Linking land-use change to economic drivers and the biophysical limits of agricultural expansion in the Cerrado

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Overview

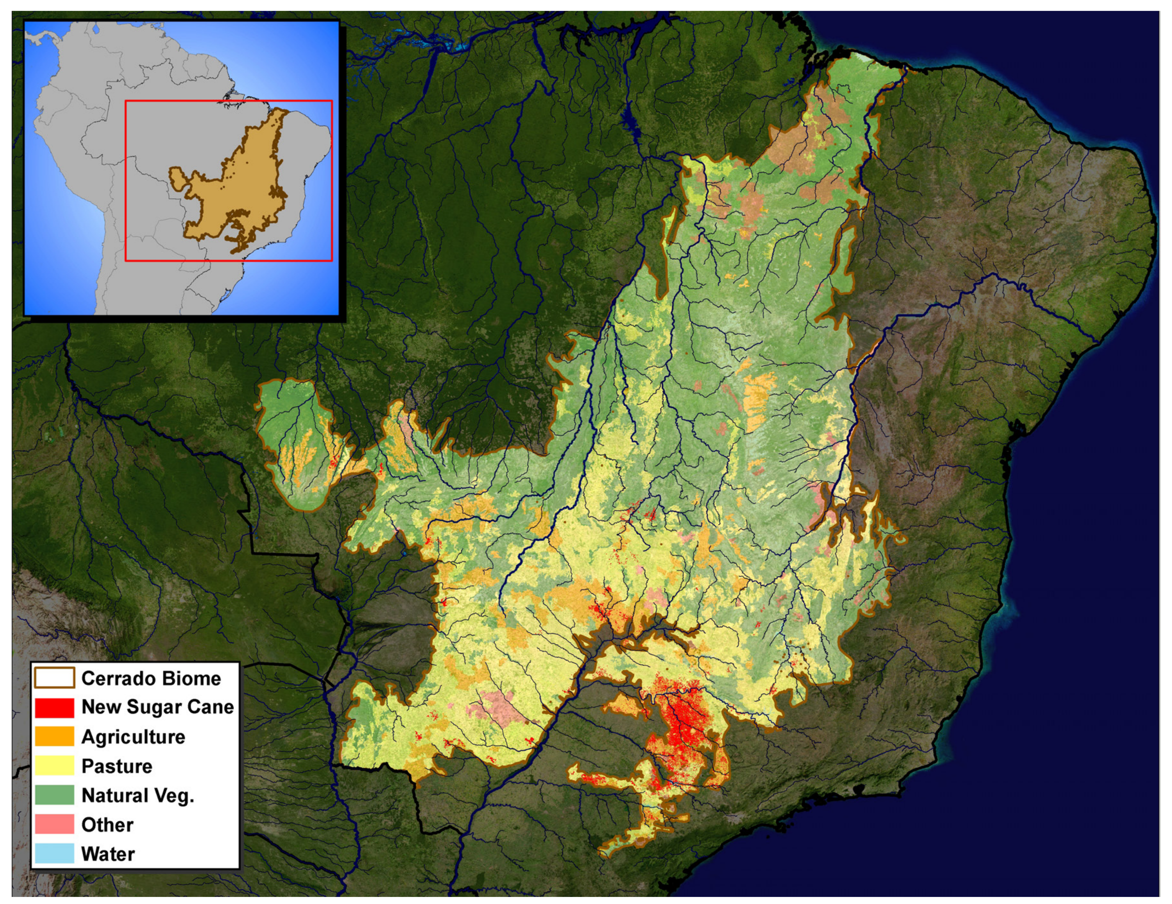

Figure 1. The Cerrado region of Brazil with agricultural lands (orange), pasture (yellow), native savanna vegetation (green), and sugarcane (red). *Map produced by Paul Lefebvre (WHRC).*

The Brazilian Cerrado is the second largest biome of tropical South America (Figure 1), spanning 2 million km². This savanna ecosystem is a biodiversity hotspot, encompasses the headwaters of several major watersheds, and stores globally significant carbon stocks. While national and international conservation efforts were focused on curbing Amazon deforestation, high deforestation rates in the Cerrado converted 50% of the biome into cattle pastures and croplands. As global demand for commodity crops grows, more efficient use of degraded (low-productivity) pastures has been suggested as a solution for avoiding further deforestation – thus minimizing environmental degradation, while increasing agricultural productivity. This project aims to quantify the extent of degraded pasturelands and their potential to mitigate future deforestation and associated environmental impacts.

Objectives

1) Quantify the area of **low productivity pastures,** using multiple resolution satellite sensors.

2) Assess the potential **impacts of sugarcane expansion** on future land-use changes in the Cerrado.

3) Appraise **inter-regional shifts in agricultural production** and their potential impact on deforestation in the Cerrado.

4) Estimate historical and potential future changes in **carbon stocks and greenhouse gas emissions** from agricultural conversion.

5) Assess the **hydrological impacts** of historical and future scenarios of deforestation and conversion to intensive agriculture.

Pasture productivity

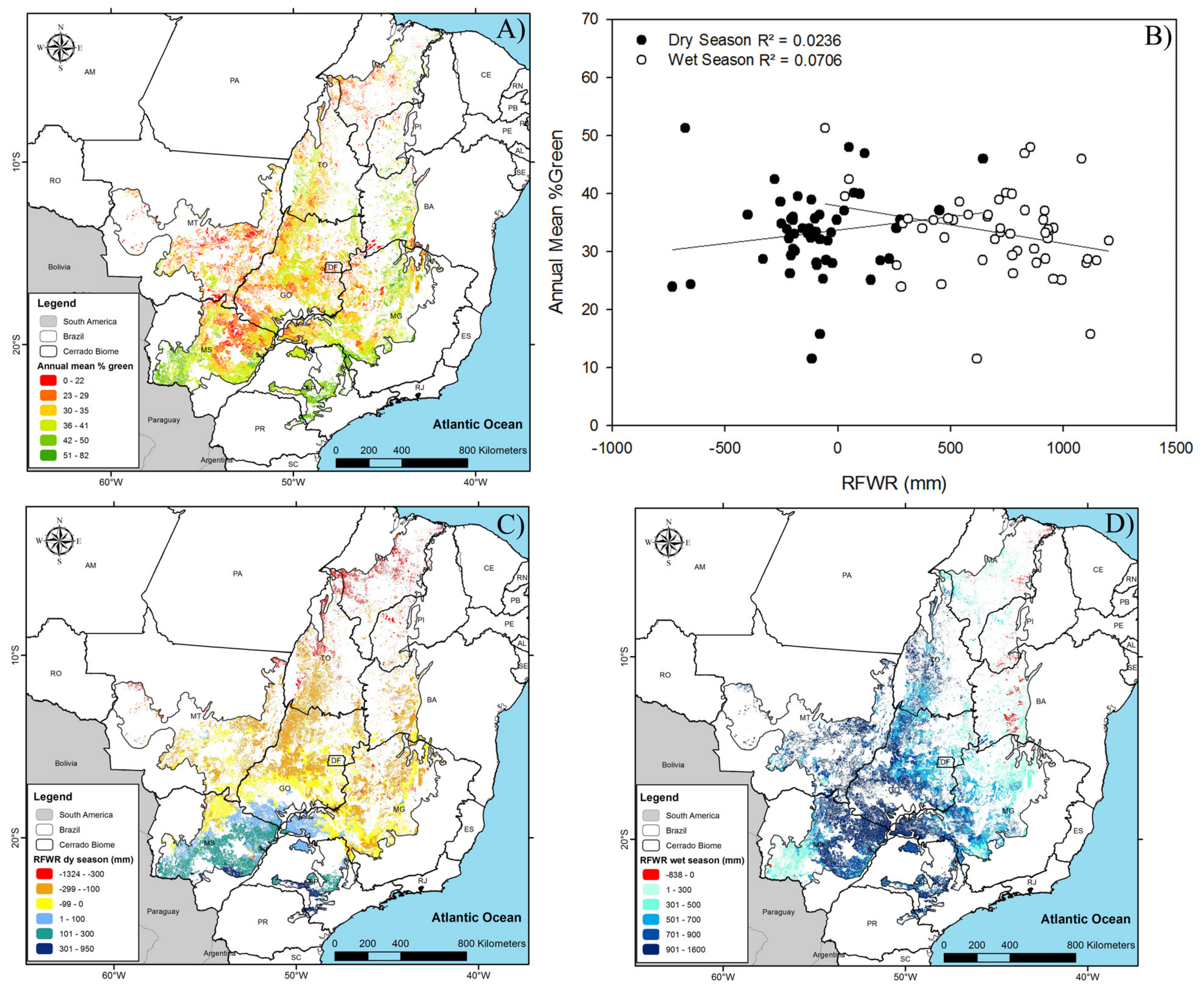

Figure 2. Annual mean greenness values for 2009-2010 (A); relationship between dry- and wet-season RFWR (renewable freshwater resources) and annual mean % green cover (B); and accumulated available water for dry (C) and wet (D) seasons. Soil fertility and the degree of pasture degradation, common in the Cerrado, are more important predictors of pasture greenness than water deficit (RFWR). *Figure adapted from Ferreira et al. (2013).*

Sugarcane expansion

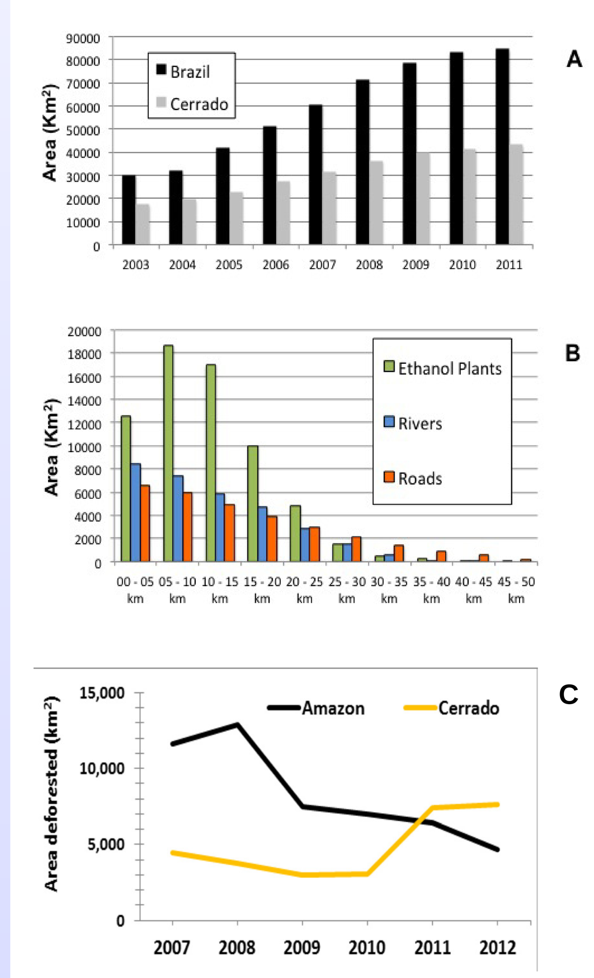

Figure 3. Sugarcane area (km²) in Brazil and the Cerrado biome from 2003 to 2011 (A); sugarcane area as a function of distance to ethanol plants, rivers and roads (B); deforestation in the Cerrado and Amazon biomes from 2007 to 2012 (C).

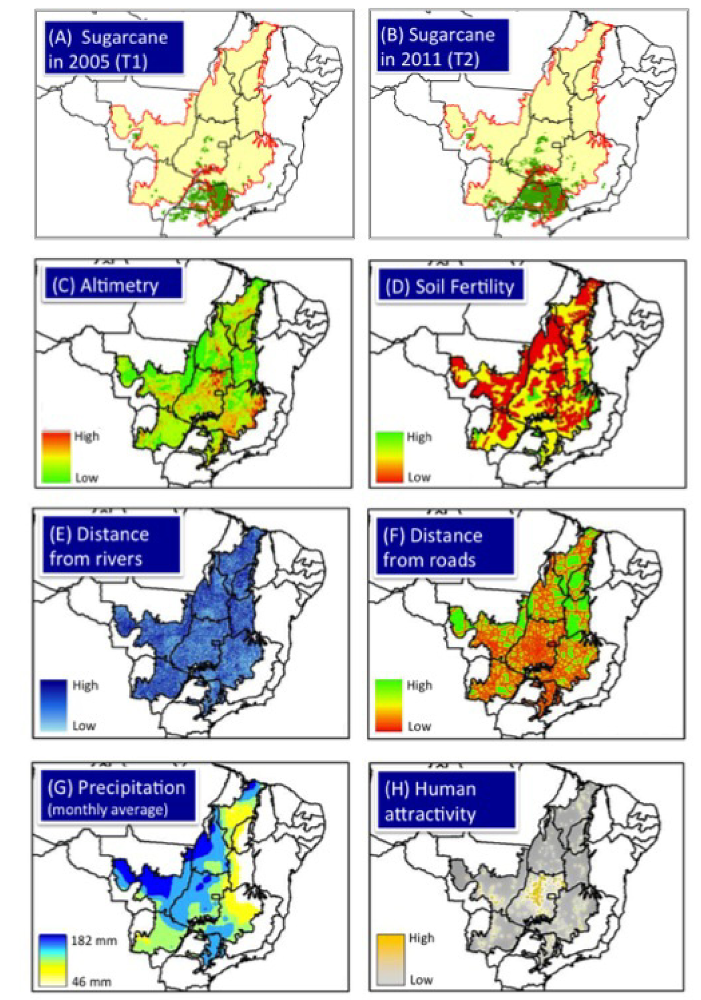

Figure 4. Main geographic layers to be used for modeling future scenarios of sugarcane in the Cerrado biome. These data were compiled and standardized for the entire study region and preliminary tests of the model are being conducted for Minas Gerais state.

Cerrado deforestation

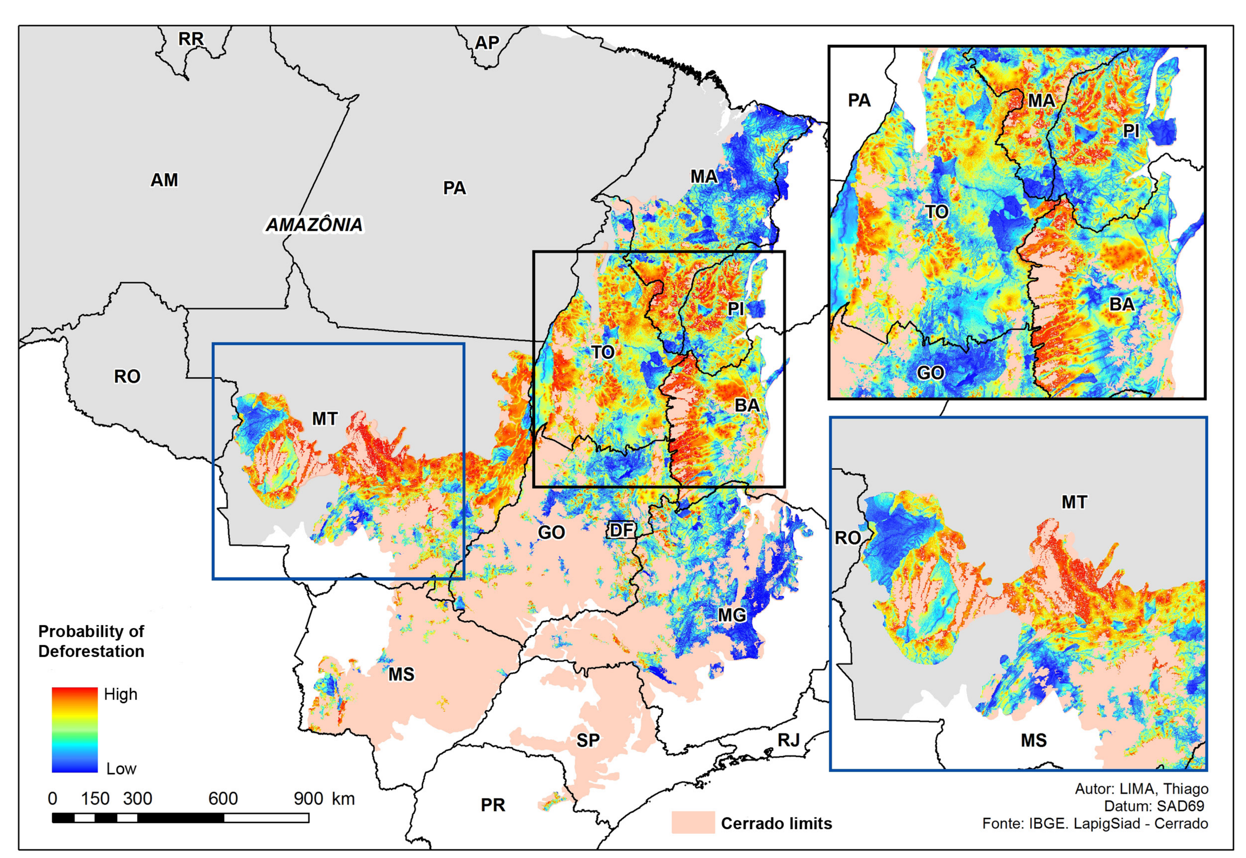

Figure 5. Probability of deforestation from 2000 to 2009, based on a weights-of-evidence econometric model that considers biophysical attributes, land use, and human development variables (R^2 = 0.61). The dynamic deforestation model, implemented in the Dinamica EGO software platform, corresponds well with observed historic deforestation (91% agreement) and will be used in future scenarios simulations. *Map produced by Thiago Lima (UFMG).*

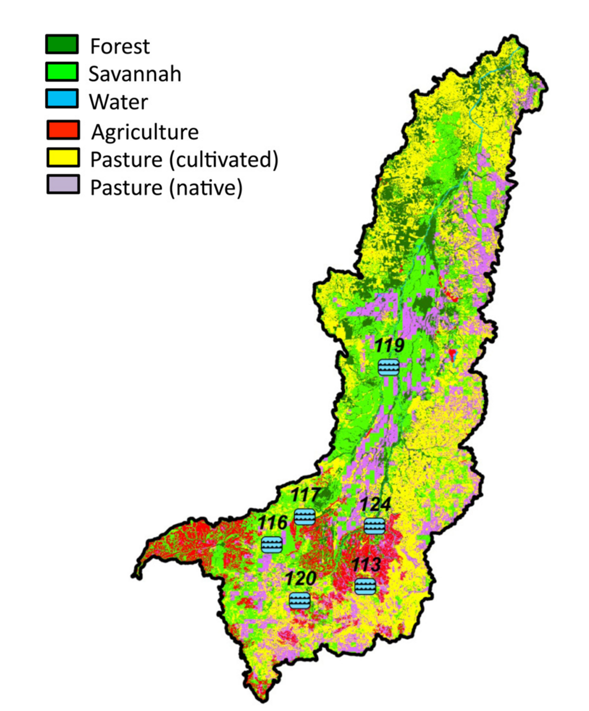

Table 1. Total observed deforested fraction as of 1996 and fractional change in discharge from the 1970s to the 1990s for six gauges in the Araguaia basin .

Gauge	Deforested (%)	Discharge (%)
113	71%	27%
116	11%	15%
117	12%	16%
119	9%	15%
120	62%	11%
124	60%	18%

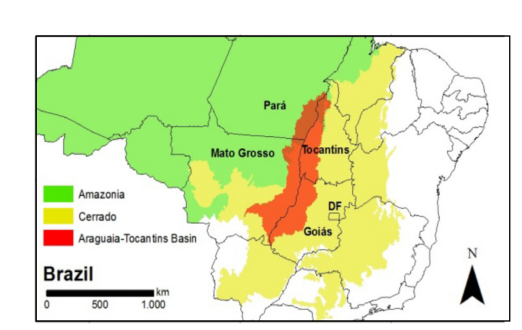

Figure 6. Land cover classification of the 370,000 km² Araguaia River basin, derived from Landsat TM and MODIS imagery. Numbers designate the location of six stream gauges, maintained by Brazil's National Water Agency (ANA). *Lower right:* location of the Araguaia basin within the Cerrado.

Agricultural suitability & policy

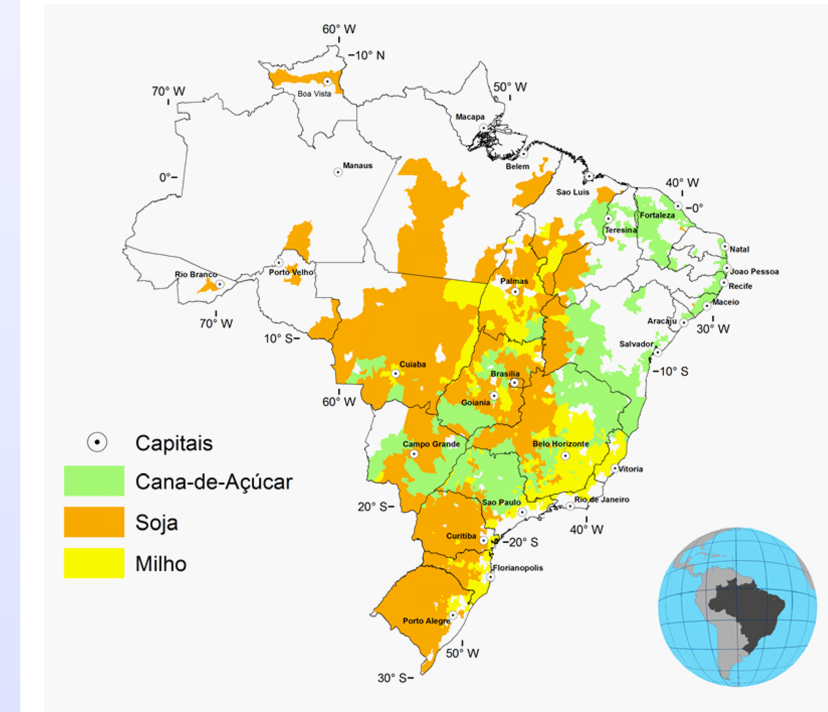

Figure 7: Highest potential rent crop in Brazil, considering a competition between sugarcane, soybeans, and corn. Although much of the Cerrado is dominated by native and planted pastures, the region is highly suitable for soybeans. This suitability modeling is complicated by the fact that many regions with intensive soybean production are moving towards double-cropping -- with soybeans as the primary crop, followed by a fast-growing corn crop planted after the soy harvest. The location of sugarcane production is limited by proximity to ethanol processing plants and transportation infrastructure. *Figures 7 and 8 produced by Soares-Filho et al. (UFMG).*

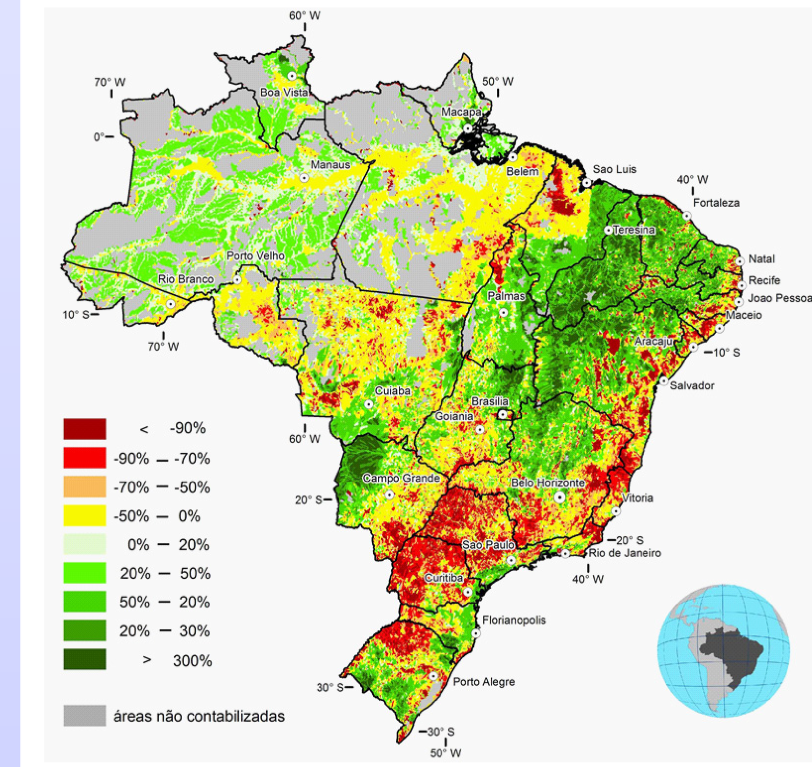

Figure 8: Availability of land for agricultural conversion under the rules specified by the newly revised Brazilian Forest Code (FC). Data are presented per microwatershed, the smallest management unit recognized by the Brazilian National Water Agency (ANA). Percentages represent the amount of deforestation allowed (positive) or reforestation required (negative) to be in compliance with the new FC. We calculate that reforestation (where required) could become the largest Clean Development Mechanism (CDM) project in the world, with the potential to sequester up to 21 billion tons of CO_2. On the other hand, if all legal deforestation in the Cerrado were to go forward, much of the biome's remaining native vegetation would be lost -- with a tremendous impact on biodiversity, carbon cycling, and the water balance.

Project publications

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