

Logging in the Amazon >2.3 million hectares (1999) (Maticardi et al. 2005).



Selective logging (the removal of a few valuable trees), increases the probability (fold) of a forest burning. Data below show that even 7 years after logging, affected forests are more likely to burn. (Cochrane et al. 2004)

Abstract

Tropical forests are increasingly impacted by degrading activities as well as outright deforestation. Landscapes have been transformed from continuous tracts of unbroken forest into mosaics of pastures, agricultural plots and forest fragments that have often been subjected to varying degrees of increased disturbance from sun, wind, fire and logging operations. Multitemporal case studies from within the Brazilian Amazon are used to illustrate the linkages and synergy between forest fragmentation, selective logging and forest fire. A geographic information system is then used to quantitatively and spatially relate disturbance across the landscape so that spatially articulated disturbance regimes can be mapped. These maps provide both knowledge of the current state of existing forests as well as the likely future of given parcels of forest. Preliminary results have shown that forest fragmentation and forest fire are directly linked with fires becoming edge effects that penetrate kilometers into standing forests. Selective logging also exacerbates fire probability but with larger effects at larger distances from forest edges. In typical anthropogenic landscapes, fragmentation effects, fire and logging can involve nearly all of the remaining forests and pose special challenges for sustainable management of these resources.

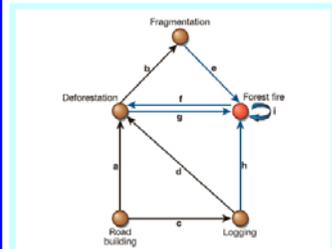


Figure 1 Diagram of interrelationships between tropical land-use changes and forest fires. Arrows indicate forcing of each node upon others in the system. Blue arrows directly affect forest fire occurrence; black arrows indirectly influence forest fire occurrence. Events a-i are: a, Road building results in forest access that is strongly associated with deforestation¹⁶; b, Deforestation fragments the remaining forests, increasing amounts of edge^{16,c}; c, Road building and paving directly affect transportation costs and areas of economic accessibility¹⁶; d, Logging results in limited amounts of deforestation for roads and log landings. Post-logging colonization can increase deforestation¹⁶; e, Forest edges suffer biomass collapse and microclimate changes¹⁶ making them susceptible to frequent fires¹⁶; f, Repeated forest fires can lead to unintentional deforestation¹⁶; g, Deforestation and pasture/land maintenance fires result in many accidental forest fires¹⁶; h, Logging degrades forests, increasing fire susceptibility¹⁶; i, Forest fires can create a positive feedback cycle where recurrent fires become more likely and more severe with each occurrence¹⁶. (Cochrane 2005)

The Synergism of Fire, Forest Fragmentation and Selective Logging in the Brazilian Amazon

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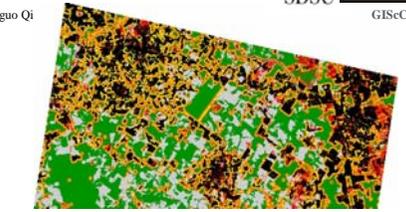
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Logging operations frequently result in the death of 6 trees for every tree extracted (Uhl et al 1997)



Amazonian forest fire: The first fire may be of very low intensity (<50 kw/m) but is slow moving and kills 40% of the trees (Cochrane and Schulze 1999)



16,800 km² sample landscape showing combined effects of deforestation (black), fragmentation (yellow/orange), fire in 1999 (red) and selective logging 1992-1999 (gray).

Fragments become progressively smaller

Fragment number and size distribution

Paragominas	1984	1991	1995	1995
Size (ha)	#	#	#	#
>10,000	3	2	3	7
5,000 <10,000	4	9	5	5
100 <5,000	8	20	16	21
10 <100	40	41	48	53
<10	147	157	149	156
total	161	192	88	66
Total	392	411	309	353

Tailândia	1991	1993	1995	1997
Size (ha)	#	#	#	#
>10,000	3	2	4	4
5,000 <10,000	2	3	1	1
100 <5,000	3	11	21	21
10 <100	54	56	94	94
<10	107	168	193	193
total	40	88	103	104
Total	224	238	418	418

Disproportionate representation of fires along forest edges. Table gives the distance from the forest edge where fire was disproportionately experienced in each year and at each site. The percentage of all burning represented by the given distance and year is also presented.

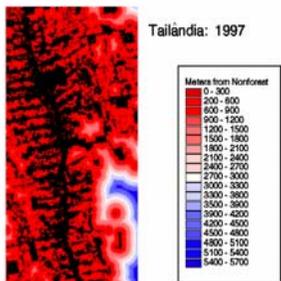
	Paragominas	Tailândia
Distance (m) % of total	Distance (m) % of total	
1984 360 75%	?	?
1991 180 75%	190 73%	
1995 450 66%	390 66%	
1999 270 73%	270 76%	
1997 ?	?	300 74%

Distance distribution of forest fires and fire rotations. Data are presented as the percentage of the total forest and percentage that burned for each given year and study site. The fire rotation values are those implied by the observed forest burning. The detected fires are from 1-2 years and so the data are presented as a range.

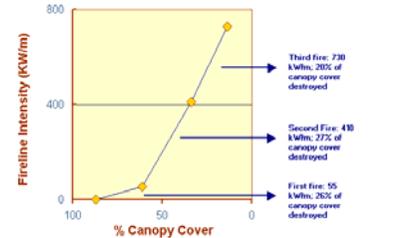
Paragominas		Tailândia		Fire Rotation (Years)	
Distance (m)	Forested (Burned) / Forested (Burned)	Forested (Burned) / Forested (Burned)	Forested (Burned) / Forested (Burned)	Low	High
<300	30.7% / 12.2%	31.4% / 1.8%	47.3% / 19.9%	55.6%	11.7%
300 <1,000	38.5% / 6.7%	37.1% / 1.5%	38.8% / 42.1%	34.9%	0.7%
1,000 <2,000	11.5% / 2.1%	11.1%	13.2%	27.8%	5.9%
>2,000	4.9%	0.0%	0.5%	0.0%	1.6%
				6.6%	6.6%

Tailândia		Fire Rotation (Years)			
Distance (m)	Forested (Burned) / Forested (Burned)	Forested (Burned) / Forested (Burned)	Low		
<300	46.0%	1.7%	49.1%	36.3%	41.8%
300 <1,000	37.7%	18.4%	26.9%	16.8%	33.0%
1,000 <2,000	11.3%	0.2%	10.7%	1.3%	0.7%
>2,000	5.0%	0.0%	3.3%	0.2%	0.6%
				6.6%	6.6%

Forests as a function of distance from deforested (black) edges. Forests in red can not survive the current fire regime. Forest in blue may persist (Cochrane 2001)

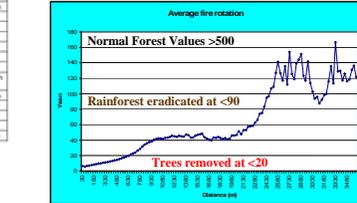


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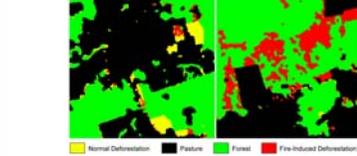


The cumulative capacity of recurrent tropical forest fires (Cochrane 2000)

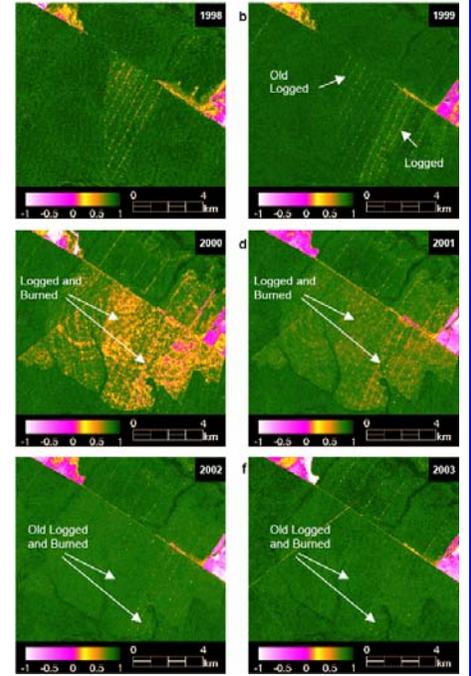
Spatially articulated fire regime: Fire rotation values by distance for a 250,000 hectare study region. Indications are that forests within 2 km of current edges can not persist under the current disturbance regime and will be replaced with grass or scrub vegetation (Cochrane 2001)



Two 64-km² imagery subsections illustrating the differences in location and form of normal deforestation (e.g. slash and burn for pasture or crops) and fire-induced deforestation, caused by accidental forest fires (Cochrane et al. 1999)

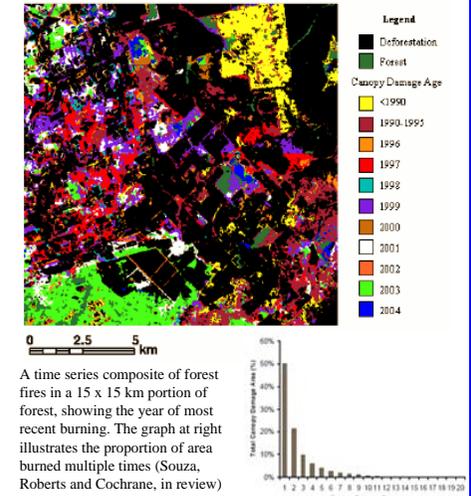


An example of fire-induced deforestation. The white lines are the ashes from trees which were completely consumed by fire.



Time series of images showing canopy damage in a logged, and subsequently burned, forest. The images illustrate the transitory nature of both logging and forest fire signatures in Landsat imagery.

Classifications are made based on the NDFI index of canopy damage (Souza, Roberts and Cochrane 2005)



A time series composite of forest fires in a 15 x 15 km portion of forest, showing the year of most recent burning. The graph at right illustrates the proportion of area burned multiple times (Souza, Roberts and Cochrane, in review)