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ESTIMATING THE PROBABILITY OF FIRES IN AMAZONIA

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1. INTRODUCTION

Fires are a major process in the Earth System. They can affect vegetation structure (Uhl and Kauffman 1990), change air composition, and disturb biogeochemical cycles both locally and at large scales (Andreae et al. 1988). In Amazonia, fires are used as an inexpensive tool for land clearing and management (Guild et al. 1998). However, they may have important unintended consequences (Cochrane 2003).

Accidental fires are a major threat to forests (Cochrane 2003). Frequent fires may reduce productivity and can lead to permanent conversion of forest areas into savannas (Cochrane and Schulze 1999). Emissions from fires in this region are a potential major source of greenhouse gases and aerosols to the atmosphere, which may have further implications to both regional weather and global climate conditions (van der Werf et al. 2004).

Fire models have thus become important tools for environmental studies in Amazonia. In addition to be used in warning systems for monitoring the likelihood of fires (CPTEC-INPE 2006a), they are needed to represent disturbance in vegetation and ecosystems models (Thonicke et al. 2001), and to help evaluate the sustainability of land-use practices in the region (Cardoso et al. 2003).

In order to contribute for better models of fire dynamics in Amazonia, we built on results from previous studies and begun to improve known relations between fires and their explanatory factors by producing estimates at 0.05º and ~3-monthly, in units of probability or chance of fires to occur.

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2. METHODS

Forest cover, rainfall and distance from main roads were selected to represent fuel, flammability and ignition conditions, respectively. The study region was divided into grid cells classified according to the combination (*C*) of these major factors. The probability of fires (*Pf*) could be then evaluated as a function of *C*, as expressed in Equation 1:

$$Pf(C) = \frac{nf(C)}{N(C)} \qquad (1)$$

In this equation, *N* is the number of all grid cells under similar fuel, flammability and ignition conditions *C*, and *nf* is the number of these grid cells that had fires. Equation 1 was applied only when *N(C)* was equal to or greater than 50.

Pf was calculated for the Brazilian Amazonia (from 18ºS to 6ºN, and from 75ºW to 41ºE) for years 2000-2002. Three separate analyses were performed for sub-regions that present seasonal reduction of precipitation (and increase of flammability) at different periods. In the north of Amazonia (0º-6ºN), rainfall is lowest from January to April. In the south (18ºS-6ºS), the dry season is from May to September, and in the northeast (0º-6ºS) is from October to December (CPTEC-INPE 2006b).

Distance from main roads was calculated based on maps from the Brazilian Institute for Geography and Statistics (IBGE), and tabular data from the Brazilian Ministry of Transportation. Precipitation data are from CPTEC/INPE, based on interpolated daily observations. Because the large extent of the region, estimates of burning activity were based on satellite active-fire detections using AVHRR (Setzer and Malingreau 1996).

3. RESULTS AND DISCUSSION

Results, in Figure 1, are shown as the probability of a 0.05º grid cell to present fire activity sometime during the dry season, as a function of total precipitation and distance from main roads. The values are averages for years 2000-2002, and do not include the effect of forest cover (fuel load).

The trends in our results are in good agreement with trends in results from previous studies, showing that low precipitation and proximity to roads are important factors for fires in Amazonia (e.g. CPTEC-INPE 2006, Cardoso et al. 2003). In all cases, the likelihood of fires decreased with the distance from main roads, ranging in average from 45% (close, 0-25km) to <2% (far, >175km from main roads). In most cases, *Pf* decreased with the amount of rainfall, with a small number of exceptions located generally close to main roads.

Pf was highest in the northeast of Amazonia, for places close to main roads. In the north and northeast of the region, *Pf* was very small (<5%) for places located farther than 100km from main roads. In the south, however, the decrease in *Pf* for remote locations was less intense. In this sub region, even grid cells located 150-175km from main roads had in average ~8% of chance to present fire activity during the dry season, if they received less than 100mm of precipitation.

It is interesting that the likelihood of fires for places located >50km from main roads was higher in the south than in the north and northeast of the region. This result can be an indication that secondary roads in the south may play a more important role in land-use dynamics and fires than in other regions. Other interpretation is that the roads network information we compiled is incomplete, or perhaps the accuracy of the satellite-based fire detections was not the same for all regions.

4. CONCLUSIONS AND FUTURE WORK

The results from this work have relevant implications for building fire models and estimating fire consequences in Amazonia. They are useful for estimating the likelihood

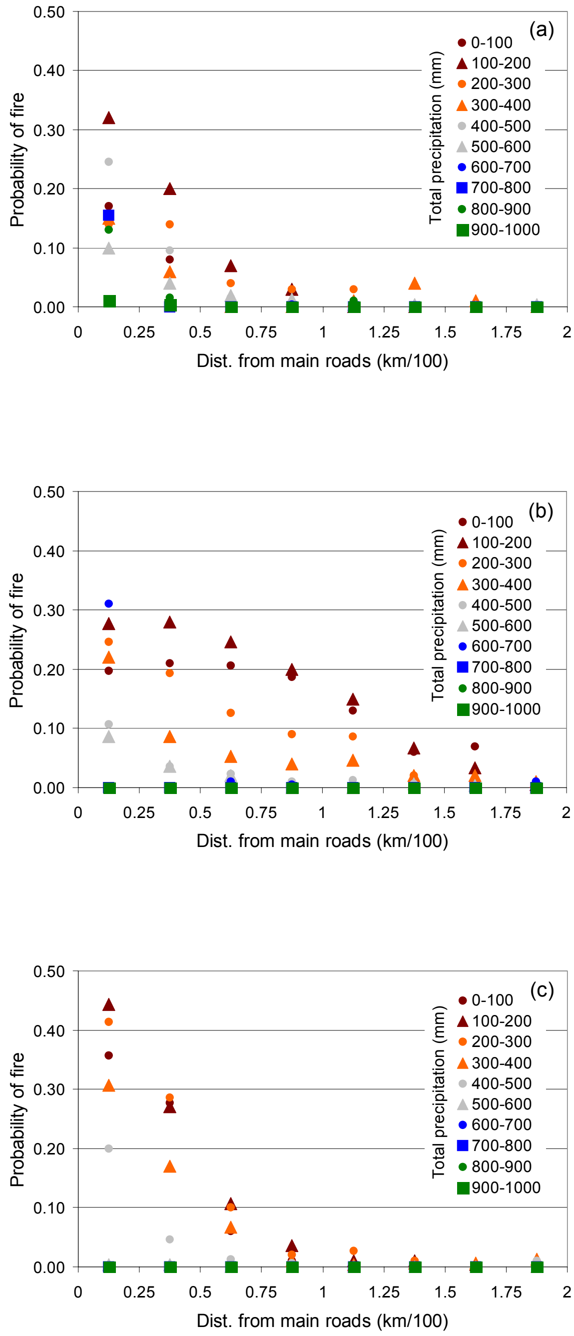

Figure 1 – Probability of fire in Amazonia (study region is from 18ºS to 6ºN, and from 75ºW to 41ºE) as a function of the distance from main roads and total precipitation, as averages for years 2000-2002. Results in (a) are for the north (0º-6ºN), in (b) for the south (18ºS-6ºS), and in (c) for the northeast (0º-6ºS) of the region, where precipitation is lowest from January to April, May to September, and October to December, respectively. Roads data are from IBGE. Precipitation and fire activity information are from INPE-CPTEC.

of fires for the whole region at relatively high spatial and temporal resolution. In addition, they can be combined with fire behavior information and be coupled to vegetation and land-use and -cover change models. Potential broad applications include estimates of fire effects such as area burned, change in vegetation species and emissions of greenhouse gases and aerosols, considering contemporary trends in fire dynamics. Further work should also consider the effect of fuel load on fire activity by estimating *Pf* also as a function of land cover. Revised road information and new precipitation datasets may also be considered in future analyses.

5. REFERENCES

Andreae, M.O., E.V. Browell, M. Garstang, G.L. Gregory, R.C. Harriss, G.F. Hill, D.J. Jacob, M.C. Pereira, G.W. Sachse, A.W. Setzer, P.L.S. Dias, R.W. Talbot, A.L. Torres, and S.C. Wofsy (1988) Biomass-burning emissions and associated haze layers over Amazonia, *Journal of Geophysical Research* **93**, 1509-1527.

Cardoso, M.F., G.C. Hurtt , B. Moore III, C.A. Nobre, and E.M. Prins (2003). Projecting future fire activity in Amazonia, *Global Change Biology*, **9**, 656-669.

Cochrane, M.A. (2003). Fire science for rainforests, *Nature*, **421**, 913-919.

Cochrane, M.A., and M.D. Schulze (1999). Fire as a recurrent event in tropical forests of the eastern Amazon: effects on forest structure, biomass, and species composition. *Biotropica*, **31**(1), 1-16.

CPTEC-INPE (2006a). Fire Risk Monitoring and Forecast. Center for Weather Forecasts and Climate Studies - Brazilian National Institute for Space Research (CPTEC-INPE). available from: www.cptec.inpe.br/queimadas.

CPTEC-INPE (2006b). Monthly Climatology of Precipitation over Brazil. Center for Weather Forecasts and Climate Studies - Brazilian National Institute for Space Research (CPTEC-INPE), available from: www.cptec.inpe.br/clima (in Portuguese).

Setzer, A.W., and J.P. Malingreau (1996). AVHRR monitoring of vegetation fires in the tropics: towards a global product. In J.S. Levine (Ed.) *Biomass Burning and Global Change*, (pp. 25-39), MIT Press, Cambridge.

Thonicke, K., S. Venevsky, S. Sitch, and W. Cramer (2001). The role of fire disturbance for global vegetation dynamics: coupling fire into a Dynamic Global Vegetation Model, *Glob. Ecol. Biogeogr.*, **10**, 661-677.

Uhl, C., and J.B. Kauffman (1990). Deforestation, fire susceptibility, and potential tree responses to fire in the eastern Amazon. *Ecology* **71**:437-449.

van der Werf, G.R., J.T. Randerson, G.J. Collatz, L. Giglio, P.S. Kasibhatla, A.F. Arellano, S.C. Olsen, and E.S. Kasischke (2004). Continental-scale partitioning of fire emissions during the 1997 to 2001 El Niño/La Niña period, *Science*, **303**, 73-76.