

# Savannization of a Tropical Forest Frontier: Carbon Consequences of Climate and Anthropogenic Fire from a Height-Structured Ecosystem Model

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## Project Summary

The main objective of the project is to evaluate the sensitivity of forests in the southern Brazilian Amazon to savannization through anthropogenic fires, ignited for land clearing and management, and climate change. High resolution modeling of forest disturbance in this project will generate a more complete understanding of the patterns and processes that drive savannization than recent studies that relied on coarse resolution models and simplifying assumptions of fire behavior. Project components include:

1. Direct measurement of factors that influence anthropogenic fire spread
2. Satellite-based estimates of vegetation canopy height
3. Modeling of vegetation competition under fire and climate change scenarios with Ecosystem Demography (ED), a height-structured ecosystem model

## Methods

- The combination of field, remote sensing, and modeling techniques is essential to appropriately scale results from localized disturbances to the landscape level to understand the overall impacts of these events on ecosystem structure and carbon storage.
- Field research will address the question of fire spread across a fragmented landscape of cattle pasture, cropland, forest, and savanna land cover types.
- Remotely sensed data from a variety of satellite platforms is being used to:

1. Characterize land cover with respect to fire use (e.g., MODIS NDTV time series analysis to classify clearings as cattle pasture or cropland)
2. Confirm high-resolution landscape features important to fire spread (e.g., ASTER for road, river, and property boundary designation)
3. Estimate vegetation height—a key predictor of forest flammability and aboveground biomass (e.g., ICESat and SRTM comparison to establish canopy heights for savanna and forest cover)

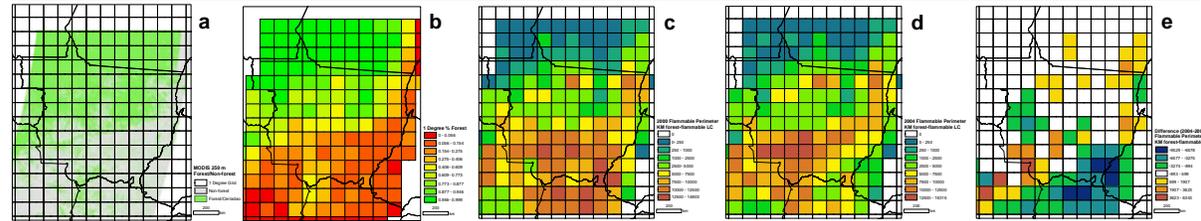
- A height-structured ecosystem model, Ecosystem Demography (ED), is being modified for anthropogenic fire spread, remote sensing analysis of land cover types and vegetation heights, and data from climate model scenarios.

- Model runs will test the sensitivity of different vegetation types in current and potential future landscape configurations to savannization through fire, climate, and combined climate and fire scenarios.

## Study Hypotheses

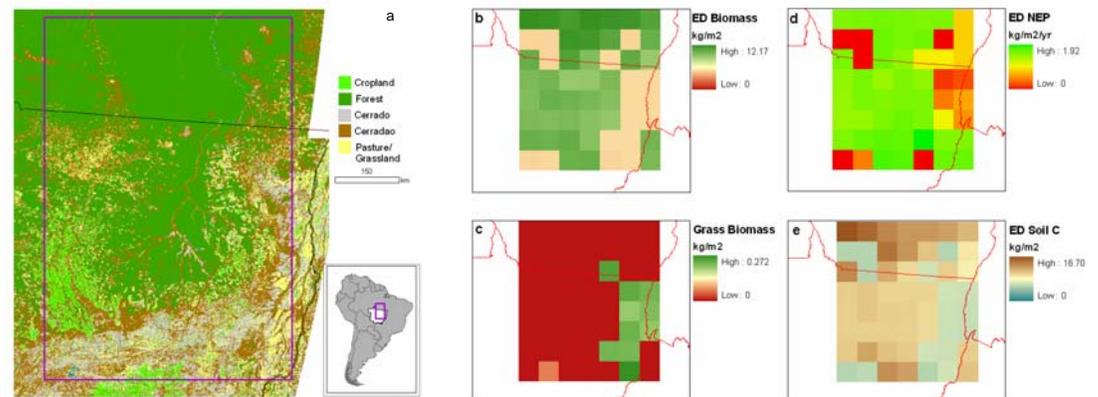
1. Fire spread from anthropogenic ignitions is a function of the landscape configuration of flammable vegetation types, previous disturbance history, and inflammable natural and anthropogenic barriers.
2. Under current climate conditions, anthropogenic fire is insufficient to create widespread savannization. Savannization that does occur will follow existing pasture-forest edges.
3. Water and temperature stress from climate change alone will not lead to widespread savannization within the modeling timeframe (100 years). Savannization that does occur will follow the patterns of natural disturbances such as canopy-tree deaths, where lower soil moisture and higher temperatures will limit tree regeneration in canopy gaps.
4. The synergistic effects of anthropogenic fire and climate will be sufficient to cause widespread savannization of current forest cover within the modeling timeframe.

## Understanding the Edge: Fragmented Forest vs. Flammable Forest



- The degree of forest fragmentation is insufficient to understand the influence of fire on forest structure; characterizing the susceptibility of forest edges to anthropogenic fire is critical to understand the potential for savannization of forest fragments.
- **Figures a and b** show the degree of forest fragmentation in the study area in 2000 at 250m MODIS resolution and summarized as the percent of 1 degree grid cells covered by forest and cerradao, respectively.
- The frequency and severity of anthropogenic fires depends on the land cover (fuel loading) and land management decisions. **Figures c and d** summarize the perimeter of flammable forest edge in 2000 and 2004, derived from MODIS 250 m resolution data, for each 1 degree grid cell. Flammable land cover types include cattle pasture and cerrado. In both years, the patterns of forest susceptible to fire-induced savannization differ substantially from the pattern of forest fragmentation (figure b).
- Between 2000-2004, important changes can be seen in the susceptibility of remaining forest fragments to fire (**Figure e**). Flammable edge conditions increased in the northeast and southeast corners of Mato Grosso State, while susceptibility to anthropogenic fire declined in central and southeastern portions as pasture and cerrado were converted to cropland.

## Preliminary Results—Ecosystem Demography Model



- **Figure a**) MODIS land cover classification of study area showing existing distribution of cropland, cattle pasture, forest, and savanna physiognomies (cerrado, cerradao) in northern Mato Grosso State, Brazil (Morton et al., in press)
- **Figures b-e**) Preliminary ED model results for total aboveground biomass (**b**), grass biomass (**c**), net ecosystem production (**d**), and soil carbon (**e**) for the study region at 1 degree resolution.
- Modeled biomass is similar to the land cover distribution from the MODIS classification. However, model fire disturbance rates do not match anthropogenic fire regimes in the study region. Future model modifications will add a more realistic treatment of anthropogenic fire for both ignition and spread to provide a more detailed look at anthropogenic fire as a driver of savannization.
- The long-term response of tropical forest vegetation to anthropogenic fire and climate change has important ramifications for the global carbon cycle. Modeling anthropogenic ignition and spread across a spatially explicit landscape generates insight into how different land use possibilities alter the long-term response to climate change.

## References and Contact Information

Morton, DC, RS DeFries, YE Shimabukuro (In press). Cropland expansion in cerrado and transition forest ecosystems: Quantifying habitat loss from satellite-based vegetation phenology. In Klink, C., DeFries, R., and Cavalcanti, R. (editors): Cerrado Land-use and Conservation: Assessing Trade-offs Between Human and Ecological Needs.