MINISTÉRIO DA CIÊNCIA E TECNOLOGIA
INSTITUTO NACIONAL DE PESQUISAS ESPACIAIS

INPE-15374-RPQ/819

THE IMPACT OF RIVERINE SETTLEMENT ON THE MAINTENANCE OF AMAZONIAN BIODIVERSITY: A BIOECONOMIC MODEL

Luke Parry
Silvana Amaral
Carlos A. Peres

Report of the research activities of the scientific expedition.

.

INPE
São José dos Campos
2008

Publicado por: **esta página é responsabilidade do SID**

Instituto Nacional de Pesquisas Espaciais (INPE)
Gabinete do Diretor – (GB)
Serviço de Informação e Documentação (SID)
Caixa Postal 515 – CEP 12.245-970
São José dos Campos – SP – Brasil
Tel.: (012) 3945-6911
Fax: (012) 3945-6919
E-mail: pubtc@sid.inpe.br

Solicita-se intercâmbio
We ask for exchange

MINISTÉRIO DA CIÊNCIA E TECNOLOGIA
INSTITUTO NACIONAL DE PESQUISAS ESPACIAIS

INPE-15374-RPQ/819

THE IMPACT OF RIVERINE SETTLEMENT ON THE MAINTENANCE OF AMAZONIAN BIODIVERSITY: A BIOECONOMIC MODEL

Luke Parry
Silvana Amaral
Carlos A. Peres

Report of the research activities of the scientific expedition.

.

INPE
São José dos Campos
2008

ACKNOWLEDGEMENTS

We are grateful to the Brazilian government for permission to do this research
We would also like to thank the people in Amazonas for their enthusiasm and assistance during fieldwork. In particular, we are grateful to the *prefeituras* of the municipalities we visited, as well as the support and cooperation of the hundreds of river-dwellers (*ribeirinhos*) that participated in this research. We would also like to thank the principal funder for this research, the Natural Environment Research Council (NERC) from the United Kingdom. Additional funding also came from the Center for International Forestry Research (CIFOR).

THE IMPACT OF RIVERINE SETTLEMENT ON THE MAINTENANCE OF AMAZONIAN BIODIVERSITY: A BIOECONOMIC MODEL

ABSTRACT

This report describes the data obtained during fieldwork in the Brazilian Amazon in 2007. River-dwelling people (*Ribeirinhos*) exert major environmental impacts in the Brazilian Amazon through agricultural and extractive activities. Despite the conservation significance of rural-to-urban migration, little is known about the parameters influencing patterns of river settlement. We explored riverine settlement patterns in 8 sub-regions of Amazonas state, Brazil. We used observation and interviews to investigate rural-urban gradients from the local urban centre to the last household on a proximate sub-tributary (≤ 750 km). Based on 184 river settlements we examined relationships between fluvial distance from urban centre and social, economic and environmental factors. Settlement density rapidly decreased with distance upriver. Local human population density appears to be negatively related to the relative abundance of hunted wildlife. Riberinhos paid higher costs for essential goods and received lower prices for produce further from towns. Transport opportunities were scarcer and more expensive. The availability of healthcare, education and electricity was also negatively associated with distance from urban centre. However, land availability was higher further from towns, and encounter distances to game animals were lower. This dataset will be used to construct simulation models in order to understand the likely environmental consequences of future patterns of riverine settlement in Amazonia.

SUMMARY

Pág.

FIGURE LIST

Pág.

TABLE LIST

Pág

1 INTRODUCTION

1.1 Ribeirinhos – The Amazon riverine inhabitants

Of the 5-8 million rural inhabitants of Brazilian Amazonia, most are *ribeirinhos* (also known as *caboclos*) or neo-colonists. The colonists are largely occupiers and agriculturalists of the upland *terra firme*, the majority arriving during the national settlement campaigns of the 1970s and 1980s (Moran et al, 2005). *Ribeirinhos* however, have a much longer history of settlement in the Amazon (Nugent, 2002), and they have traditionally pursued extractive lifestyles though the collection of rubber, Brazil nuts, wild game and fish. Riverine settlement is the major form of Amazonian settlement, in both prehistoric (pre 1492) times and contemporary *caboclo* culture (Denevan, 1996), reflecting riverine resources (fertile soils, abundance of fish and game) and the transport opportunities that rivers provide. Despite their number, widespread distribution and long history in the Amazon, *ribeirinhos* remain understudied as compared to indigenous people and recent colonists (Nugent, 2002). Yet they are providing the principal human pressure on the environment for most of the Amazon, and are important for biodiversity conservation (Hiraoka, 1992). Understanding patterns of migration and settlement have been identified as crucial to understanding the human impact on the environment (Hogan 1992). This is of particular relevance in remote headwaters, given recent indications that Amazonian headwaters are especially rich in biodiversity and thus of high conservation importance (Fernandes et al., 2004).

1.2 Rural Exodus

Many areas of the humid tropics have seen rapid and sustained rural-to-urban migration in recent decades. Brazil is no exception, and the trend of a declining rural population and rapidly increasing urban population looks set to continue. (Figure 1.1). However, there is still a paucity of information relating to the

process and environmental consequence of rural-urban population distributions. For Brazilian Amazonia, research has focussed on coarse-scale municipal datasets from the Instituto Brasileiro de Geografía e Estatística (IBGE), or occasionally at the finer scale of *setor censitario* (e.g. Pfaff et al 2007). At the other end of the scale, exists research examining peri-urban settlement and migration in Amazonia (Browder, 2002).

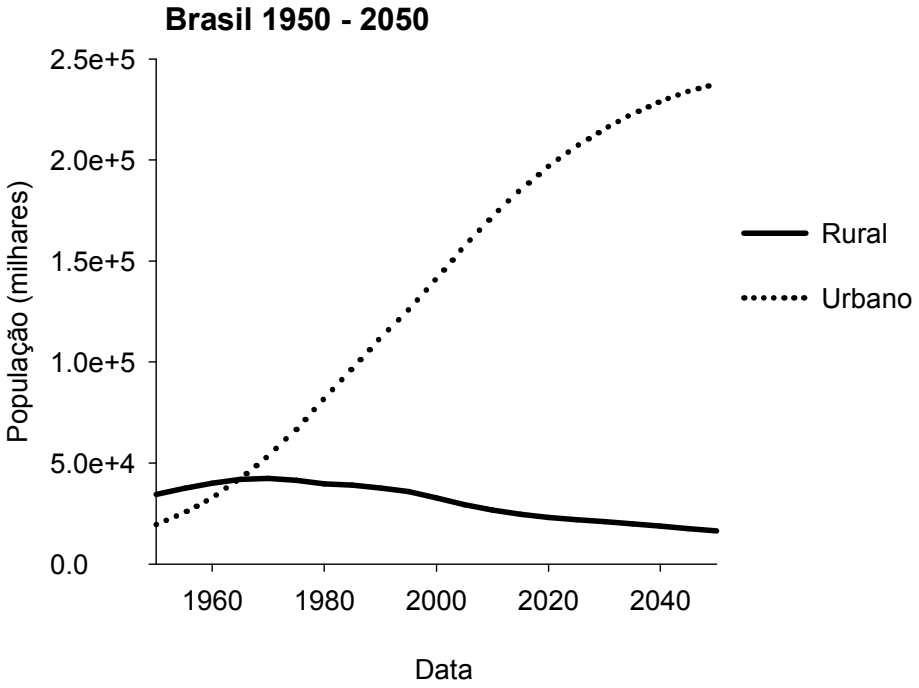

Figure 1.1. Past, present and future rural and urban population trends in Brazil. Source: Population Division of the Department of Economic and Social Affairs of the United Nations Secretariat (2008)

1.2 Amazonas

Fieldwork for this project was exclusively in the state of Amazonas. Due to rural-to-urban migration, and ongoing endogenous growth within urban areas, 75% of the population of Amazonas live in towns and cities (IBGE, 2000). There are only 680 km of paved roads in the entire state, and the vast majority of the rural population live along watercourses (Figure 1.2). Although the state of

Amazonas has a relatively large indigenous population, 83,966 people (FUNAI, 2008), the majority of rural people (600,000 or 85%) are nontribal *riberinhos/caboclos* (IBGE, 2000).

Figure 1.2. The municipal sede of Tapauá, along the Rio Purus.

1.3 Debated role in conservation

Rural people have been portrayed in a positive light in terms of their sustainable use of the forest and their potential role in ensuring forest longevity (Campos and Nepstad, 2006), particularly through the extraction of non-timber forest products (Plotkin and Famolare, 1992) and the increasing acreage of, and interest in, sustainable use reserves (e.g. Fearnside, 1989). However, the agricultural and extractive activities of rural Amazonians also exert negative environmental impacts which can jeopardize both forest cover and important ecological processes. The principal structural impacts of the rural activity are deforestation through slash-and-burn agriculture, and associated fire, and timber extraction (Nepstad et al., 1999). The non-structural impacts of over-harvesting animals and plants are harder to observe yet compromise the long-

term integrity of processes such as seed dispersal (e.g. Peres 2000; Peres et al 2003).

1.4 Projects Aims

Premise: Understanding the vulnerability, distribution and movement of *ribeirinhos* will help us predict (+ minimize/buffer) the impact of the arrival of deforestation in the Central and West Brazilian Amazon.

Questions:

1. How is the riverine population distributed?

2. What causal factors explain the distribution?

3. What is the environmental impact of settlement on hunted vertebrates?

2 METHODS

2.1 Experimental Approach

1) Exploring rural-to-urban gradients along sub-tributaries, to municipal sedes, in Amazonas state (Figure 2.1).

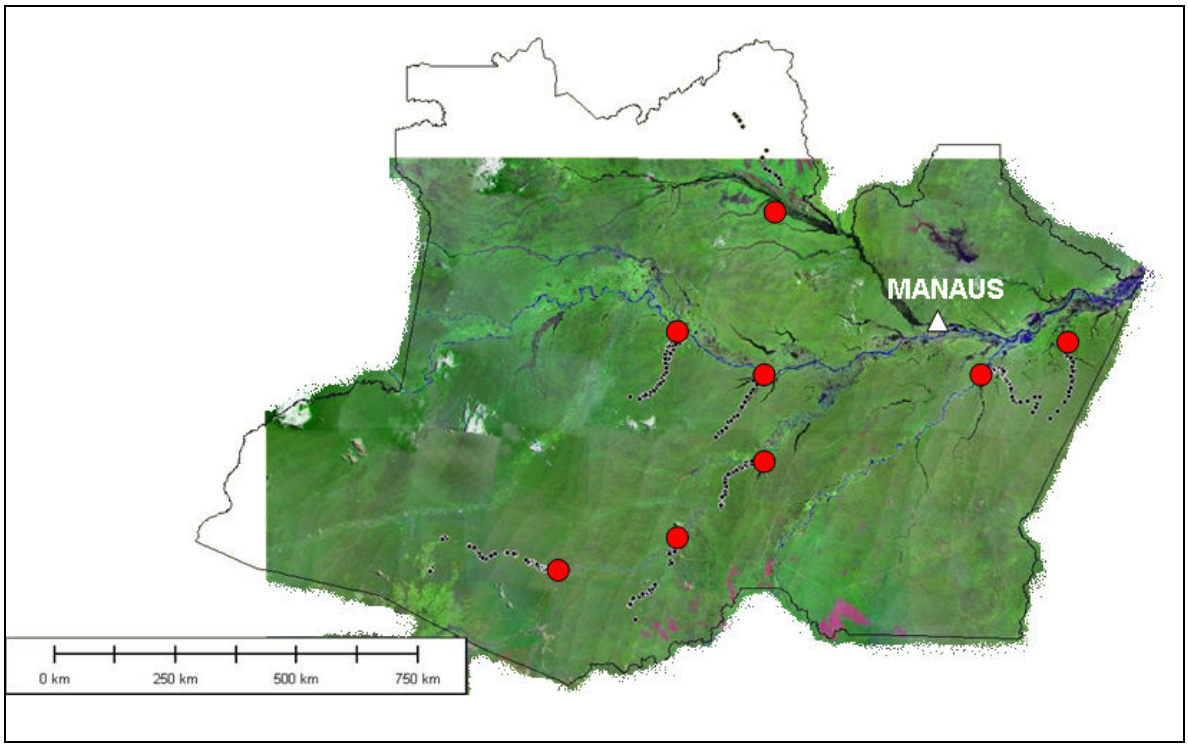

Figure 2.1. Map of the study sites for fieldwork in Amazonas state. Red dots indicate urban centres and black dots indicate rural settlements.

Guidelines:

a) Avoid sub-tributaries that are bisected by roads.

b) Try and avoid *Unidades de Conservação* and *Terras Indígenas*

c) Investigate tributaries in which there is a single urban pull.

d) Avoid tributaries whose confluence with a larger triburary lies a long way from the municipal *sede*.

2) Taking longitudinal data to assess temporal trends. Data was sourced from parochial missions (Catholic Church data on christenings etc) and publicy-available IBGE data. However, although census data from IBGE is available for

1980 and 1991, there remain problems with the interpretation of *setor censitario* data due to the major changes to sector boundaries between each national census.

2.2 The Fieldework

The field campaign accomplished the purpose of our study. We sampled 8 rivers, in different sub-regions of Amazonas state (Table 2.1). We reached the last house on each of the rivers (Figure 2.2), and surveyed 184 settlements in total. We also have demographic information for all settlements (including unsurveyed) along each of the study river, based on interviews and secondary data sources (often *Secretarías de Saúde*) in urban centres. The timing of rivers to minimize dry season disruption to navigation (particularly in reaching the final houses upriver) was a major logistical challenge, though we were able to complete our anticipated rivers due to seeking local knowledge in urban centres and hiring boats suited to the current river state (see Figure 2.3 for an example of dry season travel). Transport between urban centres was also challenging, especially on the Alto Rio Purus.

Table 2.1. Sub-tributaries sampled during fieldwork, and number of settlement-level interviews conducted.

Sub-tributary sampled	Urban centre	Municípios	Distance to last household (km)	Interviews
R. Maués / R. Parauari	Maués	Maués	248	23
R. Ituxi	Lábrea	Lábrea	409	21
R. Pauini	Pauini	Pauini	740	32
R. Jacaré	Tapauá	Tapauá	198	17
R. Tefé	Tefé	Tefé/ Alvarães	272	28
R. Abacaxis	Nova Olinda do Norte	N. Olinda / Borba	276	26
R. Coari	Coari	Coari	406	21
Total				**184**

Figure 2.2. The last house along the Rio Pauini. This *barraca* is > 740 km the town of Pauini, and its occupants still survive by tapping rubber.

Figure 2.3. Luke Parry alongside a *voadeira* on the Rio Aracá, a sub-tributary of the Rio Negro, in the município of Barcelos.

3 RESULTS

3.1 Patterns of Settlement

The vast majority of the rural population in the Amazon live close to urban centres. Over 85% live within one day's travel of these towns (see Figure 3.1 for an example). Large stretches of sub-tributaries are now uninhabited, and there has been a contraction of the inhabited length of sub-tributaries in recent decades. Much of the remaining inhabitants of remote rural communities are considering leaving, in most cases to their nearest urban centre. Settlements further from town tend to be smaller.

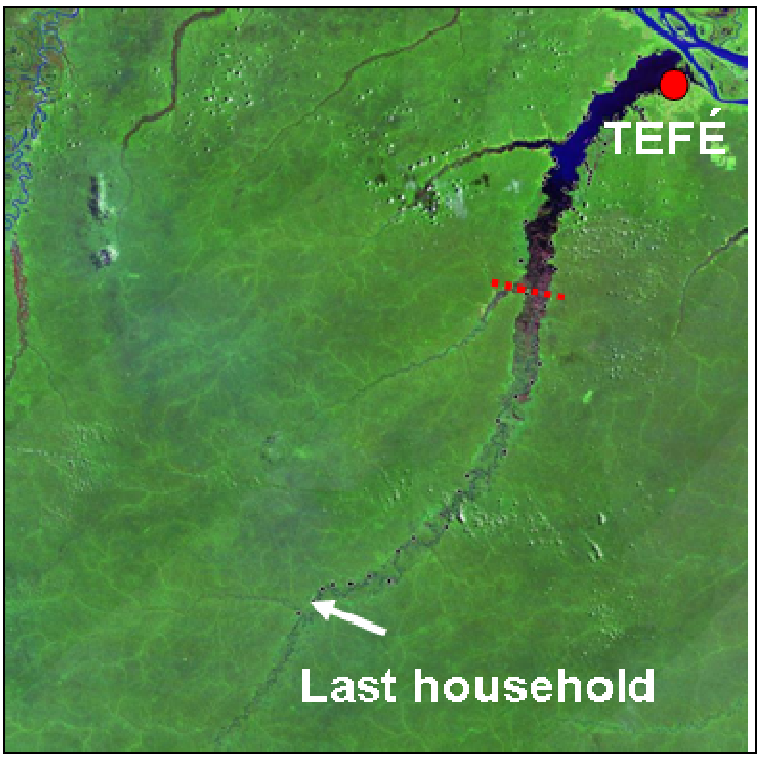

Figure 3.1. Map showing the Rio Tefé in Amazonas. The last house along the river is shown by a white arrow. However, 85% of the rural population live within 80 km fluvial distance of the city. The 80 km limit is shown with a red-dotted line.

3.2 Factors affecting settlement

Navigation. Navigation is severely restricted along sub-tributaries in the dry season. Navigation is particularly restricted for larger boats (10m +) with inboard engines. Most *riberinhos* use small canoes and removable outboard engines (commonly 5.5 HP) in order to reduce transport costs, investment costs, and allow transport year-round. However, even if a settlement is reachable by canoe in the dry season, the navigation problems of larger boats restricts the supply of goods and services (both public and private) to these settlements

Urban contact. Families that are farther from town make less trips to their nearest urban centre. Families that live further than one or two hundred kilometres from town tend to go to town less than once a month. This severely restricts integration with the regional economy and the welfare state.

Health and education. Even accounting for settlement size (as a co-factor in models) settlements further upriver are less likely to have access to a local school or healthcare (using the basic services supplied by *agente de saúde* as a proxy).

Government spending. Settlements further upriver receive less government funding in the forms of employment (in schools or as health agents), disability or retirement benefit, or welfare payments. Families upriver are less likely to receive *Bolsa Famíla*.

Energy Provision. Independently of settlement size, settlements further upriver were less likely to have access to electrical power (normally generators). Even when there were generators, there was major variation among *municípios* in terms of their efficiency in repairing generators, and distributing fuel.

Trade. With increasing distance upriver, the price of staple goods from riverine traders increased, and the price they paid for agricultural and extractive produce

decreased. People living closer to town tended to independently buy goods in town, and avoid the transaction costs of riverine traders (Figure 3.2).

Figure 3.2. Photographs of an urban trader or *comércio* in Maués. On the right is a riverine trader, or *regatão*, a dying breed in Amazonas.

Access to farmland. As settlement size and density decreased upriver, *ribeirinhos* further from urban centres had a higher availability of unfarmed land.

4 RESEARCH CONTINUITY

Analysis is on-going. In particular, we are focusing on i) assessing patterns of rural settlement, and ii) understanding patterns of rural settlement. Much of the socio-economic data comes from interviews. Other factors (such as local population density) come from spatial analysis (largely using ArcGIS 9.2) of publicly available data. Multi-variate statistics are being used to explore the bio-physical and socio-economic factors affecting settlement presence, settlement size and settlement growth along sub-tributaries, at varying distances from urban centres. Methods include model selection based on Akaike's Information Criterion (Akaike, 1974). These analyses utilize the data-set of settlement interviews based on fieldwork along eight rivers in Amazonas.

4.1 Spatial and Economic Modelling

Once analyses relating to our fieldwork are complete, we will be equipped with an understanding of the relationships between rural settlement and both biophysical and socio-economic factors. These factors are likely to be generalizable across space, if we have a) sufficient measurements of the contexts in which fieldwork was conducted, and b) sufficient knowledge of other locations in Amazonia. This is likely possible, because detailed information is publicly available for hydrology, soil, transport, navigation and other geographical parameters. Provisional analyses show that many of the socio-economic factors (such as the availability of health and education) are closely related to distance from urban centre. As such these parameters can be inferred for other locations using state- or region-wide analysis.

The utility of this project and its findings will largely rest on the potential to make predictions and inferences in space and time. There is excellent potential to produce a predictive model, based on the extensive spatial replication inherent in the interview data-set. As such we plan on eventually producing a model that could investigate

a) The impacts of socio-economic (or biophysical) change on rural population distributions in the Amazon. Examples include changes in fuel prices, increases in the availability of rural education, or the introduction of new markets for non-timber forest products.

b) The impact of future changes in riverine settlement on the natural environment. Specific questions include the consequences of change for source-sink dynamics and consequent population growth for vulnerable hunted vertebrates across the Amazon basin.

A predictive spatial model would be best-developed with the *Instituto Nacional de Pesquisa Espacias* (INPE). The scientists at INPE are world experts with spatial modelling, and have developed their own modelling platform which would be suitable for the task, TerraME. This work would be in collaboration with Tiago Garcia Carneiro, also from UFOP (Ouro Preto Federal University) and INPE.

5 LITERATURE CITED

AKAIKE, H. A New Look at Statistical Model Identification. **IEEE Transactions on Automatic Control**, v. 19, n. 6, p. 716-723

BROWDER, J. O. The urban-rural interface: Urbanization and tropical forest cover change. **Urban Ecosystems**, v. 6, n. 21-41

CAMPOS, M. T.; NEPSTAD, D. C. Smallholders, the Amazon's new conservationists. **Conservation Biology**, v. 20, p. 1553-1556

DENEVAN, W. D. A bluff model of riverine settlement in Prehistoric Amazonia. **Annals of the Association of American Geographers**, v. 86, p. 654-681

FEARNSIDE, P. M. Extractive Reserves in Brazilian Amazonia. **BioScience** v. 39, p. 387-393

FERNANDES, C. C.; PODOS, J.; LUNDBERG, J. G. Amazonian ecology: tributaries enhance the diversity of electric fishes. **Science** v. 305

FUNDAÇÃO NACIONAL DO ÍNDIO (FUNAI). **Grupos indígenas -** Amazonas. 2008. Disponível em: http://www.funai.gov.br/. Acesso em: Sept 25, 2008.

HIRAOKA, M. Caboclo and ribero resource management in Amazonia - a review. **Conservation of neotropical forests :** working from traditional resource use. New York: K.H. Redford, C. Padoch. Columbia University Press, 1992.

HOGAN, D. J. The impact of population growth on the physical environment. **European Journal of Population**, v. 8, p. 109-123

INSTITUTO BRASILEIRO DE GEOGRAFIA E ESTATÍSTICA (IBGE). **Contagem de população.** dados de universo. Rio de Janeiro: Instituto Brasileiro de Geografia e Estatística, 2000. Disponível em: www.ibge.gov.br.

MORAN, E. F.; BRONDIZIO, E. S.; VANWEY, L. Population and environment in Amazonia: landscape and household dynamics. In: Entwisle, B.; Stern, P. (Ed.). **Population, land use and environment** Washington: National Academies Press, 2005.

NEPSTAD, D. C.; VERISSIMO, A.; ALENCAR, A.; NOBRE, C.; LIMA, E.; LEFEBVRE, P.; SCHLESINGER, P.; POTTER, C.; MOUTINHO, P.; MENDOZA, E.; COCHRANE, M.; BROOKS, V. Large-scale impoverishment of Amazonian forests by logging and fire. **Nature**, v. 398, n. 6727, p. 505-508 Disponível em: <Go to ISI>://WOS:000079662800046 Times Cited: 362.

NUGENT, S. Whither O Campesinato? Historical peasantries of Brazilian Amazonia. **The Journal of Peasant Studies**, v. 29, p. 162-189

PERES, C. A. Effects of subsistence hunting on vertebrate community structure in Amazonian forests. **Conservation Biology** v. 14, p. 240-253

PERES, C. A.; BAIDER, C.; ZUIDEMA, P. A.; WADT, L. H. O.; KAINER, K. A.; GOMES-SILVA, D. A. P.; SALOMAO, R. P.; SIMOES, L. L.; FRANCIOSI, E. R. N.; VALVERDE, F. C.; GRIBEL, R.; SHEPARD, G. H.; KANASHIRO, M.; COVENTRY, P.; YU, D. W.; WATKINSON, A. R.; FRECKLETON, R. P. Demographic threats to the sustainability of Brazil nut exploitation. **Science**, v. 302, p. 2112-2114

PFAFF, A.; ROBALINO, J.; WALKER, R.; ALDRICH, S.; CALDAS, M.; REIS, E.; PERZ, S.; BOHRER, C.; ARIMA, E.; LAURANCE, W.; KIRBY, K. Road investments, spatial spillovers, and deforestation in the brazilian amazon. **Journal of Regional Science**, p. 109-123

PLOTKIN, M.; FAMOLARE, L. **Sustainable harvest and marketing of rain forest products** Island Press, 1992.

UNITED NATIONS. POPULATION DIVISION OF THE DEPARTMENT OF ECONOMIC AND SOCIAL AFFAIRS OF THE UNITED NATIONS SECRETARIAT. **World Population Prospects: The 2006 Revision and World Urbanization Prospects: The 2007 Revision**. 2008. Disponível em: http://esa.un.org/unup Acess: Sept, 25, 2008.

.

PUBLICAÇÕES TÉCNICO-CIENTÍFICAS EDITADAS PELO INPE

Teses e Dissertações (TDI)

Teses e Dissertações apresentadas nos Cursos de Pós-Graduação do INPE.

Manuais Técnicos (MAN)

São publicações de caráter técnico que incluem normas, procedimentos, instruções e orientações.

Notas Técnico-Científicas (NTC)

Incluem resultados preliminares de pesquisa, descrição de equipamentos, descrição e ou documentação de programa de computador, descrição de sistemas e experimentos, apresentação de testes, dados, atlas, e documentação de projetos de engenharia.

Relatórios de Pesquisa (RPQ)

Reportam resultados ou progressos de pesquisas tanto de natureza técnica quanto científica, cujo nível seja compatível com o de uma publicação em periódico nacional ou internacional.

Propostas e Relatórios de Projetos (PRP)

São propostas de projetos técnico-científicos e relatórios de acompanhamento de projetos, atividades e convênios.

Publicações Didáticas (PUD)

Incluem apostilas, notas de aula e manuais didáticos.

Publicações Seriadas

São os seriados técnico-científicos: boletins, periódicos, anuários e anais de eventos (simpósios e congressos). Constam destas publicações o Internacional Standard Serial Number (ISSN), que é um código único e definitivo para identificação de títulos de seriados.

Programas de Computador (PDC)

São a seqüência de instruções ou códigos, expressos em uma linguagem de programação compilada ou interpretada, a ser executada por um computador para alcançar um determinado objetivo. São aceitos tanto programas fonte quanto executáveis.

Pré-publicações (PRE)

Todos os artigos publicados em periódicos, anais e como capítulos de livros.