DEFORESTATION RATE IN BRAZILIAN AMAZONIA

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Estimates of the deforestation rate in Brazil's Amazon region over the last few years have varied by a factor of four. Reliable estimates are needed because of deforestation's contribution to global concerns such as greenhouse warming and loss of biodiversity. A new estimate for forest area cleared through 1989 (Tardin et al., 1990) provides a much more reliable point of reference than was previously available, and permits the re-evaluation of previous data to derive deforestation rates. In the recent study, 222 LANDSAT Thematic Mapper (TM) images covering all of the forested portion of Brazil's Legal Amazon region were interpreted manually on color composites of TM bands 3, 4 and 5 at a scale of 1:250,000. The measured deforested area in the region covered by the map sheets of that work was 394,722sq.km. Inclusion of small deforested areas in the remainder of the region (totalling 1,930sq.km), and adjustment for cloud cover, weighted by deforestation extent for each image, yields a best estimate for the deforested area by 1989.

The value, 396,689sq.km ±5%, corresponds to the average date of August 1989.

This includes 97,643sq.km of "old" (approximately pre-1960) secondary forests distributed continuously in the states of Pará and Maranhão, as determined from recent re-analysis of LANDSAT MSS 1977-78 images, and 5,445sq.km of flooding by hydroelectric dams. The 1989 estimate benefitted from this year being unusually free of cloud cover over Amazonia. All but one-third of one image were from 1989. The fact that deforestation takes place in the dry season and LANDSAT images are also obtained in the dry season, makes this and all LANDSAT-derived results correspond to the evolution of deforestation smoothed over the seasonal variation, a point to be kept in mind especially when interpreting the meaning of the dates associated with the data.

Available previous estimates include studies for images for 1978 and 1988. The 1978 study (Tardin et al., 1980) used bands 5 and 7 of the LANDSAT Multispectral Scanner (MSS) at a scale of 1:500,000.

The reported 77,172sq.km of clearing by 1978 was obtained with a different methodology, for it included clearing in the "cerrado", it did not include

the "old" deforestation, and the region of study extended south of 16S in Mato Grosso. Re-analysis of the 1978 data set, to make the results compatible with the 1989 survey resulted in a best estimate of 54,130sq.km of deforested area by 1978, in addition to the "old" deforestation.

The average rate of clearing over the 11.6 year period from the 1978 to the 1989 data sets was therefore 21,218 sq.km/year, ±10%.

The above uncertainty range results from 5% uncertainty from human inconsistency in measuring overlays of 1:250,000 scale images (tested by Tardin et al., 1990), and the rest from the uncertainty associated with the reanalysis of the 1978 data set.

By 1988, deforestation in the forested portion of the region was estimated to have reached 343,972sq.km (Tardin and da Cunha, 1989), including old secondary forest area as deforested. This estimate was originally done with 101 LANDSAT-TM 1:250.000 images. Tardin et al. (1990) reported the value of 358,743sq.km, the difference being attributed to the inclusion of 26 additional such images. Both estimates include 3,861sq.km of hydroelectric dams and 92,546sq.km of "old" secondary forest. Cloud cover over the region in 1988 forced the interpretation team at Brazil's Institute for Space Research (INPE) to use (in addition to 77 images from 1988), 38 images from 1987, 6 from 1986, 5 from 1985 and 1 from 1984. The average date for the 1988 data set is April 1988.

The rationale for not analysing the remaining 222-127 = 95 images for 1988 was the fact that a mosaic of black-and-white LANDSAT TM images in the scale of 1:1,000,000 showed no evidence of deforestation. The possible remaining doubt has now been eliminated with the extension of the analysis to the 222 images for 1989, as reported above.

In order to derive now a best estimate for the deforested area by 1988, the small deforested areas previously disregarded were computed by assuming that their extent increased linearly from 0 in 1978 to the value measured in 1989 (of the order of 2,000sq.km), and interpolating for 1988.

The new estimate for the deforested area by 1988 is thus 362,051sq.km ±5%, and it corresponds to the average date April 1988.

Another deforestation rate can be also determined from the 1988 and 1989 data sets, resulting in 26,664sq.km ±5%. This rate corresponds to a

period of 1.05 year (+.87, -.03) preceding August 1989. The skewed uncertainty range is due to the skewed distribution of the dates of the LANDSAT images.

Table I presents the results by individual states, and Figure I summarizes the time evolution of the deforested area for the region.

The average rate of deforestation for the period 1978/89 of 21,218sq.km±10% conflicts sharply with rates that have been used in several recent publications on deforestation and its impacts. The World Resources Institute (WRI) Report for 1990-1991 (WRI, 1990) uses 80,000sq.km as the annual rate for "the 1980's." Norman Myers (1989) uses 50,000sq.km/year as the rate as of 1988. Both estimates are based on calculations of the burning area derived from the number of fires estimated with the thermal infrared band 3 (3.5-3.9 micrometer) of the Advanced Very High Resolution Radiometer (AVHRR) on the US National Oceanographic and Atmospheric Administration (NOAA-9) meteorological satellite. The 80,000sq.km/year rate used by WRI was that calculated for the year 1987, which apparently had much more deforestation and burning than other years due to a combination of dry weather and a constitutional debate on confiscating forest areas from large ranchers for redistribution in a proposed agrarian reform program.

The 1987 estimate (Setzer et al., 1988), as well as the value for 1988 used by Myers (Setzer and Pereira, nd) suffer from severe (and possibly insolvable) methodological problems for estimating areas (reviewed in Fearnside, 1990a, nd-a). The AVHRR area estimates were a by-product of studies designed to locate and count fires. The correction factors used to adjust for partially burning pixels (0.7) and for the proportion of the burning attributed to new forest clearing (0.4) could both be high by as much as a factor of two. A correction factor for partially burning pixels is difficult to derive because of large increases in the proportion of overestimation caused by small increases in fire temperature (a highly variable parameter) -- theoretical calculations show that a fire of only 900sq.m is sufficient to trigger an entire pixel of 1,200,000sq.m (Robinson, nd), although practical experience suggests that narrow flame fronts up to 2 km in length can escape detection (A.W. Setzer, personal communication, 1990). The correction factor for non-forest is high because cerrado was apparently included in the numerator but not in the denominator when deriving the factor (see Fearnside, nd-a).

The LANDSAT-based estimates on the order of 21×10^3 sq.km/year for the past decade, or 26×10^3 sq.km/year for 1989, represent the most reliable values at present for the forest clearing rate in Brazilian Amazonia.

We emphasize that the average rate for 1978/1989 does not imply that the pace of deforestation was constant over this period. Although the data for intermediate years reported by other Brazilian agencies are not as complete as those for the end-points, they suggest that the rate increased through about 1987, after which it tapered off (in part due to heavy rainfall during the 1989 burning season). This confirms subjective impressions of deforestation activity in the region over this period.

Translating information on deforestation rates into releases of greenhouse gases requires knowledge of the spatial distribution of the clearing, the corresponding spatial distribution of vegetation types and their respective biomasses and the biomass of replacement vegetation, as well as the fate of biomass and soil carbon under prevailing agricultural and ranching practices in cleared areas (Fearnside, 1990b). Studies of these factors indicate annual carbon releases on the order of 0.3 gigatons (Fearnside, nd-b).

Although deforestation rates in Brazilian Amazonia are much lower than some have believed, the pace of forest loss remains high. Among other impacts, Amazonian deforestation makes a significant contribution to the global greenhouse effect.

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TABLE I - DEFORESTED AREA IN BRAZILIAN LEGAL AMAZONIA FROM COMPREHENSIVE LANDSAT MSS AND TM SURVEYS

deforested area in square kilometer
(percentage of area of state)

STATE	DATE	JAN 1978	APR 1988	AUG 1989	area of state (sq.km)
ACRE		2,206(1.4%)	7,292(4.7%)	8,836(5.7%)	153,698
AMAPA		167(0.1%)	781(0.5%)	1,016(0.7%)	142,359
AMAZONAS		1,611(0.1%)	18,559(1.2%)	21,551(1.4%)	1,567,954
MARANHÃO		6,076(2.3%)	24,451(9.4%)	30,840(11.9%)	260,233
(in addition to "old" deforestation,57,824sq.km or 22.2%)					
MATO GROSSO		20,005(2.5%)	71,414(8.9%)	79,594(9.9)	802,403
PARÁ		16,525(1.3%)	88,531(7.1%)	99,786(8.0%)	1,246,833
(in addition to "old" deforestation,39,819sq.km or 3.2%)					
RONDÔNIA		4,242(1.8%)	29,678(12.4%)	31,476(13.2%)	238,379
RORAIMA		132(0.1%)	2,743(1.2%)	3,621(1.6%)	225,017
TOCANTINS		3,166(1.2%)	20,959(7.8%)	22,327(8.3%)	269,911
LEGAL AMAZONIA		54,130(1.1%)	264,408(5.4%)	299,046(6.1%)	4,906,784

(in addition to "old" deforestation:97,643sq.km or 2.0%)

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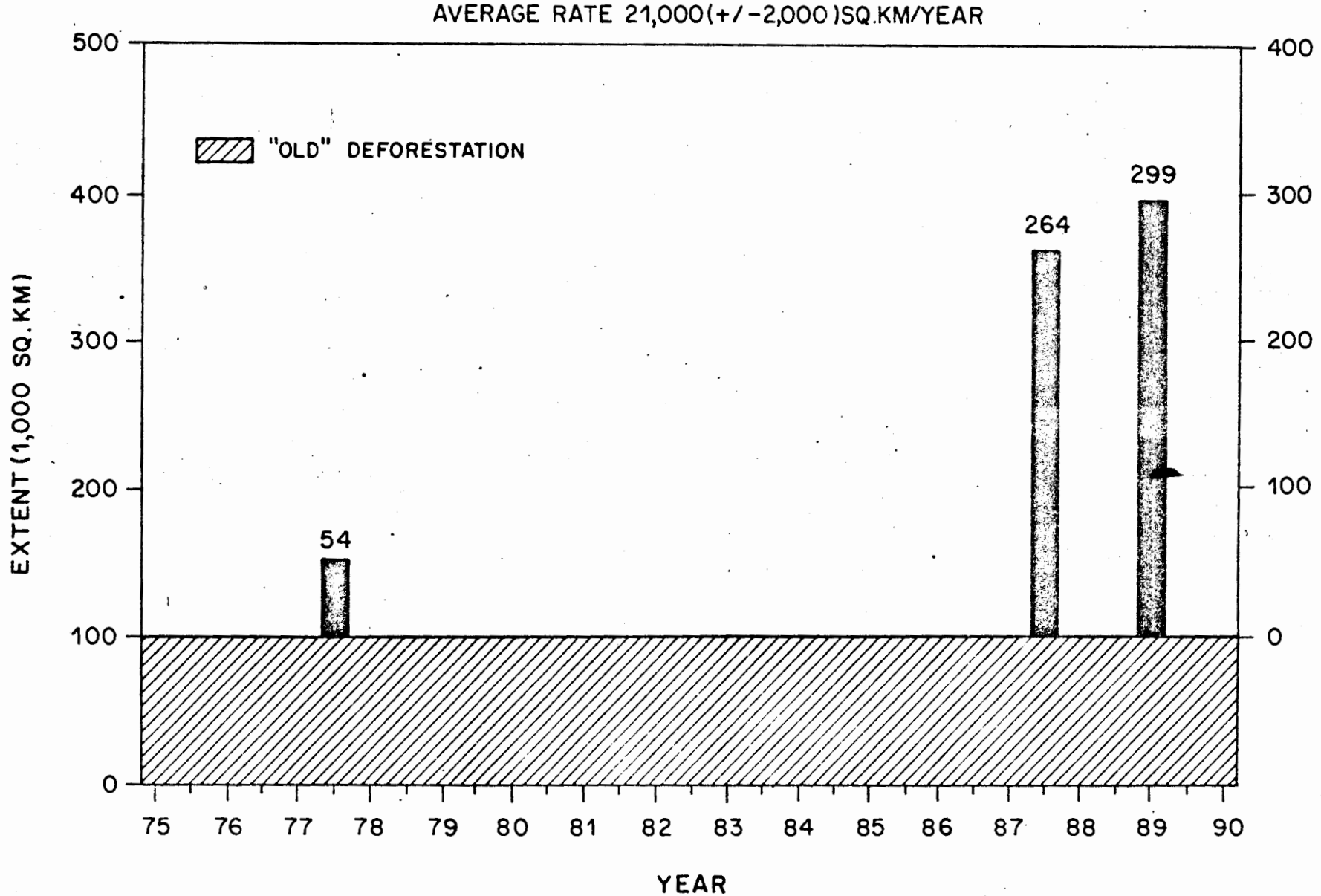

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