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The "*Lavrados*" of Roraima: Biodiversity and Conservation of Brazil's Amazonian Savannas

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ABSTRACT

The savannas (*lavrados*) of Roraima are located in the far northern portion of the Brazilian Amazon and are part of the "Savannas of Guyana" ecoregion of the Amazonian Biome. They cover an area of approximately 43,358 km^2, or 70% of the total area of savannas that straddle the borders of Brazil, Guyana and Venezuela. This ecoregion contains diverse types of phytophysionomies forming a mosaic of non-forest (open areas) and forest ecosystems associated with different soil types, altitudinal gradients and climates. This diversification of ecosystems generates a great heterogeneity of habitats and is reflected in the diversity of plants and animals. The few existing studies of biological diversity are almost all concentrated along the main highways and therefore fail to indicate the true magnitude of the biodiversity of Roraima's savannas. In spite of Brazilian authorities having classified these ecosystems as having extremely high priority for conservation, no protected areas exist in the savannas of Roraima. However, 57.3% are protected in the form of Indigenous Lands. Large rural properties and settlements occupy 19.4% of the total area. The number of settlements in these savannas can be expected to increase significantly in the coming years due to legal impediments to creation of settlements in forest areas in Amazonia and due to the expansion of soy production, irrigated rice and commercial tree plantations in the state. It is estimated that 23.3% of the savanna area in Roraima is still available for creation of conservation areas.

Keywords: fauna, flora, cerrado, protected area, Rio Branco, Rio Rupununi

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INTRODUCTION

Savannas are tropical phytophysionomies with open vegetation dominated by the herbaceous stratum (herbs and grasses), where trees and bushes may or may not be present (Sarmiento 1984: Eiten 1986: Huber 1987). The largest continuous block of savannas in the northern portion of the Brazilian Amazon is located in the state of Roraima. Under the classification of biomes and ecoregions that Brazil's Ministry of Environment adopts for the national territory as a whole, this landscape group belongs the "Savannas of Guyana" ecoregion, which is a part of the Amazonian Biome (Ferreira 2001; Capobianco *et al*. 2001; WWF 2007). These savannas are part of the "Rio Branco-Rupununi" great landscape complex that occurs at the borders of Brazil, Guyana and Venezuela (Myers 1936; Beard 1953; Eden 1970). The most recent estimate made using the SIPAM (2004) georeferenced database at a scale of 1:250,000, and the work of Alencar *et al*. (2006), indicates that the area of this landscape complex in the three countries covers approximately 61,664 km^2 (**Fig. 1**). Of this total, 43,358 km^2 (70%) is located in Roraima (Brazil).

In Roraima, these great extensions of savannas are denominated "*campos do Rio Branco*" or "*lavrado*". The latter term is very common among the local inhabitants and was introduced in the literature by Luciano Pereira (1917), although the term had long been in popular use in the region (Barbosa and Miranda 2005). This terminology is derived from archaic Portuguese language, but it can still be found in the current dictionaries, meaning a "... *place where trees are absent*" (Vanzolini and Carvalho 1991). The word "cerrado" can also be used to describe this vegetation in the far

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Invited Review

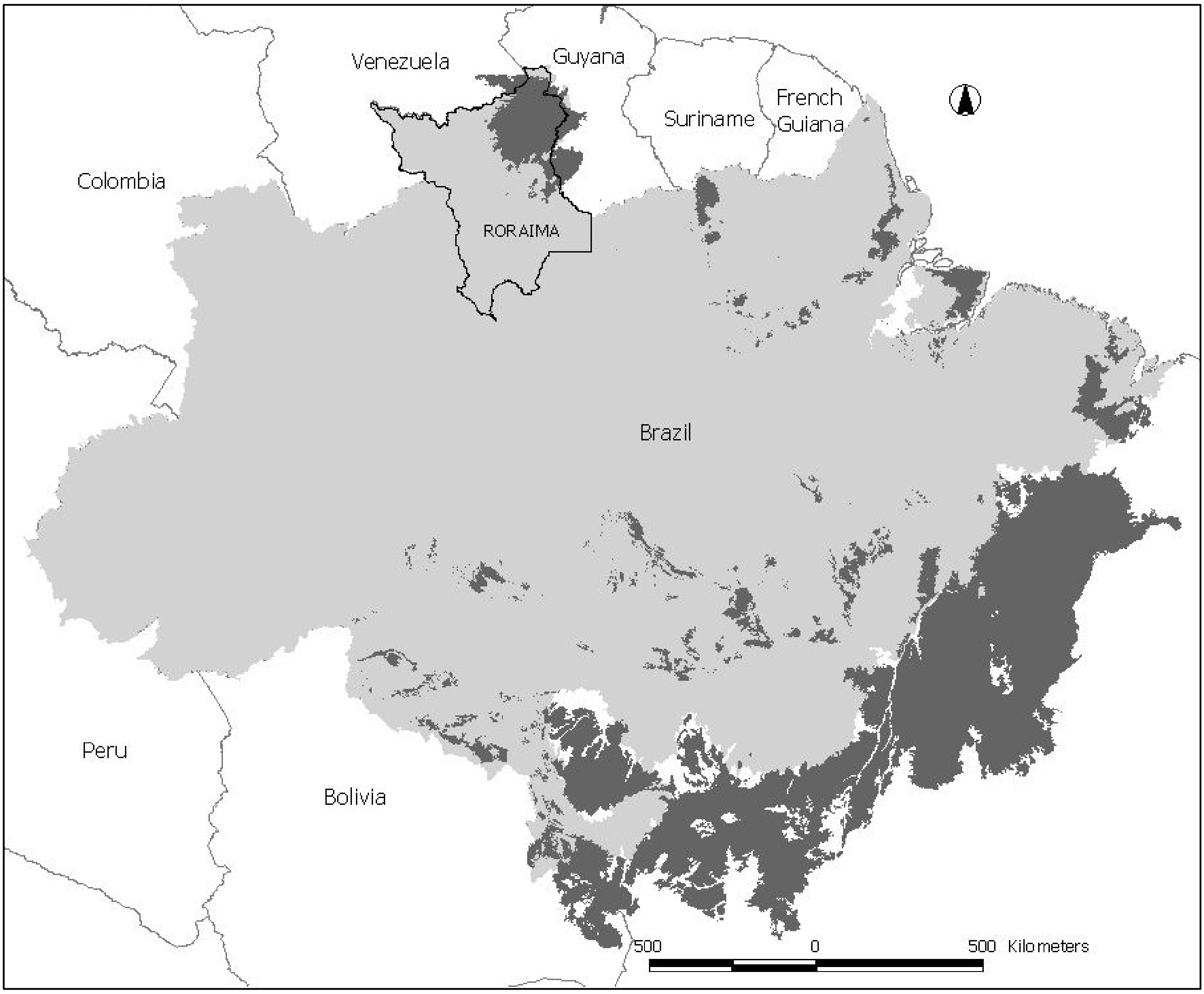

Fig. 1 Approximate distribution of savannas (dark grey) in the Amazonian Biome (light grey), including areas of the *cerrado* biome (central Brazil). The highlighted area on the map in the far northern part of Brazil is the state of Roraima and the savanna complex at the borders of Brazil, Guyana and Venezuela (see Alencar *et al* 2006).

northern part of Amazonia because it defines physiognomies in the Brazilian Cerrado Biome that are very similar in their structure and in the organization of the landscape. However, the savannas of the Amazonian north are phytoecological formations that are distinct from those of central Brazil with both functional and floristic differences (Eiten 1977; Ratter *et al*. 1996, 2003). This being the case, the terms *lavrado*, *savanna* and *cerrado* can all be used to identify the landscape of open vegetation located at the borders of Brazil, Guyana and Venezuela.

Construction of the current landscape

The process of construction of the current landscape of savannas in this northernmost portion of the Brazilian Amazon is directly linked to tectonic events and to past fluctuations of climate and erosion (Ruellan 1957; Brazil 1975; Carneiro-Filho 1991; Schaefer and Vale Jr. 1997). Most of this landscape is found on the Boa Vista Formation, which is the geomorphological result of an erosional leveling that totally buried the Takutu's Graben with more than 2000 m of sediments derived from the destruction of remnants of the Roraima Group (Schaefer and Vale Jr. 1997). This geological formation is a flat surface dated to the Pre-Cambrian (1.8-2.0 billion years before present - BP) and, Takutu's Graben, is an extrusion caused by tectonic collapse that was produced by distensive forces in the Earth's crust at the end of the Jurassic, when the separation of the Gondwana supercontinent began (± 190 × 10^6 years BP) (Brazil 1975). This lateral leveling of very old surfaces gradually imposed a new landscape on this area, which subsequently came to be dominated by very open and dry vegetation with low plants: continental vegetation with predominantly Cryptogrammic plants. This landscape must have dominated from the Cretaceous (± 70-100 × 10^6 years BP) until the pre-Tertiary period (± 60-65 × 10^6 years BP) over almost all of northern South America. Starting from the Eocene (± 55 × 10^6 years BP), with climatic conditions becoming more and more humid, the vegetation of the Cretaceous was progressively replaced by graminoid plants (Poaceae and Cyperaceae) and herbs (an increasing presence of low-stature Phaneragammic vegetation), with a greater level of diversification, creating landscapes similar to the current savannas. These physiognomies of more recent geological periods must have dominated the entire landscape in northern South America starting from the Miocene/Pliocene (12-23 × 10^6 years BP), according to Schaefer and Vale Jr. (1997) based on the paleoecological studies of van der Hammen and Wijmstra (1964) and van der Hammen (1982).

Throughout almost all of the Tertiary, the hydrographic drainage in the locations that are now occupied by the savannas of Roraima emptied into the Atlantic Ocean via the Caribbean, with a great load of sediments being deposited along all of the former bed of Takutu's Graben (Schaefer and Dalrymple 1996). The Amazonas/Proto-Berbice paleodivide, which was the great divide between the Amazon River basin and those of the Essequibo and Orinoco in this area, was eroded more intensely beginning in the Oligocene

($25\text{-}30 \times 10^6$ years BP) in the southernmost portion; more or less in the area of the "Bem Querer" rapids (approximately 2°N, 61°W). This meant that the entire drainage of this area was captured in a single great hydrographic basin, the Branco River, which now flows into the Negro River, the largest tributary on the left bank of the Amazon River (Cooper 1981). Since this was already the case in the Pleistocene, between the end of the Tertiary and the beginning of the Quaternary ($1.8\text{-}2.0 \times 10^6$ years BP), this whole area already had a landscape that was very similar to the current one, forming a large continuous block of open vegetation.

Throughout the Quaternary and up to the present day the construction of the current landscape of savannas has been influenced by short-period climatic cycles (glacial and inter-glacial), with the result that the limits between the savannas and the continuous areas of forest fluctuate as a function of the changes in climate (Carneiro-Filho 1993; Dejardins *et al*. 1996; Simões-Filho *et al*. 1997; Toledo 2004). Therefore, this whole area of savannas at the northern edge of the Brazilian Amazon, which also covers the southern part of Venezuela and the western part of Guyana, can be considered as a "relict" landscape that appeared during the more recent dry periods of Pleistocene in the Amazon (Eden 1974; Carneiro-Filho 1990). In this case, the term "relict" expresses a remnant of old formations of savannas that dominated a large part of northern South America, providing ecological patterns and specific biological diversity in these remaining areas. Although this entire great ecoregion is now almost totally confined to what is today the Boa Vista Formation (Ab'Saber 1997), with most of the relief being of low altitude (80-120 m), several savanna phytophysionomies can be recognized in a gradient that reaches altitudes as high as 2000 m, thus providing a rich set of terrestrial and aquatic ecosystems.

Physical-climatic characterization

The climate that characterizes the savannas of Roraima is Awi (tropical humid without a cold season) under the Köppen classification (Nimer 1972; Barbosa 1997). The most complete historical series for the area is for the city of Boa Vista (capital of Roraima), located in the center-south portion of the local savannas. The precipitation measured at the Boa Vista Meteorological Station, operated by the National Institute of Meteorology (INMET) has an annual average of 1612 ± 400 mm for the 1910-2003 period, while the monthly average relative humidity of the air ranges from 66 to 82% (modified from Barbosa 1997; Araújo *et al*. 2001). The driest months are between December and March (± 10% annual precipitation), and the rainiest months are between May and August (± 70% annual precipitation) (**Fig. 2**).

This climatological pattern can be considered as a general average for savanna ecosystems in the center-south portion of this ecoregion. However, because they are the result of various erosion and climatic cycles, the Roraima's

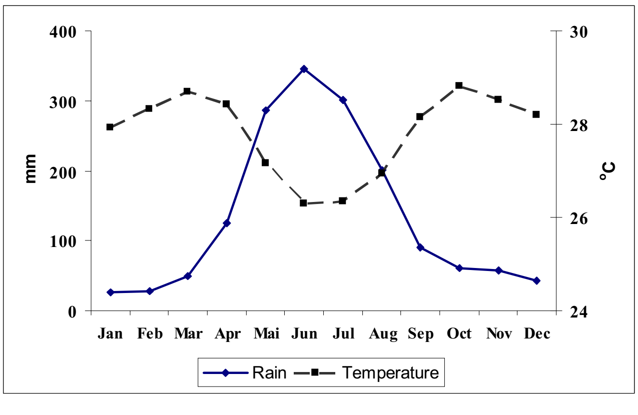

Fig. 2 Monthly precipitation (mm) and average temperature (°C) in the city of Boa Vista, Roraima.

savannas are established along a relief gradient that rises from the southwest towards the northeast, where it reaches the Roraima Group with summits up to 2750 m (Monte Roraima). The altitudinal variability results in a precipitation gradient, with differences among areas caused by local natural barriers (such as the Pacaraima Mountain Complex). These barriers block the movement of oceanic humidity brought by the trade winds along Intertropical Convergence Zone (ITCZ); these winds transport large volumes of water to this area (Nimer 1972). The barriers result in very dry areas in the northeastern portion of this great local ecosystem, with annual average precipitation below 1100 mm and less than 100 days of rain per year (Barbosa 1997).

The low and mid-altitude savannas (average altitude < 600 m) are almost all located in the center and the south of this ecoregion, amid basaltic geological residues and depressions in the land (*abaciamentos*) that generate systems of perennial and seasonal lakes. In both cases drainage networks exist in interconnections denominated as "*veredas*" (paths) of *buritizais* (meaning stands of buriti palm - *Mauritia flexuosa* L.) which are nothing more than streams that connect the lakes to the larger rivers. In normal and/or rainy years, these watercourses become natural barriers against fire. However, in dry years (especially El Niño years), the "*veredas*" become corridors of fire because they have a higher load of dry biomass (fuel) on the ground.

ECOSYSTEMS AND BIODIVERSITY OF PLANTS

The origin of the current flora and diversity of natural savanna ecosystems in Roraima are now more clearly explained as the result of interactions between climate and edaphic factors during the last glacial and interglacial periods (for more explanation see van der Hammen and Hooghiemstra 2000; Haffer and Prance 2002; Rull 2007). These interactions, associated, for instance, with the soil type and the fluctuation dynamics of the water table, produced ecosystems in mosaics forming *buritizais*, lakes, riverine forests, forest islands and montane forests. The natural interactions of these environments produce "routes" for dispersion and genetic interchange that are very specific to this Amazonian environment. However, the high frequency of fire, the extensive grazing of cattle and other domestic animals, the unsustainable use of natural resources (fauna and flora) and the recent redirection of public policies to support large development projects in savanna areas (soybeans, commercial tree plantations and irrigated rice) are altering the natural landscapes and breaking the ecological interactions of these ecosystems (see Furley 2006 for general comments of these aspects in tropical savannas).

Floristic richness and diversity

From the point of view of floristic diversity, these human impacts could be provoking loss of plant species and reducing the richness of these already weakened ecosystems. Large-scale studies of the region's flora are still rare, the most prominent being the works of Coradin (1978), studying grasses and herbs, Sette Silva (1993), in forest ecosystems located in the proximities of the city of Boa Vista, Miranda and Absy (2000) and Miranda *et al*. (2003), characterizing the composition, structure and diversity of Phaneragammic plants in different locations in the savannas of Roraima, and Sanaiotti (1996, 1997), developing the idea of disjunctive savanna ecosystems in Amazonia through data collection in the tree stratum. These represent the most recent studies and have the largest sample sizes.

In spite of the reduced number of studies about plant diversity in the savannas of Roraima, it is already possible to draw some conclusions the about phytophysionomies and local diversity. The first is that this whole area of the Amazonian Biome, defined as "Savannas of Guyana," is formed by the group of two great ecosystems: (1) "forest", which is divided into small patches or forest islands, riverine forests, montane forests, etc. and, (2) "non-forest", which are the

Table 1 Areas of the "forest" and "non-forest" ecosystems present in the savanna ecoregion of Roraima.

System	Group	Ecosystems	Code	Area	
				km^2	%
FOREST	**Ecotones**	Seasonal Forest - Savanna	SN	3479	8.02
		Rain Forest - *Campinarana*	LO	104	0.24
		Rain Forest - Seasonal Forest	ON	1126	2.60
		Rain Forest –Savanna	SO	1372	3.16
		Sub-total Ecotones		**6081**	**14.0**
	Seasonal	Semideciduous (Degraded)	F (AA)	178	0.41
		Semideciduous Alluvial	Fa	259	0.60
		Semideciduous Submontane	Fs	1841	4.25
		Sub-total Seasonal		**2277**	**5.3**
	Rain forest	Open Submontane	As	580	1.34
		Dense Alluvial	Da	0	0.00
		Dense Montane	Dm	438	1.01
		Dense Submontane	Ds	1	0.002
		Sub-total: Rain Forest		**1019**	**2.3**
	Forested Savanna	Forested Savanna (Dense Woodland)	Sd	-	-
		Steppe-like Savanna Forested	Td	3396	7.83
		Sub-total: Savanna+ Steppe-like Savanna		**3396**	7.83
	Total Florest			**12,773**	**29.5**
NON-FOREST	**Pioneer**	*Buritizal*	Pa	28	0.06
		Sub-total Pioneer		**28**	**0.06**
	Montane Refuge	Montane Refuge	rm	1	0.002
		Sub-total: Montane Refuge		**1**	**0.002**
	Savanna	Grassland Savanna	Sg	9643	22.24
		Parkland Savanna	Sp	12,473	28.77
		Open Woodland Savanna	Sa	4088	9.43
		Steppe-like Savanna Grassland	Tg	915	2.11
		Steppe-like Savanna Parkland	Tp	3022	6.97
		Steppe-like Savanna Open Woodland	Ta	3	0.01
		Human-altered Savanna	S (AA)	117	0.27
		Sub-total: Savanna+Steppe-like Savanna		**30,262**	**69.8**
	Total Non-forest			**30,290**	**69.9**
WATER		Water bodies		294	0.68
Grand Total				**43,358**	100

[1] Code used in the Brazilian system of vegetation classification (IBGE 1992)

true savannas, characterized typically by the open vegetation that dominates the largest area of the landscape. In this last case, the system of classification of Brazilian vegetation (IBGE 1992) adopts an additional division: "savannas" and "steppe-like savannas." The basic difference is that the steppe-like savannas are found at high altitude (> 600 m) under dry climate and stony soil. **Table 1** presents the area and a synthesis of all of the systems "forest" and "non-forest" that are present in the ecoregion of the Roraima savannas, taking as a database the georeferenced system of SIPAM (2004). This synthesis corresponds to the reading that the geographical information system registers at a scale of 1:250,000 (**Fig. 3**). Barbosa and Miranda (2005) give a detailed description of all of the ecosystems present in the local savannas and the way that each can be identified.

For the forest systems of this ecoregion (29.5% or 12,731 km^2) the only floristic survey available is that carried out by Sette Silva (1993) in the proximities of Boa Vista, presenting a total richness of 188 species (43 botanic families) of trees distributed among five different sample areas and covering four forest types (**Table 2**). Analysis of this group of species indicates that the species with the highest importance index value in these ecosystems were, in decreasing order, *Ocotea bracteosa* Mez. (Lauraceae) and *Licania discolor* Pilg. (Chrysobalanaceae), which were present in gallery forest that is continuous with the Branco River alluvial forest, and *Tabebuia uleana* (Kranz.) Gentry (Bignoniaceae) in low hill ecosystems. The main species common to all five sampling areas were *Simarouba amara* Aubl. (Simaroubaceae), *Protium aracouchili* March. (Burseraceae) and *T. uleana* (*Kranz*.) Gentry (Bignoniaceae).

The non-forest ecosystems (open savannas: >30,000

Table 2 Description, species richness and families of closed forest ecosystems in the city of Boa Vista, Roraima, ecoregion of the Savannas of Guiana (modified from Sette Silva 1993).

Station	Environmental Description	Classification of IBGE (1992)	Code of IBGE (1992)	Species (n)	Genera (n)	Families (n)	Dominant Families (in ascending order)
1	Dense Tropical Forest with Uniform Cover	Dense Alluvial Rain Forest	Da	70	50	27	Lauraceae, Chrysobalanaceae, Caesalpinaceae
2	Enclave of Tropical Seasonal Semidesciduous Forest with Uniform Cover and Parkland Savanna	Dense Alluvial Rain Forest	Da	102	74	35	Caesalpinaceae, Chrysobalanaceae, Lauraceae
3	Enclave of Open Tropical Forest with palms and Semidesciduous Seasonal Forest with Uniform Cover	Contact Savanna - Seasonal Forest	SN	46	33	23	Arecaceae, Mimosaceae Boraginaceae
4	Enclave of Semidesciduous Seasonal Forest with Uniform Cover and Parkland Savanna with temporary water courses	Seasonal Semideciduous Alluvial Forest	Fa	60	44	27	Caesalpinaceae, Mimosaceae, Bignoniaceae
5	Enclave of Semidesciduous Seasonal Forest with Uniform Cover and Parkland Savanna with temporary water courses	Contact Savanna - Seasonal Forest	SN	56	43	28	Caesalpinaceae, Chrysobalanaceae, Lauraceae

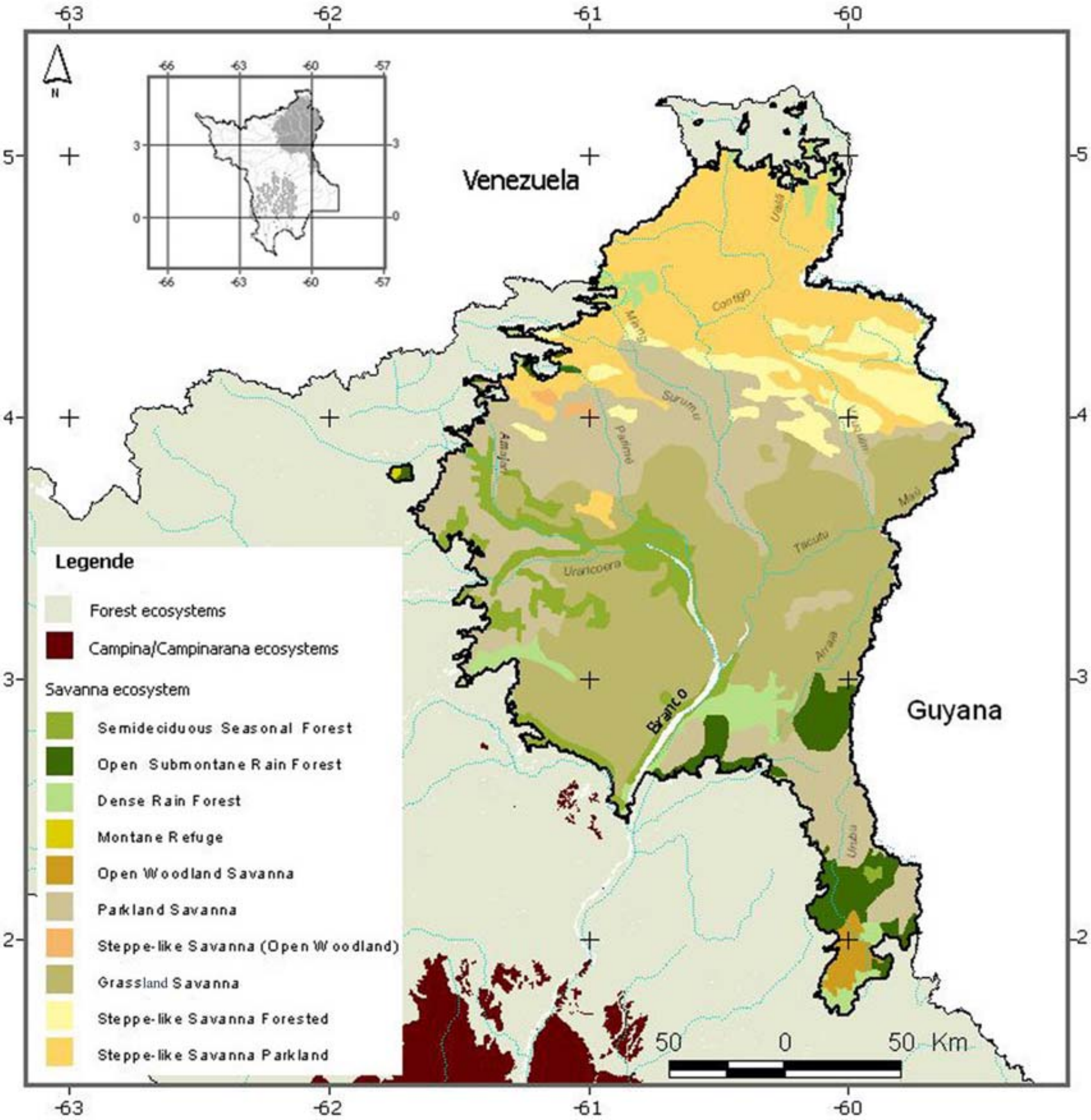

Fig. 3. Phytophysionomies present in the savannas of Roraima.

km²) have low diversity in the tree and shrub stratum, with the Shannon Index almost always with values close to 1.0 (Miranda *et al*. 2003; Barbosa *et al*. 2005). This finding result from the high concentration of individuals in few species, especially *Curatella americana* L. (Dilleniaceae), *Byrsonima crassifolia* (L.) Kunth. (Malpighiaceae) and *B. coccolobifolia* Kunth. (Malpighiaceae). These are considered to be key (decisive) species. Together, they represent about 60-70% of the number of individuals and more than 80% of the total live aboveground biomass in the savannas of Roraima (Barbosa 2001). Added to other common tree species, such as *Bowdichia virgilioides* Kunth. (Fabaceae), *Himatanthus articulatus* (Vahl.) Woods. (Apocynaceae), *Antonia ovata* Pohl. (Loganiaceae), *Roupala montana* Aubl. (Proteaceae), *Xylopia aromatica* (Lam.) Mart. (Annonaceae), and five additional species described in Barbosa and Fearnside (2004, 2005), they form the base of the tree and shrub stratum of the whole area of open savannas in Roraima. These species are considered to be nurse trees because they form an environment under their crown (nutrients and shade) that facilitates the recruitment of different species of the herbaceous and tree strata. These recruited species can come from the individual itself, or they can come from seeds transported to these environments by wind (anemochory) or, in most cases, by birds (zoochory) that use these trees as rest perches and/or for procreation (A. G. Corleta, pers. comm.).

Table 3 Basal area and species richness, genera and families of the main open savannas in the ecoregion of "Savannas of Guianas", Roraima (modified from Miranda 1998 and Miranda *et al.* 2003).

Environment[1]	Code (IBGE 1992)	Basal area (m^2/ha)	Species	Genera	Families	Dominant families
Grassland Savanna (*campo limpo*)	Sg	1.1	15	12	11	Malpighiaceae Loganiaceae Dilleniaceae
Grassland Savanna (*campo sujo*)	Sg	3.4	45	35	23	Dilleniaceae Malpighiaceae Rubiaceae
Parkland Savanna	Sp	4.8	37	32	18	Dilleniaceae Malpighiaceae Fabaceae
Open Woodland Savanna (non-dense)	Sa	8.7	26	21	16	Dilleniaceae Annonaceae Fabaceae

[1] includes sub-bushes (<1 m height), bushes (1-2 m) and trees (> 2 m).

In an analysis restricted to the most recent studies on the flora of the open savannas of Roraima (Coradin 1978; Dantas and Rodrigues 1982; Miranda and Absy 2000), more than 250 species were found in the herbaceous stratum, such as Poaceae, Cyperaceae and other herbs of low stature, in addition to 71 species (52 genera and 30 families) of trees and shrubs (Sanaiotti 1996, 1997; Miranda *et al*. 2003; **Table 3**). The sum of the richness of both ecosystems (forest and non-forest) totals approximately 500 species of higher plants. Although much less than the absolute total that has already been identified for the savannas of central Brazil, which have more than 6400 species of vascular plants in five floristic sub-provinces covering about 2.0×10^6 km^2 (Mendonça *et al*. 1998; Felfili 2003), it is possible that, with an intensification of inventories and a better distinction of the regional landscapes, a value higher than the one currently observed could be found.

Large-scale studies based on phytophysionomic inventories carried out in different areas of Brazilian savannas have indicated a substantial floristic distance between savannas located in Amazonia and those in central Brazil, with special prominence for the isolated area of Roraima (Miranda and Carneiro-Filho 1994; Ratter *et al*. 2003). This floristic separation has been justified by the fact that the savannas at the northern edge of Amazonia are isolated points and are poor in arboreal plant species as compared to sites in central Brazil (Sanaiotti 2003). The geographical discontinuity with the central Brazilian plateau and its position bordering the Guyana Shield contribute to variability in the factors that determine floristic diversity and the maintenance of this ecosystem type, such as, latitude, soil, fertility, relief and climate.

FAUNAL BIODIVERSITY

In addition to the limited knowledge about the species that compose the fauna of the savannas of Roraima, little it is known about the dynamics of the populations and the composition of the communities. In the same way, few studies exist on the fauna of the savannas of Rupununi, in Guyana, and the high-altitude savanna in Venezuela, both of which are extensions of the savannas of Roraima and jointly form the great complex of the "Savannas of Guyana".

In spite of little being known, several factors make the area one of special interest for conservation. Due to the thermal and altitudinal amplitude and to the great variety of soils and phytophysionomies, the area forms a mosaic of ecosystems with great heterogeneity of habitats harboring elements of the fauna of the Guiana Shield in such ecosystems as *tepui* (tabulate mountains), forests and open areas (Brazil 1975; Miranda and Absy 2000; Barbosa and Miranda 2005; Santos 2005; Silva 2005; Vale Jr. and Souza 2005). In addition to the endemic species and species threatened with extinction, this ecoregion predominantly of open vegetation has species that do not occur in the central Brazilian savanna (*cerrado*) or in the other savannas in Amazonia. The connection between the basins of the rivers Amazon and Essequibo and the formation of thousands of temporary lakes during the rainy season plays roles that are important and still little studied in the distribution of aquatic organisms and migratory birds. In addition, it is important to point out the risk of loss of biodiversity in the near term due to substitution of the natural landscape with monocultures of rice, soybeans and commercial tree plantation (Lowe-McConnell 1963; Capobianco *et al*. 2001; Aguiar and Camargo 2004; Oliveira and Marquis 2001).

Birds are the best-studied animal group in the savanna, followed by the herpetofauna and by the icthiofauna. However, for all of the groups of animals there are some phytophysionomies of savannas that have not yet been sampled. Invertebrates and mammals are the least-studied groups. Most of the information on the occurrence of these two groups is the result of the Maracá Project inventories, carried out by the Brazilian government in partnership with the Royal Geographic Society, from 1986 to 1988 (Rafael and Py-Daniel 1989; Hemming and Ratter 1993; Nunes and Bombadilla 1997; Milliken and Ratter 1998; Kinouchi and Lamberts 2005; Silva 2005). This project was undertaken in the Maracá Ecological Station, a conservation unit located in Roraima on Maracá Island and managed by the Brazilian government through the Brazilian Institute for Environment and Renewable Natural Resources (IBAMA). However, because these inventories were concentrated in continuous forest environments, the savanna's fauna was only collected in the small enclaves of open areas in the interior of the island and in the forest-savanna ecotone surrounding it. The list of species of Maracá is therefore not a representative sample. Nevertheless it offers indirect information on the fauna of the savannas, even without determining in what measure or with that frequency these species use the resources of the savanna.

Arthropods

Except for a few floral visitors (Barbosa *et al* 2003; Benezar and Pessoni 2006) and insects of medical interest (Barros *et al* 2006), almost all of the information on insects and arachnids collected in the savannas is contained in the list of species compiled by the Maracá Project. This British/Brazilian collaborative project found approximately 1200 species distributed among 18 orders and 120 families (Rafael and Py-Daniel 1989; Rafel 1991; Hemming and Ratter 1993; Rafael *et al*. 1997; Milliken and Ratter 1998; Lise 1998; Silva 2005; Kinouchi and Lamberts 2005).

Some data on the distribution of butterflies, dragonflies and wasps show that the species of these groups in the savanna are more common and thoroughly distributed than are those in the forest, which are rarer and less abundant. For these three groups, more than half of the species collected in the savannas were not reported in other ecosystems, showing that there is a group of species that is exclusive to open areas (Rafael and Py-Daniel 1989; Machado *et al*. 1991; Mielke and Casagrande 1991; Hemming and Ratter 1993; Raw 1998; Milliken and Ratter 1998).

Although the inventories carried out in Maracá represent the largest and the most expressive collection effort so far, these inventories did not collect specimens of the orders Collembola and Ephemeroptera, or of the classes Chilopoda (centipedes), Diplopoda (millipedes) and Crustaceans. In addition, some orders that are important for their richness of species, such as Coleoptera (beetles) and Hemiptera (true bugs) were sampled very superficially (Rafael and Py-Daniel 1989; Bührnheim 1991; Hemming and Ratter 1993; Barrett 1998; Bührnheim 1998; Kinouchi and Lamberts 2005). In other parts of Roraima studies have been made of Trichoptera (Flint Jr. 1991) and Megaloptera (de Azevedo and Hamada 2006).

Teams from INPA (linked to the Research Program in Biodiversity and to the Coordination for Research in Entomology) are currently carrying out the first systematic study on the soil fauna, arboreal arthropods and spineless aquatic arthropods directed specifically at the savanna area.

Few studies of genetic diversity have been carried out in the state of Roraima. Hamada and Adler (1999) observed that of four dipteran species of the subgenus *Simulium* (Ectemnaspis) studied cytologically, *Simulium maroniense* Floch & Abonnenc was the most polymorphic, with four cytotypes ("A"-"D"). Roraima had two cytotypes "A" and "B", the other two were observed in the states of Amapá and Pará ("C") and in Amazonas ("D"). The "A" cytotype was collected in the area of forest of the Pacaraima mountain chain while the "B" cytotype was collected in other watercourses in forests on the same mountain chain and in savanna areas; cytotypes "A" and "B" have distinct chromosomal rearrangements, indicating a high genetic diversity at that transition area between savanna and forest.

Icthyofauna

With the recent updating done by Ferreira *et al*. (2007), the list of species of the Branco River basin (which drains both forest and non-forest ecosystems) has approximately 500 species, most belonging to the orders Characiformes, Siluriformes and Perciformes. Most of the specimens collected in Roraima are deposited in the icthyological collections of INPA, in Manaus, of the Museum of the University of São Paulo (USP), in São Paulo, and of the Integrated Museum of Roraima (MIRR), in Boa Vista (Hemming and Ratter 1993; Alves-Gomes 1997; Nascimento 2002a; Briglia-Ferreira 2004, 2005; Ferreira *et al*. 2007). Although a list of collected species does not exist strictly for the savanna ecoregion, it is probable that most of the species collected along the channel of the Branco River and of their main tributaries also applies to the middle reaches of the river, which runs into the area of open vegetation.

The savanna area is of special importance for conservation of the icthyofauna because it is, among other things, an obligatory route for the fish that occur in the middle reaches of the Tacutu and Uraricoera Rivers, which are the main tributaries to the Branco River (Briglia-Ferreira 2005). However, most of the area has not yet been sampled, especially the temporary lakes that are formed during the rainy period and the northern part where the steppe-like savannas are located. It is important to emphasize that thousands of these temporary lakes exist distributed over the center-south portion of the savannas, harboring a fauna of fish and other aquatic organisms that still needs to be evaluated.

Another important factor for the distribution of the aquatic fauna is the temporary connection among the drainage networks of the Amazon and Essequibo Rivers during the flood period. In this period, the waters of the Tacutu and Rupununi Rivers are shared in an area of flooded savanna that the indigenous people denominate as Lake Amuku. Dozens of fish species that inhabit the savanna lakes have been collected in these common waters during the reproduction period. The collections carried out in the savanna areas of Rupununi have species numbers close to those found for the entire state of Roraima. A total of 461 species of fish were reported in the forest of Iwokrama (Guyana) and in the surrounding area that is inhabited by Indians of the Macuxi tribe (Forte 1996; Watkins *et al*. 2004).

Herpetofauna

The inventories of the herpetofauna have been made in several savanna areas, including their forest islands and gallery forests, revealing the occurrence of species that have not been collected in any other area of Roraima (Nascimento 2005). Systematic studies on the herpetofauna of Roraima began with the works of Cunha and Nascimento (1980, 1981). These studies built on the foundation laid by the team of Paulo Vanzolini and Celso Morato de Carvalho, which provided information not only on species richness but also on the diversity, variability, ecology and biogeography of the herpetofauna in the savannas (see Vitt and Carvalho 1992; Heyer 1994; Vitt and Carvalho 1995; Carvalho 1997). Collections were carried out in several phytophysionomies, including the steppe-like savannas, which is the least-sampled area for all faunal groups. The sampled locations are in the basins of the Rivers Branco, Surumu, Tacutu, Uraricoera, Mucajai, Maú, Parimé, Igarapé (stream) Água Boa, Lago (Lake) Caracaranã and Monte Caburaí (Rebelo *et al*. 1997; Nascimento 2002b, 2003, 2005; SMGA 2006; Strong 2005).

Of the 158 species of reptiles and amphibians reported in Roraima, 76 are found in the savannas. The order Ophidia has 34 species reported, distributed among five families. The order Anura has 20 species reported in five families. The list also includes 17 species of lizards distributed in eight families, three crocodilians and two terrestrial turtles (Nascimento 2005). Although not included in the official list, several species of aquatic turtles occur in the stretch of the Branco River that cuts through the savannas.

Avifauna

More than half of the birds found in Amazonia are resident in Roraima. The most updated list mentions 736 species, including 31 migrants and 44 not reported in other areas of the country. In the savannas of Roraima 291 species were observed, a number considered to be high taking into account that 84% of the state is covered by forests and that most of the birds reported in Roraima depend on forest formations. If the birds listed for the Rupununi savannas of Guyana are also considered, this number increases to 503 species. This area of savannas at the northern limit of Amazonia is important for the conservation of avifauna on a continental scale not only due to the presence of endemic and vulnerable species, but also because of their particularities and differences from the fauna of central Brazilian savannas and from the other Amazonian savannas, where most of the species are dependent on forest formations. At a local scale, the bird fauna of the *lavrado* forms a separate group that has little similarity with the fauna of the other ecosystems found in Roraima (Phelps 1938; Phelps and Phelps 1947, 1962; Phelps 1973; Cohn-Haft *et al*. 1997; Stotz 1997; Oren 2001; Nascimento 2002a, 2003; Santos 2004, 2005; Naka *et al*. 2006).

Of the 13 globally important areas for conservation in Roraima, eight are in *lavrado*, mainly in the southern portion where they also make up half of the locally important areas for conservation (Santos 2005). Because these are level areas close to highways and outside of indigenous lands, they are targeted for the expansion of soybeans, rice and commercial tree plantation (Arco-Verde *et al*. 2005; Cordeiro 2005; Gianluppi and Smiderle 2005).

Conservation units (CUs) for integral protection and indigenous lands cover more of the half of Roraima and, taken together, they contain 88% of the species of resident birds in the state. Although most of the birds in Roraima are represented inside of the system of CUs, many species of birds in the *lavrado* only occur in areas that are under strong pressure from agribusiness and where conservation projects or public policies for the protection of these species do not exist. One of the most common impacts, besides the destruction of habitat, is the mortality of birds as a consequence of poisons used in the rice fields (Cordeiro 2005).

Lavrado areas, according to Santos (2005), have more than 90 vulnerable species and at least six endemic species. Although not included in the official list of Brazilian species under threat of extinction, two species in these open areas are on the International Union for the Conservation of Nature (IUCN) list: *Poecilurus kollari* (vulnerable) and *Cercomacra carbonaria* (endangered), with high extinction risk over the short term (Santos 2004).

Most of the fauna in the savannas of Roraima is not dependent on forest formations; the fauna of the *lavrado* of Roraima shows more similarities with the fauna of open areas in Venezuela (*llanos*) than with the fauna of central Brazilian savanna (*cerrado*) or with the other Amazonian savannas. Most of the almost 60 families of birds observed in the local savannas are represented by less than five species. The best represented families are Tyrannidae (23), Emberizidae (15) and Accipitridae (17). Only one family (Burhinidae) has been reported exclusively in the savannas (Borges 1994; Stotz 1997; Santos 2005). Although the sampling points for birds are well distributed, the number of species is still underestimated because the phytophysionomies of the steppe-like savannas (high altitude) have not yet been sufficiently sampled.

Mammals

A list of mammals collected strictly in the savannas does not exist. Most of the collection effort and ecological studies for mammals has been concentrated the Maracá Island in Brazil (Nunes 1998; Fragoso *et al.* 2003; Silvius and Fragoso 2003) and in the Iwokrama forest in Guyana (Burton and Engstrom 2005); both are CUs for integral protection. However, these studies only supply indirect evidence since the inventories were mainly carried out inside the forests, including in some cases the forest-savanna ecotone. Nevertheless, this information contributes to knowledge of the fauna in the savanna since many species use the edges of the forest, the forest islands and the riparian forests, although it is not possible to determine with what frequency or with that intensity these species use the resources of the savannas.

Most of the phytophysionomies of the savanna, however, have not been inventoried, above all the steppe-like savannas in the northernmost portion of the state. It is also important to mention that the forest ecosystems that belong to the savannas of Roraima, such as the forest islands, gallery forests and mid and high-altitude forests remain undersampled.

Some studies of short duration were carried out in the area surrounding the city of Boa Vista, at Surumu and Limão (Raposa-Serra do Sol Indigenous Land) and in the area of the Kanuku mountains in Guyana near the border with Brazil. Although the knowledge of the indigenous populations is not reported with the same methodological rigor as that of taxonomists, the ethno-environmental surveys that have been carried out in the two countries also contribute important information on the mammals of the savannas.

Although the species richness is larger in Iwokrama (225) than in Maracá (96), the mammal fauna of the two areas shows much similarity. Almost all species of the orders Carnivora, Primata, Xenarthra and Didelphimorphia collected in Maracá were reported in Iwokrama, except for five species (*Ateles belzebuth belzebuth*, *Aotus trivirgatus*, *Nasua nasua*, *Dasypus septemcintus* and *Conepatus semistriatus*). The main differences between the two lists are observed for bats (121 in Iwokrama and 48 in Maracá) and small mammals, in addition to aquatic mammals in the orders Cetacea and Sirenia (these last were not observed in Maracá).

Considering only the collections carried out in Maracá, Boa Vista and the Raposa-Serra do Sol indigenous area, the species of mammals reported totaled a little more than 102 (48 bats) distributed among the orders Carnivora, Perissodactyla, Artiodactyla, Primata, Chiroptera, Xenarthra, Rodentia and Didelphimorphia. Among these they represent some vulnerable species or species in danger of extinction, such as *Panthera onca* (jaguar) *Tapirus terrestres* (tapir), *Pteronura brasiliensis* (giant river otter), *Mazama americana* (brocket deer) and *Myrmecophaga tridactyla* (giant anteater) (Nunes *et al*. 1988; Mendes-Pontes 1997; Nunes and Bobadilla 1997; Mendes-Pontes 2002; Weksler *et al*. 2001; Cordeiro and Oliveira 2005; SMGA 2006).

In the Kanuku mountains a rapid survey was carried out, where 38 species were reported: 31 bats, four rodents and three marsupials. The ethno-environmental surveys carried out with indigenous people of the Macuxi tribe mention the occurrence of 52 species, 33 of which are consumed as food.

Among the best-known species listed for the savannas of Roraima are the cougar (*Puma concolor*), fox (*Cerdocyon thous*), otter (*Otter longicaudis*), white-lipped peccary (*Tayassu pecari*), collared peccary (*Tayassu tacaju*), capybara (*Hydrochaeris hydrochaeris*), paca (*Agouti paca*), agouti (*Dasyprocta leporine*, *Dasyprocta agouti*), armadillo (*Dasypus novemcintus*, *D. kappleri*, *D. septemcintus*), in addition to six species of monkeys, armadillos and marsupials (Nunes *et al*. 1988; Nunes and Bobadilla 1997; Weksler *et al*. 2001; Cordeiro and Oliveira 2005; SMGA 2006, **Table 4**).

Table 4 Species richness and families of the fauna collected exclusively in the savannas of Roraima.

Grupos	Orders	Families	Species
Arthropods	18	120	1200[1]
Icthiofauna	13	49	500[1]
Herpetofauna	5	20	76
Avifauna	-	60	291
Mastofauna	8	26	103
Estimated Total	-	275	2412

[1] approximate number.

CONSERVATION STATUS OF THE "*LAVRADO*"

The biodiversity of the *lavrado*, conceived as a great system of forest and non-forest landscapes, is still little known, hindering the formulation of appropriate proposals for priority areas for the conservation in this ecosystem when the objecive is conservation of endemic species or areas of high biological diversity. Besides little known, the biodiversity of these savannas is little protected, with no CU existing that includes a significant portion of the savanna phytophysionomies in this Amazonian ecoregion. Considering the system of CUs in Roraima, the representativeness of the *lavrado* is low, totaling only 198 km^2 or less than 0.5% of the *lavrado* area. The Monte Roraima National Park (PARNA), which overlaps completely with the Raposa-Serra do Sol indigenous area, is the only CU that possesses a significant continuous area of savanna, equal to 99 km^2 or 8.7% of the area of the PARNA. This area is covered by a mosaic of steppe-like savanna and areas that are forested, woodland, parkland and grassland vegetation (**Fig. 4**).

Taking into account the databases and the maps elaborated at a scale of 1:250,000 by the System for Protection of Amazonia (SIPAM 2004), about 70% of the savannas of Roraima are covered by vegetation phytophysionomies of open savanna, 14% by savanna-forest ecotones, 5.3% by seasonal forests and 2.3% by rain forests (see **Fig. 3** and **Table 1**). Water bodies, montane refuges and *buritizais* are the physiognomies that are less represented in *lavrado* at this scale, jointly contributing less than 1% of the original covering. The last two phytophysionomies and the savanna-forest ecotones are considered to have priority for conservation because of their low representation and because they possess unique characteristics of the transition zones between the savannas and the other plant formations.

The montane refuges are located mainly at the northern end of Roraima in the transition between the high-altitude savannas on the Brazilian side, the Rupununi savannas in Guyana and the Gran Sabana in Venezuela. The Maturuca and Mel mountain ranges are also included in this context. The Monte Roraima PARNA is also located in this same area, which possesses a mosaic of phytophysionomies of open savannas with patches of rain forest and montane refuges. Therefore, this PARNA has an important role in protecting 11.7% of the ecosystems of the montane refuges of the *lavrado*, representing an area of 28 km^2 of this rare system.

At the scale of the work of SIPAM (2004), the *buritizais* have little visibility, in the same way as in the case of the montane refuges, although they thoroughly populate the whole area of the savannas of Roraima. This landscape type, which involves gallery forest and aquatic ecosystems such as lakes and small rivers, is especially important for the maintenance of hydrological resources and for gene flow of different animal and plant species in the *lavrado*. Conservation of *buritizais* should be a regional priority so that one can better understand the real function and ecological importance of these ecosystems when considering their associated fauna (consumers and dispersers of fruits), in addition to understanding how the fauna and the flora use these areas as a refuge and as a displacement corridor.

Indigenous Lands (IL) have a fundamental role in the preservation of savannas (**Fig. 5**). More than half of the ecosystem, 24,864 km^2 (57.3%), is occupied by 27 indigenous lands, belonging to the Macuxi, Patamona, Ingaricó, Taurepang and Wapichana tribes. Only the Raposa-Serra do Sol IL, together with the São Marcos IL, represent 48.3% of the whole area of the *lavrado*. Its importance is even more significant when analyzed in terms of the representativeness of the phytophysionomic landscapes and their occurrence in indigenous lands, especially for those that occur in less than 1% of this macro-ecosystem and that have a frequency of

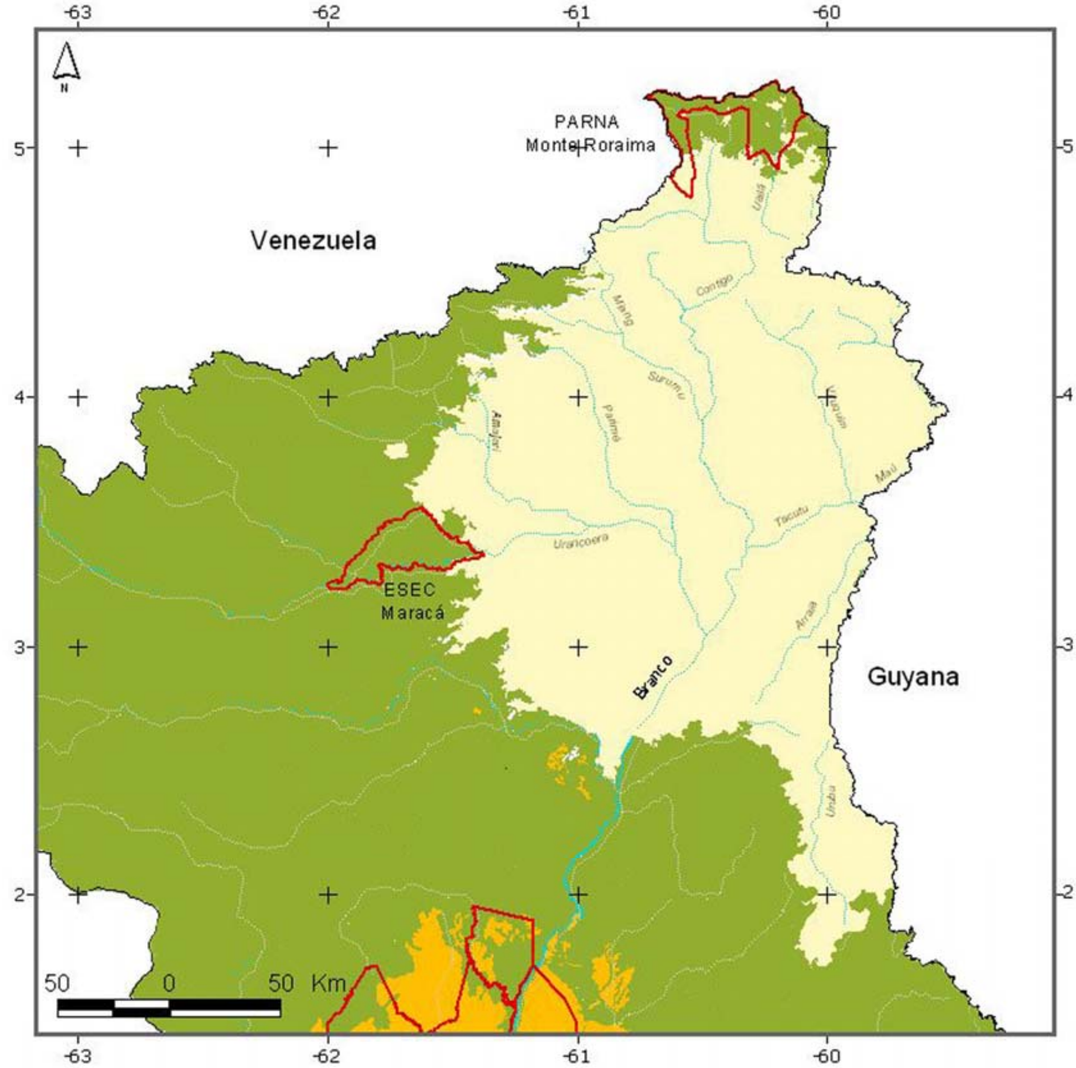

Fig. 4 Conservation units (CUs) with physical presence in the savannas of Roraima.

over 90% in indigenous lands. They are (1) the seasonal forests with *buriti* palms present in the Raposa-Serra do Sol IL the microbasin of the Viruquim River; (2) the montane rain forests in the Monte Roraima PARNA belonging to Raposa-Serra do Sol indigenous area; (3) the seasonal forests with montane refuges present in the Surumú River basin, the São Marcos IL; (4) the rain forests with montane refuges present in the microbasin of the Ailã River, the area of the Monte Roraima PARNA and (5) the patches of forested savannas present in the Surumú microbasin, São Marcos indigenous area, and in the microbasins of the Mau, Contigo and Uailan Rivers in the Raposa-Serra do Sol IL. Some areas in the indigenous territories are of special prominence: (1) the montane refuges of the Mel mountain chain (Serra do Mel) in the São Marcos indigenous area; (2) the montane refuges of the Maturuca mountain chain (Serra do Maturuca) in the Raposa-Serra do Sol IL and (3) the area of rocky outcrops associated with the woodland savanna in the area of the Mel mountain chain in the São Marcos indigenous area.

Ignoring the area of indigenous lands in the *lavrado*, as of March 2004, 35.2% of the remaining area are occupied by rural properties and 4.4% by agrarian reform settlements according to the georeferenced data maintained by the National Institute for Colonization and Agrarian Reform office in Roraima (INCRA-Roraima). The largest concentration of rural properties (65%) is in the municipal districts of Boa Vista and Bonfim. Of these properties, 41% are between 100 and 1000 ha in area. However, it is the large properties (>1000 ha) that occupy 80% of the total area of private land. It is also in the municipal district of Boa Vista that the most recent agrarian-reform settlements in the savannas of Roraima are located: the Nova Amazônia Settlement Project (PANA), which includes the Murupú-Cauamé and Truarú *Glebas* (blocks of Brazilian lands for agrarian reform). The first directed settlement in the savanna ecosystems of Roraima was established in the early 1980s in the Monte Cristo area, near the city of Boa Vista (Oliveira Jr. *et al*. 2005). However, no reliable estimate exists of the agricultural production and yield of these family agriculture initiatives in the local ecosystems. The transformation of some lots in Monte Cristo into small leisure farms and, the increasing real-estate speculation in several of the lots of PANA are readily apparent consequences of the proximity of these land-reform settlements to Boa Vista.

Removing areas that are possibly unsuitable for the agricultural use (15.6%), areas of agrarian-reform settlements (3.8%) and indigenous lands (57.3%), only 23.3% of the savannas would be available for the creation of integral-protection CUs, considering the current land use. Considering only the largest extensions of land, three areas are suitable now as priorities for conservation of the *lavrado* of Roraima: the Tucano mountain chain (Serra do Tucano) and the Lua mountain chain (Serra da Lua), both located in the basin of the Tacutu river; and the area of lakes located in the municipal district of Boa Vista.

The Tucano mountain chain includes a transition area among patches of seasonal forest, around the mountain, and grassland savanna in a mosaic with parkland reaching as far as the Tacutu River, which is the northern boundary of the Raposa-Serra do Sol and São Marcos indigenous areas. The area stands out for its paleodunes (Carneiro-Filho 1991), for the vertical stratification of the vegetation and for the great extensions of its *buritizais*. In order to maintain the patches of seasonal submontane forest and the *buritizais* it is essential to maintain a reasonable level of connectivity with the

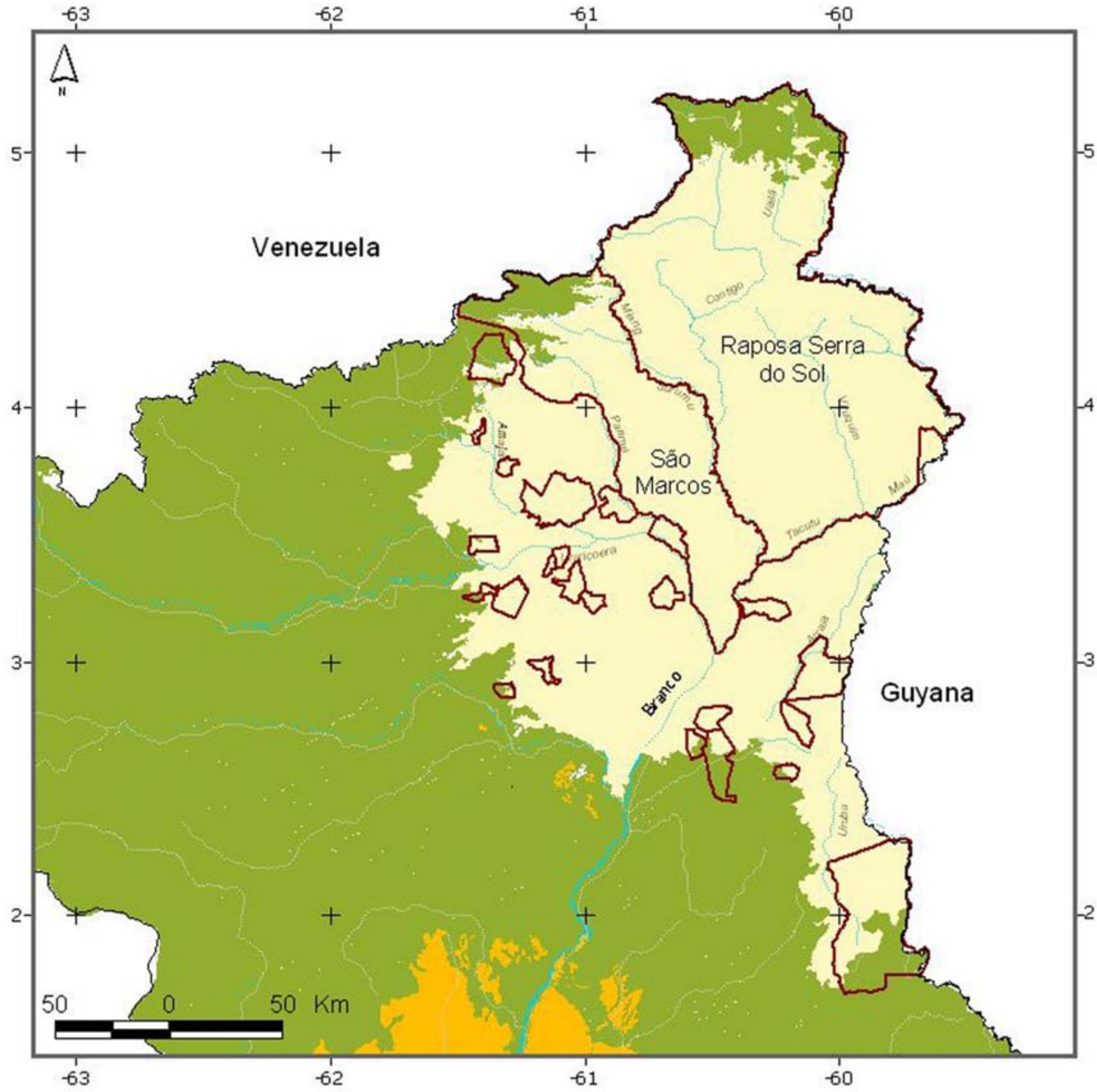

Fig. 5 Indigenous lands present in the savannas of Roraima (light color area = savannas; red lines = indigenous lands contour).

great expanses of rain forest that exist to the south. These considerations merit implementing changes in land-use policy to give priority to conservation. However, the area is currently under pressure from rice growing and extensive livestock operations on the banks of the Tacutu River, and these pressures can be expected to increase in the future with the implementation of the Arco Norte Program. This program seeks to integrate of Roraima through the BR-401 Highway with Guyana, Surinam, French Guiana and Amapá. The project has financing from the Initiative for Integration of South American Infrastructure (IIRSA), with a forecast of investment US$ 365 million in the Guiana Shield area. For Roraima investments are foreseen for duplication of BR-401, for export through Guyana, and construction of a bridge over the Tacutu River. The local political plans for this area are for building silos for storing grain and for granting incentives to existing rice-growing agribusiness enterprises and to soy production. The investments will facilitate export of the production through the port of Berbice in Guyana, or through the construction of a tri-national port in the Courentyne River delta on the boundary between Guyana and Surinam. It is expected that environmental pressures from the rice growing will increase in the next five years. The pressures are centered on the canalization of a great volume of water for irrigation of the rice (between 12 and 15,000 m^3 ha^{-1} in contrast with the 8000 $m^3.ha^{-1}$ used in the south of the country), the percolation of a surplus from the 500 kg ha^{-1} of fertilizers (N, P, K and Zn) used in the rice production, the use of insecticides through aerial spraying to control pests, the use of the Roudup herbicide (Carneiro 2005), the deforestation of areas of permanent protection and increasing erosion of the banks of the Tacutu River. Is it urgent that a plan be implemented for sustainable use of the area, such as the one that is being implemented on the BR-163 (Cuiabá-Santarém) Highway in Pará (based on Federal Decree 5886 – 13 February 2006) creating an "Area of Provisional Administrative Limitation" or ALAP).

The area of the Lua mountain chain stands out as being the only transition area between *lavrado* and the *campinas/campinaranas* (white-sand scrub forests) and the rain forests of Roraima. This area is the headwaters for the microbasins of the Rivers Quitauaú, Urubu and Baraúna. The area is highly heterogeneous both because of its ecotone areas and because of its proximity to the rocky complex of the Lua mountain chain, which is over 1000 m in altitude. In the area dominated by savannas the prevailing typologies are woodland and parklands with enclaves of seasonal submontane forest, dense rain forest-savanna ecotone, and seasonal alluvial forest-savanna ecotone along the Tacutu River. The area is highly threatened by the advancing deforestation frontier promoted by the invasion of public lands. This movement is stimulated by the presence of four agrarian-reform settlements in the area surrounding the Lua mountain chain: the União, Esperança, Taboca and Vilhena settlement programs, which were created by INCRA in areas of primary forest that are in contact with areas of open savanna. The area still has high connectivity with forest ecosystems and five indigenous lands, constituting a strategic area for establishing a mosaic of protected areas. Because of its importance, the *lavrado* in the area of the Lua mountain chain is also proposed for conservation under the Economic-Ecological Zoning of Roraima (Marques *et al*. 2002).

Lavrado contains a system of perennial and seasonal ponds related to drainage networks that are young and little developed. They are formed in level areas associated with small basins in the Boa Vista formation, usually without influence from medium or large fluvial discharges (Simões-Filho *et al.* 1997). These areas stand out for their importance for conservation both for hydrological reasons and because of their associated flora and fauna. The ponds are directly related to recharging the aquifers and they may or may not be interconnected among themselves or with streams and *buritizais*. These ponds have a high diversity of species when analyzed together, have been reported for the basin of Igarapé Auai Grande, in the municipal district of Boa Vista, 90 species of aquatic plants (Carranza 2006). The existent area of lakes to west of the city of Boa Vista, on the border between the municipal districts of Boa Vista and Alto Alegre, stands out as a priority area for conservation in the state because its drainage network and because of the associated organisms. These lakes are a part of the drainage system of the Cauamé and Mucajaí Rivers, which are direct tributaries of the Branco River. Human pressure on this ecosystem is growing with the expansion of the urban limit of Boa Vista, where badly planned neighborhoods established through invasions have been causing degradation of urban streams, leading to problems for public health and sanitation. In spite of being areas that are protected by law, the lack of policies for inspection and protection have been putting these springs at risk in areas close to urban centers. The creation of conservation units that protect these ecosystems is urgent for Roraima.

FINAL CONSIDERATIONS

Despite significant advances in recent years, there are still gaps to be covered to improve biological understanding of the savannas of Roraima. Characterization of its structure and ecological dynamics and recognition of its biodiversity contribute to understanding the differences or similarities that exist among the great South American ecosystems. In addition, there has been little progress in determining the natural potentialities of these ecosystems, in the sense of implementing public policies for environmental management that are translated into regional realities. A greater advance in studies of the region's flora and fauna would demonstrate, on a solid scientific basis, that the savannas of Roraima may not be as poor as is sometimes imagined. Its value for conservation should not be measured by species richness alone, but should also be based on its role in protecting springs at the headwaters of watercourses, conservation of terrestrial carbon, ecological corridor and scenic patrimony that make the savannas of Roraima an irreplaceable ecological area in Amazonia. These regional ecosystems have their own ecological identity but do not have a single conservation unit to preserve their biological richness. The lack of conservation areas in these ecosystems at the northern edge of Amazonia is incongruent and represents a setback in the progress that Brazil has achieved in recent years for the Amazonian biome as a whole. The initiatives promoted by the Program of Protected Areas of Amazonia (ARPA) in meetings held in Brasília, Cuiabá, Belém and Manaus at the end of 2006 took advantage of the moment to begin a discussion of this type, at the same time that rapid expansion is occurring in agriculture and industrial silviculture throughout the whole ecological area called "*lavrado*." Collaboration among institutions and research groups that are active in these savannas, shared by Brazil, Guyana and Venezuela should be stimulated with the objective of promoting international-cooperation projects capable of filling out sampling gaps and to systematizing knowledge generated in the three countries. This would be an important step towards building unified international public policies for the conservation of this whole landscape block at the northern edge of Amazonia.

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