

**DEFORESTATION ESTIMATES THROUGH REMOTE SENSING:**

**THE STATE OF THE ART IN THE LEGAL AMAZONIA**

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**ABSTRACT**

The study presents recent measurements (1988) of deforestation obtained from Landsat - TM imagery for the whole Legal Amazônia (4 906 784.4 Sq.Km). Focus is given on forest depletion rates for the Legal Amazônia based on the analysis of deforestation rates available in the last thirteen years. Deforestation measurements are contrasted with mathematical deforestation projections published elsewhere which mainly assume exponential rates of forest depletion.

The study shows that up to the year of 1988, 251 429.55 Sq.Km of the Legal Amazônia have been deforested, this is equivalent to 5.12% of the area of the Legal Amazônia and does not include very old deforestation values for the Pará and Maranhão State. If one assumes a linear deforestation growth and uses the highest deforestation rates observed in the last thirteen years in the Legal Amazônia one should expect a projected value of 272 858.16 Sq.Km by the end of 1989.

## INTRODUCTION

The Legal Amazônia is a complex domain which embraces several amazônias, and has an area of 4 906 784.4 Sq.Kilometers (as taken throughout this study).

Evaluations of deforestation in such large area is most efficiently done through satellite remote sensing data. Access to areas in Amazônia is limited and the study area to be covered is enormous. Synoptical view provided by satellite remote sensing data permits a comprehensive study. This paper presents results obtained from most recent Landsat Thematic Mapper coverage available until 1988.

The first part of the paper presents a brief review of the Amazônia and the existing deforestation estimates available. Also, both the most recent deforestation measurements made by the Space Research Institute of Brazil (INPE, 1989) and discussions on deforestation estimates and forest depletion rates are presented.

Through tables and graphs provided, the reader will have the opportunity to compare assumptions of exponential deforestation growth contrasted with actual deforestation measurements. Finally, measured deforestations values are presented in comparison with previous and recent projections for the year of 1989.

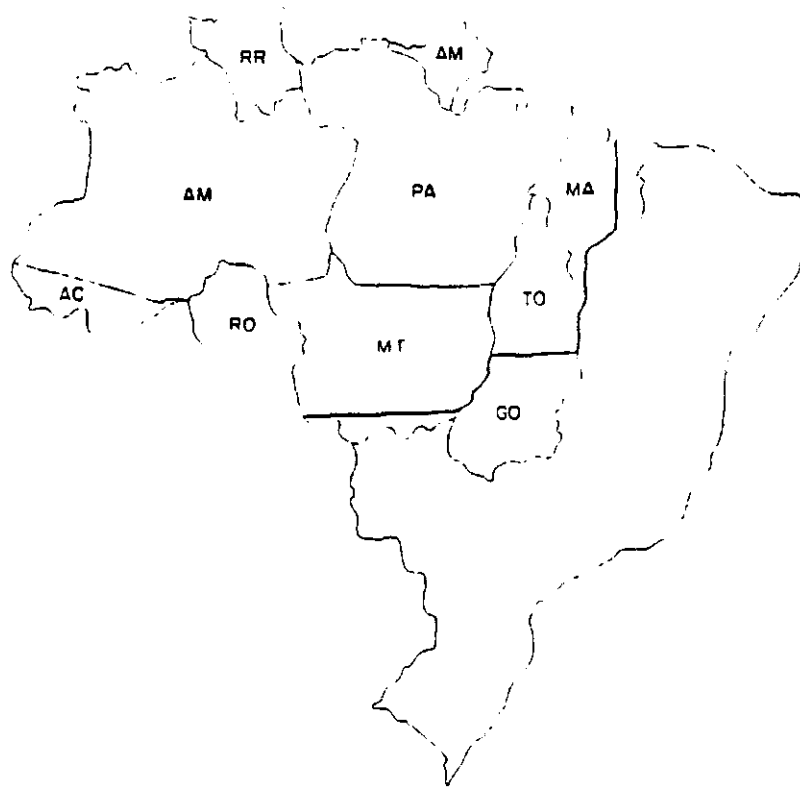
## AMAZÔNIAS

There is Amazônia and amazônias. The most commonly known is the Classical Amazônia or the "Hileia Brasiliensis" which includes, mainly, tropical rain forest. However the Amazonia is a much more complex domain, which embraces grasslands, wetlands, shrublands, "Terra Firme" forests, large water masses etc. (see Fig. 1).

Throughout this publication we use the concept of Legal Amazônia (LAM). The Legal Amazônia as original defined\* encompasses the states and territories of Acre, Amapá, Amazonas, Pará, Rondônia and Roraima, the so called North Region. Additionally the Legal Amazônia also includes part of the Tocantins - Goiás State (north of the parallel 13o), the Mato Grosso State (north of the parallel 16o) and the Maranhão State (west of the meridian 44o, see figure 1). The Legal Amazônia represents a political boundary and has served as a basis for government development policies and taxes purposes. For our purposes, the Legal Amazônia is the sum of ours individual study units which are the states and the territories. Therefore the current study is a state by state or territory by territory analysis which all together composes a larger physical unit called Legal Amazônia. There are historical reasons to proceed this way. All the previous studies (historical data) in the Amazônia Region have used the states and territories as areas of reference. As we will see in this paper all the deforestation studies done so far relate percentages of deforestation to physical areas (states, territories, North Region, Legal Amazônia) which allows for comparisons through the time.

Forest cover information in the Legal Amazônia (taken as an area of 4 906 784.4 Sq.Km) varies from source to source. FAO estimates mention about 3.500.000 Sq.Km (Guppy, 1984). Also there are estimates from the IBGE (Brazilian Institute of Geography and Statistics) of c.a. 3.7000.000 Sq.Km and the Terra Firme forests cover varies between 2.600.000 and 2.800.000 Sq.Km. Senator Jarbas Passarinho has done some exercices on this matter (e.g. Passarinho, 1989). It should be mentioned that most of the estimates do not take in account the water (variable) masses which in the North Region occupy considerable areas. Futhermore the forest cover estimates should express the cover in a state by state basis or other smaller units and then present the total for Legal Amazônia.

\* Federal government decree of 1953.



ÁREA 4 906 784,4 km<sup>2</sup>

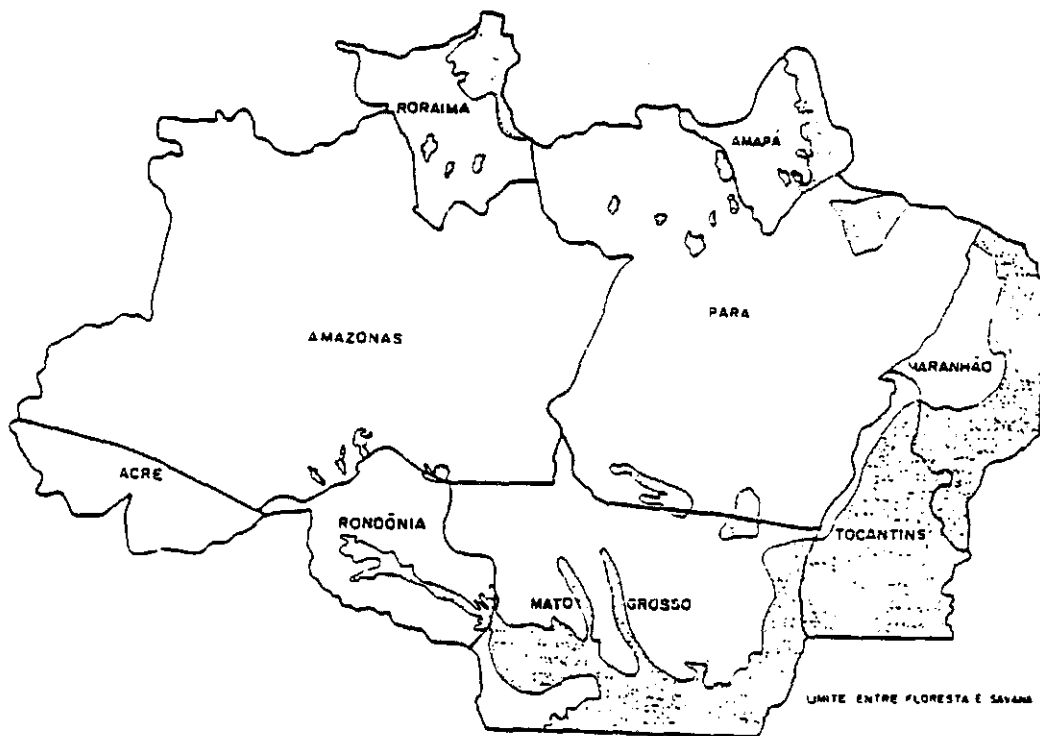


Figure 1 - Legal Amazon  
Study area. Forest and  
Savannah distribution

## DEFORESTATION EVALUATION STUDIES

Since the last year an avalanche of percentage figures on Amazônia deforestation have been announced, mainly through the media. It seems like almost everyone had its own number. International symposia have also been the forum for announcement of variety of deforestation percentages figures.

Percentages are one form to express deforestation but are not the most important. As we will see later, in the author opinion, more important are deforestation rates. As a result, there is a need of coherent historical data bases which we will see next.

There are few published reports on deforestation of the Amazônia which cover the whole area or the Legal Amazônia.

The first report was published back in 1980 by INPE (Space Research Institute of Brazil - INPE) and until April 1989, it has been the only complete evaluation of the Legal Amazônia, in the sense it contained measured deforestation results. The 1980 INPE report (Tardin et al, 1980) has served as a data source for mathematical projections as we will see through this paper. The results of 1980 INPE's report are summarized in the tables 1 and 2. These deforestation estimates were obtained from the interpretation of black and white, 1:500 000 scale images of the remote sensing satellite Landsat-Multispectral Scanner (MSS). At that time two bands (5 and 7, red and infrared) were used for the Legal Amazônia area which have accounted for a total of 1244 images. The same results could eventually be obtained employing much less images if stratification techniques have been used. Stratification procedures have been used in the 1989 study.

Based on the data published by INPE (Tardin, et al, 1980), Fearnside (1982) started a series of publications which, using mathematical projections, yielded deforestation estimates (see Table 3). After Fearnside (1982) publications none deforestation estimates for the whole Legal Amazônia have been published, except scattered data for some states published by the Brazilian Institute of Forest Development (e.g. IBDF, 1980, 1983).

Mahar (1988) published in 1988 a report on government policies of the Amazônia occupation. This report, although not a specific deforestation study, has allowed for the establishment of public opinion that the deforestation in the Legal Amazônia was 12%. This also contributed to the melange between the author and the World Bank opinion, since the report is an official publication of the World Bank. The results of this publication are summarized on Table 4. While Fearnside's (1982) results are projections of 1978 to 1988, Mahar's (1988) are projections from the year 1980 to 1988.

TABLE 1 DEFORESTATION: INPE/IBDF 1975 MEASUREMENTS. MODIFIED  
 FROM INPE'S REPORT: "DEFORESTATION PROJECT" FOR COMPARISON PURPOSES  
 (INPE 1649 - RPE/103)

STATE/TERRITORY UNITS*	DEFORESTATION UP TO 1975(1)		
	Area (SQ KM)	Absolute (SQ KM)	Relative (%)
ACRE	153 697.5	1 165.5	0.7
AMAPÁ	142 358.5	152.5	0.1
AMAZONAS	1 565 953.7	779.5	0.05
PARÁ	1 246 833.1	8 654.0 (2)	0.7
RONDÔNIA	238 378.7	1 216.5	0.5
RORAIMA	225 017.0	55.0	0.02
SUB-TOTAL NORTH REGION	3 574 238.5	12 023.0	0.34
TOCANTINS-GOIAS-LAM	269 910.5	3 507.25	1.3
MARANHÃO - LAM	260 232.7	2 940.75 (2)	1.1
MATO GROSSO - LAM	802 402.7	9 227.63	1.15
TOTAL LAM	4 906 784.4	27 698.63	0.6

LAM - Legal Amazônia. Federal Government decree of 1953.

\* Data Source: All the state and territories areas throughout this report are based on information kindly provided by the Brazilian Institute of Geography and Statistics - Geoscience Division (IBGE, 1989).

- 1 - Measurements obtained from LANDSAT Multispectral Scanner - MSS. Measurements at scales of 1:500 000. Nominal resolution of 0.0064 Sq.km.
- 2 - For the Pará and Maranhão States only. The study did not include, very old, historical deforestation for those states. See table 6.

TABLE 2A - DEFORESTATION: INPE/IBDF 1978 MEASUREMENTS MODIFIED FROM INPE'S  
 REPORT: "DEFORESTATION PROJECT" (INPE 1649 - RPE/103) FOR COMPARISON PURPOSES

STATES/TERRITORY UNITS	DEFORESTATION UP TO 1978 (1)		
	Area (SQ KM)	Absolute (SQ KM)	Relative (%)
Name			
ACRE	153 697.5	2 464.5	1.6
AMAPÁ	142 358.5	170.5	0.1
AMAZONAS	1 567 953.7	1 785.75	0.1
PARÁ	1 246 833.1	22 445.25(2)	1.8
RONDÔNIA	238 378.7	4 184.5	1.7
RORAIMA	225 017.0	143.5	0.06
SUB-TOTAL NORTH REGION	3 574 238.5	31 194.25	0.9
TOCANTINS-GOIAS-LAM	269 910.5	10 288.5	3.8
MARANHÃO - LAM	260 232.7	7 344.0	2.8
MATO GROSSO - LAM	802.402.7	25 821.3	3.2
TOTAL LAM	4 906 784.4	74 648.1	1.52

LAM - Legal Amazônia - 1 and 2 see table 1.

TABLE 2B - DEFORESTATION INCREMENTS: 1975 TO 1978

STATE/TERRITORY UNITS	DEFORESTATION INCREASE		DEFORESTATION RATE (YEARLY) *	
	SQ. KM	%	SQ. KM	% OF UNIT
ACRE	1 299.0	111.5	433	0.282
AMAPÁ	18	11.8	6	0.004
AMAZONAS	1 006.25	129.1	335.4	0.021
PARÁ	13 791.25	159.4	4 597.1	0.37
RONDÔNIA	2 968.0	244.0	989.3	0.415
RORAIMA	88.7	161.4	29.6	0.013
SUB-TOTAL NORTH REGION	19 171.25	159.45	6 390.4	0.18
TOCANTINS-GOÍÁS-LAM	6 781.25	193.3	2 260.4	0.84
MARANHÃO LAM	4 403.25	149.7	1 467.7	0.56
MATO GROSSO LAM	16 593.7	179.8	5 531.22	0.69
TOTAL LAM	46 949.5	169.5	15 649.8	0.32

\* Linear.



TABLE 3 - DEFORESTATION: FEARNSIDE PREDICTION. MODIFIED  
FROM FEARNSIDE (1982) FOR COMPARISON PURPOSES

STATE/TERRITORY UNITS	DEFORESTATION (UP TO 1988) (1)		
	Area - SQ KM	Absolute (SQ KM)	Relative (%)
ACRE	153 627.5	29 906.9	19.5
AMAPÁ	142 358.5	247.3	0.17
AMAZONAS	1 567 953.7	28 302.2	1.8
PARÁ	1 246 833.1	538 064.8 (2)	43.1
RONDÔNIA	238 378.7	257 078.0	107.8
RORAIMA	225 017.0	3 535.4	1.6
SUB-TOTAL NORTH REGION	3 574 238.5	857 134.6	24.0
TOCANTINS-GOÍÁS-LAM	269 910.5	371 789.1	137.7
MARANHÃO - LAM	260 232.7	154 482.9 (2)	59.3
MATO GROSSO - LAM	802 402.7	790 211.4	98.6
TOTAL LAM	4 906 784.4	2 173 618.0	44.3

1 - Mathematically, exponentially, calculated from data of 1978.  
Ten years forecast.

2 - For the Pará and Maranhão States only; Fearnside (1982) values do not take into account, very old, historical deforestation in those states. These values were only known in 1989 through INPE measurements.

TABLE 4 - DEFORESTATION: "WORLD BANK" PREDICTION MODIFIED  
FROM MAHAR (1988) FOR COMPARISON PURPOSES

STATE/TERRITORY/UNITS (1)	Area - (SQ KM)	Absolute (SQ KM)	Relative (%)
ACRE	153 697.5	19 673.3	12.8
AMAPÁ	142 358.5	569.3	0.4
AMAZONAS	1 567 953.7	106 620.8	6.8
PARÁ	1 246 833.1	119 696.0 (3)	9.6
RONDÔNIA	238 378.7	56 495.7	23.7
RORAIMA	225 017.0	3 150.2	1.4
SUB-TOTAL NORTH REGION	3 574 238.5	306 205.3	8.6
TOCANTINS-GOIAS-LAM	269 910.5	31 309.6	11.6
MARANHÃO - LAM	260 232.7	51 265.8 (3)	19.7
MATO GROSSO - LAM	802. 402.7	189 367.0	23.6
TOTAL LAM	4 906 784.4	578 147.7	11.8

LAM - Legal Amazônia

- 1 - Source: Brazilian Institute of Geography and Statistics Geosciences Division (1989).
- 2 - Mathematically calculated from data of 1978 and 1980 and projected to 1988. Eight to ten years forecast.
- 2 - For the Pará and Maranhão states only, Mahar (1988) values do not take into account historical, secular deforestation. For those States, values were only known in 1989 through INPE measurements.

Fearnside (1989), during the year of 1989, concluded a new prediction study on deforestation estimates, now introducing linear mathematical projection instead of exponential one as formerly used (see Table 5). Fearnside (1989) projections varies state by state, and may include up to ten year projections.

Setzer (1988) introduced an study for burning areas which primarily does not envisage deforestation evaluation. The deforestation in that report are probalistic assumptions that 4 out of 10 burnings correspond to forest clearing. The universe of occurrence of the burnings is more probalistic yet, because the distribution of burning areas are not discriminated among forest and non-forest terrains, and deforest/previous forest areas. Therefore without knowing the previous land cover scenario is difficult to evaluate land cover change. However it was undoubtly a useful tool in the lack of more adequate high resolution remote sensing satellite results. Setzer (1988) results are not included in this study because they are not cumulative results. In other words, while Landsat images cumulatively records the history of land use (deforestation) through the years, weather satellites, as used in the case of burning areas, only provide a snapshot of particular situation in a particular time. Additionally, the study does not considers, for instance, the fact that agricultural practice may include repetitive yearly burnings. Futhermore deforestation may be not followed by burning, and, as a result it may remain undetected.

#### DEFORESTATION MEASUREMENTS TO 1988

The remote sensing approach

As we have seen, the available results for deforestation estimates, for the whole Legal Amazõnia after 1980 were done based not in remote sensing measurements but rather based on mathematical projections or predictions.

In 1989, INPE decided to make a wall to wall assessment of the deforestation in the Legal Amazõnia. For this study a mosaic of 234 Landsat - Thematic Mapper was assembled. This mosaic at scale of 1:1 000 000 served as the basis for area stratification and separation of forest/non forest domains with the help of ancillary information (vegetation maps). Later, experiment photointerpreters selected those images which showed deforestation patterns. This resulted in a set of 101 LANDSAT images which were used at the scale of 1:250 000 in color composite combinations of two infrared bands (TM 4 and 5) and one visible band (TM - 3). The color composite 3-4-5 was elected among others combinations since it has shown to be the best combination to discriminate forest from non-forest and secondary forest units. The 101 images were visually interpreted and the results were displayed in plastic film overlays. From the overlays, deforestation measurement were obtained on a image by image basis using grid-cell point

TABLE 5 -- DEFORESTATION: "INPA" PROJECTION, MODIFIED FROM  
FEARNSIDE (1989) FOR COMPARISON PURPOSES

STATE/TERRITORY/UNITS	DEFORESTATION UP TO 1989 (1)		
	Area (SQ.KM)	Absolute (SQ KM)	Relative (%)
Name			
ACRE	153 697.5	8 760.8	5.7
AMAPÁ	142 538.5	285.1	0.2
AMAZONAS	1 567 953.7	4 703.9	0.3
PARÁ	1 246 833.1	11 5 955.5	9.3
RONDONIA	238 378.7	40 762.8	17.1
RORAIMA	225 017.0	3 600.3	1.6
SUB-TOTAL NORTH REGION	3 574 238.5	174 068.4	4.9
TOCANTINS-GOIAS-LAM	269 910.5	15 924.7	5.9
MARANHÃO - LAM	260 232.7	24 201.6	9.3
MATO GROSSO - LAM	802 402.7	138 013.3	17.2
TOTAL LAM	4 906 784.4	352 208.0	7.2

1 - Mathematically obtained through linear projections from different data sources from different years. Some predictions were yielded through ten years forecast. (say from 1978 to 1988).

2 - For the Pará state only, very old deforestation values (Bragantina region) were excluded for comparison purposes. See note below.

3 - Fearnside's (1989) projections do not take into account very old deforestation in the Maranhão State.

counting. The measurements were grouped on state by state, territory by territory basis. The sum of these measurements constitute, in this paper the deforestation estimates for the Legal Amazônia (see Table 6).

#### FOREST DEPLETION RATES

From the data and the discussion of the results previously presented, we will start to discuss deforestation rates or forest depletion rates.

#### Rabbit growth and radioactive decay

Classical ecology books present (e.g. Ricklefs, 1979) the equation of population growth as

$$N(t) = N_0 e^{rt}$$

which allows for population estimates (free exponential growth). The equation permits to know the value of a population  $N(t)$  in a given time  $t$ , knowing the values of the original population ( $N_0$ ) and the rate of growth. The same equation may be applied to radioactive decay, and geologists may calculate the age of a rock. However, geologists know that even negative ages may result if the system is not closed. By analogy, certainly the Legal Amazônia is not a closed system. Government changes, development policy changes, road opening, road abandonment, etc. affects "the forest system". Therefore one should bear in mind all these factors when one makes a projection of deforestation for, say, 8 to 10 year period based on equations such as the above mentioned. The exponential projections of Fearnside (1982) and Mahar (1988) see Tables 3 and 4, have assumed the growth of deforestation or forest depletion in the Amazonas as rabbit growth or radioactive decay (B and D on the forest depletion curves). Later, Fearnside (1989) recognized that deforestation rates for the Legal Amazônia have, rather, a linear growth.

TABLE 6A - DEFORESTATION: INPE MEASUREMENTS. FROM INPE EXPLANATORY  
NOTE: "EVALUATION OF THE AMAZON FOREST" (INPE, 1989)

STATE/TERRITORY UNITS	DEFORESTATION UP TO 1988(1)		
	Area (SQ.KM )	Absolute (SQ KM)	Relative (%)
Name			
ACRE	153 697.5	5 509.64	3.6
AMAPÁ	142 358.5	842.25	0.6
AMAZONAS	1 567 953.7	12 836.58	0.8
PARÁ	1 246 833.1	88 741.45(2)	7.1
RONDÔNIA	238 378.7	30 046.40	12.6
RORAIMA	225 017.0	2 187.40	1
SUB-TOTAL NORTH REGION	3 574 238.5	140 163.72	3.9
TOCANTINS-GOIAS-LAM	269 910.5	20 279.12	7.5
MARANHÃO - LAM	260 232.7	23 771.07(2)	9.1
MATO GROSSO - LAM	802 402.7	67 215.64	8.4
TOTAL LAM	4 906 784.4	251 429.55	5.1

1 - Measurements obtained from LANDSAT - THEMATIC MAPPER Satellite data at scale of 1:250 000 with a nominal ground resolution of 0.0009 sq.km. Area evaluation obtained by grid-cell point counting with resolution of 0.0625 sq.km.

2 - For the Pará and Maranhão states only; deforestation values do not include historical deforestation values. These values were obtained in 1989 by INPE and are respectively 31 822 sq.km (Bragantina Region, Para State) and 60 724.43 sq km (Maranhão State).

## Deforestation rates

Tables 2B, 6B show the deforestation increments in the Legal Amazonia for the intervals 1975 to 1978 and 1978 to 1988 respectively. Table 7 presents the deforestation rates which have occurred from 1975 to 1988 time interval and also presents the most recent rates available for each state or territory based on scattered information available (mainly from IBDF reports see reference list). An average of those observed rates are also presented.

For each state was plotted the existing deforestation information available and this yielded the construction of "curves" of deforestation. For comparison purposes the measured deforestation curves are sided with the predictions established by exponential and linear projections for each state or territory (Figures 2 through 12). All comparisons obey the same criteria of area size, and deforestation observation period in order to have comparisons in a same basis.

The highest deforestation rates were observed for the state of Rondônia in the 1986-1988 period. (1.492% year). The lowest rate was observed for the Amapá State in the 1975 to 1978 interval. It is important to mention that some states have very few observations (e.g. Amapá, Roraima units).

From the deforestation rate data and the forest depletion curves it is possible to see that deforestation did not progress at exponential pace. The results show rather a linear trend.

## Deforestation estimate exercises

After INPE 1988 deforestation measurements (Table 6, figure 2 through 12) it became clear that for the eighty decade the Legal Amazonia was characterized and portrayed with deforestation predictions instead of deforestation measurements. Lack of cloud free remote sensing data, lack of commitment to make the measurements allowed all that. Lack of deforestation estimates and the need of deforestation indexes led to the predictions of such indexes. As a result some authors decided to make deforestation estimates exercises.

Unvariably in all deforestation estimates exercises, INPE's measurements for 1975 and 1978 (Tables 1, and 2) have been used as a source of the mathematical projections. In addition to this, Mahar (1988) and Fearnside (1989) also used scattered information existent for some states provided by measurements made by the IBDF.

TABLE 6B - DEFORESTATION INCREMENTS: TEN YEARS INTERVAL  
1978 TO 1988

STATE/TERRITORY	DEFORESTATION Sq. Km	INCREASE %	DEFORESTATION RATE (YEARLY) Sq. Km	% OF UNIT
UNITS				
ACRE	3 045.1	123.6	304.5	0.198
AMAPÁ	671.75	394.0	67.2	0.047
AMAZONAS	11 050.8	618.8	1 105.1	0.071
PARÁ	66 296.2	295.4	6 629.6	0.53
RONDÔNIA	25 861.9	618.0	2 586.2	1.085
RORAIMA	2 043.6	1 421.7	204.4	0.091
SUB-TOTAL NORTH REGION	108 969.5	349.3	10 896.9	0.305
TOCANTINS-GOIAS-LAM	9 990.6	97.1	999.06	0.370
MARANHÃO LAM	16 427.1	136.0	1 642.7	0.63
MATO GROSSO LAM	41 394.3	160.3	4 139.4	0.52
TOTAL LAM	176 781.5	236.8	17 678.1	0.36



ACRE STATE  
FOREST DEPLETION  
ABSOLUTE (SQ. KM ) AREA EQUIVALENT (%)

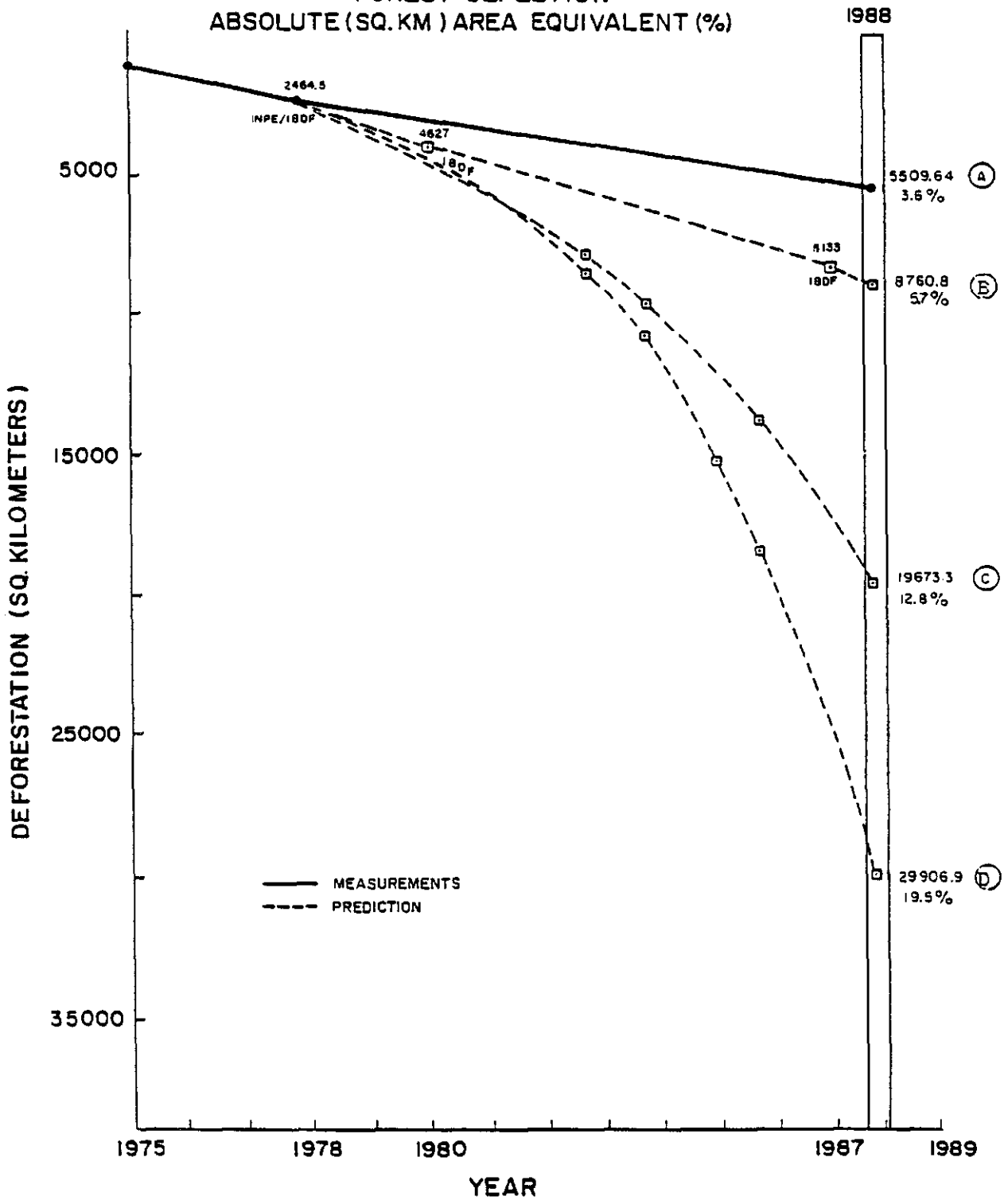


Figure 2 - Acre State forest depletion rates  
1988 data from: A - INPE(1989)  
B - Fearnside (1989) C - World Bank (Mahar, 1988)  
D - Fearnside (1982)

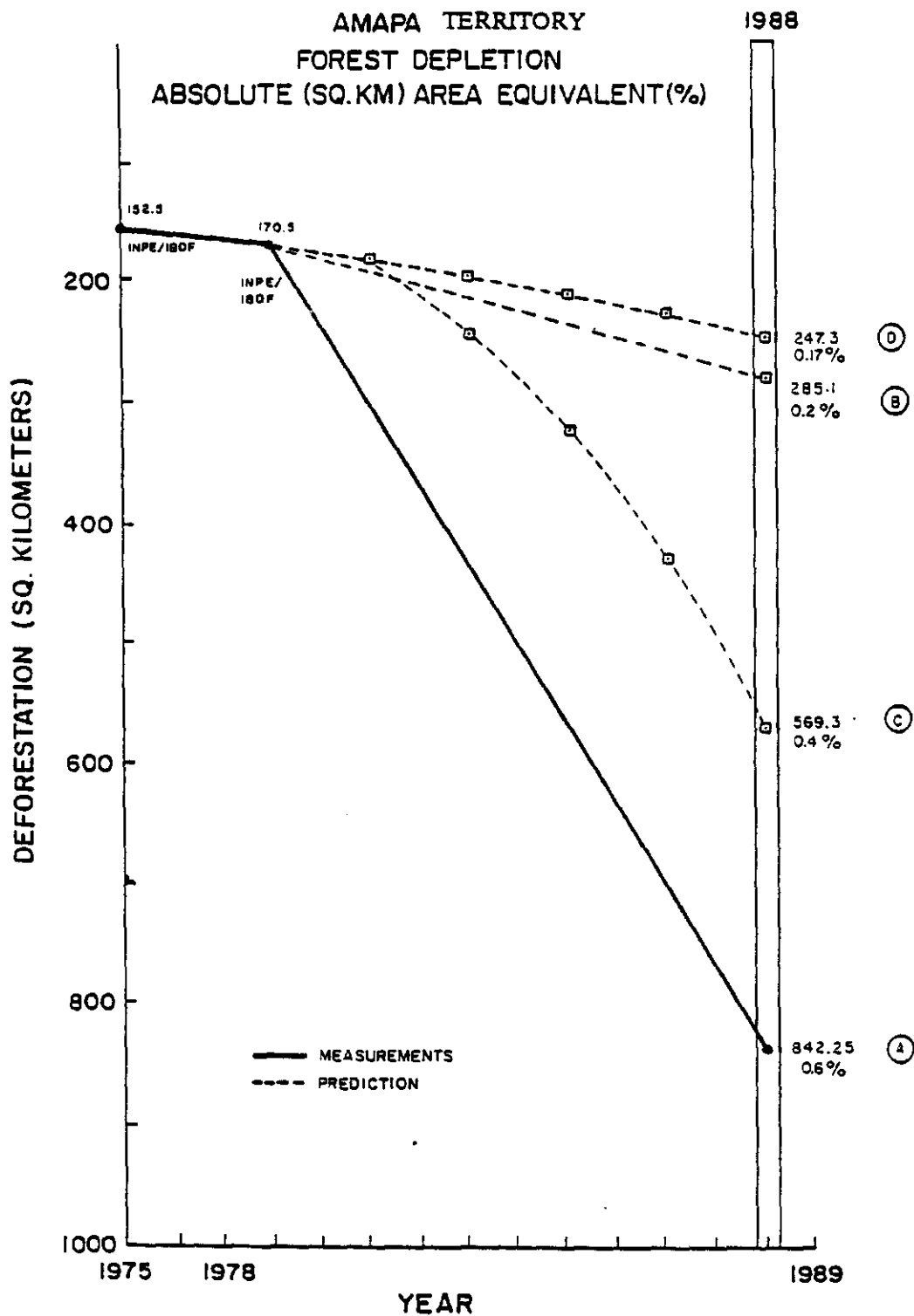


Figure 3 - Amapa State forest depletion rates  
 1988 data from: A - INPE (1989) B - Fearnside (1989)  
 C - World Bank (Mahar, 1988) D - Fearnside (1982)

AMAZONAS STATE  
 FOREST DEPLETION  
 ABSOLUTE (SQ.KM) AREA EQUIVALENT (%)

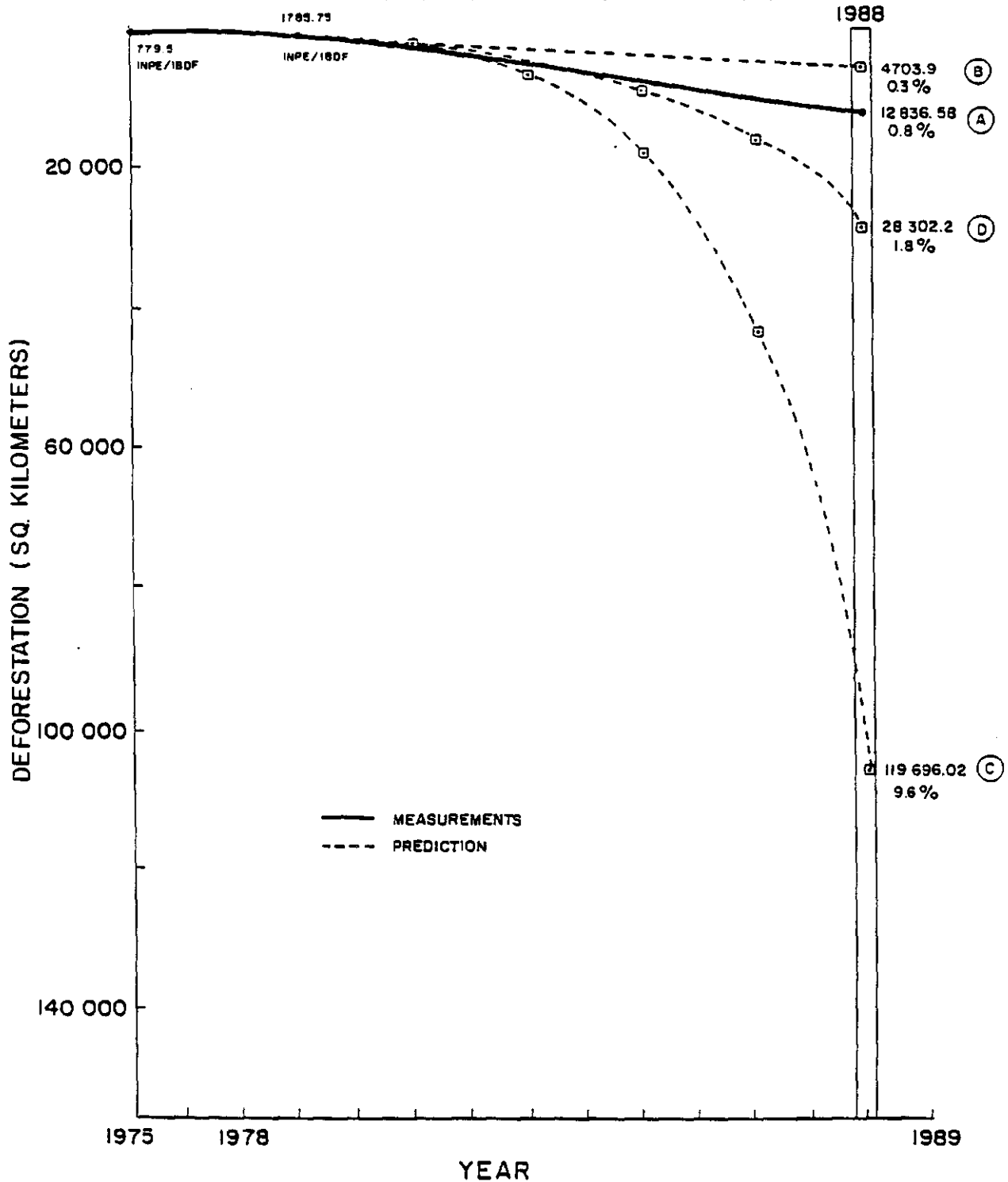


Figure 4 - Amazonas State forest depletion rates  
 1988 data from: A - INPE (1989) B - Fearnside (1989)  
 C - World Bank (Mahar, 1988) D - Fearnside (1982)

PARA STATE\*  
 FOREST DEPLETION  
 ABSOLUTE (SQ.KM) AREA EQUIVALENT (%)

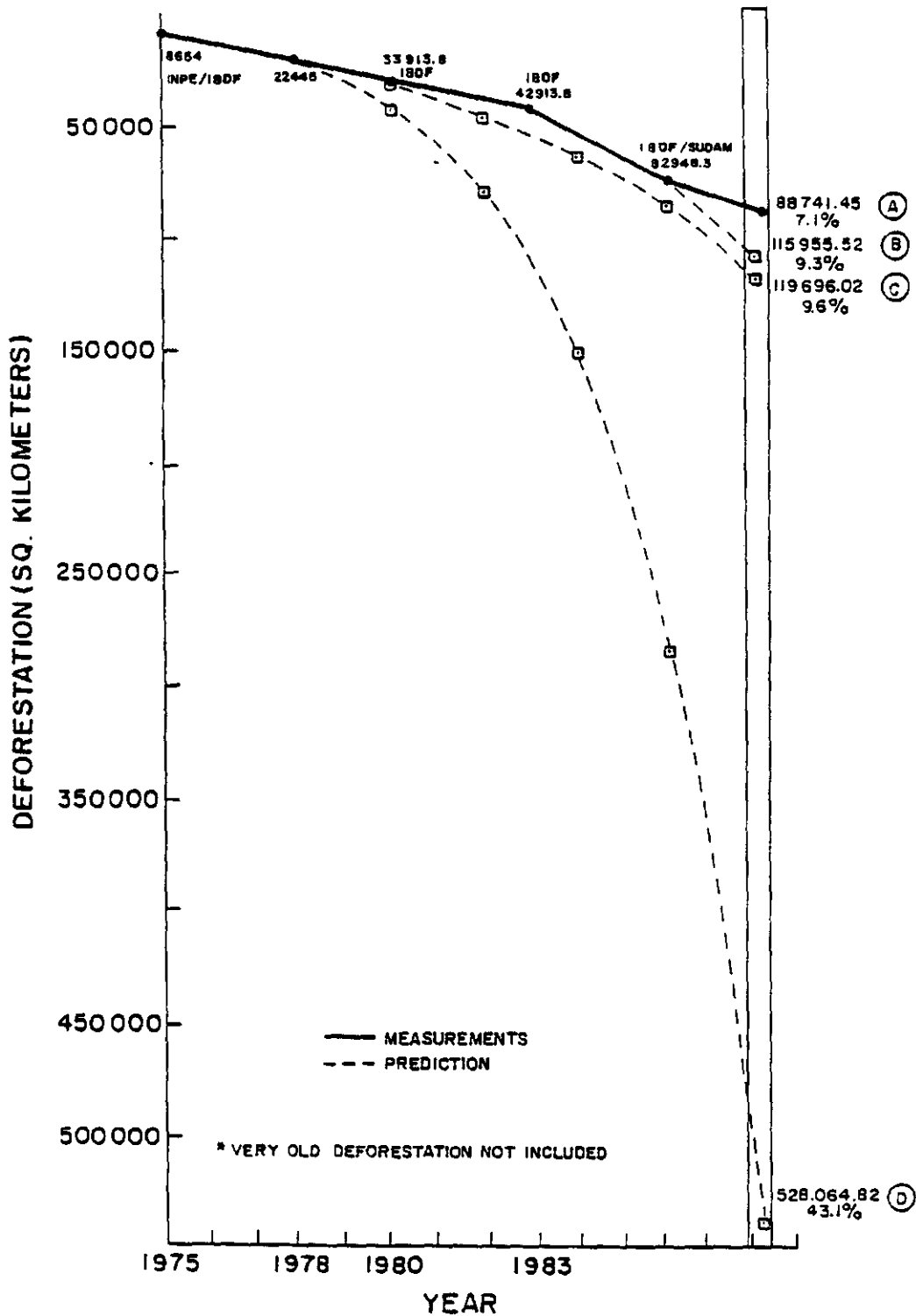


Figure 5 - Para State forest depletion rates  
 1988 data from: A - INPE (1989) B - Fearnside (1989)  
 C - World Bank (Mahar, 1988) D - Fearnside (1982)

RONDONIA STATE  
FOREST DEPLETION  
ABSOLUTE (SQ. KM ) AREA EQUIVALENT (%)

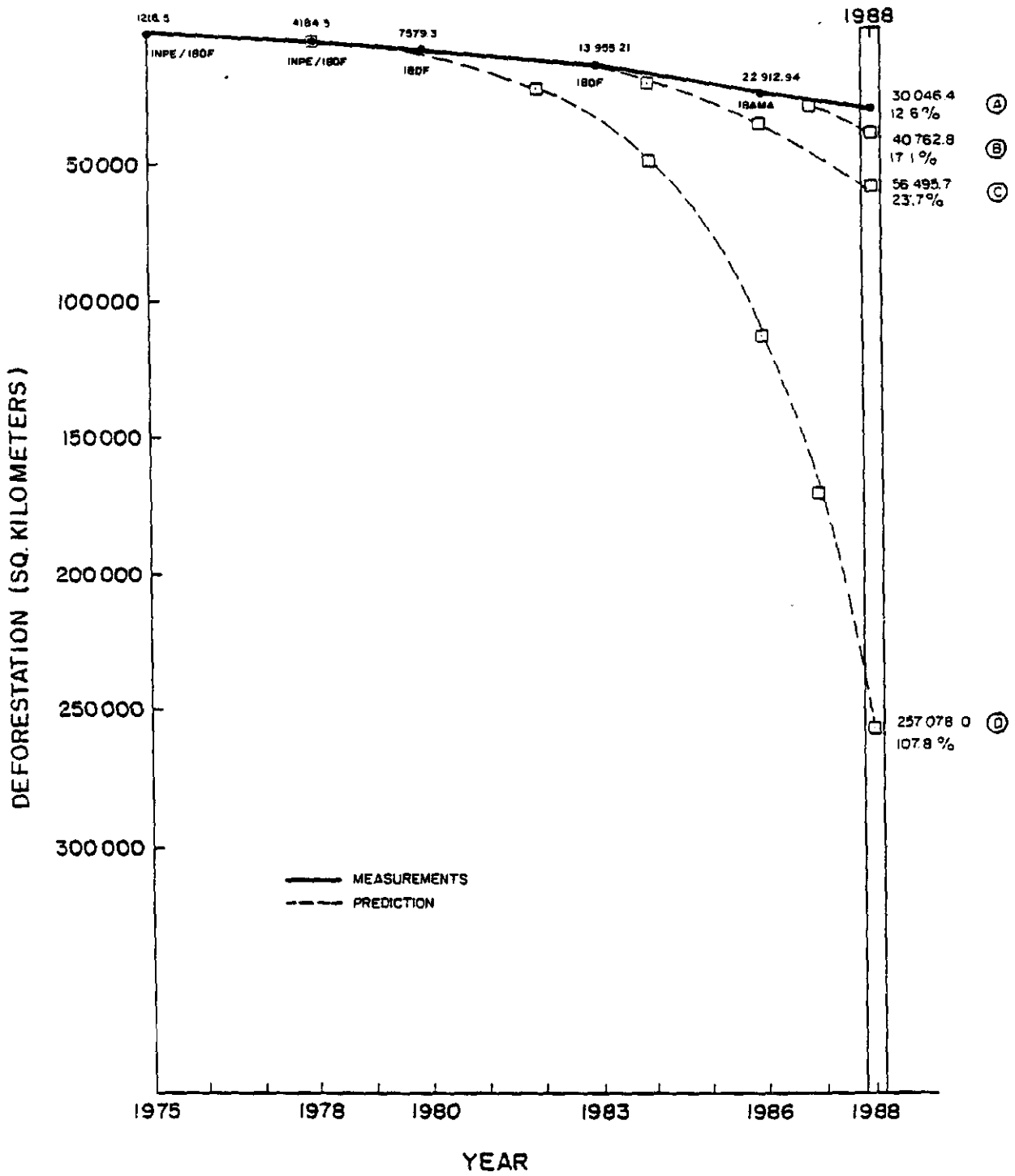


Figure 6 - Rondonia State forest depletion rates  
1988 data from: A - INPE (1989) B - Fearnside (1989)  
C - World Bank (Mahar, 1988) D - Fearnside (1982)

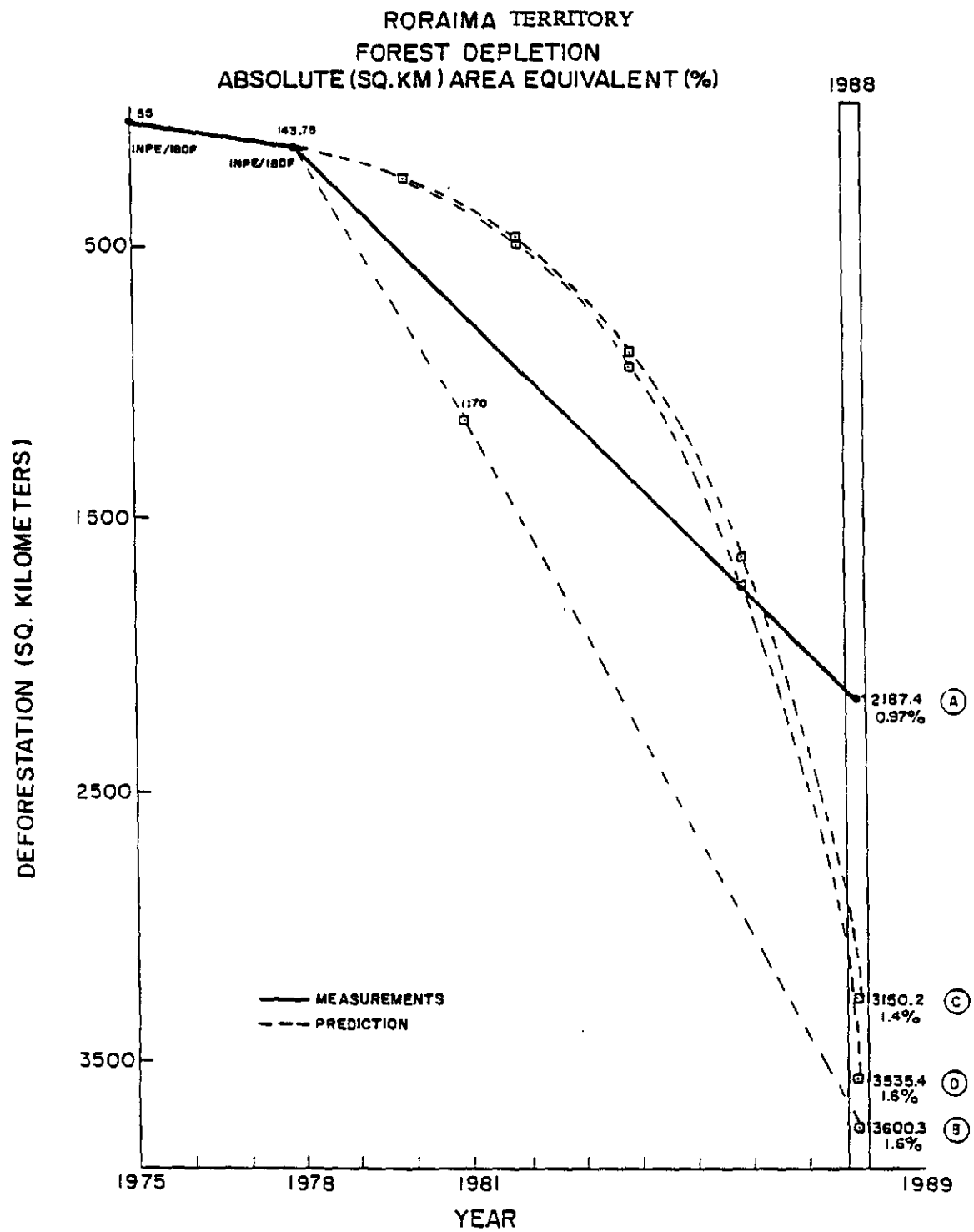


Figure 7 - Roraima State forest depletion rates  
 1988 data from: A - INPE (1989) B - Fearnside (1982)  
 C - World Bank (Mahar, 1988) D - Fearnside (1982)

NORTH REGION  
 FOREST DEPLETION  
 ABSOLUTE (SQ.KM) AREA EQUIVALENT (%)

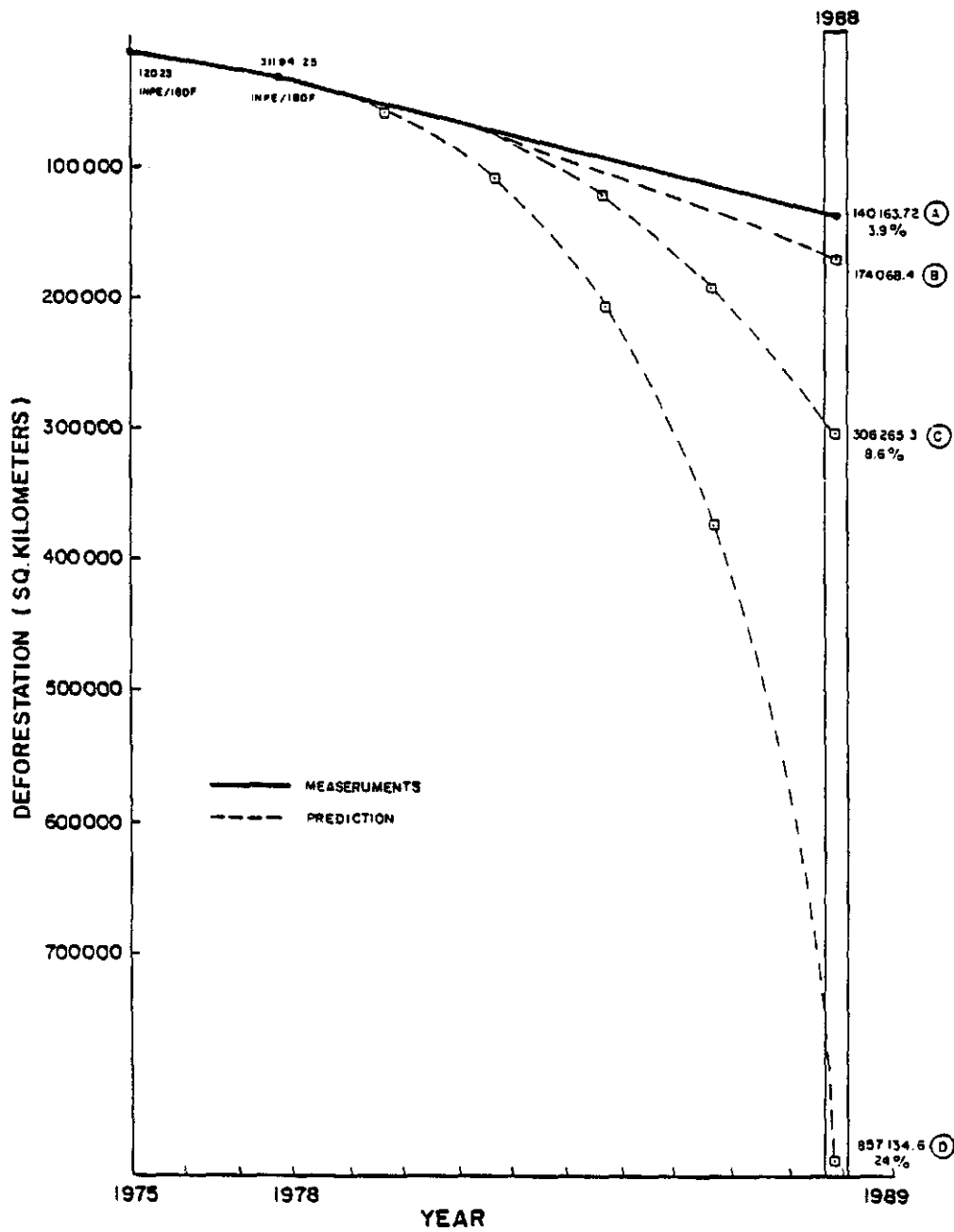


Figure 8 - North Region forest depletion rates  
 1988 data from: A - INPE (1989) B - Fearnside (1989)  
 C - World Bank (Mahar, 1988) D - Fearnside (1982)

TOCANTINS -GOIAS LAM STATE  
 FOREST DEPLETION  
 ABSOLUTE(SQ.KM)AREA EQUIVALENT(%)

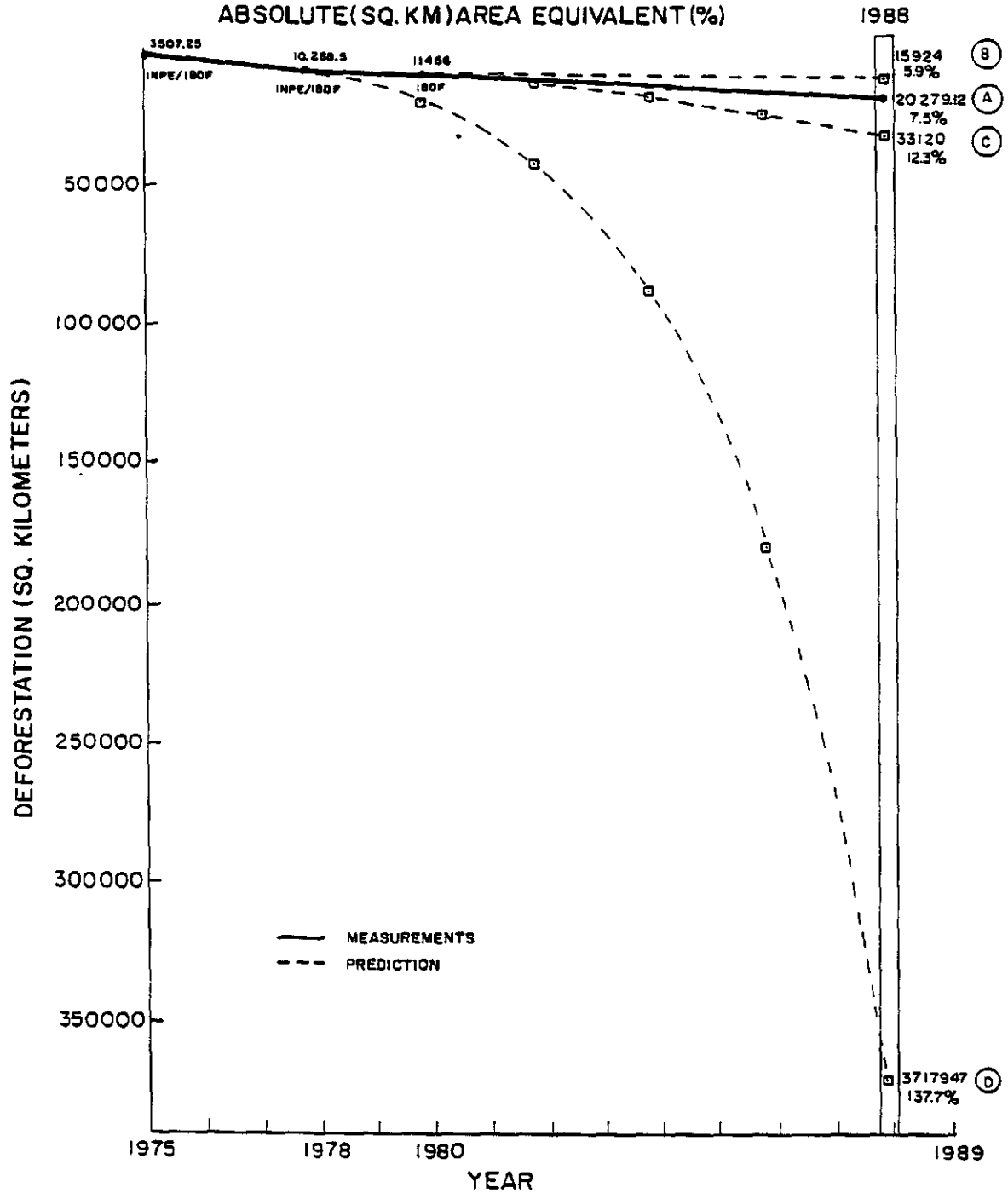


Figure 9 - Tocantins-Goiás LAM State forest depletion rates  
 1988 data from: A - INPE (1989) B - Fearnside (1989)  
 C - World Bank (Mahar, 1988) D - Fearnside (1982)



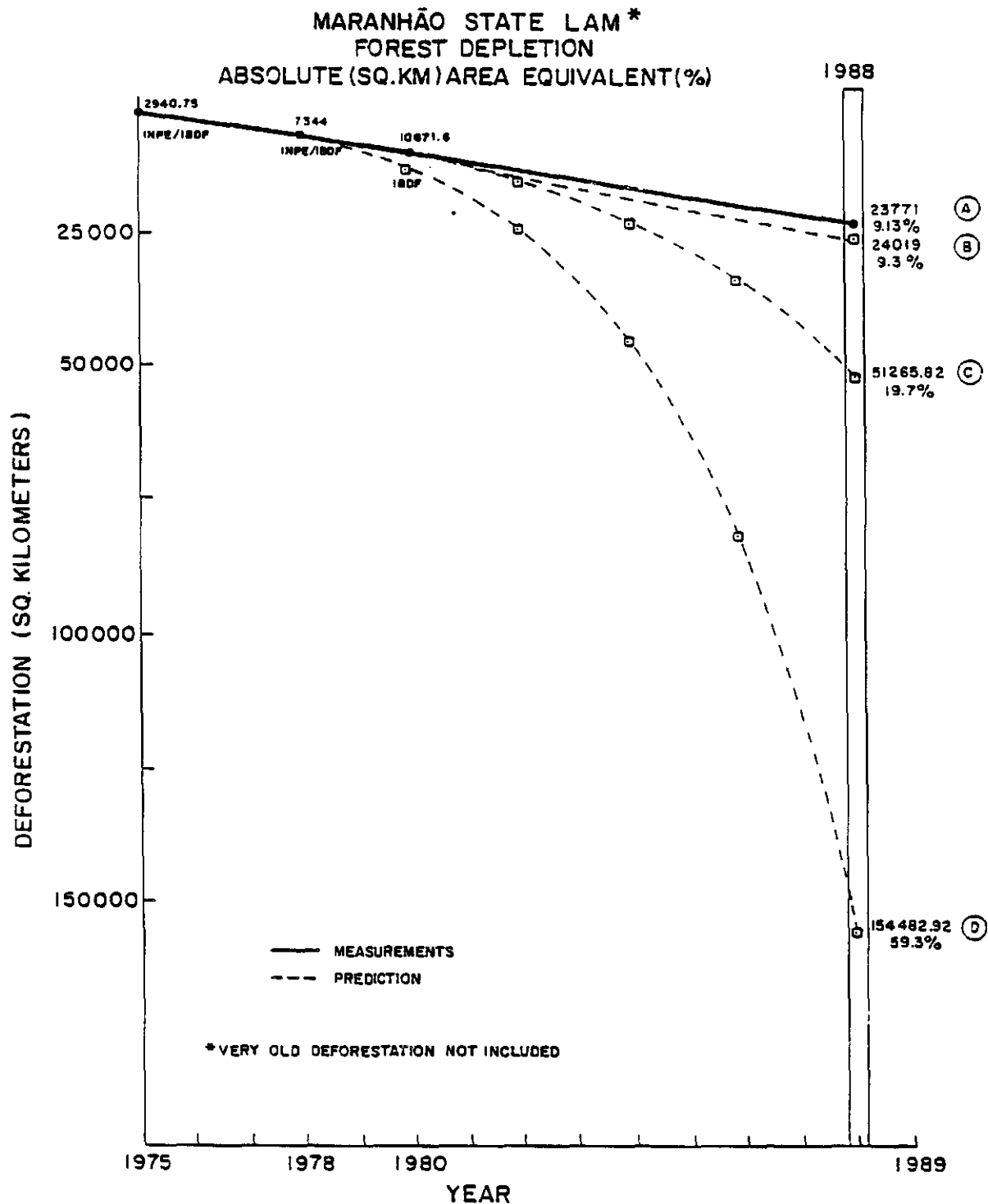


Figure 10 - Maranhão State LAM forest depletion rates  
 1988 data from: A - INPE (1989) B - Fearnside (1989)  
 C - World Bank (Mahar, 1988) D - Fearnside (1982)

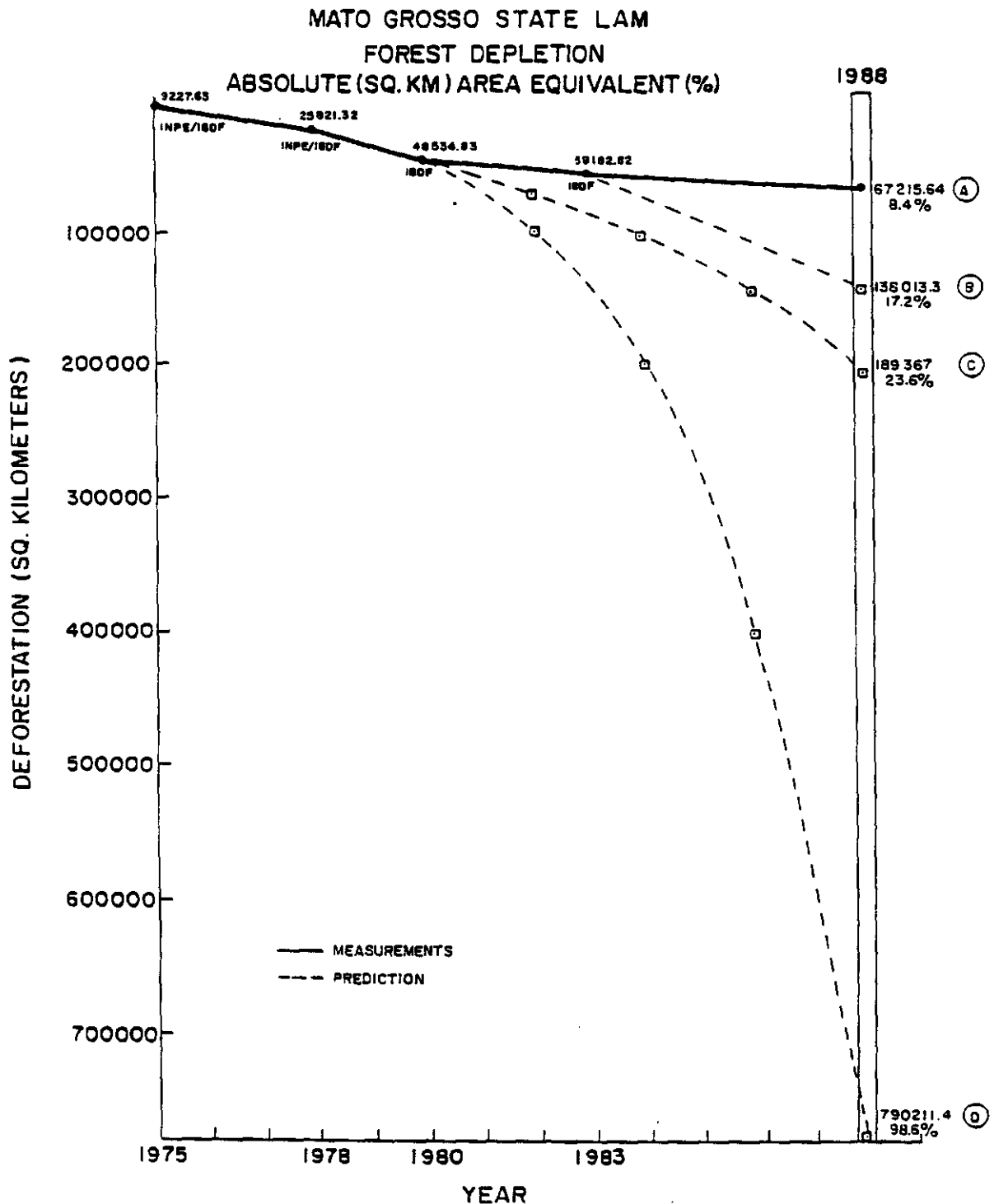


Figure 11 - Mato Grosso State LAM forest depletion rates  
 1988 data from: A - INPE (1989) B - Fearnside (1989)  
 C - World Bank (Mahar, 1988) D - Fearnside (1982)

LEGAL AMAZONIA  
 FOREST DEPLETION  
 ABSOLUTE (SQ.KM) AREA EQUIVALENT (%)

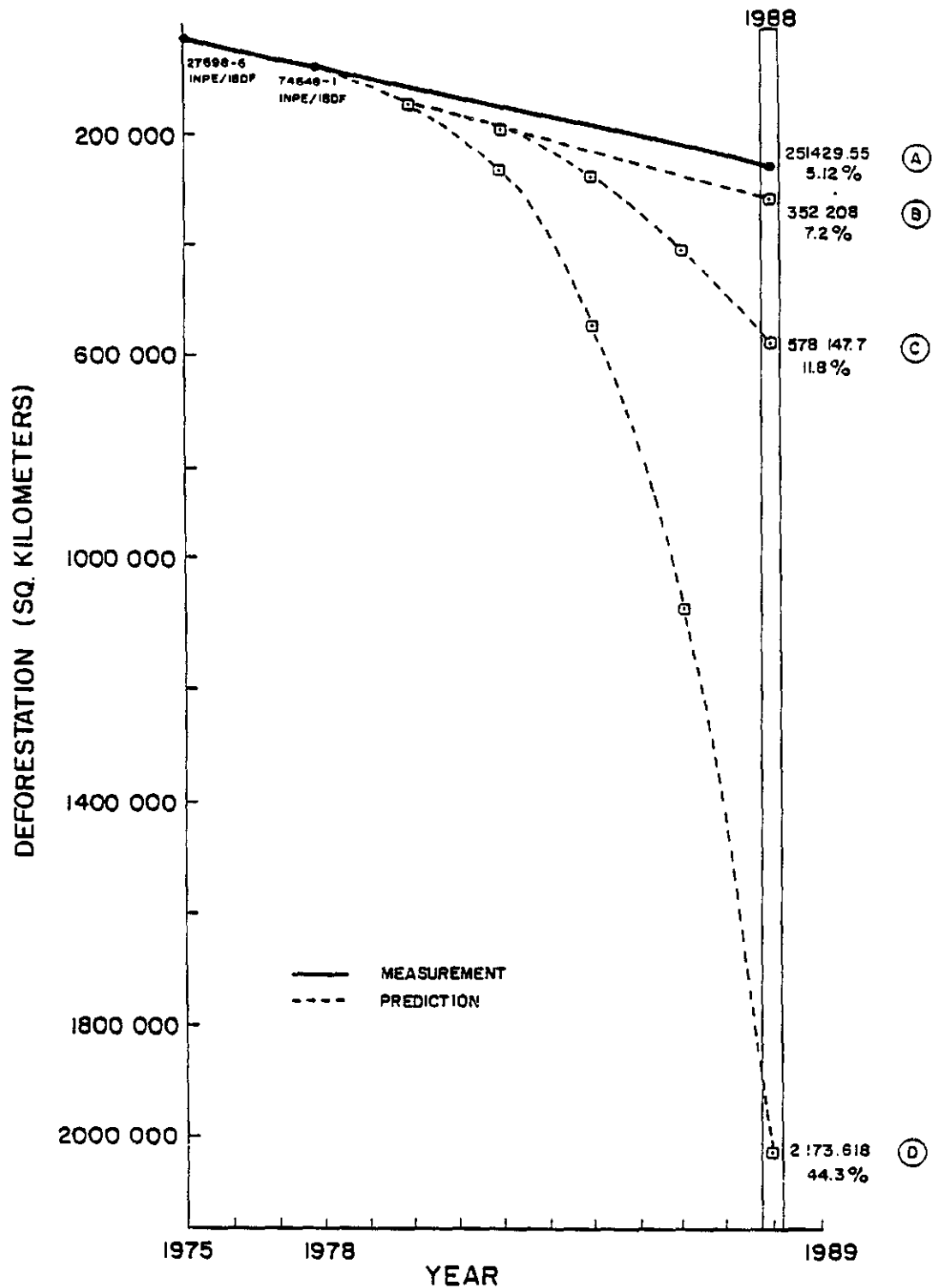


Figure 12 - Legal Amazonia forest depletion rates  
 1988 data from: A - INPE (1989) B - Fearnside (1989)  
 C - World Bank (Mahar, 1988) D - Fearnside (1982)

The projections have failed due to the following aspects:

- 1 - Have assumed exponential deforestation rates instead of linear rates and do not have analysed all possible, state by state, rates obtainable (see Table 7).
- 2 - Projections were made for very long time intervals yielding up to ten year forecasts. Mahar (1988) projection for the Pará State for example, is very close to the 1988 INPE measurements. Possibly in this case Mahar (1988) made a projection based on the available 1986 IBDF measurements and not from the available 1980 IBDF measurements as mentioned on his paper (Mahar, 1988 page 6, Table 1). Fearnside (1989) deforestation projection of 7.2% for the Legal Amazônia is close to INPE's 1988 measurements not only because the author has used linear projection but also because the projections have been based on more recent data available.
- 3 - Finally, deforestation projections were based on states or territory physical areas without discrimination of forested and non-forested terrains (see fig. 1). As a result, those portions of states and territories without forest cover were also "deforested" by the projections.

An exercise of deforestation projection for 1989

With the available 1988 INPE deforestations measurements (Table 6) and knowing the deforestation rates for each state and territories in the last thirteen years (Table 7) a projection exercise was done. Table 8 presents a linear projection of the INPE's 1988 measurements for the year 1989. This projection was done using the highest deforestation rates observed in the last thirteen years, and only serves for illustrative purposes (hopefully, INPE shall make new deforestation measurements by the end of the year). The mathematical projection has yielded a value of deforestation of 272 858.16 Sq.kilometers which, in turn, is equivalent to 5.6% of the area of the Legal Amazônia.

TABLE 7 - YEARLY DEFORESTATION RATES. VALUES OBTAINED FOR  
DIFFERENT TIME INTERVALS AND BETWEEN THE TWO  
MORE RECENT DATA AVAILABLE

STATE/TERRITORY	1975-1978	1978-1988	LTDA	AVERAGE
UNIT:	YEARLY RATE (%)	YEARLY RATE (%)	YEARLY RATE (%)	YEARLY RATE (%)
ACRE	0.282	0.198	0.2851	0.255
AMAPÁ	0.004	0.047	0.047	0.033
AMAZONAS	0.021	0.071	0.071	0.046
PARÁ	0.37	0.53	0.232	0.377
RONDÔNIA	0.415	1.085	1.492	0.984
RORAIMA	0.013	0.091	0.091	0.051
SUB-TOTAL NORTH REGION	0.18	0.305	0.305	0.2425
TOCANTINS-GOIÁS-LAM	0.84	0.37	0.409	0.54
MARANHÃO - LAM	0.56	0.52	0.629	0.57
MATO GROSSO - LAM	0.69	0.52	0.200	0.47
TOTAL LAM	0.32	0.36	0.36	0.34

LTDA - Last two more recent data available.

TABLE 8 - PROJECTIONS FROM 1988 TO 1989 USING HIGHEST AND  
AVERAGE RATIOS OBSERVED IN THE LAST THIRTEEN YEARS

STATE/TERRITORY	MEASURED	WITH HIGHEST RATIO*	WITH AVERAGE RATIO*
UNIT	DEFORESTATION UP TO 1988		
ACRE	5 509.64	"5 947.83"	"5 901.57"
AMAPÁ	842.25	"909.16"	"899.23"
AMAZONAS	12 836.58	"13 949.82"	"13 557.83"
PARÁ	88 741.45	"95 349.66"	"93 442.01"
RONDÓNIA	30 046.4	"33 603.01"	"32 392.05"
RORAIMA	2 187.4	"2 392.16"	"2 304.41"
SUB-TOTAL NORTH REGION	140 163.7	"152 151.64"	"148 487.1"
TOCANTINS-GOIÁS-LAM	20 279.12	"22 546.37"	"21 736.64"
MARANHÃO - LAM	23 771.07	"25 407.93"	"25 254.4"
MATO GROSSO - LAM	67 215.64	"72 752.22"	"70 986.93"
TOTAL LAM	251 429.55	"272 858.16"	"266 465.07"

\*See Table 7.

## CONCLUSIONS AND DISCUSSIONS

Deforestation data for the whole Legal Amazônia in the last nine years is limited to the INPE's 1980 report (Tardin et al, 1980) and to the INPE's 1989 report (INPE, 1989, Explanatory Note). The Brazilian Institute of Forest Development (IBDF, actually IBAMA) offers scatter data for some years in some states; these information is not enough to assemble a complete set of data to make the evaluation of the whole Legal Amazônia. Therefore, there are only two reports with complete evaluation of deforestation in the history of the Legal Amazônia: INPE 1980 and INPE 1989 reports, both done through remote sensing techniques. Other published deforestation estimates, for example Fearnside (1982), Mahar (1988) and Fearnside (1989) are results of mathematical projections (deforestation predictions) and do not represent true deforestation measurements.

The most internationally known deforestation index for 1988 of 12% for the Legal Amazônia, attributed to the World Bank (Mahar, 1988) corresponds to a mathematical projection from deforestation measurements done by INPE and IBDF in the years 1975, 1978 and 1980.

The study has shown that for the 1975 to 1988 time interval forest depletion rates were not exponential but rather linear deforestation rates. The maximum rate being observed in the state of Rondônia in the 1986 to 1988 time interval (1.492% year). Forest depletion rates seems to vary from year to year and vary from region to region. Although Rondônia has high rates it is not representative of the Legal Amazônia which shows smaller rates. Areally this state only represents 5% of the whole Legal Amazônia.

Deforestation estimate projections were largely in error because exponential rates were assumed. Besides, projections did not discriminate forested from non-forested terrains and as a result deforestation estimates for non-forest areas were included in the total deforestation estimates.

The most recent deforestation measurements (INPE, 1989) indicate a deforested area of 251 429.55 Sq. Kilometers which, in turn, is equivalent to 5.12% of the area of the Legal Amazônia. INPE studies also have permitted to evaluate historical deforestation in the states of Pará (31 822 Sq.Km) and Maranhão (60 724.43 Sq.Km). Those values have not been included in previous studies and for comparison purposes are also not included now. Therefore, compared with the World Bank deforestation projections of 11.8% (Mahar, 1988), 44.3% of Fearnside (1982) and INPA of 7.2% (Fearnside, 1989) measured deforestation by INPE (1989) point to an index of 5.12% of the area of the Legal Amazônia.

Finally, as an exercise of speculation, if we apply a linear deforestation projection, using the highest deforestation rates observed for each state or territory in the last thirteen years, combined with the 1988 INPE measurements, we may expect for 1989 a deforestation estimate of 272 858.16 Sq.Kilometers equivalent to 5.6% of the area of the Legal Amazônia. Naturally, we hope that new remote sensing measurements will come by the end of the year in order to know the real situation of the deforestation for the year of 1989 in the Legal Amazônia.



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