FIRE IN NEOTROPICAL SAVANNAS

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Summary

This chapter reviews the main characteristics of tropical savannas and their interactions with fire, a main factor involved in the dynamics of these ecosystems. Burning in savannas generally takes place by the end of the dry season, favored by the accumulation of dry biomass in the herbaceous layer. Several factors affect fire characteristics and behavior, such as quantity, quality and composition of the combustive matter, wind direction and velocity, relative humidity of air, and season of burning. Although fire is a mortality factor, common savanna plant species seem to be adapted to burning. Adaptations include underground reserves, protected meristems, re-sprout capacity, clonal multiplication, growth seasonality, thick cork layer, and sclerophyllous leaves. Deleterious effects of fire are greater in the younger or smaller size classes in the population. On the other hand, the passage of fire restores light and nutrients on the topsoil, that together with the return of rains create better conditions for seasonal growth. Under fire exclusion herbs escape from the direct mortality effects of burning but exclusion promotes shading and nutrient depletion which are harmful for the renewal of herbaceous growth. Species differ in their responses to fire regime, therefore the fire regime affects species composition. The fire regime is also important in terms of the physiognomy of the savanna. Frequent burning causes qualitative and quantitative changes in plant community structure and composition promoting open physiognomies with fewer woody elements. Conversely, fire exclusion has been shown to increase tree density in tropical savannas transforming open savannas in woodlands. In modern times, most fires are set by humans. However, natural fires by electric discharges during storms do occur although less frequently than human induced fires. Although fire has been used in savanna management since pre-Columbian times, it remains a complex issue that needs further research.

1. Introduction

The tropical savanna is one of the most extended terrestrial ecosystems, present in old and new tropical regions, and covering about 23 million km^2. In broad terms it refers to vegetation with a continuous herbaceous layer and a discontinuous layer of shrubs and/or trees. Most savanna plant species are perennial.

The woody layer varies widely in relative importance of shrubs vs. trees; it also varies in density of woody elements. Trees are usually low in height and gnarled in shape. The herbaceous layer of Neotropical savannas is mostly made up by grasses and sedges usually referred to as “graminoids” that represent more than 90% of the total biomass. Other less important components are sub-shrubs, and large and small herbs (for details in the structure and function of Neotropical savannas see Sarmiento, 1983). Fire, whose frequency is variable, is considered an intrinsic factor in savanna ecology. Savanna fires, natural or induced, take place in the herbaceous layer. This is due to the accumulation of dry biomass in this layer, which takes place progressively throughout the growth season and increases rapidly as the dry season advances. This dry biomass becomes the fuel for fires that usually take place during the last part of the dry season. Most fires in modern times are of human origin, but some natural fires take place, although at much lower frequency.

2. Fire Behavior in Neotropical Savannas

Fire behavior depends on different factors such as quantity, quality and composition of the combustive matter, wind direction and velocity, relative humidity of air, and the season of burning. The amount of combustive matter available is determined by the rates of biomass production and biomass accumulation. The former depends on water availability during the growing season (and hence on rainfall), whereas the latter depends on grazing intensity and time after last burning. Quality of combustive matter determines the ignition temperature, and in turn depends on the biomass species composition, water contents and plant phenology.

Ignition temperature depends on species composition, wind speed and water content of the vegetation. In some Venezuelan savannas dominated by *Trachypogon spp.*, ignition temperature ranges from 129 ^oC with no wind to 135 ^oC with 3 ms^{-1} wind in the middle of dry season; when other grass species are dominant, ignition temperatures ranges between 130 ºC and 160 ºC without wind. In December, at the start of the dry season, ignition temperature reaches 205 ^{o}C without wind.

Based on its behavior, fires may be “head fires” or “back fires”. The former run fast aided by the wind, whereas the latter run against the wind, moving slowly and causing greater damage to the vegetation. Fire can also be classified as “ground fire”, “surface fire”, and “crown fire”. Ground fires move on the surface, beneath the litter layer; surface fires move within the herbaceous layer; and crown fires propagate through the tree canopy.

Savanna fires are commonly surface fires, with heights between one and five m measured in experimental head fires and between 0.5m and 1.5m measured in back fires. Since adult trees are above 2-4m, they are rarely ignited but could be badly charred. Furthermore, low tree density usually observed in tropical savannas does not favor crown fires, although occasionally the foliage of individual trees may get torched. This occurs more frequently in trees that keep dry leaves on the stem, such as palms (Bond & Keeley, 2005).

Savanna fires are patchy increasing environmental heterogeneity that favors biodiversity and allowing survival of fire-sensitive species.

It is not easy to measure the intensity of fire front, which has been reported in a range of 1200 to 8000 $kJm^{-1}s^{-1}$ (Miranda *et al.*, 1996). Some authors use proxies such as the height of leaf-scorch or char and the percentage area of grassland burnt. These variables are significantly correlated to fire intensity. The burning front moves briskly, and the rise in temperature lasts no longer than five minutes. Since factors affecting temperature during the passage of fire vary widely, reports on air temperature at soil surface show a wide range: from 32 to 600 ^{o}C in African savannas (Gillon, 1983) from 600 to 750 ^{o}C in Brazilian savannas (Miranda *et al*., 1996); in Venezuelan savannas temperatures range from 70 ^{o}C to 472 ^{o}C, depending on the grass layer composition, rate of fire spread and composition of the grass layer.

Top soil is not affected by fire due to the low thermal conductivity of soils and the generally low temperatures of the passage of fire. Temperatures at 2 cm below soil surface seldom exceed 35 ºC. At 5 cm there seems to be no change in temperature. Under high intensity fires heat may penetrate up to 3 cm deep in the soil.

Burning substantially decreases the albedo. In experimental fires in Brazil, albedo decreased from 0.11 to 0.03-0.05, which is lower than soil without vegetation. Decrease of albedo, although results in higher radiation absorption, does not imply higher temperatures but greater temperature oscillations. Normal daily oscillation measured in a Brazilian savanna was 10ºC before and 25-26ºC after burning.

Also important is the fire regime, especially if fire is used as a management tool. In this case, burning is usually programmed to take place annually, every two years, every four years or even more. Concerning season of burning, it could be early, middle or late dry season. For more details on these aspects, see the Section 6 on Fire as a Management Tool.

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Bibliography

Bond, W. J. & J. E. Keeley (2005) Fire as a global "herbivore": the ecology and evolution of flammable ecosystems. *Trends in Ecology and Evolution*, 20(7):387-394. [This article proposes that fire acts as global herbivore destroying all the aerial biomass].

Coutinho, L.M. (1982) Ecological Effects of Fire in Brazilian Cerrado. In: Huntley, B.J. and Walker, B.H. (eds), *Ecology of Tropical Savannas*, pp. 273-291. Springer-Verlag, Berlin. [This is a very important article reviewing the consequences of fire and fire suppression in Brazilian savannas].

Frost, P., Medina, E., Menaut, J.C., Solbrig, O., Swift., M. & Walker, B.H. (1986) *Responses of savannas to stress and disturbance*. International Union of Biological Sciences. Special Issue. Nº 10. Paris. [This is a classical publication that has oriented ecological research on tropical savannas since the 1980s. It is the result of international cooperation under the program "Decade of the Tropics" of the International Union of Biological Sciences (IUBS)].

Guidon, N. & Delibrias, G. (1986) Carbon-14 dates point to man in the Americas 32,000 years ago. *Nature*, 321: 769-771. [This article presents evidences that suggest American natives already managed savannas using fire 32,000 years ago].

McPherson, G.R. (1997) *Ecology and Management of North American Savannas*. The University of Arizona Press, Tucson. [This essential book gathers most of the previous knowledge on North American savannas].

Medina, E. & Silva, J.F. (1990) Savannas of northern South America: a steady state regulated by water-fire interactions on a background of low nutrient availability. *Journal of Biogeography*, 17:403-413. [Analyzes the relationships between water and nutrient availability with fire effects on savanna vegetation].

Miranda, H. S., Rocha e Silva, E. P. & A. C. Miranda (1996) Comportamento do fogo em queimadas de campo sujo. In In Miranda, H. S., Saito, C. H. y B. F. de Souza D. (editors) *Impacto de Queimadas em Areas de Cerrado e Restinga*. Pp. 1-10. [Compares the temperature and fire effects on several experimental conditions in Brazilian open savanna ("campo sujo")].

Pivello, V.R. & Norton, G.A. (1996) FIRETOOL: an expert system for the use of prescribed fires in Brazilian savannas. *Journal of Applied Ecology*, 33:348-356. [This article represents the first attempt to produce an expert system for the management of South American savannas].

San José, J.J. & Fariñas, M.R. (1983) Changes in tree density and species composition in a protected *Trachypogon* savanna, Venezuela. Ecology, 64:447-453. [This article analyzes the changes on a 3ha plot in a savanna excluded from fire and grazing in the Venezuelan Llanos].

San José, J.J. & Fariñas, M.R (1991) Temporal changes in the structure of *Trachypogon* savanna protected for 25 years. *Acta Œcologica*, 12:237-247. [This article presents additional results in the analysis of the changes in the arboreal and herbaceous layers of a 3ha protected savanna in Venezuelan llanos].

Sarmiento, G. (1983) The savannas of Tropical America. In: Bourliere, F. (ed), *Tropical Savannas*, pp. 245-288. Elsevier, Amsterdam. [This is a classical article reviewing the knowledge on Neotropical Savannas].

Sarmiento, G. (1984) *The ecology of Neotropical savannas*. Harvard University Press, Cambridge, Mass. [In this important book, an authority in tropical savannas reviews the structure and functioning of the savanna ecosystem in the early stage of savanna ecological research].

Silva, J.F. (1996) Biodiversity and stability in tropical savannas. In: Solbrig, O.T., Medina, E. & Silva, J.F. (editors), *Biodiversity and savanna ecosystem processes: a global perspective*. pp. 161-174. Springer-Verlag, Berlin. [Proposes the study of life story traits of savanna plants in order to understand and predict the stability of tropical savanna].

Silva, J. F., A. Zambrano & Fariñas, M. R. (2001) Increase of the woody component of seasonal savanna under different fire regimes in Calabozo, Venezuela. *Journal of Biogeography*, 28:977-983. [Presents results showing how the arboreal cover increased in both a protected savanna plot and in burnt plots under different management regimes].

Solbrig, O.T., Medina, E. & Silva, J.F. (1996) Biodiversity and tropical savanna properties: a global view.

In: Mooney H.A., J.H. Cushman, E. Medina, O.E. Sala and E.D. Schulze (editors), *Biodiversity and global change.* pp. 185-205. SCOPE 55, J.Wiley. [This chapter presents a general view of the functioning on the savanna ecosystem, based on the published research done since the 1980s].

Biographical Sketches

Mario R. Fariñas was born in Venezuela. Trained in France, he received his “Troisieme Cycle” Doctorate degree in 1982 and the “Docteur d’Etat en Science” in 1987, both from the Université de Sciences et Techniques du Languedoc. Since 1972 is a faculty member at the Universidad de Los Andes (ULA) in Merida, Venezuela. Since the 1970s he has been doing research on several aspects of the ecology of tropical vegetation. In recent years he participated in an international cooperative effort sponsored by the Inter American Institute for Global Change Research (IAI) with scientists from Argentina, Brazil, Colombia, Cuba and Venezuela. He has been the Venezuelan National Coordinator of the Program on Global Change and Terrestrial Ecosystems (GCTE). He has directed the Tropical Ecology Research Group and the Graduate Program in Tropical Ecology at ULA in several occasions. His current interests include biodiversity and global change, structure and functioning of tropical ecosystems, biometry, multivariate analysis and vegetation complexity
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