THE ROLE OF NATURAL FIRES IN TROPICAL SOUTH AMERICAN BIOMES

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ABSTRACT

A simple climate-vegetation-natural fire model was developed to study the role of natural fires on forest-savanna transition dynamics in tropical South America. Quantitative results of this model lend weight to the ecological theories suggesting that lightning-triggered fires play a significant role in determining the location of the tropical forest-savanna boundaries. Our model calculations suggest that in the absence of fires, tropical forests would extend about 200 km into the presently-observed savanna domain.

INTRODUCTION

In the past few decades, the role of natural and human-induced fire regimes and disturbances have received considerable attention in ecosystem studies. Most investigations focus on anthropogenic fire disturbances particularly associated to tropical degradation in South America, mostly due to cropland and pastureland expansion. Although human-triggered fires practically overcome the effects of natural fire events in this tropical zone, understanding and modeling the natural dynamics of the forest-savanna transition remain an open issue particularly because tropical savannas and tropical forests may occur under the same climatic envelope in portions of this tropical region (Coutinho, 1990).

Unlike the humid tropical forests, which are quite impenetrable to fire due mostly to high humidity, tropical savannas are naturally influenced by fires triggered by lightning activity. In tropical South America, for instance, natural fires have shown to be one of the major forces in determining the tropical savanna biome in South America (Miranda *et al.*, 2002), i.e., it shapes forest-savanna boundary, balancing forest vegetation advances and retreats.

In this context, inspired by conceptual models, we propose a simplified representation of the climate-vegetation-natural fire (CVFN) system for tropical South America to study how natural fires affect the transition between forest and savanna biomes within Neotropics.

MODEL DESCRIPTION

The simplified dynamics of the climate-vegetation-natural fire system in tropical South American zone is represented by an 1-D model, which has a 0.5- longitudinal spatial grid for an average latitudinal band 5S – 15S (Hirota *et al.*, 2010). The climate-vegetation-natural fire (CVNF) model is composed by a simples set of modified Lotka-Volterra competition equations to represent the time evolution of fractional coverage area (%) of grasses (*g*) and trees (*a*).

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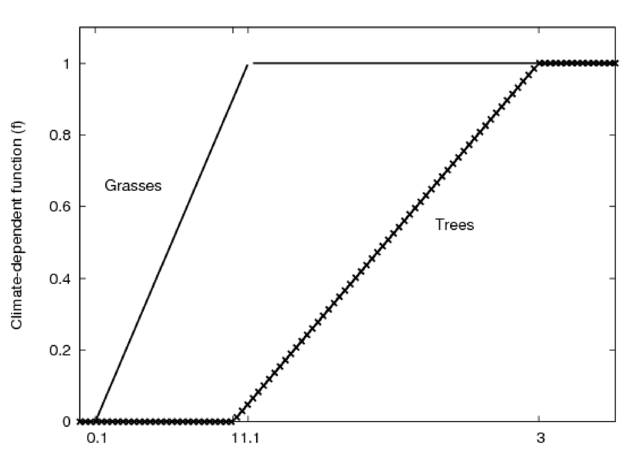
Plant growth parameters

$$\beta_i = \frac{f_i}{\gamma_i}, i = g, a,$$

$$f_i = \max\left[\min\left(\frac{HI - HI_{l,i}}{HI - HI_{l,i}}, 1\right), 0\right]$$

$$HI = \frac{1}{AI} = \frac{P}{PET},$$



$$\frac{dg}{dt} = \underbrace{\beta_g g}_{I}\left(1 - \underbrace{\frac{g}{g^*}}_{II} - \underbrace{c_{ga}\frac{a}{a^*}}_{III}\right) - \underbrace{\nu g}_{IV} - \underbrace{d_g fir_g g}_{V},$$

$$\frac{da}{dt} = \underbrace{\beta_a a}_{I}\left(1 - \underbrace{\frac{a}{a^*}}_{II}\right) - \underbrace{d_a fir_a a}_{V},$$

Natural mortality for grasses

Feeds litter pools (L)

Inter-specific competition

Intra-specific competition

Fire submodel: **Explicit ignition**, **Intensity**, **Effects**

Ignition

Fuel availability $L > L_{min} = 0.45$

+

Fuel flammability $HI < HI_{max} = 1.2$

+

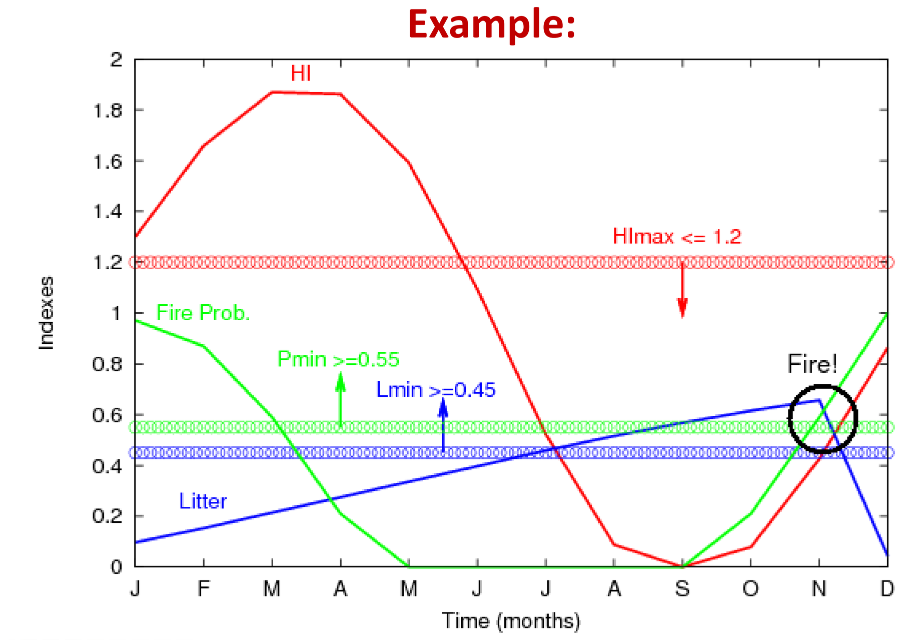
Lightning Probability

$$R(t) = \max\left[\mu_R + \Delta\cdot\sigma_R + A_R\cos\left(\frac{2\pi t}{\tau} + \phi_R\right), 0\right].$$

$$P_R = \max\left[\min\left(\frac{R - R_l}{R_u - R_l}, 1\right), 0\right],$$

$P_R > P_{R,min} = 0.55$

Example:

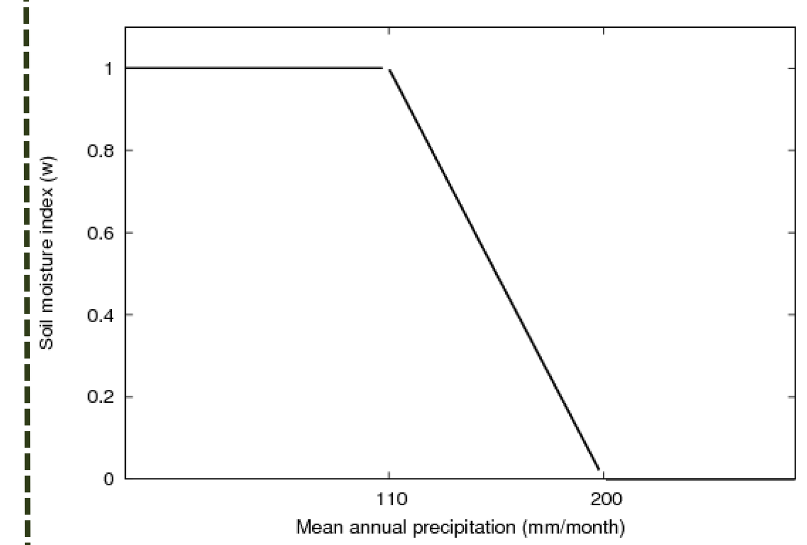


Intensity

$$I = I(w, L) = w \cdot h(L, \alpha_L, b_L).$$

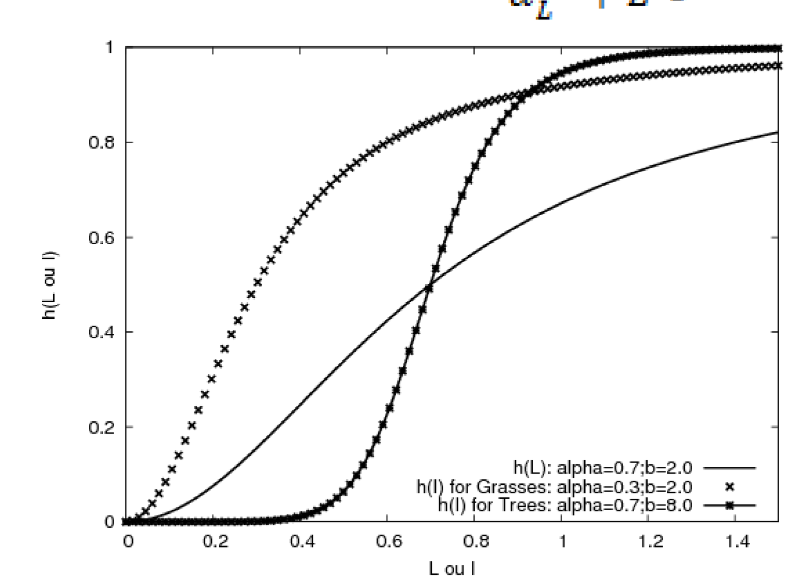
Soil moisture index

$$w = \max\left[\min\left(\frac{w_u - \mu_P}{w_u - w_l}, 1\right), 0\right],$$



Litter pools (grasses)

$$h(L, \alpha_L, b_L) = \frac{L^{b_L}}{\alpha_L^{b_L} + L^{b_L}},$$

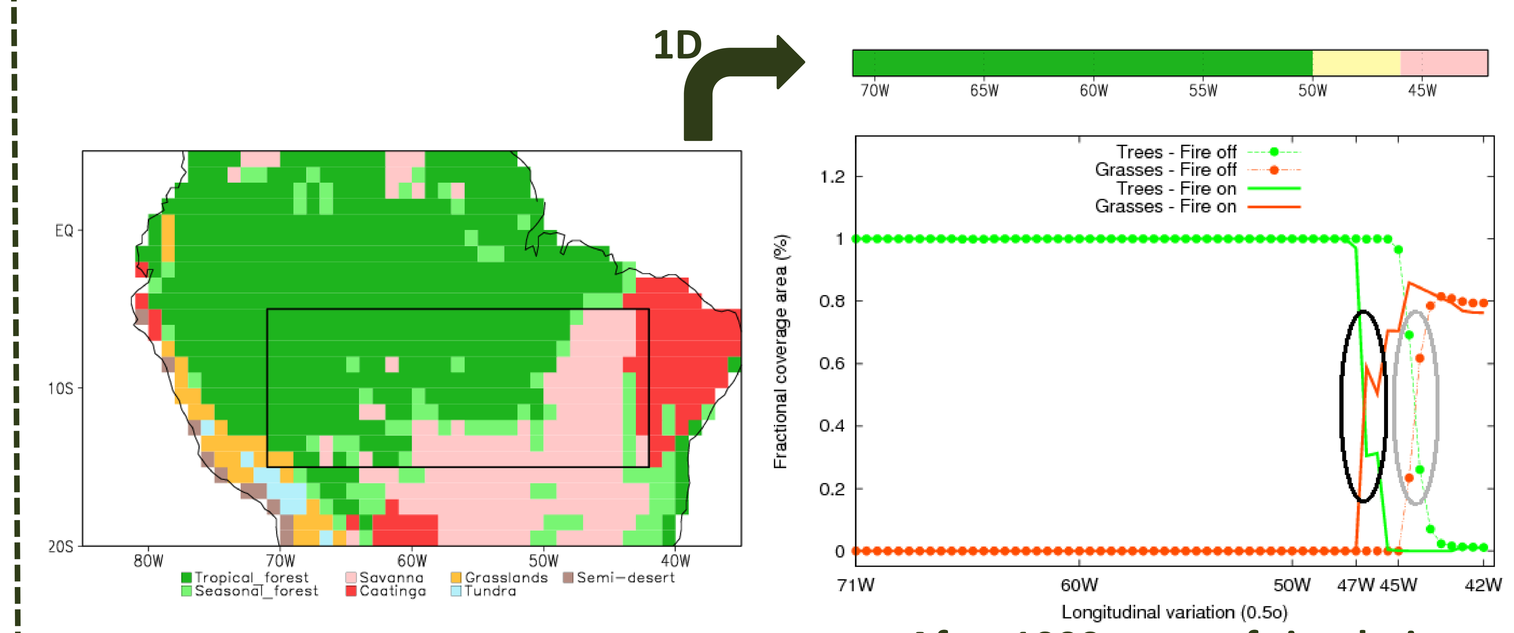


Effects

$$fir_i = h(I, \alpha_i, b_i) = \frac{I^{b_i}}{\alpha_i^{b_i} + I^{b_i}}$$

Different effects for grasses and trees

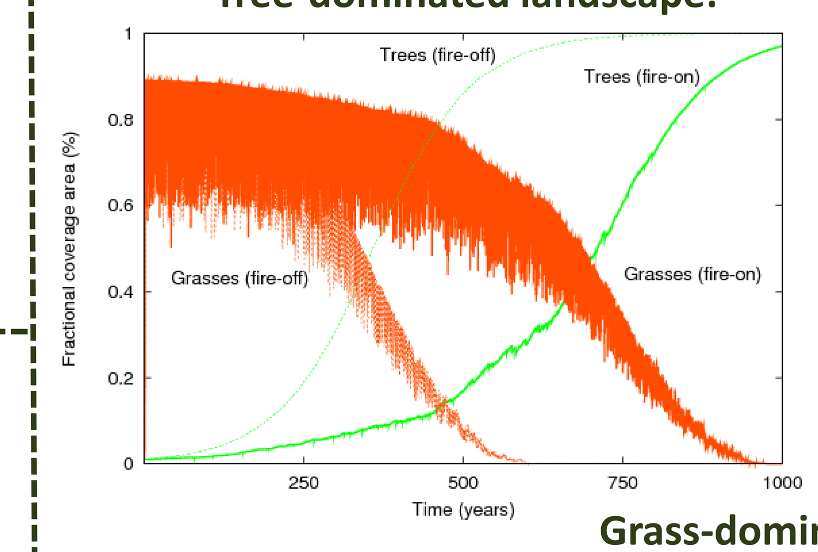
RESULTS



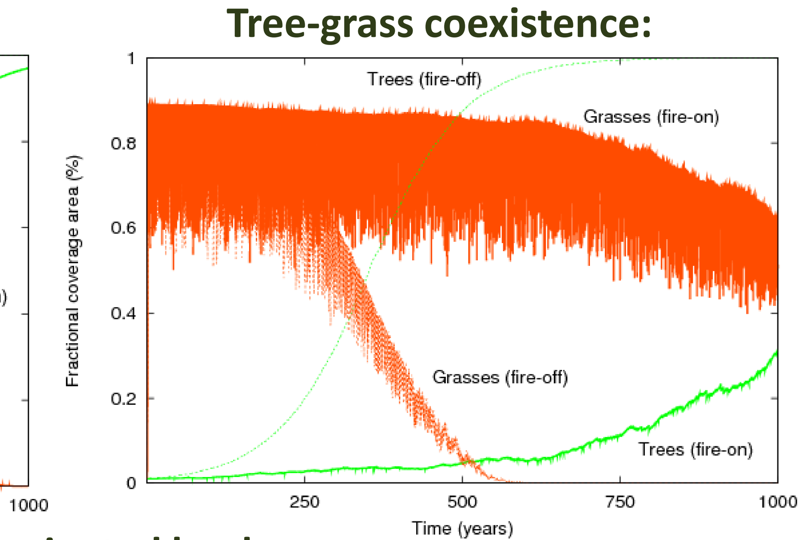
After 1000 years of simulation...

Time evolution where natural fires influence vegetation distribution:

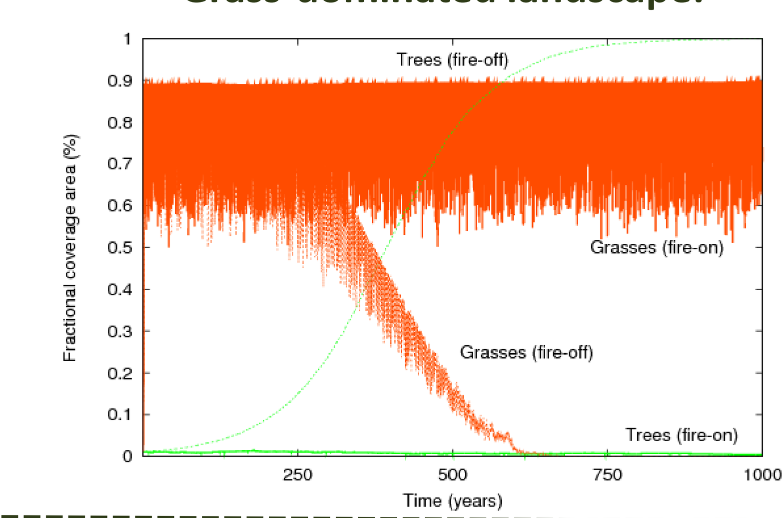
Tree-dominated landscape:



Tree-grass coexistence:



Grass-dominated landscape:



CONCLUDING REMARKS

The simulation without fire, i.e. driven solely by climate, presents an equilibrium distribution that does not fit precisely the 1-D map. In this case, tree cover starts to decrease and to coexist with grasses approximately at 44W-43W, which corresponds in the 1-D map to a savanna area. This result is supported by ecological theories which postulate that if fire did not exist and the system dynamics was only climate-driven, tropical forest areas would expand into areas which are currently covered by savannas. When fire is switched on in the model, forest-savanna boundary moves westward and its location compares more realistically with the 1-D map. This displacement is about 200 km.

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