The Impact of Land Cover Change on Surface Energy and Water Balance in Mato Grosso, Brazil

Julia Pongratz

Department for Earth and Environmental Sciences, Ludwig-Maximilians-University, Munich, and Max Planck Institute for Meteorology, Hamburg, Germany

Lahouari Bounoua

Earth System Science Interdisciplinary Center, University of Maryland, College Park, College Park, and Biospheric Sciences Branch, NASA GSFC, Greenbelt, Maryland

Ruth S. DeFries*

Earth System Science Interdisciplinary Center, and Department of Geography, University of Maryland, College Park, College Park, Maryland

Douglas C. Morton

Department of Geography, University of Maryland, College Park, College Park, Maryland

Liana O. Anderson

Instituto Nacional de Pesquisas Espaciais, São José dos Campos, Brazil

Wolfram Mauser

Department for Earth and Environmental Sciences, Ludwig-Maximilians-University, Munich, Germany

Carlos A. Klink

Departamento de Ecologia, Universidade de Brasília, Brasília, Brazil

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* Corresponding author address: Ruth S. DeFries, Department of Geography, University of Maryland, College Park, College Park, MD 20742.
E-mail address: rdefries@mail.umd.edu

ABSTRACT: The sensitivity of surface energy and water fluxes to recent land cover changes is simulated for a small region in northern Mato Grosso, Brazil. The Simple Biosphere Model (SiB2) is used, driven by biophysical parameters derived from the Moderate Resolution Imaging Spectroradiometer (MODIS) at 250-m resolution, to compare the effects of different land conversion types. The mechanisms through which changes in vegetation alter surface fluxes of energy, momentum, water, and carbon are analyzed for both wet and dry seasons. It is found that morphological changes contribute to warming and drying of the atmosphere while physiological changes, particularly those associated with a plant's photosynthetic pathway, counterbalance or exacerbate the warming depending on the type of conversion and the season. Furthermore, this study's results indicate that initial clearing of evergreen and transition forest to bare ground increases canopy temperature by up to 1.7°C. For subsequent land use such as pasture or cropland, the largest effect is seen for the conversion of evergreen forest to C3 cropland during the wet season, with a 21% decrease of the latent heat flux and 0.4°C increase in canopy temperature. The secondary conversion of pasture to cropland resulted in slight warming and drying during the wet season driven mostly by the change in carbon pathway from C4 to C3. For all conversions types, the daily temperature range is amplified, suggesting that plants replacing forest clearing require more temperature tolerance than the trees they replace. The results illustrate that the effect of deforestation on climate depends not only on the overall extent of clearing but also on the subsequent land use type.

KEYWORDS: Land cover change; Surface climate; Amazon; Deforestation

1. Introduction

Most of the deforestation in the Amazon has occurred in the transitional areas between moist tropical forest and drier, more seasonal cerrado (Alves 2002). The cerrado, a type of savanna–woodland (Klink et al. 1995; Miranda et al. 1997), is Brazil's second largest biome covering an area of approximately 2 million km^2. Cattle ranching has been the traditional form of land use following deforestation. More than 50% of the cerrado's primary vegetation has been transformed within recent decades (Klink and Machado 2005). In the last few years, commercial cropland has extended into the transition forest zone between cerrado and moist tropical forest (Morton et al. 2005a; Morton et al. 2005b). These new types of land cover transformations potentially affect climate through altered exchanges of water, energy, and momentum compared with traditional conversion to pasture (Klink et al. 1993).

Vegetation affects climate through distinct mechanisms. Its morphological structure alters the turbulent transfer of energy through roughness elements. Its optical properties alter the net solar radiation absorbed by the canopy and its physiological activity controls the partitioning of the incoming energy into turbulent fluxes. The impact of land cover change on climate has been explored in previous studies (e.g., Dickinson and Kennedy 1992; Zhang et al. 1996; Collatz et al. 2000; Costa and Foley 2000; Bounoua et al. 2002; Zhao and Pitman 2002; Nobre et al. 2004). While these studies focused on large-scale tropical deforestation, few have explicitly assessed the mechanisms through which changes in vegetation affect energy and water balance for specific land cover changes occurring in the transition zone where deforestation is most rapid.

In this paper, we analyze the mechanisms through which vegetation affects local energy and water balance by examining the interactions of morphological and physiological aspects of vegetation and comparing their effects on energy and water balance for different conversion types. We pay particular attention to land cover change occurring in the transitional areas between cerrado and tropical rain forest, including the conversion of tropical moist forest and seasonal transition forest to cattle pasture or cropland as well as the secondary transition of pasture to cropland.