiflora*	Malpighiaceae	28.12	1.81	7200	1.76	1.92	5.49
14	*Styrax guianensis*	Styracaceae	28.12	1.81	4056	0.99	1.92	4.72
15	*Margaritaria nobilis*	Lauraceae	18.75	1.2	9092	2.22	1.28	4.7
16	*Pseudobombax tomentosum*	Bombacaceae	14.06	0.9	11224	2.74	0.96	4.6
17	*Symplocos nitens*	Symplocaceae	32.81	2.11	1893	0.46	1.92	4.49
18	*Piptadenia gonoacantha*	Leg.-Mimosoideae	18.75	1.2	6253	1.52	1.28	4.01
19	*Coussarea hydrangeaefolia*	Rubiaceae	28.12	1.81	1099	0.27	1.92	4
20	*Roupala brasiliensis*	Proteaceae	28.12	1.81	1940	0.47	1.6	3.88
21	*Protium almecega*	Burseraceae	9.37	0.6	10444	2.55	0.64	3.79
22	*Guapira graciliflora*	Nyctaginaceae	23.44	1.51	2668	0.65	1.6	3.76
23	*Cupania vernalis*	Sapindaceae	28.12	1.81	1421	0.35	1.6	3.76
24	*Aspidosperma subincanum*	Apocynaceae	18.75	1.2	4054	0.99	1.28	3.48
25	*Emmotum nitens*	Icacinaceae	18.75	1.2	5305	1.29	0.96	3.46
26	*Vochysia tucanorum*	Vochysiaceae	18.75	1.2	2125	0.52	1.28	3
27	*Tabebuia impetiginosa*	Bignoniaceae	14.06	0.9	4096	1	0.96	2.86

Table 12 - cont...

	Species	Family	Density		Dominance		Frequency	IVI
			n/ha	%	cm/ha	%	%	
28	*Callisthene major*	Vochysiaceae	9.37	0.6	5885	1.43	0.64	2.68
29	*Qualea dichotoma*	Vochysiaceae	14.06	0.9	2989	0.73	0.96	2.59
30	*Ocotea corymbosa*	Lauraceae	9.37	0.6	4014	0.98	0.64	2.22
31	*Lafoensia pacari*	Lythraceae	14.06	0.9	1286	0.31	0.96	2.18
32	*Schefflera morototoni*	Araliaceae	14.06	0.9	1242	0.3	0.96	2.17
33	*Cheiloclinium cognatum*	Hippocrateaceae	14.06	0.9	886	0.22	0.96	2.08
34	*Xylopia sericea*	Annonaceae	14.06	0.9	560	0.14	0.96	2
35	*Qualea multiflora*	Vochysiaceae	4.69	0.3	5288	1.29	0.32	1.91
36	*Jacaranda puberula*	Bignoniaceae	14.06	0.9	1007	0.25	0.64	1.79
37	*Terminalia glabrescens*	Combretaceae	9.37	0.6	1818	0.44	0.64	1.69
38	*Kielmeyera coriacea*	Guttiferae	9.37	0.6	1518	0.37	0.64	1.61
39	*Guarea guidonia*	Meliaceae	9.37	0.6	1133	0.28	0.64	1.52
40	*Piptocarpha macropoda*	Compositae	9.37	0.6	1063	0.26	0.64	1.5
41	*Alibertia edulis*	Rubiaceae	9.37	0.6	579	0.14	0.64	1.38
42	*Myrsine umbellata*	Myrsinaceae	9.37	0.6	446	0.11	0.64	1.35
43	*Sclerolobium paniculatum var. rubiginosum*	Leg.-Caesalpinioideae	9.37	0.6	403	0.1	0.64	1.34
44	*Vitex polygama*	Verbenaceae	9.37	0.6	361	0.09	0.64	1.33
45	*Prunus brasiliensis*	Rosaceae	9.37	0.6	326	0.08	0.64	1.32
46	*Eriotheca gracilipes*	Bombacaceae	4.69	0.3	2210	0.54	0.32	1.16
47	*Chomelia pohliana*	Rubiaceae	4.69	0.3	1002	0.24	0.32	0.87
48	*Inga alba*	Leg.-Mimosoideae	4.69	0.3	896	0.22	0.32	0.84
49	*Tabebuia umbellata*	Bignoniaceae	4.69	0.3	622	0.15	0.32	0.77
50	*Cecropia lyratiloba*	Moraceae	4.69	0.3	557	0.14	0.32	0.76
51	*Eriotheca pubescens*	Bombacaceae	4.69	0.3	530	0.13	0.32	0.75
52	*Maytenus salicifolia*	Celastraceae	4.69	0.3	513	0.13	0.32	0.75
53	*Micropholis rigida*	Sapotaceae	4.69	0.3	406	0.1	0.32	0.72
54	*Faramea cyanea*	Rubiaceae	4.69	0.3	361	0.09	0.32	0.71
55	*Ouratea castaneaefolia*	Ochnaceae	4.69	0.3	346	0.08	0.32	0.71

Table 12 - cont...

	Species	Family	Density		Dominance		Frequency	IVI
			n/ha	%	cm/ha	%	%	
56	*Aspidosperma discolor*	Apocynaceae	4.69	0.3	312	0.08	0.32	0.7
57	*Ocotea spixiana*	Lauraceae	4.69	0.3	260	0.06	0.32	0.69
58	*Mollinedia oligantha*	Monimiaceae	4.69	0.3	254	0.06	0.32	0.68
59	*Cordia sellowiana*	Boraginaceae	4.69	0.3	248	0.06	0.32	0.68
60	*Machaerium acutifolium*	Leg.-Faboideae	4.69	0.3	230	0.06	0.32	0.68
61	*Symplocos mosenii*	Symplocaceae	4.69	0.3	230	0.06	0.32	0.68
62	*Luehea grandiflora*	Tiliaceae	4.69	0.3	218	0.05	0.32	0.68
63	*Erythroxylum sp.*	Erythroxylaceae	4.69	0.3	165	0.04	0.32	0.66
64	*Hirtella glandulosa*	Chrysobalanaceae	4.69	0.3	151	0.04	0.32	0.66
65	*Siparuna guianensis*	Monimiaceae	4.69	0.3	133	0.03	0.32	0.65
66	*Cybianthus gardnerii*	Myrsinaceae	4.69	0.3	133	0.03	0.32	0.65
67	*Guatteria sellowiana*	Annonaceae	4.69	0.3	120	0.03	0.32	0.65
68	*Miconia chartacea*	Melastomataceae	4.69	0.3	107	0.03	0.32	0.65
69	*Cordia trichotoma*	Boraginaceae	4.69	0.3	107	0.03	0.32	0.65
70	*Lamanonia ternata*	Cunoniaceae	4.69	0.3	107	0.03	0.32	0.65
71	*Xylopia emarginata*	Annonaceae	4.69	0.3	96	0.02	0.32	0.65
	Totals		1556 ind /ha	100%	410190 cm2/ha	100%	100%	300%

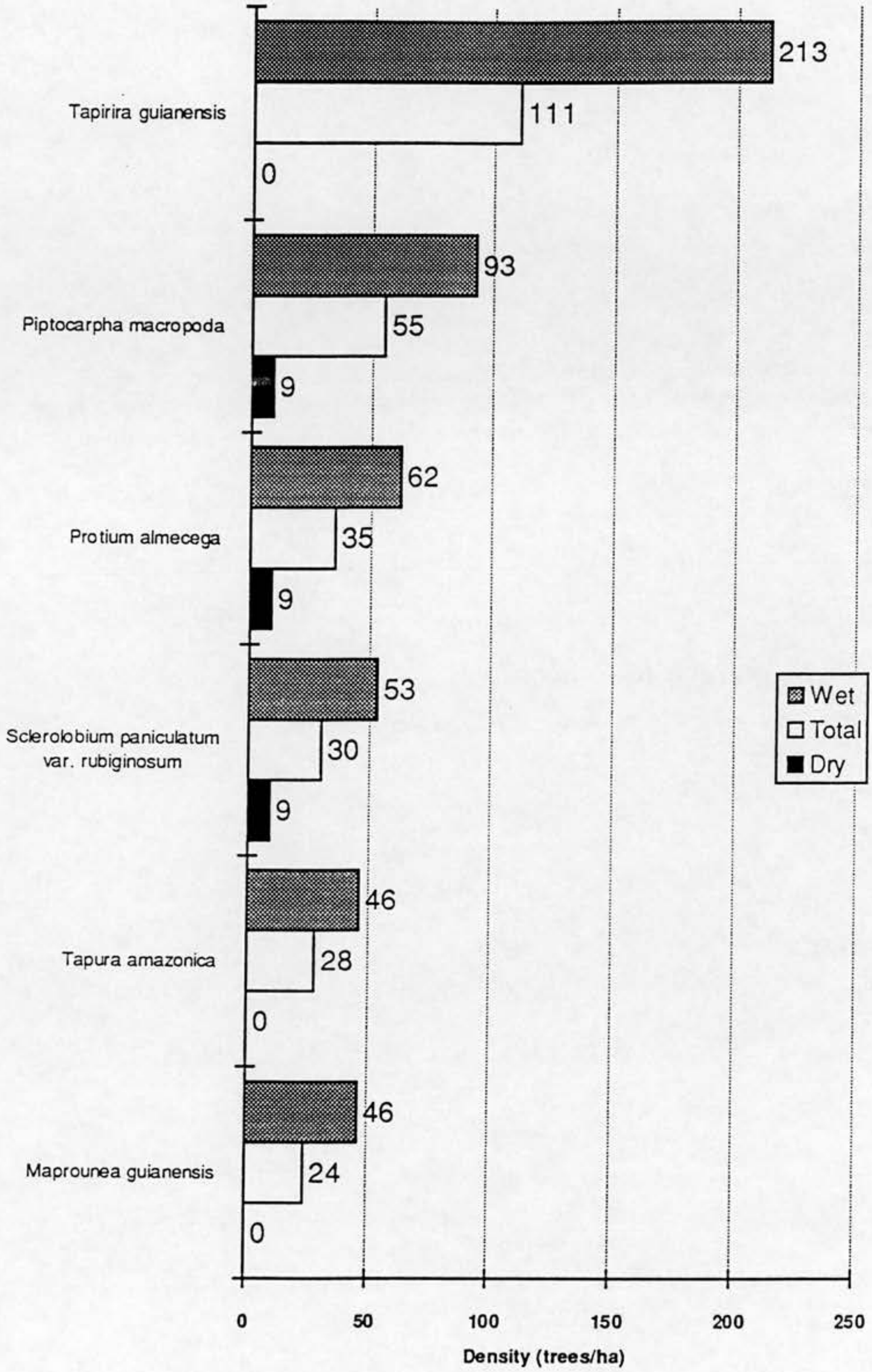


Figure 23 -Density values for species of the wet community of the Taquara gallery forest. Scores for total sampling and the dry community are also displayed for comparison.

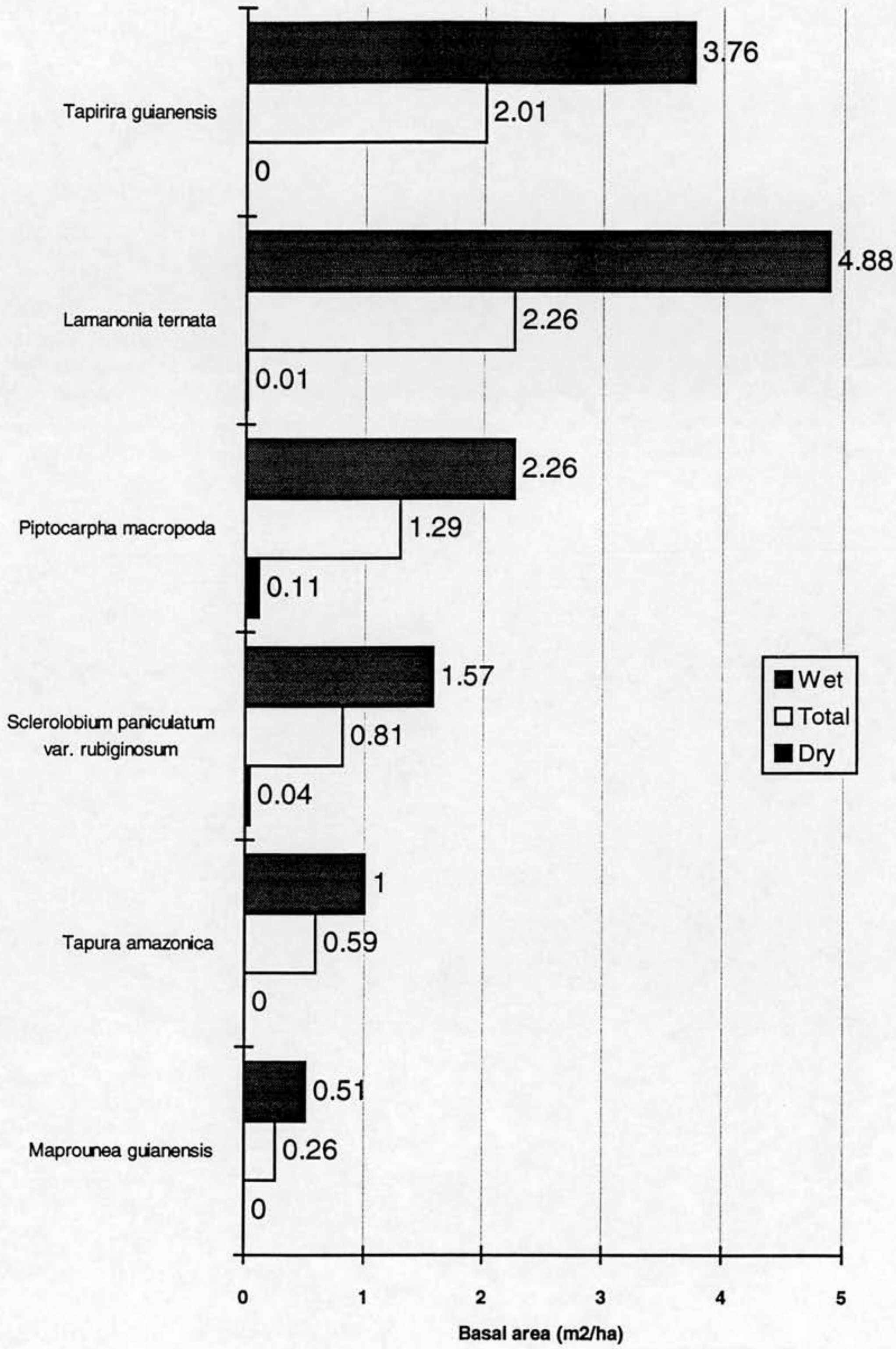


Figure 24- Basal area values for species of the wet community of the Taquara gallery forest. Scores for total sampling and the dry community are also displayed for comparison.

Table 13 - Phytosociological parameters for trees recorded in the Taquara wet community.

	Species	Family	Density		Dominance		Frequency	IVI
			n/ha	%	cm/ha	%	%	
1	*Tapirira guianensis*	Anacardiaceae	213.52	14.14	37582	9.85	11.66	35.64
2	Dead Trees		86.65	5.74	46316	12.13	6.05	23.93
3	*Lamanonia ternata*	Cunoniaceae	34.04	2.25	48769	12.78	2.24	17.27
4	*Piptocarpha macropoda*	Compositae	92.83	6.15	22617	5.93	5.16	17.23
5	*Sclerolobium paniculatum var. rubiginosum*	Leg.-Caesalpinioideae	52.61	3.48	15730	4.12	3.36	10.97
6	*Protium almecega*	Burseraceae	61.89	4.1	8834	2.31	3.59	10
7	*Tapura amazonica*	Dichapetalaceae	46.42	3.07	10039	2.63	3.14	8.84
8	*Maprounea guianensis*	Euphorbiaceae	46.42	3.07	5134	1.35	3.14	7.56
9	*Myrcia rostrata*	Myrtaceae	52.61	3.48	2390	0.63	3.36	7.47
10	*Ixora warmingii*	Rubiaceae	37.13	2.46	6534	1.71	2.69	6.86
11	*Emmotum nitens*	Icacinaceae	18.57	1.23	12287	3.22	1.35	5.79
12	*Hymenaea coubaril var. stilbocarpa*	Leg.-Caesalpinioideae	9.28	0.61	16068	4.21	0.67	5.5
13	*Ocotea corymbosa*	Lauraceae	27.85	1.84	4781	1.25	2.02	5.11
14	*Inga alba*	Leg.-Mimosoideae	27.85	1.84	4355	1.14	2.02	5
15	*Ocotea spixiana*	Lauraceae	21.66	1.43	6304	1.65	1.57	4.66
16	*Miconia cuspidata*	Melastomataceae	21.66	1.43	7139	1.87	1.35	4.65
17	*Schefflera morototoni*	Araliaceae	30.94	2.05	2204	0.58	2.02	4.64
18	*Copaifera langsdorffii*	Leg.-Caesalpinioideae	9.28	0.61	12374	3.24	0.67	4.53
19	*Symplocos mosenii*	Symplocaceae	24.76	1.64	3326	0.87	1.79	4.3
20	*Pseudobombax tomentosum*	Bombacaceae	6.19	0.41	12878	3.37	0.45	4.23
21	*Diospyros hispida*	Ebenaceae	18.57	1.23	6137	1.61	1.35	4.18
22	*Licania apetala*	Chrysobalanaceae	21.66	1.43	4068	1.07	1.57	4.07
23	*Matayba guianensis*	Sapindaceae	21.66	1.43	2993	0.78	1.57	3.79
24	*Virola sebifera*	Myristicaceae	21.66	1.43	2963	0.78	1.57	3.78
25	*Anadenanthera colubrina var. cebil*	Leg.-Mimosoideae	21.66	1.43	3739	0.98	1.35	3.76
26	*Symplocos nitens*	Symplocaceae	21.66	1.43	2072	0.54	1.57	3.55
27	*Cecropia lyratiloba*	Moraceae	18.57	1.23	3353	0.88	1.35	3.45
28	*Terminalia glabrescens*	Combretaceae	15.47	1.02	4772	1.25	1.12	3.4

Table 13 - cont....

	Species	Family	Density		Dominance		Frequency	IVI
			n/ha	%	cm/ha	%	%	
29	*Cecropia pachystachya*	Moraceae	21.66	1.43	1465	0.38	1.57	3.39
30	*Cheiloclinium cognatum*	Hippocrateaceae	21.66	1.43	2081	0.55	1.35	3.32
31	*Qualea dichotoma*	Vochysiaceae	6.19	0.41	8579	2.25	0.45	3.11
32	*Hieronyma ferruginea*	Euphorbiaceae	15.47	1.02	3353	0.88	1.12	3.02
33	*Byrsonima laxiflora*	Malpighiaceae	15.47	1.02	3095	0.81	1.12	2.96
34	*Jacaranda puberula*	Bignoniaceae	18.57	1.23	1014	0.27	1.35	2.84
35	*Bauhinia rufa*	Leg.-Caesalpinioideae	18.57	1.23	621	0.16	1.35	2.74
36	*Myrsine coriacea*	Myrsinaceae	18.57	1.23	703	0.18	1.12	2.53
37	*Xylopia sericea*	Annonaceae	12.38	0.82	2451	0.64	0.9	2.36
38	*Nectandra cissiflora*	Lauraceae	15.47	1.02	610	0.16	1.12	2.31
39	*Machaerium acutifolium*	Leg.-Faboideae	12.38	0.82	2819	0.74	0.67	2.23
40	*Pseudolmedia guaranitica*	Moraceae	12.38	0.82	985	0.26	0.9	1.97
41	*Eriotheca gracilipes*	Bombacaceae	6.19	0.41	4040	1.06	0.45	1.92
42	*Micropholis rigida*	Sapotaceae	12.38	0.82	749	0.2	0.9	1.91
43	*Styrax guianensis*	Styracaceae	12.38	0.82	537	0.14	0.9	1.86
44	*Guatteria sellowiana*	Annonaceae	12.38	0.82	289	0.08	0.9	1.79
45	*Cryptocarya aschersoniana*	Lauraceae	9.28	0.61	1834	0.48	0.67	1.77
46	*Gomidesia brunea*	Myrtaceae	9.28	0.61	1669	0.44	0.67	1.72
47	*Siphoneugena densiflora*	Myrtaceae	3.1	0.2	4536	1.19	0.22	1.62
48	*Alibertia macrophylla*	Rubiaceae	9.28	0.61	942	0.25	0.67	1.53
49	*Aspidosperma subincanum*	Apocynaceae	6.19	0.41	2526	0.66	0.45	1.52
50	*Vochysia tucanorum*	Vochysiaceae	9.28	0.61	844	0.22	0.67	1.51
51	*Coussarea hydrangeaefolia*	Rubiaceae	9.28	0.61	749	0.2	0.67	1.48
52	*Ouratea castaneaefolia*	Ochnaceae	9.28	0.61	496	0.13	0.67	1.42
53	*Cordia sellowiana*	Boraginaceae	9.28	0.61	355	0.09	0.67	1.38
54	*Aspidosperma spruceanum*	Apocynaceae	3.1	0.2	3547	0.93	0.22	1.36
55	*Erythroxylum sp.*	Erythroxylaceae	6.19	0.41	1451	0.38	0.45	1.24
56	*Hirtella glandulosa*	Chrysobalanaceae	6.19	0.41	1216	0.32	0.45	1.18
57	*Calophyllum brasiliense*	Gutiferae	3.1	0.2	2843	0.74	0.22	1.17

Table 13 - cont....

	Species	Family	Density		Dominance		Frequency	IVI
			n/ha	%	cm/ha	%	%	
58	*Myrcia tomentosa*	Myrtaceae	6.19	0.41	705	0.18	0.45	1.04
59	*Myrciaria glanduliflora*	Myrtaceae	6.19	0.41	527	0.14	0.45	1
60	*Guarea guidonia*	Meliaceae	6.19	0.41	479	0.13	0.45	0.98
61	*Casearia grandiflora*	Flacourtiaceae	6.19	0.41	255	0.07	0.45	0.93
62	*Pouteria ramiflora*	Sapotaceae	6.19	0.41	199	0.05	0.45	0.91
63	*Ocotea aciphylla*	Lauraceae	3.1	0.2	1435	0.38	0.22	0.81
64	*Faramea cyanea*	Rubiaceae	3.1	0.2	1011	0.26	0.22	0.69
65	*Tabebuia serratifolia*	Bignoniaceae	3.1	0.2	779	0.2	0.22	0.63
66	*Blepharocalyx salicifolius*	Myrtaceae	3.1	0.2	662	0.17	0.22	0.6
67	*Myrsine umbellata*	Myrsinaceae	3.1	0.2	562	0.15	0.22	0.58
68	*Sacoglottis guianensis*	Humiriaceae	3.1	0.2	504	0.13	0.22	0.56
69	*Tetragastris balsamifera*	Burseraceae	3.1	0.2	490	0.13	0.22	0.56
70	*Sloanea guianensis*	Elaeocarpaceae	3.1	0.2	219	0.06	0.22	0.49
71	*Callisthene major*	Vochysiaceae	3.1	0.2	219	0.06	0.22	0.49
72	*Roupala brasiliensis*	Proteaceae	3.1	0.2	206	0.05	0.22	0.48
73	*Pera glabrata*	Euphorbiaceae	3.1	0.2	184	0.05	0.22	0.48
74	*Vismia guianesis*	Guttiferae	3.1	0.2	130	0.03	0.22	0.46
75	*Guapira graciliflora*	Nyctaginaceae	3.1	0.2	119	0.03	0.22	0.46
76	*Laplacea fruticosa*	Theaceae	3.1	0.2	100	0.03	0.22	0.46
77	*Sorocea guilleminiana*	Moraceae	3.1	0.2	100	0.03	0.22	0.46
78	*Siparuna guianensis*	Monimiaceae	3.1	0.2	100	0.03	0.22	0.46
79	*Dalbergia densiflora*	Leg.-Faboideae	3.1	0.2	100	0.03	0.22	0.46
80	*Prunus brasiliensis*	Rosaceae	3.1	0.2	87	0.02	0.22	0.45
81	*Qualea multiflora*	Vochysiaceae	3.1	0.2	79	0.02	0.22	0.45
82	*Hedyosmun brasiliense*	Chloranthaceae	3.1	0.2	79	0.02	0.22	0.45
83	*Ficus citrifolia*	Moraceae	3.1	0.2	74	0.02	0.22	0.45
84	*Eriotheca pubescens*	Bombacaceae	3.1	0.2	66	0.02	0.22	0.45
85	*Cardiopetalum calophyllum*	Annonaceae	3.1	0.2	66	0.02	0.22	0.45
	Totals		1510 ind/ha	100%	381,692 cm2/ha	100%	100%	300%

5.3.3.3.- Indifferent species.

Emmotum nitens, Cupania vernalis, Cheiloclinium cognatum and *Jacaranda puberula* occur with similar densities and basal areas in both dry and wet-steeper communities and in the total sampling and so are considered indifferent.

5.4.- Discussion.

Pitoco's dryness, Monjolo's wetness and Taquara's intermediate soil moisture provided a field experiment where species related to the different communities could have their performance checked to investigate whether their behaviour is consistent. Species consistently related to dry and wet communities are chosen for comparison.

Callisthene major is known as a forest/cerrado margin species advancing into cerrado and producing conditions allowing gallery species to colonise the area. This pattern is also displayed by *Guettarda viburnioides* (P, T), *Lamanonia ternata* (P), *Pera glabrata* (P, T), *Platypodium elegans* (P, M, T), *Ouratea castaneaefolia* (M) and *Alibertia macrophylla* (T).

Copaifera langsdorffii has been recorded within various forest and savanna communities and is considered one of the most widespread species in the central Brazilian gallery forests (Ratter 1986, Brasil 1990, Felfili & Silva Júnior 1992, Felfili 1993, Oliveira-Filho & Ratter in press). Machado (1990) studied this species from both forest and cerrado provenances under natural and artificial flooding regimes and found it intolerant to waterlogging. The present results suggest that it is best adapted to intermediate soil moisture conditions. The following species are found to follow a similar ecological pattern: *Bauhinia rufa* (P), *Jacaranda puberula* (P, M), *Matayba* *guianensis* (P, M, T), *Myrsine coriacea* (M), *Sacoglottis guianensis* (M) and *Diospyros hispida* (T).

Anadenanthera colubrina var. *cebil, Roupala montana* and *Myrcia tomentosa* of the Taquara dry community are not recorded in Pitoco so could not be compared. However, the first two are believed to follow the *Copaifera* pattern, while *Myrcia tomentosa*, like *Callisthene major,* is a typical forest/cerrado border species.

The wet communities are inferred as being under a stronger water table influence. *Tapirira guianensis* is the only species consistently 'related' to the wet communities of all three sites. It is also the most important species in Monjolo's wet-steeper community where damp soil conditions are very unlikely to occur. This latter is probably a common situation in most of the central Brazilian gallery forests where *Tapirira guianensis* is one of the most widespread species (Oliveira-Filho & Ratter in press) and always among the most important (Brasil 1990, Felfili & Silva Júnior 1992, Felfili 1993, Silva Júnior et al. in prep.). Reinforcing this observation Eiten (personal communication) suggested that most of the galleries in the cerrado region do not lie over hydromorphic soils as indicated erroneously by EMBRAPA (1980). This agrees with the majority of profiles description in the Pitoco, Monjolo and Taquara galleries classified as Cambisols (see Chapter 7).

Protium almecega (P, T), *Pseudolmedia guaranitica* (P, M), *Emmotum nitens* (P, M), *Licania apetala* (P, M) and *Virola sebifera* (P, M) are related to wet communities in two sites.

The following species are recognised as related to the wet communities at least in one of the three sites and followed *Tapirira's* pattern: *Virola sebifera* (P, M), *Cecropia lyratiloba* (M), *Inga alba* (M),*Ocotea aciphylla* (P), *Sclerolobium paniculatum* var. *rubiginosum* (T), and *Tapura amazonica* (T).

The most typical species within the flatter sites in Monjolo is *Licania apetala*, another widespread species found in gallery forests of many Brazilian regions. The following species characterised the same habitat: *Protium almecega* (P, T), *Pseudolmedia guaranitica* (P, M), *Amaioua guianensis* (M), *Aspidosperma subincanum* (M), *Cheiloclinium cognatum* (M), *Cryptocarya aschersoniana* (M), *Maporunea guianensis* (T), *Piptocarpha macropoda* (T), *Pouteria ramiflora* (M) and *Salacia elliptica* (M). Of these, some typical species such as *Protium almecega* and *Pseudolmedia guaranitica* are well known as streamside colonisers where wetter soil conditions prevail. The absence of species such as *Calophyllum brasiliense* and *Xylopia emarginata* demonstrates that little of the area is subjected to more extreme seasonal floodings.

One feature of particular interest is the occurrence of some of the typical indicator species of mesotrophic soils such as *Anadenanthera colubrina* var. *cebil*, *Guettarda viburnioides* and *Platypodium elegans* in the Taquara gallery forest were such soils are present. The characteristic flora of mesotrophic soils is described and discussed by Ratter (1978).

The results presented here are to be taken as hypothesis generators for further studies on habitat selection of species in gallery forests. However, they are strongly indicative of the presence of communities and related species competitive ability, suggesting detailed studies on their relationships with environmental features which is the subject of Chapter 8 and 9.

Chapter 6 - Comparison between the Pitoco, Monjolo and Taquara gallery forests and their constituent communities.

6.1 - Introduction

In the previous chapter, communities with distinct floristic composition, density and basal area are described in the Pitoco, Monjolo and Taquara gallery forests. Distance from the stream margin, site elevation and the phytosociological importance of well known indicators species point to their relationship with a topographic-moisture gradient.

In this chapter a qualitative and quantitative comparison is carried out using an agglomerative cluster analysis to assess the floristic links *between* the communities of these galleries. This comparison is based on the idea that the floristic similarity between two sites should express their ecological relationship or resemblance (van Tongeren 1987). These analyses address question number 3: Do these three galleries show similarities in floristic composition, density and basal area?

6.2 - Material and Methods.

The analyses were carried out using an agglomerative hierarchical classification by UPGMA (Unweighted Pair Groups Method using Arithmetic averages) which is the most popular in ecological studies (James & McCulloch 1990, Belbin & McDonald 1993). This technique combines samples based on their minimum average distance, the two groups of samples that resemble each other closest are always fused (van Tongeren 1987) until all are in one group (James & McCulloch 1990, Kent & Coker, 1992). Groupings of sites are made according to a similarity measure. The results of the analysis are presented in dendrograms where the hierarchical structure of the site groups are expressed. Evaluation of the ecological relationship between communities can be made at each dichotomy level of the dendrograms as far as it allows biological interpretation (van Tongeren 1987, James & McCulloch 1990).

The floristic comparison is undertaken on the basis of a presence/absence (qualitative) matrix. The Sørensen Index (Sørensen 1948) is used as a measure of similarity. It is calculated as follows:

Sørensen Index = 2C / (A + B)

where: A = total number of species in community a.

B = total number of species in community b.

C = number of species shared by both communities.

The result equals 1 when both sites have identical sets of species and 0 if there is no single species in common.

A similar procedure is used to combine floristic information with that of density and basal area in a comparison. Here Morisita's index (Horn 1966) is used as a measure of similarity:

$$\textbf{Index of Morisita} = 2 \Sigma X_i Y_i / (C_1 + C_2) N_1.N_2$$

where: Xi = is the basal area or density of species $_i$ in community C1.

$$C_1 = X_i (X_i - 1) / N_1(N_1 - 1)$$

Yi = is the basal area or density of species $_i$ in community C2.

$$C2 = Y_i (Y_i - 1) / N_2 (N_2 - 1)$$

N1 = is the total number of species in community C1.

N2 = is the total number of species in community C2.

It may range from 0, where there is no similarity, to 1, indicating identical communities.

As a general rule with both Sørensen and Morisita indices, similarities greater than 0.5 are considered high.

FITOPAC-2, a software developed by Dr George Shepherd of the State University of Campinas is used to perform these analyses.

6.3.- Results and discussion

6.3.1.- Floristic comparison.

The Sørensen similarity indices between all sites are shown in table 14. The UPGMA dendrogram (Figure 25) shows the floristic links among the galleries and their constituents communities. Some important patterns arise related to physical characteristics of the three sites. The groups are presented below with brief descriptions of their environment.

Group A - comprises the communities of the Taquara and the drier communities of the Pitoco galleries. The most important environmental feature present at these sites is relative soil dryness. The Pitoco site is the steepest studied (see Chapter 5) and although the Taquara site is on a flat terrain the stream lies in a deep bed. These characteristics provide better drained substrates and less high water table influence.

Within group A the analysis emphasises the floristic individuality of each site by the high levels of most clusterings (ranging from 58 to 85%).

Group B is separated from group A at 54% Sørensen similarity, the minimum value found in Figure 25. Group B comprises all communities of the Monjolo gallery and Pitoco wet community. The environmental feature which relates the sites is the moister soil conditions. The Monjolo sites show strong influence of a high water table. The flat terrain, the presence of the wet community as far as 80 m from the stream margins and the presence of dense populations of *Olyra latifolia* demonstrate

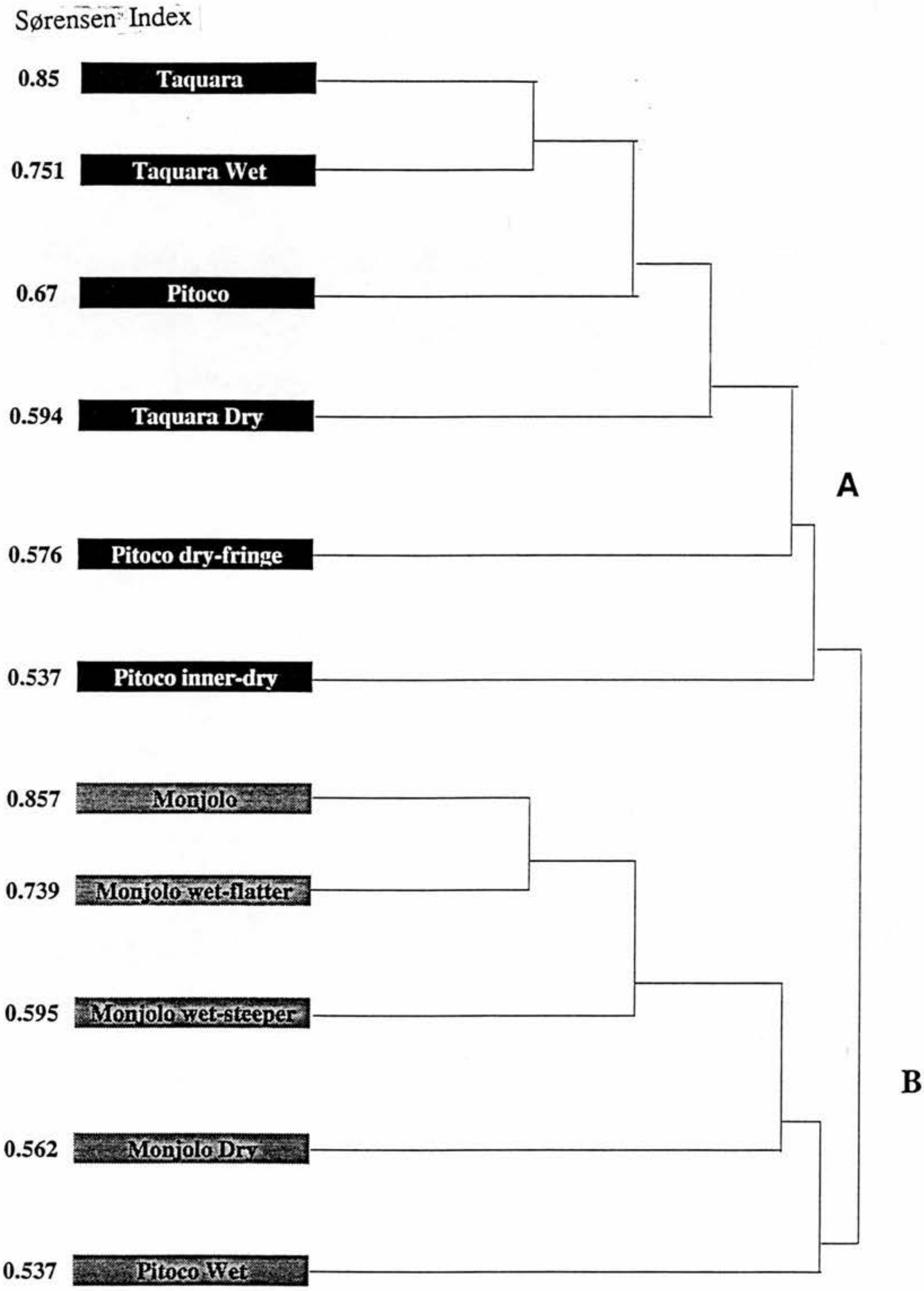


Figure 25 - Similarity dendrogram yielded by UPGMA, using Sorensen Similarity Index, showing the hierarchical classification of the communities of the Pitoco, Monjolo and Taquara gallery forests.

	P	P - Border	P - Inner	P - Wet	M	M - Flatter	M - Steeper	M - Dry	T	T- Dry	T - Wet
Pitoco	1.00										
Pitoco dry-fringe	0.68	1.00									
Pitoco inner-dry	0.7059	0.5143	1.00								
Pitoco wet	0.6928	0.419	0.537	1.00							
Monjolo	0.7151	0.4886	0.6269	0.6119	1.00						
Monjolo wet-flatter	0.6164	0.4144	0.5614	0.5614	0.8571	1.00					
Monjolo wet-steeper	0.5638	0.4356	0.5962	0.5962	0.7692	0.7091	1.00				
Monjolo dry	0.4823	0.4946	0.5208	0.4792	0.6885	0.5098	0.587	1.00			
Taquara	0.7656	0.559	0.561	0.5488	0.6632	0.5765	0.5125	0.4211	1.00		
Taquara dry	0.6071	0.5833	0.4878	0.4228	0.5369	0.4496	0.4538	0.3784	0.771	1.00	
Taquara wet	0.7363	0.5522	0.6131	0.5547	0.7117	0.6294	0.5865	0.496	0.8497	0.6316	1.00

Table 14 - Similarity matrix showing the Sorensen Index between the communities of the Pitoco (P), Monjolo (M) and Taquara (T) gallery forests.

this. Pitoco's wet community occurs only within 10-20 m of the stream margins where the water table influence is stronger.

The first dichotomy in this group separates the Pitoco wet community from the Monjolo group. At the next dichotomy, the Monjolo wet sites are isolated from its dry community, demonstrating once again the importance of soil moisture as the most important factor associated with floristic differentiation of the communities.

The classifications provided by both TWINSPAN in Chapter 5 and UPGMA, lead to the same interpretation. This is of particular methodological interest, as mentioned by Oliveira-Filho & Ratter (in press), since UPGMA analyses the whole data set (i.e. includes all species), while in our TWINSPAN analysis the rare species are eliminated so the fact that the two give the same results indicates that rare species have little or no effect.

The overall interpretation is that the differential soil moisture regime along the topographic gradient, from the stream margins to the forest-cerrado borders , is the most important environmental feature and explains the higher clustering levels in the classification. However, lower clustering levels suggest that other environmental variables might also be involved. A detailed soil characterisation and study on the relationships with the communities are the focus of Chapters 7, 8 and 9.

6.3.2.-Density.

When weighting the species presence and absence with information on species density it is well to consider the factors influencing the number of individuals in each site. These, as pointed out by Harper (1977) and Bailie et al. (1987), are mainly the result of a concatenation of chance events running from the presence of a fertile parent through flowering, pollination, fruit set, seed dispersal, germination, survival and growth in seedling and pole stages to the occurrence finally of an opportune gap in the canopy, enabling the understorey juvenile to be recruited. These opportunistic

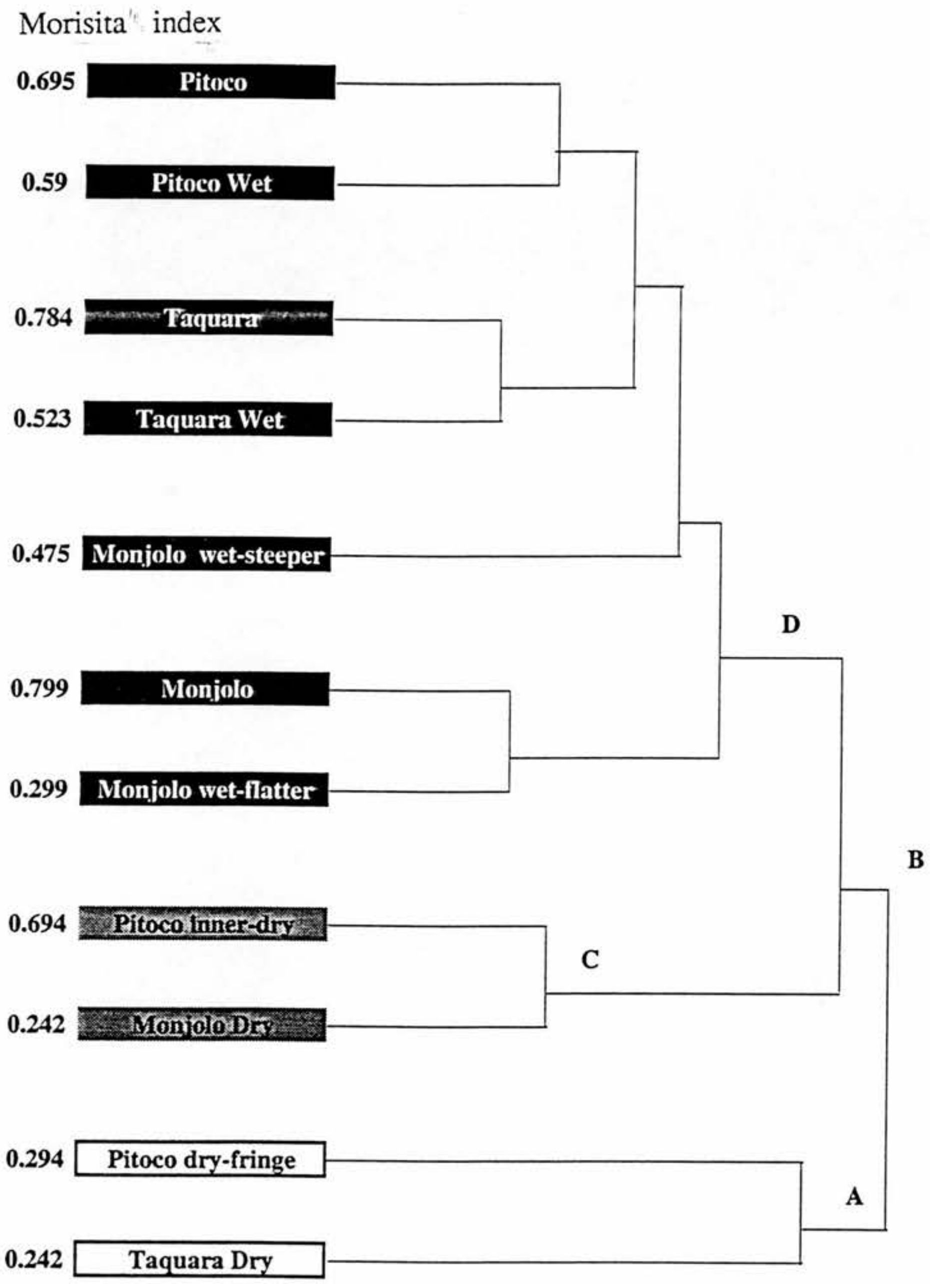


Figure 26 - Similarity dendrogram yielded by UPGMA, using Morisita Similarity Index based on density showing the hierarchical classification of the communities of the Pitoco, Monjolo and Taquara gallery forests.

	P	P - Border	P - Inner	P - Wet	M	M - Flatter	M - Steeper	M - Dry	T	T- Dry	T - Wet
Pitoco	1.00										
Pitoco dry-fringe	0.579	1.00									
Pitoco inner-dry	0.5497	0.2046	1.00								
Pitoco wet	0.695	0.1409	0.2046	1.00							
Monjolo	0.6686	0.2027	0.4621	0.5238	1.00						
Monjolo wet-flat	0.3907	0.055	0.2217	0.4209	0.7994	1.00					
Monjolo wet-stee	0.4947	0.1863	0.3704	0.5043	0.658	0.2571	1.00				
Monjolo dry	0.3978	0.3518	0.6942	0.1014	0.3245	0.092	0.1701	1.00			
Taquara	0.6697	0.3297	0.3924	0.4148	0.5813	0.2706	0.4516	0.3304	1.00		
Taquara dry	0.286	0.2939	0.2751	0.0594	0.1545	0.0708	0.0761	0.3079	0.6513	1.00	
Taquara wet	0.659	0.2594	0.3477	0.6161	0.6414	0.3358	0.6396	0.2241	0.7842	0.1587	1.00

Table 15 - Similarity matrix showing the Morisita Index based on density/ha between the communities of the Pitoco (P), Monjolo (M) and Taquara (T) gallery forests.

events are guided to some extent by site conditions which exert considerable effect on interespecific competition and determine consistent associations of species, many of which exhibit significant environmental preferences (Ashton 1976). The Morisita similarity levels are thus interpreted as largely indicative of ecological similarities among sites providing the opportunities for colonisation and maintenance of the same species.

The Morisita indices for species density among the 11 sites are presented in Table 15 and the UPGMA dendrogram is in Figure 26.

Two groups, A and B, are recognised at the lowest clustering levels. Group A includes the Pitoco dry-fringe community and the Taquara dry community. Both occur on better drained soils (see Chapter 5), Pitoco because of its steep topography and Taquara as a result of the deep stream bed. They are considered as the driest sites in the study.

At a second clustering level, group B is made up of a large number of subgroups. Of these, group C includes Pitoco inner-dry and Monjolo dry communities. The first is located between the dry-fringe and the wet community of Pitoco while Monjolo's dry community occurs on a steep slope and is considered the driest site in this gallery. Both communities of this group seem to be in less dry than those of group A.

Group D comprises all other sites and includes all communities showing an influence of high water table.

6.3.3.-Basal area.

Figure 27 shows the UPGMA-derived similarity diagram using the Morisita Index based on basal area. At the lowest clustering level the Pitoco dry-fringe, forming group A, separates from the rest of the sites (group B) at 23% of Morisita

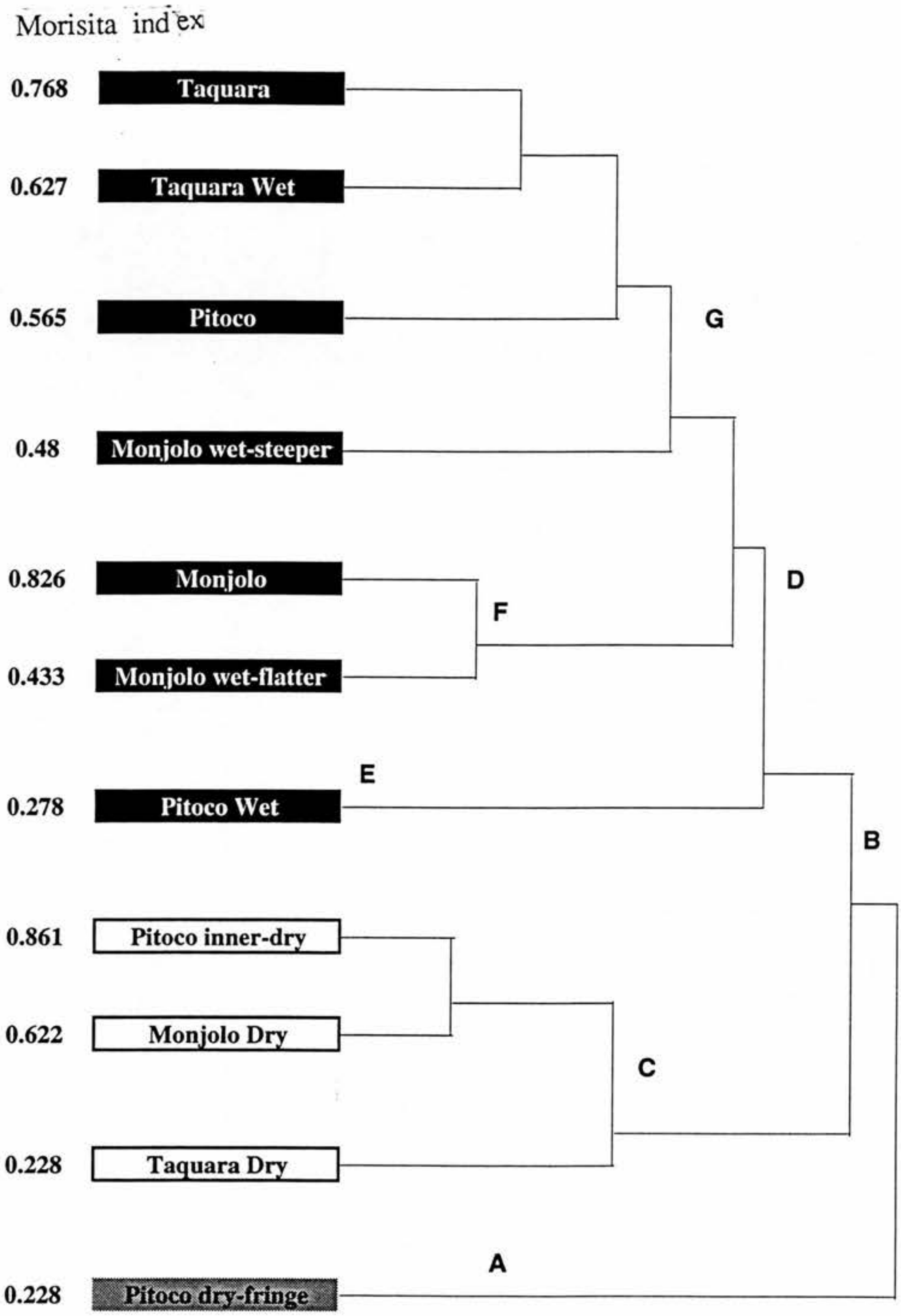


Figure 27- Similarity dendrogram yelded by UPGMA, using Morisita Similarity Index based on basal area showing the hierarchical classification of the communities of the Pitoco, Monjolo and Taquara gallery forests.

	P	P - Border	P - Inner	P - Wet	M	M - Flatter	M - Steeper	M - Dry	T	T- Dry	T - Wet
Pitoco	1.00										
Pitoco dry-fringe	0.5126	1.00									
Pitoco inner-dry	0.4928	0.1859	1.00								
Pitoco wet	0.5655	0.0904	0.0704	1.00							
Monjolo	0.6714	0.1889	0.4197	0.4182	1.00						
Monjolo wet-flatter	0.3736	0.0389	0.2449	0.3618	0.826	1.00					
Monjolo wet-steeper	0.519	0.1491	0.1745	0.5123	0.6687	0.4126	1.00				
Monjolo dry	0.4925	0.4092	0.8611	0.0374	0.3987	0.1618	0.162	1.00			
Taquara	0.6619	0.2774	0.4114	0.3103	0.6031	0.2813	0.5208	0.4249	1.00		
Taquara dry	0.3993	0.1426	0.6192	0.0785	0.3442	0.1651	0.125	0.6247	0.6607	1.00	
Taquara wet	0.5914	0.2867	0.2029	0.4286	0.5386	0.2889	0.6544	0.2003	0.7678	0.1702	1.00

Table 16 - Similarity matrix showing the Morisita Index based on basal area/ha, between Pitoco (P), Monjolo (M) and Taquara (T) gallery forests.

similarity. As already mentioned, this community is considered as occupying the driest habitat of those studied.

Group B divides into (i) subgroup C which includes Pitoco inner-dry and Monjolo dry, forming a group of 86% Morisita similarity suggesting equivalence of environmental conditions, and the Taquara dry community, and (ii) subgroup D which includes all the wetter communities aggregated more or less according to their moisture levels.

Thus, as in the floristic comparison and in the Morisita indices based on density, the Morisita indices based on basal area demonstrate that soil moisture is the most important factor controlling differences of communities.

6.4.- **Conclusions.**

The analysis demonstrated the influence of the soil moisture regime, principally related to the topographic gradient of the galleries, as the strongest environmental feature determining variation of the vegetation. Communities under similar soil moisture regimes are clustered as a result of their similar floristic composition, species density and basal area characteristics.

The influence of other complementary environmental factors might be responsible for the lower clustering.

The next chapters are devoted to characterise and ordinate chemical and physical properties of the soils and to study communities and their abiotic environmental relationships.

Chapter 7 - Characterisation of the soils.

7.1.- Introduction.

There have been a number of studies on gallery forest soils in Central Brazil. The first attempt at a systematic survey of soils of the Federal district (EMBRAPA 1979) indicated that gallery forests were associated with hydromorphic soils. However, more recent studies suggest that no such simple generalisation should be made since a variety of soil units with a range of nutrient levels have been found (Furley 1985, Cavedon & Sommer 1990, Silva 1991, Felfili 1993, Ramos 1994).

As a requirement of the RECOR first management plan, a detailed soil survey was carried out in 1992 including some of the area of the galleries. These results are not yet available and data analysed here will add important information to the RECOR soils' description.

In Chapters 4, 5 and 6 the floristic composition and structure of the Pitoco, Monjolo and Taquara gallery forests is found to be distinct, both between the galleries and within them. The aim of this chapter is to characterise and compare their soils in order to assess whether or not variations in chemical and physical properties determine the pattern of plant communities.

7.2 - Sampling and methods.

In each of the gallery forests, mixed soil samples (0-10 cm) for each of the numbered sites were collected (see Figures 28, 29 and 30). Chemical and physical analyses were carried out at the soil laboratory of EMBRAPA/CPAC (the National Agricultural Research Agency, the Centre for Agricultural Research of Cerrado),

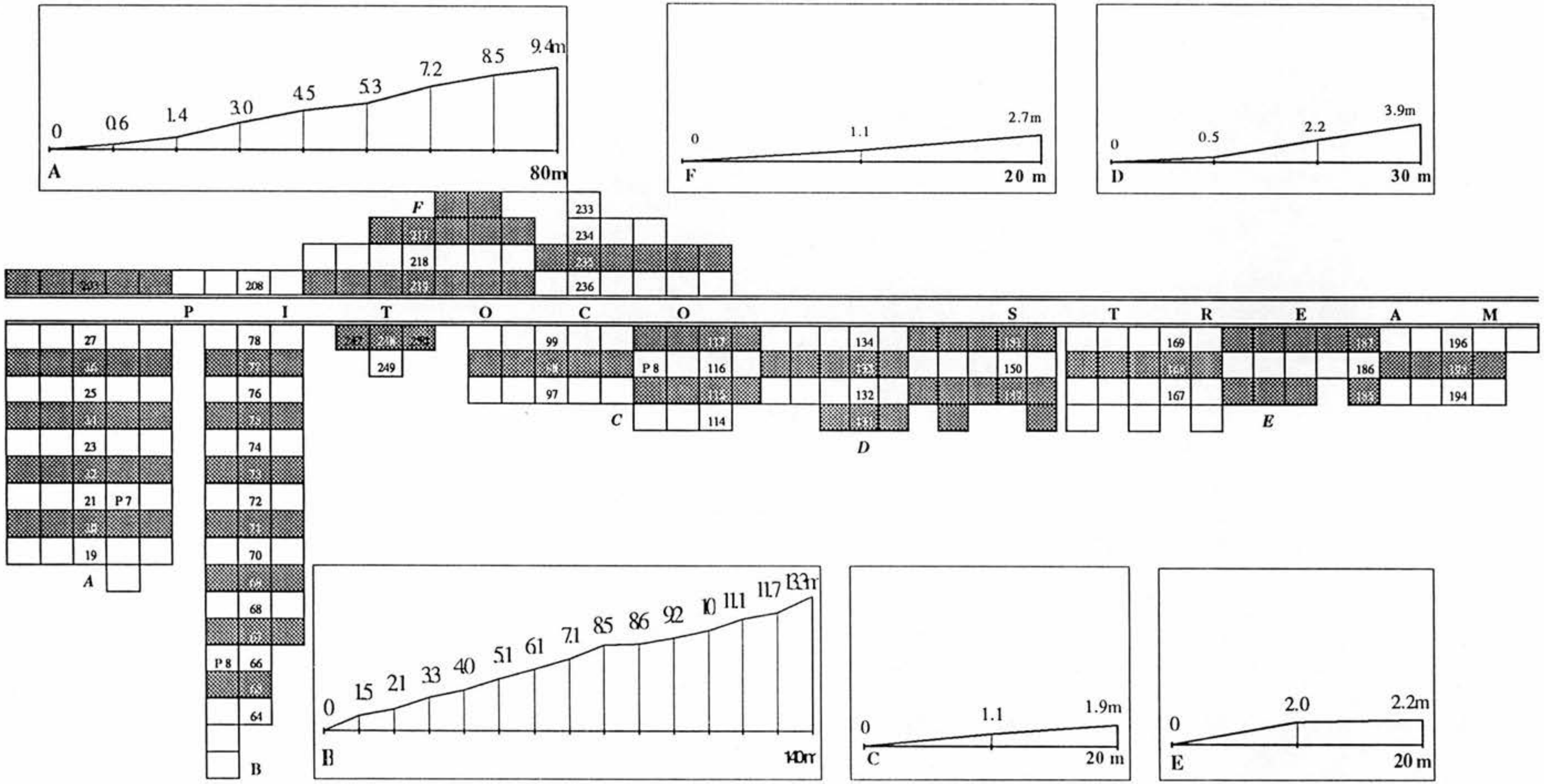


Figure 28 - The distribution of soil samples groups in the Pitoco gallery forest, including elevation diagrams and soil profiles (P7, P8 and P9)

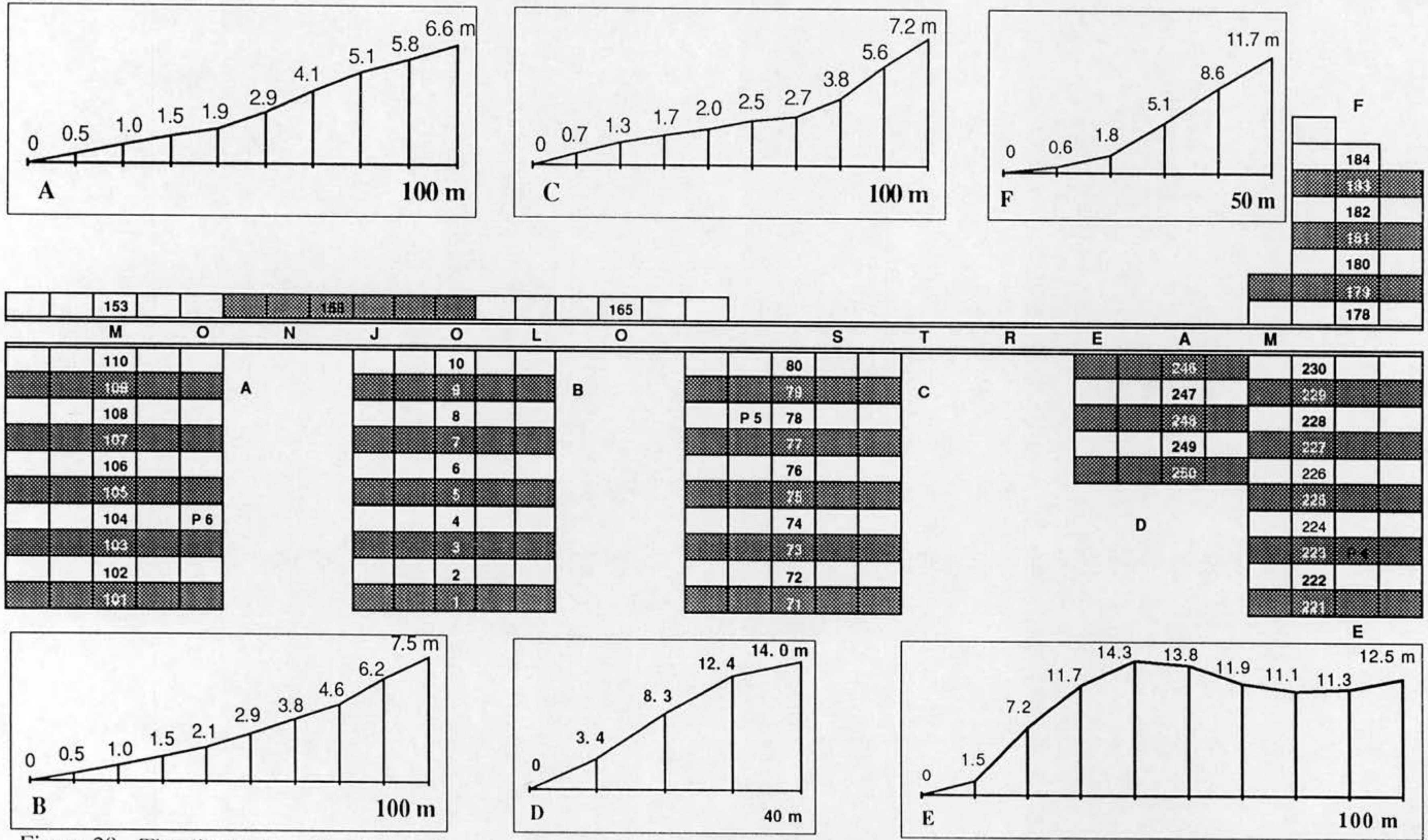


Figure 29 - The distribution of soil samples groups in the Monjolo gallery forest, including elevation diagrams and soil profiles (P4, P5 and P6)

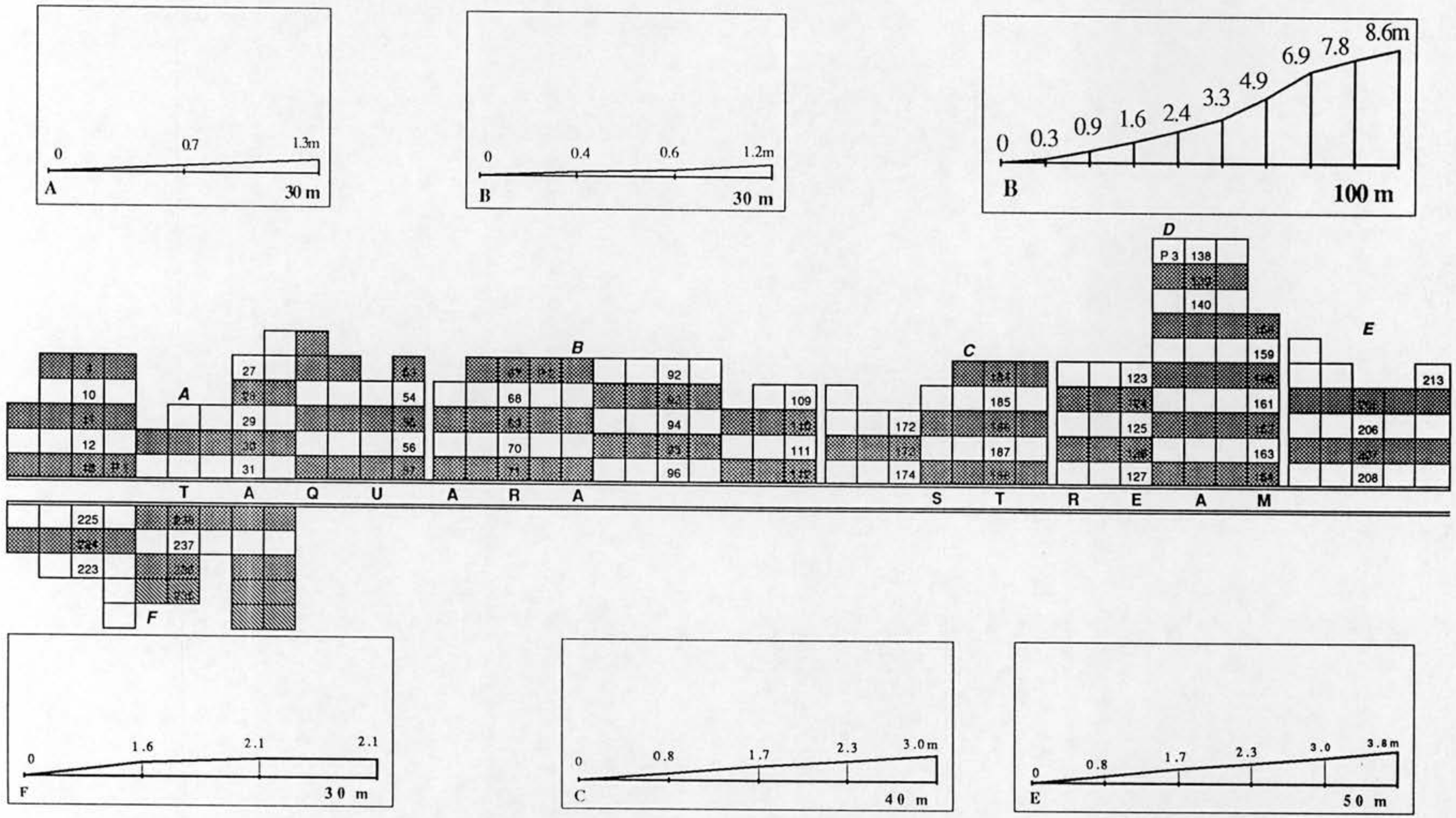


Figure 30 - The distribution of soil samples groups in the Taquara gallery forest, including elevation diagrams and soil profiles (P1, P2 and P3).

following the procedures specified by EMBRAPA (1979). Analyses were made of pH(H_2O), Al, H + Al, Ca + Mg, Ca, P, K, Mn, Cu, Zn, Fe, organic matter and the percentages of sand, silt and clay. From these results, Al saturation (%), Cation Exchange Capacity (CEC), Total Base Saturation (TEB%) and the percentage of base saturation (V) were calculated following Kiehl (1979) as follows:

$$\text{Al sat (\%)} = (\text{Al} / \text{TEB} + \text{Al}) \,.\, 100$$

$$\text{CEC} = \text{Ca} + \text{Mg} + \text{K} + \text{H} + \text{Al}$$

$$\text{TEB} = \text{Ca} + \text{Mg} + \text{K}$$

$$\text{V (\%)} = \text{TEB} / \text{CEC} \,.\, 100$$

Soil pH was measured with a potentiometer in a 1:2.5 soil-water suspension. Available P, K, Fe, Mn, Zn and Cu were determined in soil extracts of a diacid mixture (0.05 *N* HCl + 0.025 *N* H_2SO_4). Exchangeable Ca + Mg, and exchangeable Al were determined in soil extracts of 1 *N* KCl solution; Al was titrated with 1 *N* NaOH solution while Ca + Mg and Ca were separately titrated with 0.025 *N* EDTA. Total acidity (H + Al) was obtained using a 1*N* calcium acetate extracting solution at pH 7.0. Organic Carbon was determined by the Tuirin method and the percentage of organic matter was calculated using the Bremelem constant (1.724). Texture was obtained by the hydrometer method of Bouyoucos.

The soil samples are grouped as shown in Figures 28, 29 and 30. The vegetation classification generated from TWINSPAN (see Chapter 5) and the distance from the stream margins indicates the community to which they belong. Tests of significance (student t-test) were carried out to compare the average values of soil properties within and between the galleries.

7.3.- Results and discussion.

The raw data from the soils analyses are presented in Tables 17, 18 and 19. Table 20 includes averages, standard deviations and coefficients of variation for each gallery and its constituent tree communities.

As a consequence of the small number of studies carried out in gallery forest soils, the present results are compared with the ranges of values established for the cerrado region as a whole (Eiten 1972, Adamoli et al. 1985, Furley & Ratter 1988). The few studies carried out on mineral nutrition of tree species have shown their generally much lower nutrient requirements and much higher levels of tolerance to toxicity when in comparison with cultivated plants (Barros 1979). However, the critical levels for crop species, which have been extensively studied, are taken as a reference for data interpretation.

7.3.1.- pH (H_2O)

The levels of pH in cerrado soils are reported as ranging mostly between 4.5 and 5.0 (Eiten 1972, Lopes 1980). Values below 5.0 indicate high acidity and are more likely to be measured at the surface layer due to the higher levels of H and Al (Ranzani 1971). Lopes & Cox (1977) studying soils samples over a large area of the cerrado domain, found that 91% showed high levels of acidity.

The pH on its own is not directly related to productivity and growth but it can affect nutrient availability. The soil's exchange capacity is pH-dependent, such that the negative charges of the clay fraction increase as pH is increased. Concurrently Al availability is reduced making possible the adsorption of other cations (Ca, Mg and

Table 17- Raw data of soil samples (0-10 cm) of the Pitoco gallery forest, grouped in constituent communities.
Where: CS= coarse sand and FS= fine sand.

■ = wet , ░ = inner-dry and □ = dry-fringe community.

areas	pH	OM	Al	H+Al	Ca	Mg	Ca+mg	K	P	Fe	Cu	Zn	Mn	CEC	TEB	V	Al sat	Clay	Silt	CS	FS	Texture
	(H2O)	(%)	cmol/Kg						ppm					cmol/Kg		%	%			%		
p19	5	9.36	0.94	16.24	1.14	1.79	2.93	0.22	2.7	55	0.5	2.99	57.06	21.37	5.13	24.0	112.3	64	16	7	13	very clayey
p20	4.7	11.46	2.05	21.34	0.44	0.81	1.25	0.20	3.6	106.4	0.8	3.33	26.6	24.64	3.30	13.4	267.2	67	16	4	13	very clayey
p21	4.8	8.01	1.95	16.98	0.25	0.54	0.79	0.18	3.3	56.1	1	1.7	28.7	19.59	2.61	13.3	269.8	59	21	5	15	clay
p22	4.4	9.49	2.69	17.18	0.15	0.46	0.61	0.18	2.4	104.5	0.6	1.99	5.22	19.55	2.37	12.1	382.3	62	21	3	14	very clayey
p23	4.3	6.9	2.22	16.32	0.13	0.47	0.6	0.14	2	86.4	0.6	1.45	11.42	18.35	2.03	11.1	331.2	64	18	4	14	very clayey
p75	5.2	4.93	1.22	11.4	0.17	0.36	0.53	0.21	1.6	88.3	0.8	1.46	23.41	14.00	2.60	18.6	168.9	66	20	5	9	very clayey
p116	4.5	10.84	3.52	21.82	0.11	0.44	0.55	0.25	3.1	161	0.9	3.55	3.44	24.88	3.06	12.3	467.2	59	24	4	13	clay
p132	4.6	14.42	3.87	24	0.24	0.34	0.58	0.46	4.2	133.6	0.9	2.91	7.69	29.18	5.18	17.8	461.7	48	24	7	21	
p133	4.5	11.21	3.4	20.22	0.23	0.18	0.41	0.24	2.3	157.9	0.8	1.55	1.58	23.01	2.79	12.1	461.9	60	24	3	13	very clayey
p150	4.7	13.92	3.17	25.12	0.38	1.2	1.58	0.61	3.8	154	0.8	2.09	12.22	32.79	7.67	23.4	358.3	50	24	6	20	clay
p24	4.9	8.38	1.52	14.2	0.13	0.34	0.47	0.13	3.9	40.2	0.6	1.71	7.58	15.95	1.75	11.0	238.9	46	25	8	21	clay
p25	4.7	8.38	2.54	15.78	0.15	0.39	0.54	0.17	2.2	90.2	0.6	1.75	2.67	18.01	2.23	12.4	368.0	60	20	3	17	very clayey
p26	4.8	5.79	1.66	11.94	0.11	0.38	0.49	0.14	2	66.5	0.8	1.61	2.17	13.84	1.90	13.7	253.5	67	17	3	13	very clayey
p27	5	7.89	1.48	12.78	0.11	0.37	0.48	0.13	3.7	29.9	0.6	1.72	3.91	14.51	1.73	11.9	233.4	53	21	7	19	clay
p76	5	8.38	1.57	15.9	0.25	0.43	0.68	0.23	2.2	100.2	0.8	2.51	16.14	18.88	2.98	15.8	209.7	70	16	3	11	very clayey
p77	4.9	8.87	2.17	19.48	0.1	0.31	0.41	0.42	4.4	180.8	1	2.01	8.73	24.08	4.60	19.1	264.1	70	17	3	10	very clayey
p78	4.9	12.57	2.66	23.32	0.2	0.4	0.6	0.25	3.3	122.3	0.8	3.64	7.33	26.45	3.13	11.8	350.9	52	26	7	15	clay
p98	4.8	9.86	2.25	17.44	0.16	0.27	0.43	0.21	2.3	138.5	0.8	1.43	5.56	20.02	2.58	12.9	312.3	70	18	5	7	very clayey
p99	4.5	16.51	3.98	25.12	0.17	0.25	0.42	0.23	5.4	113.3	0.6	2.87	1.51	27.87	2.75	9.9	542.9	39	24	10	27	clay sand
p117	4.5	10.1	3.64	20.64	0.12	0.3	0.42	0.45	4.6	128.7	1	1.74	5.75	25.51	4.87	19.1	438.7	60	24	3	13	very clayey
p134	4.4	17.5	3.41	24.74	0.36	0.12	0.48	0.24	3.3	194.2	0.5	4.03	7.48	27.60	2.86	10.4	460.3	42	21	6	31	clay
p151	4.6	10.72	3.35	21.8	0.18	0.3	0.48	0.41	3.2	156.5	0.9	4.34	2.94	26.35	4.55	17.3	408.7	57	17	6	20	clay
p169	4.8	14.66	2.6	26.9	0.14	0.34	0.48	0.51	3.4	229.9	1	4.45	7.89	32.52	5.62	17.3	306.3	46	19	13	22	clay
p187	4.9	19.59	4.59	26.82	0.11	0.74	0.85	0.22	3.5	105.6	1.1	2.67	6.34	29.84	3.02	10.1	610.8	29	12	19	40	loamy clay sand
p195	4.8	8.38	2.31	18.94	0.26	0.42	0.68	0.24	2.4	156	1.6	3	8.42	21.97	3.03	13.8	307.2	74	11	4	11	very clayey
p196	4.5	16.63	3.38	28.94	0.23	0.67	0.9	0.28	5.2	181.7	1.4	3.14	5.42	32.68	3.74	11.4	428.4	52	20	9	19	clay
p203	5.2	23.41	2.42	26.64	0.3	0.48	0.78	0.30	8.2	284.8	1.2	4.84	4.12	30.39	3.75	12.3	306.6	20	16	40	24	loamy clay sand
p208	4.6	19.34	5.11	33.64	0.35	0.27	0.62	0.25	5.8	418.1	1.7	3.28	1.64	36.72	3.08	8.4	677.2	30	22	14	34	loamy clay sand
p218	4.6	12.94	3.81	25.25	0.18	0.38	0.56	0.22	3.9	138.8	1.1	3.7	3.65	27.98	2.73	9.8	520.4	45	19	11	25	clay

[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	clay
p236	4.5	18.36	4.57	31.34	0.25	0.4	0.65	0.25	7.3	83.6	1.5	2.75	2.12	34.47	3.13	9.1	603.0	22	13	26	39	loamy clay sand
p248	4.4	13.43	2.78	21.54	0.22	0.22	0.44	0.19	7.5	56.5	0.7	2.83	4.49	23.90	2.36	9.9	395.9	35	19	15	31	loamy clay sand
p249	4.7	8.25	2.27	17.58	0.12	0.35	0.47	0.12	2.8	36.7	1	3.45	4.32	19.20	1.62	8.4	367.0	55	18	6	21	clay
p64	5.5	8.25	0.1	10.22	4.98	2.26	7.24	0.22	1.7	46.1	0.4	2.47	41.43	19.69	9.47	48.1	11.1	65	18	4	13	very clayey
p65	5.4	5.91	0.54	12.02	1.27	1.25	2.52	0.22	1.3	63.7	0.5	2.85	76.59	16.74	4.72	28.2	65.4	69	17	4	10	very clayey
p66	5.7	8.87	0.24	14.24	3.2	2.16	5.36	0.25	1.6	19.2	0.3	3.71	110.5	22.13	7.89	35.7	27.0	55	20	8	17	clay
p67	5.3	6.16	0.86	11.06	0.52	0.51	1.03	0.19	1.4	63.5	0.6	1.75	44.68	13.96	2.90	20.8	115.7	70	15	4	11	very clayey
p68	5.3	9.24	1.27	17.8	1.84	1.5	3.34	0.21	1.6	45.8	0.3	1.67	73	23.21	5.41	23.3	150.5	61	18	5	16	very clayey
p69	5.2	6.65	1.44	12.7	0.41	0.56	0.97	0.21	1.6	124.1	0.7	1.88	46	15.82	3.12	19.7	190.2	72	13	3	12	very clayey
p70	5.5	7.76	0.44	11.9	1.82	1.59	3.41	0.16	1.3	37	0.6	3.93	92.88	16.95	5.05	29.8	52.7	62	22	5	11	very clayey
p71	5.2	6.28	1.1	13.14	0.74	0.88	1.62	0.20	1.4	107.4	0.8	2.27	45.7	16.75	3.61	21.6	140.4	70	16	3	11	very clayey
p72	5	8.75	1.74	17.56	0.25	0.88	1.13	0.22	1.5	70.3	0.6	1.89	31.98	20.89	3.33	15.9	226.3	69	17	4	10	very clayey
p73	5	7.15	1.21	12.02	0.23	0.64	0.87	0.20	1.6	99.2	0.9	2.28	26.56	14.91	2.89	19.4	162.9	70	18	4	8	very clayey
p74	5	12.81	1.97	21.62	1.24	1.81	3.05	0.45	2.5	105.3	0.6	3.77	29.45	29.12	7.50	25.8	223.3	55	22	5	18	clay
p97	4.9	9.73	2	17.38	0.15	0.6	0.75	0.25	2.5	124.5	0.9	1.84	12.71	20.66	3.28	15.9	260.9	65	21	3	11	very clayey
p114	5.3	15.77	0.69	20.16	2.77	3.12	5.89	0.60	2.6	29.6	0.3	2.81	93.53	32.01	11.85	37.0	74.8	40	25	13	22	clay
p115	4.7	14.66	3.26	23.72	0.19	0.51	0.7	0.46	4	136.5	0.8	1.96	11.01	29.02	5.30	18.3	387.5	50	26	6	18	clay
p131	4.9	10.1	2.28	19.64	0.37	0.83	1.2	0.51	3.8	65	0.6	3.73	58.15	25.98	6.34	24.4	264.0	54	23	10	13	clay
p149	5	9.98	1.06	16.82	1.4	1.5	2.9	0.26	2.1	60.3	0.6	2.13	36	22.30	5.48	24.6	125.3	54	23	7	16	clay
p167	4.9	8.99	1.64	17.24	0.17	0.33	0.5	0.25	1.8	115.7	0.9	1.81	12.61	20.20	2.96	14.6	219.5	59	17	9	15	clay
p168	4.9	11.58	2.5	20.62	0.11	0.26	0.37	0.24	2.5	148.3	0.8	2.5	21.45	23.39	2.77	11.9	340.1	52	16	12	20	clay
p185	5	9.24	1.49	15.44	0.11	0.29	0.4	0.26	2	106.5	1	1.97	16.46	18.42	2.98	16.2	198.9	56	16	12	16	clay
p186	4.8	10.72	2.61	20	0.12	0.72	0.84	0.48	2.7	92.52	1.4	1.19	12.88	25.67	5.67	22.1	307.0	60	16	9	15	very clayey
p194	4.5	16.76	3.92	25.6	0.24	0.58	0.82	0.20	2.4	104.7	1.2	7.95	8.77	28.47	2.87	10.1	528.8	56	17	10	17	clay
p217	4.5	12.2	3.83	24.82	0.1	0.36	0.46	0.23	3.3	82.4	0.8	3.01	12.56	27.53	2.71	9.8	524.3	47	17	6	30	clay
p233	4.7	11.33	3.08	21.4	0.14	0.49	0.63	0.34	4.4	88.4	1.6	6.35	11.98	25.41	4.01	15.8	384.9	49	22	4	25	clay
p234	4.6	13.92	3.65	21.16	0.14	0.44	0.58	0.35	4.2	90.2	1.5	2.86	4.04	25.24	4.08	16.2	454.4	50	22	4	24	clay
p235	4.5	16.76	5.44	32.46	0.16	0.5	0.66	0.22	7.8	218	1.2	3.12	3.79	35.29	2.83	8.0	736.0	27	17	20	36	loamy clay sand

Table 18- Raw data of soil samples (0-10 cm) of the Monjolo gallery forest, grouped in constituent communities.
Where:CS= coarse sand and FS= fine sand.
■ = wet steeper, ▒ = wet flatter and □ = dry community.

sites	pH	OM	Al	H+Al	Ca	Mg	Ca+mg	K	P	Fe	Cu	Zn	Mn	CEC	TEB	V	Al sat	Clay	Silt	CS	FS	Texture
	(H2O)	(%)	cmol/Kg						ppm					cmol/Kg		%	%	%				
m1	4.4	7.27	1.52	14.5	0.39	0.38	0.77	0.13	1.9	118.2	1.3	1.82	9.44	16.52	2.02	12.24	227.1	79	10	2	9	very clayey
m2	4	9.24	2.82	19.22	0.25	0.23	0.48	0.14	2.2	104.4	1.4	2	3.33	21.13	1.91	9.05	429.5	77	11	2	10	very clayey
m7	4.3	6.9	1.79	13.08	0.12	0.29	0.41	0.15	2.7	91.3	1.1	2.15	3.66	14.97	1.89	12.64	273.5	79	10	1	10	very clayey
m102	5	11.09	1.93	16.72	0.33	0.44	0.77	0.19	3	137.3	1	2.52	14.74	19.38	2.66	13.74	265.5	77	14	2	7	very clayey
m103	5.3	10.47	1.1	16.52	1.05	1.61	2.66	0.15	9.5	117.8	0.8	7.3	156.1	20.64	4.12	19.95	136.7	69	13	7	11	very clayey
m104	5	12.32	2.21	17.74	0.2	0.32	0.52	0.17	5.6	79.8	0.6	2.81	14.59	19.97	2.23	11.18	320.0	63	19	5	13	very clayey
m106	4.5	12.2	2.5	17.98	0.19	0.23	0.42	0.18	3.4	94.5	0.6	2.15	40.3	20.19	2.21	10.95	363.1	73	16	1	10	very clayey
m107	4.7	14.42	4.08	24.36	0.16	0.25	0.41	0.17	4.5	62.6	0.5	2.27	4.12	26.43	2.07	7.84	604.9	57	17	6	20	clay
m108	4.4	17.74	3.1	22.84	0.18	0.33	0.51	0.15	11.9	70.8	0.5	2.66	14.29	24.81	1.97	7.93	467.5	22	15	34	29	loamy clay sand
m109	4.1	21.81	4.54	30.54	0.3	0.64	0.94	0.15	10.1	147.1	1.7	4.64	6.06	33.01	2.47	7.5	637.5	15	12	12	61	loamy sand
m110	4.3	16.02	1.34	18.94	0.15	0.18	0.33	0.10	11.5	109.4	0.7	2.69	10.12	20.32	1.38	6.78	231.2	25	17	28	30	loamy clay sand
m180	4.1	12.32	3.73	22.16	0.14	0.36	0.5	0.16	4	57.3	0.5	1.54	2.14	24.3	2.14	8.79	547.6	64	21	2	13	very clayey
m181	3.9	11.58	4.32	24.24	0.1	0.35	0.45	0.19	5.9	105.4	1	2.16	2.47	26.58	2.34	8.81	616.4	60	23	3	14	very clayey
m183	4.3	12.81	2.8	23.4	0.12	0.32	0.44	0.19	3	126.2	0.9	2.85	7.04	25.71	2.31	8.97	401.4	52	22	10	16	clay
m241	4.1	8.38	0.78	15.54	0.25	0.24	0.49	0.14	2.4	133.7	0.8	2.93	2.14	17.44	1.9	10.88	119.1	60	26	2	12	very clayey
m243	4.5	11.7	0.78	20.42	0.22	0.2	0.42	0.26	3.8	96.8	0.5	4	8.5	23.4	2.98	12.73	104.2	33	20	6	41	loamy clay sand
m3	4.2	9.12	2.12	17.24	0.3	0.23	0.53	0.18	3.2	113.7	1.3	2.26	5.58	19.56	2.32	11.86	303.4	78	10	2	10	very clayey
m4	4	8.75	2.35	17.6	0.49	0.43	0.92	0.12	2.9	56.5	1	1.86	2.9	19.75	2.15	10.88	344.4	72	13	3	12	very clayey
m5	3.9	14.05	3.2	21.8	0.19	0.31	0.5	0.13	2.8	67.4	1.1	4.88	4.53	23.63	1.83	7.74	494.9	61	16	4	19	very clayey
m6	3.9	12.57	3.13	21.68	0.12	0.41	0.53	0.20	3	63	1.5	2.34	4.37	24.18	2.5	10.34	438.2	68	16	2	14	very clayey
m8	4.1	11.33	3.32	18.64	0.14	0.33	0.47	0.17	2.2	80.8	1.3	2.56	2.74	20.77	2.13	10.27	487.7	69	11	3	17	very clayey
m9	4.3	11.33	2.15	17.62	0.11	0.3	0.41	0.07	7.8	25.3	0.8	2.87	5.04	18.77	1.15	6.14	401.7	51	14	11	24	clay
m10	3.8	22.3	3.29	28.98	0.2	0.14	0.34	0.12	8.4	45.1	0.9	2.11	2.21	30.55	1.57	5.13	538.9	23	15	28	34	loamy clay sand
m71	4.4	8.25	1.44	12.84	0.35	0.49	0.84	0.18	2.1	100	1.5	2.5	16.56	15.47	2.63	17	198.8	78	15	1	6	very clayey
m72	4.1	9.24	2.24	16.74	0.25	0.42	0.67	0.23	3.2	128.8	1.8	2.37	6.76	19.66	2.92	14.86	300.7	80	11	1	8	very clayey
m73	4	6.41	2.04	13.86	0.12	0.3	0.42	0.10	2.1	99.3	1.4	1.94	3.78	15.25	1.39	9.13	350.6	81	12	1	6	very clayey
m74	4	7.15	2.21	13.48	0.14	0.34	0.48	0.15	2.3	104.1	1.2	1.83	2.75	15.44	1.96	12.71	333.6	63	14	3	20	very clayey
m75	4.2	17.99	4.02	26.92	0.34	0.49	0.83	0.18	3.1	86	1.2	2.66	9.08	29.57	2.65	8.95	553.9	75	13	1	11	very clayey
m76	3.8	12.57	3.15	17.74	0.13	0.31	0.44	0.14	3	68.5	1.4	2.97	4.52	19.56	1.82	9.31	488.0	82	12	1	5	very clayey
m77	4.1	6.78	2.34	14.46	0.14	0.24	0.38	0.10	1.6	123.7	0.7	1.84	2.21	15.84	1.38	8.7	403.9	58	14	4	24	clay

Table 18 - cont....

sites	pH	OM	Al	H+Al	Ca	Mg	Ca+mg	K	P	Fe	Cu	Zn	Mn	CEC	TEB	V	Al sat	Clay	Silt	CS	FS	Texture
	(H2O)	(%)	cmol/Kg						ppm					cmol/Kg		%	%	%				
m78	4	6.78	4.43	27.48	0.2	0.27	0.47	0.12	3.2	67.2	0.5	1.92	2.96	29.15	1.67	5.74	707.9	77	12	1	10	very clayey
m79	4.3	9.12	2.66	15.18	0.14	0.22	0.36	0.17	2.3	88.7	0.7	1.86	3.14	17.23	2.05	11.89	395.9	80	14	3	3	very clayey
m80	4.6	13.06	2.8	18.96	0.14	0.17	0.31	0.13	3.3	35.8	0.8	1.94	2.16	20.55	1.59	7.73	456.2	70	14	1	15	very clayey
m105	4.5	10.23	2.65	18.16	0.18	0.32	0.5	0.16	4.4	126.1	0.8	2.13	3.2	20.22	2.06	10.19	393.6	78	12	2	8	very clayey
m153	4.9	21.44	2.49	19.74	0.2	0.22	0.42	0.16	10.1	29.5	0.5	3.53	3.04	21.75	2.01	9.22	373.2	21	18	21	40	loamy clay sand
m158	4.7	18.85	1.26	17.74	0.17	0.14	0.31	0.09	32.8	26.8	0.2	1.98	1.68	18.97	1.23	6.49	228.4	16	17	29	38	loamy sand
m163	4.2	23.04	5.26	35	0.16	0.26	0.42	0.17	6.9	62.8	0.4	3.58	5.5	37.13	2.13	5.75	772.5	33	18	17	32	loamy clay sand
m167	4.7	11.95	2.96	19.94	0.12	0.28	0.4	0.22	2.7	123.6	1.2	2.7	7.38	22.57	2.63	11.63	408.8	77	14	1	8	very clayey
m178	4.2	8.75	2.88	19.34	0.14	0.19	0.33	0.12	3.6	68.8	0.5	1.9	3.19	20.9	1.56	7.45	472.9	64	21	1	14	very clayey
m179	4.7	13.18	2.76	20.94	0.14	0.27	0.41	0.15	5.6	42.5	0.3	1.97	2.72	22.83	1.89	8.29	421.8	51	21	11	17	clay
m182	4.6	13.06	3.45	18.92	0.14	0.25	0.39	0.19	4.2	94	0.6	1.83	6.13	21.25	2.33	10.98	492.8	46	25	11	18	clay
m228	4.3	9.98	3.18	16.62	0.19	0.34	0.53	0.17	3.5	210.7	1.1	1.76	2.92	18.89	2.27	12.01	458.1	66	22	3	9	very clayey
m229	3.7	10.6	0.97	16.9	0.11	0.35	0.46	0.17	3.1	129.7	0.8	3.38	3.17	19.07	2.17	11.4	141.6	64	22	2	12	very clayey
m230	4.1	10.72	0.76	17.5	0.25	0.32	0.57	0.13	4.5	89.3	0.6	3.36	2.08	19.4	1.9	9.79	116.0	64	22	2	12	very clayey
m242	4.5	10.47	0.64	16.08	0.19	0.24	0.43	0.20	3.2	95.3	0.5	4.07	3.33	18.5	2.42	13.1	90.4	63	23	2	12	clay
m101	5	8.38	1.68	14.16	0.13	0.23	0.36	0.18	1.9	176.8	1.3	2.31	10.07	16.34	2.18	13.32	245.2	77	13	2	8	very clayey
m221	5.6	15.03	0.07	11.68	9	3.31	12.31	0.44	3.6	23.3	0.4	4.5	91.63	28.36	16.68	58.82	7.4	48	17	19	16	clay
m222	5.6	14.91	0.07	16.82	7.2	4.25	11.45	0.49	4.1	28.1	0.7	5.26	135.2	33.21	16.39	49.35	7.4	42	15	23	20	clay
m223	5.2	12.07	0.64	16.96	2.08	2.37	4.45	0.40	3.6	80.3	1.1	3.46	103.5	25.4	8.44	33.23	71.6	65	15	8	12	very clayey
m224	5.5	15.89	0.17	17.74	5.81	4.03	9.84	0.33	3.8	38.1	0.6	3.63	139.9	30.88	13.14	42.55	18.3	68	18	2	12	very clayey
m225	5	22.05	0.72	20.8	5.79	1.98	7.77	0.83	6.3	69	0.8	6.53	142.3	36.86	16.06	43.56	76.5	32	16	39	13	loamy clay sand
m226	5.2	18.85	2.05	21.78	1.12	1.38	2.5	0.23	5.4	40.2	0.6	7.01	150.4	26.58	4.8	18.06	247.7	34	12	34	20	loamy clay sand
m227	5.2	17	2.6	25.36	0.63	0.94	1.57	0.33	4.2	36.9	0.5	2.4	14.79	30.23	4.87	16.11	313.4	53	19	14	14	clay
m244	4.7	20.21	0.78	22.8	0.83	0.88	1.71	0.25	6.7	65.1	0.4	6.01	33.6	26.99	4.19	15.53	96.6	60	20	17	3	very clayey
m245	4.5	11.46	0.64	21.42	0.33	0.42	0.75	0.19	3.1	107.2	1.2	3.56	19.29	24.09	2.67	11.08	88.0	69	16	4	11	very clayey

Table 19- Raw data of soil samples (0-10 cm) of the Taquara gallery forest, grouped in constituent communities.

Where: CS= coarse sand and FS= fine sand.

■ = wet and □ = dry community.

areas	pH	OM	Al	H+Al	Ca	Mg	Ca+mg	K	P	Fe	Cu	Zn	Mn	CEC	S	V	Al sat	Clay	Silt	CS	FS	Texture
	(H2O)	(%)	cmol/Kg						ppm					cmol/Kg		%	%			%		
t9	5.1	11.95	2.21	18.08	0.68	0.61	1.29	0.16	1.7	72	1.4	16.04	11.92	20.98	64.3	13.83	297.2	60	22	3	15	very clayey
t10	5.2	8.13	2	13.32	0.45	0.88	1.33	0.16	2	75.1	1.4	6.17	27.3	16.28	65.3	18.22	267.4	71	17	2	10	very clayey
t53	5.6	9.86	0.08	8.7	4.61	1.52	6.13	0.16	1.3	30.5	1	5.3	50	16.47	70.1	47.17	9.0	67	17	5	11	very clayey
t67	5.3	10.6	0.32	11.3	3.26	2.32	5.58	0.26	1.6	30.8	1	4.04	40.3	19.49	107.6	42.02	35.9	63	20	3	14	very clayey
t68	5	7.27	1.13	9.82	0.71	0.81	1.52	0.20	1.7	56	1.2	4.18	25.8	13.39	81.5	26.64	144.7	67	20	2	11	very clayey
t93	5.8	10.47	0	9	6.37	2.9	9.27	0.29	1.8	29.7	0.9	4.11	51.1	21.16	122.3	57.47	0.0	61	22	5	12	very clayey
t94	6.1	22.55	0	9.38	13.84	3.93	17.77	0.50	4.9	13	0.9	7.48	92.33	32.19	214.8	70.86	0.0	27	15	17	41	loamy clay sand
t95	5.7	16.51	0.01	14.14	8.76	3.33	12.09	0.40	4.3	28.9	0.9	5.66	105.5	30.19	167.1	53.17	1.1	42	17	17	24	clay
t109	6.1	18.85	0	8.76	15.6	2.68	18.28	0.44	4.8	17.7	1	5.66	77.2	31.41	189.3	72.11	0.0	43	16	13	28	clay
t110	6.4	21.81	0	7.56	18.29	3.14	21.43	0.49	9.3	18	0.9	7.63	71.6	33.90	213.4	77.70	0.0	27	15	29	29	loamy clay sand
t111	6.1	18.6	0	14.6	10.59	4.04	14.63	0.26	8.8	23.9	0.8	6.25	85.6	31.84	116.6	54.14	0.0	25	13	36	26	loamy clay sand
t112	5.8	15.89	0.01	12.76	7.68	2.9	10.58	0.25	4	23.6	1	4.83	85.5	25.85	108.6	50.63	1.1	44	14	24	18	clay
t123	5.8	12.32	0	9.82	7.48	2.59	10.07	0.48	1.9	55.6	1	3.62	39.9	24.65	196.1	60.16	0.0	52	21	12	15	clay
t124	6.1	19.1	0	8.2	14.92	3.1	18.02	0.52	10.1	26.2	0.9	6.08	84.4	31.39	220.0	73.87	0.0	23	15	28	34	loamy clay sand
t125	6	19.84	1	15	14.69	4.12	18.81	0.54	4.1	11.4	1	8.06	108.7	39.26	231.8	61.79	104.1	36	12	19	33	loamy clay sand
t126	5	16.39	2.5	26.9	1.89	2.15	4.04	0.61	5.3	82.1	1.6	3.97	44	37.05	243.0	27.40	274.6	47	14	15	25	clay
t138	5.7	14.05	0	10.32	8.94	2.58	11.52	0.25	2.7	48.9	0.9	3.52	65.3	24.32	108.5	57.57	0.0	37	20	24	19	loamy claysand
t139	5.3	13.5	1.16	15.7	4.25	1.78	5.86	0.28	4.1	48.35	0.75	5.56	47.8	21.84	6.1	28.11	154.6	50	17	14	19	clay
t140	5.0	14.64	0.87	16.2	8.4	1.38	9.78	0.16	4.3	46.8	0.68	4.35	45.2	26.14	9.9	38.02	95.8	35	18	22	25	loamy clay sand
t158	5.4	16.88	0.21	17.32	7.3	1.84	9.14	0.27	3.7	54.7	0.2	6.47	59.12	29.17	115.1	40.63	22.8	38	15	21	26	loamy clay sand
t159	5.6	15.52	0.14	16.84	6.93	2.7	9.63	0.23	22.2	24.4	0.1	6.11	66.29	28.77	99.6	41.47	15.2	27	13	34	26	loamy clay sand
t160	4.9	18.6	2.7	29.62	1.68	1.78	3.46	0.25	4.5	49.2	0.1	4.79	26.12	35.56	100.5	16.71	315.4	24	13	33	30	loamy clay sand
t161	4.9	15.65	1.57	24.12	2.44	1.73	4.17	0.16	3.9	39.3	0.1	5.2	64.33	29.90	67.2	19.33	184.2	31	14	34	21	loamy clay sand
t172	5.3	17.86	0.08	13.82	9.44	2.17	11.61	0.39	3.8	27.2	0.1	14.16	95.6	29.34	164.6	52.90	8.5	34	18	24	24	loamy clay sand
t173	5.7	15.52	0.06	11.76	10.12	4.26	14.38	0.89	2.3	19.7	0	9.58	111	35.07	363.4	66.46	6.3	40	17	22	21	clay
t185	5.7	19.71	0.05	15.06	12.87	3.37	16.24	0.27	3.3	20.2	0	13.33	158.1	33.99	121.2	55.69	5.3	26	16	32	26	loamy clay sand
t186	5.6	21.31	0.1	16.92	6.31	2.27	8.58	0.24	4.1	21.6	0	16.86	157.7	27.85	100.6	39.25	10.9	74	15	35	26	very clayey
t187	5.3	21.56	0.24	25.22	5.5	2.37	7.87	0.69	4	58	0.4	11.96	52.1	40.02	278.9	36.98	25.6	32	15	29	24	loamy clay sand
t205	5.3	8.75	0.65	12.86	2.19	1.62	3.81	0.18	2.1	29.2	0.3	2.88	34.8	18.49	74.8	30.43	76.6	65	21	3	11	very clayey
t213	5.1	8.38	1.63	13.92	0.61	1.13	1.74	0.22	2.6	61.1	0.7	4.4	53.15	17.83	86.7	21.95	204.6	65	18	4	13	very clayey

Table 19- cont...

areas	pH	OM	Al	H+Al	Ca	Mg	Ca+mg	K	P	Fe	Cu	Zn	Mn	CEC	S	V	Al sat	Clay	Silt	CS	FS	Texture
	(H2O)	(%)	cmol/Kg						ppm					cmol/Kg		%	%			%		
t55	5.1	12.32	1.33	15.44	1.63	1.56	3.19	0.26	3.5	89.6	0.7	5.47	51.6	21.21	104.2	27.21	156.0	66	20	5	9	very clayey
t11	5	11.58	2.48	15.88	0.29	0.59	0.88	0.20	2.5	51.2	1.3	5.21	31.98	18.73	77.9	15.21	335.0	65	19	4	12	very clayey
t12	5	8.62	2.56	14.8	0.26	0.4	0.66	0.10	2.8	22.1	1.4	4	4.53	16.48	40.7	10.21	408.1	76	16	2	12	very clayey
t13	5	8.62	2.62	14.06	0.25	0.43	0.68	0.12	2.3	31.7	1.3	6.74	4.77	15.89	45.7	11.52	405.1	73	12	5	7	very clayey
t27	5.4	8.62	0.77	10.98	1.54	1.26	2.8	0.18	1.5	55.4	1.1	3.56	24.93	15.60	73.8	29.60	93.7	69	16	3	12	very clayey
t28	5.3	9.73	1.55	14.3	0.38	0.76	1.14	0.17	2.1	27.8	1	4.43	38.06	17.10	66.1	16.39	210.3	60	19	7	14	very clayey
t29	4.7	8.01	2.38	14.04	0.12	0.37	0.49	0.16	1.8	64.6	1	2.81	8.11	16.17	64.5	13.16	349.9	64	19	4	13	very clayey
t30	5	10.47	2.08	14.34	0.14	0.4	0.54	0.18	2.3	63.3	1.1	2.95	11.01	16.70	71.5	14.11	296.3	68	18	4	10	very clayey
t31	4.8	9.98	2.43	14.1	0.21	0.41	0.62	0.19	2.4	74.6	1.2	2.64	5.74	16.66	76.6	15.39	337.8	66	17	3	14	very clayey
t54	5.4	6.78	0.29	7.8	1.91	1.25	3.16	0.15	0.9	64.6	1.3	1.86	19.22	12.47	62.2	37.44	35.2	70	18	3	9	very clayey
t56	5	8.87	1.56	14.38	0.45	1.31	1.76	0.25	3	110.4	0.7	4.64	44.9	18.60	97.8	22.67	193.0	70	16	3	11	very clayey
t57	4.9	8.87	1.72	15.08	0.89	1.02	1.91	0.23	2.4	105	0.6	5.63	36.3	19.29	91.9	21.83	212.8	68	17	3	12	very clayey
t69	5	6.65	0.98	8.62	0.77	0.78	1.55	0.20	1.4	65.6	1.6	3.5	27.97	12.14	78.6	28.99	125.8	68	18	3	11	very clayey
t70	5.1	6.9	1.28	10.36	0.47	0.91	1.38	0.16	1.6	84.4	1.4	3.31	29.8	13.33	63.4	22.26	171.2	71	18	2	9	very clayey
t71	5	9.36	1.28	11.7	1.17	1.12	2.29	0.21	1.6	75.4	1.4	3.4	41.3	16.09	84.3	27.27	157.2	68	18	2	12	very clayey
t92	5.9	9.86	0	7.8	12.74	0.41	13.15	0.24	1.8	12.6	0.7	4.36	43.7	23.30	105.2	66.53	0.0	52	27	6	15	clay
t96	5.5	22.3	0.02	11.18	5.48	5.44	10.92	0.28	3.8	13.2	0.8	11.79	85.2	24.86	118.9	55.03	2.1	38	15	32	15	loamy clay sand
t127	5.2	17.99	0.63	22.98	5.48	3.31	8.79	0.31	4.3	47.6	1.1	6.24	87.99	34.92	131.8	34.18	68.3	43	13	22	22	clay
t162	4.9	9.98	1.4	17.16	0.36	0.9	1.26	0.21	2.6	81	0.5	3.23	72.04	20.57	85.3	16.57	181.1	56	17	14	13	clay
t163	4.8	9.73	1.05	15.16	0.65	1.13	1.78	0.19	1.8	64.4	0.4	1.98	24.6	18.81	74.8	19.39	133.8	59	17	11	13	clay
t164	5.3	10.84	1.41	17.02	0.53	1.67	2.2	0.23	2.2	84.8	0.5	2.11	47.1	21.52	92.2	20.92	172.3	55	18	10	17	clay
t174	5	17	0.51	25.56	0.97	1.2	2.17	0.39	3	98.6	0.6	8.26	31.68	31.64	155.2	19.22	59.4	45	15	19	21	clay
t184	5.6	24.39	0.05	15.22	12.11	3.6	15.71	0.26	5.3	8.9	0	12.09	86.87	33.56	118.7	54.65	5.3	28	18	16	38	loamy clay sand
t188	5	9.24	0.4	16.74	0.59	0.72	1.31	0.16	1.6	51.2	0.5	8.54	9.57	19.69	65.3	14.97	53.6	54	19	15	12	clay
t208	5.4	7.39	0.38	10.7	1.9	1.69	3.59	0.19	2.2	28.3	0.4	2.75	30.8	16.18	77.6	33.88	44.9	62	23	4	11	very clayey
t206	5	12.07	1.76	16.82	1.22	1.51	2.73	0.19	2.8	61.6	0.4	4.62	50.6	21.44	76.7	21.56	214.1	69	17	2	12	very clayey
t207	4.9	11.7	1.35	15.44	2.29	1.43	3.72	0.34	3.1	79	0.4	3.17	28.1	22.56	136.7	31.56	154.0	64	15	4	17	very clayey
t223	4.9	15.15	2.28	26.74	0.16	0.42	0.58	0.14	4.6	45.6	0.3	2.95	15.09	28.75	56.6	7.00	341.3	33	13	21	33	loamy clay sand
t224	4.6	18.11	3.66	30.9	0.14	0.37	0.51	0.12	10.6	52.4	0.2	2.47	18.85	32.59	46.5	5.18	583.0	20	14	32	34	loamy sand
t225	4.3	14.91	3.28	26.74	0.11	0.48	0.59	0.10	19	46.9	0.3	2.54	2.4	28.30	38.6	5.52	538.0	26	19	25	30	loamy clay sand
t235	4.5	13.8	3.92	24.22	0.18	0.6	0.78	0.23	3.3	0.58	0.5	2.67	4.37	27.33	91.8	11.37	518.2	47	15	18	20	clay
t236	4.9	14.91	1.47	27.16	0.1	0.48	0.58	0.18	8.3	29.8	0.3	2.95	5.75	29.50	69.6	7.95	209.7	29	11	33	27	loamy clay sand
t237	5	8.25	2.1	17.84	0.08	0.36	0.44	0.17	6.2	133.1	0.4	2.68	3.02	20.02	68.4	10.89	306.4	54	16	6	24	clay
t238	4.5	10.6	3.32	25.34	0.18	0.26	0.44	0.16	5.2	96.7	0.8	2.35	2.52	27.34	61.4	7.32	498.0	43	14	19	24	clay

K) and reducing losses through leaching whilst increasing base cation availability to plants (Barros 1979). Higher pH also favours higher levels of organic matter and soil biological activity (Brady 1990).

The pH results for Pitoco gallery forest range from 4.3 to 5.7 and average 4.8. The majority of the samples (67.2%) are classified as very acid (<5.0). Among the Monjolo forest samples, 80% are classified as very acid, with values ranging from 3.7 to 5.6 and an average of 4.4. The Taquara forest results show that only 22% of the samples classified are very acid with a range from 4.7 to 6.4 and an average of 5.3. Amongst these, 10% are classified as slightly acid to neutral (>6.0). The standard deviation for the averages gave coefficients of variation lower than 9% for all the gallery soil pHs (see Table 20).

The pH levels range from very acid in the majority of samples, where base saturation is expected to be very low as a consequence of the high aluminium solubility, to above 5.8. The last group of samples may show 70 to 90 % base saturation and acidity only affecting sensitive crops; in this situation Al saturation would be virtually eliminated (Sanchez 1976).

The average values and the frequency classes for pH show that there is a clear distinction between the Pitoco, Monjolo and Taquara samples. Taquara dry had the highest average (5.5) and Monjolo wet-flatter the lowest (4.2). Tests of significance indicated significant differences ($P < 0.01$) between the majority of the sites (Table 21). The dry community soils always show significantly higher pHs when compared with the wet community soils.

The pH levels and their relationships with the gallery communities are considered in detail in Chapter 8.

Table 20- Average, standard deviation and coefficient of variance for the Pitoco, Monjolo and Taquara gallery forests and their constituent communities.

Sites and communities			pH (H2O)	OM (%)	Al	H+Al	Ca	Mg	Ca+mg	K	P	Fe	Cu	Zn	Mn	CEC	TEB	Al sat	Clay	Silt	CS	FS
					cmol/Kg						ppm					cmol/Kg		%	%			
PITOCO	Total	$\bar{X}$	4.8	11.23	2.44	19.66	0.52	0.69	1.21	0.27	3.25	112.43	0.86	2.79	21.33	21.14	5.37	320.71	54.69	19.29	7.74	18.28
		s	0.3	3.99	1.25	5.58	0.87	0.59	1.41	0.12	1.67	66.93	0.33	1.23	25.81	5.37	1.43	165.70	12.97	3.60	6.37	7.90
		CV (%)	6.6	35.5	51.1	28.4	166.3	86.4	116.7	43.6	51.4	59.5	38.6	43.9	121.0	25.40	26.60	51.7	23.7	18.7	82.3	43.2
	inner-dry	$\bar{X}$	4.7	10.05	2.50	19.06	0.32	0.66	0.98	0.27	2.90	110.32	0.77	2.30	17.73	20.31	1.25	328.09	59.90	20.80	4.80	14.50
		s	0.3	2.96	0.99	4.18	0.31	0.49	0.78	0.15	0.84	39.98	0.16	0.81	16.90	4.38	0.81	123.81	6.38	3.26	1.48	3.54
		CV (%)	5.9	29.5	39.7	21.9	94.4	74.2	79.0	54.8	28.9	36.2	20.4	35.4	95.3	21.60	64.80	37.7	10.7	15.7	30.7	24.4
	wet	$\bar{X}$	4.7	12.66	2.96	21.70	0.19	0.37	0.57	0.25	4.17	137.97	0.96	2.93	5.43	22.51	0.82	397.76	49.39	19.00	9.87	21.74
		s	0.2	4.75	1.05	5.88	0.08	0.13	0.14	0.10	1.77	87.45	0.34	1.01	3.23	5.99	0.17	133.55	15.67	3.95	3.95	9.27
		CV (%)	4.7	37.5	35.5	27.1	39.8	35.7	25.1	41.7	42.5	63.4	34.9	34.5	59.4	26.60	20.70	33.6	31.7	20.8	40.1	42.6
	dry-fringe	$\bar{X}$	5.0	10.38	1.93	18.03	0.91	0.98	1.89	0.29	2.54	89.77	0.80	2.87	37.39	20.21	2.18	246.87	57.48	18.96	6.96	16.60
		s	0.3	3.25	1.34	5.37	1.22	0.74	1.89	0.12	1.45	43.19	0.36	1.50	30.80	5.04	1.91	178.11	10.61	3.37	4.12	6.66
		CV (%)	6.7	31.3	69.1	29.8	134.0	74.9	100.1	41.2	56.9	48.1	45.4	52.4	82.4	24.80	87.60	72.1	18.5	17.8	59.2	40.1
MONJOLO	Total	$\bar{X}$	4.5	12.75	2.27	19.38	0.77	0.63	1.51	0.19	4.89	86.74	0.87	2.98	23.01	20.98	1.60	336.11	59.31	16.15	8.31	16.24
		s	0.5	4.45	1.23	4.61	1.81	0.90	2.66	0.12	4.57	39.45	0.38	1.37	43.11	4.92	2.75	185.64	18.95	4.11	10.12	10.86
		CV (%)	10.8	34.9	54.2	23.8	234.0	142.4	175.9	60.9	93.4	45.5	43.7	45.8	187.4	23.40	171.90	55.2	31.9	25.4	121.8	66.9
	wet-steeper	$\bar{X}$	4.4	12.27	2.46	19.89	0.26	0.40	0.66	0.16	5.34	103.29	0.87	2.91	18.69	20.71	0.82	359.07	56.56	16.63	7.69	19.13
		s	0.4	3.86	1.24	4.50	0.23	0.34	0.56	0.03	3.45	26.64	0.36	1.41	37.81	4.47	0.55	179.17	21.42	4.88	4.88	14.55
		CV (%)	8.9	31.5	50.5	22.6	87.1	85.8	84.9	20.9	64.6	25.8	41.8	48.5	202.3	21.60	67.10	49.9	37.9	29.4	63.5	76.1
	wet-flatter	$\bar{X}$	4.2	12.04	2.63	19.24	0.19	0.30	0.49	0.15	4.87	84.59	0.92	2.51	4.33	19.88	0.64	398.92	62.38	15.90	5.93	15.79
		s	0.3	4.59	1.03	4.91	0.09	0.09	0.15	0.04	5.74	40.11	0.41	0.79	2.94	4.90	0.17	154.30	18.66	4.19	8.04	9.82
		CV (%)	7.4	38.2	39.3	25.5	45.8	30.9	31.7	25.1	118.0	47.4	44.9	31.2	67.8	24.70	26.60	38.7	29.9	26.3	135.5	62.2
	dry	$\bar{X}$	5.2	15.59	0.94	18.95	3.29	1.98	5.27	0.37	4.27	66.50	0.76	4.47	84.07	24.59	5.64	117.21	54.80	16.10	16.20	12.90
		s	0.4	4.19	0.88	4.21	3.31	1.47	4.64	0.19	1.47	46.83	0.31	1.67	58.67	4.34	4.76	110.96	15.51	2.51	12.98	5.15
		CV (%)	7.1	26.9	92.9	22.2	100.5	74.2	88.1	52.6	34.4	70.4	41.3	37.5	69.8	17.60	84.40	94.7	28.3	15.6	80.1	39.9
TAQUARA	Total	$\bar{X}$	5.3	13.35	1.15	15.67	4.19	1.73	5.92	0.27	4.04	49.52	0.74	5.58	47.99	24.27	107.50	154.54	50.76	16.81	14.31	19.00
		s	0.5	4.83	1.09	6.00	4.98	1.23	5.97	0.15	3.74	28.91	0.45	3.47	36.22	7.34	64.53	158.47	16.83	2.97	11.38	8.37
		CV (%)	8.6	36.2	95.2	38.3	118.9	71.0	100.8	55.7	92.5	58.4	60.5	62.2	75.5	30.20	60.00	102.5	33.2	17.7	79.6	44.1
	dry	$\bar{X}$	5.5	15.39	0.62	14.50	7.10	2.43	9.52	0.35	4.49	39.23	0.71	7.03	68.84	27.26	135.90	74.71	45.31	16.72	18.28	21.45
		s	0.4	4.56	0.87	5.74	5.19	1.00	6.02	0.18	4.07	21.91	0.47	3.82	36.06	7.18	79.53	105.85	16.86	2.95	11.93	8.27
		CV (%)	7.5	29.7	139.6	39.6	73.1	41.2	63.2	52.5	90.6	55.8	66.8	54.4	52.4	26.30	58.50	141.7	37.2	17.6	65.3	38.5
	wet	$\bar{X}$	5.0	11.55	1.61	16.70	1.64	1.12	2.76	0.20	3.65	58.56	0.77	4.32	29.66	24.37	2.96	224.69	55.55	16.88	10.82	16.85
		s	0.3	4.37	1.07	6.13	3.07	1.09	3.77	0.07	3.43	31.52	0.43	2.58	24.95	6.22	3.80	164.98	15.52	3.03	9.79	7.98
		CV (%)	6.6	37.8	66.4	36.7	187.5	97.1	136.6	32.6	94.2	53.8	55.9	59.8	84.1	25.50	128.40	73.4	27.9	17.9	90.5	47.3

Table 21- Comparison of soil properties (depth 0-10 cm) of the Pitoco (P), Monjolo (M) and Taquara (T) gallery forests and their constituent communities. Student t-test: 1% (P<0.01), 5% (P<0.05) and NS, non-significant differences.

Sites	pH	OM	Al	H+Al	Ca	Mg	Ca+mg	K	P	Fe	Cu	Zn	Mn	CEC	TEB	V	Al sat	Clay	Silt	CS	FS
	(H2O)	(%)	cmol/kg						ppm					cmol/kg		%					
Pitoco / Monjolo	1%	NS	NS	NS	NS	NS	NS	1%	5%	5%	NS	NS	NS	NS	NS	NS	NS	NS	%	NS	NS
P itoco / Taquara	1%	1%	1%	1%	1%	1%	1%	NS	NS	1%	NS	1%	1%	NS	1%	1%	1%	NS	1%	1%	NS
Monjolo / Taquara	1%	NS	1%	1%	1%	1%	1%	1%	NS	1%	NS	1%	1%	NS	1%	1%	1%	1%	NS	1%	NS
P(inner-dry) / P(dry-fringe)	1%	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	5%	5%	NS	NS	5%	5%	NS	5%	5%	NS
P(inner-dry) / P(wet)	NS	5%	NS	NS	5%	1%	5%	NS	5%	NS	5%	5%	1%	NS	NS	5%	NS	1%	NS	1%	1%
P(dry-fringe) / P(wet)	1%	5%	1%	5%	1%	1%	1%	NS	1%	5%	NS	NS	1%	NS	1%	1%	1%	5%	NS	NS	5%
M(wet-flatter) / M(wet-steeper)	5%	NS	NS	NS	NS	NS	NS	NS	NS	5%	NS	NS	5%	NS	NS	NS	NS	NS	NS	NS	NS
M(wet-flatter) / M(dry)	1%	1%	1%	NS	1%	1%	1%	1%	NS	NS	NS	1%	1%	1%	1%	1%	1%	NS	NS	1%	NS
M(wet-steeper) / M(dry)	1%	5%	1%	NS	1%	1%	1%	1%	NS	5%	NS	5%	1%	1%	1%	1%	1%	NS	NS	5%	NS
T(wet) / T(dry)	1%	1%	1%	NS	1%	1%	1%	1%	NS	1%	NS	1%	1%	1%	1%	1%	1%	5%	NS	1%	5%
P(inner-dry) / M(wet-flatter)	1%	5%	NS	NS	5%	1%	1%	1%	1%	1%	NS	NS	1%	NS	1%	1%	5%	NS	1%	NS	NS
P(inner-dry) / M(wet-steeper)	NS	NS	NS	NS	NS	NS	NS	1%	5%	NS	NS	NS	NS	NS	1%	1%	NS	NS	1%	NS	NS
P(inner-dry) / M (dry)	1%	1%	1%	NS	5%	5%	1%	NS	5%	5%	NS	1%	1%	NS	5%	5%	1%	NS	1%	5%	NS
P(dry-fringe) / M(wet-flatter)	1%	NS	5%	NS	1%	1%	1%	1%	NS	NS	NS	NS	1%	NS	1%	1%	1%	NS	1%	NS	NS
P(dry-fringe) / M (wet-steeper)	1%	NS	NS	NS	5%	1%	1%	1%	1%	NS	NS	NS	NS	NS	1%	1%	5%	NS	NS	NS	NS
P(dry-fringe) / M(dry)	NS	1%	1%	NS	1%	1%	1%	NS	1%	NS	NS	1%	1%	5%	1%	5%	1%	NS	1%	1%	5%
P(wet) / M (wet-flatter)	1%	NS	NS	NS	NS	5%	NS	1%	NS	1%	NS	NS	NS	5%	1%	1%	NS	1%	1%	NS	5%
P(wet) / M(wet-steeper)	1%	NS	NS	NS	NS	NS	NS	1%	NS	5%	NS	NS	NS	NS	1%	NS	NS	NS	NS	NS	NS
P(wet) / M(dry)	1%	5%	1%	NS	1%	1%	1%	5%	NS	1%	5%	1%	1%	NS	1%	1%	1%	NS	1%	5%	1%
P(dry-inner) / T(wet)	1%	5%	1%	5%	1%	1%	1%	5%	5%	1%	NS	1%	1%	NS	1%	1%	1%	NS	1%	1%	NS
P(dry-inner) / T(dry)	1%	1%	1%	1%	1%	1%	1%	5%	1%	1%	NS	1%	1%	5%	1%	1%	1%	1%	1%	1%	1%
P(dry-border) / T(wet)	NS	NS	NS	NS	NS	NS	NS	1%	1%	1%	NS	5%	5%	NS	1%	NS	NS	NS	1%	5%	NS
P(dry-border) / T(dry)	1%	1%	1%	5%	1%	1%	1%	NS	5%	1%	NS	1%	1%	1%	1%	1%	1%	1%	1%	1%	5%
P(wet) / T(wet)	1%	NS	1%	1%	5%	1%	1%	5%	NS	1%	NS	5%	1%	5%	1%	1%	1%	NS	5%	NS	5%
P(wet) / T(dry)	1%	5%	1%	1%	1%	1%	1%	5%	NS	1%	5%	1%	1%	NS	1%	1%	1%	NS	5%	1%	NS
M(wet-flatter) / T(dry)	1%	1%	1%	1%	1%	1%	1%	1%	NS	1%	NS	1%	1%	1%	1%	1%	1%	1%	NS	1%	5%
M(wet-flatter) / T(wet)	1%	NS	1%	NS	5%	1%	1%	1%	NS	1%	NS	1%	1%	NS	1%	1%	1%	NS	NS	5%	NS
M(wet-steeper) / T(wet)	1%	NS	1%	5%	5%	1%	1%	1%	5%	1%	NS	1%	NS	NS	1%	1%	1%	NS	NS	NS	NS
M(wet-steeper) / T(dry)	1%	1%	1%	1%	1%	1%	1%	1%	NS	1%	NS	1%	1%	1%	1%	1%	1%	5%	NS	1%	NS
M(dry) / T(wet)	NS	1%	1%	5%	1%	1%	1%	1%	NS	NS	NS	NS	1%	1%	1%	5%	1%	NS	NS	5%	1%
M(dry) / T (dry)	1%	NS	NS	1%	1%	NS	5%	NS	NS	1%	NS	1%	NS	NS	1%	1%	NS	5%	NS	NS	1%

7.3.2.-Organic Matter (%).

In highly weathered tropical soils, organic matter makes a vital contribution in soil fertility, supplying nutrients, retaining cations, anions and moisture and maintaining good soil structure (Ross 1993). Measurements of organic C (%) (c.60% of OM) are often made as a quantification of the organic matter in soils which is, in turn, taken as a crude indicator of fertility status (Landon 1991). This is an extremely complex and largely unknown fraction of the soils of great importance in adding stability to soil aggregates, enhancing water retention capacity and CEC, and providing good conditions for micro-organic activity. Presence of organic matter can also enrich the availability of nutrients such as N, P, K, S, Ca, Fe and Mn, reducing negative effects of high Al levels (Barros 1979, Pereira & Peres 1985).

Levels of organic matter in cerrado soils range from 0.7 to 6.1 % with the great majority of the values lying between 2 and 3% and regarded as 'medium' (Lopes 1975).

All the soil samples of Pitoco, Monjolo and Taquara are considered to have high levels of organic matter, ranging respectively from 5.79 to 23.41% (χ = 11.23), 6.4 to 23.04% (χ = 12.75) and 6.78 to 24.39% (χ = 13.35). The OM standard deviations (Table 20) give coefficients of variation around 30% of the average.

However, significant differences are found. Pitoco's soils contained the lowest levels and Taquara's the highest. Monjolo's levels are found to be intermediate. Within Pitoco, the wet community predictably shows significantly higher levels than its dry communities. The opposite is found in Monjolo and Taquara's sites where the dry community soils have significant higher levels than their respective wet communities (Table 21).

It would be difficult to state the relation of OM to the vegetation attributes by simply examining analytical values. However soil variable ordination in Chapter 8 will provide bases for such an assessment.

7.3.3.- Al, H + Al and Al saturation.

One of the most marked features of cerrado soils is the high level of exchangeable Al. Very frequently, the levels are regarded as toxic to cultivated plants (Eiten 1972, Malavolta 1976) often taken to affect plant metabolism where values lie over 1.0 cmol/kg and severe over 3.0 cmol/kg. In fact, as emphasised by Lopes (1980), despite the acid conditions, the Al levels are not extremely high, but due to the general low values of Ca and Mg and the low contribution of K to CEC, Al levels can impose crucial constraints on nutrient availability.

Levels over 1.0 cmol/kg of exchangeable Al, and/or 5,0 cmol/kg of H + Al and/or 20% of Al saturation are considered limiting to cultivated plants (Malavolta 1976, Lopes 1980). The term *allic* is conferred on soils with more than 50% of Al saturation or Al levels higher than 0.3 cmol/kg (Cavedon & Sommer 1990).

At Pitoco only 3.4% of the samples show low levels of exchangeable Al, which had an average of 2.43 cmol/kg. Al saturation is high in 98.3% of the samples, of which 96.5% show an *allic* character. Total acidity is classified as high for all soil samples.

High levels of Al are found for 78.2% of the Monjolo's samples which average 2.27 cmol/kg. Al saturation and total acidity are classified as high for all samples and 94.5% of the samples are considered to be *allic*.

Taquara's soils show an average of 1.15 cmol/kg, high levels of Al for 50% of the samples, high Al saturation for 80% of the samples, and high total acidity for all the samples, among which 61.3% are classified as *allic*. The coefficient of variation is high, suggesting care in the interpretation of the differences between average values.

Comparing the soil Al levels, significant differences are found within and between the galleries and their inside communities (Table 21). Pitoco (the highest levels) and Monjolo soils show similar Al levels (not-significantly different). Taquara's Al contents are significantly lower ($P < 0.01$). The soils of the gallery wet communities have Al levels always higher than those of their dry communities.

The total acidity, H + Al, and Al saturation are found with similar levels in Pitoco and Monjolo soils, although significantly different ($P < 0.01$) when compared with Taquara's soils which contain much lower levels. The dry communities always show significant ($P < 0.01$) lower total acidity and Al saturation when compared with the wet community levels. The average standard deviations resulted in coefficients of variation around 30% for H + Al. Al saturation levels show much higher variability (see Table 20).

Aluminium/plant relationships in the cerrado region have been studied since Goodland (1969) proposed a biomass gradient negatively correlated with soil Al levels. Further studies have found higher Al levels where vegetation had higher biomass (Medeiros 1983, Ribeiro 1983, Araújo 1984, Silva 1991). Some autoecological studies have shown the inability of some species to grow under low levels of Al (Machado, 1985). Recently, Silva (1991) reported 51% of the 54 gallery forests species analysed as Al-accumulators. In the Pitoco, Monjolo and Taquara forests, representing the highest, intermediate and lowest aluminium contents in the present study, five, three and one Al-accumulator species respectively are ranked amongst the 10 species of highest IVI. This suggests a direct relationship between soil Al levels and the occurrence of Al-accumulator species, as also indicated by Silva (1991).

Al and total acidity levels, ranging from the highest in the Pitoco's wet community soils to the lowest in the Taquara's dry community soils, may be partially responsible for the differences found in the floristic composition, density and basal area of the vegetation (Chapters 4, 5 and 6).

7.3.4.- Ca and Mg.

Calcium levels for most of the soils within the cerrado region show values lower than 0.4 cmol/kg. Ca availability varies due to a number of factors and only acidic soils with low CEC are expected to show very low Ca concentrations (Landon 1991). Calcium has always been reported as related to the improvement of growth in forest plantations (Barros 1979). However, some cerrado Al-accumulator trees have low growth expectancy even when Ca is available in soil or nutrient solution - as occurs in *Vochysia thyrsoidea* (Machado 1985). Silva (1991) reported 51% of the species recorded in four gallery forests in the Federal District as Al-accumulators but calcifugous or calcicolous behaviour has yet to be assessed.

Results for Mg are more variable but the levels are lower than 0.5 cmol/kg, which is considered to be the deficiency threshold for crops in tropical soils (Landon 1991, Lopes 1980). Furthermore, high acidity is a limiting factor for Mg-availability to plants (Landon 1991).

Among the Pitoco samples, 89.6% have very low levels of Ca + Mg (< 3.0 cmol/kg) with an average of 1.2. Ca represents in general 43 % of the Ca + Mg scores and are consistently found at very low levels (χ = 0.52). Monjolo's soils show a similar tendency and Ca (χ = 0.77) accounts for 55 % of the Ca + Mg scores which average 1.51 cmol/kg. Conversely, at Taquara 38.7% of the samples contain high levels of Ca + Mg. Ca represents in general 71 % of the Ca + Mg scores with an average of 5.92 cmol/kg. These figures indicate that the Taquara soils have six times more Ca than other sites. Standard deviation of the Ca and Mg averages indicate high variability among the individual samples (Table 20).

Tests of significance indicate that the Pitoco Ca levels (with the lowest average) are similar to Monjolo levels. Both are found significant ($P < 0.01$) lower than Taquara's levels (Table 21). Dry community soils have significantly higher ($P < 0.01$) Ca levels when compared with their wet community levels.

Magnesium levels in each gallery and community follow the same patterns found in the Ca analysis.

The Ca and Mg levels in each community may be interpreted as a gradient ranging from Pitoco's wet community with the lowest levels to Taquara's dry community with the highest levels, providing a field experiment where tree species could have their performance evaluated.

7.3.5.- Potassium.

Exchangeable cation levels give no direct indication of the capacity of the soil to release tightly held or bonded nutrients (Mengel & Bush 1982 in Landon 1991). Most of the total potassium in soils is 'unavailable' (90 - 98%), with 2 - 8% as exchangeable ions and only 0.1 to 0.2% in solution. However, much of that potassium is weakly adsorbed and is subjected to leaching especially where CEC values are low (Goedert 1985).

Cerrado soils are normally poor in available nutrients, dominated by 1:1 layer clays and few primary minerals which could release potassium to plants on decomposition. As a consequence, potassium levels are found mostly below the critical limit of 0.15 cmol/kg (60 ppm) (Goodland 1979).

Potassium leaf contents are found correlated with its availability, at lower levels in cerrado soils (Haridassan 1982, Medeiros 1983, Ribeiro 1983) and at higher level in mesophytic forest (Araújo 1990) and gallery forests (Silva 1991).

Despite its importance in many physiological processes, soil potassium levels have not been considered as a constraint to native plant growth in central Brazil, consequently not much attention have been given to it in autoecological and synecological studies.

Results for potassium in the present analysis range from 0.11 to 0.61, 0.10 to 0.83 and 0.10 to 0.89 cmol/kg at Pitoco, Monjolo and Taquara respectively. With respect to the average values, Monjolo's soils have almost 30% less potassium than other sites. Individual samples are quite variable in their potassium levels resulting in high coefficients of variance.

The analysis of significance indicate that Pitoco and Taquara contain significantly ($P < 0.01$) higher potassium levels than the Monjolo soils. Within Pitoco's communities no differences are found; however, soils associated with the dry communities in Monjolo and Taquara have significantly higher levels than the soils of their respective wet communities (Table 21).

Potassium levels are very low in the Monjolo soil samples, which could affect floristic composition of the vegetation there; this would be an interesting subject for future investigation. Details on the relationship of vegetation and soil variables are given in Chapter 8 and 9.

7.3.6.- Phosphorus.

In general, cerrado soils possess small reserves of P, of which organic P accounts for over 50% of the total. In the majority of the analyses the values are lower than 2 ppm (Goodland 1969, Eiten 1972). These limits are so low that interpretation of P-availability within the region is difficult (Lopes 1980). Furthermore, P is strongly adsorbed in the clay fraction, and remains mostly unavailable to plants (CPAC 1976). Iron and aluminium, generally found at high levels in mineral soils under acid conditions, react with it resulting in insoluble Al + Fe-phosphate forms. As pH approaches 6.0, there is precipitation in the form of calcium phosphates. Even after achieving optimum pH levels of around 6.0, the P availability to plants is still a major problem in crop production.

Phosphorus levels at the Pitoco, Monjolo and Taquara sites are much higher than the averages quoted for cerrado soils and range respectively from 1.3 to 7.8 (χ = 3.25), 1.6 to 32.8 (χ= 4.89) and 0.9 to 22.2 (χ= 4.04). Variability between individual samples resulted in high standard deviations (Table 20).

Monjolo and Taquara P levels are found to be similar but significantly higher than those of Pitoco. Pitoco's and Monjolo's wet community soils show higher P levels than those of their dry communities, but the difference is only statistically significant at Pitoco. Taquara's dry community has similar levels to the wet communities.

The range of values found in the galleries and communities does not suggest that P is a limiting factor in the distribution of vegetation. However, phosphorus is one of the main constraints to crop growth in the cerrado region and presumably also affects natural vegetation.

7.3.7.- Micronutrients.

Availability of micronutrients in soils is affected by a number of factors including the redox equilibrium and measured values can vary greatly. Frequently, foliar analyses are taken as an indication of the level of micronutrients (Landon.

1991). In acid soil conditions the concentrations of Cu, Fe, Mn and Zn are often sufficiently high to be toxic to common plants (Brady 1991).

7.3.7.1.- Copper.

Copper interacts strongly with OM but no major effects have been reported in its availability to plants in the area. Most crops are sensitive to Cu deficiency but toxicity is not usually reported as important (Landon 1991). Within the cerrado region, around 70% of the soil analyses fail to reach 1 ppm, which is considered a critical minimum level (Lopes 1980).

Results for the three gallery forest soils range from 0.3 to 1.6 ppm (χ = 0.86) at Pitoco with 79.3% of the samples lower than 1 ppm; 0.2 to 1.8 ppm (χ = 0.90) with 61.8% lower than 1 ppm at Monjolo; and 0.0 to 1.6 ppm (χ = 0.74) with 75.8% lower than 1 ppm at Taquara.

Non-significant differences are found for Cu levels in most of the comparisons between the soils of the galleries and their constituent communities (Table 21).

7.3.7.2.- Iron.

Iron is the fourth most abundant element in the Earth and soils rarely have less than 1% iron content. The very low solubility of iron compounds results in its low concentration in soil solution, which tends to decrease when pH is increased. Deficiencies leading to chlorosis could be expected in calcareous soils (Landon 1991).The range between requirements and toxic levels is not yet established for most cultivated plants in the cerrado region (Galrão 1985). Generally, Fe-concentrations in soils range from 3.7 to 74, with an average of 32.5 ppm (Lopes 1980).

Results for Pitoco, Monjolo and Taquara soils demonstrate a wide range of levels from 19.2 to 418.1 (χ = 112.4), 23.3 to 210.7 (χ = 86.7) and 11.4 to 133.1 (χ = 49.5) respectively.

Iron levels in the galleries soils are found to be significantly different despite the considerable overlap in the ranges. The highest levels in the Pitoco soils are almost always different from those found in the other galleries communities. Monjolo's soils intermediate levels are also found to vary from the Taquara's soils which contained the lowest average. In each gallery the wet communities had significantly higher averages than the dry communities.

7.3.7.3.- Manganese.

Manganese solubility decreases with increasing pH. Toxicity can be expected at pH < 5.5 but plant responses vary widely (Brady 1990, Landon 1991). Lopes (1975) showed that cerrado soils are well supplied with Mn, and it is more likely that toxic levels can be expected. In fact Foy (1984) considered Mn toxicity as the second most limiting factor to crop growth in acid soils.

The present results indicate generally high levels of Mn. Pitoco's scores vary from 1.58 to 110.5 ppm (χ = 21.3), those of Monjolo from 1.68 to 156.1 ppm (χ = 23) and Taquara's soils show a variation of 2.4 to 158.1 ppm (χ = 48).

Taquara's soils have significantly higher levels than the other galleries, with the exception of Monjolo's dry community soils which show the highest overall levels. Pitoco and Monjolo have similar levels. The dry community soils always have significantly higher Mn levels than the wet communities.

7.3.7.4.- Zinc

Zinc availability is greatly reduced by increasing soil pH and deficiencies in acid soils are not reported as important, unless native reserves are very low. Toxic Zn levels are rare (Landon 1991). Cerrado soils are very poor in this element with levels reported as ranging from 0.5 to 0.8 ppm (Lopes 1975). These levels result in general deficiency for exotic crops (Galrão 1985).

Pitoco, Monjolo and Taquara values range from 1.19 to 7.95 ppm (χ = 2.79), 1.54 to 7.01 ppm (χ = 2.98) and 1.86 to 16.86 ppm (χ = 5.58) respectively. All the results are above the proposed critical level of 1 ppm (Lopes 1980).

Taquara's soils have the highest Zn levels among the galleries, found significantly different ($P < 0.01$) from Pitoco and Monjolo both of which show similar levels. Soils of the dry communities have significantly higher Zn levels than soils of the wet communities.

Standard deviations for the average level of micronutrients indicate high variability among the individual soil samples suggesting care in the interpretation of the differences is necessary (Table 20).

7.3.8. - Cation Exchange Capacity (CEC), Total Exchangeable Bases (TEB) and Percentage of Base saturation (V).

Cation Exchange Capacity (CEC) is commonly used as part of the assessment of the soil potential fertility, reflecting the quantity of cations that soils can hold (Landon 1991, Richer & Babbar 1991). Average CEC values for cerrado soils vary from 3.9 to 13.9 cmol/kg (Adamoli et al. 1985) and most of the sites are occupied by H and Al cations.

Results for the Pitoco soils show a variation of 13.8 to 36.7 cmol/kg with an average of 23.6 cmol/kg. At the Monjolo site, CEC varies from 15.0 to 37.1 cmol/kg (χ = 22.7). Taquara's CEC measures range from 12.1 to 40.1 cmol/kg (χ = 24.3). Standard deviations (Table 20) give coefficients of variation between 20 and 30% for the galleries and constituent community soils.

Tests of significance do not show differences between most of the galleries and their constituent communities (Table 21). This reflects the high H and Al levels found in the majority of the soil samples. With the exception of two samples in the Taquara site, where exchangeable Al is measured as zero as a consequence of the high Ca levels, all others are classified as of high CEC (>13.3 cmol/kg). These results indicate that the soils are better provided for CEC than the average values for the cerrado.

Total exchangeable bases (TEB) is a measure of the proportion of CEC occupied by exchangeable bases (such as Ca, Mg and K) and is used as an indicator of soil fertility (Landon 1991). Most of the analyses of cerrado soils show low base contents (< 2.62 cmol/kg) (Lopes 1980); which probably reflects the extreme level of leaching in these acidic, well drained soils.

The results indicate a range from 1.6 to 11.9 with an average of 3.9 cmol/kg for Pitoco, from 1.2 to 4.9 cmol/kg (χ = 3.4) for Monjolo, and from 1.6 to 26.3 with an average of 8.6 cmol/kg for Taquara which is twice as high than those of the other galleries. Standard deviations for the average values are presented in Table 21. 51.6% of the Taquara samples have high TEB levels (> 6.3 cmol/kg), while most of the Pitoco samples (70.7%) have medium levels (2.62 - 6.3) and amongst the Monjolo samples, 70.9% show low levels (< 2.63).

Taquara's soils have significantly higher levels ($P < 0.01$) than Pitoco's and Taquara's soils which have similar averages. In each gallery the dry community soils have significantly higher TEB levels than those of the wet communities.

The expression of base saturation (V) as a proportion of CEC is also used as an indicator of soil fertility status. Scores of up to 50% denote dystrophic status and occur in 100, 98.2 and 72.6% of the samples for Pitoco, Monjolo and Taquara respectively. Mesotrophic status (scores above 50%) is reached in only one sample (1.8%) from Monjolo, and 17 samples (27.4%) from Taquara.

7.3.9. - Clay, Silt and Sand contents.

The proportions of clay, silt and sand are used for the determination of the soil textural classes. The USDA Soil Survey staff (1975) suggest a classification range as follows: 'very clayey' for soils with a clay content above 60%; 'clay' for soils with 35% to 60% clay; 'loamy' for soils with 18 to 35%; clay and 'sandy' for soils below 18% clay.

Most of the soil samples, 90, 82 and 76% for Pitoco, Monjolo and Taquara respectively, are classified as clay-rich (≥35%) (see Figures 31, 32 and 33). Individual levels vary considerably giving high standard deviations for the average values.

Tests of significance for clay contents show few differences between the galleries and their constituent communities (Table 21). Taquara's soils showing the lowest average clay contents, are significantly different from Monjolo's soils with the highest contents.

Silt contents are significantly higher in Pitoco's soils, while they are similar in those of Monjolo and Taquara. Standard deviation presented in Table 21 result in

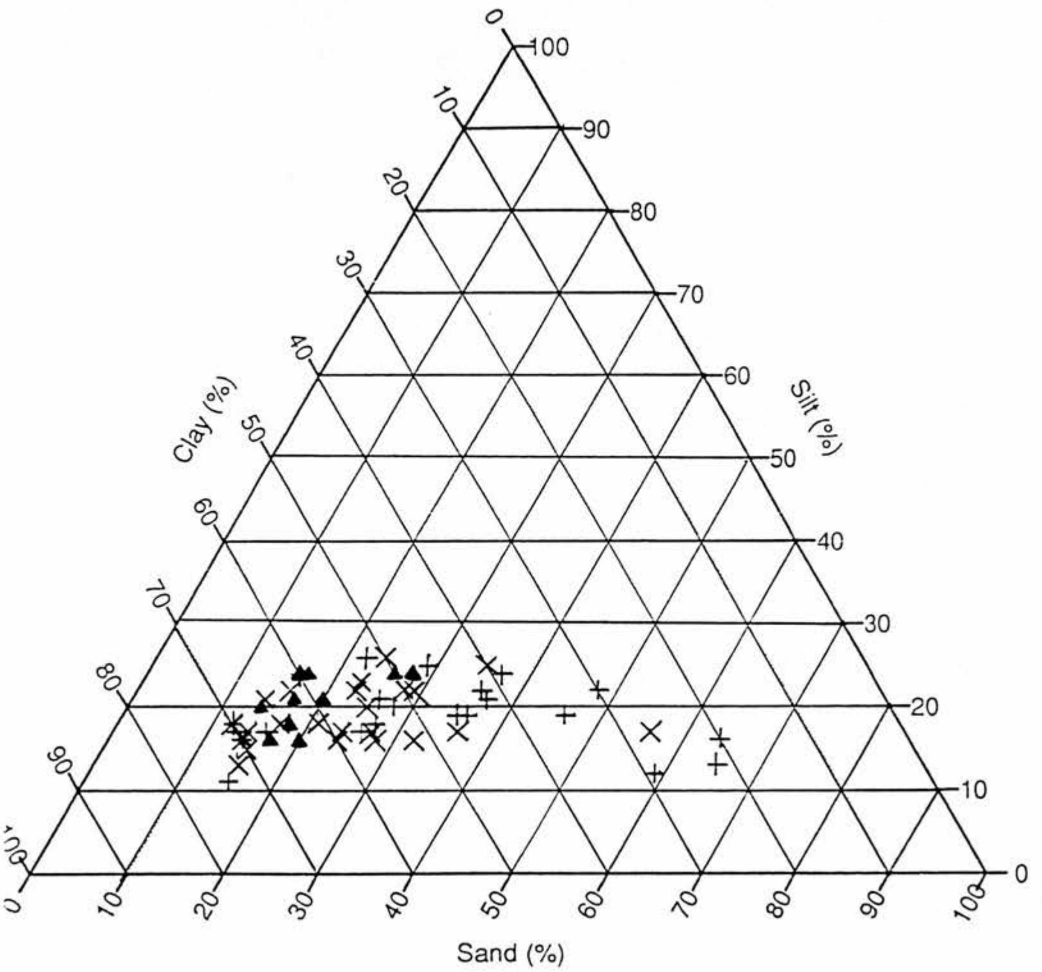


Figure 31 - Percentages of clay, silt and sand particles in the Pitoco gallery forest soils: (Δ) represents the Inner-dry, (X) the dry-fringe and (+) the wet community.soil samples.

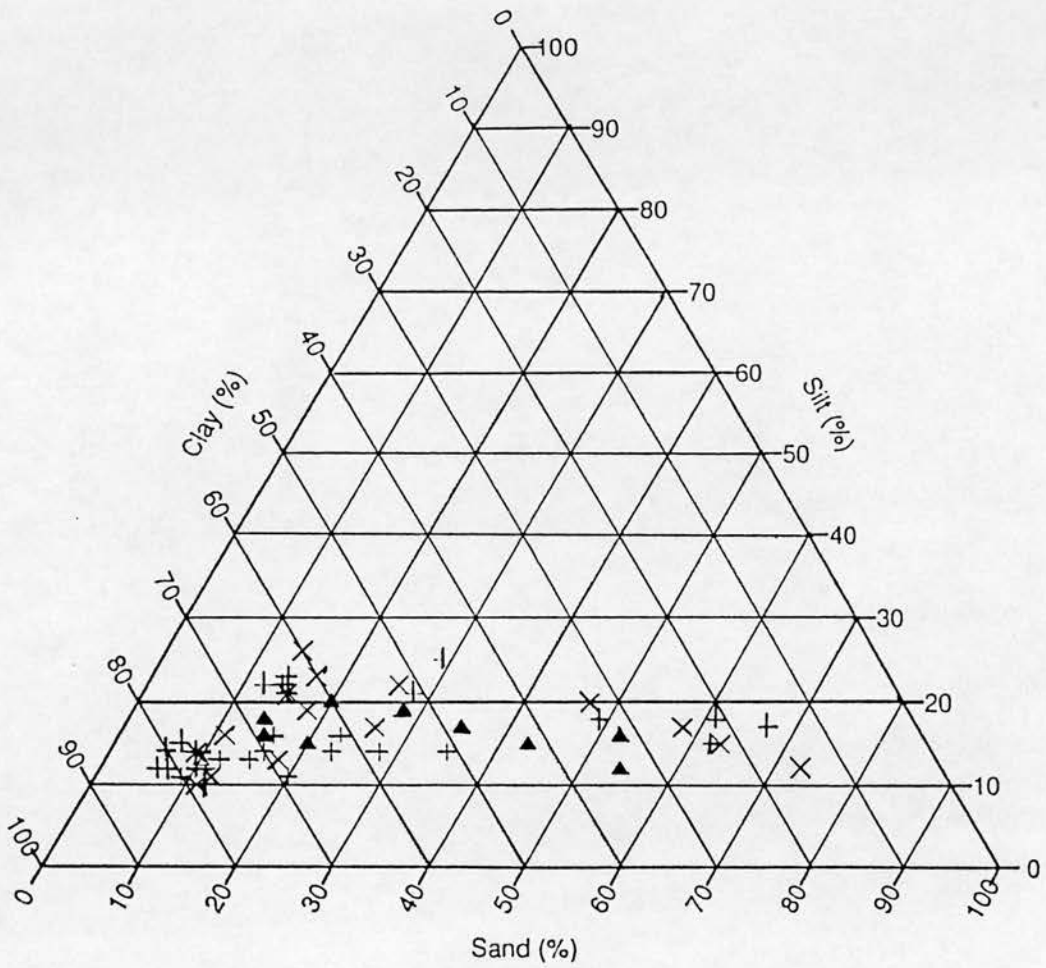


Figure 32 - Percentages of clay, silt and sand particles in the Monjolo gallery forest soils: (Δ) represents the dry, (X) the wet-steeper and (+) the wet-flatter community.soil samples.

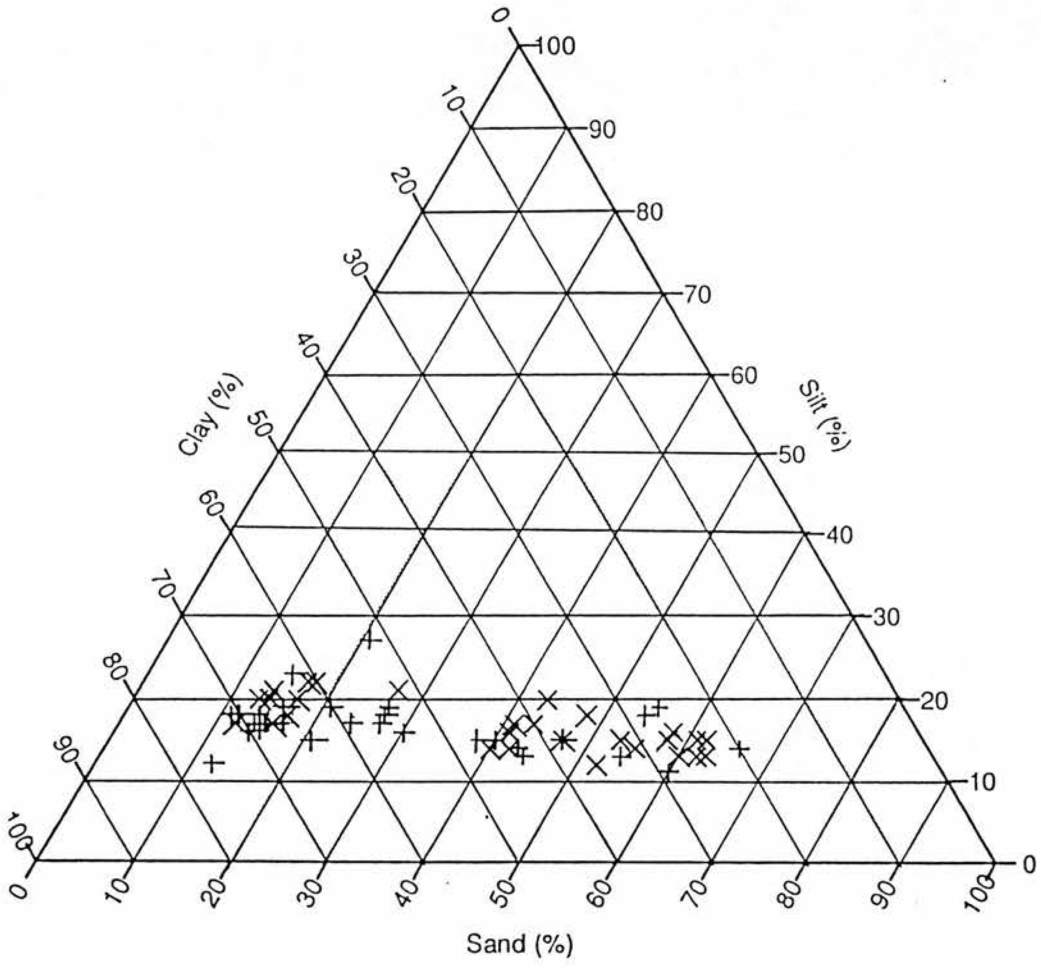


Figure 33 - Percentages of clay, silt and sand particles in the Taquara gallery forest soils: (X) represents the dry and (+) the wet community soil samples.

coefficient of variation lower than 20% for all the galleries and constituent community soils.

The coarse sand contents are significant higher in Taquara's soils than in those of Pitoco and Monjolo, both of which have similar contents. Soils of the dry communities in Monjolo and Taquara have significant higher contents than those of their respective wet communities. On the other hand, Pitoco's wet community soils show higher coarse sand average than its dry community soils.

The content of fine sand for most of the soils are of similar level (Table 21).

7.4. -The soils of the gallery forests: summary.

7.4.1.-The Pitoco gallery forest.

To summarise the general trends of the soil properties in each gallery and their constituent tree communities terms such as lowest, intermediate and highest are used in accordance with the average values presented in Table 20. Tests of significance are shown in Table 21.

On average the **Pitoco** soils show the highest levels for Al, H + Al, K, Fe and silt, intermediate levels for pH, Mg, Cu, CEC, Al saturation, clay and fine sand contents, and the lowest levels for OM, Ca, P, Zn, Mn, V and coarse sand. The Pitoco site is regarded as the driest amongst all, based on the measurements of topography over the catchment slopes (see Chapter 5).

7.4.2.- The Monjolo gallery forest.

The **Monjolo** soils show the highest P, Cu, Al saturation and clay levels, intermediate OM, Al, H + Al, Ca, Fe, Zn Mn, V and coarse sand levels, and the lowest pH, Mg, K, CEC, silt and fine sand contents. Monjolo is regarded as the wettest site of all, judging by the predominance of its wet communities and its topography (see Chapter 5).

7.4.3.- The Taquara gallery forest.

The **Taquara** soils are found to have the highest pH, OM, Ca, Mg, K, Zn, Mn, CEC, TEB, V and coarse sand levels, intermediate levels for P and silt, and the lowest Al, H + Al, Fe, Cu, Al saturation and clay contents. In a comparison of the galleries, the Taquara site is interpreted as having intermediate moisture conditions because of its deep stream bed indicating a deeper water table.

7.5. -Soil variation over the gallery communities.

7.5.1 - The Pitoco communities.

Within the **Pitoco** forest, soils associated with each constituent community are found to be significantly different in most of the soil variables (Table 21). The **wet community** soils shows the highest OM, Al, H + Al, P, Fe, Cu, Zn, CEC, Al saturation and fine and coarse sand contents, intermediate levels for pH and silt, and the lowest Ca, Mg, K, Mn, TEB, V and clay contents.

The **inner-dry community** soils have the highest clay and silt contents, intermediate AL, H, + Al, Ca, Mg, K, P, Fe, Mn, TEB, V and Al saturation, and the lowest pH, OM, Cu, Zn, CEC, coarse and fine sand levels.

The **dry-fringe community** soils show the highest pH, Ca, Mg, K, Mn, TEB and V, intermediate levels for OM, Cu, Zn, CEC, clay, coarse and fine sand, and the lowest Al, H + Al, P, Fe, Al saturation, and silt.

7.5.2.- The Monjolo communities.

The **wet-flatter community** soils have the highest Al, H + AL, Cu and clay contents, intermediate levels for P, Fe, Al saturation and fine sand, and the lowest pH, OM, Ca, Mg, K, Zn, Mn, CEC, TEB, V, silt and coarse sand levels.

Its **wet-steeper community** soils show the highest level for P, Fe, Cu, Al saturation, silt and fine sand, and intermediate levels for pH, OM, H + Al, Ca, Mg, K, Zn, Mn, CEC, TEB, V, clay and coarse sand. None of its soil properties have the lowest levels amongst Monjolo's soils.

The **dry community** soils have the highest pH, OM, Ca, Mg, K, Zn, Mn, CEC, TEB, V and coarse sand, intermediate levels for Cu and silt and the lowest Al, H + Al, P, Fe, Al saturation and clay contents.

7.5.3.- The Taquara communities.

Taquara's wet community soils have the highest Al, H + Al, Fe, Cu, Al saturation and clay, while the soils of its **dry community** show the highest pH, OM, Ca, Mg, K, P, Zn, Mn, CEC, TEB, V, silt, coarse and fine sand contents.

7.6.- Conclusion.

Different soil moisture regimes, produced by topography, determine many of the soil properties studied. Newberry & Proctor (1984), Baille et al. (1987), Burke et al. (1989), Oliveira-Filho et al. (1994 a, b), Schiavini (1992) Felfili (1993), Ramos (1994) and Bendix (1994) have also indicated topography's importance in determining other environmental features and consequently the vegetational distribution. Brady (1990) emphasised topography as having a major direct effect on soil formation, imposing a distinct moisture regime in the ridgetop and lowerslope soils. In turn, different soils may act selectively on species establishment, resulting in identifiable communities. These communities interact and transform the soil environment, producing even more distinct differences: here cause and effect are somewhat difficult to distinguish.

Despite the different soil classes within the galleries (see profiles in the appendix), those associated with the wet communities at stream margins always have higher levels of Al, H + Al, Cu, Fe, Zn and Al saturation.

The soils of the dry communities, positioned upslope, always have the highest pH, Ca, Mg, K, Mn, TEB and V. Most profiles described in dry community soils are regarded as Cambisols (see profile 7 at Pitoco, 4 at Monjolo and 2 and 3 at Taquara) in which weatherable material is still present in B horizons and higher base saturation is expected because of the relative youth of the soils which are constantly renewed due to slope. However, it is worth mentioning that most of these soils in the Federal District are derived from metamorphic acid bedrock which produces poor and acid soils (Adamoli et al. 1985, Haridasan 1991).

These contrasting wet versus dry soil patterns are found regardless of the sites and differences found in other characteristics of the respective profiles.

Ross (1989) indicated that the much lower CO_2 solubility in moist soils results in the formation of acid compounds thus reducing pH. Temperature is also reduced because of the cooling effect of the water. Consequently microbial activity is also reduced and OM accumulation is expected. Under wetter, more acid and OM-richer soil conditions the solubility of Al and micronutrients is expected to be higher (Brady 1990).

The intermediacy of Pitoco's inner-dry and Monjolo's wet-steeper communities found between the wettest and the driest extremes of each site is striking. They showed intermediate average values for 12 and 15, respectively, out of the 21 soil properties analysed, showing their position on a progressive gradient of soil properties from the stream margins to the forest cerrado border.

The analysis of soil properties show significant differences within and between the galleries and their constituent communities. Together with topography and its effect on soil moisture, they apparently control the distribution pattern of floristic communities.

Chapter 8 - Ordination of the Pitoco (P), Monjolo (M) and Taquara (T) soil properties.

8.1. - Introduction.

Plant communities reflect the variability of the environment. The pattern of plant distribution results from the interaction of individual plants with their immediate physical environment and with a limited circle of neighbouring individuals. As soil conditions are unlikely to be uniform, different plant species and communities preferentially select habitats (Crawley 1986). There may be fairly distinct zones in which some species are dominant, as can be seen over quite minor environmental gradients (Metzler & Damman 1985).

Studies on plant-environment relationships produce intricate results which represent only an approximation of the natural complexity. Unless the number of variables is reduced and grouped, the results cannot be properly understood. Ordination techniques contribute by summarising data objectively and analysing the precise nature of variation. If environmental data are ordinated and generate meaningful groups of soil properties, they can be related to vegetation data and the two sets of data can be analysed complementarily (Kent & Coker 1992). If vegetation communities are well separated along the soil gradient evidence is given of distinct vegetation/soil associations (Newbery & Proctor 1984).

Many ordination techniques have been applied to ecological studies amongst which Principal Component Analysis (PCA) (Orlóci 1966) has been widely utilised and quoted as an efficient, lucid and simple summarisation technique (Orlóci 1978, van der Maarel 1979, Jackson 1993). Although not recommended for floristic data due to the so-called 'arch or horse shoe' effect (Gauch 1982, Greig-Smith 1983), PCA is an extremely important method of summarising variation in soil data (Kent & Cocker 1992, Newbery & Proctor 1984). The technique reduces highly correlated variables into fewer components which are expected to retain more information than a single variable (Jackson 1993) and are said to be orthogonal, thereby removing the problem of intercorrelation (Kent & Cocker 1992).

The aim of this chapter is to find a combination of soil variables which may, collectively, account for the spatial patterns of the gallery community. For this, soil data from each gallery is subjected to ordination by Principal Components Analysis (PCA) in order to answer question 5. (Is there any pattern of soil distribution related to different communities within these gallery forests?).

8.2. - Material and methods.

Principal Components Analysis (PCA) was carried out using the CANOCO program, version 3.1 (Ter Braak 1988), to reduce the 17 soil chemical and physical variables (pH, H + Al, exchangeable Al, Ca, Mg, K, P, Al-saturation, Organic matter (OM), Mn, Fe, Cu, Zn, Clay, Silt, Coarse sand (CS) and Fine sand (FS)) to a small number of key components for each gallery. The variables CEC, TEB and V had to be excluded since they have exact linear dependence on cation levels.

Data for the 58, 55 and 64 soil samples for Pitoco, Monjolo and Taquara respectively, were logarithmically transformed for normalisation purpose. Newbery & Proctor (1984) tested soil data for normality and found that transformations are necessary for most variables. Without transformation, PCA cannot be used to investigate non-linear relationships (James & McCulloch 1990). Since each variable is measured in different units, they are standardised (zero mean and unit variance) (Jongman et al. 1987), thereby giving equal weights to all of them (Noy-Meir et al. 1975).

Ordination by Principal Component Analysis (PCA) yields two types of diagram. The first (see Figure 35) refers to the soil variable loadings, which represents the correlations of an original variable with the components constructed by the analysis. In the second type (see Figure 36), correlations between the soil samples and the components are displayed. In this way, the analysis assesses the most important variables defining the extremes of the soil gradient (Newbery & Proctor 1984).

An assessment of the vegetation and soil relationships is made possible by labelling each of the soil samples in the second type of diagram with their corresponding plant community classification (TWINSPAN, see Chapter 5). A joint analysis of the two diagrams illustrates the relationships between the tree communities and the soil variables.

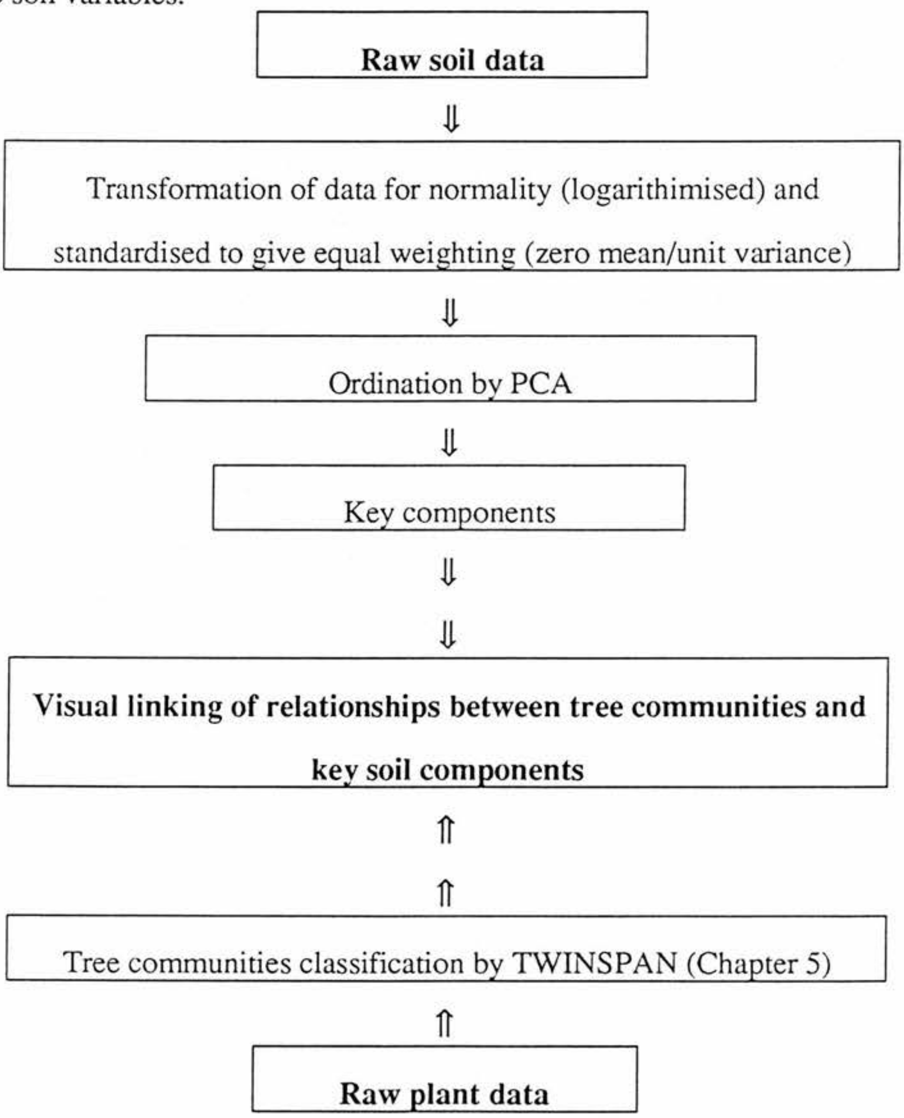


Figure 34- Flow diagram showing the sequence of analysis.

8.3. - Results and discussion.

8.3.1. - Pitoco soils.

The first two axes have eigenvalues of 0.484 and 0.184 and account for 66.8% of the total variance. Gradient axis I is much more important in terms of explaining the distribution of samples than axis II.

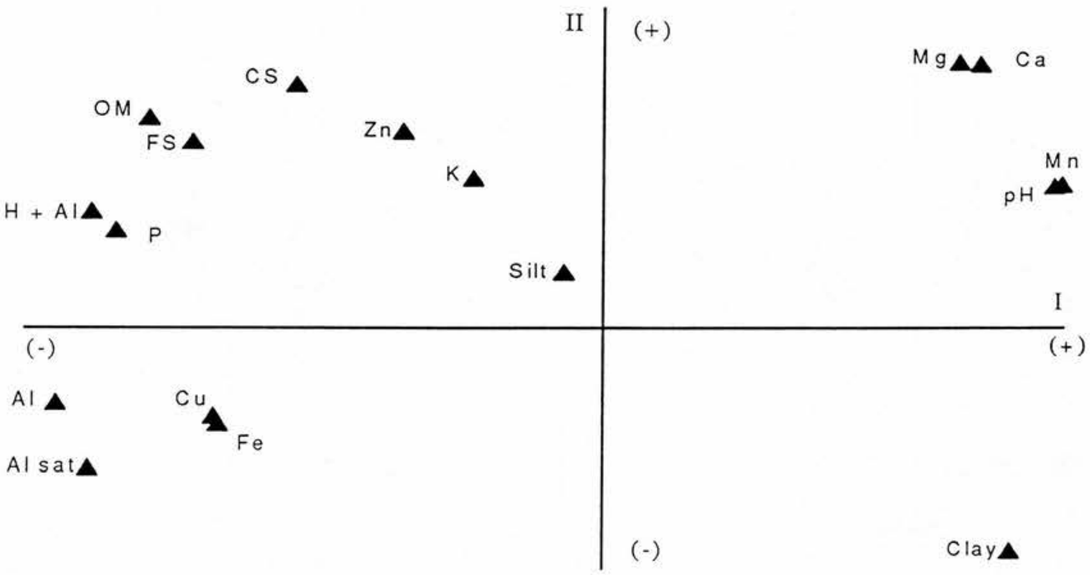


Figure 35 - Principal Component Analysis of 58 (0-10cm depth) soil samples from the Pitoco gallery forest measured for 17 chemical and physical variables.

The diagram shows the distribution of soil variables along the two axes. On axis I, which explains most of the variance, there is a negative correlation which groups acidity values (Al, Al saturation, and H + Al), organic values (P and OM), some trace elements (Cu and Fe) and sand fraction (fine sand). At the positive end of the same axis, there is pH, clay and a group of base-cations (Ca, Mg and Mn). These correlations define axis I as a strongly marked fertility-textural gradient. Axis II is interpreted as representing a gradient ranging from the sandier and base-rich soils to the clay-rich soils. The variable loadings of components I and II are shown in Table 22.

Figure 36 shows that soil samples mostly occur in a continuous diagonal ranging from the upper-left to the lower-right quarters of the diagram. This suggests that the correlation of soil variables with both axes is responsible for the position of the samples (Werger et al. 1979 in Mucina & Polácik 1982) and also that the sampling design is able to detect the whole range of the gradient (Mucina & Polácik 1982). Some of the dry-border samples are placed in the upper-right quarter of the diagram, as outliers, showing very distinct soil characteristics. In fact they represent the soils collected at the forest-cerrado border of the Pitoco gallery (see Chapter 5).

The results in Figure 36 are interpreted as showing that the soils related to the communities are differentially placed at either extreme of the fertility gradient defined by both axis I and II in Figure 34. The wet community samples display better correlation with Al, P and OM-rich very acid soils and a wide range of textures from sandy to clay-rich soils. The dry-fringe community samples shows the strongest correlation with the higher Ca, Mg, Mn, pH levels and coarser textures. The dry-inner community soil samples are placed mostly in the intermediate position between the wet and dry-fringe community.

The variables with the highest loadings, Al, P, OM are found with significant higher levels in the wet community soils. Levels for Ca, Mg, Mn and clay contents are significant higher in the dry-border community soils (see Chapter 7). Thus, these together with the moisture regime are the properties which distinguish the wet and dry community soils. Differences are greater when compared with the wet community soils (see Table 21, Chapter 7). The inner-dry soils show significantly higher Ca, Mg, Mn and clay contents and significantly lower OM and P. These results agree with the intermediate placement of the community samples between those of the wet and dry-fringe communities (see Figure 36).

Table 22 - Loadings of nine standardized soil variables on axes I and II of principa component analysis of 0-10cm soil samples from the Pitoco, Monjolo and Taquara gallery forests.

	Pitoco		Monjolo		Monjolo wet		Taquara	
Axis	I	II	I	II	I	II	I	II
Variance (%)	48.4	18.4	38.7	25.5	32.6	16.6	45.9	24.7
Cumulative variance (%) loadings	**66.8**		**64.2**		**49.2**		**70.7**	
pH	0.78	0.35	0.78	-0.21	0.02	-0.17	0.77	-0.53
OM	-0.79	0.53	0.61	0.63	0.83	0.34	0.85	0.42
Al	-0.95	-0.18	-0.65	0.5	0.39	0.66	-0.76	0.53
H+Al	-0.88	0.29	0.04	0.7	0.71	0.55	-0.15	0.89
Ca	0.65	0.66	0.86	-0.36	-0.25	0.27	0.92	-0.32
Mg	0.62	0.66	0.84	-0.39	-0.26	0.67	0.87	-0.24
P	-0.84	0.24	0.42	0.74	0.85	-0.14	0.47	0.68
K	-0.23	0.38	0.71	-0.34	-0.29	0.58	0.72	-0.18
Fe	-0.67	-0.24	-0.53	-0.32	-0.06	0.31	-0.53	-0.001
Cu	-0.67	-0.22	-0.44	-0.42	-0.58	0.52	-0.37	-0.49
Zn	-0.35	0.49	0.73	-0.03	0.23	0.42	0.61	-0.07
Mn	0.8	0.36	0.81	-0.35	-0.16	0.36	0.74	-0.37
Al-sat	-0.89	-0.35	-0.77	0.49	0.43	0.54	-0.81	0.46
Clay	0.71	-0.55	-0.45	-0.78	-0.87	0.01	-0.69	-0.58
Silt	-0.69	0.14	0.21	0.27	0.37	-0.27	-0.27	-0.64
CS	-0.53	0.61	0.68	0.58	0.85	-0.11	0.73	0.57
FS	-0.71	0.47	0.26	0.73	0.84	0.03	0.69	0.59

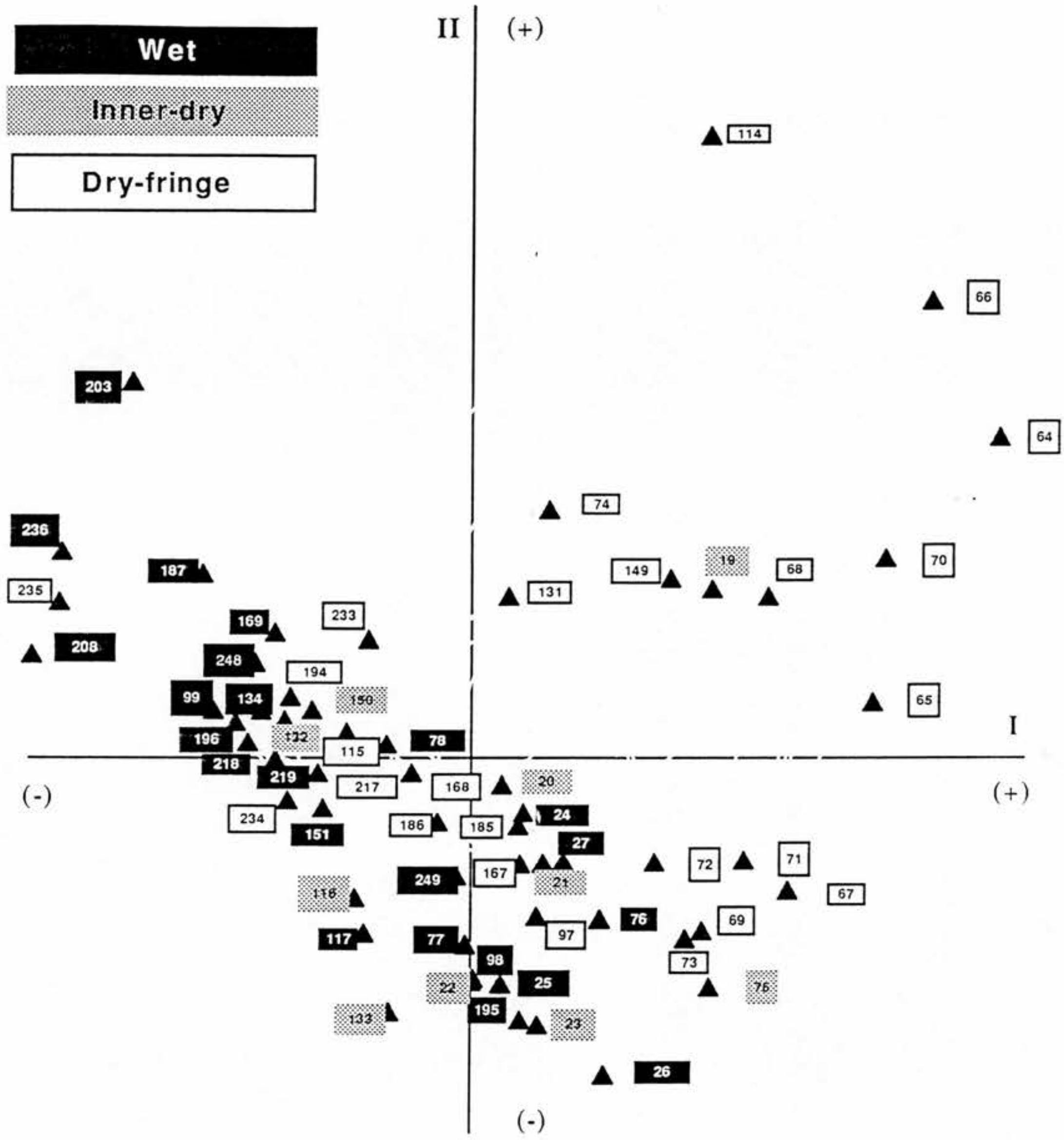


Figure 36 - Correlations of 58 soil samples from Pitoco gallery forest with gradient axes I and II from Principal Component Analysis, defined by loadings of 17 chemical and physical variables. The labels indicate tree communities provided by TWINSPAN classification.

The soil ordination deals with 66.8% of the data variance. The analyses do not include soil-water availability or topographical variables, which would have strong influence on the vegetation patterning as found in many studies worldwide (Wildi 1983, Proctor & Newbery 1984, Miller & Johnson 1986, Burke et al. 1989, Schiavini 1992, Oliveira-Filho et al. 1992, 1993, 1994, Backeus et al. 1994, Bendix 1994).

Nevertheless, the results emphasise a strong association between the soil and the topographic-moisture gradient, which is also closely followed by the distribution of tree communities within the galleries.

The results lead to inferences on species related to each community , and their relationships with soils provided by PCA ordination. Thus, *Callisthene major, Lamanonia ternata* and *Pera glabrata,* related to the dry-fringe community (see Chapter 5), appear to colonise selectively the driest, base-rich and less acid soils. On the other hand, species such as *Protium almecega, Tapirira guianensis* and *Pseudolmedia guaranitica*, related to the wet community (see Chapter 5) seem to colonise preferentially the wettest, Al-rich and more acid soils of the Pitoco gallery forest. In addition, species such as *Faramea cyanea, Copaifera langsdorffii* and *Jacaranda puberula,* related to the inner-dry community, apparently show the best potential for competing at sites with intermediate levels of moisture availability, Ca, Mg, Mn, P, OM and clay.

8.3.2. - Monjolo soils.

The first two components have eigenvalues of 0.387 and 0.255 accounting for 64.2% of the total variance.

The diagram shows the correlation of soil variables with the two axes. On axis I, which explains most of the variance (38.7%), there is a negative correlation which groups acidity values (Al and Al saturation) and some trace elements (Cu and Fe). At the positive end of axis I, there is a group of base-cations (Ca, Mg and K), Mn, pH and Zn. This correlation defines axis I as a strongly marked fertility gradient. Axis II is interpreted as representing a textural gradient ranging from the soils with higher sand levels, positively correlated with the axes, to the clay-rich soils, negatively correlated with the axes. The variable loadings on components I and II are shown in Table 22.

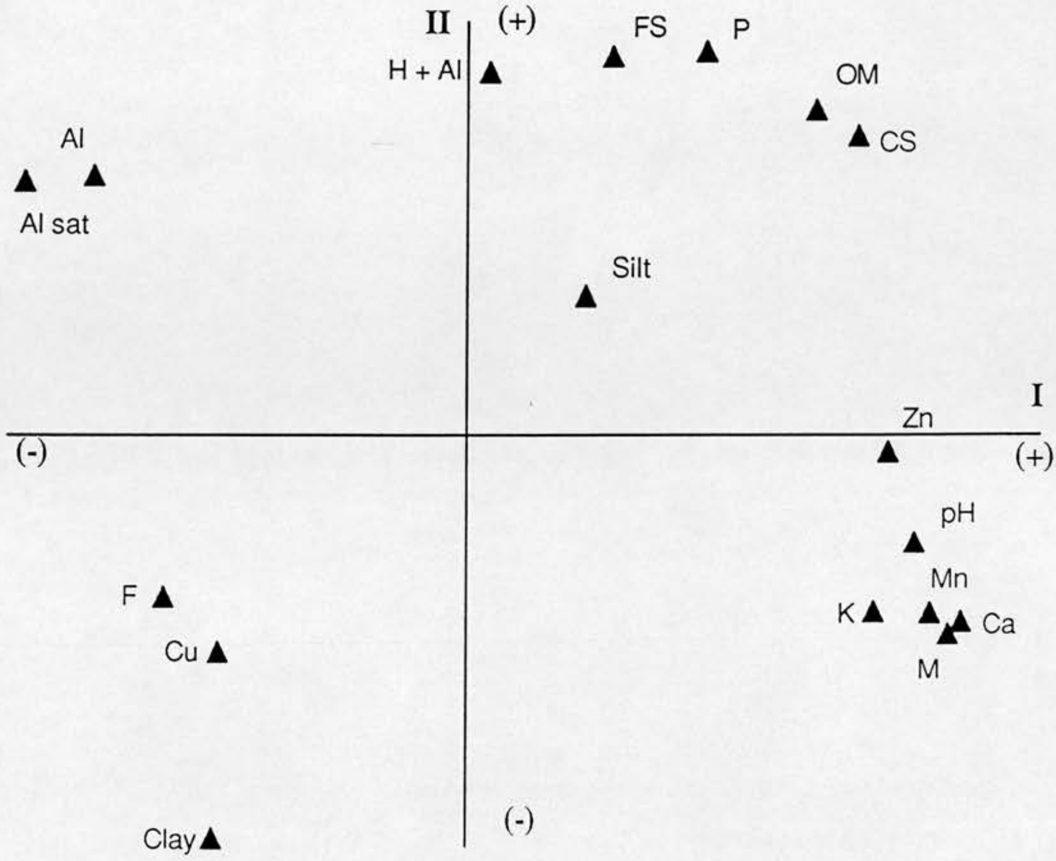


Figure 37 - Principal Component Analysis of 55 (0-10cm depth) soil samples from the Monjolo gallery forest measured for 17 chemical and physical variables.

The interpretation of the highest loadings (Table 22) to axis I, in Figure 37, indicates that it corresponds largely to variation in the soil fertility status. In Figure 38 axis I is effectively distinguishing the communities along the gradient. The wet-flatter community is found correlated with the highest Al level, and the highest Ca, Mg, Mn, pH, Zn and K levels are correlated with the dry community soils.

Loadings to axis II (Figure 37) characterise a textural gradient ranging from the coarser, P-rich and very acid soils to those of clay-rich texture. Inspection of Figure 38 shows that most of the dry community soils are correlated with high clay content. On the other hand, the great majority of both wet community samples are positioned at the negative end of axis I with Al-rich soils, and range along axis II by having a complete range of textures from clay to sand-rich soils.

Tests of significance, run in Chapter 7, support the ordination results, indicating higher levels of Al in the wet community soils, and higher base and Mn levels than those of the dry community. Comparisons between the results for texture show non-significant differences between soils of both communities in clay, silt and fine sand. However, coarse sand contents are significantly higher in the dry community than in the wet community soils, mainly due to very high levels (34 and 39%) found in two of the dry community samples.

Figure 38 shows that samples of both wet communities are grouped at the left hand side of the diagram. This is due to the very different scores of the dry community soils which are responsible for most of the variation in the analysis.

To discover the relationship between the wet-flatter and wet-steeper community samples and the gradient axis, a second PCA was carried out excluding the dry community soil samples as outliers. This analysis indicates a textural gradient defined by loadings to component I and II which account for 49% of the total variance (Table 22). A slight difference was found but insufficient to show clearly in a diagram. In fact non-significant differences occur between the great majority of their soil properties (see Chapter 7). Topography is the main difference between the two communities, conferring on them the descriptive names used in this thesis, namely : 'flatter' and 'steeper'.

The analyses provide evidence for the presence of a soil fertility and textural gradient associated with site toposequence and consequent soil moisture availability which are, in turn, related to the tree communities. It further allows inferences on their associated species, as listed in Chapter 5.

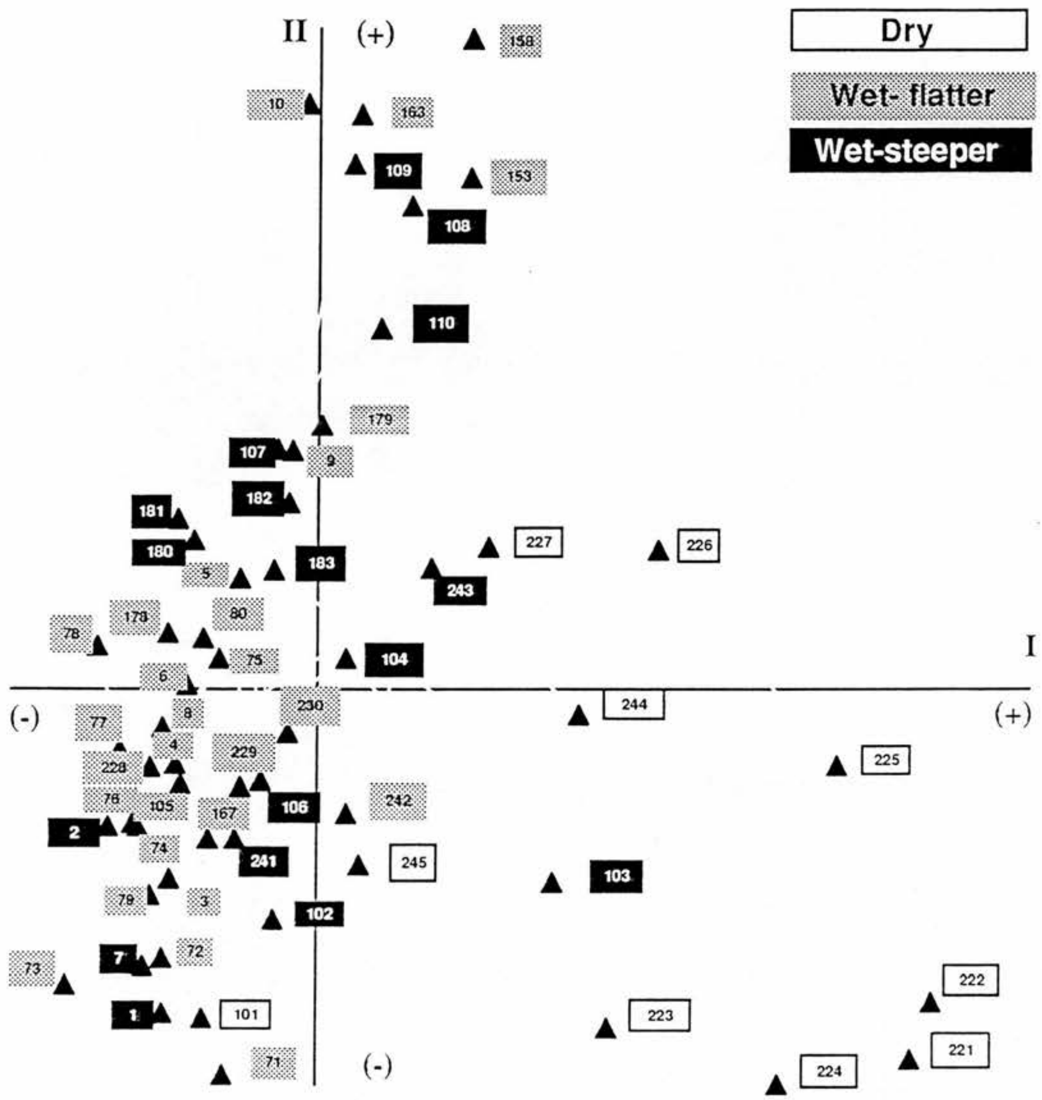


Figure 38 - Correlations of 55 soil samples from Monjolo gallery forest with gradient axes I and II from Principal Component Analysis defined by loadings of 17 chemical and physical variables. The labels indicate tree communities provided by TWINSPAN classification.

As demonstrated in Chapter 6, there are close floristic links between the dry communities of distinct galleries. Therefore, species such as *Copaifera langsdorffii, Jacaranda puberula* and *Callisthene major* occur preferentially on the driest, less acidic, base-rich and argillic soils in Monjolo, as they do within the same habitats of the Pitoco gallery forest.

Species such as *Miconia cuspidata, Cryptrocarya aschersoniana* and *Licania apetala*, related to the wet-flatter community, and *Inga alba, Tapirira guianensis* and

Virola sebifera related to the wet-steeper community occur preferentially on the wettest and Al-rich soils of the Monjolo gallery forest.

8.3.3. - Taquara soils.

Soil ordination gives components I and II with eigenvalues of 0.460 and 0.247 which explain 70.7% of the total variance. The variable loadings to axis I and II (Table 22) define a marked fertility gradient (Figure 39), varying in accordance with the main topographic gradient which is closely associated with the gallery tree communities.

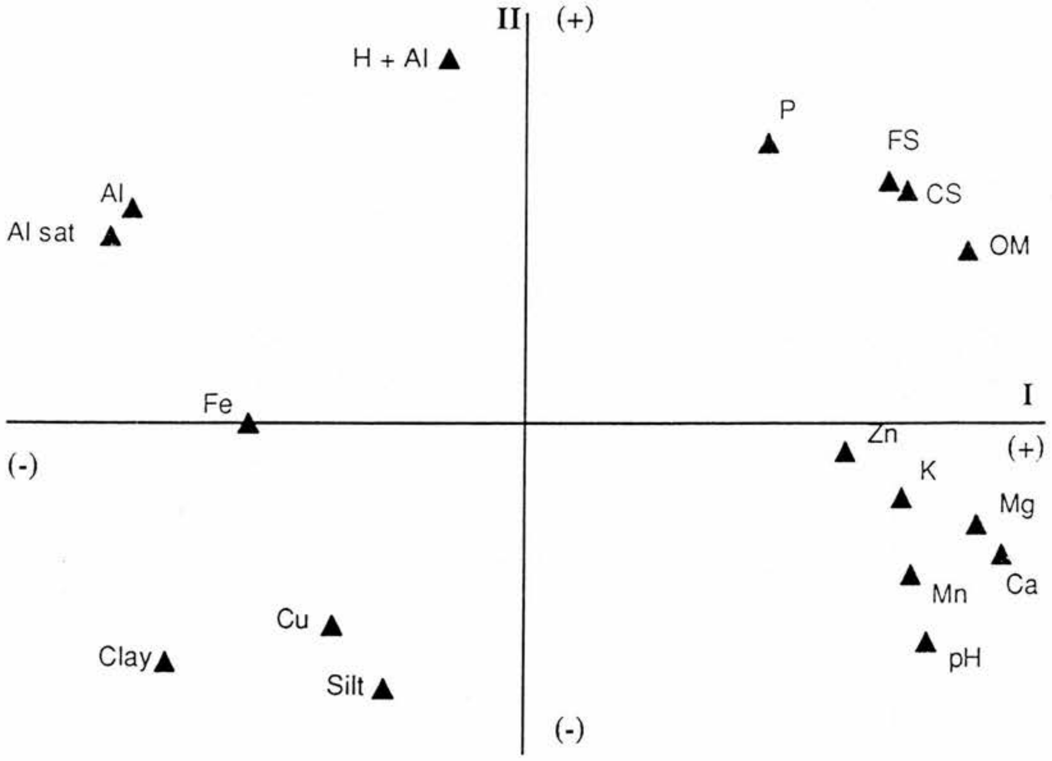


Figure 39- Principal Component Analysis of 64 (0-10cm depth) soil samples from the Taquara gallery forest measured for 17 chemical and physical variables.

The diagram shows the correlation of soil variables with the two axes. On axis I, which explains most of the variance (46%), there is a negative correlation which groups acidity values (Al and Al saturation) and clay fractions. At the positive end of axis I, there is a group of base-cations (Ca, Mg and K), Mn, pH and Zn. These correlations define axis I as a strongly marked fertility gradient. Axis II, which explains 24.7% of the variance, shows the stronger positive correlations with total acidity, P and sand fractions and the stronger negative correlations with silt and clay fractions. It is interpreted as representing a chemical-textural gradient ranging from the coarser and acid soils to the fine textured and less acid soils. The variable loadings to components I and II are shown in Table 22.

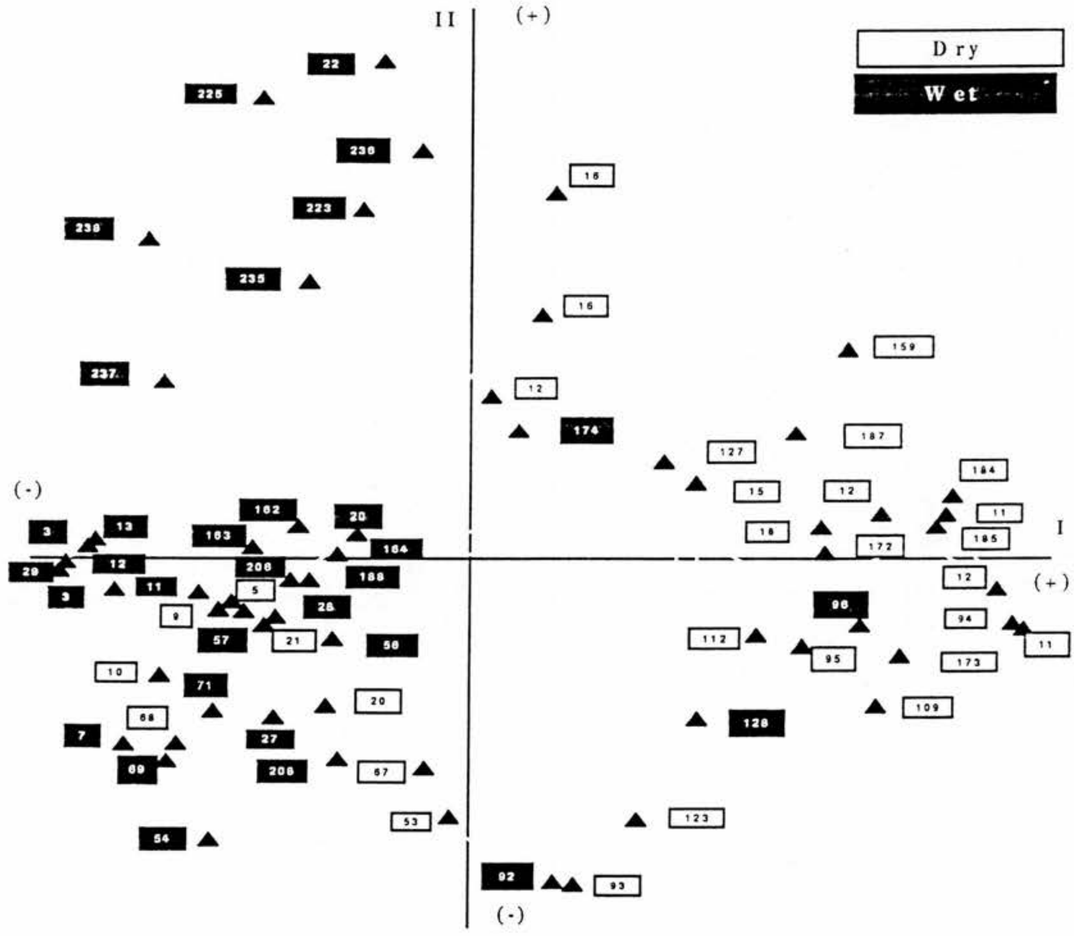


Figure 40- Correlations of 64 soil samples from Taquara gallery forest with gradient axes I and II from Principal Component Analysis defined by loadings of 17 chemical and physical variables. The coloured labels indicate tree communities provided by TWINSPAN classification.

Figure 40 can be interpreted as an ordination where most of the dry and wet community samples are split at either end of axis I contrasted by their differences in soil fertility and texture. The gradient is arranged along a topographic-moisture range, from the stream margins to the forest-cerrado border. The base- (Ca, Mg and K)-, OM- and Mn-rich and less acid soil samples are associated with the dry community at the positive end of the axis. Conversely, the wet community soil samples show the strongest correlations with the negative end of the axis, indicating higher Al and clay contents. Comparisons between the soils of the Taquara communities (see Chapter 7) show that almost all the properties are found to be significantly different between wet and dry communities. This emphasises a pronounced soil gradient.

The highest loadings for axis II are related to soil total acidity (H + Al), P and fine and coarse sand contents at the positive end and silt and clay at the negative end. Among these variables P and silt have similar levels in soils of both wet and dry communities (see Chapter 7). Differences in total acidity, coarse sand and clay fails to separate the communities, since in any case a wide range in levels of these factors occurs (see Figure 40).

Taquara's conspicuous dry community has species such as *Copaifera langsdorffii*, *Anadenanthera colubrina* var. *cebil* and *Alibertia macrophylla* which are inferred from the present analysis as preferentially related to the driest, base-rich, Mn-rich, organic and less acid soils, whilst *Tapirira guianensis*, *Piptocarpha macropoda* and *Protium almecega* are relate to the wet community and preferentially occur on the wettest, Al- and clay-rich soils.

8.4. - Conclusions.

It has already been stated that there exists a clear topographic-moisture gradient, from the stream margins to the forest-cerrado border, along which the vegetation communities can be placed (Chapter 5). Seventeen soil variables are characterised and compared and give a consistent pattern, following the topographic gradient, at all the three sites (Chapter 7). The principal components analyses has produced a succinct summary, highlighting the variables responsible for most of the data variance. These, together with the topography-moisture gradient, would explain most of the variation in the spatial distribution of the tree communities.

The high Al levels and very acid soils at the stream margins and the Ca-, Mg-, Mn-rich and less acid soils at the forest-cerrado border, define the extremes of a soil fertility gradient which divides the gallery communities. Soil texture varies in each gallery and is not identified as a factor to help separate the communities.

Differences in the soil chemical properties along the topographical gradient could be explained by the water-table fluctuation which causes changes in soil aeration and consequently in the redox-related processes, resulting in leaching and acidification (Ross 1989).

Dynamic changes in the stream courses create new situations of drought or excessive water supply, changing the soil characteristics and consequently affecting the boundaries between the vegetation communities. Hobbs & Grace (1981) pointed out the different directions and rates of community change, especially when physiographic and soil changes occur. In such situations, species respond to variations affecting the availability of various resources which in turn influence the growth of other species (Tilman 1986). Cause and effect relationships in such dynamic processes can only be demonstrated through experimentation. In this study, evidence of dynamic changes in the stream courses are provided by the presence of typical cerrado species recorded within the galleries, such as *Blepharocalyx salicifolia* and *Pouteria ramiflora*. The sampling points in each gallery have been established permanently. This will make possible the assessment of the dynamic relationships between the vegetation and environment by continuous observation and experimentation.

Chapter 9 - Relationships between the tree communities of the Pitoco, Monjolo and Taquara gallery forests and environmental factors.

9.1 - Introduction.

There have been few quantitative studies of the Brazilian gallery forests. The majority of works consists of descriptive surveys and little is known about the relationships between tree species distribution and environmental factors (Oliveira-Filho et al. 1994). More detailed analysis including the application of numerical techniques would provide a better understanding of the spatial and temporal patterns of this very complex vegetation.

Over the last three decades, following the construction of the city of Brasília, increased land-use has drastically reduced the vegetation cover in the Federal District. The need for restoration is already an urgent issue. However, relatively little is known about the nature of the vegetation and its dynamics and consequently about suitable strategies for maintenance and restoration of the environment. The gallery forests stand out as a priority, since they maintain environmental health by storing and regulating the volume and quality of water needed by a fast developing area. The galleries are protected by law and some of the principal catchments are inside conservation units such as the Brasília National Park, the Botanic Garden and the IBGE Ecological Reserve.

It is important on both theoretical and practical grounds to study both physical and biological aspects of the galleries together. Such investigation would generate comprehensive data on the vegetation and environment relationships and, as a consequence, should indicate the steps required for efficient environmental restoration.

The gallery forests are located along valley bottoms and provide good field experimental sites for investigating how heterogeneity of the physical environment affects the distribution of plant communities (Brison 1990). The slope gradient produces variations in ground water which are primarily responsible for strongly marked changes in the species composition and growth in the riverine forests (Schiavini 1992, Felfili 1993, Oliveira-Filho et al. 1994). In Chapters 4, 5 and 6, the Pitoco, Monjolo and Taquara galleries are characterised, classified, and compared, and their constituent communities are found to be closely associated with topography.

Newbery & Proctor (1984), Baillie et al.(1987) and Oliveira-Filho et al. (1994) have found that soil properties are significantly different along the topographic-moisture gradient. Soil fertility and texture can considerably affect the distribution of plant species in riverine forests (Oliveira-Filho et al. 1990, 1994). In Chapters 7 and 8, the gallery soils are characterised and ordinated showing a fertility and textural gradient which varies consistently in accordance with slope.

Site history and biotic factors may also impose important patterns on vegetation communities. Historical factors usually leave little or no direct, independent and measurable evidence at the site and are infrequently (if ever) repeated. Furthermore, the dynamic succesional change is also a barrier to measuring the effects of historical factors (McCune & Allen 1984). At the time of the present field survey, the galleries had been free from major disturbance for at least 20 years. The biotic interactions are extremely variable and demand continuous experimentation for their accurate assessment.

Strong patterns emerged from the vegetation classification and soil ordination analysed in the previous chapters. The main purpose of this chapter is to use an ordination technique which deals with vegetation and environmental data simultaneously to give an integrated picture of their relationships. The idea is to illustrate the patterns of variation in species composition and also to focus on the principal relations between species and each of the environmental variables. The data will therefore address Question 6 (Are the structure and communities of the gallery forest related to the environmental variables studied?).

9.2 - Material and methods.

The computer program CANOCO, version 3.1, was used to run a Detrended Correspondence Canonical Analysis (DCCA) of the data sets. This is an ordination technique that requires two data matrices, in this case the species and the environmental data sets, and incorporates correlation and regression within the ordination analysis, itself summarising their variability (Kent & Cocker 1992). The Canonical correlation calculates linear combinations within the vegetation data and within the environmental data simultaneously. The overall correlation is selected from the combination that maximises the correlation between the two data sets (James & McCulloch 1990). The detrended version of the analyses is intended to remove the 'arch effect', which represents the second axis of the ordination as a quadratic distortion of the first (Gauch 1982). However debate on whether or not detrending technique contributes to the analysis is still an ongoing issue. Contrasting views are given by Hill (1979b), Hill & Gauch (1980), Wartenberg et al. (1987), and Palmer (1993).

The analysis is carried out by building four groups of data sets. The first three includes species and environmental data matrices for each gallery separately and the fourth includes data from all three galleries to run a combined analysis.

Only those species recorded with more than 1% of the total density (≥10 individuals) in each gallery were selected, representing 33 for Pitoco, 33 for Monjolo, 34 for Taquara and 56 for the combined analysis. Rare species are eliminated as they have a little or no influence on the results (Gauch 1982, Causton 1988).

The total basal area of selected species was calculated for sampling points corresponding to those of the soil sample groups shown in Figures 28, 29 and 30 in Chapter 7. The following soil values were measured for each soil sample: pH, Al, OM, H + Al, Ca, Mg, P, K, Fe, Cu, Zn, Mn, Al saturation, CEC, TEB, S (percentage of bases), V, percentage of clay, silt, coarse and fine sand. Soil data from each gallery forest are displayed in Tables 17, 18 and 19 of Chapter 7.

The elevation of the same sequence of sampling sites for each gallery from stream to the forest-savanna transition was measured (Chapter 5, Figures 10, 15 and 20), giving an indirect assessment of the drainage and level of the water-table.

The environmental variables are logarithmicaly transformed to approximate to normality (Boeye & Kerheyen 1994) and standardised to a mean of 1 and variance of 0 before the analysis. The standardisation removes arbitrariness in the units of measurement of the environmental variables and makes the canonical correlations comparable. These procedures do not distort the canonical ordination techniques (Ter Braak 1987).

Three nominal variables, which involve categorisation without numerical values or ranks (Kent & Cocker 1992), are included in the analysis: the 'Border Zone', 'Intermediate Zone' and 'Stream Zone'. Their inclusion provides meaningful groups of species and samples, once they are categorised in accordance with TWINSPAN community classification, which are inferred as related to differences in water-table influence (see Chapter 5, figures 10, 15 and 20). Consequently, samples indicated as dry-community receive a score of 1 for the 'Border' zone and '0' for the 'Intermediate' and 'Stream' zones. Those of the wet community are given a score of 1 for the 'Stream' zone and 0 for 'Border' and 'Intermediate' zones. In the Pitoco and Monjolo analysis, their respective inner-dry and wet-steeper communities, found between the wet and dry communities, receive a score of 1 for 'Intermediate' and 0 for the 'Border' and 'Stream' zone. This is a common approach used to analyse species and environmental relationships (Bendix 1994).

The environmental variables which are highly correlated with each other are indicated by the analysis with high Variance Inflation Factor (VIF). Those showing VIF greater than 20 are excluded from the analysis. This procedure eliminates the colinearity problem and only slightly decreases the eigenvalues and significance of species-environment correlations (Ter Braak 1987).

The CANOCO program includes the Monte Carlo test of significance which is run to test whether or not the canonical axes are significantly related to the environmental variables (Ter Braak 1988).

The analysis produces an ordination diagram biplot in which species, samples and environmental variables can be represented together in the same diagram. The species and samples are represented as points and environmental factors as arrows projecting the direction of maximum change. The arrow lengths are proportional to the correlation between the variables and that axis (Ter Braak & Prentice 1988). However, to clarify the results, the ordination of species, samples and environmental variables are presented separately. TWINSPAN community classification is labelled in the species and sample diagrams to show community trends along the gradients.

9.3 - Results and discussion.

9.3.1 - The Pitoco gallery forest.

The variables loadings on the ordination axes are shown in Table 23 which resulted in eigenvalues for the axes of 0.472, 0.178, 0.098 and 0.052 respectively. The cumulative percentage variance accounted for by the axes I and II are respectively 10.8, 14.8, 17.1 and 18.3 % for species data, and 33.6, 51.0, 58.9 and

62.3 % for the species-environment relations and the sum of all canonical eigenvalues is 1.408. Axes III and IV explain only a little variance and are not discussed further here. These results indicate that the environmental variables considered in the analysis are apparently sufficient to explain most of the species basal area variation among the Pitoco gallery forest samples. These values of cumulative percentage of variance normally infer that a variety of other environmental features not included in the analysis may be involved in determining the species distribution patterns.

The Monte Carlo test carried out for the first two axes showed that species distributions are significantly ($p \leq 0.01$) related to the environmental variables included in the analysis, indicating differences in the species basal area among samples.

9.3.1.1. - The environmental gradients.

Figure 41 a shows the environmental variables selected by showing the highest correlations with axes I and II. Table 23 shows the weighted correlations between the environmental variables and the species and environmental axes. The first ordination axis is highly and positively correlated with the 'Stream zone' effect, indicating soils with a high water-table influence, and also with the highest P, OM, Al, H + Al and Fe levels. The most prominent negative correlations are found with the higher elevation and 'Border zone', both indicating soils less affected by high water-table, and also with higher Mn, Mg and clay contents. Axis I is interpreted as representing a topographic-moisture gradient along which a strongly marked soil fertility and textural gradient is also inferred, ranging from the stream margins to the forest-cerrado border. Correlation values with the secondary environmental gradient are lower indicating weak relationships.

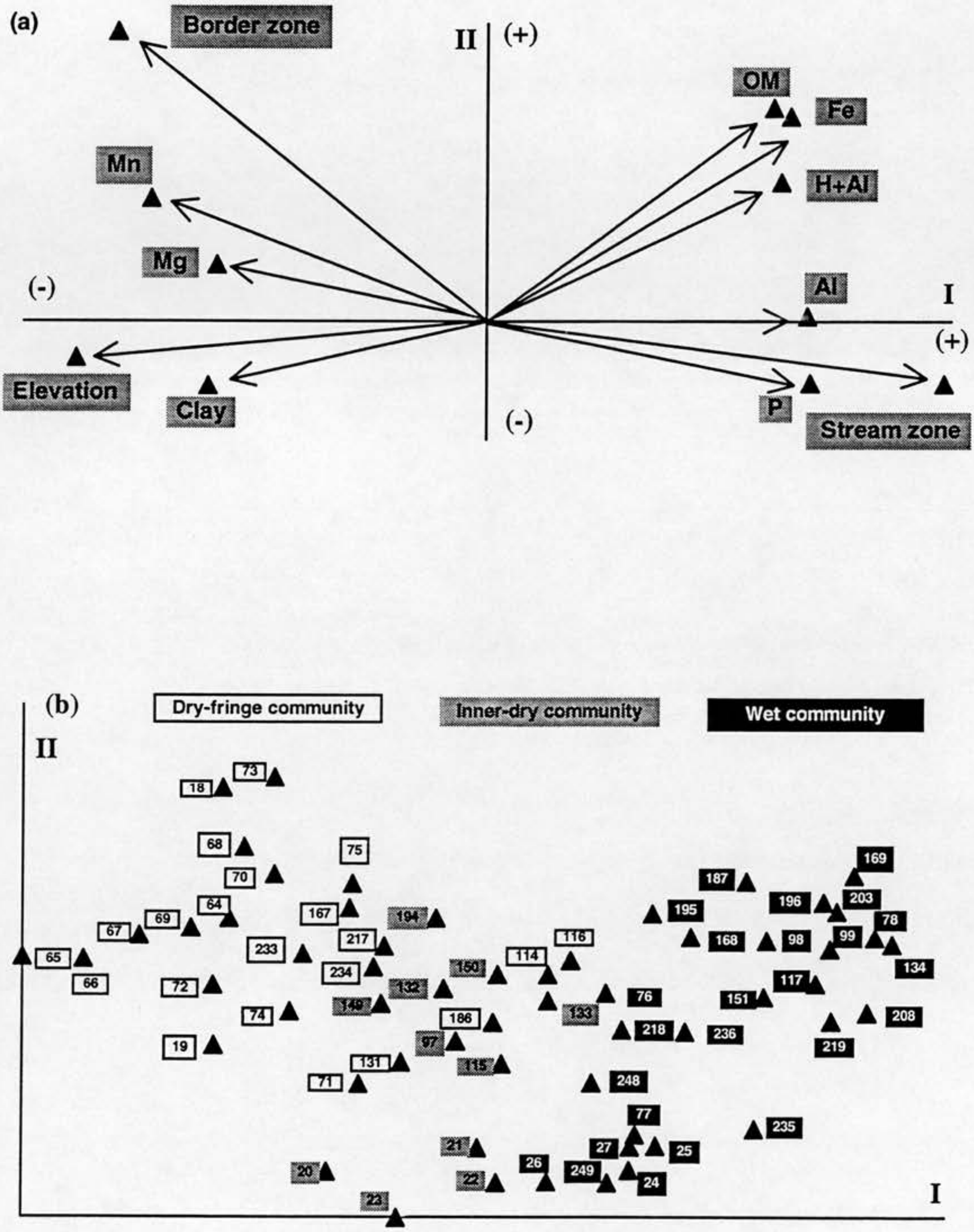
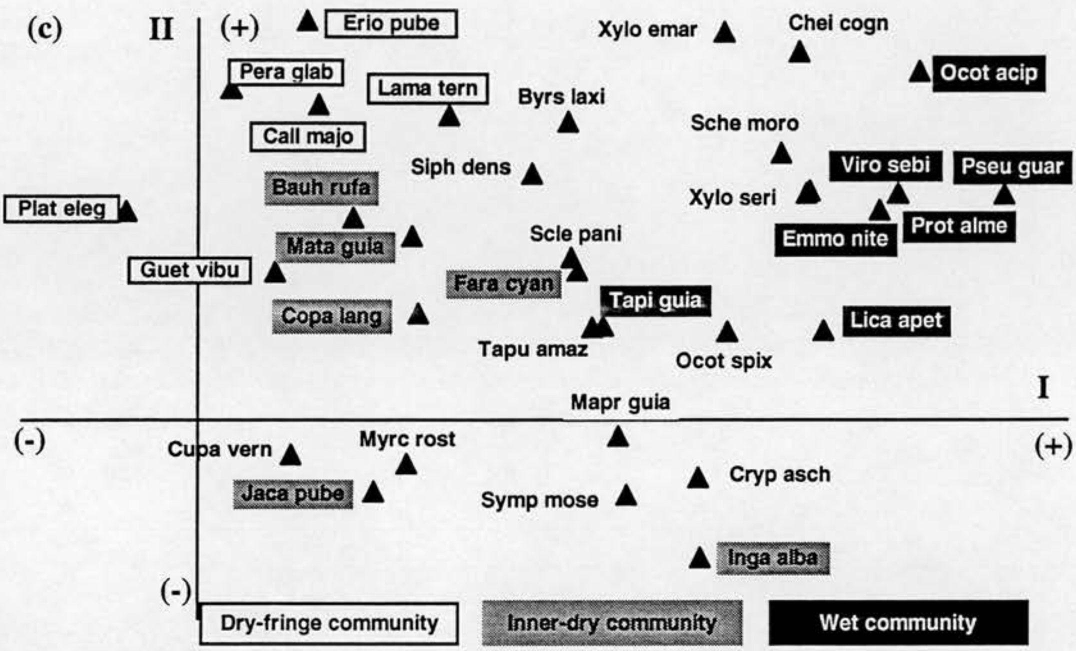


Figure 41 a, b and c - Ordination yielded by Detrended Correspondence Canonical Analysis (DCCA) based on the basal area of trees ≥ 5cm DBH of 33 species represented by ≥ 10 individuals in the Pitoco gallery forest. Species are identified by abbreviations (full names in table 27) and samples are identified by numbers.

Figure 41 c - cont...



The diagrams show:

(a)- Axis I and II which represent linear combinations of the environmental variables selected in the analysis, by showing the highest correlations which are displayed in Table 23. These environmental variables maximise the dispersion of the species scores represented in diagram (c). Each arrow can be interpreted as an axis that represents the variation of each variable. The arrows points in the direction of maximum correlation. The longest arrows represent the 'Border Zone, Elevation and 'Stream Zone' variables most strongly correlated with the ordination axes, and therefore most closely related to the pattern of variation in samples and species composition shown in the species and samples ordination in diagrams (b) and (c). Thus, axis I and II in the diagram define an ordination space representing a topographic-moisture and chemical-textural gradient as a consequence of the correlations between the environmental variables and the axis.

(b)- Sample ordination which arranges site points in a continuum, where points which are closer correspond to sites that are similar in species composition, and points which are far apart correspond to sites which are dissimilar. The projection of the sample points on to the arrows of diagram (a) represents the main relationship between samples and each of the environmental variables. Samples are labelled with their respective community classification provided by TWINSPAN to allow visual interpretation of the relationships.

(c)- Species ordination showing position along the environmental axes. The position of the species if superimposed on diagram (a) would represent the main relationships between species and each of the environmental variables. Species are coloured to show their community classification provided by TWINSPAN.

	SP AX1	SP AX2	SP AX3	SP AX4	EN AX1	EN AX2	EN AX3	EN AX4
SP AX1	1							
SP AX2	-0.0299	1						
SP AX3	0.0266	-0.009	1					
SP AX4	0.0738	0.1164	-0.1315	1				
EN AX1	**0.9429**	-0.0192	-0.0142	0.0576	1			
EN AX2	-0.0236	**0.7671**	-0.0653	0.0708	-0.025	1		
EN AX3	-0.019	-0.0708	0.7079	-0.1378	-0.0201	-0.0923	1	
EN AX4	0.0909	0.0909	-0.1634	0.5972	0.0964	0.1185	-0.2308	1
OM	0.5289	0.2936	-0.1608	-0.0298	0.5609	0.3827	-0.2272	-0.0498
Al	0.5909	0.0098	0.1697	-0.072	0.6267	0.0128	0.2398	-0.1205
H+Al	0.5435	0.1925	-0.1791	-0.1078	0.5764	0.251	-0.2531	-0.1805
Mg	-0.4994	0.0753	-0.0426	-0.2197	-0.5296	0.0982	-0.0601	-0.368
P	0.595	-0.0811	-0.0532	-0.2269	0.631	-0.1057	-0.0752	-0.38
Fe	0.5612	0.2835	-0.2299	0.0751	0.5952	0.3695	-0.3248	0.1257
Mn	-0.6189	0.1648	-0.0667	-0.1778	-0.6563	0.2148	-0.0942	-0.2978
Clay	-0.5159	-0.091	-0.0014	0.2311	-0.5471	-0.1187	-0.002	0.387
Elevation	-0.756	-0.054	-0.087	-0.0643	-0.8017	-0.0704	-0.123	-0.1077
Border Zone	-0.6808	0.3904	0.1586	-0.1951	-0.7221	0.5089	0.2241	-0.3267
Stream Zone	0.8397	-0.0812	-0.0005	-0.0067	0.8906	-0.1059	-0.0008	-0.0113

Table 23 - Detrended Canonical Correspondence Analysis (DCCA) for the Pitoco gallery forest: Matrix of weighted correlations between the species axis (SP) and environmental axis (EN) and the environmental variables.

Interpretation of the ordination axes can be made by using :

a - The correlations between the species and the environmental axes as a measure of their association which is found to be high between the environmental axis I and the species axes I (0.94) and II (0.76) (values given in bold).

b - The correlation coefficients between the environmental variables and the ordination axes (variable loadings) give significance to the axis interpretation. E.g. Elevation (-0.80) and Stream Zone (0.89) are the best correlated with the environmental axis I, while Border Zone (0.50) and Clay (-0.11) are the best correlated with axis II.

Relevant differences among the soil samples are stressed in previous chapters. Soil variables detected by the DCCA analysis to distinguish species and samples, are significantly different between the wet and dry communities and non-significantly different between both dry communities (dry-fringe and inner-dry) (see Chapter 7). Additionally, the PCA analysis extracted as contrasting variables in the soils of different communities high Al levels versus high base, Mn, pH and clay contents (see Chapter 8).

In Figure 41 b, samples are ordinated as a continuum along the axis, indicating that the sampling design covers the whole range of the environmental variation. It can also be clearly observed that the dry-fringe and the wet community samples are divided, forming distinguishable groups at either end of the environmental gradient provided by axis I. The dry-inner community samples are situated between the extreme groups.

In Figure 41 c there is a clear definition of groups of species related to the dry and wet communities, which are ordinated at the end points of axis I. At the dry end species such as *Eriotheca pubescens, Guettarda viburnioides, Lamanonia ternata, Pera glabrata* and *Platypodium elegans* seem to avoid soil saturation, at least in the superficial soil layer, and are able to establish their largest basal areas in the drier, Mg-, Mn- and clay-rich soils. Species of this group seem to possess another common characteristic in demanding higher light intensity, which is reported as an important aspect in defining the forest border communities (Kellman & Tackaberry 1993). *Eriotheca pubescens, Pera glabrata* and *Platypodium elegans* can also be found colonising the cerrado open communities, while *Callisthene major* and *Lamanonia ternata* are frequently recorded as tall and large trees with full crowns at the border sites.

The species typical of the wet community, *Emmotum nitens, Licania apetala, Ocotea aciphylla, Pseudolmedia guaranitica* and *Virola sebifera* are suggested as performing better at the wettest, most acid and P-, OM-, and Al- rich soils as indicated by their greatest diameter growth. They could also be regarded as species able to survive seasonal soil saturation, since *Licania apetala* and *Pseudolmedia guaranitica* are well known moist sites colonisers. However, the presence of *Emmotum nitens* and *Virola sebifera*, commonly recorded in cerradão (dense and tall cerrado woodland), would indicate drier soil conditions and higher light availability. The paradox of their occurrence here may be partially explained by the site characteristics, as Pitoco is the driest of the galleries as a result of steeper topography, and these species are presumably finding 'subsites' appropriate for their needs (see Chapter 5).

Pitoco's inner-dry community related species show two tendencies. A group of species including *Bauhinia rufa, Copaifera langsdorffii, Faramea cyanea, Jacaranda puberula* and *Matayba guianensis* are ordinated closer to the dry-border community, while *Inga alba,* is closer to the wet community group of species.

A number of species are not considered as related to any community. They are ordinated towards the middle of the axis, showing their largest basal area at the more intermediate conditions of the environmental gradient. However, trends are still observable, for instance species such as *Byrsonima laxiflora, Cupania vernalis, Myrcia rostrata* and *Siphoneugena densiflora* are ordinated closer to the group of dry community species. In contrast, *Cheiloclinium cognatum, Cryptocarya aschersoniana, Ocotea spixiana, Schefflera morototoni, Xylopia emarginata* and *Xylopia sericea* tend to be more closely associated with the wet community species. Finally, species which are recorded as widely dispersed among the communities, such as *Maprounea guianensis, Ocotea spixiana, Sclerolobium paniculatum* var. *rubiginosum, Symplocos mosenii* and *Tapura amazonica,* seem to be best adapted to intermediate positions of the axis I gradient.

A topographical-moisture gradient from the stream margin to the forest-cerrado border is found in the Pitoco analysis. The analysis strongly suggests that species related to the wet community occur preferentially in the very acid, Al-, Fe and OM-richer soils of the stream margins. On the other hand, species related to the dry communities are closely connected to the Mn-, Mg- and clay-richer soils of the forest-cerrado edge. These differences in soil chemical and textural variations are strongly correlated with the variations in tree community structure.

9.3.2 - The Monjolo gallery forest.

The results of the DCCA are shown in the three ordination diagrams of Figure 42. Table 24 presents the weighted correlations among the environmental variables and the environmental axes which resulted in eigenvalues for the axes of 0.425, 0.165, 0.066 and 0.048 respectively. The cumulative percentages of variance for the species data accounted for by the axes are 9.4, 13.0, 14.5 and 15.5 % respectively. The variance accounted for the species-environmental relationships are 42.5, 61.8, 70.1 and 76.1 % and the sum of all canonical eigenvalues is 1.026. The scores of axes III and IV are not discussed further because they account for only a small amount of the species basal area variation. The amount of variance explained by the environmental variables is an indication of the inherent complexity of species-environmental relationships in nature. A number of other physical, biological and historical variables, not measured in the present study, may have influenced the species basal area variation among sites within the Monjolo gallery forest.

The Monte Carlo test run for the first two axes, indicated that the intersite variations of species basal area are significantly ($P \leq 0.01$) related to the variations of environmental variables studied.

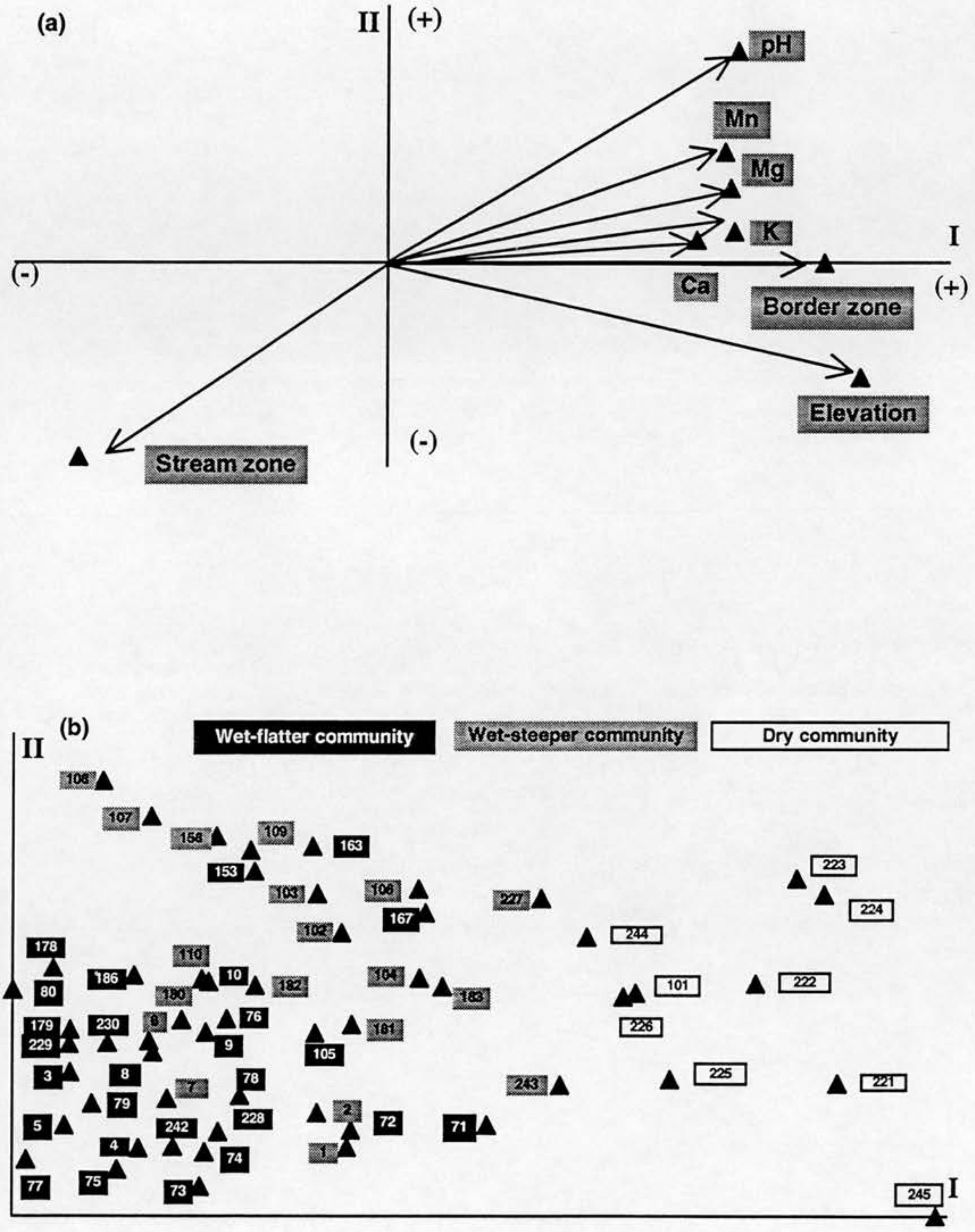
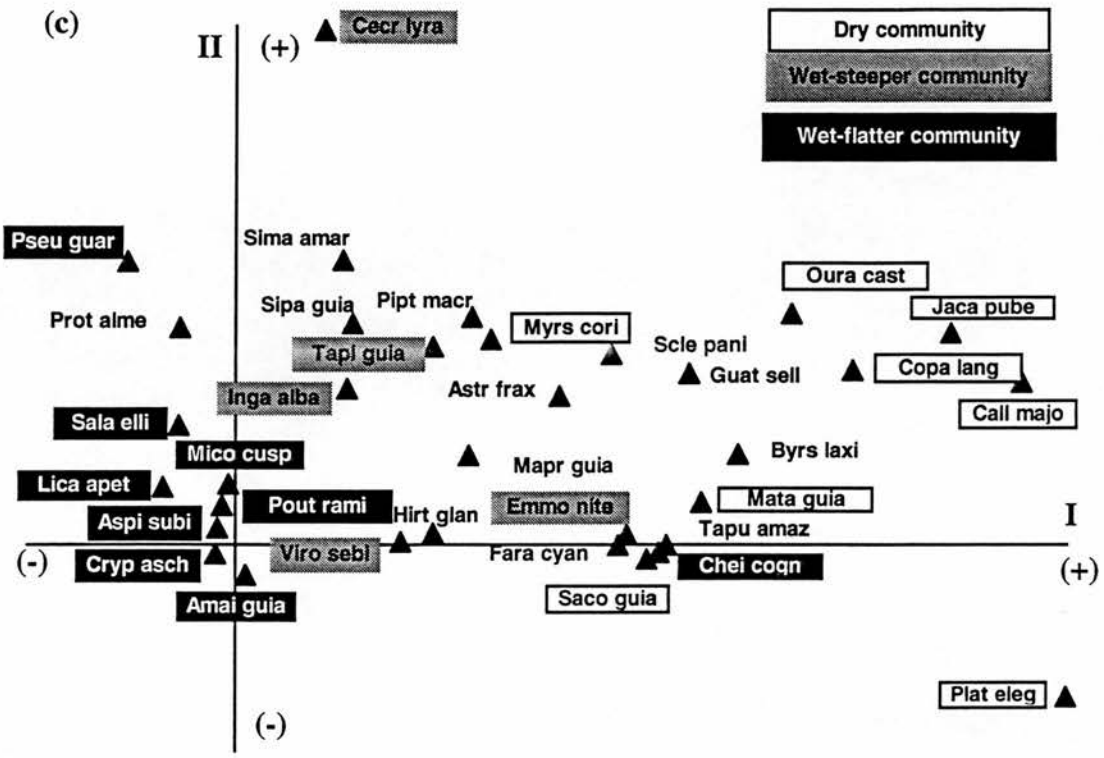


Figure 42 a, b and c - Ordination yielded by Detrended Correspondence Canonical Analysis (DCCA) based on the basal area of trees ≥ 5cm DBH of 33 species represented by ≥ 10 individuals in the Monjolo gallery forest. Species are identified by abbreviations (full names in table 27) and samples are identified by numbers.

Figure 42 c - cont...



The diagrams show:

(a)- Axis I and II which represent linear combinations of the environmental variables selected in the analysis, by showing the highest correlations which are displayed in Table 24. These environmental variables maximise the dispersion of the species scores represented in diagram (c). Each arrow can be interpreted as an axis that represents the variation of each variable. The arrows points in the direction of maximum correlation. The longest arrows represent the variables 'Stream Zone', Elevation, 'Border Zone' and pH variables most strongly correlated with the ordination axes, and therefore most closely related to the pattern of variation in samples and species shown ordination diagram (b) and (c). Thus, axis I and II in the diagram define an ordination space representing a topographic-moisture and chemical-textural gradient as a consequence of the correlations between the environmental variables and the axis.

(b)- Sample ordination which arranges site points in a continuum, where points which are closer correspond to sites that are similar in species composition, and points which are far apart correspond to sites which are dissimilar. The projection of the sample points on to the arrows of diagram (a) represents the main relationship between samples and each of the environmental variables. Samples are labelled with their respective community classification provided by TWINSPAN to allow visual interpretation of the relationships.

(c)- Species ordination showing position along the environmental axes. The position of the species if superimposed on diagram (a) would represent the main relationships between species and each of the environmental variables. Species are coloured to show their community classification provided by TWINSPAN.

	SP AX1	SP AX2	SP AX3	SP AX4	EN AX1	EN AX2	EN AX3	EN AX4
SP AX1	1.00							
SP AX2	0.1679	1.00						
SP AX3	0.0614	0.0579	1.00					
SP AX4	0.0393	-0.0221	0.3775	1.00				
EN AX1	0.8855	0.1423	0.0443	0.0222	1.00			
EN AX2	0.1699	0.7415	0.0297	-0.0995	0.1919	1.00		
EN AX3	0.0717	0.0403	0.5474	0.0375	0.081	0.0543	1.00	
EN AX4	0.0382	-0.1436	0.04	0.5138	0.0432	-0.1936	0.073	1.00
pH	0.6471	0.4427	-0.1654	0.044	0.7308	0.597	-0.3022	0.0857
Ca	0.5479	0.1088	-0.1958	-0.0435	0.6187	0.1467	-0.3577	-0.0848
Mg	0.6147	0.2061	-0.1171	-0.0667	0.6942	0.278	-0.214	-0.1299
K	0.6162	0.1315	-0.198	-0.0451	0.6959	0.1774	-0.3617	-0.0878
Mn	0.6103	0.2671	-0.1813	-0.2565	0.6892	0.3602	-0.3312	-0.4993
Elevation	0.8193	-0.0903	0.0055	0.0117	0.9253	-0.1218	0.01	0.0228
Border Zone	0.7723	0.0978	0.0375	0.0131	0.8722	0.1318	0.0686	0.0256
Stream Zone	-0.5764	-0.4045	-0.2342	0.1481	-0.651	-0.5455	-0.4279	0.2883

Table 24 - Detrended Canonical Correspondence Analysis (DCCA) for the Monjolo gallery forest: Matrix of weighted correlations between the species axis (SP) and environmental axis (EN) and the environmental variables.

Interpretation of the ordination axes can be made by using :

a - The correlations between the species and the environmental axes as a measure of their association which is found to be high between the environmental axis I and the species axes I (0.88) and II (0.74)

b - The correlation coefficients between the environmental variables and and the ordination axes (variable loadings) give significance to the axis interpretation. E.g. Elevation (0.92) and Stream Zone (-0.65)are the best correlated with the environmental axis I, while pH (0.59) and Stream zone (-0.54) are the best correlated with axis II.

9.3.2.1. - Environmental gradients.

Among the environmental variables, higher elevation and 'Border zone' (nominal variable), (both indicating better drained soils) higher pH, K, Mg, Mn and Ca are strongly and positively correlated with environmental axis I. At the other end of the axis, only the nominal variable 'Stream zone' has a high loading. Environmental axis II has in general much lower correlations with the environmental variables. Only pH and 'Stream zone' show positive and negative correlations respectively, and give meaning to axis interpretation. Figure 42 a shows axes I and II and their relations with the environmental variables.

The axes define an ordination space which is interpreted as representing a topographic-moisture gradient, interconnected with a prominent soil chemical and textural gradient, ranging from the Monjolo stream margins towards the higher sites of the forest-cerrado border.

Figure 42 b shows that samples are ordinated as a continuum along both axes, indicating that the sampling design recorded data over the whole range of the environmental gradient. There is also a distinct positioning among the wet and dry communities along the axis. The wet community samples are found related with the very acid soils under stronger high water-table influence, while the dry community samples form a more isolated group correlated to the highest pH, Mn and levels of exchangeable bases. Axis II provides the distinction between both wet communities. The majority of the wet-steeper community samples are found related to drier and less acid soils than those associated with the wet-flatter community.

In support of these conclusions comparisons made in Chapter 7 show differences between the dry and wet flatter and steeper communities for the majority of the factors considered here, while few differences are detected between the wet community soils. Furthermore, in Chapter 8, the ordination of soil variables indicates high Al levels versus high pH, base, Mn and Zn levels as the most important factors separating the soils of the communities .

Figure 42 c shows clear grouping of the wet and dry communities species along the ordination axes. The wet-flatter community species apparently have the ability to exploit resources from wet, very acid and dystrophic soils. Among these, *Miconia cuspidata* and *Pseudolmedia guaranitica* are frequently recorded colonising the moist sites in the RECOR galleries. Although *Amaioua guianensis, Cryptocarya aschersoniana, Hirtella glandulosa, Licania apetala, Pouteria ramiflora, Salacia elliptica* and *Virola sebifera* are widespread in the Gama gallery forest in the neighbouring Fazenda Água Limpa Reserve (Felfili 1993), they are restricted in Monjolo to the wettest sites and it would be interesting to study their ability to cope with soil saturation. Within this group, *Pseudolmedia guaranitica* is separated along axis II. This community is characteristic of the poorest and wettest soils within Monjolo.

Species related to the wet-steeper community included *Cecropia lyratiloba, Emmotum nitens* and *Virola sebifera* which are also regarded as light demanding. Felfili (1993) found that these species preferred the naturally disturbed sites such as gaps and forest-border areas subjected to fire. In fact *Cecropia lyratiloba* is a fast growing pioneer species and the other two are commonly recorded in the more open formations of cerradão. Additionally, their distinct positioning along axis II (Figure 42 c) suggests the pioneer species *C. lyratiloba* is able to show better diameter grow in the less acid soils while *E. nitens* and *V. sebifera* are located on the wetter and very acid soils. *Tapirira guianensis* has a very wide distribution throughout Brazil and has been always recorded with continuous distribution in the gallery forests in the central region (Silva 1991, Felfili & Silva Júnior 1992, Schiavinni 1992, Felfili 1993). At Monjolo it seems that the intermediate soil moisture conditions and dystrophic soils typical of the wet steeper community provides its best habitat.

Among the species related to the Monjolo dry community *Callisthene major* is well known as forest border species which advances into the cerrado creating conditions for establishment of other gallery species. Moreover it is an Al-accumulator species adapted to dystrophic soil conditions (Dr. M. Haridasan, personal communication). *Copaifera langsdorffii* has been recorded in many wood formations but it is indicated as preferring galleries where it is abundant in non-saturated (Machado 1990) and dystrophic soil (Silva 1991). The dystrophic character of the soils of the community (see Chapter 7) and the ecological preferences of its characteristic species seem to indicate that free drainage and good aeration, at least in the superficial soil layers, are key factors controlling the species establishment and growth. This is illustrated in the picture of the soil profile 4 (in the appendix) related to the Monjolo's dry community.

It is important to consider less common species such as *Simarouba versicolor* and *Siparuna guianensis* which are ordinated at the moist but less acid portion of the gradient, while *Maprounea guianensis* and *Hirtella glandulosa* are found on moist but very acid soils. On the other hand, *Sclerolobium paniculatum* var. *rubiginosum* and *Guatteria sellowiana* are ordinated closer to dry and richer soil. *Byrsonima laxiflora, Faramea cyanea* and *Tapura amazonica* are characteristically on drier and more acid soils within the site. Species found at intermediate portion of the gradient are *Astronium fraxinifolium, Myrsine coriacea* and *Piptocarpha macropoda.*

The great majority of the Monjolo's sampling points are classified as wet. Only when there is steep topography is the dry community recorded (see Chapter 5). The widespread presence of the grass *Olyra latifolia* is also an indication of seasonally humid soils. Most soils are characterised as dystrophic, with K levels 30% lower than those found in the other galleries. Not surprisingly, K is selected among the variables with the highest loadings on the environmental axes and clearly should be included in any further investigation of mineral nutrition of Monjolo's tree species.

In the Monjolo analysis, it is found that the topographical-moisture gradient, from the stream margin to the forest-cerrado border, is closely connected to differences in soil chemical variations. Species related to the wet communities are apparently indifferent to the sites very poor soils, since the proximity to the stream margins ('Stream Zone' effect), is the only environmental variable selected in the analysis. The dry community species seems to need soils of higher fertility (Ca-, Mg- , K- and Mn-richer), higher pH and freedom from high water-table influence at least in the superficial layers (up to 1 m depth).

9.3.3 - The Taquara gallery forest.

The results of the DCCA are shown in the ordination diagrams in Figure 43. Table 25 shows the weighted correlations among the environmental variables and the species and environmental axes. These correlations resulted in eigenvalues for the axis of 0.378, 0.100, 0.056 and 0.039 respectively. The cumulative percentage of variance accounted for by the axis are 8.2, 10.4, 11.6 and 12.4% for species data and 43.0, 56.6, 65.0 and 70.1 % for the species-environmental relationships and the sum of all canonical eigenvalues is 0.890. Axes III and IV account only for a small amount of the total variance and are not considered further here. These results indicate that variables supplied to the analysis explained most of the species basal area variation among sites. Additionally, the Monte Carlo test, run for the first two axes, indicates that the species basal area variation is significantly ($p \leq 0.01$) related to the environmental intersite variation.

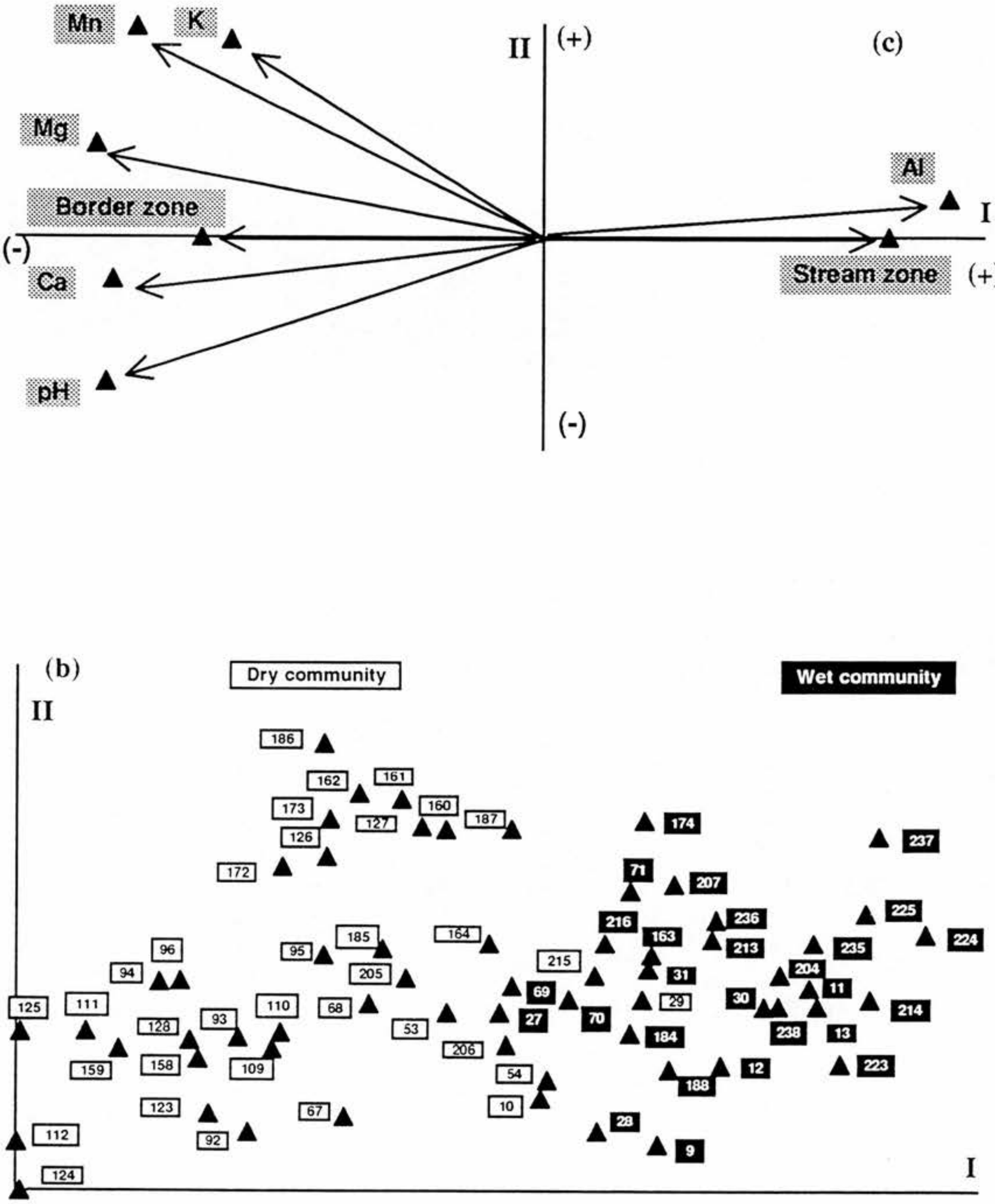
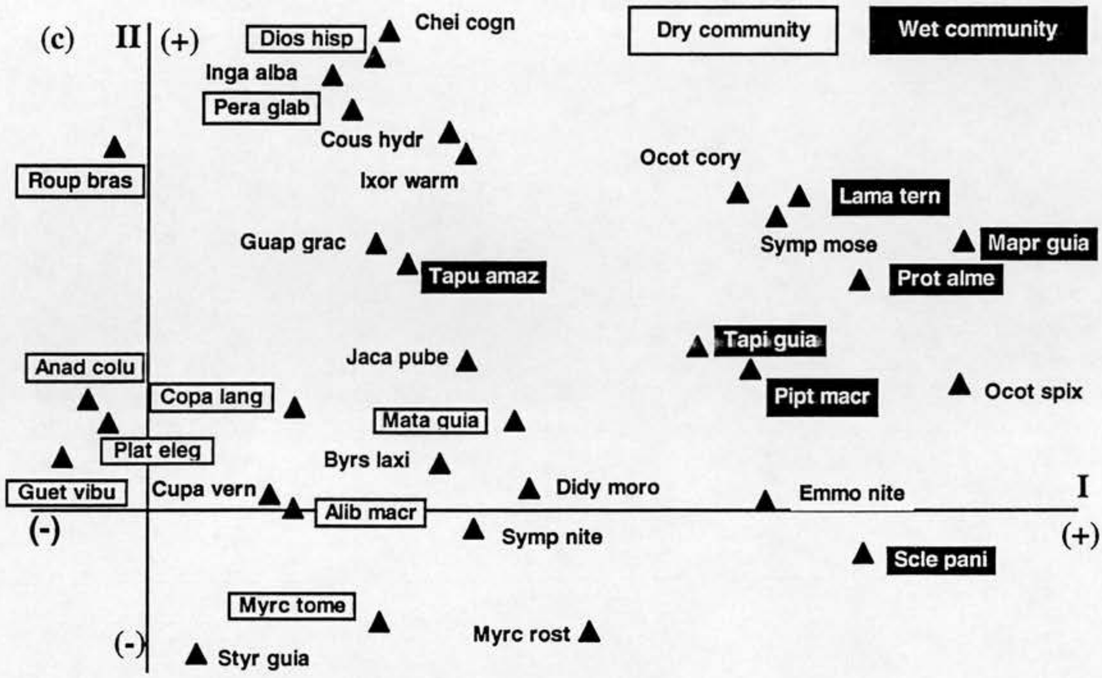


Figure 43 a, b and c - Ordination yielded by Detrended Correspondence Canonical Analysis (DCCA) based on the basal area of trees ≥ 5cm DBH of 34 species represented by ≥ 10 individuals in the Taquara gallery forest. Species are identified by abbreviations (full names in Table 27) and samples are identified by numbers.

Figure 43 c - cont...



The diagrams show:

(a)- Axis I and II which represent linear combinations of the environmental variables selected in the analysis, by showing the highest correlations which are displayed in Table 25. These environmental variables maximise the dispersion of the species scores represented in diagram (c). Each arrow can be interpreted as an axis that represents the variation of each variable. The arrows points in the direction of maximum correlation. The longest arrows represent the pH, Mg and Al variables most strongly correlated with the ordination axes, and therefore most closely related to the pattern of variation in samples and species composition shown in the species and samples ordination in diagrams (b) and (c). Thus, axis I and II in the diagram define an ordination space representing a topographic-moisture and chemical-textural gradient as a consequence of the correlations between the environmental variables and the axis.

(b)- Sample ordination which arranges site points in a continuum, where points which are closer correspond to sites that are similar in species composition, and points which are far apart correspond to sites which are dissimilar. The projection of the sample points on to the arrows of diagram (a) represents the main relationship between samples and each of the environmental variables. Samples are labelled with their respective community classification provided by TWINSPAN to allow visual interpretation of the relationships.

(c)- Species ordination showing position along the environmental axes. The position of the species if superimposed on diagram (a) would represent the main relationships between species and each of the environmental variables. Species are coloured to show their community classification provided by TWINSPAN.

	SP AX1	SP AX2	SP AX3	SP AX4	EN AX1	EN AX2	EN AX3	EN AX4
SP AX1	1							
SP AX2	0.1518	1						
SP AX3	0.1209	-0.0645	1					
SP AX4	0.1296	0.0811	-0.1684	1				
EN AX1	0.8883	0.1364	0.0579	0.0455	1			
EN AX2	0.1628	0.7444	-0.0229	0.0515	0.1833	1		
EN AX3	0.0754	-0.025	0.6817	-0.0995	0.0849	-0.0335	1	
EN AX4	0.0712	0.0676	-0.1196	0.5674	0.0802	0.0908	-0.1754	1
pH	-0.8087	-0.3162	-0.0041	-0.0115	-0.9104	-0.4247	-0.006	-0.0203
Al	0.7361	0.1596	-0.0563	0.1885	0.8286	0.2143	-0.0826	0.3322
Ca	-0.7878	-0.1726	0.0489	-0.0494	-0.8869	-0.2319	0.0718	-0.087
Mg	-0.8036	0.0115	-0.1443	0.1484	-0.9047	0.0155	-0.2117	0.2615
K	-0.5526	0.19	-0.3718	-0.0206	-0.6221	0.2552	-0.5454	-0.0362
Mn	-0.721	0.1827	0.1738	0.0465	-0.8116	0.2455	0.255	0.0819
Stream Zone	0.6219	0.09	0.1622	0.0468	0.7	0.121	0.238	0.0824
Border Zone	-0.6219	-0.09	-0.1622	-0.0468	-0.7	-0.121	-0.238	-0.0824

Table 25 - Detrended Canonical Correspondence Analysis (DCCA) for the Taquara gallery forest: Matrix of weighted correlations between the species axis (SP) and environmental axis (EN) and the environmental variables.

Interpretation of the ordination axes can be made by using :

a - The correlations between the species and the environmental axes as a measure of their association, which is found to be high between the environmental axis I and the species axes I (0.88) and II (0.74)

b - The correlation coefficients between the environmental variables and and the ordination axes (variable loadings) give significance to the axis interpretation. E.g. pH (-0.91) and Al (0.82) are the best correlated with the environmental axis I, while pH (-0.42) and K (0.25) are the best correlated with axis II.

9.3.3.1.- Environmental gradients.

Figure 43 a shows the environmental variables which had the highest loadings to axes I and II. The first ordination axis shows a strong negative correlation with pH, Mg, Ca, Mn, K and the nominal variable 'Border zone' (little high water-table influence). Al levels and the nominal variable 'Stream zone' (high water-table influence) have a strong positive correlation with this axis. Axis II has much lower correlations with the environmental variables, where the highest is pH ($r = -0.42$). For the first time in the analysis elevation is not selected among the variables with the highest loadings. In fact Taquara, amongst the three galleries, is characterised as the flattest site with a stream flowing along a deep stream bed, indicating a deep water-table. Table 25 presents the weighted correlation between the environmental variables and both the species and environmental axis.

Interpretation of these results suggests that axis I (Figure 43 a) represents a soil chemical gradient associated with a slight topographic variation, ranging from the Taquara stream margins to the forest-cerrado border.

Taquara's soil characterisation (see Chapter 7) shows significant differences between the dry and wet communities. In fact only total acidity, P, Cu and silt contents are found at similar levels in both group of soils. In Chapter 8 the ordination of the soil variables extracts soil bases, OM, Mn and pH of the dry community soils and Al and clay-rich of the wet community soils as the most important differentiating factors.

Figure 43 b shows that samples are ordinated as a continuum along the axes, and this suggests that the sampling system covers the whole range of the environmental changes along the gradient. It also shows that samples of both communities are clearly separated. Taquara's dry community samples are associated with the drier, less acid, base- and Mn- rich soils, while the wet community samples are associated with the wettest and Al-rich soils. Samples of both communities range along the axis II gradient indicating a wide variation in their soil pH.

Figure 43 c shows species ordination where those found as preferential to any community (see Chapter 5) are labelled. The dry-community species are separated in two groups by axis II, reflecting the presence of patches of both dystrophic and mesotrophic (calcium-rich) soils. Around the axis origin there are *Anadenanthera colubrina* var. *cebil, Copaifera langsdorffii, Guettarda viburnioides, Platypodium elegans* and *Alibertia macrophylla.* The first of this list is well known as an indicator Ca-rich soils. The highest pH levels indicated by the analysis are closely related to the highest Ca levels measured. The second in the group, *C. langsdorffii*, is a widely distributed species in Brazil. Machado (1990) and Silva (1991) found it abundant in the drier and dystrophic soils, of the Federal District. Machado (1990) studied the species from different provenances and concluded that the gallery forests seedlings grew better in the dystrophic soils of the galleries rather than in mesotrophic soils. In Taquara the well drained soils of the border may have provided the best environment for growth despite the high Ca levels. The relationship of this species with environmental factors and particularly mineral nutrition require attention.

The other dry-community group includes *Diospyros hispida, Pera glabrata* and *Roupala montana,* showing higher correlations with more acid soils. *Pera glabrata* shows a consistent performance (as also in the Pitoco analysis) correlated with the dry and dystrophic soils of the forest-cerrado border. Species not selected as preferential to the dry community which perform similarly are *Inga alba, Ixora warmingii, Cheiloclinium cognatum* and *Coussarea hydrangeifolia.*

Species classified as preferential to the wet community include *Tapura amazonica*, ordinated apart from the main group in an intermediate position along axis I gradient. Axis II separates *Sclerolobium paniculatum* var. *rubiginosum,* apparently able to establish larger trees on the moist and less acid soils. A closer group is formed by *Lamanonia ternata, Maprounea guianensis, Piptocarpha macropoda, Protium almecega* and *Tapirira guianensis*. Among these, *T. guianensis* and *M. guianensis* are abundant in the central Brazilian gallery forests and are ordinated at the intermediate portion of the Pitoco and Monjolo gradients. *L. ternata* is related to Pitoco's dry community. *P. almecega* is the only species in the group well known as an indicator of soil saturation, but other species of very wet gallery soils such as *Pseudolmedia guaranitica, Miconia cuspidata* and *Licania apetala* are notably absent. These results indicate that Taquara's wet community is drier than the wet communities of Pitoco and Monjolo's.

Some other species occupy intermediate position along the axis I gradient, e.g. *Tapura amazonica, Myrcia rostrata, Symplocos nitens, Schefflera morototoni* and *Guapira graciliflora.*

In this analysis it is found that the topographical-moisture gradient, from the stream margin to the forest-cerrado border, is closely connected to differences in soil chemical and textural variations which correspond to a great extent to variations in the tree community structure.

Species related to the wet communities seem to prefer the Al-rich sites under high water-table influence, since Al and the 'Stream Zone' effect, are the only environmental variables selected in the analysis. The dry community species apparently show preference for sites of higher fertility (Ca-, Mg- , K- and Mn-richer), less acid (pH) at the forest-cerrado boundary.

9.3.4 - The Pitoco, Monjolo and Taquara gallery forests: a joint analysis.

Two matrices of data on the basal areas of species and environmental variables (soil and topography) of the gallery forests were built for a joint analysis.

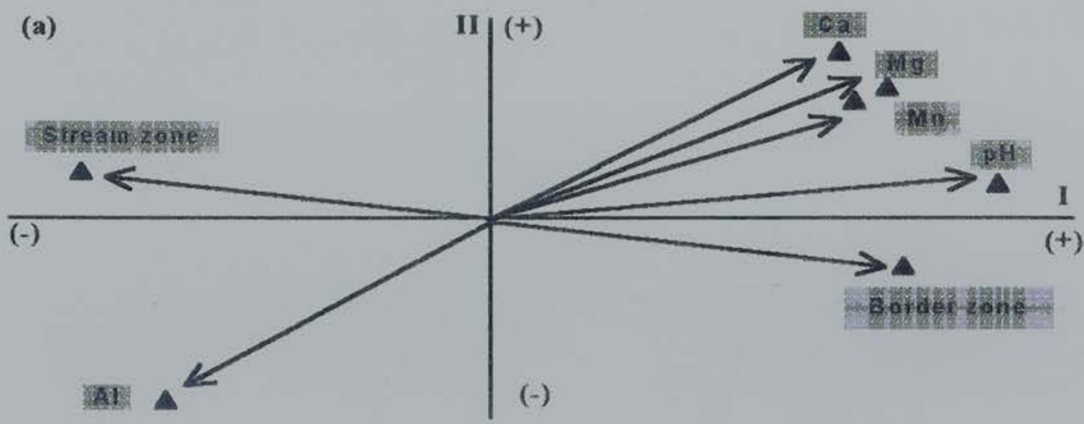
The results of the DCCA are shown in Figure 44. The weighted correlations among the environmental variables and the environmental and species axes are presented in Table 26. These correlations resulted in eigenvalues for the axes of 0.478, 0.108, 0.080 and 0.046 respectively. The cumulative percentages of variance accounted for by the axes are respectively 5.9, 7.2, 8.2 and 8.7 % for species data and 46.6, 63.1, 73.6 and 78.6 % for species-environmental relationships. The results show that the environmental variables supplied are sufficient to explain most of the species basal area variations. The Monte Carlo test indicates that intersite variations of species and environmental attributes are significantly ($p \leq 0.01$) related.

9.3.4.1.- Environmental gradients.

Figure 44 a shows the variables with the highest loadings on the axes. Axis I is strongly and positively correlated with the environmental variables pH, Mg, the nominal variable 'Border zone' (lower high water-table influence) and Mn. At the other end of the axis only 'Stream zone' (greater high water-table influence) is negatively correlated. Axis II is strongly and positively correlated with Ca and negatively with Al levels. Table 26 shows the weighted correlation between the environmental variables and both the species and environmental axis.

Among the soil variables selected in the analysis, pH is significantly different amongst the gallery soils, while Al, Ca, Mg, and Mn occur with similar levels in the Pitoco and Monjolo soils and at significantly higher levels in those of the Taquara.

Interpretation of these results indicates axis I as representing an environmental gradient ranging from the wettest soils around the Monjolo's stream margins towards the drier, less acid and Ca-, Mg- and Mn-richer soils of the forest-cerrado borders in the Taquara gallery. Axis II is indicated as a gradient between the Al-rich and the Ca-rich soils.



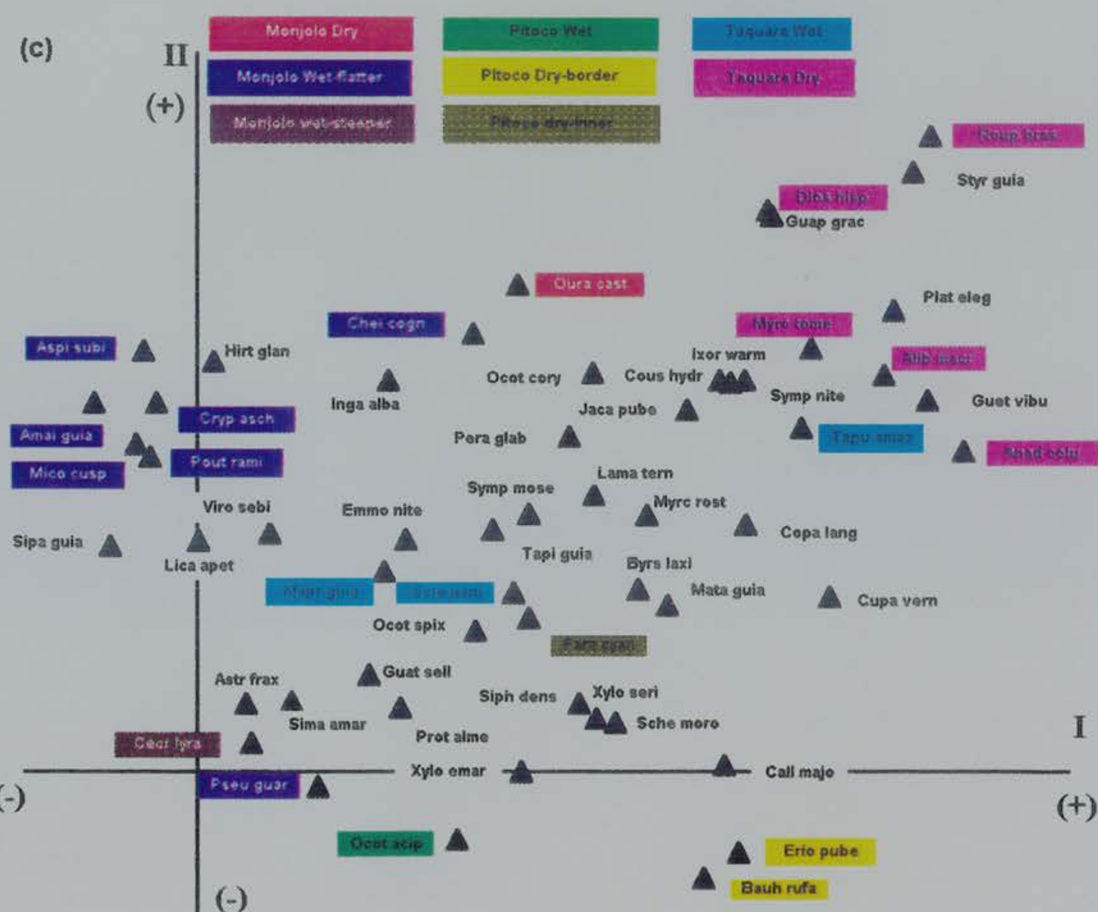


Figure 44 a, b and c - Ordination yielded by Detrended Correspondence Canonical Analysis (DCCA) based on the basal area of trees ≥ 5cm DBH of 33 species surveyed with more than 10 individuals in the Pitoco, Monjolo and Taquara gallery forests. Species are identified by their abbreviated names (full names in table 27) and samples are identified by their correspondent number.


(b)
II
I
Monjolo wet -flatter
Monjolo wet -steeper
Monjolo dry
Pitoco wet
Pitoco dry -border
Pitoco dry-inner
Taquara wet
Taquara dry

The diagrams show:

(a)- Axis I and II which represent linear combinations of the environmental variables selected in the analysis, by showing the highest correlations which are displayed in Table 26. These environmental variables maximise the dispersion of the species scores represented in diagram (c). Each arrow can be interpreted as an axis that represents the variation of each variable. The arrows points in the direction of maximum correlation. The longest arrows represent the 'Stream Zone, Al, pH and 'Border Zone' variables most strongly correlated with the ordination axes, and therefore most closely related to the pattern of variation in samples and species composition shown in the species and samples ordination in diagrams (b) and (c). Thus, axis I and II in the diagram define an ordination space representing a topographic-moisture and chemical-textural gradient as a consequence of the correlations between the environmental variables and the axis.

(b)- Sample ordination which arranges site points in a continuum, where points which are closer correspond to sites that are similar in species composition, and points which are far apart correspond to sites which are dissimilar. The projection of the sample points on to the arrows of diagram (a) represents the main relationship between samples and each of the environmental variables. Samples are labelled with their respective community classification provided by TWINSPAN to allow visual interpretation of the relationships.

(c)- Species ordination showing position along the environmental axes. The position of the species if superimposed on diagram (a) would represent the main relationships between species and each of the environmental variables. Species are coloured to show their community classification provided by TWINSPAN.

	SP AX1	SP AX2	SP AX3	SP AX4	EN AX1	EN AX2	EN AX3	EN AX4
SP AX1	1.00							
SP AX2	0.1876	1.00						
SP AX3	-0.0156	0.1281	1.00					
SP AX4	0.0706	0.0124	0.2596	1.00				
EN AX1	0.8674	0.1567	-0.0743	0.0585	1.00			
EN AX2	0.1959	0.6938	-0.0206	-0.0302	0.2259	1.00		
EN AX3	-0.1014	-0.0225	0.6352	0.1137	-0.1169	-0.0324	1.00	
EN AX4	0.1038	-0.0429	0.1479	0.4884	0.1197	-0.0618	0.2328	1.00
pH	0.8109	0.2185	0.1182	0.094	0.9349	0.3149	0.1861	0.1925
Al	-0.5605	-0.5156	0.0803	0.0449	-0.6462	-0.7431	0.1264	0.092
Ca	0.5908	0.4876	0.0719	0.0364	0.6811	0.7028	0.1132	0.0745
Mg	0.6576	0.4147	-0.003	0.2414	0.7582	0.5977	-0.0046	0.4943
Mn	0.6036	0.3751	-0.1437	0.1885	0.6959	0.5407	-0.2263	0.3859
Border Zone	0.6422	-0.0008	-0.4316	-0.0288	0.7404	-0.0012	-0.6794	-0.059
Stream Zone	-0.6422	0.0008	0.4316	0.0288	-0.7404	0.0012	0.6794	0.059

Table 26 - Detrended Canonical Correspondence Analysis (DCCA) for the Pitoco, Monjolo and Taquara gallery forests (joint analysis): Matrix of weighted correlations between the species axis (SP) and environmental axis (EN) and the environmental variables.

Interpretation of the ordination axes can be made by using :

a - The correlations between the species and the environmental axes are a measure of their association. which is found to be high between the environmental axis I and the species axes I (0.86) and II (0.69)

b - The correlation coefficients between the environmental variables and and the ordination axes (variable loadings) give significance to the axis interpretation. E.g. pH (0.93) and Stream Zone (-0.74) are the best correlated with the environmental axis I, while Al (-0.74) and Ca (0.70) are the best correlated with axis II.

The ordination space defined by the axes shows samples related to the gallery communities clearly forming groups (Figure 44 b). The gradient has the Monjolo wet-flatter samples, correlated with the wettest and Ca-richer soils, and the Taquara dry community samples, correlated with dry, the less acid but base- and Mn- rich soils at either end of axis I. The other communities are positioned between these two extremes. A comparative analysis suggests:

1) - Among the wet communities, Monjolo's samples are correlated with the wettest sites while Taquara's are at the other extreme, over drier, less acid Mg- and Mn-richer soils. Pitoco's samples are found in an intermediate position in this gradient. Axis II gradient distinguishes Monjolo's and Taquara's which are positively correlated with higher Ca levels, from the Pitoco samples which are positively correlated with the highest Al levels.

2) - Among the dry communities, Taquara's samples are positively correlated with the highest Mg, Mn and pH levels. Monjolo's samples have a wide range of scores along axis I. Pitoco displayed a stronger correlation with the border effect probably related to the driest soil conditions. The gradient shown by axis II indicates that both Taquara's and Monjolo's dry communities correlate with higher Ca levels, while Pitoco's samples correlate with higher Al levels.

9.4.4.2.- Species performance.

The species ordination in Figure 44 c shows a group of 11 species at the left hand side of the diagram which occur in the moist and Ca-richer soils. The strong correlation with Ca is interesting since most of the values in these soils are at comparatively low levels (see Chapter 7). The majority of species are classified as preferential to the Monjolo wet-flatter community. Within this group *Cheiloclinium cognatum, Inga alba, Miconia cuspidata* and *Hirtella glandulosa* are regarded as indicators of soils in which seasonal saturation occurs. *Aspidosperma subincanum, Amaioua guianensis* and *Cryptocarya aschersoniana* maintain the same strong correlation in the combined analysis as found in the Monjolo's separate analysis, stressing preference for moist soil conditions. *Pouteria ramiflora* and *Virola sebifera* are also recorded in the more open cerrado and cerradão communities found exclusively over deep and well drained soils. This indicates their ability to cope with a wide variation of soil moisture regimes.

Supporting evidence for the present results is provided by Silva (1991) who reported on the nutritional status of many tree species in the Federal District gallery forests. Their leaf nutrient levels were regarded as indicative of their relative ability to exploit soil resources. Species from the above group showed lower levels of Ca, Mg, P and K than the forest's average levels and of them only *Miconia cuspidata* was an Al-accumulator. Referring back to Monjolo's individual analysis (Figure 44 a), the 'Stream Zone' is extracted as the only variable positively correlated with the wet community samples, indicating that species are apparently indifferent to soil nutrient levels.

Clustered around the origin of the axis of the Figure 44 c, are *Astronium fraxinifolium, Cecropia lyratiloba, Guatteria sellowiana* (*), *Ocotea aciphylla, Protium almecega* (*), *Pseudolmedia guaranitica* (*), *Simarouba versicolor* and *Xylopia emarginata* (*). These species are apparently able to exploit resources better from the wettest and Al-richest soils in the galleries. Such moist and Al-rich soils are common around the stream margins in the gallery forests of the Federal District. From the above list, species marked with an asterisk, are well known indicators of soils under seasonal saturation (Ratter 1986, Felfili & Silva Júnior 1992, Schiavinni 1992, Felfili 1993) and are here suggested as also related to high soil Al levels.

Leaf analyses for most species in this group demonstrate a clear Al accumulator character (Silva 1991). Furthermore, *Protium almecega* and

Pseudolmedia guaranitica are found with K, Ca and Mg contents below the average levels for the forests. This suggests their ability to grow on dystrophic and Al-rich soils subjected to seasonal saturation regime.

It is worth mentioning that *Pseudolmedia guaranitica, Guatteria sellowiana* and *Protium almecega* had leaf levels of Mn at concentrations which would be toxic for cultivated plants (Silva 1991). The first two species were also regarded as Mn accumulators. Mn toxicity for cultivated plants is important and limits growth under acid soil conditions (Landon 1991). It would be interesting to investigate the strategy used by native species to avoid Mn toxicity.

At the other extreme of axis I are species related to the dry communities. They are divided in two main groups: the first includes *Callisthene major, Eriotheca pubescens* and *Bauhinia rufa* which are mainly related to Pitoco's dry-fringe community and well correlated with the driest soil sites among the galleries. The Pitoco dry-fringe community is distinguished from the Monjolo and Taquara dry communities by having stronger correlations with the highest Al levels (Axis II). None of the species in this group is included in the study of Silva (1990), who worked in the internal gallery sites. *Callisthene major* fits the results perfectly: it is an obligate Al-accumulator (Haridasan, personal communication) which is abundant on dystrophic soils but is rare in the Taquara dry community where the soils are richer and poor in Al.

The second group of species, related to the richer soils of the border and less acid soils, include *Anadenanthera colubrina* var. *cebil, Alibertia macrophylla* and *Myrcia tomentosa,* all exclusively related to Taquara's dry community, *Guettarda viburnioides* (Pitoco and Taquara), and *Platypodium elegans* (all dry communities). *Diospyros hispida, Guapira graciliflora, Roupala brasiliensis* and *Styrax guianensis* also in this group in the extreme of the diagram, are interpreted as rare species which occur by chance at these sites. In the above group, *A. colubrina* is a well known mesotrophic soil indicator and the others are always related to the frequently richer soils of the Pitoco and Monjolo border sites. Taquara's exclusive species may be closely related to Ca-rich soils and should be investigated as potential indicators of such soils.

There has been no research on the autecology of most of the gallery species and little on their relationships with environment. Figure 44 b, provides the ordination of many gallery species, from which information may be extracted following interpretation of the axes. In this group there are some of the most widespread species recorded in the galleries of Central Brazil (Brasil 1990, Silva 1991, Schiavini 1992, Felfili & Silva Júnior 1992, Felfili 1993, 1994, Ramos 1994, Oliveira-Filho & Ratter, (in press)) which should be discussed because of their phytosociological importance in the galleries in the Federal District:

• *Tapirira guianensis, Symplocos mosenii, Pera glabrata* and *Lamanonia ternata* form a group in the middle portion of the Figure 44 b. The species are classified as preferential to distinct communities, either wet or dry, in the three galleries (see Chapter 5), and in fact they are recorded over a wide range of environments. In the present analysis they are found performing better in dystrophic soils under intermediate moisture regimes. *Tapirira guianensis* has been recorded as common and includes some large individuals always giving the species a high phytosociological importance in the Federal District gallery forests. It is related to the wet communities of the three galleries and this is in agreement with Silva (1991) who reported its success within patches of Taquara's and Olho D'água's seasonally flooded galleries in the Federal District. Its leaf nutrient concentration was highlighted with the highest P, Ca and Mg levels displaying an exceptional ability to exploit soil resources even under dystrophic conditions. This probably allows its wide colonisation potential. Oliveira-Filho & Ratter (in press) indicated *T. guianensis* as having a 'jack-of-all-trades' character, which may be extended to the other species of this list. However, further research is required to define their environmental requirements.

• *Copaifera langsdorffii, Matayba guianensis, Cupania vernalis, Byrsonima laxiflora, Siphoneugena densiflora, Xylopia sericea* and *Schefflera morototoni* tend to be located towards the drier and Al-rich soils, mainly associated with Pitoco's dry community. The first species also occurs in cerrado (sensu stricto), cerradão and mesophytic forest in Central Brazil. The galleries are reported as its preferential habitat, where it is predominantly represented by large individuals (Machado 1990). Oliveira-Filho & Ratter (in press) suggested that it is one of the most frequently recorded species in the galleries of Central Brazil over a wide array of soil types. Machado (1990) suggested its intolerance to long term flooding and demonstrated that it showed better growth when cultivated in gallery forest dystrophic soils, rather than in mesotrophic soils from mesophytic forests where Ca levels were higher. Silva (1991) found that the species is a weak Al-accumulator. In this study *C. langsdorffii* is related to dry communities with dystrophic soils in both Pitoco and Monjolo and to similar communities with mesotrophic soils in Taquara. Its ability to colonise both dystrophic and mesotrophic drier soils probably accounts for its widespread distribution and success in Central Brazil. Of the other species, *Siphoneugena densiflora* is found abundantly and *Matayba guianensis* and *Cupania vernalis* also occur in dystrophic cerradão, demonstrating their ability to exploit the poorer, well drained soils.

• *Emmotum nitens, Maprounea guianensis, Sclerolobium paniculatum* var. *rubiginosum* and *Faramea cyanea* showed their best performance in moist and Al-rich soils, mostly recorded in the Pitoco wet community. The first three species are very frequently recorded in the galleries in Central Brazil and are also regarded as light-demanding (Felfili 1993, Oliveira-Filho & Ratter in press), while *Faramea cyanea* is a treelet adapted to shaded environments. The first two are frequently recorded in cerradão, indicating their capability to cope with a variety of soil moisture regimes.

• *Jacaranda puberula, Myrcia tomentosa* and *Tapura amazonica* form a group of two well known forest-cerrado border preferential species, while *T. amazonica* also occurs in cerradão vegetation. The present analysis suggests a tendency for them to be associated with the drier and base-richer soils associated mostly with Taquara's dry community.

• *Inga alba, Cheiloclinium cognatum* and *Virola sebifera* tend to occur in the wetter and Al-poor soils associated with Monjolo's wet community. The first two species are known as moist site colonisers (Schiavinni 1992, Felfili 1993, Oliveira-Filho et al. 1990, 1994) while *Virola sebifera* has been also recorded in the more open formation of the cerradão under well drained soils.

9.4.2 - Species growth strategies.

Environmental heterogeneity can be responsible for the coexistence of a large number of species within a small forest area (Crawley 1985). Although in the present study only spatial components of the environment are analysed (topography, water table influence and soil properties), vertical zonation in the canopy in response to light stratification may also promote a differential species distribution (Crawley 1985, Whitmore 1990). Disturbances resulting from tree fall also produce different light intensities within the forest and the frequency and distribution of gaps may account for the maintenance of some species, resulting in distinct spatial patterns (Swaine 1989). Within these gaps seed germination and seedling growth are crucial in determining the successional pattern after disturbance, which can have long term effects on the community dynamics (Gecy & Wilson 1990, Ribeiro 1991). This is a very neglected subject in studies of the gallery forests of Central Brazil. Felfili (1993) provided the only detailed study on the dynamics of gallery forest regeneration. She found a mosaic of areas at different stages of succession, from a closed canopy to new gaps where seedlings and pole density indicated future changes in the forest floristic composition.

An attempt is made in the present analysis to classify species by their growth strategy, based on field observations and previous work (Gandolfi 1991, Felfili 1993, Oliveira-Filho et al. 1994 a & b). This is presented in Table 27 which also lists species abbreviations and habitats.

Most of the species of the dry communities tend to be light-demanding, a growth strategy compatible with the observations of Furley & Ratter (1988) and Ratter (1980, 1992) on gallery forest expansion into the surrounding cerrado vegetation in Central Brazil. Felfili's (1993) results indicated that light-demanding trees were mainly associated with the natural disturbed patches (gaps) and forest-cerrado boundary sites. McDougall & Kellman (1993) found increased light levels moving from inside the galleries to the forest-savanna boundary and suggested this was an important factor explaining the spatial patterning within the forest.

Species of the wet communities and the intermediate portion of the gradient in Figure 44 b are classified as having both light-demanding and shade-tolerant strategies. Such non-pioneer characteristics, together with the very low number of pioneer species actually recorded (three only), emphasise the lack of disturbance of the IBGE reserve vegetation which has been protected for at least 20 years. Oliveira-Filho et al. (1994) found that shade-tolerant and light-demanding species were

Table 27- Growth strategy of the 56 species included in the Pitoco (P), Monjolo (M) and Taquara (T) joint analysis, their abbreviations and habitats.

Species	Abbrev.	Habitat	Growth Stratedy
1 *Alibertia macrophylla*	Alib macr	Dry (T)	Light demanding
2 *Amaioua guianensis*	Amai guia	Wet (M)	Shade tolerant
3 *Anadenanthera colubrina*	Anad colu	Dry (T)	*
4 *Aspidosperma subincanum*	Aspi subi	Wet (M)	*
5 *Astronium fraxinifolium*	Astr frax	Wet	*
6 *Bauhinia rufa*	Bauh rufa	Dry (P)	Light demanding
7 *Byrsonina laxiflora*	Byrs laxi	Dry	Light demanding
8 *Callisthene major*	Call majo	Dry (P, M)	Light demanding
9 *Cecropia lyratiloba*	Cecr lyra	Wet (M)	Pioneer
10 *Cheiloclinium cognatum*	Chei cogn	Wet (M)	Shade tolerant
11 *Copaifera langsdorffii*	Copa lang	Dry (P, M, T)	Shade tolerant
12 *Coussarea hydrangeifolia*	Cous hydr	*	Shade tolerant
13 *Cupania vernalis*	Cupa vern	Dry	Light demanding
14 *Cryptocarya aschersoniana*	Cryp asch	Wet (M)	Light demanding
15 *Diospyros hispida*	Dios hisp	Dry (T)	Light demanding
16 *Schefflera morototoni*	Sche moro	*	Light demanding
17 *Emmotum nitens*	Emmo nite	Wet (P, M)	Light demanding
18 *Eriotheca pubescens*	Erio pube	Dry (P)	Light demanding
19 *Faramea cyanea*	Fara cyan	Dry (P)	Shade tolerant
20 *Guapira graciliflora*	Guap grac	*	Shade tolerant
21 *Guatteria sellowiana*	Guat sell	Wet	*
22 *Guettarda viburnioides*	Guet vibu	Dry (P, T)	Light demanding
23 *Hirtella glandulosa*	Hirt glan	Wet	Light demanding
24 *Inga alba*	Inga alba	Wet (P, M)	*
25 *Ixora warmingii*	Ixor warm	*	Shade tolerant
26 *Jacaranda puberula*	Jaca pube	Dry (P, M)	Light demanding
27 *Lamanonia ternata*	Lama tern	Dry (P, T)	Light demanding
28 *Licania apetala*	Lica apet	Wet (P, M)	*
29 *Maprounea guianensis*	Mapr guia	Wet (T)	Light demanding
30 *Matayba guianensis*	Mata guia	Dry (P, M, T)	Light demanding
31 *Miconia cuspidata*	Mico cusp	Wet (M)	Light demanding
32 *Myrcia rostrata*	Myrc rost	Dry	Pioneer
33 *Myrcia tomentosa*	Myrc tome	Dry (T)	Light demanding
34 *Ocotea aciphylla*	Ocot acip	Wet (P)	*
35 *Ocotea corymbosa*	Ocot cory	Dry (M)	Light demanding
36 *Ocotea spixiana*	Ocot spix	*	*
37 *Ouratea castaneaefolia*	Oura cast	Dry (M)	*
38 *Pera glabrata*	Pera glab	Dry (P, T)	*
39 *Piptocarpha macropoda*	Pipt macr	Wet (T)	Pioneer
40 *Platypodium elegans*	Plat eleg	Dry (P, M, T)	Light demanding
41 *Pouteria ramiflora*	Pout rami	Wet (M)	Light demanding
42 *Protium almecega*	Prot alme	Wet (P, T)	Shade tolerant
43 *Pseudolmedia guaranitica*	Pseu guar	Wet (P, M)	Shade tolerant
44 *Roupala montana*	Roup bras	Dry (T)	Light demanding
45 *Sclerolobium paniculatun*	Scle pani	Wet (T)	Light demanding
46 *Simarouba versicolor*	Sima amar	*	*
47 *Siparuna guianensis*	Sipa guia	*	Shade tolerant
48 *Siphoneugena densiflora*	Siph dens	*	Light demanding
49 *Styrax guianensis*	Styr guia	*	*
50 *Symplocos mosenii*	Symp mose	*	*
51 *Symplocos nitens*	Symp nite	*	*
52 *Tapirira guianensis*	Tapi guia	Wet (P, M, T)	Light demanding
53 *Tapura amazonica*	Tapu amaz	Wet (T)	*
54 *Virola sebifera*	Viro sebi	Wet (P, M)	Light demanding
55 *Xylopia emarginata*	Xylo emar	*	*
56 *Xylopia sericea*	Xylo seri	*	*

equally important in both the ridgetop and the middle slope of the forest. This may be a direct consequence of the more elaborate stratification in response to light expected at inner galleries sites, which provide a suitable environment for species having a wide range of ecological adaptations.

9.4 - Conclusion.

Topography is directly related to water-table levels which have been reported as the main determining factor of gallery forest boundaries, structure, floristic composition, richness and density (Camargo 1971, Ratter 1980, Metzler & Donnaman 1985, Furley 1985, 1992 Powell 1985, Oliveira-Filho et al. 1990, Dunhan 1990, Ribeiro 1991, Felfili 1993, Ramos 1994, Oliveira-Filho et al. 1994 a & b). It also seems that soil physical and chemical properties are correlated with the topographical gradient within the forests and that the distribution of forest species is partially determined by these factors (Richards 1976). Other variables are undoubtedly important in explaining community and species patterns but their influence is disguised by the strength of the topographical effects.

In the Pitoco, Monjolo and Taquara sites there is a consistent variation in the soil chemical properties across the topographical gradient. Soils at the stream margins are always correlated with the more acid, OM, P and Al-rich soils, whilst the forest-cerrado border sites always displayed higher Ca, Mg and pH levels. Among the micronutrients only Mn is consistently higher at the dry sites. Water table variation along the topographic gradient seems to result in differential redox potential which provides chemical differences in soils.

A textural gradient is also detected which, however, is not consistent over the three sites. In the Pitoco forest the higher clay contents of the drier sites seem to be important in differentiating the vegetation communities. On the contrary, Monjolo

Taquara have coarser soils at the dry sites. Local differences in parent rock material and soil formation processes may account for the wide range of soil textural classes.

Thus, the analysis of the tree vegetation at the three sites reveals conspicuous communities apparently closely related to both chemical and textural gradients.

In the joint analysis the sequential positioning of the gallery communities along the gradient (Figure 44 b) is consistent with their soil moisture regime and chemical characteristics. There are two trends evident: (i) from the wettest sites of the wet-flatter community at Monjolo to the driest sites of the steep dry-fringe community at Pitoco, and (ii) a soil chemical gradient from the poorest sites of the Monjolo wet-flatter community to the richest soils of the Taquara dry community.

Undisturbed vegetation has profound effects on soil chemical and physical properties which, in turn, also affect the predominance of some species over the others (Lal 1987). Cause and effect relationships are always very difficult to define. The distinct communities of the Pitoco, Monjolo and Taquara galleries are correlated with the environmental gradients established in each site. Intensive and long term research would be required in order to understand the dynamic relations between the vegetation and soil moisture and chemical-textural variation.

Chapter 10 - Conclusion.

The cerrado region was given priority for development in Brazil and it was considered a promising agricultural frontier. Over the last two decades, approximately half of the original vegetation has been destroyed. Only 1.2% of what remains is legally protected in parks and other conservation units (Dias 1990). This protection is rarely effective due to lack of protective management structure and shortage of personnel.

The gallery forests are an outstanding vegetation formation within the Brazilian Central Plateau. They form a 'homogeneous green carpet' forming a network of narrow strips of forest following the water-courses and surrounded by cerrado vegetation. They are protected by legislation but there is no local enforcement to ensure their security. Consequently, despite their vital function in the ecosystem as a whole, they have been illegally invaded, burned, poisoned with chemicals from the surrounding crop cultivation, and have had their floristic richness severely depleted as a result of selective logging for timber.

Our inadequate state of knowledge of this vegetation type has already been stressed (Pires & Prance 1987, Brasil 1990, Felfili & Silva Júnior 1992, Felfili 1993, 1994, Oliveira-Filho et al. 1994, Oliveira-Filho & Ratter in press). A vast proportion of the galleries in Central Brazil are already in need of recuperation and suitable technology for their preservation is urgently required.

The characteristic floristic composition and phytosociology of the vegetation is discussed in Chapter 3, revealing the individuality of each gallery forest. The low level of major disturbance of the galleries studied is emphasised by the tree diameter distribution analysis. Chapter 4 providing numerical support for the presence of conspicuous tree communities related to the topographic-moisture gradient within the galleries. The floristic and structural links amongst the galleries and their communities form the analysis explored in Chapter 5.

In Chapter 6 the soils of the galleries and their constituent communities are examined in parallel, emphasising their generally dystrophic nature. This indicates the efficiency of the tree species in exploiting scarce resources and/or their low nutrient requirements and tolerance to acidity. The ordination of soil variables (Chapter 7) indicates a strongly marked soil chemical and textural gradient, closely related to that of the moisture toposequence.

The final analysis (Chapter 8) examines the ordination of the vegetation and environmental data simultaneously, detecting the most important components which determine the spatial distribution of the vegetation communities. The main findings are:-

1) - Study of the three gallery forests indicates that this physiognomically homogeneous vegetation occupies a heterogeneous environment, along the gradient from the stream margins to the forest-cerrado boundaries, and this is reflected in differentiation into distinct floristic communities.

2) - Even slight elevational changes over the toposequences, as in the Taquara gallery forest, determine a different soil moisture regime. This helps to explain the soil chemical gradient, from the stream margins to the forest-cerrado boundary.

3) - The spatial patterning of trees is closely related to the topographic-moisture and soil chemical-textural gradients. Species are ordinated forming a continuum along this gradient, with each reaching peak growth at a particular point of the environmental range.

4) - Species classified as preferential for the dry communities are always related to the higher levels of pH, Ca, Mg and Mn. Those species characteristic of the wet communities perform better over the Al-rich soils. A textural gradient is also prominent but there is no consistency amongst the galleries.

5) - Species which perform better at sites close to the forest-cerrado border are, for the major part, classified as light-demanding. At the inner sites, a more

complex light stratification allows the coexistence of light-demanding canopy and dominant species together with shade-tolerant smaller trees.

Niche partitioning minimises competition and allows coexistence (Aubréville 1938). In undisturbed conditions, Felfili (1993) showed that the community seems to be robust enough to establish dense populations of trees, capable of converting the local resources into growth, maintaining the diversity and structure peculiar to the tropical forests She also suggested that niche partitioning seems to determine the abundance structure in the forest. In all of the galleries environment analysed in the present study only a very few species are found exhibiting high density and basal area in more than one situation. Species ordination along the environmental gradient and the vertical stratification of trees suggests a complex environmental partitioning, where species of the rich flora find their niche, and express their best competitive ability, producing a forest mosaic. The environmental mosaic results in communities of trees even at sites near by showing a different floristic compositions.

10.1 - Guidelines for recuperation

On the basis of our present knowledge recuperation projects should observe the major environmental interactions, established as the main determinants of the vegetation structure. These are: the ecological demands of species in respect of the soil moisture regime, soil chemical and textural characteristics, and light requirements. When a certain stage of reforestation is reached less management should be needed and fine adjustments should proceed as a result of complex and stochastic natural events (Kageyama et al. 1989).

A sequence of steps, partially based on results of this study, can be suggested which should accelerate the recuperation of deforested areas in the gallery forests of Central Brazil:

Step 1) - Incorporation of fast growing tree species or pioneers ('specialists in large gaps', Denslow 1980) where seeds germinate under high temperatures and high light intensities. Pioneer species develop an effective root system to capture all readily available nutrients (Gonçalves et al. 1992) these are transferred in large quantities to the biomass which is deposited in turn as organic matter, enhancing the soil structure and making nutrients accessible at the rooting zone (Whitmore 1989, Gómez-Pompa & Velazquez-Yanes 1981). A fast and complete crown cover results in changes in the microclimate, reducing light intensity, thermal fluctuation and increasing humidity, thereby reducing invasion by pioneer grasses, herbs and shrubs and facilitating germination of tree species present in the seed bank (Hall & Swaine 1980).

Carpanezzi et al. (1990) suggested that plantings which concentrate on native pioneer species would encourage the successional process, thus speeding the dynamic process of restoration of the forest structure, floristic and animal diversity and trophic relations. However, Kageyama et al. (1989) suggested that a mixture of native and exotic species would provide quicker of a self-sustaining forest.

In the Federal District Brazilian species such as *Schizolobium parahyba, Ochroma pyramidale* and *Enterolobium contortsiliquum* have proved to be fast growers and able to provide good crown cover in a period of 5-10 years. Felfili (1993) also cites species of the Leguminosae, Lauraceae and Vochysiaceae as tending to grow faster in the galleries. Exotic species such as some *Eucalyptus* were found to provide shelter for a large number of species of advanced successional stages which germinate and establish new trees without suffering allelopathic effects (Calegário 1992, Aubert & Oliveira-Filho 1994, Silva Júnior et al. 1994). These eucalypts are therefore potential nurse tree species for recuperation projects.

As a consequence of the low disturbance levels in the Pitoco, Monjolo and Taquara galleries, few pioneer species are recorded which would serve for initial forest recuperation. Only *Cecropia lyratiloba* is suggested for the wet and Al-rich sites and *Myrcia rostrata* for drier and base-richer soils.

Step 2) - Saplings produced in nursery areas could be planted, under the pioneer cover, to enrich the gallery understorey. The species should be from Denslow's (1980) category of 'specialists in smaller gaps', i.e. shade tolerant at the earlier stages but associated with gaps and reaching the canopy later in the succession. The present research shows that:

a)- Species such as *Bauhinia rufa, Callisthene major, Copaifera langsdorffii, Cupania vernalis, Eriotheca pubescens, Matayba guianensis* and *Schefflera morototoni* should be tested in plantations in the drier and dystrophic soils of the galleries. They also classified as light-demanding species, a characteristic that would help fast growth and successful establishment at these initial stages.

b)- Under drier but mesotrophic conditions, *Alibertia macrophylla, Anadenanthera colubrina* var. *cebil, Copaifera langsdorffii, Diospyros hispida, Guapira graciliflora, Guettarda viburnioides, Myrcia tomentosa, Platypodium elegans, Roupala brasiliensis* and *Styrax guianensis* may be appropriate for enrichment planting.

c)- Where soils with a dystrophic nutritional status and having lower Al levels are likely to be saturated during the rainy season, species such as *Amaioua guianensis, Aspidosperma subincanum, Cheiloclinium cognatum, Cryptocarya ashersoniana, Inga alba, Hirtella glandulosa, Miconia cuspidata, Pouteria ramiflora* and *Siparuna guianensis* should be tested since they appear to be potentially good colonisers in these conditions.

d)-.Species with the potential to colonise wet and dystrophic soils, showing high Al and low pH levels are *Astronium fraxinifolium, Cecropia lyratiloba, Guatteria sellowiana, Ocotea aciphylla, Protium almecega, Pseudolmedia guaranitica, Simarouba amara* and *Xylopia emarginata*.

e)- A number of species display their best growth performance at intermediate levels of moisture saturation over dystrophic soils. They are therefore suitable for plantations over a wider range of soil environments but excluding the driest and wettest sites. This group includes *Lamanonia ternata, Pera glabrata, Sclerolobium paniculatum* var. *rubiginosum, Symplocos mosenii* and *Tapirira guianensis*.

The present research, based on interpretation of data from undisturbed gallery forests, goes some way towards understanding the form and variety of the climax forest. Information derived from the study should be put to practical use in the development of suitable techniques for the recuperation of the gallery forests in Central Brazil.

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Appendix - Chapter 6 - Soil profiles descriptions:

IBGE Ecological Reserve - Brasília - DF. - **PROFILE 1**

Date: 12/10/94, clear and sunny.

Location: sampling point 18 at **Taquara stream.**

Soil class: Hydromorphic Cambisol (?) (Soils with incipient B horizon, gleyed)

Vegetation: Taquara gallery forest (**WET COMMUNITY**).

Slope: 4%

Drainage: moderately well-drained.

A_{11} - 0 to 21 cm. Very dark grey (10 YR 3/1, dry), clay; black (10 YR 2/1) moist; strong medium to coarse granular structure; hard (dry), firm (moist), sticky and plastic; few fine roots; clear smooth boundary.

A_{12} - 21 to 39 cm. Dark grey (10 YR 4/1, moist) clay; weak, medium, subangular moist structure; friable (moist); many fine roots; diffuse smooth boundary.

(B_{21}) - 39 to 89 cm. Yellowish brown (10 YR 5/6, moist) clay; massive *in situ,* breaks into weak fine to medium subangular blocky structure; friable (moist), sticky and plastic; few fine roots; abrupt smooth boundary.

(B_{22}) - 89 to 105 cm . Yellowish red (5 YR 5/6, moist) clay; massive *in situ,* structureless; sticky and plastic.

depth (cm)	pH H2O	pH KCl	Org. C %	Al me/100g	Ca ppm	Mg ppm	Fe ppm	K ppm
0-21	4.7	4.1	3.17	2.39	0.03	0.11	49.36	0.20
21-39	4.8	4.2	1.08	1.66	0.02	0.06	33.7	0.08
39-89	5.1	4.3	0.92	0.64	0.02	0.01	15.4	0.02
89-105	5.1	4.4	0.79	0.55	0.02	0.02	18.85	0.02

IBGE Ecological Reserve - Brasília - DF. - **PROFILE 2.**

Date: 12/10/94, clear and sunny.

Location: sampling point 72 at **Taquara stream.**

Soil class: Cambisol (?) (Soils with incipient B horizon)

Vegetation: Taquara gallery forest (**DRY COMMUNITY**).

Slope: 8%

Drainage: moderately well-drained.

A_{11} - 0 to 16 cm. Light brownish grey (10 YR 6/2, dry), clay; greyish brown (10 YR 5/2) moist; weak fine to medium crumbs; friable (moist), sticky and plastic; many fine roots; clear smooth boundary.

A_{12} - 16 to 42 cm. Pale brown (10 YR 6/3, dry) clay; brown (10 YR 5/3) moist; massive *in situ;* sticky and plastic ; many fine roots; gradual smooth boundary.

A_{13} - 42 to 74 cm. Light yellowish brown (10 YR 6/4, dry) clay; greyish brown (10 YR 5/2) moist; massive *in situ;* sticky and plastic; few fine roots; gradual smooth boundary.

(B_{21}) - 74 to 105 cm. Brownish yellow (10 YR 6/6, moist) clay; massive *in situ,* structureless; sticky and plastic.

depth (cm)	pH H2O	pH KCl	Org. C %	Al me/100g	Ca ppm	Mg ppm	Fe ppm	K ppm
0-16	5	4.2	1.98	0.87	0.08	1.38	46.85	0.16
16-42	4.9	4.1	1.39	1.1	0.02	0.16	76.19	0.13
42-74	5.1	4.3	0.66	0.51	0.01	0.05	26.44	0.04
74-105	5.2	4.5	0.46	0.14	0.01	0.03	17.51	0.02

IBGE Ecological Reserve - Brasília - DF. - **PROFILE 3**.

Date: 12/10/94, clear and sunny.

Location: sampling point 138 at **Taquara stream.**

Soil class: Cambisol (?) (Soils with incipient B horizon)

Vegetation: Taquara gallery forest (**DRY COMMUNITY**).

Slope: 8%

Drainage: well-drained.

0 - 2.5 to 0 cm, fine root mat plus disintegrated decomposing leaf litter.

A_{11} - 0 to 32 cm. Very dark greyish brow (10 YR 3/2, dry), clay; nearly 90% gravel by volume; structureless; clear smooth boundary.

A_{13} - 32 to 42 cm. Light yellowish brown (10 YR 6/4, dry) clay; greyish brown (10 YR 5/2) moist; massive *in situ;* sticky and plastic; few fine roots; gradual smooth boundary.

(B_2) - 42 to 74 cm. Strong brown (7.5 YR 5/8, dry) clay; more than 90% gravel by volume; structureless.

(B_{21}) - 74 to 105 cm . Brownish yellow (10 YR 6/6, moist) clay; massive *in situ,* structureless; sticky and plastic.

depth (cm)	pH H2O	pH KCl	Org. C %	Al me/100g	Ca ppm	Mg ppm	Fe ppm	K ppm
0-10	5.7	**	14.05	0	8.94	2.58	48.9	0.25

> 10 cm compacted gravels

Taquara (profile 3) - Superficial layers of the soils associated with the Taquara Dry community. The soil class is suggested as 'Cambisol', showing large concretions along the profile. There is also evidence of organic matter accumulation at the surface. The chemical analysis show that the superficie horizons have the highest base (Ca, Mg and K) and the lowest Al levels amongst all the three galleries. Physical analysis indicated a loamy clay sand texture. The soils show at least the first 1m free of direct water table influence.

IBGE Ecological Reserve - Brasília - DF. -**PROFILE 4.**

Date: 26/09/94, clear and sunny.

Location: sampling point 223 at **Monjolo stream**.

Soil class: Plinthitic Cambisol (?) (Soils with incipient B horizon, with plinthitic gravel)

Vegetation: Monjolo gallery forest (**DRY COMMUNITY**).

Slope: 14%

Drainage: well-drained, profile dry throughout on the sampling date.

A_1 - 0 to 16 cm. Very dark grey (10 YR 3/1, dry), gravely clay; black (10 YR 2/1) moist; more than 50% gravel by volume; slightly sticky and plastic; many fine roots; clear smooth boundary.

B_1 - 16 to 52 cm. Dark yellowish brown (10 YR 4/4, moist) gravely clay; structureless ; more than 50% gravel by volume; sticky and plastic; common fine roots; diffuse smooth boundary.

B_2 pl - 52 to 105 cm . Red (10 R 4/8, moist); massive plinthite mixed with dark yellowish brown (10 YR 4/4); clay.

depth (cm)	pH H2O	pH KCl	Org. C %	Al me/100g	Ca ppm	Mg ppm	Fe ppm	K ppm
0-16	5.2	4.3	4.76	0.69	2.60	2.7	51.15	0.38

> 10 cm compacted gravels

Monjolo (profile 4) - Superficial layers of the soils associated to the Monjolo Dry community. The soil class is suggested as 'Plinthitic Cambisol', showing large gravelly concretions throughout the profile. The darkish colour in the top layer indicates organic matter accumulation. The chemical analysis indicated the highest base (Ca, Mg and K) and the lowest Al levels within the gallery. Physical analysis indicated a clay-rich texture. The soils show at least the first 1m free of direct water table influence.

IBGE Ecological Reserve - Brasília - DF. - **PROFILE 5**.

Date: 26/09/94, clear and sunny.

Location: sampling point 78 at **Monjolo stream**.

Soil class: Hydromorphic Cambisol (?) (Soils with incipient B horizon, gleyed)

Vegetation: Monjolo gallery forest (**WET-FLATTER COMMUNITY**).

Slope: 7%

Drainage: well-drained, profile dry throughout on the sampling date.

A_{11} - 0 to 8 cm. Dark greyish brown (10 YR 4/2, dry), gravely clay; very dark greyish brown (10 YR 3/2) moist; structureless; slightly sticky and slightly plastic; many fine roots; clear smooth boundary.

A_{12} - 8 to 32 cm. Greyish brown (10 YR 5/2, dry) clay; dark greyish brown (10 YR 4/2) moist; moderate fine to medium subangular blocky structure; sticky and plastic; few fine roots; gradual smooth boundary.

(B_1) - 32 to 52 cm. Yellowish brown (10 YR 5/4, dry) clay; dark yellowish brown (10 YR 4/4) moist; massive *in situ;* sticky and plastic; diffuse smooth boundary.

(B_2) - 52 to 98 cm. Brownish yellow (10 YR 6/6, dry) clay; yellowish brown (10 YR 5/6) moist; massive *in situ,* sticky and plastic.

depth (cm)	pH H2O	pH KCl	Org. C %	Al me/100g	Ca ppm	Mg ppm	Fe ppm	K ppm
0-8	3.9	3.3	7.00	6.85	0.05	0.07	75.73	0.22
8-32	4.5	4.1	2.71	0.94	0.03	0.06	116.60	0.08
32-52	4.8	4.2	1.39	1.06	0.02	0.02	67.94	0.03
52-98	5.0	4.4	0.79	0.37	0.02	0.01	40.18	0.02

Monjolo (profile 5) - Superficial layers of the soils associated to the Monjolo Wet flatter-community. The soil class is suggested as 'Cambisol'. The darkish colour in the top layer indicates organic matter accumulation. The chemical analysis indicated the lowest base (Ca, Mg and K) and the highest Al levels within the gallery. Physical analysis indicated a predominantly very-clayey textures.

Pitoco (profile 7) - Superficial layers of the soils associated to the Pitoco Inner dry-community. The soil class is suggested as 'Plinthitic Cambisol'. The darkish colour in the top layer indicates organic matter accumulation. The reddish colour of the profile bottom indicates the presence of massive plinthite in the absence of direct water table influence. The chemical analysis indicated intermediate base (Ca, Mg and K) and Al contents within the gallery. Physical analysis indicated predominantly very-clayey textures.

IBGE Ecological Reserve - Brasília - DF. - **PROFILE 8.**

Date: 5/10/94, clear and sunny.

Location: sampling point 51 at **Pitoco stream**.

Soil class: Latosol

Vegetation: Pitoco gallery forest (**DRY-FRINGE COMMUNITY**).

Slope: 9.5%

Drainage: well-drained, profile dry throughout on the sampling date.

A_{11} - 0 to 12 cm. Dark yellowish brown (10 YR 4/4, dry), clay; dark brown (10 YR 3/3) moist; moderate fine subangular blocky structure; slightly sticky and plastic; many fine roots; clear smooth boundary.

A_{12} - 12 to 19 cm. Yellowish brown (10 YR 5/4, dry) clay; dark brown (10 YR 3/3) moist; moderate fine subangular blocky structure; slightly sticky and plastic; few fine roots; gradual smooth boundary.

(B_{21}) - 29 to 47 cm. Yellowish brown (10 YR 5/6, dry) clay; dark yellowish brown (10 YR 4/4) moist; weak fine to medium subangular blocky structure; slightly sticky and plastic; gradual smooth boundary.

(B_{22}) - 47 to 100 cm. Strong brown (7.5 YR 5/6, dry);clay; strong brown (7.5 YR 4/6) moist; massive *in situ*; slightly sticky and plastic.

depth (cm)	pH H2O	pH KCl	Org. C %	Al me/100g	Ca ppm	Mg ppm	Fe ppm	K ppm
0-12	4.9	4.2	3.04	1.20	0.09	0.24	84.85	0.22
12-29	5.0	4.2	1.78	0.74	0.02	0.11	81.04	0.15
29-47	5.1	4.4	1.12	0.46	0.02	0.04	40.83	0.07
47-100	5.3	4.8	0.73	0.09	0.02	0.02	13.61	0.03

Pitoco (profile 8) - Superficial layers of the soils associated to the Pitoco Inner Dry fringe-community. The soil class is suggested as Red-Yellow Latosol. The yellowish colour throughout the profile indicates the presence of oxidised iron with infrequent saturation from the water table. The chemical analysis indicated intermediate base (Ca, Mg and K) and Al contents within the gallery. Physical analysis indicated predominantly very-clayey textures

IBGE Ecological Reserve - Brasília - DF. - **PROFILE 9.**

Date: 5/10/94, clear and sunny.

Location: sampling point 108 at **Pitoco stream**.

Soil class: Humic-Gley (?)

Vegetation: Pitoco gallery forest (**WET COMMUNITY**).

Slope: 9.5%

Drainage: well-drained, profile dry throughout on the sampling date.

0 - 7 to 0 cm. - Disintegrating leaf litter and rootmat.

A_1 - 0 to 56 cm. Dark brown (10 YR 3/3, dry), clay; very dark greyish brown (10 YR 3/2) moist; massive *in situ* which breaks into weak, fine subangular blocky structure; slightly sticky and plastic; clear smooth boundary.

C_1 - 56 to 77 cm. Very dark grey (10 YR 3/1, dry) clay; black (10 YR 2/1) moist; massive *in situ;* slightly sticky and plastic; gradual smooth boundary.

C_2 - 77 to 105 cm. Light grey (10 YR 7/1, moist) clay; massive *in situ;* slightly sticky and plastic.

depth (cm)	pH H2O	pH KCl	Org. C %	Al me/100g	Ca ppm	Mg ppm	Fe ppm	K ppm
0-7	3.9	2.9	21.54	9.71	1.23	1.44	57.44	1.31
0-56	4.8	4.0	1.98	2.44	0.02	0.04	28.09	0.08
56-77	4.9	4.1	1.78	2.67	0.01	0.01	7.05	0.03
77-105	5.0	4.1	0.53	1.29	0.01	0.01	4.19	0.02

Pitoco (profile 9) - Superficial layers of the soils associated with the Pitoco Wet community. The soil class is suggested as 'Humic-Gley'. The greyish colour throughout the profile indicates the groung water gleying. The darkish colour in the bottom of the profile indicates organic matter accumulation. The chemical analysis indicated lowest base (Ca, Mg and K) and the highest Al contents within the gallery. Physical analysis indicated predominantly clayey textures.

Table 28 - Approximate correlation of the Brazilian Soil Classification System with the U. S. Soil Taxonomy and the FAO Legend.

Brazilian System	U. S. Soil Taxonomy	FAO Legend
Latosol (soils with latosolic B horizon)	Oxisols	Ferralsols
Latosol Vermelho Escuro (Dark Red Latsol)	Ustox or Orthox	Orthic or Acric Ferralsols
Latosol Vermelho Amarelo (Red -Yellow Latosol)	Ustox or Orthox	Orthic or Acric Ferralsols
Latosol Amarelo (Yellow Latsol)	Ustox or Orthox	Xanthic Ferralsols
Latosol Roxo or Terra Roxa Legitima (Dusky Red Latosol)	Eutrustox or Eutrorthox	Rhodic Ferralsols
Podzolico Vermelho Amarelo (Red Yellow Podzolic)	Ultisols	Acrisols Dystric Nitosols
Podzolico Vermelho Amarelo Eutrofico (Eutrophic Red Yellow Podzolic)	Alfisol	Luvisols Eutric Nitosols
Terra Roxa Estruturada	Alfisol	Luvisols Eutric Nitosols
Red and Yellow Sands	Psamments	Ferralic Arenosols
Podzols	Spodosols	Podzols
Grumusols	Vertisols	Vertisols
Soils with incipient B horizon	Inceptisols	Cambisols
Soils with natric B horizon	Aridisols	Solonchaks
Regisols	Entisols	Regosols
Soils with hardpan	Various	Planosols
Other hydromorphic soils	Various	Gleysols

Source: Sanchez (1976).