Proceedings of 8 ICSHMO, Foz do Iguaçu, Brazil, April 24-28, 2006, INPE, p. 909-917.

FOREST DEGRADATION AND ALTERATION OF RAINFALL REGIME IN THE BRAZILIAN AMAZON

Megumi Maruyama* and Yasushi Yamaguchi

Nagoya University, Nagoya, Japan

Abstract

Deforestation rate in the Brazilian Amazon has reached 15% in the last century and its influence on the regional climate is a matter of concern. In the Brazilian Amazon, rainforest was heavily cleared specially in the Arch of Deforestation over the last thirty years, due to the colonization projects of the Brazilian Government. The Brazilian Amazon has an average annual rainfall ranging between 2000 mm and 3000 mm, however, the microclimate of that region has turned to be drier, recently.

In the present paper, time variations of observed rainfall of the Brazilian Amazon Basin was analyzed during the period between 1970 to 2001. The ANA (Agencia Nacional de Aguas) data had gaps in some observation years (months and days) however, alteration in rainfall trends could be noted during the last thirty years. As a result, effects of the Amazonian deforestation showed a big reduction of the annual rainfall in many critical areas.

The NDVI imagery of deforestation was compatible with the decreasing trend of rainfall within heavily converted areas. These facts suggest that deforestation may have a significant impact on the short time rainfall regime in that region.

1. INTRODUCTION

Deforestation is a matter of concern all over the world, as a result of conversion by the national projects, in many developing countries. Monoculture is also taking place in the Brazilian Amazon such as tree-plantations, soybeans, sugar-cane, among others. However, cattle pasture is the main cause of deforestation (. After conversion, the water cycles are interrupted by lack of sufficient water vapor. Natural forests are replaced by vegetation of lesser evapotranspiration: pasture is 1/3 of that of the Amazonian evergreen forest. Evapotranspiration plays an important role with regard to formation of rainfall clouds in that region. From the water balance equation, $P = Q – E + \Delta S$ (where P is precipitation, Q is runoff, E is evapotranspiration and ΔS is water storage (= 0)), evapotranspiration can be evaluated from the observed values of P and Q. As a result, deforestation affect the local climate, turning the region drier, specially in the states of the deforestation arch such as Maranhão, Tocantins, Pará, Mato Grosso and Rondônia.

Corresponding author address: Nagoya University, Division of Earth and Environmental Sciences, Graduate School of Environmental Studies;Furo-cho,Chikusa,Nagoya,Aichi, 464-8601, Japan; e-mail: maruyama@system.eps.nagoya-u.ac.jp

Deforestation is causing reduced annual rainfall and longer and more severe dry seasons. A decrease in annual rainfall and longer dry seasons are affecting the structure and composition of the remaining forest. Relationship between the anthropological influence and rainfall during the period of the Amazonian development projects was studied in the present study. In some observation stations, the ENSO (El Niño Southern Oscillation) influence was clearly noted, with decreasing trends on rainfall in the critical years, however in some others not. The critical positive ENSO years were: 72~73, 76~77, 82~83, 86~87, 91~92, 93, 97~98, 02~03 with significant or not significant influence on the rainfall regime in the Amazon region (Malhi et al. 2004), (Aceituno, 1988) and (Richey et al. 1989).

The present study tried to show in figures, the decreasing trend of rainfall in the Brazilian Amazon, analyzing rain gauge data of ANA (Agência Nacional de Águas = National Water Agency), and also showing the NDVI imagery of Landsat MSS, TM and ETM+ taken in 1986 to 2003, within the critical areas of deforestation of that region.

2. STUDY AREA

The Brazilian Amazon is in the Northern Brazil. It is limited to the North with Venezuela, Guyana, Suriname and Guyane, to the West with Colombia, Peru and Bolivia and to the East with the state of Goias and to the South with the state of Mato Grosso do Sul. The area of the Brazilian Amazon is about 5,000,000 km², the variation of heights is within 70 to 600 meters and most part of the region is plain with moderate undulation. It is mountainous in limited areas.

According to the climate classification of Köppen, the climate of Amazon is Am (Equatorial) and Aw (Tropical). The climate is rainy and hot, and the variation of temperature throughout the year does not exceed 6°C. Yearly average temperature is around 26°C with relative humidity between 80% to 100%. In the Western Amazon, rainy season begins in October and lasts until May (Fig.1), however, in the Eastern Amazon it is between October and March (Fig.2).

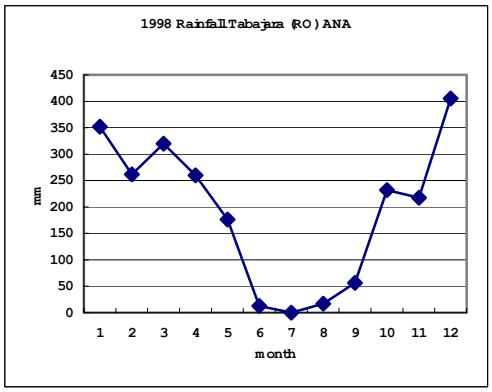

Fig. 1 Western Amazon

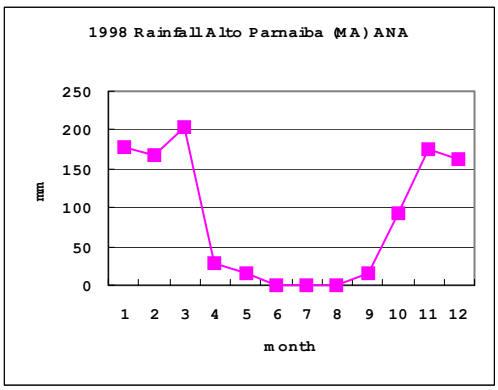

Fig. 2 Eastern Amazon

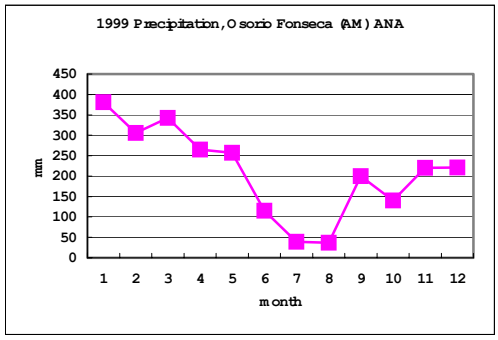

Fig. 3 Amazonas State(Central Amazon)

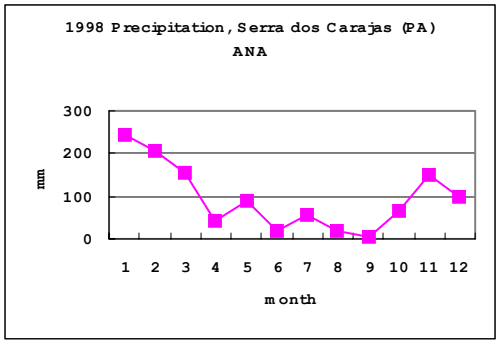

Fig. 4 Pará State (Central Amazon)

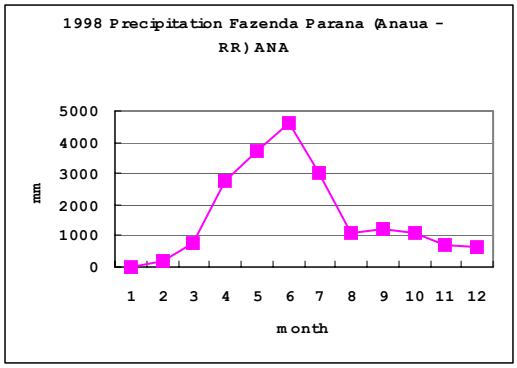

Fig. 5 Roraima State (Northern Amazon)

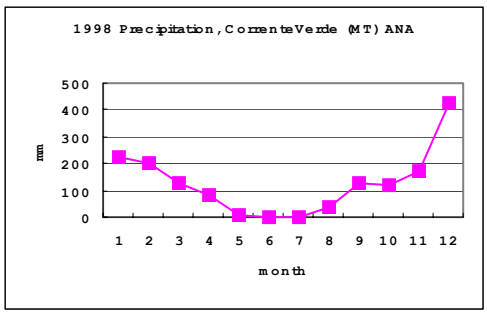

Fig.6 Mato Grosso State (Southern Amazon)

Rainy season is longer in Central Amazon being interrupted in August (Fig. 3 & Fig.4), and it happens in June to August in the extreme west of Amazon (Fig. 2). In the north (Roraima), the peak of rainy season is between April and August (Fig.5), when it is dry season in the south of Amazon (Mato Grosso) (Fig. 6).

Yearly average rainfall varies between 1750 mm/year to 4000 mm/year (Source: ANA). Insolation is about 1908 hours/year (SEDAM, 1996). July to October is burning season in Rondônia (west Amazon) and it concentrates usually at the end of dry season, during August to October. In that season, traffic accidents become frequent on the roads, airport is suspended for several days and many people get sick, because of the hard smoke.

3. MATERIALS AND METHODS

Hydrological data was taken from the ANA (Agência Nacional de Águas = National Water Agency) of Brazil. Among 1218 Rain gauge observation station points of Amazon, 600 points were used for multi-temporal analysis in the period 1970 to 2000, when development projects took place in that region. The criteria for choosing the rain gauge data was as follows: from summation of daily basis original data, monthly and annual data was calculated.

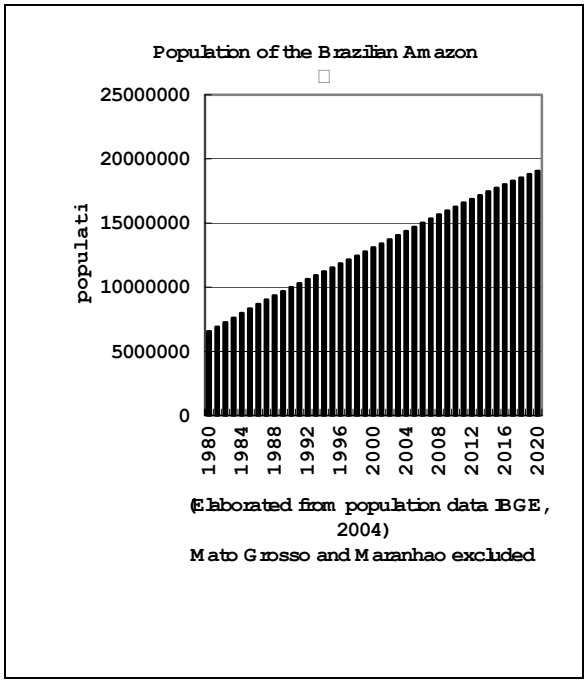

Fig. 7 Population of the Brazilian Amazon (Mato Grosso and Maranhao excluded) (elaborated from the Population data of IBGE, 2004, Projection from 2004)

If there were missing data during the rainy season (hundreds of mm), the corresponding year was skipped in full, however, if it occurred during the dry season (a few tens of mm), they were ignored and the corresponding year was put into calculation.

The NDVI imagery of deforestation was created using the scenes of the Tropical Rain Forest Information Center, Center for Global Change and Earth Observations of Michigan State University (Table 1).

Deforestation is a result of population growth, specially in the region of colonization in the Amazon (Fig. 7), where the main activities are raising crops and cattle.

Table 1. Landsat Scenes used for NDVI imagery

Path/Row	Date	Sensor	Location
227/67	2002-05-30	ETM+	Itaúba, MT
227/67	1986-07/29	MSS	Itaúba, MT
002/67	2001-07-22	ETM+	Xapuri, AC
002/67	1985-09-04	MSS	Xapuri, AC
232/65	1996-06-25	TM	Humaitá, AM
232/65	1984-06-24	MSS	Humaitá, AM
001/67	2002-08-19	ETM+	Abunã, RO
001/67	1986-07-30	MSS	Abunã, RO
232/67	2003-05-20	ETM+	Ariquemes, RO
232/67	1984-06-24	TM	Ariquemes, RO
233/67	2002-05-24	ETM+	Guaj.Mirim, RO
233/67	1986-07-07	MSS	Guaj.Mirim, RO

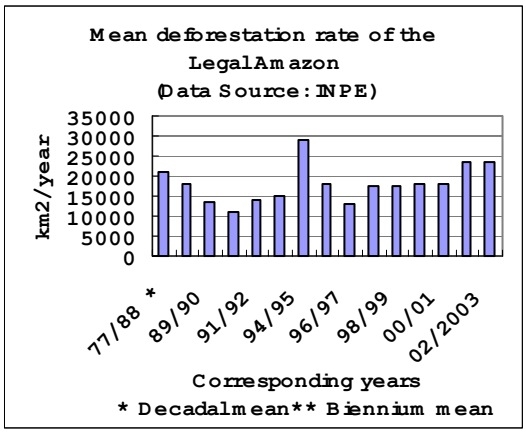

Fig. 8 Mean deforestation rate of the Legal Amazon (nine states)

The graphic of Mean Deforestation rate for the Legal Amazon（Fig. 8）was elaborated from “Mean deforestation rate” INPE, 2004.

4. MULTI-TEMPORAL ANALYSIS OF DEFORESTATION BASED ON LANDSAT DATA FROM 1986 TO 2003

In the present study, deforestation was

detected using the variation of digital numbers of bands corresponding to the NIR (near infra red) of different sensors. As vegetation presents strong reflectance between 0.7 and 1.3μm, band four was used for reference, in order to compare images of different years to detect deforestation. Consequently, NDVI was used for analysis to check the biomass variation throughout the years 1986 to 2003.

Equation used for Landsat TM and ETM+:

NDVI = (band 4 – band 3)/(band 4 + band 3)

Equation used for Landsat MSS:

NDVI = (band 4 – band 2)/(band 4 + band 2)

Tasseled cap conversion was also done to make clear visualization of the images during the visual analysis.

An unsupervised classification was performed using the ISODATA algorithm. This method uses the minimum spectral distance formula to form clusters, beginning with arbitrary cluster means. The means of these clusters are shifted each time the clustering repeats and the new cluster means are used for the next iteration. This sequence are repeated until a maximum number of iterations has been performed. The convergence threshold was specified as 95%, i.e., as soon as 95% or more of the pixels stay in the same cluster between one iteration and the next, the job stops processing.

5.RESULTS

5.1 RAINFALL TREND

Decreasing trend was observed in 90 points out of 600 points located in the deforested areas of Amazonia (Fig. 9 ~ 17).

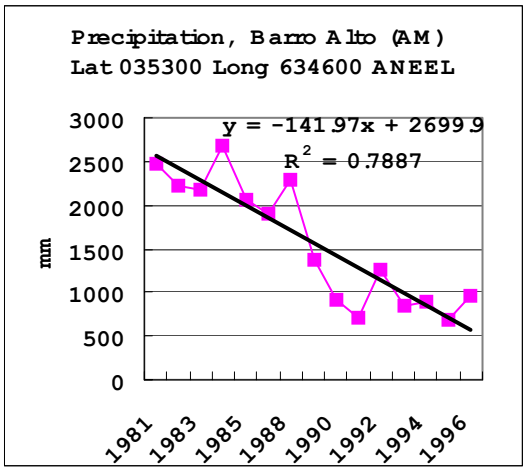

Fig. 9 Precipitation, Barro Alto (AM) 1

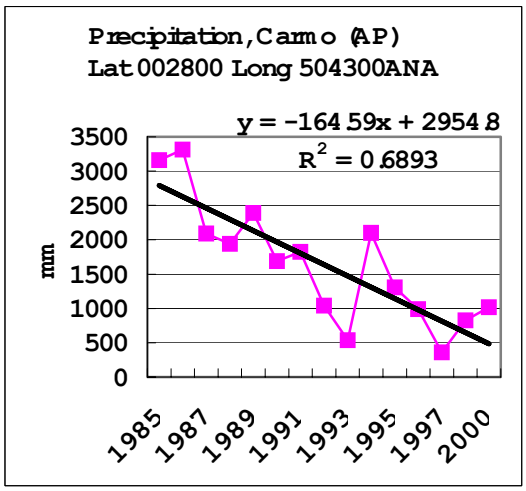

Fig. 10 Precipitation, Carmo (AP) 2

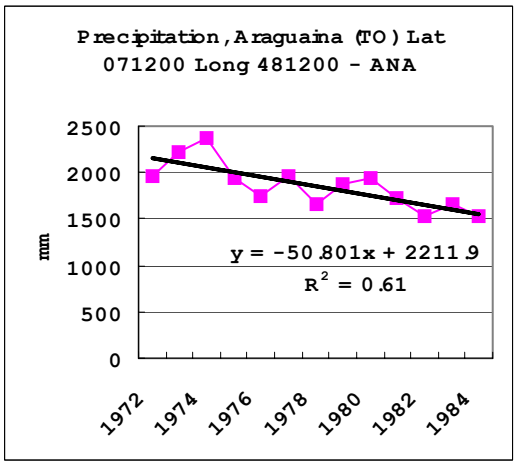

Fig. 11 Precipitation, Araguaina (TO) 3

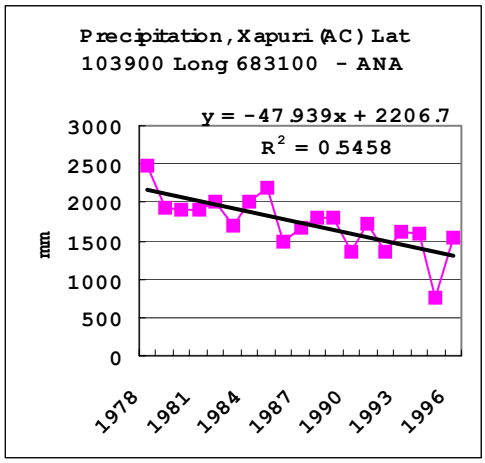

Fig. 12 Precipitation, Xapuri (AC) 4

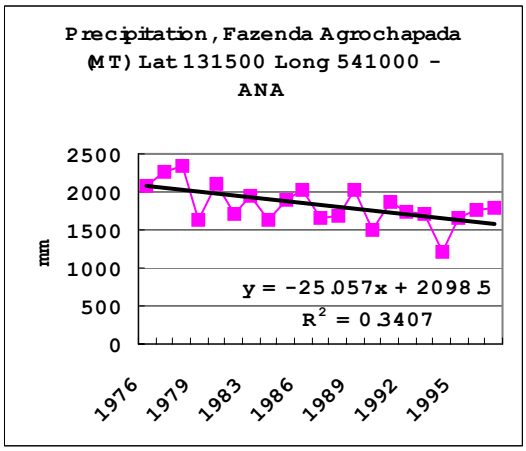

Fig. 15 Precipitation, Fazenda Agrochapada (MT) 7

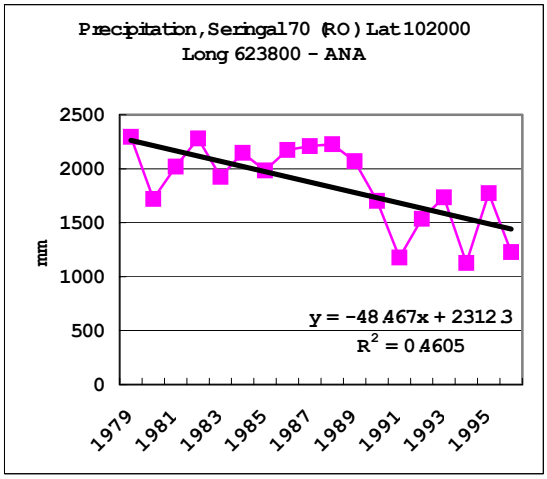

Fig. 13 Precipitation, Seringal 70 (RO) 5

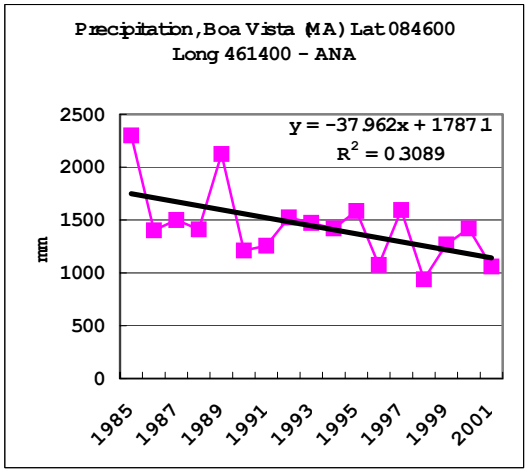

Fig. 16 Precipitation, BoaVista (MA) 8

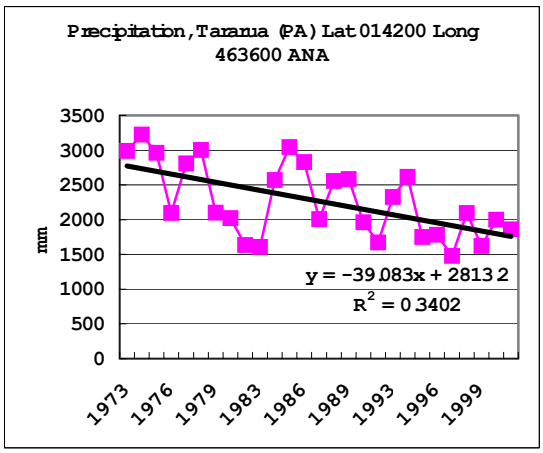

Fig. 14 Precipitation, Tararua (PA) 6

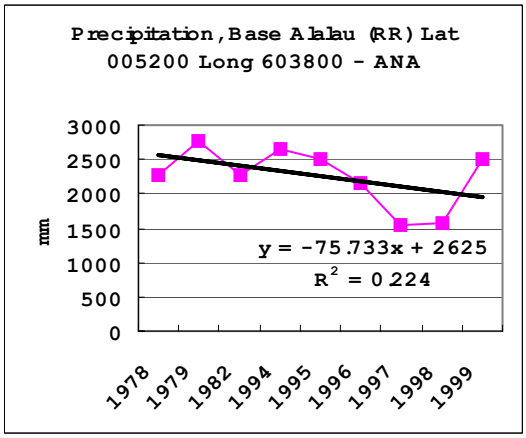

Fig. 17 Precipitation, Base Alalau (RR) 9

Fig. 18 Location of the ANA's rain gauge stations with decreasing trends

Among nine states of the Brazilian Amazon, five states showed higher decreasing trend than increasing trend in rainfall, as for: Amazonas (AM), Maranhão (MA), Acre (AC), Mato Grosso (MT) and Tocantins (TO). In these five states, Amazonas showed the most strong decreasing trend in rainfall.

5.2 SATELLITE IMAGERY DATA ANALYSIS

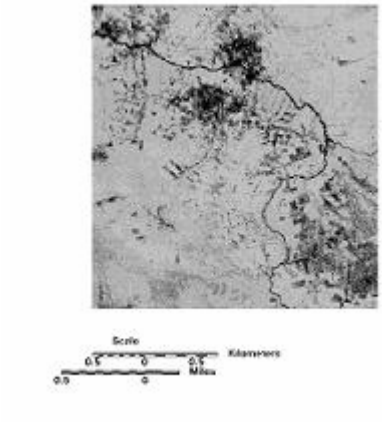

Fig. 19 NDVI image Landsat 227/67 Itaúba（MT） 1986

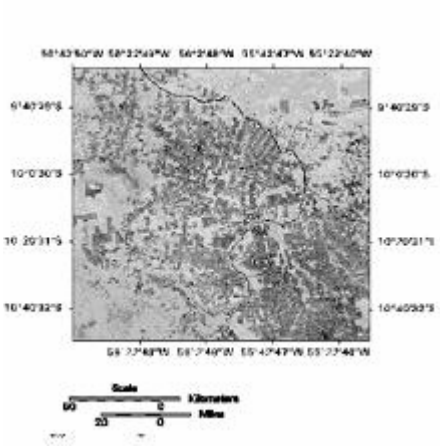

Fig. 20 NDVI image Landsat 227/67 Itaúba（MT）2002

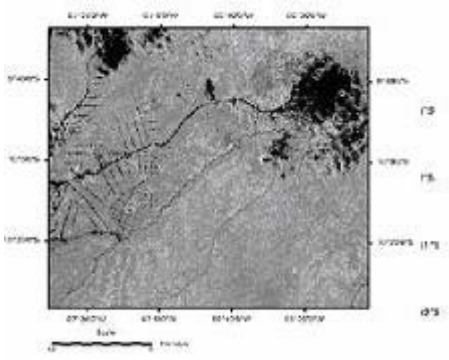

Fig. 21 NDVI image Landsat TM 001/67 Acrelândia (AC/RO) 1986

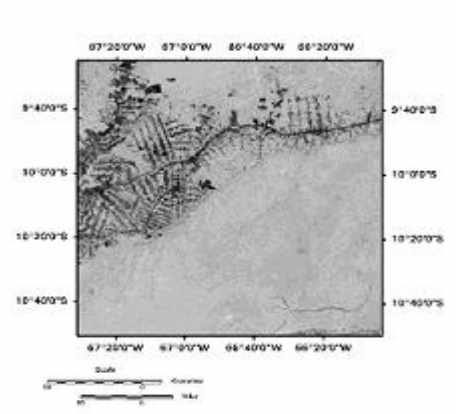

Fig. 22 NDVI image Landsat TM 001/67 Acrelândia (AC/RO) 2002

All the studied images showed an average deforestation > 30% and in the cities along the highways, deforestation was more intense, reaching 70% to 90% in several critical areas. This fact coincides with the colonization projects of that region, reflecting the population growth (Fig. 19~22).

6. CONCLUSIONS

Overall, strong decreasing trend of rainfall was noted in 57 % of the analyzed data during the developing period of 70's to 90's. Rainfall showed a decreasing trend even in the positive ENSO years. These rain gauge stations with decreasing trends were located in the areas indicated in the NDVI imagery, showing anthropologic influences in the forest cover. In terms of deforested areas, the most converted states were: Mato Grosso (MT), Pará (PA), Rondônia (RO) and Amazonas (AM).

In Rondônia State, an increase of 30.000 families was registered each year, since 1970, and drought and flooding turned to be a big disaster in this region. In October 2005, some of the rivers of the Amazon basin dried up, causing problems to the local population. One of the reason might be the Global Warming resulted from the CO_2 emissions from the developed countries and from the developing countries, and also from forest burning.

Due to the complexity of meteorological features in the Amazon Basin environment, further studies are needed, however, the observed rainfall trend in Amazon is likely to receive the deforestation influence in a regional scale.

References

Aceituno, P. , 1988. On the functioning of the Southern Oscillation in the South American Sector. Part I: Surface climate. *Monthly Weather Review*, Vol.116, 505-524.

Chagnon, F.J.F and Bras R.L. 2005. Contemporary climate change in the Amazon. Geophysical Research Letters, Vol. 32, L13703, doi: 10.1029/2005GL022722, 2005

Fernandes, Délio 1996. Inventário das Estações Pluviométricas. Departamento Nacional de Àguas e Energia Elétrica. Brasília, Brasil

Ichii, K., Maruyama, M., and Yamaguchi, Y., 2003. Multi-temporal analysis of deforestation in Rondonia state in Brazil using Landsat MSS, TM, ETM+ and NOAA AVHRR imagery and its relationship to changes in the local hydrological environment. Int. J. Remote Sensing, Vol.24, No.22, 4467-4479.

INPE, 2004. Mean rate gross deforestation (km^2/year) from 1978 to 2003. http://www.obt.inpe.br/prodes/prodes_1988_2003.htm

Malhi, Y. & Wright, J., 2004. Spatial patterns and recent trends in the climate of tropical rainforest regions. One contribution of 17 to a Theme Issue 'Tropical forests and global atmospheric change'. *Philosophical Transactions: Biological Sciences*, Vol.359, No.1443, 311-329.

Marengo, J.A. , 2004. Interdecadal variability and trends of rainfall across the Amazon

basin, *Theoretical and applied climatology.*

Marengo, J.A., Tomasella, J. and Uvo, C.R. , 1998. Trends in streamflow and rainfall in tropical South America: Amazonia, eastern Brazil, and northwestern Peru. *Journal of Geophysical Research*, Vol. 103, No.D2, pp.1775-1783.

Matsuyama, H., Marengo, J.A., Obregon G.O. and Nobre, C.A. , 2002. Spatial and temporal variabilities of rainfall in tropical South America as derived from climate prediction center merged analysis of precipitation. *Int. J. Climatol*. 22: 175-195.

Nobre, C.A., Sellers, P.J., and Shukla, J., 1991, Amazonian deforestation and regional climate change, *Journal of Climate*, 4, 957-988.

PRODES, Deforestation rate http://www.obt.inpe.br/prodes/index.html

Richey, J.E., Nobre, C. and Deser, C. (1989). Amazon river discharge and climate variability: 1903 to 1985. *Science*, Vol.246, 101-103.

Zeng, N., Dickinson, R.E., and Zeng, X., 1996. Climatic impact of Amazon deforestation – A mechanistic model study. *Journal of Climate*, 9, 853-883.