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Pedological Features and Fire Influence the Brazilian Cerrado

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ABSTRACT

The Cerrado covers 22% of the land surface of Brazil and is mainly located in the Central Region. This biome is considered the richest savanna and also has high endemism. The vegetation is very varied in form, ranging from dense grassland, usually with sparse covering of shrubs and small trees, to almost closed woodland. The presence of certain species and physiognomy is strongly related with the soil chemical and physical features. The Cerrado soil is considered acid, mainly, because of the high concentration of aluminum, but in this case, some species present different tolerance levels. *Miconia albicans*, considered an aluminum-accumulating species develops an abundant population in the Alic soil region. In the same way that tolerant species occur in high aluminum concentration, others occur only where it is lower and the fertility is greater, like *Magonia pubescens*. Besides pedological features, the physiognomic variation and the species distributions can be related with the fire frequency, too. Many species have morphological adaptations like xylopodium and thick cork bark that provide larger protection during the fire action. The relation Cerrado-fire is focused in many studies, because some species require high temperature to break dormancy, to germinate and to flower. In spite of the several environmental conditions influences, the pedological features and the fire frequency are decisive in the physiognomic diversity and in the species distribution.

Keywords: Brazilian vegetation, fire, savanna, soil

CONTENTS

INTRODUCTION

The Cerrado corresponds to the Oreades in the Martius system, occupying 2 million km^2, 23% of the Brazilian national territory. The Cerrado is considered to be the richest savanna in the world and a priority area for conservation (Myers *et al*. 2000). This biome is found basically in the Brazilian Planalto Central reaching the states of Goiás, Tocantins and Distrito Federal, part of the states of Bahia, Ceará, Maranhão, Mato Grosso, Mato Grosso do Sul, Minas Gerais, Piauí, Rondônia and São Paulo in a contiguous area. As for the non-contiguous areas they can be found in the states of Amapá, Amazonas, Pará and Roraima and in small areas in Paraná, occuring in the Amazon forest, Atlantic forest, in the Caatinga and in the Pantanal. Outside Brazil it occupies areas in Brazil and Paraguai, and similar landscapes are found in Colombia, Guiana, Suriname and Venezuela receiving other denominations such as Lhamos (Ribeiro and Walter 1998).

The cerrado is considered to be part of the xeric vegetation that includes the Caatinga in the northeast of Brazil and the Chaco in Paraguai, Bolivia and Argentina. This corridor occupies a intermediary region in between the two main tropical forests of South America, the Amazon forest to the northwest and the Atlantic Forest to the east and south east (Méio *et al.* 2003).

In Brazil it occurs from altitudes that vary from 300 m in the Baixada Cuiabana (MT) and over 1600 m, in the Chapada dos Veadeiros (GO). This contrast and the large distribution over the latitudes cause a high thermal variation (Ribeiro and Walter 1998). The Cerrado is characterized dry winters and rainy summers with a mean annual precipitation of 1500 mm, varying from 750 to 2000 mm.

The Cerrado vegetation is made up of five different phytophysiognomies that possess two floristic layers, a herbaceous subarbustive and a arbustive-arboreal layer. Both floristic layers are distributed over all the Cerrados extension, but not in a homogenous manner. Usually only the Cerradão and Campo limpo possess distinct floristic characteristics (Coutinho 1978). Considering the various floristic and physiognomic differences the same author denominated the savanical forms of Cerrado (cerrado *sensu stricto*, campo cerrado and campo sujo) as ecotonal forms in between the cerradão and campo limpo.

This vegetation mosaic is determined by patches of soils that vary from poor to not poor, and also from the irregularity of fire occurrence (Coutinho 2002), considering that it influences the structure and floristic composition of the vegetation in the Cerrado or in the Savanas in general (Dezzeo *et al*. 2004). As a function of the above factors, the different phytophysiognomies of the Cerrado could also be denominated pedoclimaxes and piroclimaxes (Coutinho 2002).

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Invited Mini-Review

SOIL AND VEGETATION

The soils of the Cerrado, in their majority, are dystrophic, with extremely low fertility as a consequence of the thousands of years of lixiviation, and with high toxicity and acidness due to the accumulation of iron oxides and aluminum (laterite) (Lopes and Cox 1977). This biome is dominated by latosoils, but the existence of a significant variety of other soils associated to the climate conditions allowed for the establishment of a great variety of herbaceous and arboreal species. The vegetation represents the best expression of the variety of environments.

The latosoil has good physical characteristics that are due mainly to the stability created by high aggregation. Clay aggregates, mainly caolinite and gibbsite, are stabilized by the high content of Fe and Al oxides, by organic matter or both. This strong stability allows a better air and water translocation, presents less resistance to root penetration and – due to stable aggregates – is less susceptible to erosion (Motta *et al.* 2002).

The latosoils have a small amount of nutrients available for the plants, mainly, P, Ca and less even micronutrients. The concentration of Al in these soils is generally very high, and many times can be toxic to the plants. In these soils agriculture is many times only possible with the application of P and $CaCO_3$ including micronutrients (Motta *et al.* 2002). The application of $CaCO_3$ diminishes the acidity, the levels of available Al and also raises the quantity of Ca^{2+} available to the plants, establishing a favorable environment for the development of microorganisms, along with organic matter. The addition of P is necessary because, generally, the little that is in the soil is coupled to the Fe and Al (Motta *et al.* 2002).

Soil studies in this biome have always been related to its vegetation and what has been the main motivation for research is the preoccupation in finding a relation to explain this association. However, evidences that the soil properties have a determinant role in the floristic and structural changes vary, and are some time contradictory. Goodland and Ferri (1979) were the first to indicate the existence of a close relation between vegetation biomass and soil fertility gradient and also emphasized the importance of aluminum in the Cerrado. Subsequent works showed a lower nutritional "status" and higher levels of aluminum saturation in some forest formations when compared to Cerrado areas (Haridasan 1982).

The Cerrado possesses species that are distributed in different phytophysiognomies. Ribeiro *et al.* (1981) evidenced the ecological plasticity of some species along the physiognomic gradient, however, no species occurred in all the areas in study. In this work, the authors stated a direct relation of the aluminum, calcium + magnesium, potassium, fosforum contents, aluminum saturation percentage and also the inverse correlation of the pH with the increase in vegetation biomass. Goodland and Ferri (1979), amongst other authors (Batista and Couto 1990), also found the same relation, but the aluminum was in greater concentrations in the areas with less biomass, contrasting with the results found by Ribeiro *et al.* (1981).

In Batista and Couto (1990), the edafic factors influenced the species richness, however the high Al content and low pH had a negative influence on the number of species and arboreal density. The same results were observed in the Floresta Nacional de Paraopeba (Paraopeba National Forest), Brazil. In this environment the amount of Al influenced negatively not only the wealth, but was also related to smaller vegetation density and biomass (Neri 2007). The Cerrado vegetation shows a close dependency not only with the chemical factors of the soil, but also with the physical. Of these, the fine sand fraction was the one that most influenced in the development of the species such as *Qualea grandiflora*, *Byrsonima verbascifolia*, with positive correlation and *Machaerium villosum*, with negative correlation, in the biological reserve of Moji-Guaçu, SP (Batista and Couto 1992).

Many times it is hard to understand the distribution of the phytophysiognomies in function of the soil properties that are in general, dystrophic. However, within each community, populations have showed consistent correlations, mainly with levels of aluminum and calcium indicating a distinct potential competitiveness (Haridasan *et al.* 1997).

In the Floresta Nacional de Paraopeba, Brazil, high soil fertility and low Al content are associated to the cerradão mesotrófico (forest vegetation), where it is possible to find species that possess smaller tolerance to low fertility and high Al content (*Luehea divaricata* Mart., *Magonia pubescens* A. St.-Hil., *Myracrodruon urundeuva* Allemão, *Dilodendron bipinnatum* Radlk. and *Terminalia argentea* Mart.). In this environment we also have the cerrado *stricto sensu* (savanna vegetation), associated to low fertility and to high Al content, in which the main species that occur are *Miconia albicans* (Sw.) Triana, *Pera glabrata* (Schott) Poepp. ex Baill., *Eugenia dysenterica* DC., *Qualea grandiflora* Mart. and *Qualea parviflora* Mart. (Neri 2007).

Neri (2007) highlighted the occurrence of 14 Cerrado species in the Floresta Nacional de Paraopeba, in environments with pedologic differences *Acosmium dasycarpum*, *Alibertia edulis*, *Bowdichia virgilioides*, *Erythroxylum* sp., *Erythroxylum suberosum*, *Eugenia dysenterica*, *Guapira noxia*, *Machaerium opacum*, *Myrcia língua*, *Ouratea castaneifolia*, *Qualea grandiflora*, *Qualea multiflora*, *Roupala montana*, *Zeyheria Montana*. These species occurred from cerrado *s.s.* areas with high Al content to areas of cerradão mesotrófico, where the available Al was not present in the 0-20 cm layer of soil.

Issues that involve soil and vegetation are quite complex and poorly understood. Other than the discussion about how the soil characteristics are responsible for the presence of a physiognomy, we have on the other side, the influence of the floristic composition of vegetation on the alterations that can occur in the soil (Kellman 1979).

When structural modifications occur along a gradient, the impacts suffered by the vegetation should be considered, mainly in the biome in question. The Cerrado is subject to many alterations such as fire (of anthropomorphic origin, or not), pasture, exploration, invasive plants and other events able to modify the structure and floristics (Pivello and Coutinho 1996). These modifications occur according to the type of alteration, intensity and time or space interval in which they occur.

This is a biome that has been modified in the past decades mainly because within it there is a large agricultural frontier in which the advance of monocultures is occurring not only in the central area but also in the marginal areas. The estimations of remaining vegetation for future years is not promising. For the year 2000 it was estimated that 41-44% of the total Cerrado area would be explored (Alho and Martins 1995).

FIRE AND THE CERRADO

Fire in the Cerrado is a question that has been discussed between many researchers, considering its positive and negative aspects for the vegetation. It is a factor that influences many ecological problems that vary from the floristic composition of the forest until the energy flux in the ecosystems they are in (Coutinho 1990).

The Cerrado vegetation is constituted of pirofitic species, that is those adapted to a environmental condition that includes the presence of fire. Seed germination can be facilitated by fire. Some species have an impermeable tegument and the rapid elevation of temperature can cause the appearance of fissures in the shell making it permeable and thus favoring its germination. Many species demand the periodic occurrence of fire in order to survive and reproduce. The fire strengthens and increase its competetive range (Coutinho 1978).

Fire can also have negative effects depending on its frequency and intensity. Some of the adverse effects of fire include the low recruitment of woody species, causing reduction of arboreal density and diminution of species diversity (Silva and Bates 2002). Fire can be an important factor of mortality amongst younger plants in the first years (Franco *et al*. 1996; Hoffmann 1998) and also limit the population growth due to the impact on the reproductive effort as a consequence of the mortality of the plants aerial part, known as top kill (Hoffmann and Solbrig 2003).

Medeiros and Miranda (2005) working in campo sujo (cerrado's open form) in the reserva Ecológica do Instituto Brasileiro de Geografia e Estatística, located in Brasília, Brazil, where three annual burnings were prescribed, observed a 37% reduction in the number of live individuals. The mortality affected mainly the smaller individuals between 1 m and 2 m. After three burnings, the dead individuals plus the individuals that presented top kill increased to 73%.

According to Eiten (1990) the Cerrado occurs in a gradient of physiogonomic natural forms that are modified by periodic fire caused by man or by natural causes such as lightning. The effect of fire on its physiognomy reaches mainly the arbustive layer, specially those with thin stems, and also depends on the height and density of the graminoide layer because when these dry they become the main source of fuel for fire. If fire does not occur for some years, the arbustive layer reassumes its normal density, which depends on the soil. If fire occurs twice a decade or less, the basic physiognomy of the Cerrado does not change. This variation of the characteristics of the soil, fire occurrence, exploration and recovery produces a continuum of Cerrado forms.

VASCULAR FLORA OF THE CERRADO

The first floristic list of the Cerrado was elaborated in 1892 by Warming from a study in the Lagoa Santa, Minas Gerais region and later other authors seeked to compile more data about the Cerrado flora, highlighting Rizzini (1963), that presented 537 species of arbustive and arboreal species; Heringer *et al*. (1977) with 774 arbustive and arboreal species; Castro *et al*. (1999) compiled 1753 woody species, excluding lianas.

Mendonça *et al.* (1998) compiled 6062 fanerogamic species distributed in 1093 genus and 151 families, also 267 species of Pterodophyta (51 genus and 19 families) and two species of gymnosperms (one genus). From this listing of the author some species can be highlighted as more representative of the Cerrado biome, including Leguminosae, Compositae, Orchidaceae, Gramineae, Rubiaceae, Melastomataceae, Myrtaceae, Euphorbiaceae, malpighiaceae and Lytraceae.

OLIGOTROPHIC SCLEROMORPHISM AND ALUMINUM

For the native vegetation the absence of certain nutrients such as Ca^{2+}, P, S, and N, makes it impossible to use carbohydrates produced by photosynthesis and as a consequence there is a accumulation of these in certain structures such as thick subers (Arens 1963). As a function of the morphological characteristics caused by the edafic conditions, this vegetation has been classified as oligotrophic scleromorphic.

The majority of the Cerrado species has peculiar morphological characteristics. The leaves of the Cerrado plants be they thick or thin usually are hard and coriacic and crunch when folded. The surface of the plants is smooth and waxy rough or pilose. On the abaxial face the primary and secondary veins, and frequently the tertiary are evidenced and form hard edges. In the majority of species the leaves are lighter colored (frequently with yellow venation) or grayer, especially during the dry season. The gray tone is not due to the pilose layer, because this is not usually present on the superior face of the leaves, but is due to the structure of the tissue and the thickness of the cuticle (Eiten 1990).

The theory of xeromorphism is about the described characteristics and others such as: tortuosity and sub-development of the trunk and branches, the existence of xylopods, the loss of leaves in a certain period of the dry season, etc. According to these characteristics many researchers consider the Cerrado as a xerophyte vegetation, including Warming (1908 cited by Goodland and Ferri 1979).

It is interesting to notice that the Cerrado vegetation has the appearance of a vegetation that we are used to seeing in environments that lack water. On the other hand, many common plants in the Cerrado have characteristics that oppose the idea of adaptation to dry conditions. This way, many species have leaves with large surfaces such as those of the *Tocoyena*, *Salvertia* and *Kielmeyera* genus. For all this, water is necessary and obviously the plants find this water in the deep soils of the Cerrado from where they withdraw water until up to 18 m of depth. As such, it is the edafic factors that are greatly responsible for the appearance of the vegetation. The aluminum, toxic to the vegetation in abundant n the soils of the Cerrado and has an important role in the ecology of this biome (Ferri 1980).

The majority of the plants of the Cerrado do not have any restrictions to water supply, considering they keep their stomata open all day, even in the dry season. Ferri (1955) evolving his concepts explains that the Cerrado xeromorphism has nothing to do with the protection against the dry season, being originated form any other reason and that the Cerrado vegetation can eventually be subject to not so severe dry seasons, against which the protection of a few hairs, thick cuticles and stomata in depression will do. Arens (1963) admitted that the pronounced xeromorphism of the Cerrado is a consequence of the oligotrophic conditions of the soils of the Cerrado that are generally acid and poor in exchangeable bases. One of the main factors is probably the relative lack of available nitrogen that can give origin to the oligotrophic xeromorphism. This deficiency limits the use of the photosynthesis products and consequently, the scleromorphic characters. He concluded that the Cerrado's peculiar vegetation is selected by the mineral deficiencies and that they adapt to these.

Ferri (1955) considering the observations in the Caatinga and n the Cerrado concluded that the xeromorphic characters are in fact prejudicial to the plants in water deficient environments. A comparison between the characteristics of Cerrado and Caatinga plants can be seen in **Table 1**.

Table 1 Comparation of the conditions and characters of the Cerrado and Deciduous Caatinga vegetation. Adapted from Goodland and Ferri (1979).

Characters	Cerrado	Caatinga
Floristical		
Bromeliaceae	Not frequent	Frequent
Euphorbiaceae (juicy)	Not frequent	Frequent
Cactaceae	Not frequent	Frequent
Morphological		
Suculent stems	Not found	Present in many species
Ample leaves	Frequent	Not frequent
Pilose leaves	Frequent	Not frequent
Coriacic leaves	Frequent	Not frequent
Thick cuticles	Frequent	Not frequent
Stomata in depressions	Frequent	Not frequent
Abundant mechanical tissue on the leaves	Frequent	Not frequent
Thick suber	Frequent	Not frequent
Physiological		
Estomatic reactions	Very slow	Very fast
Restriction to transpiration	Rare even in the dry season	Frequent even in the rainy season
Cuticular transpiration	Generally high	Generally low
Leaf senescence	Rare	Common

FINAL CONSIDERATIONS

Fire assumes a key role in explaining the present proportion of the different vegetation formations in the biome. However, to simply affirm that fire is a natural component of the Cerrado covers up the fact that the true responsible for its occurrence today is how man in most cases deliberately causes fire.

Other than fire, the edafic factors of extreme importance in the Cerrado, mainly in the determination of the flora that occurs in a determined area. Studies involving edafic factors as well as those about fire behavior are extremely important considering that these two can be responsible for the floristic and structural variations of the Cerrado vegetation, influencing in the diversity and growth of its species. These can also help decision making activities for the establishment of conservation units, in the choice of the best adequate methodologies for the recuperation of degraded areas and also to better understand the ecology of this biome. In some regions of the Cerrado these studies are still scarce and there is the necessity of greater efforts for the knowledge of the relations in between the environmental variables and the vegetation.

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