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BOTANICAL BRIEFING

# The Brazilian Cerrado Vegetation and Threats to its Biodiversity

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The Brazilian cerrado (savanna) biome covers 2 million km² representing 23% of the area of the country. It is an ancient biome with rich biodiversity, estimated at 160000 species of plants, fungi and animals. There are about 800 species of trees and large shrubs in the savanna vegetation and several times that number of ground species (herbs and subshrubs). When the flora of gallery forests, mesophytic forests and other habitats occurring in the biome are included, the total number of vascular plant species is estimated to reach about 10000. During the last 25 years modern agriculture has been developed in the cerrado to produce soya, maize, rice, etc and enormous numbers of cattle are raised in planted pastures. Charcoal production for the Brazilian steel industry also causes great destruction of the cerrado. By 1994 an estimated 695000 km² of cerrado (representing 35% of its area) had been converted to 'anthropic landscape'. This compares to the destruction of about 400000 km² of Brazilian Amazonian forest representing 12 or 13% of the area of this biome. Conservation initiatives are now desperately needed. Only 1·5% of the cerrado biome is preserved as Federal Reserves and this area needs to be at least tripled. Surveys of the vascular flora aimed at discovering biogeographic patterns are now in progress with the objective of choosing representative areas and biodiversity 'hot spots' for conservation. 

**Key words:** Brazil, cerrado, biodiversity, conservation.

## INTRODUCTION

Mention the vegetation of Brazil and the perils of its destruction and the picture conjured up in most minds is that of the tall Amazonian forest, the 'green hell' of the more lurid travel writers, with lurking jaguars, anacondas and uncontacted Indian tribes. Few realize that the country also contains an immense species-rich savanna area, threatened to an even greater extent by destruction than the Amazonian forest. The present article is devoted to this unjustly neglected savanna with the intention of focusing attention on its importance and its present plight. Clearly, in such a brief communication, much of the field has to be omitted, and for more detailed information, readers are referred to such works as Eiten (1972, 1982), Goodland and Ferri (1979), Novaes Pinto (1990), Dias (1992) and Alho and Martins (1995).

## THE CERRADO

The Brazilian savanna vegetation is called *cerrado* and covers some 2 million km² of Central Brazil (Fig. 1), representing about 23% of the land surface of the country (the same size as Western Europe). In terms of area it is exceeded by only one vegetation formation in Brazil, the Amazonian forest covering approx. 3·5 million km². The cerrado region extends from the margin of the Amazonian forest to outlying areas in the southern states of São Paulo and Paraná, occupying more than 20° of latitude and an altitudinal range from sea-level to 1800 m; about 700000 km² of the total area of cerrado vegetation is within the Amazon basin. In addition, there are areas of cerrado in Bolivia and Paraguay, while related, but species-poor, savanna vegetation such as the Roraima and Rupununi savannas and the Venezuelan llanos occur north of the Amazon.

The cerrado climate is typical of the rather moister savanna regions of the world, with an average precipitation for over 90% of the area of 800–2000 mm and a very strong dry season during the southern winter (approx. April–September), while average annual temperatures are 18–28 °C (Dias, 1992). The soils of most of the area are dystrophic, with low pH and availability of calcium and magnesium, and high aluminium content (Lopes and Cox, 1977*a*; Furley and Ratter, 1988); most are oxisols (ferralitic soils). They are always well-drained and cerrado vegetation is intolerant of waterlogging. In this respect, the species-rich cerrado contrasts with the seasonally inundated, species-poor hydrologic savannas common north of the Amazon.

The typical vegetation landscape within the cerrado biome consists of cerrado on the well-drained interfluves with gallery forests following the watercourses. The cerrado itself is very varied in form, ranging from dense grassland, usually with a sparse covering of shrubs and small trees, to an almost closed woodland with a canopy height of 12–15 m. It is difficult to discover the causes of these differences in vegetation structure. Some workers have related them to

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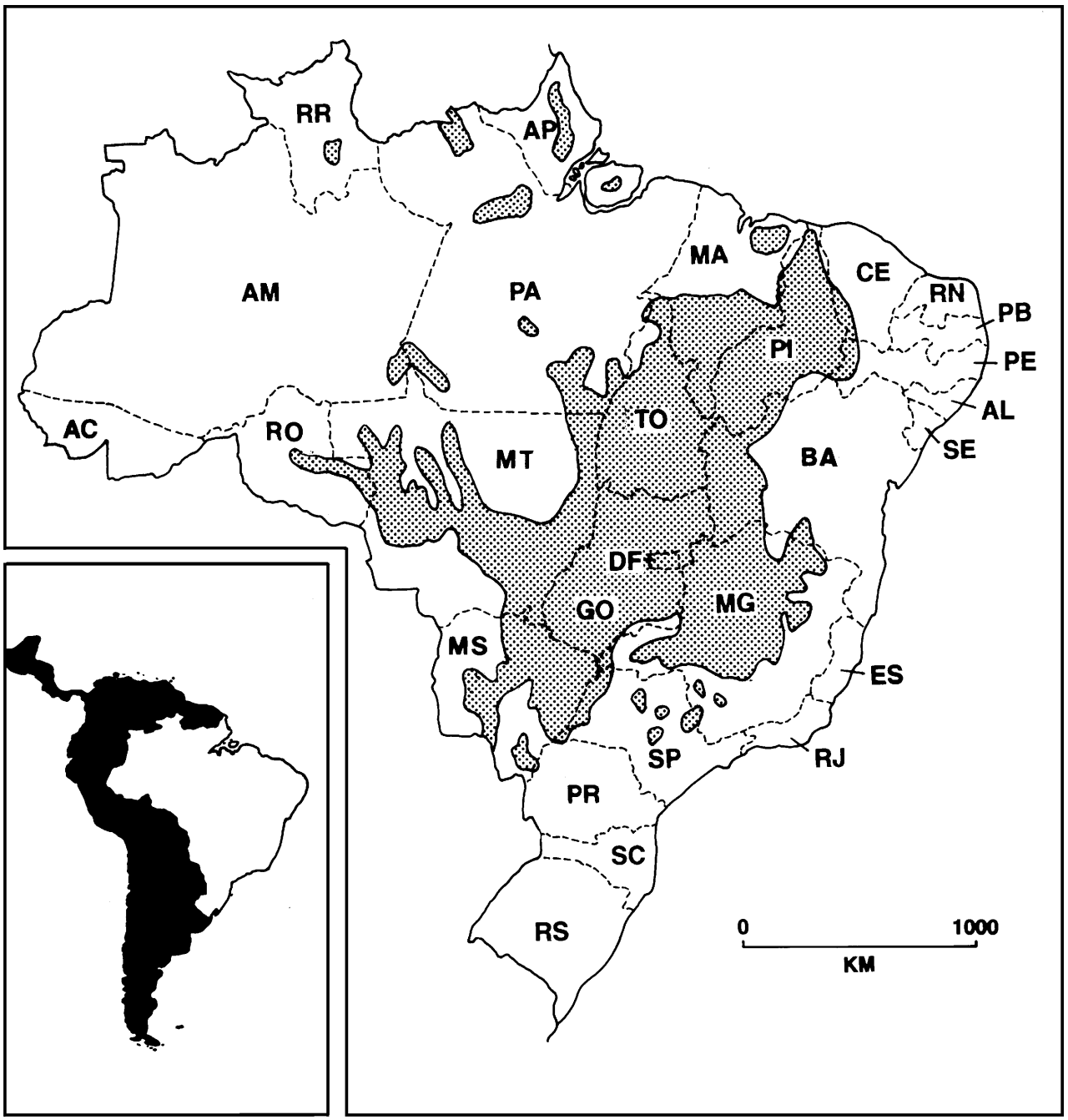


FIG. 1. Distribution of cerrado vegetation in Brazil (letters are state abbreviations). Those referred to in connection with geographical patterns are: DF, Federal District; GO, Goiás; MA, Maranhão; MG, Minas Gerais; MS, Mato Grosso do Sul; MT, Mato Grosso; PA, Pará; TO, Tocantins.

soil fertility gradients (Goodland and Pollard, 1973; Lopes and Cox 1977*b*); the data of others, however, fail to demonstrate this correlation, and show well-developed woodland on no more fertile soils than sparser forms nearby (e.g. Ribeiro, 1983). In many cases, fire is undoubtedly an important factor. The cerrado flora, like that of all savannas, is, of course, resistant to fire and shows all the usual adaptations, such as thick corky bark, xylopodia (lignotubers), tunicate leaf-bases in grasses etc. Nevertheless, too frequent burning causes destruction, particularly of trees and shrubs, and thus favours the herbaceous element of the flora at the expense of the woody.

A brief description of the most widespread form of cerrado will give the reader a better idea of its appearance. It consists of a community of trees and large shrubs, usually about 2–8 m in height, belonging to many species and producing 10–60% cover, with a well-developed grassy ground layer between. The trees are of characteristic savanna

FIG. 2. A, Cerrado vegetation in the dry season; B, charcoal burning following complete clearance of cerrado vegetation; C, soya cultivation in a featureless cleared landscape; D, area cleared and prepared for cultivation in the Federal District.

form, typically with contorted trunk, thick corky bark and hard sclerophyllous leaves; some are evergreen while others are deciduous for variable periods of the dry season. The ground layer is usually up to about 60 cm tall and consists of many species of grasses and sedges mixed with a great diversity of forbs, amongst which Leguminosae, Compositae, Myrtaceae and Rubiaceae are particularly important families. Sometimes the appearance of this low tree cerrado is not unlike an orchard. Many of the trees and smaller plants have strikingly large and colourful flowers, so virgin cerrado often resembles a beautiful wild garden.

Where areas of richer (mesotrophic) soils occur in the cerrado landscape, they are clothed in mesophytic deciduous and semi-deciduous forests. Such areas range from tiny patches where valleys have cut into base-rich rocks, to such extensive enclaves as the Mato Grosso de Goiás, estimated to cover 40 000 km$^2$ (approx. twice the size of Wales) before its destruction for agriculture.

Another conspicuous vegetation type found throughout the cerrado landscape is the wet campo, frequently occurring as a belt between cerrado and gallery forest. Here the water table rises so high during the rainy season that the area is often waterlogged, but falls drastically during the dry season; such fluctuation in moisture availability does not allow tree growth. However, such campos often contain long lines of tall, graceful, *Mauritia flexuosa* L.f. fan palms

and are then called veredas, one of the most beautiful features of the Central Brazilian landscape.

## HISTORY AND BIODIVERSITY

The cerrado is a vegetation formation of great antiquity and there are even suggestions that it existed in prototypic form in the Cretaceous, before the final separation of the South American and African continents (Ratter and Ribeiro, 1996). Unfortunately, however, there is little fossil evidence of the geological history, although deposits which can be interpreted as typical grassy savanna are known from the Tertiary in South America (Van der Hammen, 1983). As is now well known, a dynamic relationship has existed between forest and savanna type vegetation during the Pleistocene with expansion of savannas [probably including mesophytic (deciduous) forest as a dominant element (Prado and Gibbs, 1993; Ratter *et al*., 1988)], and contraction of the Amazonian forest during glacial periods, and *vice versa* during interglacial periods (see, for example, Prance, 1973, 1982). Such processes have produced complicated patterns in both flora and fauna, and fragmentation of populations has probably led to exuberant speciation. A great deal of study has been devoted to this subject in the Amazonian forest but, as yet, such aspects have received only limited attention in the cerrado.

The combination of the great age of the cerrados and the relatively recent (Pleistocene) dynamic phase in distribution patterns has probably led to their rich overall biodiversity, estimated by Dias (1992) as totalling 160000 species of plants, animals and fungi. The long history of the biome has allowed the evolution of complex interactions between organisms, e.g. the exceptionally diverse rust flora showing high specificity to the native angiosperms (J. C. Dianese, University of Brasília, pers. comm.) and the great numbers of insect and other plant galls. More recent disruption of populations probably led to the evolution of many micro-endemic species in the isolated gene pools.

The tree and large shrubby species* of the cerrado are comparatively well known. The base list for these was provided by Rizzini (1963) and added to by Heringer *et al*. (1977). In all, they recorded 774 species belonging to 261 genera, of which 336 species (43%) were regarded as endemic to the vegetation. They considered only the vegetation of the cerrado (tree savanna proper), excluding the associated gallery and mesophytic forests of the biome. Since 1977, much research has been carried out on the floristics and phytosociology of the cerrados and the number of species recorded has increased considerably. Some workers give an estimate of about 1000 species; however, one has to be careful not to include extraneous species (e.g. weedy trees such as cecropias, gallery forest species, etc.) and it is possible that the number of 'true' cerrado tree and large shrub species does not exceed 800. The most important families in terms of species numbers, using the figures of Heringer *et al*. (1977), are: Leguminosae (153 spp., all three subfamilies), Malpighiaceae (46 spp.), Myrtaceae (43 spp.), Melastomataceae (32 spp.) and Rubiaceae (30 spp.). But in many areas the vegetation is dominated by Vochysiaceae (an almost entirely South American family, with 23 spp in the cerrado), largely because of the abundance of three species of *Qualea*, one of the family's largest genera.

Heringer *et al*. (1977) analysed the geographic affinities of the 261 genera they recorded and found that 205 had species in common with the Brazilian Atlantic Forest, 200 with the Amazonian forest, 30 with the mesophytic forests, 51 with species of the cerrado ground layer, while seven (three of which were monotypic) only occurred as cerrado trees. The strongest affinities of the woody vegetation of the cerrado lie then almost equally with the Atlantic and Amazonian rainforests, and in our opinion the cerrado may represent the progenitor of both of these formations.

Recent work by Ratter and Dargie (1992), Ratter *et al*. (1996) and Castro (1994*a*, *b*) have been directed towards discovering patterns of distribution of cerrado vegetation by comparisons using multivariate techniques of floristic surveys covering the entire cerrado region (Ratter and colleagues compared 98 areas, while Castro has worked on a similar number). The results of the two studies are much in accord. Our research demonstrated a strong geographic pattern in the distribution of the flora and allowed the recognition of southern (São Paulo and S. Minas Gerais), southeastern (largely Minas Gerais), central (Federal District, Goiás and parts of Minas Gerais), central-western (largely Mato Grosso, Goiás and Mato Grosso do Sul) and northern regions (principally Maranhão, Tocantins and Pará), as well as a disjunct group of Amazonian savannas (see Fig. 1).

Diversity of trees and large shrubs occurring at a single site (alpha diversity) may reach as many as 120 species per hectare, but is generally considerably lower than this, while at the other extreme it can be less than ten species in the isolated Amazonian savannas. On the other hand, a remarkable intersite heterogeneity (beta diversity) occurs, as demonstrated by our recent work comparing 98 sites throughout the cerrado region (Ratter *et al*., 1996). In total, 534 species were recorded, of which 158 (30%) occurred at a single site only, while none occurred at all sites and only 28 species (5%) were present at 50% or more sites. The extreme floristic heterogeneity (beta diversity) of cerrado vegetation has important consequences for conservation planning, since it will necessitate the establishment of many protected areas to preserve the biodiversity adequately. The sites we have recorded with the highest species numbers ('biodiversity hot-spots') are in Mato Grosso, Goiás (Alto Araguaia region), Tocantins and in the Federal District (see Fig. 1). The number of congeneric species growing together in a small area of cerrado can be surprisingly high: for instance, at the ecological reserve of the University of Brasília in the Federal District, one can find six species of *Miconia* and *Byrsonima*, and five species of *Erythroxylum* and *Kielmeyera*.

Recent research has thrown light on the mechanisms underlying the maintenance of so much diversity in the

* In cerrado, and other savanna vegetations, it is difficult to distinguish between trees and shrubs, and the same species can often be found in flower and fruit between 1–2 m and 15 m in height. We regard the definition of a 'large shrub' as attaining 2 m in height and having perennial aerial woody shoots (i.e. exclusive hemixyles which have woody shoots of short duration).

cerrado vegetation. Various workers have demonstrated that the vast majority of cerrado species so far investigated are obligate outbreeders and that self-incompatibility is very widespread (see Gibbs, 1990), indicating that the breeding systems are such as to promote a high level of outcrossing and thus much diversity and flexibility. In addition, strong barriers to interspecific hybridization in the form of seasonal isolation, differences in pollination systems, and internal genetic barriers, seem to be common. This type of information, detailing how the cerrado really functions at the genetic level, is vital for the long-term planning of conservation strategies. For example, knowledge of breeding systems is important in determining the size of populations which should be conserved to maintain the genetic viability of a species.

The diversity of the ground layer (herbs, subshrubs and small shrubs) is much richer than for taller plants, and species numbers are so high that detailed floristic lists are only available for comparatively few localities. Rizzini (1963) gives figures of more than 500 genera of smaller plants against less than 200 (increased to 261 by Heringer *et al*., 1977) for taller woody vegetation, while the results of detailed studies in the Brazilian Federal District (Ratter, 1986; Pereira, Silva and Mendonça, 1993) show between four and seven times the number of ground layer species compared to trees and large shrubs. A wild 'guesstimate' of the ground layer might suggest about 4000 species, but clearly more research is needed to produce accurate figures. A large number of families are important in the ground layer, particularly Gramineae, Compositae, Leguminosae (all three subfamilies) and Rubiaceae.

So far we have only dealt with species diversity of vascular plants of the 'true' cerrado vegetation (i.e. forms of savanna), but it must be remembered that the cerrado biome also contains an abundance of gallery forests and, where richer soils occur, great extensions of mesophytic forests. A number of recent surveys have shown a much greater diversity of tree/large shrub species in the gallery forests than in the cerrado itself; for instance Cesar (1994) found 260 species in the galleries of the Brasília National Park, but only 109 species in the cerrado (a ratio of 2·4:1), while Pereira *et al*. (1993) list 183 species from the galleries and 84 from the cerrado of the Reserva do Roncador, also in the Federal District (ratio 2·2:1). Furthermore, there are great differences in floristic composition of galleries across the vast cerrado region: those of the west and north show strong links to the Amazonian forests, while those of the centre and south show stronger affinity with the montane semi-deciduous forests of south eastern Brazil (Oliveira-Filho and Ratter, 1995). The great majority of the species of the gallery forests occur in other vegetation formations, but a significant number are 'gallery endemics'. The mesophytic forests have a very characteristic flora, but with a greater tendency for species dominance and a much lower floristic diversity than occurs in the cerrado.

We do not intend to discuss the diversity of groups other than vascular plants here, but some mention is necessary. Dias (1992) has attempted to give estimates for all groups and, as already mentioned, his overall total for the cerrado biome is 160000 species of plants, fungi and animals, of which the numerically most important groups are insects (90000 spp), fungi (40000 spp) and angiosperms (10000 spp). His estimate for angiosperms seems reasonable but, of course, includes all the communities of the cerrado biome: cerrado (savanna) proper, gallery and mesophytic forests, wet campos, etc. The numbers for such well known groups as mammals and birds are 150 and 550 species, respectively, few of which are completely endemic to the biome.

As a final thought on biodiversity, an interesting aspect of the cerrado biome is that, unlike the African savannas, it has lost the fauna of large mammals with which it must have co-evolved throughout the Tertiary. The large herbivores (grazers and browsers) must have been eliminated as a result of competition with North American fauna which migrated across the Panama Land-Bridge in the Great American Interchange 3 million years ago in the late Pliocene, or later in Man's Pleistocene and Holocene Overkill. The only remnants of the ancient neotropical mammalian fauna now occurring in the cerrado biome are Edentates (such as the tamanduá ant-eaters and armadillos), marsupials (such as opossums), platyrrhine monkeys (such as marmosets, howlers and capuchins) and various rodents (such as agoutis, pacas, capybaras and many mouse-sized species). Many larger-fruited plant species probably lost their natural mode of dispersal as a result of the extinction of their native mammalian vectors (see Janzen and Martin, 1982). The reintroduction of grazers in the form of cattle and horses into the natural cerrado vegetation in the last few hundred years probably partially restored the balance of the vegetation to the situation prior to the Great American Interchange.

## MODERN AGRICULTURAL DEVELOPMENT

In the past the cerrado domain was sparsely populated by Brazilian country-people (backwoodsmen and Indians). Much of it was so remote that it only became incorporated into modern Brazilian life relatively recently, with the construction of railways and roads. The population practised little more than subsistence agriculture based largely on low-density cattle-grazing in the cerrado vegetation, raising small crops in clearings in the gallery or deciduous forests, charcoal-burning (if there was an accessible market), and some hunting and fishing. The native vegetation provided materials for housing (timber, palm thatch, etc.), seasonal fruits, fibre, firewood and many other products for the rural economy. All this has now changed, however, and during the last 25 or so years the cerrados have been extensively developed for agriculture with the active encouragement of the Brazilian government. Such development is an important part of the policy to develop the empty centre of Brazil and incorporate it into the national economy: the best known elements of the same policy were the building of the new capital city, Brasília, right in the core of the cerrado area, and the construction of a vast system of national highways.

Encouragement for the agricultural development of the cerrados consisted of various forms of subsidy, extremely generous tax incentives, low interest loans with no indexing (practically a donation in an economy suffering from

hyperinflation during much of the period), guaranteed prices, etc. As intended, such incentives have led to the establishment of a massive, highly mechanized, capital intensive system of agriculture. Cerrado vegetation, with its small trees, is much more easily cleared than tall forest and the soil is of a good structure for cultivation. However, before cultivation can take place a heavy application of lime and fertilizer is necessary to counteract soil acidity and to neutralize aluminium, which is present at toxic levels for virtually all cultivated crops. The cost of this application is about US $340 per hectare and represents nearly twice the purchase price of the virgin land. The arable crops planted are, in order of importance, soya, maize, rice and mandioca (manihot). Soya is grown largely for the export market and occupied 3·9 million hectares of the cerrado area in 1994, producing 8·8 million tonnes, while 4·9 million tonnes of maize were produced. However, far more of the cerrado is exploited as improved pasture, planted with such exotic grasses as *Brachiaria*, *Hyparrhenia rufa* and *Panicum maximum*, than as arable land. It is difficult to find recent figures for the number of cattle raised on the cerrado, but in 1980 it was nearly 48 million and the present number is certainly much higher. The source of all the above figures is Alho and Martins (1995) except for cattle numbers from Wagner (1985).

Clearly the intensive agribusiness practised in the cerrado is only possible with large financial resources, so it is not surprising that a high percentage of the area consists of very large properties: 1985 figures showed that slightly more than 4% of farms had more than 1000 ha but these covered 60% of the total area, whereas more than 50% had less than 50 ha but covered only 0·2% of the area.

The system of cultivation of the cerrado is far from environmentally friendly. The employment of intensive mechanization requires huge tracts of monoculture with great areas of bare soil and the concomitant problems of erosion by rain and wind, while the legally required reserve areas have to be kept in concentrated blocks so that the trees do not impede spraying aircraft. Clearly it would be better if such reserves were dispersed as a web to act as corridors for animals and a more widespread seed source for recolonization. Incidentally, the Brazilian laws for maintenance of reserve areas are extremely enlightened, requiring 50% of land to be kept under natural vegetation in Legal Amazonia and 20% in the rest of Brazil. If such laws were strictly observed, problems of conservation would be greatly reduced. Of the many other environmental problems, heavy, and often careless, use of pesticides and depletion of water reserves by giant rotating irrigators are among the most important.

Obviously the cerrado biome has received a formidable agricultural onslaught and has been much altered during the last 25 or so years. It is estimated that by 1994 some 695000 km², representing 35% of the total cerrado area, had been changed to arable land, planted pasture, or was in altered fallow. Projections for the year 2000 indicate that the figure will have risen to 817–879000 km², representing 41–44% of the total area (figures modified from Alho and Martins, 1995). It is interesting to compare this with the well-publicized figures for destruction of the Brazilian Amazonian rainforest: to date approx. 450000 km² of rainforest, representing some 13% of the original area, have been destroyed—an area far smaller in both absolute and relative terms than that of the cerrado. So much emphasis has been put on the emotive issue of the destruction of the rainforests that the world has largely forgotten the fate of their floristic cousins, the savanna woodlands!

## CHARCOAL PRODUCTION

Charcoal production for Brazil's steel industry exerts pressure on the cerrado secondary only to agriculture. The two are often closely interlinked, as the trunks and roots of trees from the areas cleared for cultivation are usually used for charcoal production, partially off-setting the costs of preparation of the land. The process is carried out *in situ* and one sees huge extensions of cleared land with rows of domed kilns emitting smoke and adding to the holocaust-like appearance of the landscape!

The Brazilian steel industry has always depended on charcoal and this has traditionally been derived from native forests and woodlands, particularly those of the cerrado. Today the steel mills in the state of Minas Gerais, lying in the cerrado region, are the largest charcoal users in the world (Alho and Martins, 1995). However, because of increasing difficulties in supply from native sources, charcoal from eucalypt plantations is now also being used and its contribution is growing. Figures for charcoal consumption from 1980 to 1991 (Alho and Martins, op. cit.) show a peak in 1989 of about 45000 m³, of which 71% was derived from native vegetation. By 1991 the figure had dropped to 30500 m³, (no doubt as a result of a downturn in the economy) of which 57% came from native vegetation. Probably more recent figures will show a strong upturn since steel production is closely linked to the performance of the economy.

## CONSERVATION—THE WAY AHEAD

The value of the species-rich cerrado biome has always been undervalued as an important centre of biodiversity. It stands alone among the major biomes of Brazil in not being recognized in the Brazilian Constitution as a National Heritage (Alho and Martins, op.cit.): a status accorded to the Amazon, Atlantic Rainforest, Pantanal and coastal areas. The cerrado has always been regarded as the poor relative of the so-called rainforests, and this is shown very strongly in the allocation of international aid, e.g. the Pilot Programme for the Protection of Tropical forests in Brazil to be financed by G-7. However, this attitude is now changing and the Brazilian Ministry of the Environment's National Biodiversity Programme (PRONABIO) and bodies interested in conservation and rational use of the environment are now acting in concert. Specialists of Brazilian Government-financed institutes such as IBAMA (the Brazilian Environmental Institute), EMBRAPA CPAC (Centre for Agricultural Research in the Cerrado) and CENARGEN (National Centre for Genetic Resources and Biotechnology) and other scientists are well aware that urgent action must be taken to safeguard the existence and

viability of the biome. In addition, non-governmental organizations such as FUNATURA, ISPN and WWF Brazil are active in the field and the last has recently produced a valuable assessment of the situation (Alho and Martins, 1995) and is doing pioneering work in establishing extractive reserves.

One matter of urgency is to increase the area of Federal Conservation Units. At present they represent only 1·5% of the total area and Alho and Martins (op.cit.) suggest that this should be at least tripled. However, research is required to choose the location of such reserves as the cerrado biome is floristically very heterogeneous and constitutes a biological mosaic (Ratter and Dargie, 1992; Castro 1994*a*; Ratter *et al*., 1996). Teams from the University of Brasília, CPAC and the Royal Botanic Garden Edinburgh have been collaborating on this project for a number of years funded by Brazilian, European Community and British funds. The project has recently been expanded into a major Anglo-Brazilian initiative, *Conservation and Management of the Biodiversity of the Cerrado Biome*, with UK Overseas Development Administration funding. Its aim is to survey the floristic patterns of cerrado vegetation and to discover representative areas and biodiversity 'hot-spots'. The method used covers the whole of the cerrado area with a grid of 1° latitude × 1°30′ longitude and plots how much information exists for each grid rectangle. Priority is given to areas where there are (*a*) little or no data, or (*b*) indications of exceptional diversity. Experienced field teams then carry out rapid surveys with techniques designed to provide the maximum data in the minimum time. The first two priority areas identified were the states of Mato Grosso do Sul and Tocantins. The survey of the former was completed last year and work in Tocantins will commence this year. A second team of the project led by Professor A. J. F. Castro (Federal University of Piauí) is studying the little-known cerrados of north-eastern Brazil (Castro *et al*., 1998). In addition, a separate initiative, the long-standing *Biogeografia dos Cerrados* project led by Prof. Jeanini Felfili-Fagg (University of Brasília) concentrates on the Chapada Pratinha (in the central cerrado core area) and is producing complementary results.

In conclusion, a growing body of scientific and lay opinion is realizing the urgency of protecting the rich biodiversity of the cerrado. Although vast areas of the biome have been exploited, and in some southern states, e.g. São Paulo, only tiny vestiges remain, one hopes that with increased scientific effort and political will a satisfactory conservation situation can be achieved.

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