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On the relative role of fire and rainfall in determining vegetation patterns in tropical savannas: a simulation study

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Tropical savannas cover 18% of the world's land surface and are amongst the most productive terrestrial systems in the world. They comprise 15% of the total terrestrial carbon stock, with an estimated mean net primary productivity (NPP) of 7.2 tCha-1yr-1 or two thirds of NPP in tropical forests. Tropical savannas are the most frequently burnt biome, with fire return intervals in highly productive areas being typically 1-2 years. Fires shape vegetation species composition, tree to grass ratios and nutrient redistribution, as well as the biosphere-atmosphere exchange of trace gases, momentum and radiative energy. Tropical savannas are a major source of emissions, contributing 38 % of total annual CO_2 from biomass burning, 30% CO, 19 % CH_4 and 59 % NO_x. Climatically, they occur in regions subject to a strongly seasonal 'wet–dry' regime, usually under monsoonal control from the movement of the inter-tropical convergence zone. In general, rainfall during the prior wet season(s) determines the amount of grass fuel available for burning while the length of the dry season influences fuel moisture content. Rainfall in tropical savannas exhibits high inter-annual variability, and under future climate change, is projected to change significantly in much of Africa, South America and northern Australia.

Process-based simulation models of fire-vegetation dynamics and feedbacks are critical for determining the impacts of wildfires under projected future climate change on i) ecosystem structure and function, and ii) emissions of trace gases and aerosols from biomass burning. A new mechanistic global fire model SPITFIRE (SPread and InTensity of FIRE) has been designed to overcome many of the limitations in existing fire models set within Dynamic Global Vegetation Models (DGVMs). SPITFIRE has been applied in coupled mode globally and southern Africa, both as part of the LPJ DGVM. It has also been driven with MODIS burnt area data applied to sub-Saharan Africa, while coupled to the LPJ-GUESS vegetation model. Recently, SPIFTIRE has been coupled to the Ecosystem Demography (ED) model, which simulates global vegetation dynamics as part of the new land surface scheme JULES (Joint UK Environment Simulator) within the QUEST Earth System Model (http://www.quest-esm.ac.uk/).

This study forms part of on-going work to further improve and test the ability of JULES to accurately simulate the terrestrial carbon cycle and land-atmosphere exchanges under different climates. Using the JULES (ED-SPITFIRE) model driven by observed climate (1901-2002), and focusing on large-scale rainfall gradients in the tropical savannas of west Africa, the Northern Territory (Australia) and central-southern Brazil, this study assesses: i) simulated versus observed vegetation dynamics and distributions, and ii) the relative importance of fire versus rainfall in determining vegetation patterns. A sensitivity analysis approach was used.