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Accelerating deforestation in Brazilian Amazonia: towards answering open questions

PHILIP M. FEARNSIDE* AND REINALDO IMBROZIO BARBOSA
National Institute for Research in the Amazon (INPA), Av. André Araújo, 2936, CP 478, 69011-970 Manaus, Amazonas, Brazil
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SUMMARY

The annual rate of deforestation in Brazilian Amazonia jumped by an estimated 40% between 2001 and 2002. This increase is in addition to a 15% upward revision by the Brazilian government of the estimated rate for 2001. Examination of the data underlying these estimates and comparisons with other measurements indicates that important questions remain unanswered, especially in the state of Mato Grosso, where assessment of the effectiveness of a deforestation licensing and control programme is critical to future efforts to contain forest destruction. The increase in deforestation rate in Mato Grosso in 2002 (23%) was less than half the increase in the remainder of Brazilian Amazonia (55%), indicating that the state government's deforestation control programme may have had some effect.

Keywords: Amazonia, Brazil, deforestation, rainforest, remote sensing, tropical forest

INTRODUCTION

A series of open questions regarding Amazonian deforestation has become the focus of public attention following the June 2003 announcement of a 40% increase in the rate of Amazonian deforestation in 2002, as compared to the rate in 2001. This increase comes on top of an additional 15% increase in the estimated deforestation rate for 2001 (Fig. 1), which was announced at the same time (Brazil, INPE [Instituto Nacional de Pesquisas Espaciais] 2003). Here, we outline some of the doubts concerning the estimates and try to suggest ways that some of them might be resolved. The impetus of the new surge in forest clearing must be translated into both increased effort to quantify and understand the deforestation process and to take the sometimes politically and financially costly measures needed to contain it. The upsurge does not indicate that deforestation control measures have failed or that the deforestation process is inherently uncontrollable.

*Correspondence: Dr Philip M. Fearnside Tel: +55 92 643 1822 Fax: +55 92 642 8909 e-mail: pmfearn@inpa.gov.br

DEFORESTATION IN 2001

Estimates for the Legal Amazon in 2001

INPE's revision of the deforestation rate estimate for 2001 increased the amount from the 15 787 $km^2\ yr^{-1}$ preliminary estimate released in 2002 to a final estimate of 18 165 $km^2\ yr^{-1}$ (a 15% increase). Considerable fanfare had accompanied the announcement of the preliminary 2001 estimate as indicating a decrease from the rate in 2000, but the revised number indicates that no decrease took place (Fig. 1). The preliminary estimate for 2001 was based on 49 LANDSAT scenes where new clearing summed to 12 695 km^2 (Brazil, INPE 2001, p. 20). A LANDSAT 'scene' is a 185 km × 185 km area of the Earth's surface where the satellite acquires an image each time it flies over the site. To produce the preliminary estimate, the 2001 deforestation total from the critical scenes was adjusted upward by 20% to represent the remainder of the 229 scenes covering Brazil's Legal Amazon region. This was based on the percentage differential in the previous year between the regional total from complete 'wall-to-wall' coverage and the same sample of 49 'critical' scenes (Brazil, INPE 2002, p. 20).

For some parts of the region the upward revision of the estimate for 2001 may still be an underestimate of the true clearing. For example, in the state of Roraima, an improbably low deforestation rate is indicated for the scene (231-60) covering part of counties of São Luiz do Anauá, São João da Baliza, Caroebe and Rorainópolis: clearing of only 49.7 km^2 by 2001. The real area is probably higher because these counties receive dozens of additional migrant families every month. Another example is the scene (233-58) covering the Trairão settlement area, which indicates zero deforestation in 2001. We visited this area in 1998, at which time the rapid advance of deforestation was readily apparent. Since that year, two new settlements have been established near Trairão. Apparently INPE was unable to obtain an image for this region (Brazil, INPE 2003). Of the 20 scenes needed to cover Roraima, 12 have no data for deforestation for the 2000–2001 period. Omissions of clearings should be leading to an underestimate of deforestation, rather than the overestimate that would be needed to explain the jump in INPE's deforestation estimate for the region.

Estimates for Mato Grosso in 2001

Inconsistent results for 2001 in the state of Mato Grosso are a major concern. In Mato Grosso, FEMA (Fundação Estadual do Meio Ambiente, i.e. State Foundation for

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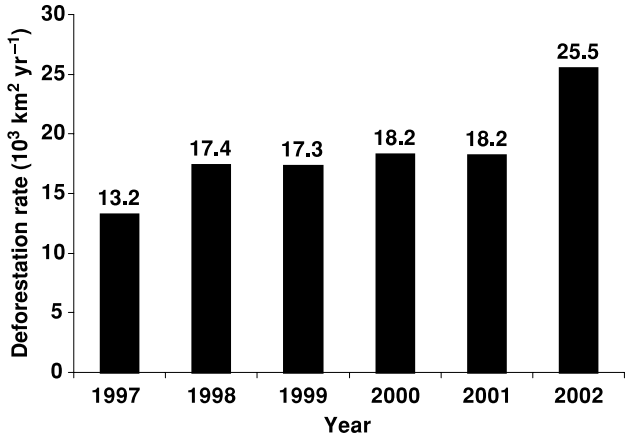


Figure 1 Estimates of deforestation in Brazil's Legal Amazon region (Brazil, INPE 2002, 2003). The 2002 estimate is preliminary.

Environment), the state government's environmental agency, has been monitoring clearing at two-year intervals, with annual surveys being instituted in 2002 (Fearnside 2003). Since the FEMA monitoring programme began, the FEMA and INPE estimates have never been in agreement, and have even differed in the direction of the discrepancy (Table 1).

The term 'deforestation' is used in a different way in Mato Grosso from other contexts, such as the annual deforestation estimates released by INPE. INPE uses the term *desflorestamento* (a term invented by INPE) to refer to clearing of vegetation that corresponds to the forest and transition categories, but does not consider clearing of *cerrado* (savannah). In Mato Grosso's state government usage, 'deforestation' (*desmatamento*) refers to clearing of all three categories. The comparison between INPE and FEMA results (Table 1) excludes *cerrado* from the FEMA estimates.

INPE has suggested that the differences between the INPE and FEMA results originate from the differing definitions of the vegetation subject to deforestation, namely 'forest' and 'transition' (dos Santos 2002). However, considering the description of vegetation types defined by INPE as forest (Brazil, INPE 2001), the explanation of differing definitions is not particularly satisfactory. Only one relatively minor vegetation type (*cerradão*, or high

Table 1 Comparison of FEMA and INPE deforestation data for Mato Grosso for forest and transition (forest–savannah ecotone) only; *cerrado* clearing, which is not monitored by INPE, is excluded from the FEMA values for this comparison. *Periods are standardized to the two-year 'biennium' that FEMA estimates adopted until 2001. FEMA and INPE use the term 'biennium' (*biênio*) differently: FEMA to refer to a 24-month period and INPE to refer to a 12-month period (dry season to dry season) spanning two calendar years.

*Two-year period**	*INPE (ha yr^{-1})*	*FEMA (ha yr^{-1})*	*Discrepancy (ha yr^{-1})*	*INPE – FEMA (%)*
1996–1997	590 700	770 130	−179 430	−30.4
1998–1999	671 450	638 066	+33 384	+5.0
2000–2001	911 900	414 507	+497 393	+54.5

Table 2 Original vegetation and clearing in Mato Grosso. [a]INPE includes *cerradão* (Sd), estimated at 26 083 km^2 (see text), in forest + transition; FEMA includes *cerradão* in the *cerrado* category. [b]INPE areas calculated from percentages multiplied by FEMA area for total vegetation. INPE percentages are measured from a map released in 2003 (Brazil, MCT & MMA 2003) ignoring 1.4% of area not classified.The forest + transition cleared area by 2001 derived here from the INPE map is greater than the 151 633 km^2 implied by past cumulative clearing (Brazil, INPE 2002) and the rate value released in 2003 (Brazil, INPE 2003). [c]INPE does not measure *cerrado* clearing.

Agency	*Original area of vegetation*		*Area cleared by 2001*	
	km^2	*% of total vegetation*	*km^2*	*% of original area*
Forest + transition[a]				
INPE [b]	509 146	59.5	163 005	32.0
FEMA	523 950	61.2	228 986	43.7
Discrepancy	−14 804	−1.7	−65 982	−11.7
INPE – FEMA	−2.9%		−40.5%	
Cerrado[a]				
INPE[b]	347 227	40.5	−[c]	−[c]
FEMA	332 423	38.8	124 121	37.3
Discrepancy	+14 804	+1.7		
INPE – FEMA	+4.3%			

cerrado), designated 'Sd' in the RADAMBRASIL map code (Brazil, Projeto RADAMBRASIL 1973–1983), is considered as forest by INPE and as *cerrado* (i.e. non-forest) by FEMA. Measurements from RADAMBRASIL 1:250 000 and 1: 1 000 000-scale maps indicate this vegetation type as totalling 26 083 km^2 in Mato Grosso, or only 3% of the state's vegetation (Fearnside & Barbosa 2003).

One possibility is that the prose descriptions of the vegetation types considered to be 'forest' by INPE do not match the areas considered as such in their geographical information system (GIS). INPE has not yet made its GIS coverage publicly available, although the intention to do so has been mentioned on various occasions over the years.

INPE's separation of the original (pre-Columbian) vegetation into 'forest' (forest and transition) and non-forest (*cerrado*) is based on a mix of information types, including both RADAMBRASIL maps and appearance on LANDSAT imagery. Since INPE has never released estimates for the original forest areas by state derived using the definition of 'forest' that INPE applies to the annual deforestation estimates (see reviews in Fearnside 1997, 2000), an estimate for Mato Grosso (Table 2) is derived from a coarse-scaled map (6 km^2 pixel^{-1}) released in 2003 (Brazil, MCT [Ministério da Ciência e Tecnologia] & MMA [(Ministério do Meio Ambiente] 2003). Measurements indicate that INPE considers 'forest' (forest and transition) to be the original vegetation in 32.0% of the state's land area, substantially less than the 43.7% indicated by FEMA (Mato Grosso, FEMA 2002). This discrepancy, however, is in the wrong direction to explain the different results of the deforestation estimates; with less

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area considered as originally 'forest' (i.e. potentially subject to deforestation), INPE would be expected to find less, rather than more, deforestation than FEMA.

In the case of FEMA, the limits between what was considered to have had original vegetation as forest, transition and *cerrado* were (possibly subject to change following a change of state government on 1 January 2003) defined exclusively on the basis of RADAMBRASIL maps. This was important as a legal matter in order to avoid opportunities for corruption influencing reclassification of land into categories where greater percentages of clearing would be legally permitted. Since 2000, federal requirements specify that the 'legal reserve' that Brazil's 1965 Forestry Code requires in each property must cover 80% of the property in forest areas and 35% in *cerrado* areas. A Mato Grosso state government decision specifies a 'legal reserve' of 50% in the 'transition' area. The FEMA definitions in use through 31 December 2002 are contained in digital maps distributed to forestry engineers preparing applications for licensing (Mato Grosso, FEMA 2001*a*). Measurements from these maps indicate that 572 645 km^2, or 63.2% of the state, was originally either forest or transition according to FEMA's definition (Mato Grosso, FEMA 2002). The difference between the FEMA and INPE definitions of forest + transition indicated by the maps is 14 804 km^2, but the size of the discrepancy is partially hidden by the 26 083 km^2 area of *cerradão* that is included as 'forest' by INPE but not by FEMA. If *cerradão* is subtracted from the INPE forest area, the difference for the remaining 'forest' vegetation is 40 887 km^2, an area the size of Belgium.

Another possible explanation could lie in differences in the dates of the images used. Neither the FEMA estimates nor the state-level estimates from INPE are normalized, for example by projecting the clearing for each scene to the end of the year. However, the images used are almost always from the most cloud-free period at the height of the dry season (after most felling is complete), and we believe it unlikely that different image dates could explain such a large discrepancy (up to 54.5%; Table 1).

DEFORESTATION IN 2002

Estimates for the Legal Amazon in 2002

The 25.5×10^3 km^2 yr^{-1} preliminary figure for 2002 is not only higher than the rate for 2001, it is also higher than the 19×10^3 km^2 yr^{-1} figure for 2002 that was leaked to the press on 5 May 2003 (Via Ecológica 2003). Delays in releasing bad news have been a repeated pattern, as in the cases of the upturn of deforestation beginning in 1992 (not revealed until 1995), and the record peak of 29.1×10^3 km^2 yr^{-1} in 1995, not revealed until one month after the end of the December 1997 Kyoto conference on global warming (see Fearnside 1997, 2000). Release of the 2002 preliminary estimate was accompanied by the announcement that future deforestation estimates will be released without delays.

Table 3 Deforestation in 50 sample scenes. Data from Brazil, INPE (2003). *In one of the scenes assigned to Amazonas, but most of this increase is probably in the portion of the scene located in Rondônia.

State	*Number of scenes*	*Deforestation (10^3 km^2)*		*Change (%)*
		2001	*2002*	
Mato Grosso	19	6250	7695	+23.1
Rondônia	9	2628	3956	+50.5
Pará	13	3388	4589	+35.4
Maranhão	4	751	1561	+108.0
Amazonas	2	171	376	+119.6*
Tocantins	2	454	398	−12.3
Acre	1	106	704	+566.8
Total	50	13 747	19 279	+40.2

Estimates for Mato Grosso in 2002

The location of changes in deforestation rate is important for understanding the increase in 2002. The deforestation in the 50 sample scenes used for a preliminary estimate of deforestation in 2002 can be apportioned among the states, with any scenes that overlap more than one state being assigned to the state with the largest share of the scene (Table 3). Deforestation increased less in Mato Grosso (23.1%) than in the other states (54.5%). Particularly important are the larger increases in the two other major states for deforestation activity: Pará (35.4%) and Rondônia (50.5%). Tocantins, where deforestation rate decreased by 12.3%, is of limited importance for two reasons: Tocantins never had much forest because most of the state was originally *cerrado*, and, since much of the forest that did exist has already been cut, the decrease in deforestation rate is best explained by the dwindling of forest areas available for clearing. The smaller percentage increase in Mato Grosso relative to the increase in the total from sample scenes in other states suggests that the FEMA licensing and control programme may have been having some effect on clearing. However, some of the lower rate of clearing in Mato Grosso is due to the diminishing areas of forest available for clearing. Mato Grosso is of particular importance because of the deforestation licensing and control programme that was undertaken there by the state government's environmental agency over the 1999–2001 period (Mato Grosso, FEMA 2001*b*).

CONCLUSIONS

Questions remain to be answered regarding deforestation estimates in Amazonia. Most important is clarification of the 2001 estimate for the state of Mato Grosso, where data from the state-government agency (FEMA) indicate that the deforestation rate decreased in forest and transition vegetation, while data from the federal agency (INPE) indicate that the rate increased. This clarification is needed to assess the effectiveness of Mato Grosso's programme to license and control deforestation. Several indications point to an effect from the programme, despite open questions regarding

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interpretation of the INPE data. For 2002, a major upsurge in deforestation occurred throughout Brazilian Amazonia, both inside and outside of Mato Grosso, but the increase was less in Mato Grosso than in the rest of the Amazonian region. Both INPE and FEMA should release their data and metadata (i.e. documentation of the derivation of all intermediary results for each component of the estimates), allowing unrestricted public access via internet, so that the scientific community at large can examine the results, clarify outstanding discrepancies, and improve future monitoring procedures.

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References

Brazil, INPE (2001) *Monitoramento da Floresta Amazônica Brasileira por Satélite/Monitoring of the Brazilian Amazon Forest by Satellite: 1999–2000*. São José dos Campos, São Paulo, Brazil: INPE.

Brazil, INPE (2002) *Monitoramento da Floresta Amazônica Brasileira por Satélite/Monitoring of the Brazilian Amazon Forest by Satellite: 2000–2001*. São José dos Campos, São Paulo, Brazil: INPE.

Brazil, INPE (2003) Taxas nos períodos 2000–2001 e 2001–2002 para 50 cenas críticas [www document]. URL http://www.obt.inpe.br/prodes/prodes_2002_2002.htm

Brazil, MCT & MMA (2003) Mapeamento do Desmatamento da Amazônia com Imagens de Satélite [www document]. URL http://www.obt.inpe.br/prodes.html

Brazil, Projeto RADAMBRASIL (1973–1983) *Levantamento de Recursos Naturais, Volumes 1–31*. Rio de Janeiro, Brazil: Ministério das Minas e Energia, Departamento Nacional de Produção Mineral (DNPM).

dos Santos, J.R. (2002) Visita técnica dos pesquisadores do INPE/S.J. Campos à FEMA-MT. Instituto Nacional de Pesquisas Espaciais (INPE), São José dos Campos, São Paulo, Brazil. Report to Ministério do Meio Ambiente (MMA), Secretaria de Coordenação da Amazônia (SCA), Sub-Programa de Recursos Naturais (SPRN), 31 July 2002. São José dos Campos, São Paulo, Brazil: INPE.

Fearnside, P.M. (1997) Monitoring needs to transform Amazonian forest maintenance into a global warming mitigation option. *Mitigation and Adaptation Strategies for Global Change* **2**(2–3): 285–302.

Fearnside, P.M. (2000) Effects of land use and forest management on the carbon cycle in the Brazilian Amazon. *Journal of Sustainable Forestry* **12**(1/2): 79–97.

Fearnside, P.M. (2003) Deforestation control in Mato Grosso: a new model for slowing the loss of Brazil's Amazon forest. *Ambio* **32**(5): 343–345.

Fearnside, P.M. & Barbosa, R.I. (2003) Avoided deforestation in Amazonia as a global warming mitigation measure: the case of Mato Grosso. *World Resource Review* **13**(2): 352–361.

Mato Grosso, FEMA (2001*a*) Sistema de licenciamento ambiental único, Versão 1.0 (CD-ROM). Cuiabá, Mato Grosso, Brazil: FEMA, Diretoria de Recursos Florestais (DRF).

Mato Grosso, FEMA (2001*b*) Environmental control system on rural properties in Mato Grosso. Cuiabá, Mato Grosso, Brazil: FEMA.

Mato Grosso, FEMA (2002) Dinâmica do desmatamento no Estado de Mato Grosso 2001. Cuiabá, Mato Grosso, Brazil: FEMA.

Via Ecológica (2003) Satélites mostram que agricultura ajudou a destruir mais floresta na Amazônia. *Via Ecológica* **5 May 2003** [www document]. URL http://www.viaecologica.com.br

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