



Porto Velho, the capital of the Brazilian state of Rondônia in the upper Amazon River basin

## Hierarchy of Urban Areas in the Brazilian Amazon and Its Environmental Implications

*Gilvan Guedes, Sandra Costa, Eduardo Brondízio*

The Legal Brazilian Amazon shares the reputation of being the largest rainforest in the world and an area of exponential urban development. Yet, population-environment research in the Amazon has focused mainly on rural areas, despite the increasing prominence of cities in the region. There is a growing, but still limited, literature discussing and proposing analytical models of urbanization dynamics in the Amazon, their spatial-temporal distribution and relation to road-river networks, and their social and economic interconnections and consequences (e.g., Becker, 1985; Machado, 1989; Browder & Godfrey, 1997; Perz, 2000; Browder, 2002; Padoch et al., 2008). This report summarizes the analytical approach and results within a forthcoming article (in *Population & Environment*) in which we contribute to this emerging literature by examining the level of primacy among Amazonian cities, their relative importance and infrastructural differences, and their level of interdependency

resulting from inter-urban demographic movements. We test the proposition by Browder and Godfrey's *Rainforest Cities* (1997) of the inexistence of a regional urban hierarchy ("disarticulated urbanization") and use the methodological approach presented by Garcia and colleagues (2007) to analyze it.

Our model uses a combination of nationally representative surveys and community-level data, which allows us to test a classical articulated urban model (e.g., Christaller, 1966) at three different spatial levels: regional, sub-regional, and local. Our analysis of regional urban articulation complements other efforts that have called attention to intra-regional differences (e.g., Perz,

2000) and attempted to stratify and qualify sub-regional urban networks using similar methodology as presented here (e.g., Garcia et al., 2007; IPEA, 2002). Our analysis also aims to support current efforts to develop regional and state level Ecological-Economic Zoning (ZEE) and to inform predictive models of deforestation and expansion of human occupation in different parts of the region. Attention to the formation of urban networks, their axis of expansion and their intersection with a growing but largely disconnected system of protected areas is necessary to understand the future of population distribution, the surrounding human landscapes around protected areas, gradients



Urban development in Macapá, the capital of Amapá on the Amazon River in Brazil

of land and resource rent value, pollution sources and sinks, the formation of market chains, and regional variations in patterns of economic development.

We used several data sources to study and analyze urban growth, development, and hierarchy at three different spatial levels of the Legal Brazilian Amazon (LBA) – regional, sub-regional and local. Our analytical sample includes 747 observations at the level of municipalities, derived from micro level data collected by the Brazilian Demographic Census (IBGE 1991, 2000). We also used databases from the Brazilian National Council of Municipalities (CNM, 2007), the Brazilian Hospital Information System (MS, 1998 & 2002), the Brazilian Population Tally (IBGE, 2007) and the Brazilian National Archive of Health Establishments (MS, 2002) for analysis of the regional and sub-regional urban levels. For the local level, we used ethnographic field data, community surveys, and archival research collected by members of the Anthropological Center for Training and Research on Environmental Global Change (ACT) at Indiana University of 181 communities located in the municipalities of Santarém, Belterra, and Monte Alegre. Our community sample, surveyed in 2004, ranges, in terms of population size, from 10 to over 5,000 individuals.

### The Grade of Membership Model

The Grade of Membership (GoM) model, a statistical methodology, was used to delineate clusters of elements within a heterogeneous dataset (Manton et al., 1994). The GoM model is classified as a fuzzy cluster technique because the same individual is allowed to have a certain level of pertinence to multiple sets. In the GoM method, an estimate of the degree of pertinence for each individual relative to all the sets is created, resulting in a fuzzy set or partition for each individual. For each element in a fuzzy set, there is a score of the degree of pertinence,  $g_{ik}$ , which represents the degree to which that element  $i$  belongs to the reference group,  $k$ . The value  $g_{ik}$  represents the intensity of pertinence to each of the extreme profiles. The number of extreme profiles

can be established according to two criteria: by means of a theoretical orientation, or by using the Akaike Information Criterion (AIC) as the test statistics for comparison of a model with  $k+1$  and a model with  $k$  profiles (see Manton et al., 1994). In our analysis, we based our criterion on the three hierarchical regional levels proposed by Garcia and colleagues (2007) and Browder and Godfrey (1997) and applied random selection of the first three elements of the sample defining the extreme profiles. Technical details, including the algorithms used to delineate the mixed profiles, are available in a forthcoming article (Guedes, Costa & Brondízio, n.d.).

### Urban Hierarchies

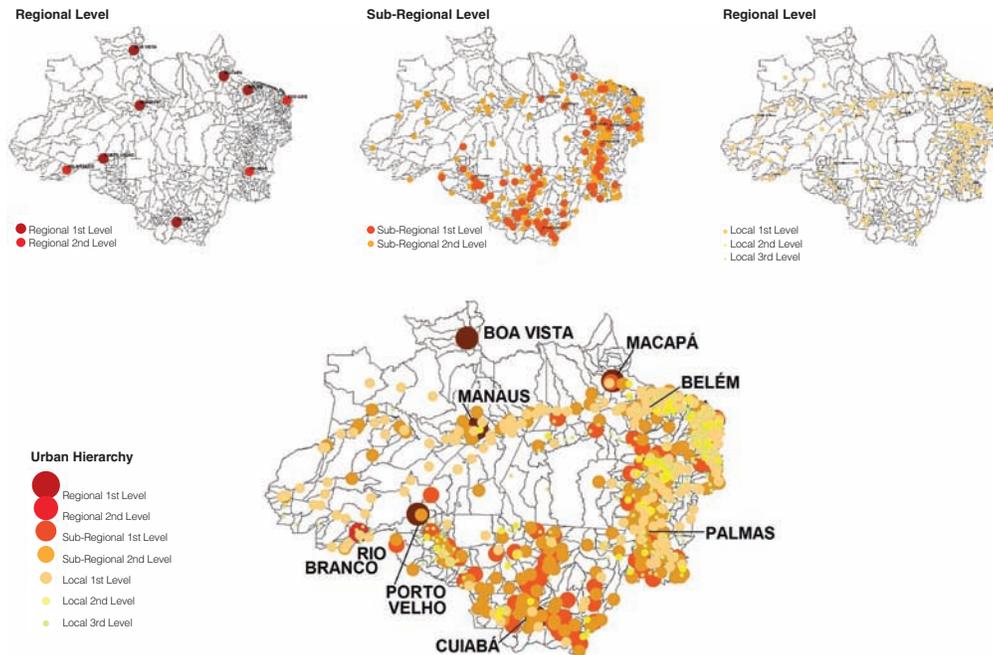
Based on the profiles from the GoM model, we classified the Amazonian cities into seven different levels of urban hierarchy (Figure 1): a) regional first level (Belém, Manaus, Cuiabá, Porto Velho, Macapá and Boa Vista); b) regional second level (São Luís, Rio Branco and Palmas); c) sub-regional first level (the cities of Imperatriz, Araguaína, Ji-Paraná, Marabá, Santarém, Altamira and Rondonópolis, plus 68 other cities); d) sub-regional second level (211 cities); e) local first level (224 cities); f) local second level (56 cities), and g) local third level (173 cities).

At the regional level, the disarticulated nature of urbanization in the Legal Brazilian Amazon suggested by Browder and Godfrey (1997) can be visualized in Figure 1. Some small urban areas of limited importance offer the only urban alternative for some populations in hundreds of square kilometers. Similarly, important sub-regional cities are “disconnected” from regional urban centers, creating a pattern that does not correspond to Christaller’s theory (1966). This disarticulation also creates unexpected linkages within and between cities and between different states, calling attention to the limits of using municipal area boundaries as units of analysis.

At the sub-regional level, our results suggest a more traditional hierarchy. Node cities, as called by Costa and Brondízio (n.d.), appear in our model as a reference for a set of small surrounding cities. They function as central places providing services and attracting temporary workers and students who reside in different municipalities. They also have an important position as receptors of migrants coming from the surrounding areas. The relative isolation of some small cities to larger urban centers reinforces their dependence on these sub-regional node cities, as they represent within the Amazonian region, the only connection to an urban reality for rural residents and those living in impoverished villages and towns.

No clear hierarchical pattern, on the other hand, seems to emerge at the local level (Figure 2), as there are similar numbers of

**Figure 1** | Urban Hierarchy Based on the GoM Profiles for the Legal Brazilian Amazon

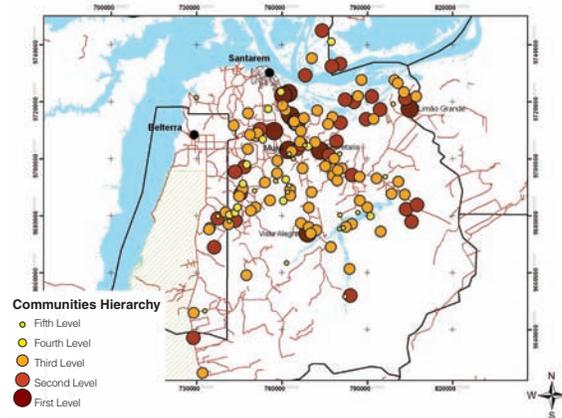


communities within each hierarchical category. This is not totally surprising given that many communities receive similar levels of support from municipalities and can access services in urban centers. There are, however, large and important communities located away or in-between regional urban centers, which provide important services to other surrounding communities and farms. In a region where distances and travel conditions are significant constraints, communities in-between urban centers assume a micro-hierarchical position in the provisioning of services and social activities.

### Implications for Urban Development and the Environment

This unique nature of urban hierarchies in the Brazilian Amazon, with a disarticulated urbanization at the regional level but with more traditional hierarchies at the sub-regional levels, has important environmental implications. Along with the exponential growth of urban areas since the late 1980s, the region has seen a similar growth of both reserves and conservation areas and agro-pastoral activities. The confluence of these systems, their spatial overlaps and adjacencies, and their respective institutional arrangements are defining the future axis of occupation and connectivity within the region. The growing network of urban areas is contributing to a situation of high level connectivity between land use systems and social groups within and between ecosystems and watersheds (Brondizio, Ostrom, & Young, 2009) As a result, the region is starting to witness blocks of protected areas surrounded by urban and agrarian systems, thus creating “island conservation”

**Figure 2** | Settlement Hierarchy at the Local Level



effects and fragmentation of habitats. The propagation of impacts within such situations also increases, particularly given the distribution and size of important watersheds in the region.

Intra-regional connectivity and urban network complexity create new challenges for conservation and regional planning. Projected scenarios of climate change in the region raise further concerns about the impact of urban network expansion in the region and vice-versa, the impact of climate change on urban populations. Understanding the forms and fronts of urban network expansion and their intersection with conservation areas and expanding land use systems is an important component of any program aimed at improving the quality of life for regional populations and finding sustainable solutions for reconciling conservation and development in the Amazon.

The references for this article are available on our website: <http://ugec.org/docs/ViewpointsIssue2References.pdf>