Conservation of the Brazilian Cerrado

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Abstract: *The Cerrado is one of the world's biodiversity hotspots. In the last 35 years, more than 50% of its approximately 2 million km² has been transformed into pasture and agricultural lands planted in cash crops. The Cerrado has the richest flora among the world's savannas (>7000 species) and high levels of endemism. Species richness of birds, fishes, reptiles, amphibians, and insects is equally high, whereas mammal diversity is relatively low. Deforestation rates have been higher in the Cerrado than in the Amazon rainforest, and conservation efforts have been modest: only 2.2% of its area is under legal protection. Numerous animal and plant species are threatened with extinction, and an estimated 20% of threatened and endemic species do not occur in protected areas. Soil erosion, the degradation of the diverse Cerrado vegetation formations, and the spread of exotic grasses are widespread and major threats. The use of fire for clearing land and to encourage new growth for pasture has also caused damage, even though the Cerrado is a fire-adapted ecosystem. Ecosystem experiments and modeling show that change in land cover is altering the hydrology and affecting carbon stocks and fluxes. Cerrado agriculture is lucrative, and agricultural expansion is expected to continue, requiring improvements in and extension of the transportation infrastructure, which will affect not only the Cerrado but also the Amazon forest. Large-scale landscape modification and threats to numerous species have led to renewed interest from various sectors in promoting the conservation of the Cerrado, particularly through strengthening and enlarging the system of protected areas and improving farming practices and thus the livelihoods of local communities.*

Conservación del Cerrado Brasileño

Resumen: *El Cerrado es uno de los sitios de importancia para la biodiversidad global. En los últimos 35 años, más de 50% de sus aproximadamente 2 millones de km² ha sido transformado en tierras agrícolas con cultivos comerciales y de pastoreo. El Cerrado tiene la flora más rica entre las sabanas del mundo (>7000 especies) y altos niveles de endemismo. La riqueza de especies de aves, peces, reptiles, anfibios e insectos es igualmente alta, mientras que la diversidad de mamíferos es relativamente baja. Las tasas de deforestación han sido mayores en el Cerrado que en la selva lluviosa del Amazonas, y los esfuerzos de conservación han sido modestos: solo 2.2% de su superficie esta legalmente protegido. Numerosas especies de animales y plantas están amenazadas de extinción, y se estima que 20% de las especies amenazadas y endémicas no existen en áreas protegidas. La erosión del suelo, la degradación de diversas formaciones vegetales y la expansión de pastos exóticos son las amenazas principales y generalizadas. El uso de fuego para desmontar terrenos y estimular pastura nueva también ha causado daño, a pesar de que el Cerrado es un ecosistema adaptado al fuego. Experimentos y modelos del ecosistema muestran que el cambio en la cobertura del suelo esta alterando la hidrología y afectando las reservas y flujos de carbono. La agricultura en el Cerrado es lucrativa, y se espera que la expansión agrícola continué, lo que requerirá de mejoras en y la extensión de la infraestructura de transporte, lo que no solo afectará al Cerrado sino también a la selva Amazónica. Debido a la modificación del paisaje a gran escala y las amenazas a numerosas especies, hay un renovado interés de varios sectores para promover la conservación del Cerrado, particularmente mediante el reforzamiento y expansión del sistema de áreas protegidas, el mejoramiento de las prácticas agrícolas y del medio de vida de las comunidades locales.*

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The Brazilian Cerrado

Cerrado is the Portuguese word for central Brazil's plateau of woodlands, savannas, grasslands, and gallery and dry forests (Eiten 1977; Ribeiro et al. 1981). The Cerrado is the second largest of Brazil's major biomes, after Amazonia. Occupying 21% of the country's land area, it is one of the world's last great frontiers (Borlaug 2002). The climate is seasonal—wet from October to March and dry from April to September—and mild year around, with temperatures ranging from 22° to 27° C. Average annual rainfall is 1500 mm. The remnant Cerrado ecosystems we see today have developed on old, highly weathered, deep, acidic, poor soils that have high concentrations of aluminum, which many native trees and shrubs accumulate in their leaves (Haridasan 1982). Fertilizer and lime are required to correct soils for loss of crop productivity caused by the high aluminum levels, but this has been no obstacle to the conversion of vast tracts of land to agriculture (primarily soybeans, today one of Brazil's biggest exports) and cattle ranching.

More than half of the Cerrado's 2 million km^2 has been transformed into pasture, cash-crop agriculture, and other uses in the past 35 years (Table 1). Pastures cultivated with African grasses cover at least 500,000 km^2, and crops cover more than 100,000 km^2. The area under conservation is roughly 33,000 km^2.

The destruction of the forest, woodlands, and savannas of the Cerrado continues at a fast pace. Using MODIS imagery data from 2002, a recent survey showed that 55% of Cerrado has already been cleared or transformed for human uses (Machado et al. 2004*b*). This is about 880,000 km^2—three times the deforested area in the Brazilian Amazon. Annual clearing is also higher: between 1970 and 1975, the average was 40,000 km^2/year—1.8 times the deforestation rate for the Amazon from 1978 to 1988 (Klink & Moreira 2002). Current deforestation ranges from 22,000 to 30,000 km^2/year (Machado et al. 2004*b*), still higher than that seen in Amazonia. This difference is, at least in part, due to the fact that Brazil's Forest Code requires that 20% of a holding in the Cerrado be maintained in its natural state as "legal reserve." In the Amazon rainforest, this portion is 80%.

This transformation has come at a high environmental cost—fragmentation, loss of biodiversity, invasive species, soil erosion, water pollution, land degradation, changes in fire regime, imbalances in the carbon cycle, and probable regional climate modification. Although the Cerrado is a fire-adapted ecosystem, burning regimes for pasture (frequent burning to stimulate new growth) have resulted in major problems with leaching, soil impaction, and erosion that cover enormous areas, especially in the more montane regions such as eastern Goiás and western Minas Gerais. Fire avoidance and control can also result in soil degradation and native flora loss. Farmers tend to burn at the end of the dry season when fuel (plant biomass) is high and humidity is low, resulting in fires that are extremely hot and prejudicial to plants and soil fauna (Klink & Moreira 2002).

Species Richness

The Cerrado has a rich and generally unappreciated biodiversity. The number of vascular plants exceeds that of most floras in the world: known herbs, shrubs, trees, and lianas exceed 7000 species (Mendonça et al. 1998). Forty-four percent of the flora is endemic (Table 2), and in this sense the Cerrado is the richest tropical savanna in the world. There is high habitat diversity and species turnover. For instance, a floristic survey revealed that of 914 trees and shrubs recorded in 315 Cerrado sites, only 300 species occurred at more than 8 sites, and 614 species were found in just 1 site (Ratter et al. 2003).

Although higher than previous counts, the latest revision of the mammal fauna still indicates that it is relatively poor at 199 species (Aguiar 2000; Marinho-Filho et al. 2002). Mammals are mostly associated with or restricted to forest patches or gallery forests (Redford & Fonseca 1986). The avifauna is rich (>830 species), but

Table 1. Principal land use in the Cerrado.[a]

Land use	*Area (ha)*	*Percent core area[b]*
Native areas[c]	70,581,162	44.53
Planted pastures	65,874,145	41.56
Agriculture	17,984,719	11.35
Planted forests	116,760	0.07
Urban areas/bare soil	3,006,830	1.90
Others	930,304	0.59
Total	158,493,921	

[a] *Categories classified according to extent of land cover (Machado et al. 2004a).*
[b] *Core area of the Cerrado.*
[c] *Estimates without ground truthing and including native areas with varying protection.*

Table 2. Number of species, percent endemism, and the proportion of estimated species richness in Brazil for vertebrates and plants.*

	No. of species	*Endemic to the Cerrado (%)*	*Percentage of total species occurring in Brazil*
Plants	7,000	44	12
Mammals	199	9.5	37
Birds	837	3.4	49
Reptiles	180	17	50
Amphibians	150	28	20
Fishes	1,200	?	40

* *Sources: Fonseca et al. 1999; Fundação Pró-Natureza et al. 1999; Aguiar 2000; Colli et al. 2002; Marinho-Filho et al. 2002; Oliveira & Marquis 2002; Aguiar et al. 2004.*

Table 3. Protected areas in the major Brazilian biomes—strictly protected areas, protected areas of sustainable use, and indigenous reserves compared.[a]

Biome	*Area (km²)*	*Strictly protected areas[b]*	*Sustainable use areas[c]*	*Indigenous lands*
Cerrado	2,116,000	2.2	1.9	4.1
Amazon rainforest (includes ecotones)	4,239,000	5.7	7.7	17.7
Atlantic Forest	1,076,000	1.9	0.11	0.15
Pantanal	142,500	1.1	0	2.4
Caatinga	736,800	0.8	0.11	0.15
Brazil	8,534,000	3.5	3.4	8.8

[a] *Values are given as percentages of the original extent of the biome (Cavalcanti & Joly 2002; Arruda 2003; Rylands et al. 2005).*
[b] *Based on World Conservation Union categories I to III.*
[c] *Federal and state protected areas.*

endemism is low (3.4%). The numbers of fishes, reptiles, and amphibians are high. Although the number of endemic fishes is not known, endemism for the herpetofauna is much higher than for mammals or birds (Table 2). Invertebrates are poorly known, but estimates place insects at 90,000 species (Dias 1992), or an estimated 13% of the butterflies, 35% of the bees, and 23% of the termites of the Neotropics (Cavalcanti & Joly 2002). Despite this rich biodiversity, the Cerrado has received less attention than the Amazon or Atlantic forests in terms of conservation measures. Only 2.2% is legally protected (Table 3), and the indications are that 20% of endemic and threatened species remain outside of any of the region's parks and reserves (Machado et al. 2004*a*).

The Cerrado is one of the world's biodiversity hotspots (Myers et al. 2000; Silva & Bates 2002). At least 137 Cerrado animals are threatened with extinction (Fundação Biodiversitas 2003; Hilton-Taylor 2004) because of large-scale agricultural expansion and intensive local harvesting of forest products. In the Federal District (Brasília), for example, the livelihoods of hundreds of those living in poverty depend on trade in wild ornamental plants—one species is reported already extinct there and 30 others are threatened (L. Marsicano, unpublished data).

Habitat loss is leading to the loss of wild crop varieties. For example, the Cerrado is the center of diversity for cassava (*Manihot* sp.), a major food for more than 600 million people in the tropics (Olsen & Schaal 1999). Wild *Manihot* species retain vital genetic varieties for selection of, for example, protein content or tolerance to drought. Of 41 identified and surveyed in the late 1970s (Nassar 2004), only one locality remains for wild *Manihot* varieties.

Major Threats to Biodiversity

Soil and ecosystem degradation and the spread of exotic species are widespread and major threats. With poor soil management, erosion can be high: under conventional soybean cropping, topsoil loss is on average 25 tons/ha/year, although conservation practices such as minimum till can reduce erosion to 3 tons/ha/year (Rodrigues 2002). About 45,000 km² of the Cerrado is fallow land, where soil erosion can be as high as 130 tons/ha/year (Goedert 1990). Agricultural practices in the Cerrado include extensive use of fertilizers and lime (Müller 2003), which pollute streams and rivers. In addition, the widespread use of African grasses for pasture is detrimental to biodiversity, fire cycles, and ecosystem productive capacity (Berardi 1994; Barcellos 1996; Pivello et al. 1999; Klink & Moreira 2002;). For pastures, the savannas are first clearcut and burned and then seeded with grasses of African origin, such as *Andropogon gayanus* Kunth., *Brachiaria brizantha* (Hochst. ex A. Rich.) Stapf, *B. decumbens* Stapf, *Hyparrhenia rufa* (Nees) Stapf, and *Melinis minutiflora* Beauv. (molassa or fat grass) (Barcellos 1996). Half of the planted pastures (about 250,000 km²—an area equivalent to the state of São Paulo) are degraded and support few cattle because of reduced plant cover, invasion by unpalatable plants, and termite mounds (Barcellos 1996; Costa & Rehman 2005).

Invasive African grasses are major agents of change in the Cerrado. One of the most widely used is the molassa, which is highly disruptive for biodiversity and ecosystem functioning (Mack et al. 2000). Although superseded by African species in terms of its productivity, it is widespread in disturbed areas, roadsides, abandoned plantations, and nature reserves in the Cerrado (Berardi 1994; Pivello et al. 1999). It can attain extremely high biomass and, when dry, is highly combustible, initiating a grass-fire interaction capable of preventing the regrowth of natural vegetation (Berardi 1994). Where molassa becomes predominant, the local flora is considerably depressed. Fires of molassa-dominated grasslands are hotter, have a longer residence time, and generate bigger flames, which can reach the tree canopies. This alters succession on the surface and is more damaging to the soil fauna and fossorial species than fires typical of native Cerrado vegetation.

Fire is generally used to clear land. Tansey et al. (2004) estimated that 67% of the area burned in Brazil in 2000 was in the Cerrado. Frequent burnings negatively affect

tree and shrub establishment (Hoffmann & Moreira 2002), besides releasing carbon dioxide (CO_2) and other greenhouse gases (Krug et al. 2002). Simulations modeling the conversion of natural Cerrado into planted pastures show that precipitation may be reduced by up to 10%, dry spells may become more frequent, and mean surface air temperature may increase by 0.5° C (Hoffmann & Jackson 2000), with major implications for agriculture. Field studies demonstrate that the ability of Cerrado trees and shrubs to tap water stored deep in the soil during the dry season may be critical in the maintenance of the hydrological cycle (R.S. Oliveira et al., unpublished data). Some climate-change scenarios predict contractions in the distributions of many Cerrado tree species of more than 50% (Siqueira & Peterson 2003). By 1998, 49% of the Rio Tocantins basin had been converted to cropland and pastures, increasing river discharge by 24% (Costa et al. 2003). Widespread and illegal clearing of riparian forests reduces freshwater supplies for urban areas (Müller 2003).

Most of the Cerrado biomass is underground—up to 70% depending on the dominant vegetation (Castro & Kauffmann 1998). It is likely that there have been changes in the regional carbon stocks, considering the extent of landscape modification. Planted pastures may accumulate carbon if they are well managed (Davidson et al. 1995; Silva et al. 2004), but the extent of degraded pastures is already so high that they fail to serve as atmospheric CO_2 sinks (Silva et al. 2004). The CO_2 fluxes from planted pastures to the atmosphere are faster and more seasonably variable than native Cerrado (Varella et al. 2004).

Conservation Initiatives

The widespread transformation of the Cerrado landscapes and the threatened status of many of its species have led to an upsurge in conservation initiatives from government, nongovernmental organizations (NGOs), researchers, and the private sector. A network of NGOs (Rede Cerrado) has been established to promote sustainable-use practices for natural resources at the local level (Fundação Pró-Natureza 2000). In 2003 the Rede released a white paper for the Brazilian Ministry of the Environment with recommendations for urgent actions for conservation in Cerrado. The ministry consequently set up a working group, which in 2004 proposed a conservation program (Programa Cerrado Sustentável), building on the results and resolutions of the Cerrado priority-setting workshop held in 1998 (Fundação Pró-Natureza et al. 1999) and integrating actions for conservation in regions where agropastoral activities have been especially intense, damaging, and widespread.

State governments, such as that of Goiás, are focusing on creating protected areas and extending and consolidating existing protected areas, particularly with a view to establishing ecological corridors. Capacity building and technical assistance to farmers have been implemented simultaneously. As an important first step, Goiás prepared its own "state of the environment" assessment. Based on the Global Environment Outlook framework of the U.N. Environment Programme, the assessment identifies impacts on biodiversity and establishes state responses, involvement of civil society (e.g., Goiás Agenda 21), a legal framework, and recommendations of priorities (Galinkin 2003).

Conservation International, The Nature Conservancy, and the World Wide Fund for Nature (WWF) all have conservation programs in the Cerrado. Conservation International is working with the states of Goiás, Mato Grosso, and Mato Grosso do Sul, local NGOs, academia, and the private sector to establish biodiversity corridors, such as the "Emas-Taquari" and the "Cerrado-Pantanal," that maintain the integrity of protected areas in modified landscapes. Conservation International has also participated in the creation of state and federal conservation units in the Jalapão complex (Tocantins state), the largest contiguous conservation area in the Cerrado. Since 1994, WWF has been working on the establishment of a biosphere reserve centered on the Chapada dos Veadeiros National Park, has initiated projects supporting indigenous communities in the development of game management plans (in Mato Grosso and Goiás), and is also collaborating with the management of aquatic ecosystems in the Federal District (WWF 1994). The Nature Conservancy was involved in the recent expansion (May 2004)—by 147,000 ha—of the Grande Sertão Veredas National Park in northern Minas Gerais, which now extends into the state of Bahia and totals 231,000 ha (TNC 2004). All three NGOs have embarked on the promotion of alternative economic activities (e.g., ecotourism, sustainable use of fauna or flora products, medicinal plants) to support the livelihoods of local communities. The World Bank has proposed a biome-wide ecological and economic zoning (World Bank 2003) to stimulate support from both national and international agencies for the conservation and rational development of the region.

Trade-Offs between Land Use and Conservation

Expanding and modernizing agriculture in the Cerrado has generated positive socioeconomic impacts—agricultural production for Brazil's domestic and export markets, for example, has increased. Other benefits of modern technology have been gains in productivity, diversification of local economies, increased municipal revenues, and improvements in welfare services in some localities (Bonelli 2001). The Brazilian Congress recently approved the cultivation of genetically modified crops, particularly soybean and cotton, which will bring production costs down and stimulate their expansion in the Cerrado. This

will certainly have an impact on other ecosystems, particularly the Amazon Forest. Low investment since the mid 1980s has been prejudicial to the road network in the Cerrado, but considering the economic importance of Brazil's soybean production, it is now likely that considerable investments will be made for its repair and maintenance. Cerrado soy producers currently pay much higher transport costs than their major competitors in the international markets, the United States and Argentina. Infrastructure improvements include links between the Cerrado and the Amazon (e.g., the paving of the BR-163 from Cuiabá to the port of Santarém on the Rio Amazonas), a major cause of deforestation (Alencar et al. 2004).

Assessing trade-offs helps conservation by "mainstreaming" biodiversity and ecosystem functioning into the development debate. Lack of knowledge and uncertainty about drivers of deforestation have complicated and stalled conservation and management initiatives in the past. Our understanding of causes and mechanisms has improved enormously in recent years (Oliveira & Marquis 2002), but its impact on conservation has been modest, partly because a more precise targeting of research problems within a general framework of priorities is lacking for the region as a whole, but also because the beneficiaries and the potential users of the results have not been identified. Valuable knowledge gained through research is not well disseminated because appropriate networks and channels of communication are missing. Major efforts must be dedicated to the dissemination of best practices. A good example is the introduction of minimum till systems in the early 1980s to cope with inadequate soil management. Today this method of land management prevails in the better-developed agricultural zones of Cerrado (Rodrigues 2002; Müller 2003).

Past land-use policies were often formulated with little attention to their implications for Cerrado conservation, in part because the Amazon Forest was the main focus of the conservation agenda. There is, however, a window of opportunity for large-scale action for Cerrado conservation. Given the high level of habitat and landscape modification and degradation that has already occurred, the highest priority should be given to strengthening and rationalizing the protected areas system.

The 1998 Cerrado priority-setting workshop selected 87 areas for conservation, based on biological indicators such as species richness and the occurrence of endemic, rare, threatened, or migratory species (Fundação Pró-Natureza et al. 1999). Only now are policy makers using this knowledge (Cavalcanti & Joly 2002). Priority setting should also consider the diversity of ecosystems and habitats in the Cerrado. Policies on the extent to which it should be preserved or used for production will be meaningful only if the spatial scale of analysis is recognized explicitly because of the different scales (e.g., topography, proximity to markets, existence of infrastructure, and presence of NGOs) at which the determinants of the degree and form of agricultural expansion in the Cerrado act (Pufal et al. 2000). Policy formulation must make use of existing knowledge of species and habitat diversity and ecosystem functioning because landscape modification has serious and long-term implications for the occurrence of bushfires, for water and carbon cycling, and possibly even for climate modification. Finally, the creation of legal tools such as compensation mechanisms would increase the involvement of the private sector, which is necessary for the conservation of the world's richest savanna ecosystems.

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