Reducing Uncertainties of Carbon Emissions from Land Use-Related Fires with MODIS Data: From Local to Global Scale

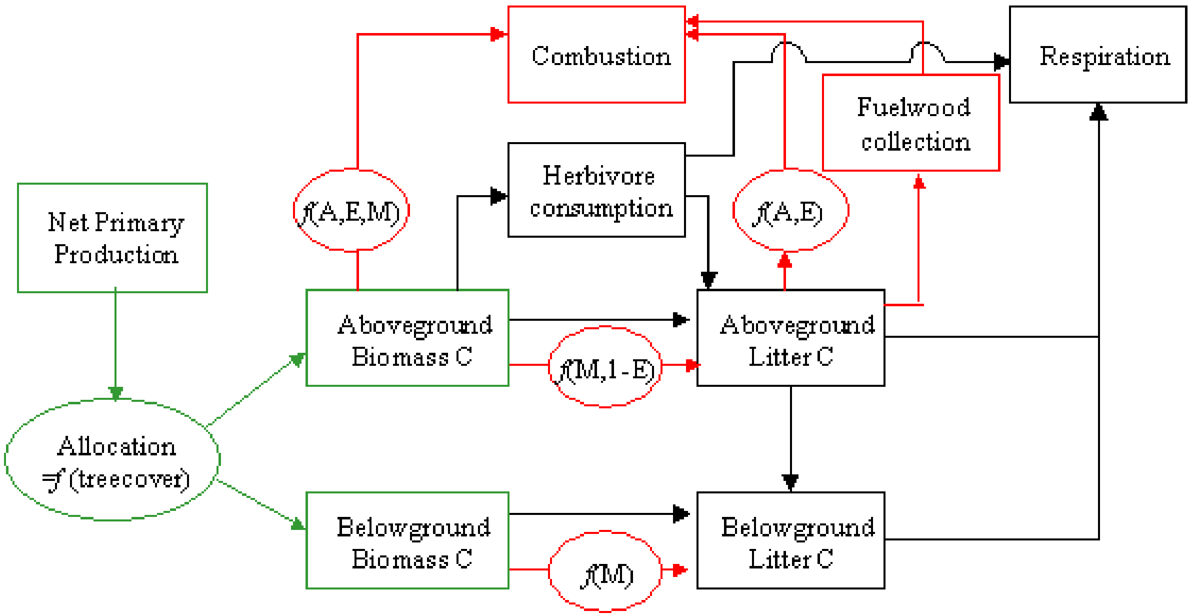
D. Morton[1], R. DeFries[1], J. Randerson[2], G. van der Werf[3], L. Giglio[4], S. Trigg[1], J. Dempewolf[1], K. Murphy[1], G.J. Collatz[5],

[1]University of Maryland [2]University of California, Irvine [3]Vrije Universiteit Amsterdam [4]SSAI [5]NASA

Summary

Fire is the primary mode of biomass removal during deforestation in the Amazon and a common tool for both land cover conversion and land management on the island of Borneo. We report our recent progress towards estimating the inter-annual carbon emissions from land use fire in these two regions using 250 m MODIS data and the DECAF model, a modified version of CASA that estimates carbon emissions from fire associated with different land management trajectories. In the Amazon, DECAF-modeled land use trajectories include forest clearing for mechanized agriculture, forest clearing for pasture, secondary conversion of pasture to cropland, and pasture maintenance. Results indicate that fires from forest clearing for pasture are the dominant carbon source to the atmosphere, but forest clearing for cropland contributes significantly more carbon per area due to near complete removal of biomass. MODIS active fire data suggest that burning associated with deforestation extends over multiple years following initial clearing, so that carbon flux to the atmosphere is not necessarily proportional to annual deforested area in that year. Unlike previous estimates of deforestation carbon emissions, we report substantial emissions from secondary land cover conversions and reduced carbon loss from respiration due to higher initial combustion completeness. In Borneo, we estimate forest loss during 2000-2006 using a 250 m Vegetation Continuous Fields tree-cover product calibrated with high resolution data from the island. Novel approaches to minimize cloud and other data artifacts allow for a high-quality change product for lowland forests, including carbon-rich peat forests that are one source of land for recent expansion of oil palm production. Our current work is centered on describing the fire dynamics for different land uses to isolate important mechanisms for DECAF trajectories. The dramatic increase in fire emissions from Borneo during the 2006 El Niño emphasizes the need to properly capture the inter-annual variability of land use fire.

DECAF Model



A = burned area
E = combustion completeness
M = mortality rate

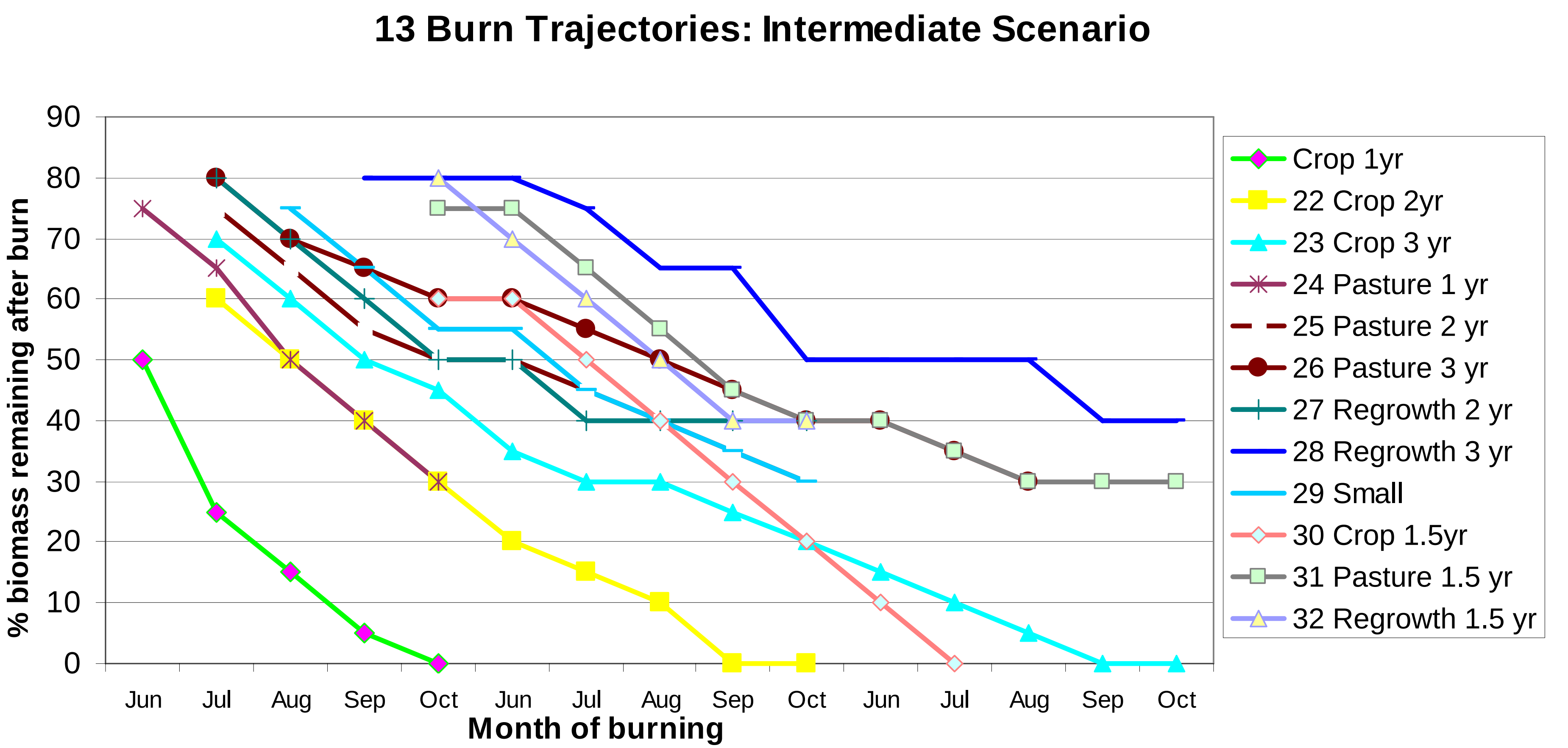
D = detritus
B = biomass
F = fuelwood

C EMISSIONS FROM FIRE

$$C_t = A_t \left[\sum^{d} E_d D_{t,d} + \sum^{b} E_b M_b B_{t,b} \right] + E_F F$$

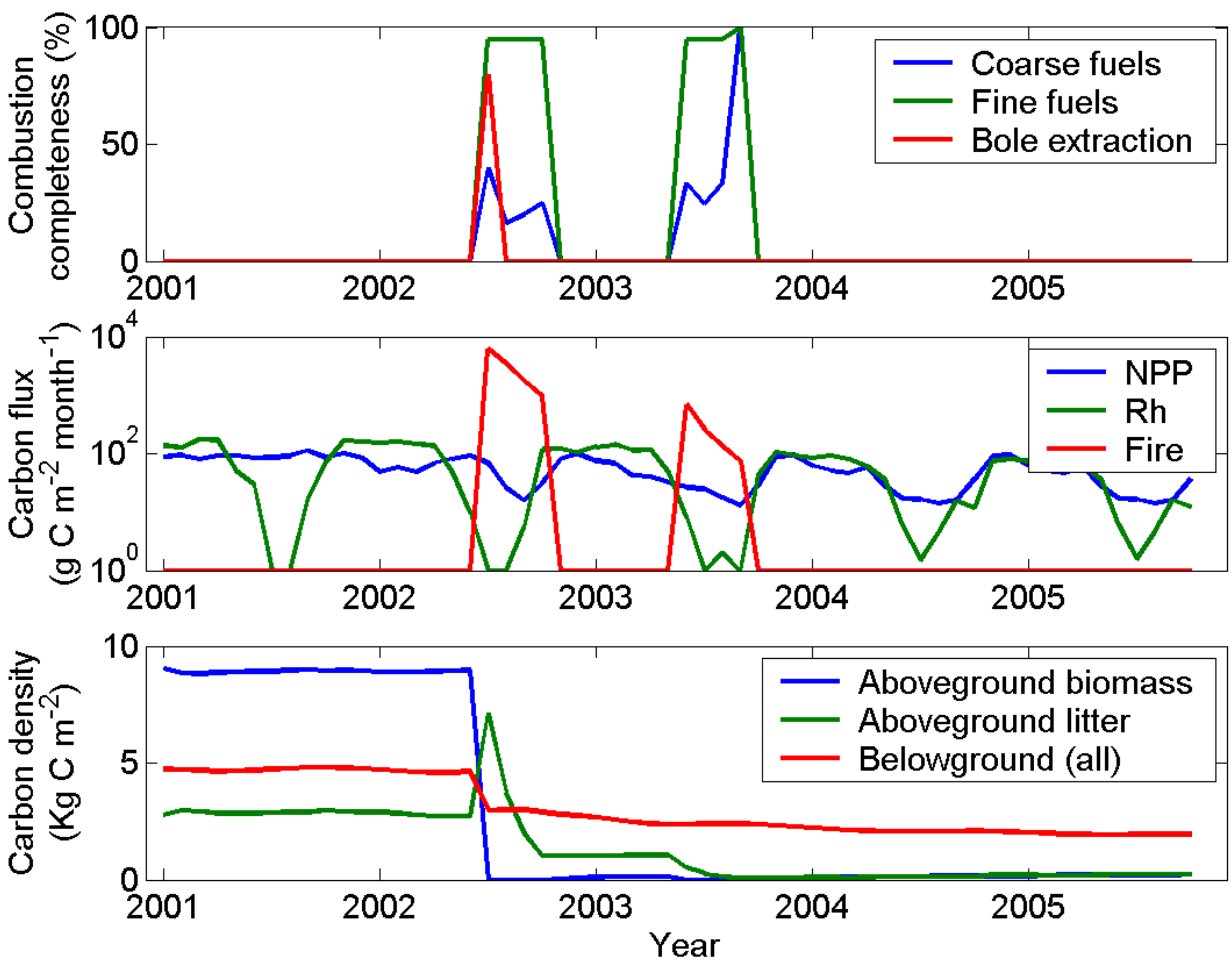
The DECAF model is a modified version of CASA designed to run at 250 m MODIS resolution. Specific accounting of fire emissions is based on the temporal dynamics of fire usage for land clearing and maintenance, variables which are captured in the duration of the clearing process and the overall combustion completeness.

Combustion completeness is a function of land management

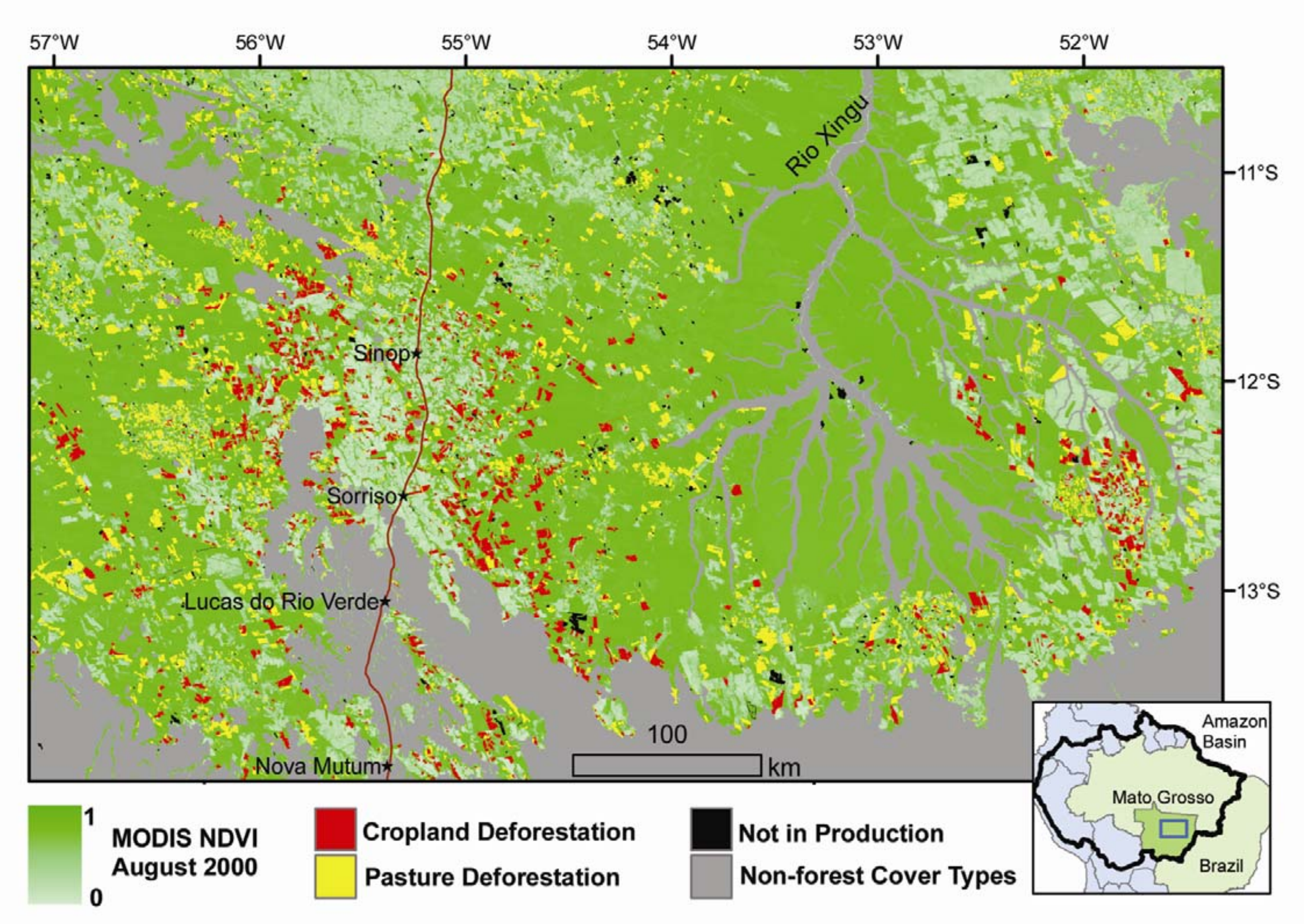


Trajectories derived from MODIS phenology, active fire, burn scars, and Landsat-based deforestation (PRODES)

Modeled C flux from forest to cropland (2 yr)



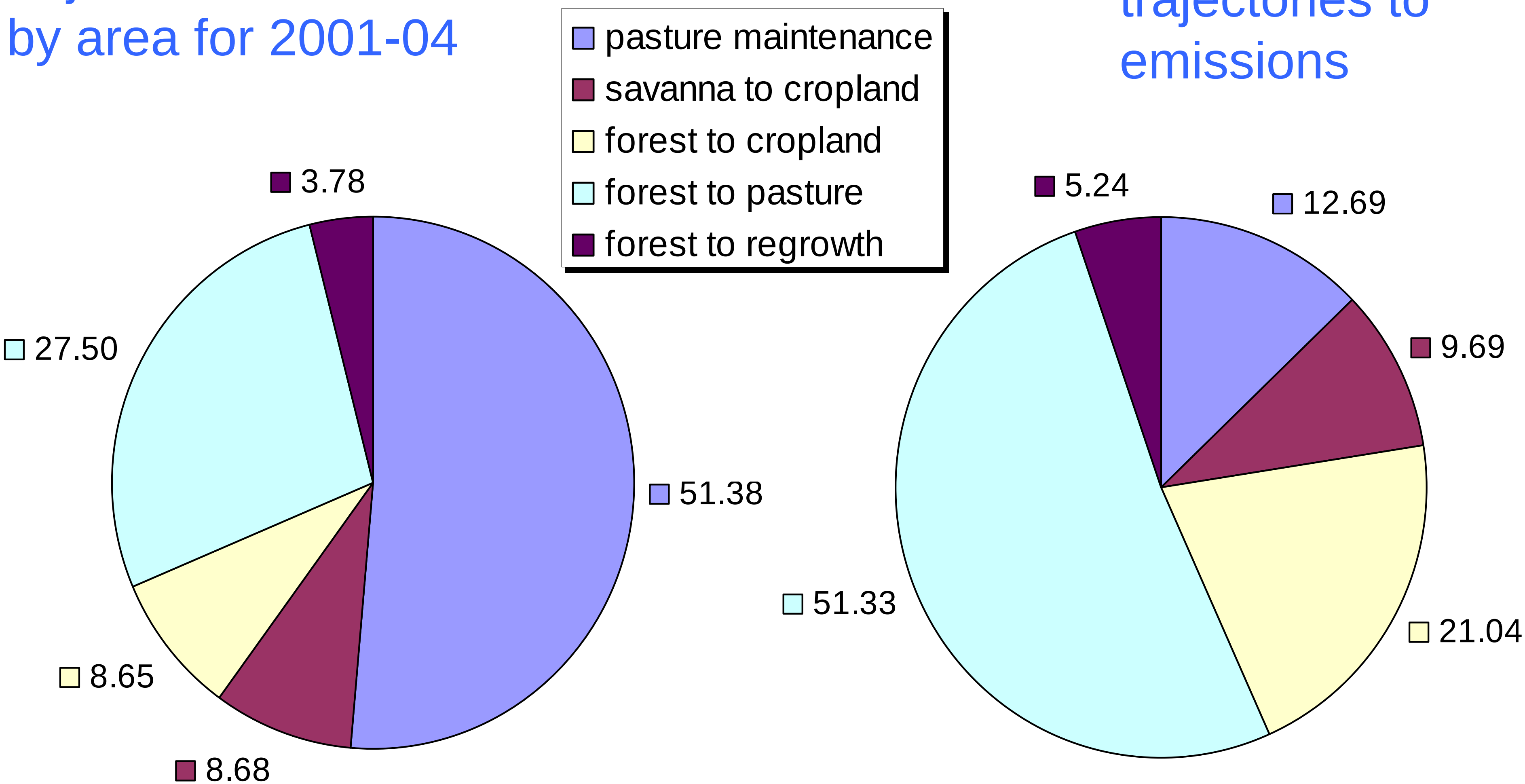
Land use following deforestation determines the magnitude and timing of C flux.



Fate of cleared land from MODIS phenology data (Morton et al., 2006) highlighting the regional variation in combustion completeness.

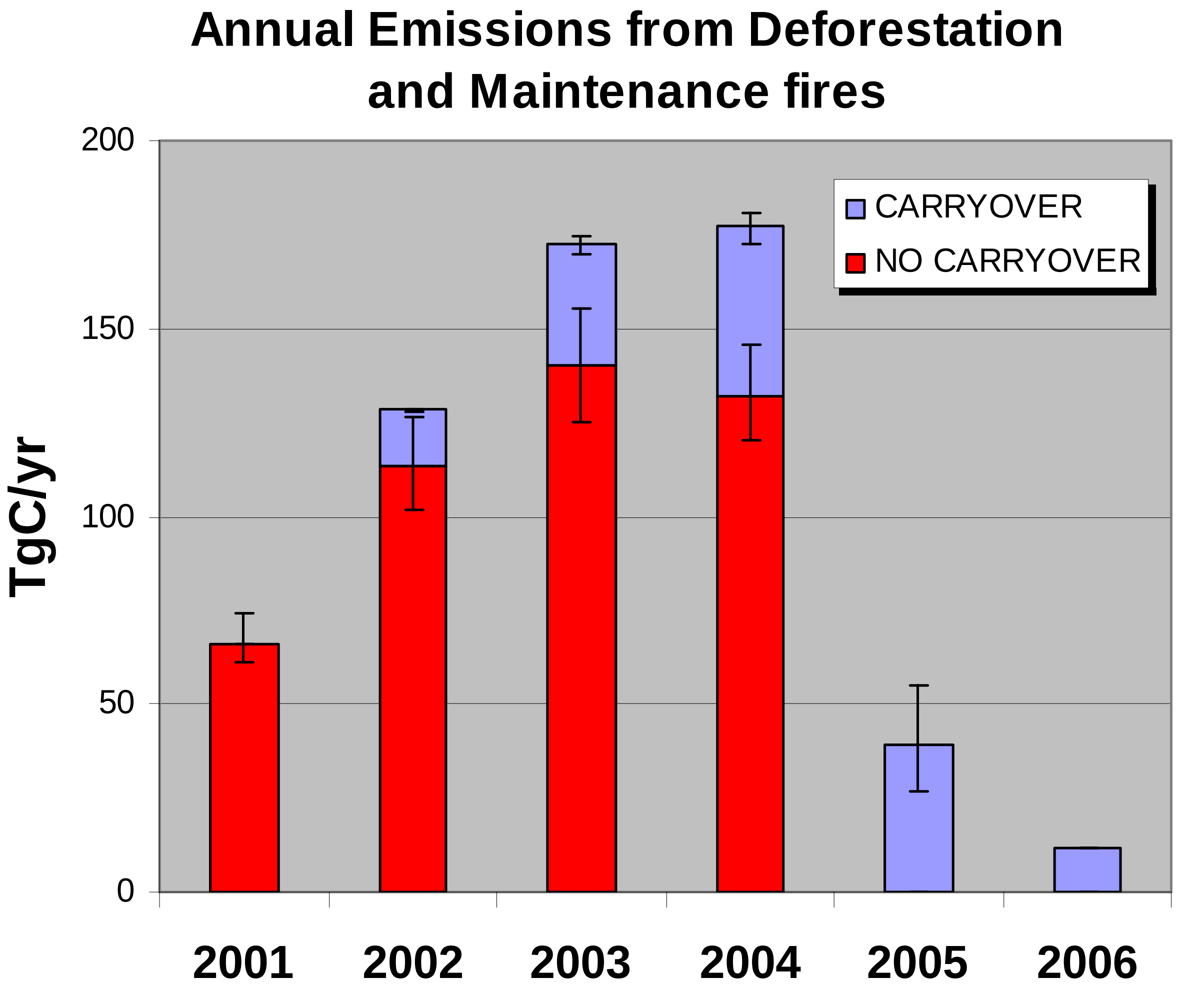
Percent contribution of trajectories by area for 2001-04

Percent contribution of trajectories to emissions

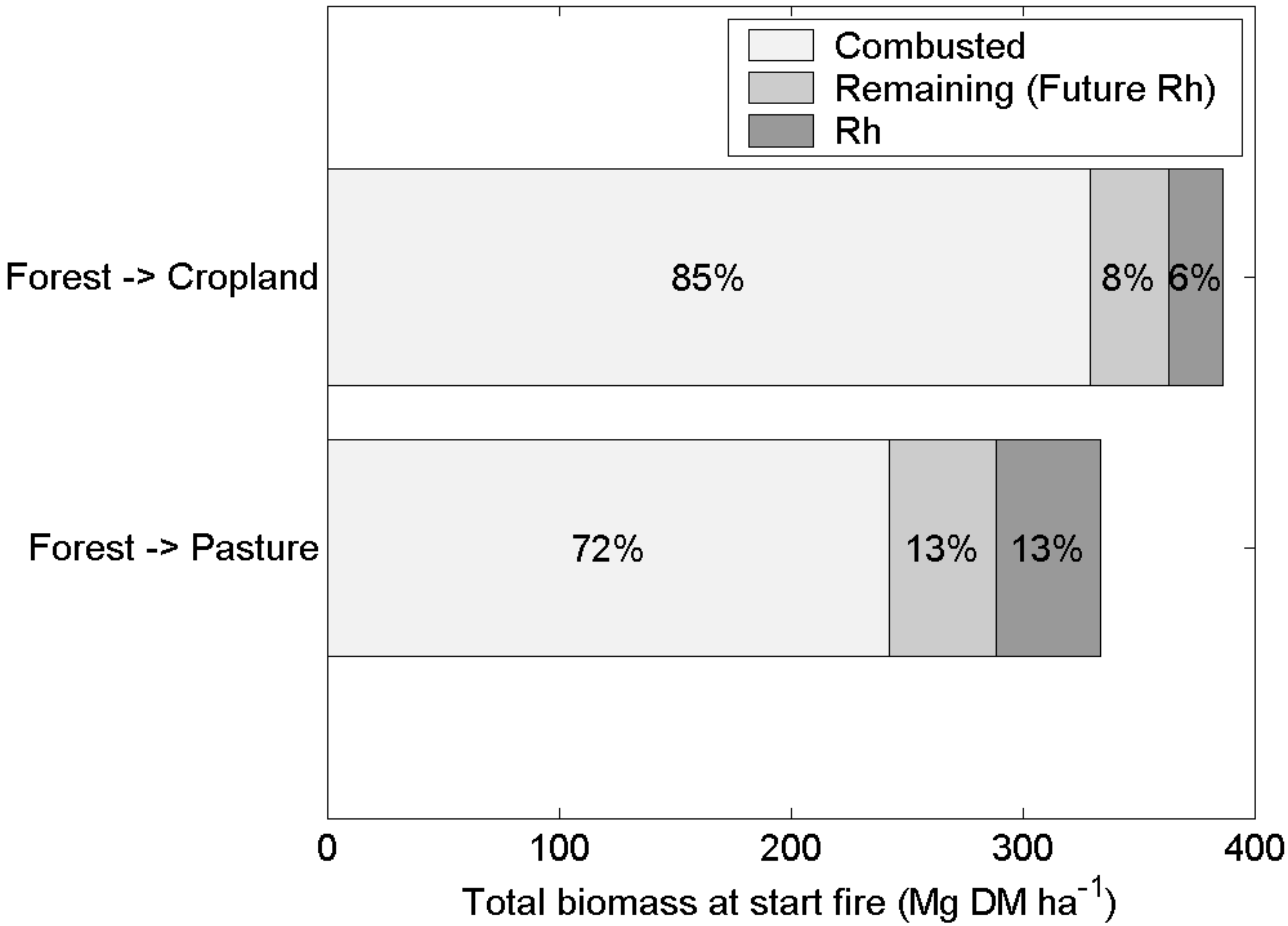


Fire-affected area (left) and corresponding carbon emissions (right) by land management trajectory. DECAF model runs from 2001-2004 show important C losses from forest clearing for mechanized agriculture, although forest conversion for cattle pasture remains the dominant source (51%) of all fire emissions from Mato Grosso state.

Timing of Amazon deforestation and emissions is different, defined by the duration of the clearing process



Deforestation carbon emissions from combustion outweigh Rh during and beyond the model timeframe.



Omissions

- As noted in previous emails with Chris Justice, we have excluded figures from DECAF/GFED comparisons, trends in fire activity and climate, and initial mapping and modeling results from Borneo and southeast Asia since these approaches are currently under review, and we would not like to circulate these graphics until those papers have been accepted.

Conclusions--Amazon

- **Lessons from Amazon modeling:** The offset in timing between deforestation and carbon emissions (carryover) is critical for assessing the annual atmospheric C contributions from land cover change.   Combustion completeness varies as a function of land use following forest clearing, but is generally higher than in previous studies, reducing contributions from respiration to C loss. High C secondary land use transitions contribute significant emissions in addition to deforestation.

Conclusions--Borneo

- **Lessons from Borneo modeling:** Inter-annual variation in C emissions from land use change are clearly linked with climate variability and C content of different types of land cover. New PWC change maps provide critical input for the high-resolution modeling effort and enable us to more accurately account for peat in both combustion and Rh model components.

Next Steps

- In the Amazon study area, we plan to incorporate more high-carbon transitions into our modeling framework, such as logging and re-clearing of secondary forest, refine our forest biomass calculations with field, radar, and lidar-based estimates, and expand to model the entire arc of deforestation.
- In Borneo, we plan to run our first DECAF model scenarios using the PWC change data and fire dynamics derived from Landsat-sized study areas and MODIS active fire dynamics. Our goal is to identify the mechanisms of fire use and landscape vulnerability that contribute to inter-annual variability in C emissions.