AN ANALYSIS OF THE FLORISTIC COMPOSITION OF 26 CERRADO AREAS IN BRAZIL

J.A. RATTER & T.C.D. DARGIE*

An analysis was made of the floristic composition of 26 cerrado areas in Brazil, encompassing most of the latitudinal and much of the longitudinal extension of this vegetation. A total of 485 species of trees and large shrubs occurred in these areas but those present at only one site were eliminated so that the number analysed was reduced to 255. Numerical classification and ordination, followed by an environmental/geographical interpretation of site patterns, were used in the analysis. The analyses revealed three major gradients of variation associated with latitude, longitude and, most strongly, soil-type (mesotrophic or dystrophic). The study demonstrated that cerrado vegetation is extremely heterogeneous: none of the 485 species recorded occurred at all sites and only 27 were present at 15 or more. Further knowledge of this distributional heterogeneity is essential for the planning of representative conservation areas of this extremely endangered vegetation.

Uma análise foi feita da composição florística de 26 áreas de cerrado no Brasil, alcançando a maioria da extensão latitudinal e uma grande parte da distribuição longitudinal desta vegetação. Um total de 485 espécies de árvores e arbustos grandes ocorreu nestas áreas mas as registradas em um só local foram eliminadas e por isso o número analisado se reduziu a 255. Uma classificação numérica e ordenação, seguida por uma interpretação ambiental/geográfica de padrões dos sítios, foram usadas na análise. As análises mostraram tres gradientes maiores da variação associadas com latitude, longitude e, mais fortemente, com características do solo (meso- ou distrófico). O estudo mostrou que a vegetação do cerrado é extremamente heterogênea: nenhuma das 485 espécies registradas ocorreu em todas as localidades e somente 27 estiveram presentes em 15 ou mais. Um conhecimento mais amplo dessa heterogeneidade da distribuição é necessário para a delimitação de áreas representativas para a conservação dessa vegetação altamente ameaçada.

INTRODUCTION

Cerrado *sensu lato* is the natural vegetation of about 22% of the land surface of Brazil. Before the profound disturbance of the region by man, it occupied approximately 2 million km^2, coming second only to the 3.5 million km^2 of the Hylaea (Amazonian Forest) in terms of the area of the country covered. The cerrado flora is very ancient, perhaps dating in prototypic form to the Cretaceous, and consists of more than 700 species of trees and large shrubs and many times that number of subshrubs and herbs.

* Independent Ecological Consultant, Dornoch, Scotland IV25 3QQ

This paper was read at the VIII Congresso da Sociedade Botânica de São Paulo in September 1990 in the session concentrating on cerrado. It was prepared to appear in the Anais of the Congress but unfortunately publication of this volume was prevented because of lack of funding.

It has long been realized that great variation in cerrado communities occurs from place to place. In general it is rare to find more than 120 species of trees and larger shrubs in even the richest locality and there are usually considerable differences in species composition between areas. Some of the differences can be attributed to variations in the soil (Goodland, 1971; Ratter et al., 1973, 77), water table, influence of fire, or as seral stages in progression towards cerradão or forest (Ratter, 1986; Ratter et al., 1973). Others may be stochastic or related to the little-studied distribution patterns of the species present.

A number of interesting phytogeographical studies have been made concentrating on the floristic affinities of the woody cerrado flora and demonstrating its relationship to the Amazonian and Atlantic forest floras (e.g. Rizzini, 1964; Heringer et al., 1977; Sarmiento, 1983). However, so far there have been few attempts to compare the floristic composition of different cerrado areas. Ferri & Coutinho (1958) compared localities in the states of São Paulo, Mato Grosso do Sul and Goiás; Ratter et al. (1988a) used Sørensen and Dice association indices to compare areas in Tocantins, the Federal District, and three localities in São Paulo, and showed a decrease in similarity with distance; while Gottsberger & Morawetz (1986) made comparisons of an isolated Amazonas savanna with other areas.

The present study attempts to discover distribution patterns by comparing floristic data from 26 areas covering a large part of the latitudinal and longitudinal extension of cerrado vegetation. Modern multivariate methods are used to seek patterns (area groupings and trends) and the species associated with them, together with the possible factors responsible for the patterns.

MATERIALS AND METHODS

FLORISTIC AND ENVIRONMENTAL DATA

Floristic lists of trees and large shrubs were obtained from literature and other sources available to us in 1986–87. In total we used data from 26 localities in the states of São Paulo, Minas Gerais, Mato Grosso do Sul, Mato Grosso, Goiás, Tocantins, Piauí, Amazonas and Roraima, and in the Federal District. The localities are listed in Table 1 and shown on the map (Fig. 1); they range from the southern outliers of cerrado in São Paulo state across the main central core area to those on the margin of the Hylaea in Mato Grosso and Goiás, and northwards to the Amazonian and Roraima savannas. Unfortunately they vary greatly in size from less than a hectare to thousands of hectares. In total 485 species were recorded from the 26 areas but those occurring in only one locality were not included in the comparisons, reducing the number to 255. The decision to remove the unicates was taken so that the odd species atypical of cerrado vegetation, which inevitably occur in such floristic records, could be eliminated. Such unicates also furnish no inter-site comparative information for use in an exercise of this kind so that they are essentially redundant. We appreciate, however, that their removal means that some true cerrado species have been excluded.

Detailed soil information is available for most of the studies made by Ratter and coworkers but there is little habitat information for the majority of other sites. The

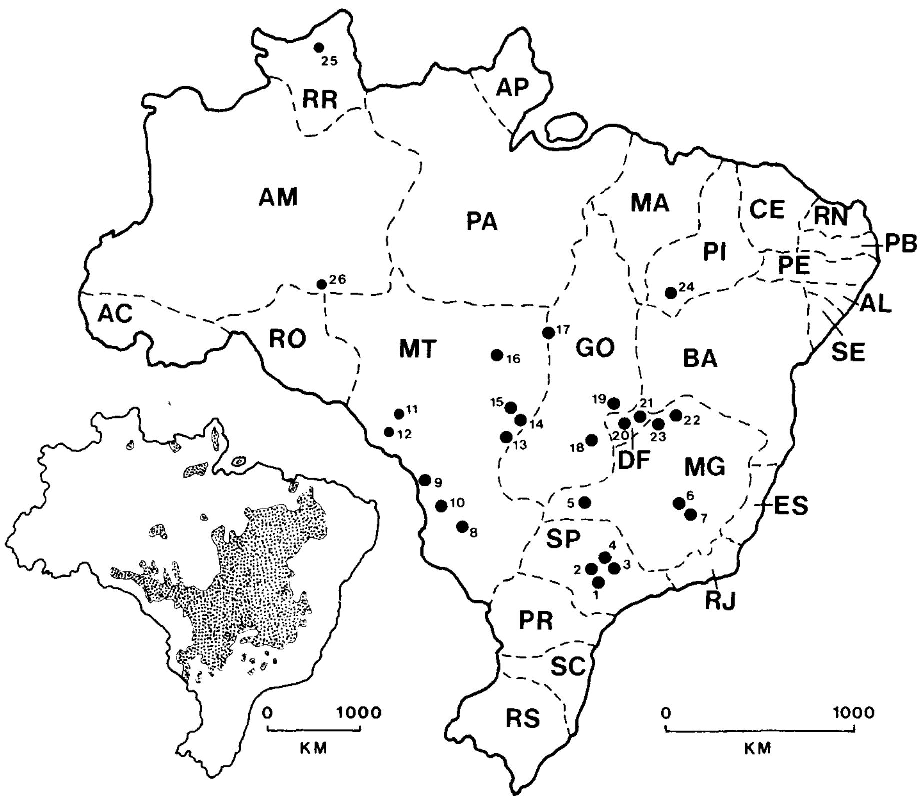

FIG. 1. Map showing sites compared in the study. See Table 1 for reference to the numbers.

occurrence of mesotrophic soils (Furley & Ratter, 1988; Ratter et al., 1973, 77) in areas studied by other workers (for which no soil data had been recorded) was determined by the presence of indicator species (Ratter et al., 1977).

DATA ANALYSIS

GENERAL APPROACH

Our aims are to seek out the latent patterns within the data set of the 255 species in 26 cerrado locations (as presence data), and to put forward initial explanations (hypotheses) for such patterns. The approach is therefore one of exploratory data analysis applied to multivariate information. We use the strategy of 'integrated interpretation' (Dargie, 1984) in which we summarize patterns of floristic variation by numerical classification and ordination, followed by an environmental/geographical interpretation of site patterns which also includes information on the species related to the site variation.

CLASSIFICATION AND ITS INTERPRETATION

The data set was classified by Twoway Indicator Species Analysis (TWINSPAN) (Hill, 1979a), a divisive method which produces groupings of both sites and species.

Table 1. Areas of cerrado (and savanna) compared in the study

No.	Code	Locality	Co-ord.	No. of spp.†	Soil type	Reference
1.	SPA	Angatuba, SP	23°28′S 48°28′W	70(53)	—	Ratter et al. (1988a)
2.	SPB	Botucatu, SP	22°45′S 48°25′W	53(51)	—	Silberbauer-Gottsberger & Eiten (1983)
3.	SPC	Faz. Campininha, SP	22°15′S 47°10′W	107(92)	—	Gibbs et al. (1983), Eiten (1963)
4.	SPE	Emas, SP	22°02′S 47°30′W	33(33)	—	Ferri & Coutinho (1958)
5.	MGG	Triângulo Mineiro, MG	19°20′S 48°50′W	122(101)	meso- & dystrophic	Goodland (1970), Goodland & Ferri (1979)
6.	MGM	Paraopeba, MG	19°20′S 44°20′W	60(55)	meso- & dystrophic	Silva (1984)
7.	MGW	Lagoa Santa, MG	19°39′S 43°44′W	83(66)	—	Warming (1982)
8.	MSF	Campo Grande, MS	20°24′S 54°35′W	24(20)	—	Ferri & Coutinho (1958)
9.	MSP	Faz. Acurizal, MS	17°45′S 57°37′W	64(49)	—	Prance & Schaller (1982)
10.	MSR	Faz. Nhumirim, MS	18°59′S 56°39′W	88(76)	meso- & dystrophic	Pott et al. (1986), Ratter et al. (1988b)
11.	MTC	Chap. Guimarães, MT	15°21′S 55°49′W	182(143)	meso- & dystrophic	Oliveira-Filho (1984), Oliveira-Filho & Martins (1986)
12.	MTP	Poconé, MT	16°16′S 56°38′W	35(33)	meso- & dystrophic	Ratter et al. (1988b & unpubl.)
13.	MTT	Torixoreu, MT	15°53′S 52°23′W	58(55)	meso- & dystrophic	Furley et al. (1988)
14.	MTV	Vale de Sonhos, MT	15°00′S 52°13′W	75(75)	meso- & dystrophic	Ratter et al. (1977 & unpubl.)
15.	MTX	Nova Xavantina, MT	14°45′S 52°20′W	124(119)	meso- & dystrophic	Ratter et al. (1973 & unpubl.)
16.	MTB	Base Camp, MT	12°49′S 51°46′W	133(116)	meso- & dystrophic	Ratter et al. (1973 & unpubl.)
17.	ToA	I do Bananal, To	10°26′S 50°25′W	107(97)	dystrophic	Ratter (1987)
18.	GoG	Goiânia, Go	16°43′S 49°18′W	29(29)	—	Ferri & Coutinho (1958)
19.	GoP	Padre Bernardo, Go	15°15′S 48°30′W	80(75)	meso- & dystrophic	Ratter et al. (1977 & unpubl.)
20.	DFF	Faz. Água Limpa, DF	15°45′S 47°57′W	134(121)	dystrophic*	Ratter (1984, 1986)
21.	DFP	Planaltina, DF	59°39′S 47°38′W	107(101)	dystrophic	Ribeiro et al. (1985)
22.	MGJ	Januária, MG	15°28′S 44°23′W	39(36)	meso- & dystrophic	Ratter et al. (1977 & unpubl.)
23.	MGS	Sagurana, MG	16°00′S 37°00′W	54(52)	mesotrophic	Ratter et al. (unpubl.)
24.	PiC	Uruçuí-Una, Pi	8°50′S 44°10′W	41(36)	—	Castro (1986)
25.	RoT	Boa Vista, Ro	3°20′S 61°26′W	12(9)	—	Takeuchi (1960)
26.	AmG	Humaitá, Am	7°31′S 63°00′W	21(7)	dystrophic	Gottsberger & Morawetz (1986)

† Figure in brackets is the number of species eliminating unicates (i.e. species which only occur at one site).
* A very small island of mesotrophic soil is also present on the 4,000ha fazenda.

A hierarchy was constructed for the site result. Environmental data were plotted at the base of the hierarchy to seek patterns, plus the number of mesotrophic indicator species in each site.

Species showing a distribution associated with one side of the hierarchy for each major division were then abstracted from the final site-species table produced by TWINSPAN. These were then related to the geographical and habitat characteristics of their groups.

ORDINATION AND ITS INTERPRETATION

The data set was ordinated by Detrended Correspondence Analysis (DCA) (Hill & Gauch, 1980), a technique which produces ordinations of species and sites on four axes using the DECORANA package (Hill, 1979b).

The four axes of the site ordination were then used as independent variables (X_1X_4) in three multiple linear regressions (first-order trend surfaces) fitted to latitude, longitude and data on the number of mesotrophic species per site (Y):

$$Y = b_0 + b_1X_1 + b_2X_2 + b_3X_3 + b_4X_4$$

This method allowed an assessment of north-south, west-east and soil trends in the site ordination.

Species related to these trends were found by rewriting the sites in their order (low to high value) along the gradients identified in the site ordination. Species were then classified into classes depending on their distribution for latitude, longitude and soil type. The site groupings produced by classification were also plotted on two-axis combinations of the ordination to assess the relationship between the two numerical methods.

RESULTS AND DISCUSSION

Space does not allow the table of species occurrence at all sites to be reproduced here; however, copies of it and relationships of species classes to environment are available from the authors. None of the 255 species analysed occur in all 26 localities. The most widespread species is *Qualea grandiflora* with 23 records, and only the following 27 species have been recorded in 15 or more of the sites:

Aspidosperma tomentosum Mart. (17)
Bowdichia virgilioides Kunth (19)
Byrsonima coccolobifolia Kunth (20)
B. verbascifolia Adr. Juss. (16)
Caryocar brasiliense Camb. (18)
Casearia sylvestris Sw. (17)
Connarus suberosus Planch. (18)
Curatella americana L. (20)
Davilla elliptica St. Hil. (16)
Dimorphandra mollis Benth. (17)
Erythroxylum suberosum St. Hil. (17)
E. tortuosum Mart. (15)
Hymenaea stigonocarpa [Mart. ex] Hayne (15)
Kielmeyera coriacea (Spreng.) Mart. (15)
Lafoensia pacari St. Hil. (15)
Machaerium acutifolium Vogel (15)
Magonia pubescens St. Hil. (16)
Palicourea rigida Kunth (15)
Plathymenia reticulata Benth. (15)
Pouteria ramiflora (Mart.) Radlk. (15)
Qualea grandiflora Mart. (23)
Q. multiflora Mart. (16)
Q. parviflora Mart. (18)
Tabebuia caraiba (Mart.) Bur.(18)
Terminalia argentea Mart. & Zucc. (15)
Tocoyena formosa (C. & S.) Schum. (19)
Xylopia aromatica Lam. (15)

These are obviously some of the most characteristic and widespread of cerrado species – most extending over the whole area of the cerrados south of the Amazon, and some such as *Bowdichia virgilioides* and *Curatella americana* into the llanos of Venezuela and even in the case of the latter to Central America. The fact that only 27 of the total of 485 species recorded occur at 15 or more sites, and no less than 230 are found at only a single locality, demonstrates the extreme heterogeneity of cerrado vegetation. Clearly knowledge of this distributional heterogeneity is essential for the planning of representative conservation areas.

CLASSIFICATION RESULTS

SITE HIERARCHY

The site hierarchy (Fig. 2) after five levels of division produces some ten groups (A–J).

INTERPRETATION OF GROUPING

The main features of groups and group sets are as follows:

Group A. This group comprises three diverse localities in São Paulo, Mato Grosso and Goiás, all recorded in the pioneer study of Ferri & Coutinho (1958). The species totals are low (33, 24 and 29 respectively) and they are the only sites lacking any unicate species.

Group B. This group consists of three well-worked southern cerrado outliers in São Paulo state. They contain few mesotrophic soil indicators and probably form a natural geographical grouping on dystrophic soils.

Groups C and D. These two groups are fairly similar, comprising central cerrado locations in southern Minas Gerais and the Federal District. Their totals of mesotrophic soil indicator species are low (range 1–7, mean 3.8 species per site), suggesting all are dominated by dystrophic soils – which is certainly the case for the Federal District sites.

Groups E, F and G. The unifying feature of these three groups is the high number of mesotrophic soil indicator species (range 1–11, mean 8.7 species per site), suggesting this factor is important. Species differences between groups are strongly related to geographical separation. Group E is made up of more western sites (from Mato Grosso and the Ilha do Bananal), Group F sites are further east, and the solitary location in Group G is a Pantanal record differentiated by southern species.

Groups H and I/J. These groups form part of the uppermost dichotomy in the classification. There are several features which suggest component sites are heterogeneous and they may represent misclassifications. The two samples from Amazonas and Roraima (Groups I and J) are very depauperate in species and therefore lack many associations with other sites. Further reasons for misclassification appear to be the absence of several widespread cerrado species common in Groups A to G (*Acosmium dasycarpum* (Vogel) Yakovlev, *Erythroxylum suberosum* and *E. tortuosum*), plus the presence of several species largely restricted to Group H. The three samples in Group H have high numbers of mesotrophic soil indicator species and, intuitively, sample MTT should have been placed in Group E, with sites MSR and MTP going to Group G because they are Pantanal locations with southern differentiators.

CLASSIFICATION PATTERN SUMMARY

Several features emerge from the interpretation of the classification hierarchy. The first is the distinction between groups with dystrophic soil (A–D) and those with mesotrophic soil (E–G), as judged by indicator species. The second is a geographical pattern of grouping, with southern (São Paulo), central (southern Minas Gerais, Federal District), western (Mato Grosso) and northern outlier (Amazonas, Roraima) types. More minor features include a group of under-recorded locations (Group A) and misclassification of a few sites (locations in Group H).

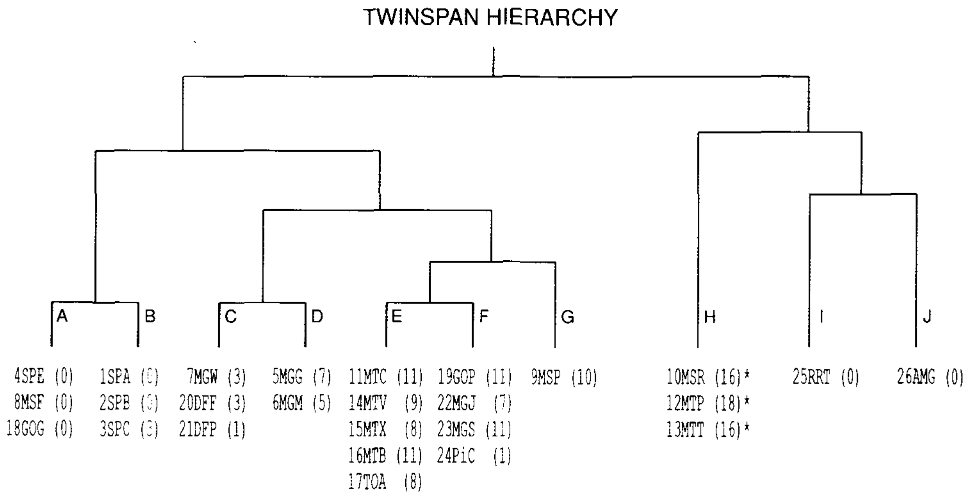

FIG. 2. Site hierarchy derived from TWINSPAN data analysis. Site code as given in Table 1. Figures in brackets after site code represent number of mesotrophic soil indicators for that location. *Misclassified site.

ORDINATION RESULTS AND DISCUSSION

TREND SURFACE PATTERNS

The equations for latitude, longitude and mesotrophic soil indicator regressions are given in Table 2. These variables together involve axes 1, 2 and 3 of the ordination and this suggests that the fourth axis is redundant and that it can be excluded from interpretation.

Table 2. Trend surface equations fitting environmental variables to a four-axis DCA ordination. (Non-significant axes are excluded from the equation.)

				Explanation (R^2)
Latitude =	27.250	$-0.038 X_1$	$-0.047 X_2$	0.704
Longitude =	39.288	$+0.037 X_1$	$+0.072 X_3$	0.686
Number of Mesotrophic Indicators =	3.532	$+0.045 X_1$	$-0.031 X_2$	0.662

All three environmental variables produce strong equations and the linear trend surfaces are plotted on two-axis ordination diagrams in Figs 3–5. All trends are oblique to the original axes of the ordination. Apart from a low correlation between latitude and longitude (r = -0.472, the result of Amazonas and Roraima outlier samples), these variables can be considered as separate trends within the first three dimensions of the ordination.

LATITUDINAL TREND

Latitude increases (becomes more southerly) from top right to bottom left of the Axis 1–2 plot (Fig. 3). Most locations are correctly positioned within 2 degrees but there are some sites which have a poorer fit: 4, 8, 12, 17, 24, 26. These include two sites (4,

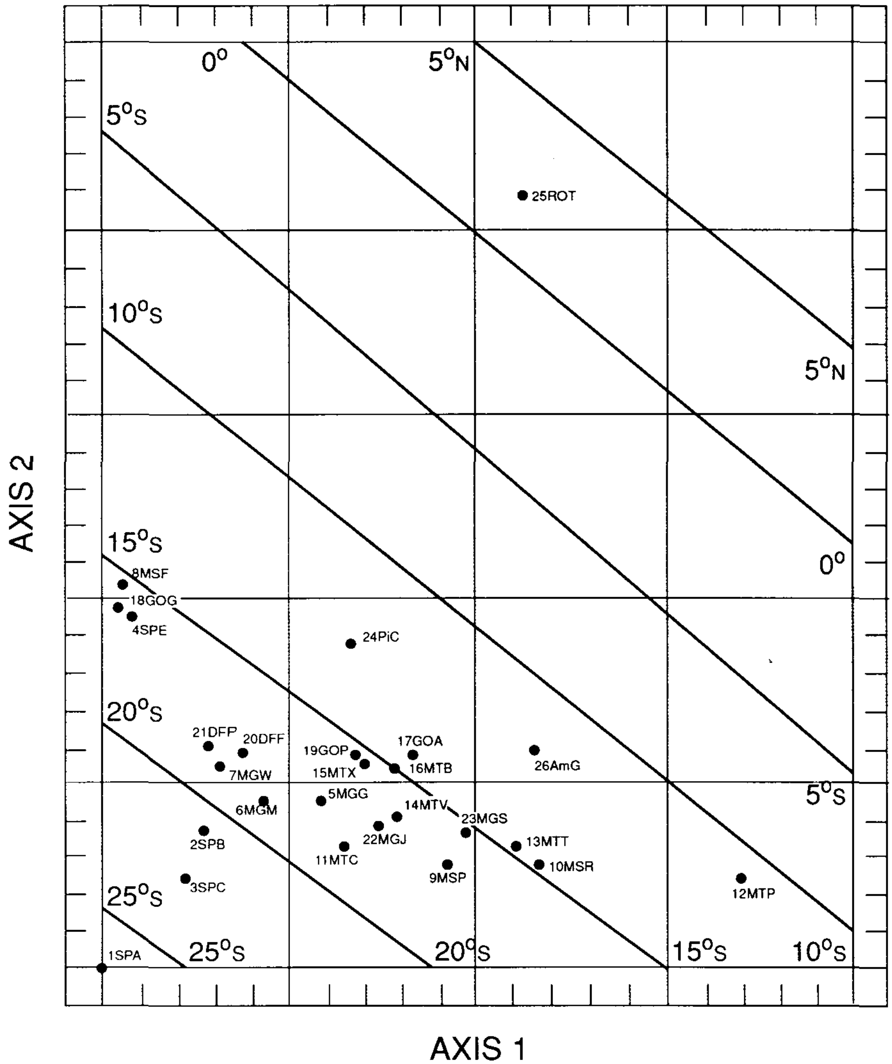

FIG. 3. Estimated latitudinal gradient on axes 1 and 2 of DCA site ordination.

8) which are probably under-recorded, and two poor in species (24, 26). The species poverty of these four locations could easily lead to bad positioning. Some 41 species show non-random restriction to parts of this gradient: there is a small total of species confined to central latitudes (5), with 24 northern and 12 southern species.

LONGITUDINAL TREND

Longitude increases (becomes more westerly) from bottom left to top right of the Axis 1–3 ordination plot (Fig. 4). As with latitude most sites are located accurately within 1–2 degrees of their true position, but with four poor fits (locations 7, 8, 24, 25). Three of these sites (8, 24, 25) are low in species and this probably explains some of the error. Some 47 species show non-random restriction to parts of the gradient, with a large

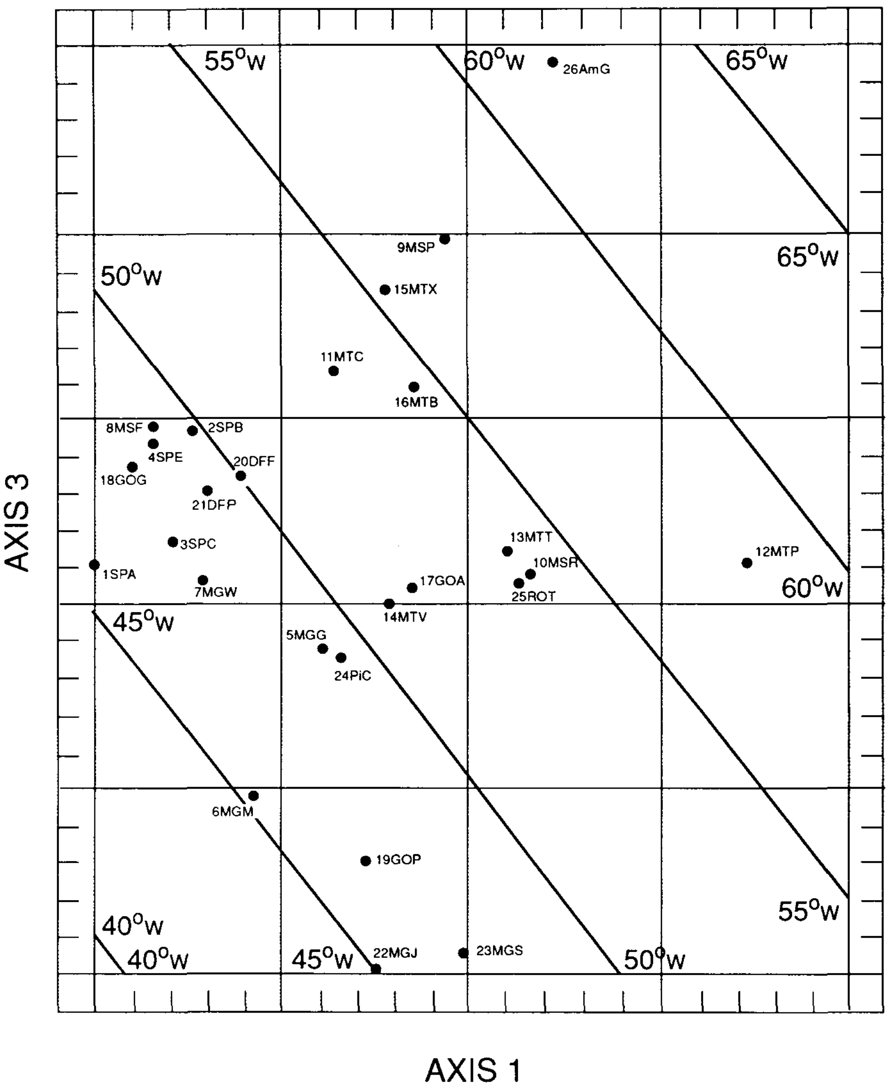

FIG 4. Estimated longitudinal gradient on axes 1 and 3 of DCA site ordination.

western total (31) contrasting with more species-poor central (15) and eastern (11) aggregates.

SOIL NUTRIENT GRADIENT

Using numbers of mesotrophic soil indicators per site (see Fig. 2) as an indirect measure of soil nutritional status, there is a clear gradient from dystrophic to mesotrophic soils from top left to bottom right of the Axis 1–2 ordination plot (Fig. 5). This is approximately at right angles to the latitudinal trend upon these axes. Most sites fit the trend contours well and there is only one bad misfit (location 26 with a very low species total). The species characteristic of this gradient are very numerous (total 71) and show a

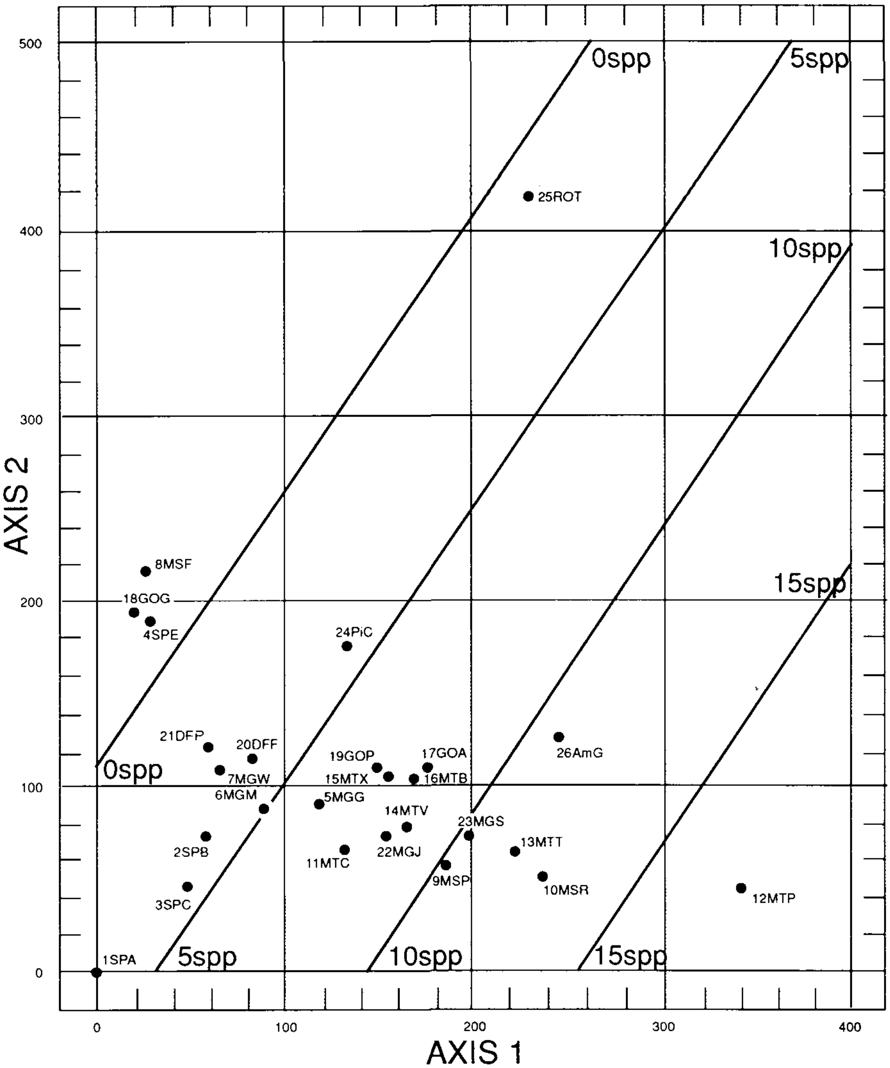

FIG. 5. Estimated gradient in numbers of mesotrophic soil indicator species per site, plotted on axes 1 and 2 of DCA site ordination.

progressive increase in moving from dystrophic (12) through intermediate (25) to mesotrophic (34) soil. An important feature of the species list is the large mesotrophic total, in excess of that used to estimate soil status. Of all three gradients detected within the ordination, this is probably the strongest.

ORDINATION PATTERN SUMMARY

The ordination yields the same interpretation as the classification result, though with greater clarity and precision. There are three major floristic trends present which seem to reflect latitude, longitude and soil nutritional status. Expressed in another way, the ordination contains a fairly accurate map of site locations in two dimensions (oblique to axes 1, 2 and 3) with a further soil nutrient trend at approximate right angles to the map plane.

RAW DATA QUALITY

Convincing patterns must be based on reliable data. A number of factors affect the quality of raw data of this study:

1. The species list (255) is long in comparison to the site total, with relatively few common species in a majority of samples (27 species are recorded in 15 or more localities). Grouping patterns and floristic trends are therefore determined by relatively infrequent species. An additional point is that there is no quantitative measure for species and numerical analysis uses only crude presence data;
2. There is variation between localities in important decisions which influence the species total for a site, notably extreme dissimilarity of the size of area sampled and the size criteria for scoring presence of individuals;
3. There are probably for the rarer species, some inconsistencies in determinations between different workers, while some confusion may also be caused by synonymy;
4. Some samples appear to have been greatly under-recorded.

These points introduce a degree of difficulty and error into the data set. However, they were the best data available for coverage of Brazil on a national scale at the time we started our study. The numerical results suggest strong underlying floristic patterns in the data which can be related strongly to geographical and soil nutrient factors. The quality of result suggests that the strength of underlying pattern is sufficiently robust to overcome the problems set by data type and quality.

ANALYTICAL AND INTERPRETATIVE METHODS

In addition to sound data, convincing patterns also depend on sound methods of analysis and interpretation. The numerical methods of classification and ordination used here (TWINSPAN, DCA) have been carefully examined by plant ecologists for use in a very wide range of habitats over a 10 year time period. They are generally accepted as being mathematically sound and robust in coping with ecological data types (Jongman et al., 1987). They have supplanted earlier techniques, such as classical Principal Components

Analysis, which can create much distortion in results, and thus lead to severe interpretation difficulties. It is now recognised that older methods applied to tropical vegetation did not produce a sound result, hence the need for a re-examination of multivariate methods based on modern techniques. The strength of results obtained is some evidence that the analytical techniques used here are sound, agreeing with other tropical studies (e.g. Dargie & Epitawatta, 1988).

Interpretation methods applied to multivariate data are frequently subjective and are not carefully applied by users, especially in ordination studies (Dargie, 1987). Our approach to classification has been largely visual appraisal of the environmental and species differences between groups. Statistical assessment of differences is very difficult due to the small number of localities and the lack of soil data for many sites.

Our approach to ordination is more rigorous, using trend surfaces to relate environmental variables to the DCA analysis. Even this can be criticised because the site point pattern produced by ordination contains a few distant outliers (notably Amazonas and Roraima samples) which inevitably influence the regression result in a study involving only 26 sites. The low number of localities prevents a statistical analysis (e.g. the chi-square tests and seriation array approach of Dargie, 1986) to isolate the species significantly restricted to sections of the three gradients found in this study. There is, therefore, a great need for an extended analysis involving a much larger number of sites throughout the range of the Brazilian cerrado.

Despite qualifications over data quality and interpretation methods, clear patterns are present and are sufficiently strong to justify extending these approaches to a more comprehensive analysis.

ECOLOGICAL FINDINGS

MAJOR HYPOTHESES

The approach used here, a form of exploratory data analysis, does not seek to formulate and test a null hypothesis, nor does it attempt to confirm, modify or deny existing ideas on cerrado variation. Instead, it is pattern-seeking and hypothesis-generating in character. Given the small number of localities involved, it could be considered a pilot sample searching for clues on the controls of cerrado vegetation at the national scale, and the floristic patterns produced by those controls.

Results from both classification and ordination (especially the latter) suggest the following hypotheses on cerrado variation:

1. That species variation, though complex, can be simplified in terms of three major gradients of variation;
2. That two of these gradients are geographical in scale and involve the influence of both latitude and longitude, perhaps acting independently;
3. That soil nutrient status is the third gradient, operating between extremes of dystrophic and mesotrophic soil types.

PATTERN INTERPRETATION

The geographical factors are probably linked to climate, both present and historical: no doubt the climatic variations of the Pleistocene had strong effects on the distribution of the cerrado flora. Studies of damage caused by exceptional frosts (Silberbauer-Gottsberger et al., 1977) have shown great variation in susceptibility in different species of the cerrado flora. Periods of colder climate in the past might therefore have brought about profound changes in the distribution patterns of cerrado species.

The floristic elements associated with the presence of mesotrophic and dystrophic soils in the cerrado have already been described in a series of papers (Furley & Ratter 1988; Ratter 1971; Ratter et al. 1973, 77, etc). The analyses presented here confirm the importance of soil type as probably the strongest factor in floristic variation in cerrado vegetation. There is no point in developing this theme further in this paper as it has already been well covered in the previous publications.

FURTHER RESEARCH

Obviously far more data than have been used in this study are required to provide adequate information on distribution patterns in the cerrado. Since we assembled these data more than three years ago other important works have become available and the Biogeography of the Cerrados project, a major research initiative supported by the Brazilian Government agency SEPLAN, has begun. The latter project is making comparative studies throughout the cerrado area, using surveys with standardized areas, uniform tree diameter classes, etc, and has already completed its work in the eastern São Francisco region and the Pratinha plateau. Analysis of these data, using the powerful microcomputers and software now available, should provide a new insight into the biogeography of the cerrado and allow centres of biodiversity for conservation to be recognized. This work must be pursued with urgency as the rate of destruction of the cerrado is alarming: present estimates are that 37–50% of the cerrado area has already been destroyed (Dias, 1990; Ratter, 1991), as compared to an accurate estimate of 10–12% for the Brazilian part of the Hylaea (see Fearnside, Tardin & Meira Filho, 1990). At present less than 5% of the cerrado area has any conserved status and clearly much more must be protected if this rich and ancient flora is not to be lost. Meticulous surveys and analyses of their results can indicate important representative areas to be saved.

ACKNOWLEDGEMENTS

We wish to thank Mrs Maureen Warwick, Royal Botanic Garden, Edinburgh, for assistance in the preparation of the paper and for drawing the figures. We are also grateful to Dr Peter Gibbs, University of St Andrews, for his interest and encouragement.

REFERENCES

CASTRO, A. A. J. F. (1986). *O cerrado e a composição florística vascular da Estação Ecológica de Uruçui-Una, Piauí: resultados preliminares.* Unpubl. MS.

DARGIE, T. C. D. (1984). On the integrated interpretation of indirect site ordinations: a case study using semi-arid vegetation in southeastern Spain. *Vegetatio* 55: 37–55.

DARGIE, T. C. D. (1986). A seriation method for summarizing vegetation – environment relationships. *Vegetatio* 65: 91–93.

DARGIE, T. C. D. (1987). An ordination analysis of vegetation patterns on topoclimate gradients in south-east Spain. *Journal of Biogeography* 14: 197–211.

DARGIE, T. C. D. & EPITAWATTA, D. S. (1988). Environment, succession and land-use potential in the semi-evergreen forests of southern Sri Lanka. *Journal of Biogeography* 15: 209–220.

DIAS, B.F. de S. (1990). Conservação da Natureza no Cerrado Brasileiro, in Pinto, M.N. (ed.). *Cerrado: Caracterização, Ocupação e Perspectivas*: 583–640. Editora Universidade de Brasília, Brasília.

EITEN, G.(1963). Habitat Flora of Fazenda Campininha, São Paulo, Brazil. *Simpósio sobre o Cerrado* 155–202. Universidade de São Paulo.

FEARNSIDE, P.M., TARDIN, A.T. & MEIRA FILHO, L.G. (1990). *Deforestation Rate in Brazilian Amazonia*. National Secretariat of Science & Technology. INPE/INPA. Brazil.

FERRI, M. G. & COUTINHO, L. M. (1958). Contribuição ao conhecimento da ecologia do cerrado. Estudo comparativo da economia d'água de sua vegetação, em Emas (Est. de São Paulo), Campo Grande (Est. de Mato Grosso) e Goiânia (Est. de Goiás). *Bol. Fac. Filos. Univ. São Paulo* 224 *Bot.* 15: 103–150.

FURLEY, P. A. & RATTER, J. A. (1988). Soil resources and plant communities of the central Brazilian cerrado and their development. *Journal of Biogeography* 15: 97–108.

FURLEY, P. A., RATTER, J. A. & the late GIFFORD, D. R. (1988). Observations on the vegetation of eastern Mato Grosso III. The woody vegetation and soils of the Morro de Fumaça, Torixoreu. *Proc. Roy. Soc. (ser. B)* 235: 259–280.

GIBBS, P. E., LEITÃO FILHO, H. de F. & SHEPHERD, G. (1983). Floristic composition and community structure in an area of cerrado in SE Brazil. *Flora* 173: 433–449.

GOODLAND, R. J. A. (1970). Plants of the Cerrado Vegetation of Brasil. *Phytologia* 20: 57–77.

GOODLAND, R. J. A. (1971). Oligotrofismo e alumínio no Cerrado. *III Simpósio sobre o Cerrado* 44–60. Universidade de São Paulo.

GOODLAND, R. J. A. & FERRI, M. G. (1979). *Ecologia do Cerrado*. 194 pp. Universidade de São Paulo.

GOTTSBERGER, G. & MORAWETZ, W. (1986). Floristic and Phytogeographic Analysis of the Savannas of Humaitá (Amazonas). *Flora* 178: 41–71.

HERINGER, E. P., BARROSO, G. M., RIZZO, J. A. & RIZZINI, C. T. (1977). A Flora do Cerrado. *IV Simpósio sobre o Cerrado* 211–232. Universidade de São Paulo.

HILL, M. O. (1979a). *TWINSPAN - a FORTRAN program for arranging multivariate data in an ordered two-way table by classification of individuals and attributes*. 90 pp. Cornell University, Ithaca, New York.

HILL, M. O. (1979b). *DECORANA - a FORTRAN program for detrended correspondence analysis and reciprocal averaging*. 52 pp. Cornell University, Ithaca, New York.

HILL, M. O. & GAUCH, H. G. Jr.(1980). Detrended correspondence analysis: an improved ordination technique. *Vegetatio* 42: 47–58.

JONGMAN, R. H. G., ter BRAAK, C. J. F. & van TONGEREN, O. F. R. (1987). *Data Analysis in Community and Landscape Ecology*. 299 pp. PUDOC, Wageningen.

OLIVEIRA FILHO, A. T. (1984). *Estudo florístico e fitosociológico em um cerrado na Chapada dos Guimarães, Mato Grosso - Uma análise de gradientes*. Master's thesis. Universidade Estadual de Campinas.

OLIVEIRA FILHO, A. T. & MARTINS, F. R. (1986). Distribuição, caracterização e composição florística das formações vegetais da região da Salgadeira, na Chapada dos Guimarães (MT). *Revta brasil. Bot.* 9: 207–223.

POTT, V. J., POTT, A., RATTER, J. A. & VALLS, J. F. M. (1986). *Flora da Fazenda Nhumirim, Nhecolândia, Pantanal. Relação preliminar*. Pesquisa em Andamento (EMBRAPA CPAP) No. 5, 26 pp.

PRANCE, G. T. & SCHALLER, G. B. (1982). Preliminary Study of some Vegetation Types of the Pantanal, Mato Grosso, Brazil. *Brittonia* 34: 228–251.

RATTER, J. A. (1971). Some notes on two types of cerradão occurring in north eastern Mato Grosso. *III Simpósio sobre o Cerrado* 100–102. Universidade de São Paulo.

RATTER, J. A. (1980). *Notes on the vegetation of Fazenda Água Limpa (Brasília, DF, Brasil)*. III pp. Royal Botanic Garden, Edinburgh.

RATTER, J. A.(1986). *Notas sobre a vegetação da Fazenda Água Limpa (Brasília, DF)*. Editora UnB, textos universitários no. 003. 136 pp. Brasília.

RATTER, J. A. (1987). Notes on the vegetation of the Parque Nacional do Araguaia (Brazil). *Notes RBG Edinburgh* 44: 311–342.

RATTER, J.A. (1991). *The Conservation Situation of the Brazilian Cerrado Vegetation*. Report for WWF(UK).

RATTER, J. A., RICHARDS, P. W., ARGENT, G. & GIFFORD, D. R. (1973). Observations on the vegetation of north eastern Mato Grosso, 1. The Woody Vegetation types of the Xavantina-Cachimbo Expedition Area. *Phil. Trans. R. Soc.* (b) 226: 449–492.

RATTER, J. A., ASKEW, G. P., MONTGOMERY, R. F. & GIFFORD, D. R. (1977). Observações adicionais sobre o cerradão de solos mesotróficos no Brasil Central. *IV Simpósio sobre o Cerrado* 303–316. Universidade de São Paulo.

RATTER, J. A., LEITÃO FILHO, H. de F., ARGENT, G., GIBBS, P. E., SEMIR, J., SHEPHERD, G. & TAMASHIRO, J. (1988a). Floristic Composition and Community Structure of a Southern Cerrado Area in Brazil. *Notes RBG Edinburgh* 45: 137–151.

RATTER, J. A., POTT, A., POTT, V. J., CUNHA, C. N. da & HARIDASAN, M. (1988b). Observations on woody vegetation types in the Pantanal and at Corumbá, Brazil. *Notes RBG Edinburgh* 45: 503–525.

RIBEIRO, J. P., SILVA, J. C. S. & BATMANIAN, G. J. (1985). Fitossociologia de tipos fisionômicos de cerrado em Planaltina - DF. *Revta brasil. Bot.* 8: 131–142.

RIZZINI, C. T. 1963. A Flora do Cerrado. *Simpósio sobre o Cerrado* 107–153. Universidade de São Paulo.

SARMIENTO, G. 1983. The Savannas of Tropical America. Pp. 245–288 in BOURLIÈRE, F. (ed.) *Ecosystems of the World 13: Tropical Savannas*. Elsevier, Amsterdam.

SILBERBAUER-GOTTSBERGER, I. & EITEN, G. (1983). Fitossociologia de um hectare de cerrado. *Brasil Florestal* No. 54: 55–70.

SILBERBAUER-GOTTSBERGER, I., MORAWETZ, W., & GOTTSBERGER, G. (1977). Frost Damage of Cerrado Plants in Botucatu, Brazil, as Related to the Geographical Distribution of the Species. *Biotropica* 9: 253–261.

SILVA JUNIOR, M. C. da (1984). *Composição Florística, Estrutura e Parâmetros Fitossociológicos do Cerrado e sua Relação com o Solo na Estação Florestal de Experimentação de Paraopeba, MG.* Master's thesis. Universidade Federal de Viçosa.

TAKEUCHI, M. (1960). A Estrutura da Vegetação na Amazônia 11 - as Savanas do Norte da Amazônia. *Bol. Mus. Paraense E. Goeldi N.S. Botânica.* No. 7.

WARMING, E. (1892). Lagoa Santa: Et bidrag til den biologiska plantegeografi. *K. danske Vidensk. Selsk. Skr.* 6: 153–488.