Forest Fire Prediction and Prevention in the Brazilian Amazon

Many Amazonian forests are spectacular in their capacity to resist burning during the severe seasonal droughts that occur in nearly half of the basin. Tree and liana root systems can extend more than 10 m down into the region's clay soils, absorbing enough soil water during periods of low rainfall to supply forest transpiration and to prevent substantial leaf shedding (Nepstad et al. 1994). During average dry seasons, dense shade keeps accumulated fuel from drying and being ignited by the fires that sweep into the forest from neighboring agricultural lands (Uhl & Kauffman 1990). Drought-tolerant forests lose their resistance to fire as logging operations perforate the forest canopy, increase the fuel load on the forest floor, and allow sunlight to heat and dry the forest interior. On a much larger scale, the intact forests of Amazonia can lose resistance to fire when severe drought—such as that of 1997 and 1998—provokes leaf shedding and a build-up of the fuel layer.

The map (Fig. 1) of the Brazilian Amazon integrates the effects of drought and logging on forest susceptibility to fire and identifies fire-prone forests that are close to sources of ignition based on data on the distribution of agricultural fires. Solicited by the Brazilian government, the map (RisQue98) is part of a larger program of the Amazonian Institute of Environmental Research (IPAM) designed to advance forest-fire prevention policies at the level of the farm community, state, and federal government (Nepstad et al. 1998).

RisQue98 assumes that forests become susceptible to fire once they have depleted plant-available soil water in the rooting zone of the soil. RisQue98 begins with a map of the maximum amount of plant-available water that can be stored in the upper 5 m of soil (Potter et al. 1998; Tomasella & Hodnett 1998) and assumes, conservatively, that the soil was fully charged with water at the beginning of the 1997 dry season. This soil water is depleted by forest evapotranspiration and replenished by rainfall, which we determined for the 1997 dry season and 1998 wet season (1 May 1997 through 30 April 1998) from weather station data provided by the Brazilian Institute of Space Research. Rainfall and evapotranspiration were assumed equal to average monthly values for the subsequent period, 1 May through 1 November 1998. Logging was incorporated into the map of soil water depletion by reducing the amount of water available to plants in those forests that occur within the logging radius of 75 regional logging centers. This radius was determined through field interviews of 1353 wood mill operators (IMAZON, unpublished data). Finally, the agricultural fires of 1997 that were detected in Amazonia by the climate satellites of the National Oceanic and Atmospheric Administration (NOAA) (Setzer & Pereira 1991) were incorporated into the map to identify those regions where sources of ignition are available.

We predict that 200,000 km^2 of Brazilian Amazonian forest will have fully depleted plant-available soil water in the upper 5 m of soil by November 1998 and will become highly susceptible to fire. Another 200,000 km^2 of forest will have less than 250 mm of plant-available water stored in the soil by November and could become susceptible to fire if rainfall is below average during the interceding months. In sum, 10% of the remaining forests of Brazilian Amazonia may become fire-susceptible during the 1998 dry season, which is an area eight times the size of Costa Rica. These forests at risk are concentrated in eastern Pará state, where numerous fires were detected by the NOAA satellite in 1997.

RisQue98 was presented to the Brazilian Congress on 28 May 1998 and has been adopted by the federal natural resources agency as a tool for prioritizing field activities aimed at enforcing federal regulations on deforestation, burning, and logging during the 1998 dry season. During public congressional hearings, IPAM also presented the results of a regional workshop held in Belém, Brazil, at which representatives of 21 Amazonian organizations identified a series of measures (the "Charter of Belém") that could be adopted by government to reduce the occurrence of accidental fire in Amazonia. A presidential decree under public review in Brazil incorporates many of these suggestions, including the recognition and encouragement of fire ordinances designed and implemented by communities of small-scale farmers. For the first time, federal environmental legislation to protect the world's largest tropical forest formation from large-scale impoverishment may originate within the Amazon region itself, instead of in

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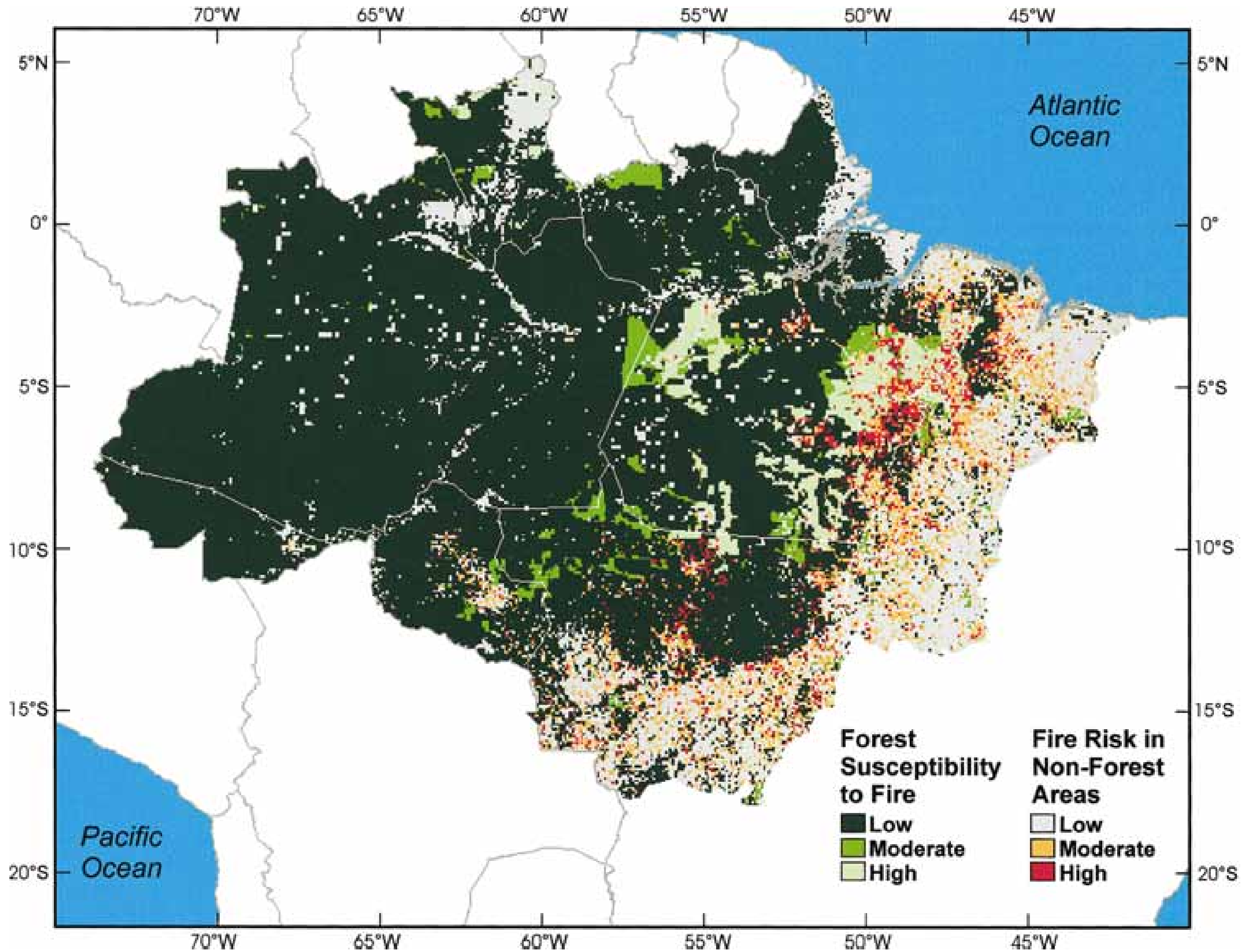

Figure 1. RisQue98, a map of fire risk in forests and on nonforest lands of the Brazilian Amazon as predicted for the end of the 1998 dry season (1 November) using data on soil water-holding capacity, rainfall, evapotranspiration, logging, and the fires recorded by satellite during the 1997 burning season. We predict that forests classified with high susceptibility will have depleted all plant-available water in the upper 5 m of soil by November 1, whereas forests of moderate susceptibility will have less than 250 mm of plant-available water remaining. Nonforest lands with a high risk of fire experienced 0.45–1.1 fires/km^2 in 1997, whereas those with moderate risk experienced 0.15–0.45 fires/km^2.

Brasília, increasing the chance of implementation.

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