ABSTRACT: The Brazilian Amazon is one of the most rapidly developing agricultural frontiers in the world. The authors assess changes in cropland area and the intensification of cropping in the Brazilian agricultural frontier state of Mato Grosso using remote sensing and develop a greenhouse gas emissions budget. The most common type of intensification in this region is a shift from single- to double-cropping patterns and associated changes in management, including increased fertilization. Using the enhanced vegetation index (EVI) from the Moderate Resolution Imaging Spectroradiometer (MODIS) sensor, the authors created a green-leaf phenology for 2001–06 that was temporally smoothed with a wavelet filter. The wavelet-smoothed green-leaf phenology was analyzed to detect cropland areas and their cropping patterns. The authors document cropland extensification and double-cropping intensification validated with field data with 85% accuracy for detecting croplands and 64% and 89% accuracy for detecting single- and double-cropping patterns, respectively. The results show that croplands more than doubled from 2001 to 2006 to cover about 100 000 km^2 and that new double-cropping intensification occurred on over 20% of croplands. Variations are seen in the annual rates of extensification and double-cropping intensification. Greenhouse gas emissions are estimated for the period 2001–06 due to conversion of natural vegetation and pastures to row-crop agriculture in Mato Grosso averaged 179 Tg CO_2-e yr^{-1}, over half the typical fossil fuel emissions for the country in recent years.

KEYWORDS: Carbon; Deforestation; Remote sensing; Agricultural intensification; Soybean; Cerrado

1. Introduction

Today, agricultural land occupies almost 40% of Earth's land surface, with rapid growth in tropical regions (Foley et al. 2005; Hansen et al. 2008). Economic development and global markets have driven large-scale conversions of tropical ecosystems to agricultural use in recent decades (Nepstad et al. 2006). Local changes in land cover and land use in tropical regions have become increasingly linked to national and international demands, moving away from subsistence agriculture to large-scale, heavily mechanized agriculture. These shifts in land cover and land use can have large environmental impacts including the release of greenhouse gases through biomass burning and biogeochemical processes affected by clearing activities (Forster et al. 2007).

Detailed measurements of tropical land-clearing activities at high temporal and spatial resolution are essential for improving estimates of impacts on carbon emissions, biogeochemical cycles, climate, and biodiversity (Hansen et al. 2008). Land clearing is particularly evident in the Brazilian Amazon, where the deforestation rate reached a high of 27 772 km^2 yr^{-1} in 2004 (INPE 2008). Mato Grosso state (Figure 1) is a global hotspot of tropical deforestation and is a major contributor to the Brazilian Amazon "arc of deforestation," because the state accounts for 38% of Amazon deforestation since 2000 (Hansen et al. 2008; INPE 2008). The clearing of forests to create pastures has been the dominant land-use transition in this region for decades. Initial clearings were government supported for colonization and border security, giving way to pasture development through various government aid programs. Today, pasture remains the largest land use in the Amazon, but its rate of growth is outpaced by the recent, rapid growth of row-crop agriculture, particularly in the southern Amazon state of Mato Grosso (Barona