

## Deforestation patterns in Brazilian Amazonia: The case of highways PA-140 and PA-150, Pará State.

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### Introduction

Many works have contributed for the understanding of the deforestation process in Amazonia through the application of remote sensing and GIS technologies, and their integration with field data. These are important frameworks to quantify and provide useful information about the spatial disturbance generated by human-altered landscapes.

The construction of road networks in forested areas may be cited as one of the most important start points concerning to landscape disturbance in the region, which have been promoted by national policies of occupation and development in Amazonia since 70's, with investments in private enterprises in the region.

These facts have contributed to an increase acceleration of colonization along the extension of the roads, resulting in forest fragmentation and landscape change, with social and environmental implications (Futemma & Brondizio, 2003).

The government of Pará has invested heavily in projects to enlarge the state road networks, integrating municipalities with high economic importance and unchaining a new front of urban expansion in the region. Accompanying this, factors such as distance from population centers, access to good roads, cost of transportation and supplying markets are among the main reasons for these projects in Amazonia (Moran, 1981).

This study shows the consequences of road development on deforestation in the region, emphasizing the deforestation process around sections of recently connected state highways, such as PA 140 and PA 150. This work also demonstrates differences in terms of temporal increment of the urban areas in Bujarú, Concórdia do Pará and Tomé Açú, in the northeast of Pará.

### Objective

Analyze and quantify the temporal and spatial distribution of forest and deforested areas around sections of highways PA 140 (Bujarú-Tomé Açú) and PA 150 (BR 316-PA 151), as well as around some cities connected to them (Bujarú, Concórdia do Pará, and Tomé Açú), using satellite images from 1991 to 2002.

### Why PA 140 / 150?

The 217 km long state highway PA140 links the municipality of São Caetano de Odivelas, in the north of Pará State to Tomé Açú. This region is characterized by agropastoral activities, fisheries activities and many igarapés along the road.

The section Bujarú - Tomé Açú, 122 km length, has been paved and inaugurated in August, 2003 with promises to facilitate the transportation and the flux of many agriculture products.

PA150, also known as Mojú – Redenção highway presents a length of 762 km, and was built to flow off the production from the south, southeast and northeast of the state to the regional market through the Vila do Conde port, being an important route for agriculture

products, cattle and wood, besides of integrating municipalities and developing the tourism in the east of Pará.

The section between the federal BR316 and the state highway PA151 has been opened recently, presenting around 65 km of road and bridges on the rivers Guamá, Acará and Mojú, and is an important alternative to the heavy traffic in the metropolitan region of Belém.

Given the importance of these roads to the region economy and development, they also have been the site of violent conflicts as in the case of massacre of several landless people at the municipality of Eldorado dos Carajás (PA150) in 1996, as well as in other land conflicts.

#### Regional Background

The município of Bujarú, located on the northeast of Pará was colonized by northeastern families in 1943, which worked primarily with agriculture. Thirty five years later (1988), Bujarú was dismembered to originate the municipality of Concórdia do Pará.

Today Bujarú has more than 20 thousand inhabitants that work in such diverse activities as commerce, agriculture, ranching and extrativism. Investments in agro industry have also been done in Bujarú, that has now an industry of manioc flour, with the implantation of mechanized crops of manioc. Ecological tourism also has an economic importance on the region.

The history of Concórdia do Pará began in 60's, when the process of occupation became more intense. This town is located at the intersection of PA152 and PA140, and just in 1988 Concórdia do Pará was politically emancipated from Bujarú, being recognized as a municipality.

Tomé Açú has been occupied predominantly by Japanese immigrants since 1929, which were successful through the employment of high technology to cultivate black pepper (*Piper nigrum* L.) during 50's decade. During the 70's occurred the introduction of cocoa and rubber tree among other crops (papaya, passion fruit, etc) in the region. Recently, activities as ranching, short cycle crops and cotton have been benefited from the high introduction of fertilizers in abandoned areas after the cultivation of black pepper. Logging has also been an important activity in Tomé Açú since late 1980's.

#### Methodological Approach

The units of analysis in this study are primarily sections of highways PA140 (Bujarú-Tomé Açú) and PA150 (BR316-PA151). The deforestation around the cities of Tomé Açú, Concórdia do Pará and Bujarú were also included in these analyses to check the relation between occupation around roads and urban expansion (Figure 1). A temporal approach was used for comparison in terms of deforestation around these roads and cities. Landsat TM and ETM+ images from June, 1991 and July, 2002 respectively, were classified through unsupervised method and visual interpretation, following land cover categories: water, forest, secondary succession and cleared land.

These four classes were based on the main processes occurring in the study area and affecting landscape transformation (forest fragmentation through deforestation, vegetation recovery through succession, and land occupation through pasture, and agriculture conversion).

These imagery were radiometrically calibrated to surface reflectance using spreadsheets for Landsat 7 created by Glen Green *et al.* (2001).

Subsets of the imagery were generated, delimitating the study area. Afterwards, these subsets were geometrically corrected and then rectified into a SAD 69 projection. Also, a mask image was generated to eliminate clouds and cloud shadows from the classification. After the classification process, a transition matrix was created allowing the analysis of landscape change between 1991 and 2002. Buffers of 5, 10 and 20 km were plotted around roads and also around the cities of Tomé Açú, Concórdia, and Bujarú. Histograms were built, plotting the number of pixels in each class by the respective distance from the roads or cities.

For the analysis, areas of forest transition (e.g. forest 1991 to secondary succession or cleared land in 2002) were considered deforested areas. Areas where forest and secondary succession remained the same along of the period 1991-2002 were also considered for further comparisons.

### Results and Discussion

Considering the results from the transition (1991-2002) image, forests are more commonly found in areas far away from the roads. The exception was found within the buffer of 20 km from highway PA150, possible consequence of the presence of urban areas like Belém in this buffering (Figures 2 and 3).

Sites with secondary succession during the interval of study (11 years) appear linked to areas near from both highways, representing areas constantly exposed to management or reforestation (Figure 4).

The change from forest to secondary succession is more intense far from PA140, probably due to the fact that the section Bujarú-Tomé Açú has been constructed before the section from PA150 (BR316-PA151), which presents high level of transformation forest-secondary succession in its neighborhood.

This event can also explain the more expressive occurrence of cleared lands at PA140 than at PA150, being more frequent within the distance of 5 km from highway PA140.

Concerning to the buffers around the municipio of Bujarú, many areas have been converted from forest to secondary succession between 1991 and 2002, and the levels of secondary succession and cleared lands look to increase in areas more peripheral (Figure 5). Recent investments in agroindustrial sector (e.g. mechanization of crops and production of manioc flour) may be collaborating for the extension of the urban area of this county.

Concórdia do Pará presents a high percentage of secondary succession within the radius of 20 km, followed by areas primarily forested that were replaced by secondary succession. Increasing the distance from the city (20 km) it is interesting to note that the percentage of replacement lands (forest to secondary succession) have a higher peak in relation to areas already considered as secondary succession in 1991. This fact is probably associated to a more recent colonization and urban expansion of this town.

In Tomé Açú city there is a growing tendency to deforestation followed by secondary succession. This event is possibly related to the expansion of this city that is still in course. Closest to the city there is also a big incidence of cleared land, and the numbers of secondary succession in 1991 presented little change in relation to 2002 within of 5, 10 and 20 km.

The deforestation near roads has been documented since the 1970's, and it is estimated that  $\frac{3}{4}$  of deforestation has occurred within 50 km of roads in the region (Nepstad *et al.*, 2000; Alves, 2002). Besides this, the paving and creation of new roads contribute directly to the migration and colonization processes, stimulated by the implementation of new agriculture and industrial projects, spreading urban areas and accelerating the rate of deforestation in Amazonia.

#### Conclusions and Considerations

In general, forest areas are located more distant from PA140 and PA150, whereas lands with secondary succession present the opposite pattern, being distributed along of highways adjacencies.

In relation to the replacement from forest to secondary succession and cleared land, these roads present a distinct distribution, resulting from the time they were opened and built.

The process of construction of roads also looks to have direct influence over the expansion of urban areas, as verified by the results of the forest change analysis surrounding Bujará, Concórdia do Pará and Tomé Açú.

This is an initial study that needs to be complemented with field data for better classification accuracy as well as for the understanding of landscape change and the spatial variation in relation to other sections of these roads. These kinds of studies are necessary to subsidize planning and development policies with the minimum lost in terms of socio-economy and environment.

In this sense, the implementation of projects related to the construction of road networks need fundamentally to evaluate social and environmental impacts, as well as promote discussions with the community as a whole. The negligence of these aspects can promote the repetition of negative consequences related to this kind of investment in the region: the aggravation of poverty and compromising of natural resources and biodiversity.

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## Data Source

NASA's Earth Observatory Team

ESRI (Environmental Systems Research Institute)

IBGE (Instituto Brasileiro de Geografia e Estatística)

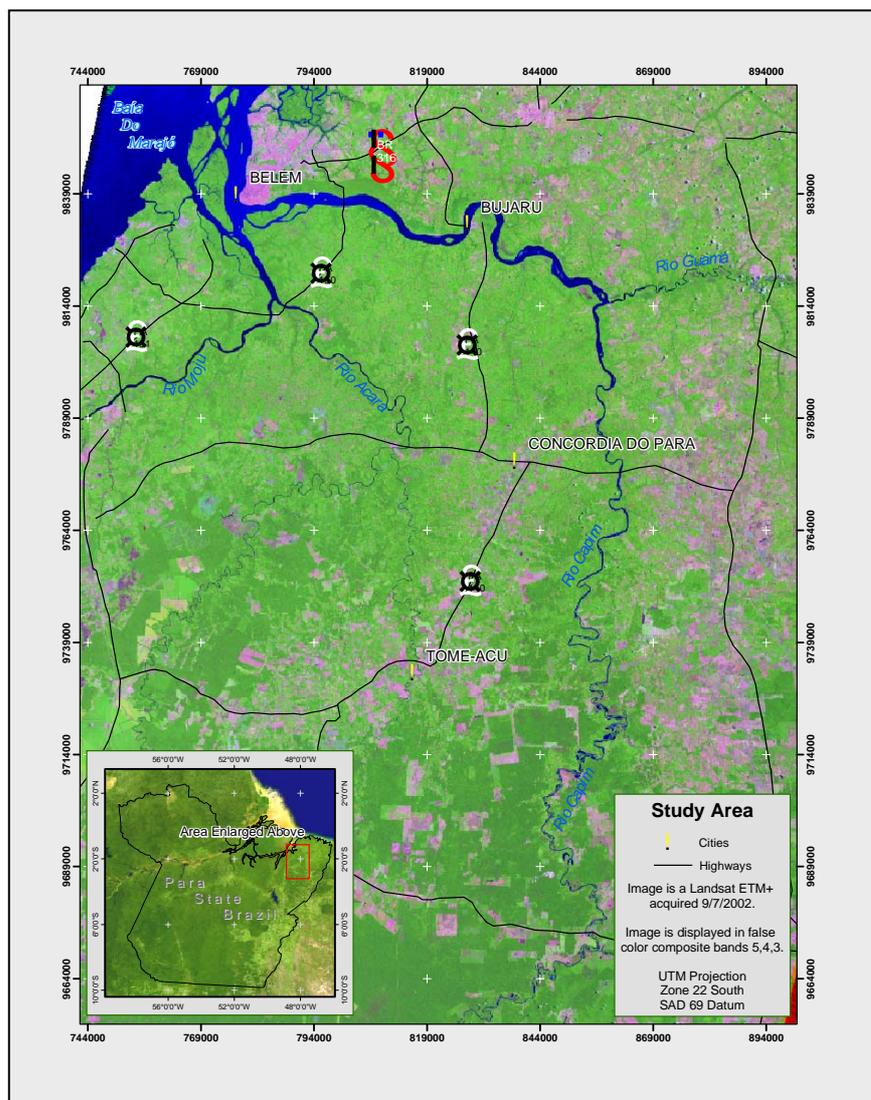


Figure 1: Map of the Tomé Açú region.

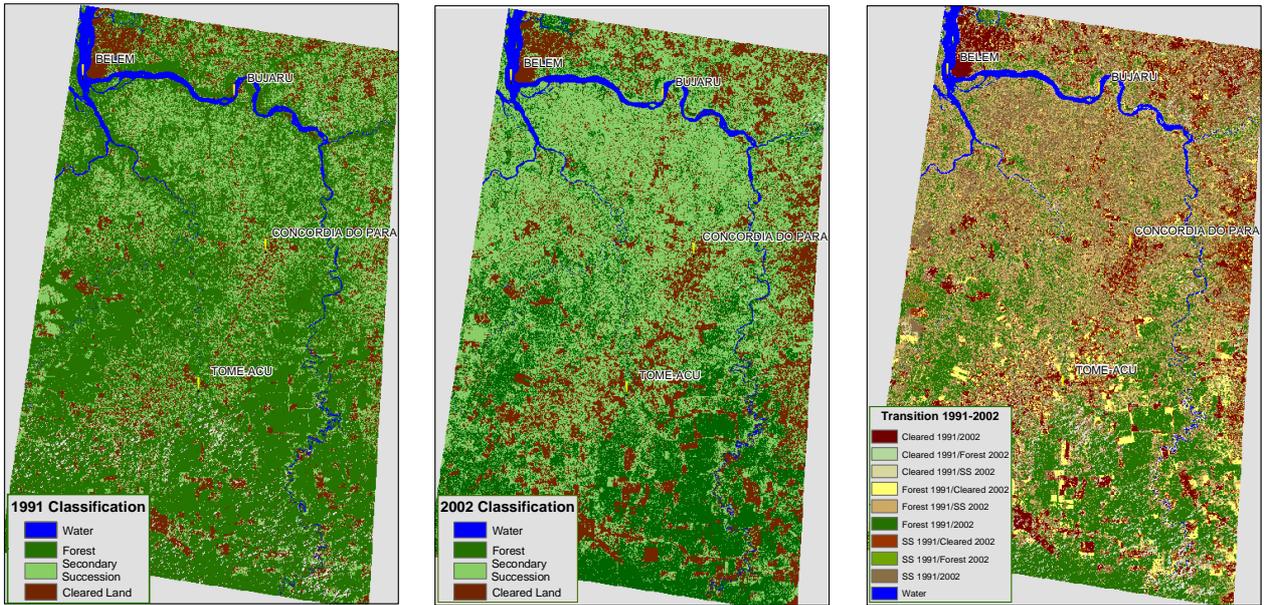


Figure 2: Unsupervised classifications of June/1991 Landsat TM and July/2002 ETM+ images, and a transition image of the study area created from the two classifications.

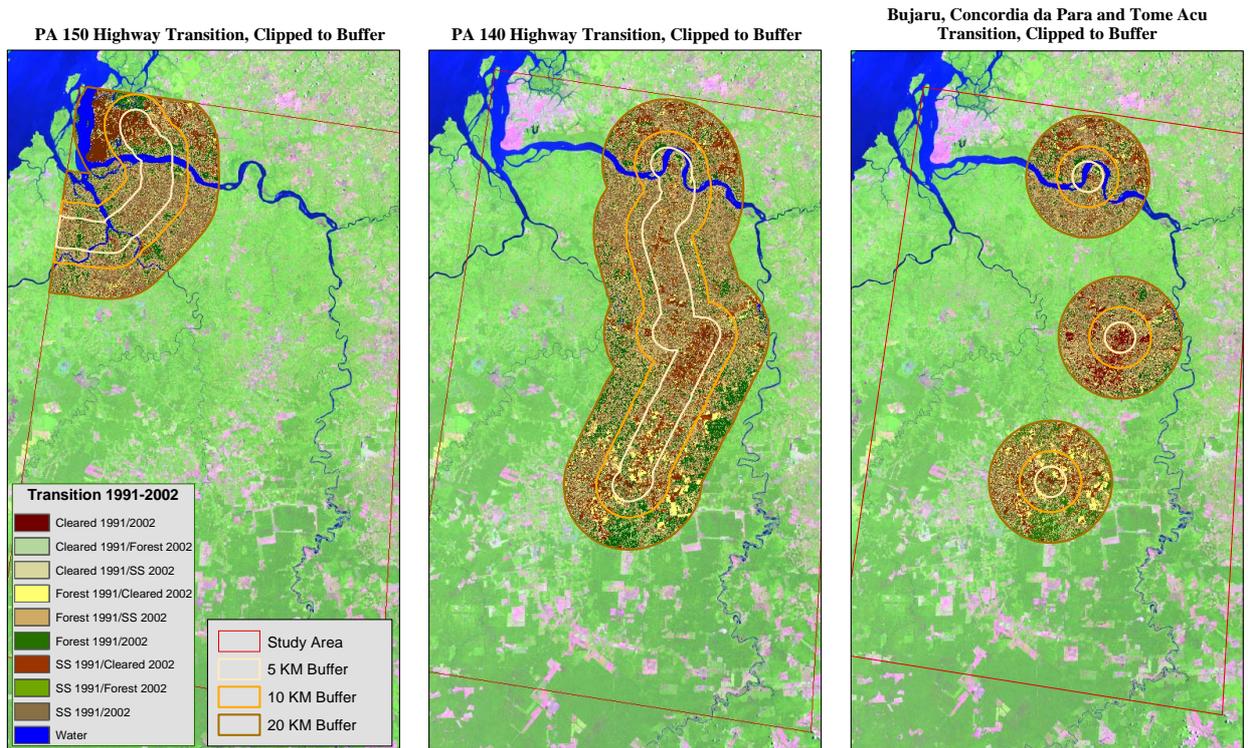


Figure 3: Buffers of 5, 10 and 20 km created from transition image (1991/2002) around PA-140, PA-150, and around the cities of Tomé Açú, Concórdia, and Bujarú.

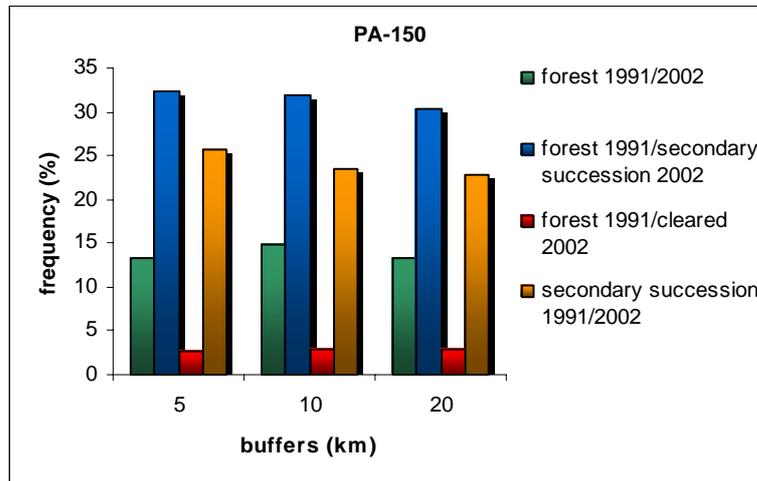
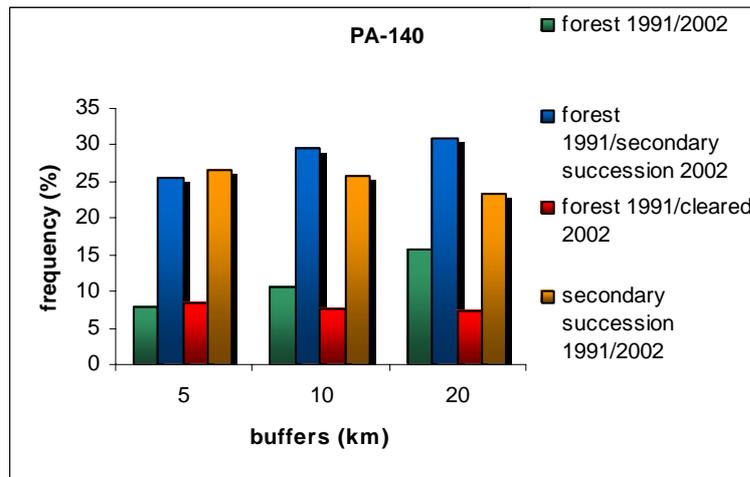


Figure 4: Histograms showing frequency of land cover classes around roads PA-140 and PA-150. This data was obtained by extracting land cover information from road buffers applied to the 1991 and 2002 transition image.

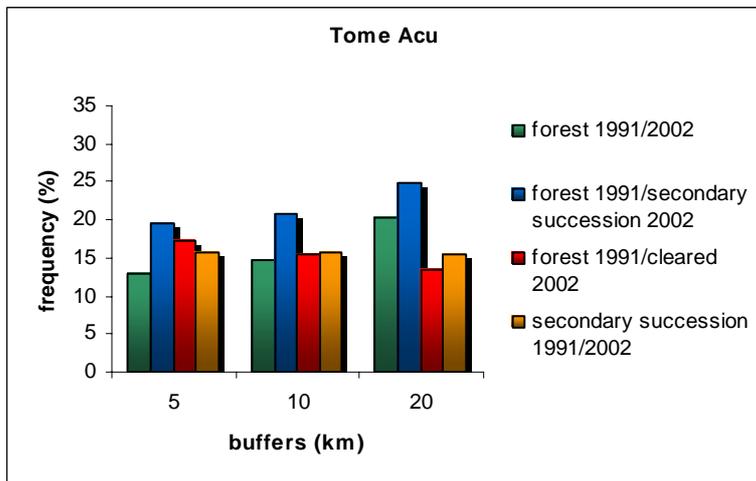
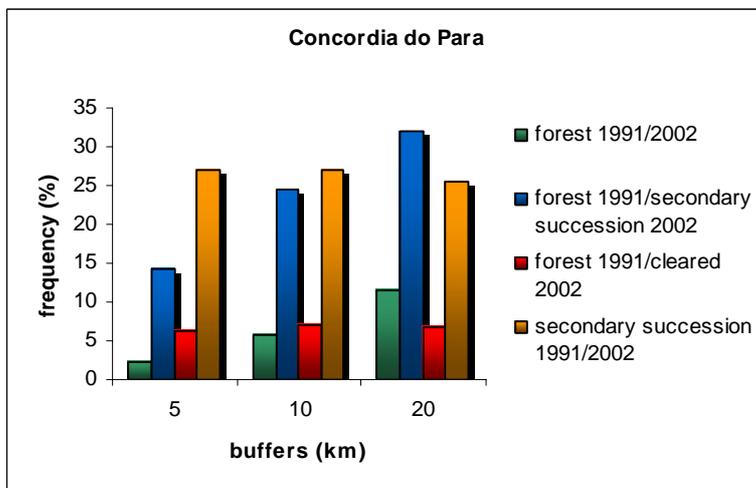
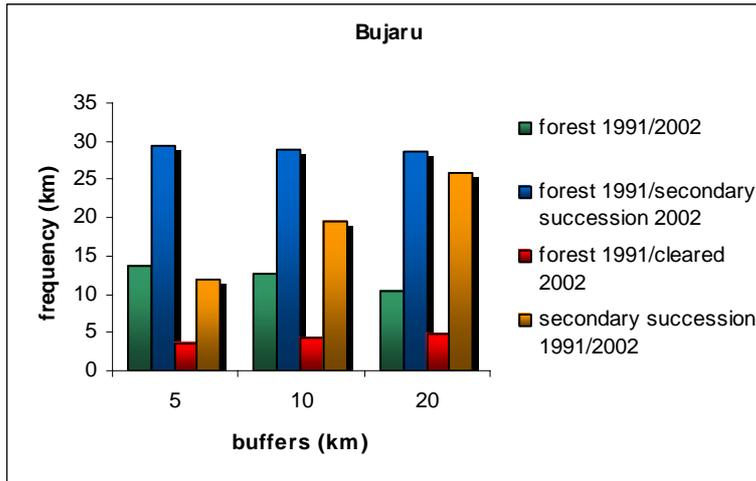


Figure 5: Histograms showing frequency of land cover classes around the cities of Bujarú, Concórdia do Pará, and Tomé Açú. This data was obtained by extracting land cover information from city buffers applied to the 1991 and 2002 transition image.