Urban hierarchy in the brazilian Amazon

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The Grade of Membership (GoM) model is used to outline profiles based on a heterogeneous and multidimensional database, which allows identifying clusters and describing the differences among them. In this study, GoM uses several types of variables so as to improve the understanding of the greatness and power of Amazonian cities. To accomplish this task, a model that takes into account a variety of aspects, which exceed a purely economic or demographic analysis, is proposed. Understanding the hierarchical organization of the cities in the Amazon seems to be a very important exercise in order to understand the dynamics and specific characteristics of regional urban nets. In this way, it is evident that policies which stimulate the establishment of more structured urban nets in the Amazon are needed. A more balanced population distribution throughout the territory could bring a series of benefits, especially when it comes to the offer and access to all different sorts of services.

Keywords: Amazon. Spatial distribution of population. Urban hierarchy. Grade of Membership (GoM).

Introduction

In the Legal Amazon, the intensification of natural resource exploration within the territory through mining and mineral extraction, organized and financed by large companies, as well as intense deforestation and land incorporation by agricultural and livestock industries, along with the colonization projects and the policies induced and funded by the State, have promoted a migratory outbreak with a demographical growth that has launched new challenges for the Region's public policies (MONTE-MÓR, 1994, 2004; SATHLER, 2009).

The opening of major highways in the frontier areas, after the 1960's, stimulated a differentiated occupation pattern in the Legal Amazon, under the influence of the intensification of flow between the main focal points belonging to a great "archway". Encouraging this type of occupation has

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provided several logistic and location advantages, unlike what occurred around the Region's main fluvial paths.

Over the past decades, a true urban explosion has been spotted in the surroundings of the Region's main highways, in face of one of the most formidable migratory movements ever recorded (MATOS, 2005). Growth rates have been higher than the national average, due to the intense migratory flow, originating mostly in the Northeastern and Southern regions.

In this context of continuous transformation, the theme of urban hierarchy in the Amazon has been attracting specialists' attention in face of the specific and complex urban nets in the Region. The search for better comprehension of the questions related to the Amazonian urbanization, urban nets and hierarchical organization's specifics seems to be extremely important. This is due to the fact that not only does most of the Amazonian population live in cities, but it is also important to take into account that, in the Amazon, many people that live in areas that exceed the limits of urban perimeters develop fundamentally urban activities.

In balanced urban nets, the hierarchy of cities, when properly planned and respected, is capable of bringing a series of economic and logistic benefits. The idea of an urban net connects to the existence of centers in a hierarchical distribution. Only in a hypothetical situation is it possible to imagine a region dominated by centers that are equally "sized" (demographically, functionally, among other aspects). In that way, it is plausible to imagine that, where there is a net, there is an urban hierarchy.

The theme is greatly relevant, since the questions on urban hierarchy in the Region are linked to a series of other relevant aspects that go beyond the studies which consider the influence radius of the organization of cities, of systems of material and immaterial flows and of urban agglomerations, as well as other traditionally approached themes. The urban hierarchy in the Amazon also converses with questions referring to social differences and poverty, deforestation, land conflicts, and others.

The urban hierarchy in the Amazon with unbalanced nets

Recent urban transformations in the Amazon have generated interpretations that often do not correspond to the regional urban scenario, supported by the untruth that Amazonian cities would not be organized in a dendritical or monocentrical type, simplified urban net model, which would have been broken when new median cities were introduced and with the growth spurt of small regional municipalities. However, even before the high growth rates of the past decades, the Amazonian urban nets did not present the same level of balance and complexity found in the dynamic regions of Brazil, or even in other developed regions of the world. In the Amazon, the economic-spatial integration promoted by globalization was not enough to significantly reduce distances between small cities and the other hierarchical levels of the urban nets, in face of a series of problems that reduce or eliminate several types of flows. Thus, deeper exploring of Amazonian specifics in this transformational context is suitable.

The fragility of Amazonian urban networks is related to the development of barriers for the flows of people, goods and services, such as: a) the long distances that separate capitals from other towns and hamlets; b) the lack of transportation and communication infrastructure in large areas of the Amazon territory; c) the large proportion of the population without material and educational resources, decisive to their active participation in the many kinds of flows (SATHLER, 2009).

In the Amazon, the great distances between local centers, middle-sized cities and the largest cities in the Region create limitations to the flows of assets, people and services between the several hierarchical urban levels. The very distribution of the urban centers in the Amazonian territory occurs rather unequally, with a clear concentration of cities in the surroundings of an "archway" formed by the large federal highways that involve and/or cut through the Region, without, however, presenting strong penetration and internal articulation

intensity with regional spaces. This creates an obvious difficulty concerning the flows between cities belonging to the "archway" and the other centers within the territory.

The lack of infrastructure in the communication and transportation sectors seems to be evident in great portions of the Amazonian territory. The low investments in urban and regional infrastructure are reflected in the creation of an environment contrary to the one needed to accelerate flows within the Region. Even in the presence of some relatively large investments in the current governmental resource distribution chart, it is possible to notice that some of them, such as the construction of large power plants, prioritize generating wealth and assets, most of which will not be distributed within the Region.

In order to better comprehend the dynamics of the Amazonian nets, it is not possible to only look at the external aspects of urban centers. It is essential to shed light upon the internal characteristics of the centers, a necessary exercise to understand the intensity and direction of flows. Once looking at the city from the inside, aiming to better comprehend the intra-urban specifics, it is easier to understand the way cities interact and integrate with each other.

In this sense, one can note that the diverse types of flows are also limited by strictly socio-economic reasons. In the Legal Amazon, as in other parts of the country, it is evident that the larger portion of the population does not have enough material and educational assets in order to actively participate in the regional and global flows, whether of goods and services or those related to social demands that are nowadays considered essential, and also those referring to more sophisticated demands, that should be available in cities relatively close, in an urban net which functions properly.

Even if some of the technological novelties of the modern world stimulate the emergence of differentiated patterns that, in certain moments, are closer to what could be seen as a *mobile net,*[1] mainly in Belém and Manaus, and that can now count almost simultaneously on all the global innovations that point towards *flexibility* and *interactivity*, it is important to bear in mind that this pattern of the world's most dynamic urban nets, in fact, is far from being solidly established in the Region.

Apart from these specifics in the functioning of Amazon's urban nets, one should also bear in mind the particularities that come from the very formation of the Region's urban spaces. In the Legal Amazon, the current conformation of the urban nets was produced by an urbanization process different from that in other regions of Brazil, hugely influenced by state interventions that have occurred since the 1960's.

The development of the *urban frontier*, which could be understood as the logistic base for the Region's quick occupation project, was boosted by the great entrepreneur incentive and by the migration policy induced and financed by the State. New centers were created, mainly in support of mining, farming and colonization projects (BECKER, 1990; 2001; 2005).

History shows that the emergence and proliferation of cities are generally directly related to the creation of surpluses in rural areas. However, it should remain clear that sometimes cities can spurt in front of fields, such as large areas in the Amazon, and the areas serve as logistic bases for the reproduction of economic activities developed around these centralities (MONTE-MÓR, 2006).

[1] The concept of a *mobile net* is suggested by Sathler (2009). Regarding the new forms of flexibility and interactivity which appeared at the turn of the millennium, it is possible to notice that nets possess more and more points that seem to change places at every moment, apart from flows that do not follow strict paths, or give off the impression of ever tracing a certain path, coming and going instantaneously, or just "being". People, companies and cities stimulate an unprecedented feeling of omnipresence. In this perspective, nets are no longer geometric. They assume visible and invisible forms, impossible to define or draw. Thus, the world gets to know not only the traditional dendritical and complex nets, counting now with vast regions that present *mobile nets*. It is worth mentioning that, unlike previous concepts which prioritize the organization form of the cities, the *mobile net* concept focuses on what is most essential in nets: the flow systems (SATHLER, 2009; SATHLER; MONTE-MÓR, 2009).

In many of the cases, Amazonian cities respond to what happens in their surroundings. In mining and deforestation areas, and even in areas taken by mechanical agriculture, the urban and industrial logic has always been present. Thus, as in other parts of the country, in vast regions of the Legal Amazon, the urbanization that exceeds city borders, favored by the development of the technical-scientific and informational environment and by the support of the strong presence of urban-industrial production relationships, could be comprehended with the help of the *extensive urbanization* concept. This term refers to the progress of the urban tissue, which exceeds city limits, generating new centralities, expressing a broad economic-spatial process (MONTE-MÓR, 1994; SATHLER, 2009).

Thus, the discussions about the urban nature in the Amazon and the urban nets in the region have raised important questions, which consider the peculiarities related to the urbanization process, spatial distribution and the intensity of material and immaterial flows. The studies on urban hierarchy have incorporated yet other relevant aspects, such as the correlations of size, power and competitiveness of regional cities.

Throughout the 20th century, a series of academic studies was produced, in which the idea of a hierarchical organization of cities appears implicitly or explicitly, basing itself on a few essential questions that have been leading theoretical and empirical efforts: why do cities present different population sizes? Is there any connection between the size and the growth of cities? How do economic activities respond to this differentiation in the demographical size of urban centers? How do economic activities create this differentiation? Is there, in fact, regularity in the population size distribution between the cities of a certain region? And if there is, why does this happen?

Overall, it is possible to state that the literature was influenced by two schools of thought. The first is supported by the Central Place Theory, developed by Christaller (1933) and improved by Lösch (1940). The second was developed, based on the urban system model, by Henderson (1974) and Krugman (1996). The Central Place Theory takes into account that different population sizes create different conditions and opportunities for the growth of economic and functional activities. Later, Henderson (1974) established a model in which the optimal size of a certain city would be influenced, mostly, by the type of economic activity.

There are other studies that are also worth mentioning, such as Zipf's in 1949, which claims the existence of an impressive empirical regularity in the distribution of urban population sizes in several regions of the world. Furthermore, the model of random city growth developed by Simon (1955) also deserves to be highlighted, since it has been commonly quoted and discussed in past decades.

More recently, the studies[2] produced within the school that is called the New Economic Geography (NEG) continue the debates, based on the idea that scale refunds, relating to city population growth, are not as constant as in Simon's (1955) model. The NEG takes into account that the city population growth would be a result of a combination between "centripetal" and "centrifugal" forces that stimulate the concentration of economic activities.

In Brazil, a study by IBGE (2008) fills a gap that has existed over past years, related to the detailed study of city influence areas and the hierarchical organization of central localities in the country. The IBGE then established the primary hubs of Brazilian urban nets in 2007 with the help of a great number of secondary information, seeking to identify the influence regions of these centers, starting from the interaction nets that connect cities.

Facing the complexity of the information brought up and used by IBGE (2008), the approach does not intend to develop a direct outline of urban hierarchy with the help of the Grade of Membership (GoM) model that exceeds the one already carried out by

[2] See Krugman (1996).

IBGE. However, it focuses on supplying a few new elements that help understanding the organization of the Amazon's urban nets. As seen in the IBGE study, the model, when applied, is based on the general idea that all of these aspects are, direct players in the hierarchical organization of cities, that is, that the "greatness" of a city and its hierarchical position in the net are not measured simply by the number of people residing there.[3]

The Grade of Membership (GoM) model

The Grade of Membership (GoM) model is used to outline profiles based on a heterogeneous and multidimensional database, which allows identifying clusters and describing the differences among them (WOODBURY et al., 1978; WOODBURY; MANTON, 1989; MANTON et al., 1994; CASSIDY et al., 2001).

In Brazil and abroad, the methodology has been widely used to prepare analyses connected to the study of epidemics and health demographics.[4] However, the method is not restricted to these research fields, since it is applicable to other studies with several other purposes. In this text, GoM will be used to broaden the possibilities of studying urban hierarchy in the Legal Amazon.

Apart from most of the cluster analysis statistic methods, GoM does not consider that people and objects are organized in well-defined groups. In GoM, a same individual (or observation) may have a certain degree of pertinence to multiple groups; hence it is also being called a fuzzy set model (MACHADO, 1997). The GoM is different from other multivariate analysis models because of its capacity to provide information on pertinence degrees towards the outlined profiles, allowing deeper analyses on the data's nature. If applied to this article's problem, it seems to be fruitful to build profiles in which municipalities possess differentiated pertinence degrees instead of defined municipality groups, such as in the cluster analysis model. Furthermore, GoM has, among others, the quality of analyzing categorical data with small samples with a large number of variables.

According to Sawyer et al. (2002), this methodology applied in delineating profiles considers that: a) the unobserved association among variable categories in the model outlines two or more well-determined profiles that are called extreme profiles; b) these extreme profiles have all the properties of classical closed sets; c) the pertinence degree to the extreme profiles are attributed to each individual. Thus, the individual that has all the characteristics of one of the extreme profiles will be 100% pertinent to that profile and 0% to the rest. The more an individual relates to an extreme profile, the higher the pertinence degree to this level. It is not unusual for them to be individuals that are equally distant to all extreme profiles, not having, therefore, characteristics that relate them to the generated profiles. d) the pertinence degrees of individuals form a fuzzy set and the higher the number of variables, the more defined is the set; e) in GoM, as the elements in this set are individual attributes, the variety issue, included and badly handled in many statistical methods, is not a problem; f) the method parameters are estimated by iterative processes and, therefore, the smaller the sample, the smaller its convergence time (Sawyer et al., 2002).

According to Sawyer et al. (2002, p. 759),

> items (c) and (d) give the method, within reasonable limits, the benefit of better results, the smaller the size of the sample and the higher the number of variables.

The authors still state that,

> as the pertinence degree of each individual is given by conjunction, in this individual, of all the variable categories in the model, the method shows, and in a very simple way, the variety included in the sample (SAWYER et al., 2002, p. 759).

[3] It is important to note that the article does not work with the database available through the IBGE (2008), it only offers a new methodological point of view with the intention of contributing towards the comprehension of the Amazonian urban hierarchy.

[4] See Sawyer et al. (2004); Alves et al. (2008); Maetzel et al. (2000); MacNamee (2004).

The method demands the estimation of a pertinence degree score for each individual, relative to the several sets, that is, the fuzzy division of the individuals, in order to obtain the extreme profiles. For each element in a fuzzy set, there is a pertinence degree score (g_{ik}) that represents the level with which element "i" belongs to the extreme profile k (*Sawyer*, 2000). These scores vary from 0 to 1: 0 indicates that the element does not belong to the set; 1 indicates that the element belongs entirely to the set. The g_{ik} represents the proportion or pertinence intensity to each extreme profile. Therefore, there are the following restrictions to the measure:

$g_{ik} \geq 0$ for each i and j

$\sum_{k=1}^{k} g_{ik} = 1$ for each i

In order to form the model and the parameter estimate (scores), the following biases are necessary, according to Woodbury et al. (1978, p. 201):

a) the random variables represented by Y_{ijl}, where "i" refers to the individual, "j" to the question and "l" to the answer category of each variable, are independent for each "i". That is, the answers to different individuals are independent;

b) the g_{ik} (k = 1, 2, …, k) are outcomes of the random vector components $\zeta_i = (\zeta_{i1}, ..., \zeta_{ik})$ with a distribution function $H(x) = P(\leq x)$. That is, GoM scores are outcomes of random variables when an individual is selected in the population. The outcome sample distribution (or scores in the sample) gives estimates for the distribution function $H(x)$;

c) if the pertinence degree g_{ik} is known, the "i" individual answers to the many Y_{ijl} questions are independent for each variable category;

d) the probability of answer "l" for the j^{th} question by an individual with the k^{th} extreme profile is λ_{kjl}. According to the model assumption, there is at least one individual that is a well defined member of the k^{th} profile. This assumption gives the probability of answer for this individual to the several levels of this question. Then, one can write this assumption as being:

$\lambda_{kjl} \geq 0$ for each k, j and l

$\sum_{k=1}^{k} \lambda_{kjl} = 1$ for each k and j

e) the probability of a level "l" answer of the j^{th} question by the i^{th} individual, conditioned to the g_{ik} score will be given by:

$$P(Y_{ijl} = 1) = \sum_{k=1}^{k} g_{ik} \lambda_{kjl} = 1"$$

According to the assumptions above, the probability model for the construction of a maximum likelihood estimation procedure is formulated. The probability model for a random sample is the product of a multinomial model by each cell probability, given by:

$$E(Y_{ijl}) = \sum_{k=1}^{k} g_{ik} \lambda_{kjl}$$

where g_{ik} is, by assumption, known and greater than or equal to zero.

Considering the assumptions above, the maximum likelihood model can be written as:

$$L(y) = \prod_{i-1}^{I} \prod_{j=1}^{J} \prod_{l=1}^{L} \left(\sum_{k=1}^{k} g_{ik} \lambda_{kjl} \right)^{yijl}$$

The software chosen to run the model is "GoM", freeware version 3.3, developed by Peter Charpentier, from the Epidemiology and Public Health Department of Yale School of Medicine, USA.

Applying GoM in the outline of urban hierarchy on the Legal Amazon

GoM uses several types of variables that aim to improve the understanding of the greatness and the power of Amazonian cities. To fulfill this task, a model that takes into account a variety of aspects which exceed the purely economic or demographic analysis is proposed. Thus, the variables which measure functionality and the ability to offer basic and specialized services are very valuable, as are indicators of access to assets and those referring to equipment and infrastructure in the city.

To generate the analysis model for the present study, only the municipalities

with a population higher than 20,000 inhabitants were taken into account. Even if the municipalities with a population between 10,000 and 20,000 could take on a certain degree of importance concerning centrality in the Legal Amazon context, only those over 20,000 were considered, focusing the analysis on the spaces which hosted the largest urban transformations in the region.

In this study, the scale chosen for the analysis is the municipality. This is due to the information available, mostly regarding municipalities and not cities. Yet, there are many issues in the legal definitions of city and field in Brazil.[5] Furthermore, the present study considers that, in many parts of the Amazon, the activities that are developed beyond the urban perimeter of a city often obey a logic far from being considered rural, minimizing the problems that may appear in this sort of approach.

Table 1 presents the list of variables present in the model, separated into six groups, according to the nature of information, such as: spatial, demographic, socioeconomic, infrastructure and services, access to assets, functional.

Including spatial variables seems to be of great importance, since urban hierarchy is also defined under the influence of the city

TABLE 1
GoM model internal variable list

Variable nature	Variables
1 - Espacial	1.1. Centrality Indicator: variable that represents the number of times the city in question was verified as being the closer urban center and with a bigger population
2- Demographic	2.1. Municipality urbanization degree
	2.2. Municipality population in 2007
	2.3. Municipality MCT (Management Commitment Term) between 2000 and 2007
	2.3. Mesoregion MCT between 2000 and 2007
3- Socioeconomic	3.1. GNP (Gross National Product)
	3.2. Value of Municipality Participation Fund
	3.3. Proportion of poor people
	3.4. Municipality HDI (Human Development Index)
4- Infrastructure and services	4.1. % of people with access to treated water service
	4.2. % of people with access to electricity service
	4.3. % of people with access to garbage collection service
	4.4. Number of fundamental learning schools
	4.5. Number of medium level learning schools
	4.6. Number of fundamental learning enrolments
	4.7. Number of medium level learning enrolments
	4.8. Number of superior level learning enrolments
	4.9. Hospitals
	4.10. Hospital beds
	4.11. Health stations
	4.12. Health centers
5- Access to assets	5.1. Vehicle fleet
	5.2. % of people with computer
	5.3. % of people with television set
	5.4. % of people with refrigerator
	5.5. % of people with telephone
6- Functional	6.1. This variable is the result of a municipality functionality matrix in relation to total (37) of functions with several levels of specialization.

Source: Elaborated by the author.

[5] See Veiga (2000) and Matos (2005).

distribution in the net, with evident impacts on how they interact and relate to each other. Variable 1.1 represents the number of times which a certain city was observed to be the closest urban center and with the largest population. Each time that a city is seen as the largest and closest to any of the 20,000-inhabitant centers (2007) in the Legal Amazon, the city gains 1 point in the so-called Centrality Indicator. Furthermore, the Centrality Indicator also accumulates points from the cities' relations to centers belonging up to the seventh order in the net, with differentiated values (0.5 for the second order, 0.25 for the third, 0.125 for the fourth and so on).

In order to build the functionality indicator (variable 6.1), the chosen functions (73) sought to include from the simplest activities, such as high schools and elementary schools, to the most sophisticated ones, such as higher education schools and the availability of Masters' courses rating 6 or 7 by CAPES.

The four profiles obtained were selected based on ten results generated with a random initial λ_{kjl}, that is, ten models were generated from four profiles. The constancy observed in the final λ_{kjl} obtained in the ten models indicated that the global maximum (mathematical criteria for optimization) was duly achieved in all models. One out of the ten models was chosen based on the coherence of the results found for the municipal population in 2007 which, without the slightest doubt, is one of the main variables regarding the apprehension of the urban hierarchy.[6] Thus, although GoM was not exclusively developed for delineating hierarchy patterns, this emerged naturally from the information, revealing profiles that matched expectations.

The profile description and denomination were performed based on the ratio between each expected probability (E) in the level (l) of the variable (j) in the extreme profile (k), that is, λ_{kjl}, and the observed probability (O) of the answer (l) of the variable (j) for any municipality (marginal probabilities). This ratio can be called, in a simplified manner, as (E/O). A ratio E/O above 1.2 is an indication that the profile has a "remarkable" or "descriptive" characteristic; this criterion is proposed by Sawyer et al. (2002).

The following profile description is made according to the expected probability (E) of each variable level relative to the observed marginal probability (O). That is, profiles are described based on the characteristics with an E/O ratio equal to or above 1.2, as seen before. It is important to point out that this description refers to the pure types (g_{ik} =1) of each profile.

Profile 1: 1) high urbanization degree (2000), above 80%; 2) average to large population (2007), greater than 50,000 inhabitants; 3) high municipal MCT (2000-2007), between 3 and 6% a year; 4) small/average positive mesoregion MCT (2000-2007), between 0.5 and 1% a year and between 1.5 and 2% a year; 5) average to high GDP (2005), higher than R$500,000,000 up to the R$12,000,000,000 or more class; 6) average/high MPF (2005), higher than R$8,000,000 up to the R$100,000,000 or more class; 7) relatively small proportion of poor people (2000) for the regional pattern, less than 45%; 8) average and high HDI (2000), between 0.71 and 0.80 or more; 9) average/high proportion of people with access to treated water supply (2000), above 60%; 10) very high proportion of people with access to electricity service (2000), above 90%; 11) high proportion of people living in urban houses with garbage collection service (2000), above 80%; 12) high number of fundamental education schools (2006), above 101 and including the class of 601 or more; 13) average/high number of medium level schools (2006), above 8.11 and including class 61.07 or more; 14) average/high number of enrollments in fundamental education (2006), above 20,001 and including class 250,001 or more; 15) average/high number of enrollments in medium level education (2006), above 2,501; 16) average/high number of enrollments in higher education (2007), above 1,001

[6] It is important to note that this selection procedure of the most adequate model is explained by Manton et al. (1994).

and including class 40,001 or more; 17) high number of hospitals (2000), above 4 and 5 or more; 18) average/high number of hospital beds (2000), higher than 101 and including the class 3,601 or more; 19) average/high number of health stations (2000), above 11 and including class 51 or more; 20) average/high number of health centers, above 3 and including class 33 or more; 21) average/high vehicle fleet (2007), above 15,001 and including class 250,001 or more; 22) average/high proportion of people living in houses with computer (2000) for the regional patterns, above 3% and including class 10.01% or more; 23) high proportion of people living in houses with electricity service and television (2000), above 80.01%; 24) high proportion of people living in houses with electricity service and refrigerator (2000), above 80.01%; 25) high proportion of people living in houses with telephone (2000) for the regional patterns, above 30%; 26) average/high/very high centrality indicator, above 2.51 and including class 30.01 or more; 27) high/average functional diversification, presenting more than 60.01% of the functionalities.

Profile 2: 1) average to high urbanization degree (2000), predominantly between 70 to 90%; 2) average size population (2007), between 30,000 and 100,000, with greater emphasis to the municipalities with more than 50,000 inhabitants; 3) very high municipal MCT (2000-2007), higher than 6% a year, or negative, between -2.99 and -1.5% a year; 4) high positive mesoregion MCT (2000-2007), between 2.5 and 3% a year and higher than 3% a year or small positive, less than 0.5% a year; 5) average/small GDP (2005), between R$500,000,000 and R$1,500,000,000 and less than R$500,000; 6) average/small MPF (2005), between R$8,000,000 and R$16,000,000 and less than R$8,000,000; 7) average proportion of poor people (2000) for the regional pattern, between 27% and 58.51%; 8) average HDI (2000), from 0.71 to 0.8; 9) average proportion of people with access to treated water supply (2000), between 40% and 80%; 10) high proportion of people with access to electricity service (2000), above 80%; 11) average proportion of people living in urban houses with garbage collection service (2000), less than 60%; 12) small number of fundamental education schools (2006), less than 50; 13) small number of medium level schools (2006), below 8.11; 14) small number of enrollments in fundamental education (2000), between 5,001 and 7,500; 15) average number of enrollments in medium level education, between 1,001 and 5,000; 16) small/average number of enrollments in higher education (2007), between 1 and 1,000; 17) average number of hospitals (2000), between 2 and 4; 18) average number of hospital beds (2000), between 101 and 400; 19) average number of health stations (2000), between 6 and 10; 20) average number of health centers, between 2 and 8 and between 17 and 32; 21) average vehicle fleet (2007), between 5,001 and 15,000; 22) average proportion of people living in houses with computer (2000) for the regional patterns, between 2% and 5%; 23) average/high proportion of people living in houses with electricity service and television (2000), between 60,01% and 90%; 24) high proportion of people living in houses with electricity service and refrigerator (2000), between 60,01 and 80%; 25) average proportion of people living in houses with telephone (2000) for the regional patterns, between 10.01% and 30%; 26) small centrality indicator, between 0.01 and 2.5; 27) average functional diversification, presenting between 40.01% and 70.01% of the functionalities.

Profile 3: 1) average urbanization degree (2000), between 50 to 70%; 2) average size population (2007), from 30,000 to 100,000, with greater emphasis to the municipalities with a population of less than 50,000 inhabitants; 3) negative municipal MCT (2000-2007), between -1.5 and 0% a year; 4) moderate positive mesoregion MCT (2000-2007), between 0.5 and 1% a year and between 1% and 1.5% a year; 5) small GDP (2005), less than R$500,000,000; 6) average/small MPF (2005), between R$8,000,000 and R$16,000,000 and less than R$8,000,000,000; 7) high proportion of poor people (2000) for the regional pattern, between 58.52% and 79.59%; 8) small HDI (2000), from 0,61 to 7; 9) small

proportion of people with access to treated water supply (2000), between 20% and 40%; 10) average proportion of people with access to electricity service (2000), between 60% to 90%; 11) average/small proportion of people living in urban houses with garbage collection service (2000), between 10% and 70%; 12) average/small number of fundamental education schools (2006), between 50 and 200; 13) small number of medium level schools (2006), inferior to 8.11; 14) average/small number of enrollments in fundamental education (2000), between 7,501 and 20,000; 15) average number of enrollments in medium level education, between 1,001 and 5,000; 16) small/average number of enrollments in higher education (2007), between 1 and 1,000; 17) small/average number of hospitals (2000), 1, 2 or 4; 18) average number of hospital beds (2000), between 101 and 400; 19) average/high number of health stations (2000), between 6 and 10 and above 31; 20) average number of health centers, between 3 and 4; 21) small vehicle fleet (2007), equal to or less than 5,000; 22) small proportion of people living in houses with computer (2000) for the regional patterns, between 1% and 2%; 23) average proportion of people living in houses with electricity service and television (2000), between 50.01% and 70%; 24) average proportion of people living in houses with electricity service and refrigerator (2000), between 40.01 and 60%; 25) small proportion of people living in houses with telephone (2000) for the regional patterns, between 5.01% and 10%; 26) average centrality indicator, between 2.51 and 5; 27) small functional diversification, presenting between 30.01% and 50.01% of the functionalities.

Profile 4: 1) average to high urbanization degree (2000), between 10 to 50%; 2) small size population (2007), from 20,000 to 30,000 inhabitants; 3) very high municipal MCT (2000-2007), between 3 and 6% a year and greater than 6% a year, or very small MCT, less than -3% a year; 4) average positive and moderately high mesoregion MCT (2000-2007), between 1 and 1.5 % a year and between 2% and 3% a year; 5) small GDP (2005), less than R$500,000; 6) small MPF (2005), less than R$8,000,000; 7) high proportion of poor people (2000) for the regional pattern, between 64.92% and 72.29% and very high, between 72.305 up to the class between 79.6% or more; 8) very small HDI (2000), less than 0.6; 9) very small proportion of people with access to treated water supply (2000), less than 20%; 10) average proportion of people with access to electricity service (2000), less than 60%; 11) small proportion of people living in urban houses with garbage collection service (2000), less than 60%; 12) small number of fundamental education schools (2006), between 50-100; 13) small number of medium level schools (2006), below 8.11; 14) small number of enrollments in fundamental education (2000), less than 10,000; 15) small number of enrollments in medium level education, less than or equal to 1,000; 16) no enrollments in higher education (2007), between 1 and 1,000; 17) small number of or no hospitals (2000), equal to 1 or 0; 18) small number of hospital beds (2000), less than 100; 19) small/average number of health stations (2000), between 11 and 20 and less than or equal to 5; 20) small number of health centers, equal to or less than 1; 21) small vehicle fleet (2007), equal to or less than 5,000; 22) very small proportion of people living in houses with computer (2000) for the regional patterns, less than or equal to 1%; 23) small proportion of people living in houses with electricity service and television (2000), less than 50%; 24) small proportion of people living in houses with electricity service and refrigerator (2000), less than 40.00%; 25) very small proportion of people living in houses with telephone (2000) for the regional patterns, less than 5.00%; 26) centrality indicator equal to 0; 27) very small functional diversification, presenting less than 40% of the functionalities.

Complementary to these descriptions, Table 2 presents the $g_{ik(s)}$ distribution in the four model profiles. The fact that, in all the profiles, 138 municipalities (57%) had a high degree of compatibility with $g_{ik(s)}$, above 0.75 (which is considered very high), is another indication that validates the profile numbers that were found and the suitability of the model to the present study

data (that is, the profiles "fit" appropriately most of the municipalities). Furthermore, 97 municipalities (40%) had $g_{ik(s)}$ between 0.51 and 0.75 (considered high). Thus, 97% of the municipalities have $g_{ik(s)}$ with amounts higher than 0.50 in one of the profiles, which is quite interesting, given almost all the municipalities have a high compatibility degree to some profile. It is worthy to point out that a municipality with a minimum of 0.51 in one profile cannot have a pertinence superior to 0.49 in any other profile.

According to Map 1, it is clear that the municipalities with a high compatibility to Profile 1 are distributed along the main roads of the Legal Amazon, especially those between Cuiabá and Rio Branco, in the outskirts of the BR 364 and BR 070: Cuiabá, Barra do Garças, Rondonópolis, Várzea Grande, Tangará da Serra, Vilhena, Ji-Paraná, Ariquemes, Porto Velho and Rio Branco. One can also find some other municipalities with a g_{ik} higher than 0.75 in the proximities of the Belém – Brasília highway, for example: Gurupi, Palmas, Araguaína, Imperatriz, Castanhal and Ananindeua. Far from each other on the map, some state capitals stand out, such as Manaus, Macapá, São Luís and Boa Vista. Out of this group of municipalities, only Sinop, on highway 163, seems farther and more out of line to the medium/large agglomerations of the region. All state capitals reached maximum compatibility with profile 1, whereas seven intermediate-sized municipalities also achieved this amount.[7]

Profiles 2 and 3, overall, present characteristics seen as intermediate in relation to the other profiles. It is worth mentioning that Profiles 2 and 3 present

TABLE 2
gik(s) distributio

Profile 1			
	Frequency	**%**	**Accumulated %**
0 – 0.25	193	79.75	79.75
0.26 – 0.50	22	9.09	88.84
0.51 – 0.75	5	2.07	90.91
0.76 +	22	9.09	100.00
Total	242	100.00	
Profile 2			
	Frequency	**%**	**Accumulated %**
0 – 0.25	164	67.77	67.77
0.26 – 0.50	20	8.26	76.03
0.51 – 0.75	22	13.22	89.26
0.76 +	26	10.74	100.00
Total	242	100.00	
Profile 3			
	Frequency	**%**	**Accumulated %**
0 – 0.25	137	56.61	56.61
0.26 – 0.50	39	16.12	72.73
0.51 – 0.75	33	13.64	86.36
0.76 +	33	13.64	100.00
Total	242	100.00	
Profile 4			
	Frequency	**%**	**Accumulated %**
0 – 0.25	136	56.20	56.20
0.26 – 0.50	22	9.09	65.29
0.51 – 0.75	27	11.16	76.45
0.76 +	57	23.55	100.00
Total	242	100.00	

Source: Elaborated by the author.

[7] Tangará da Serra, Rondonópolis, Barra do Garças, Imperatriz, Araguaína, Ananindeua, and Ji-Paraná.

very distinct spatial patterns. When it comes to municipalities with a g_{ik} higher than 0.75 in Profile 2, Map 2 makes it clear that these are concentrated in the inner region of Mato Grosso and in the eastern portion of the Legal Amazon. As for the municipalities with high compatibility rates to Profile 3, they are located in the inner region of the states of Amazonas, Acre, and in the western part of the states of Pará and Maranhão.

The municipalities that belong to Profiles 2 and 3 are demographically medium-sized. It is clear that Profile 2 municipalities, more urbanized and more populated than Profile 3, are those placed by highways and roads. Profile 3 municipalities are preferably located along the margins of the main rivers that cross the inner region. Maps 2 and 3 seem to suggest that the influence of the highway contributed, more than the traditional transportation means in the region, to this size differentiation, urbanization degree, and functional diversity, among others.

Profile 4 municipalities with an elevated $g_{ik(s)}$ are concentrated in the inner regions of Pará and Maranhão, and, on a smaller scale, in the states of Amazonas, Acre and Rondônia (Map 4). The municipalities with a high compatibility with Profile 4 were the ones with more pure types (30) in relation to the other profiles.

Applying GoM seems to suggest that the use of strictly demographic criteria would be capable of delimitating, with a certain amount of efficiency, urban hierarchical levels, given, in the Legal Amazon, many of the variables (socioeconomic, infrastructure and services indicators, access to assets and functional diversity) are positively correlated with the population size of the municipalities. That is, the less populated municipalities with high compatibility to Profile 4 are also those with the worst socioeconomic indicators and the highest needs of basic services, as well as low access to assets. The intermediate-sized municipalities, with high compatibility rates to Profiles 3 and 2, seem to be in a more favorable situation than those in Profile 4. The municipalities with a high compatibility to Profile 1, with medium/large population sizes, are those that offer the "best" socioeconomic indicators in the Region.

However, the model showed some interesting results that escape from this general trend. In the case of Santarém, the largest city in the inner region of the Amazon (non-capital), the compatibility to Profile 1 was relatively low (0.65 to Profile 1), considering its demographic size. Municipalities with less than half its population, such as Ji-Paraná and Araguaína, appear as pure Profile 1 types, amounts that are well above Santarém's. Marabá (0.57) with almost 200,000 inhabitants, Itaituba (0.25), Abaetuba (0.36), Parauapebas (0.43), and Parintins (0.28), all with population sizes above 100,000 inhabitants, also present low compatibility to Profile 1, considering the demographic size of these municipalities.

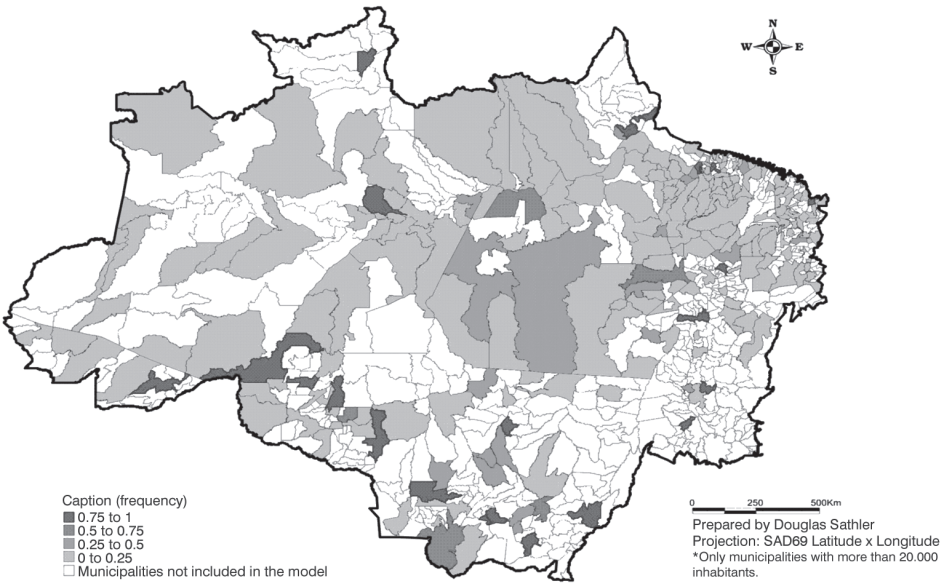
Some of the model variables caused many medium-sized municipalities to be included as pure Profile 1 types along with large municipalities, such as São Luís, Belém and Manaus. This seems to make sense in some variables. In order to have a general idea, the level of some medium-sized municipal functional diversity is very close to what was verified for the largest cities of the region. Besides, the variables that measure percentage, proportion and degree also contribute to this result.

The results of the model suggest that the position of a certain center in the Amazonian urban nets is largely influenced by variables, which relate to social differences, poverty, and the municipalities' capacity of providing several kinds of services to the population.

Probably, the findings in this article may not repeat themselves in the country's more dynamic nets, such as in the state of São Paulo, in which the demographic size may, in a balanced manner, be far more well adjusted to the centralities' functional size, and the variables related to the social differences and poverty will probably not be as defining in the small and middle-sized centers' classification.

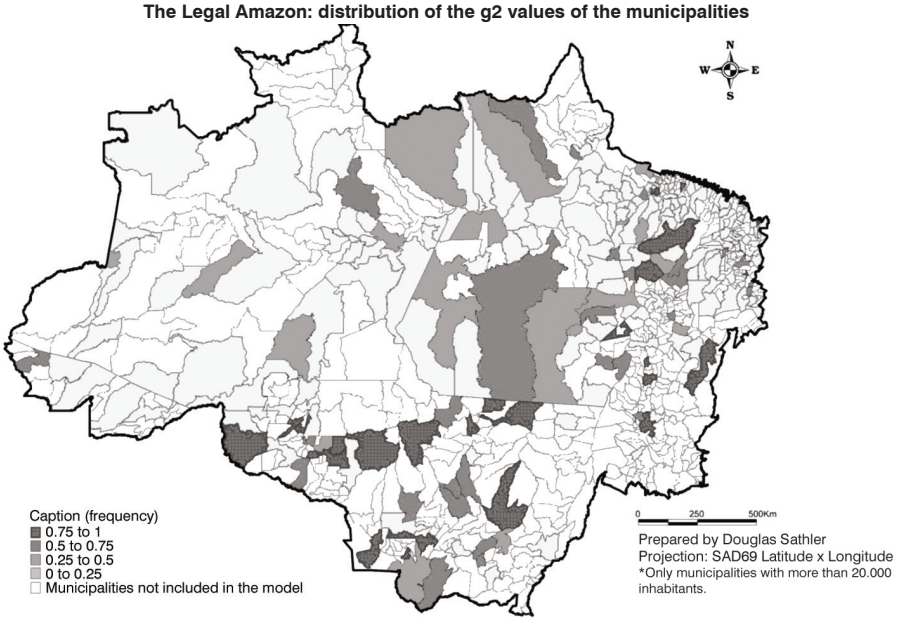
The study of urban hierarchy seems to shed light on a number of issues referring to the functioning of the Region's urban nets, providing support for the design of public policies. For comparison purposes, considering the Amazonian urban nets' specifics, which were discussed in the

MAP 1
The Legal Amazon: distribution of the g1 values of the municipalities



Source: IBGE. Censo Demográfico de 2000, Contagem da População de 2000, Atlas de Desenvolvimento Humano do Brasil 2000, Estatísticas de Saúde 2000, Perfil dos Municípios – Cultura 2006. Inep 2006. Banco Central 2004. Elaboration by the author.

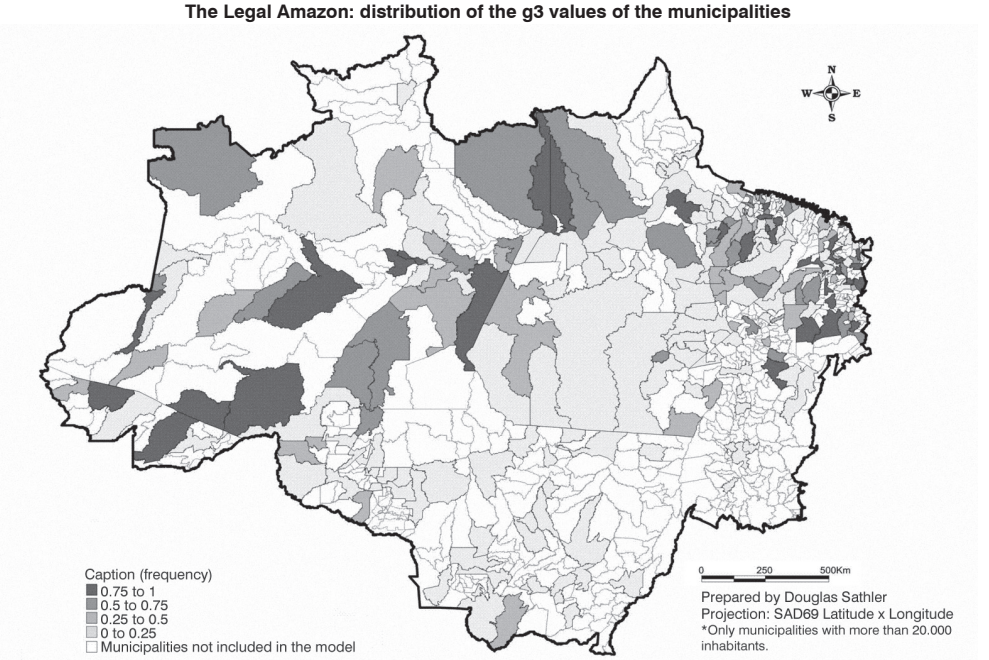
MAP 2
The Legal Amazon: distribution of the g2 values of the municipalities



Source: IBGE. Censo Demográfico de 2000, Contagem da População de 2000, Atlas de Desenvolvimento Humano do Brasil 2000, Estatísticas de Saúde 2000, Perfil dos Municípios – Cultura 2006. Inep 2006. Banco Central 2004. Elaboration by the author.

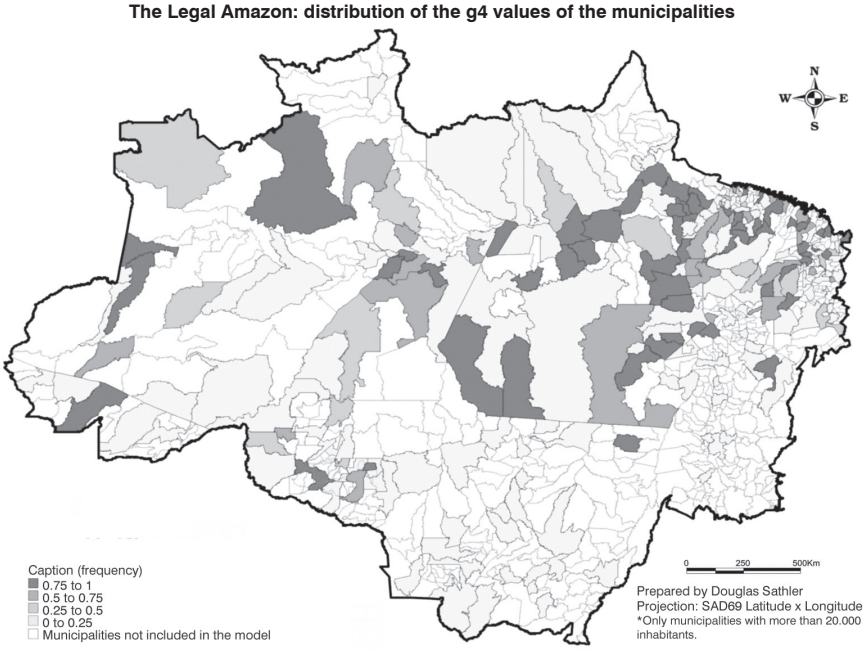
previous topic, it is possible to notice some of the localities which, on a national scale, present an intermediate demographic size and have the responsibility of being

MAP 3
The Legal Amazon: distribution of the g3 values of the municipalities



Source: IBGE. Censo Demográfico de 2000, Contagem da População de 2000, Atlas de Desenvolvimento Humano do Brasil 2000, Estatísticas de Saúde 2000, Perfil dos Municípios – Cultura 2006. Inep 2006. Banco Central 2004. Elaboration by the author.

MAP 4
The Legal Amazon: distribution of the g4 values of the municipalities



Source: IBGE. Censo Demográfico de 2000, Contagem da População de 2000, Atlas de Desenvolvimento Humano do Brasil 2000, Estatísticas de Saúde 2000, Perfil dos Municípios – Cultura 2006. Inep 2006. Banco Central 2004. Elaboration by the author.

the final destination. This instability, that is very difficult to solve, imposes on these middle-sized centers a wider array of social demands, unlike what happens in centers of the same size in a balanced urban net. Thus, managers and policy designers should notice these spatial peculiarities, when organizing the Region's public services availability, especially those that are considered basic.

Conclusion

With regard to the organization of the cities of the Amazon's urban nets in hierarchical levels, theoretical considerations suggest that the centrality condition attributed to a certain city is related to an association of qualities and characteristics. So, it is often the case that the studies that sought to understand the hierarchical organization of the cities were closely linked to the demographical size and to the way in which this variable influenced the economic variables and the functions of urban agglomerations or vice-versa. That being the case, it is possible to state that urban hierarchy is not adequately evaluated if focusing merely on the demographical size of the centers, or even on the way the population size of a city is affected by economic variables. Even when it comes to the Legal Amazon, where, as seen before, there generally is regularity in population sizes with variables of different kinds in the definition of hierarchical patterns, it is noteworthy that some municipalities seem to escape this trend.

The GoM model showed that a municipality in the inner region, with a high degree of compatibility with Profile 1, that is, with a g_{ik} higher than 0.75, is more likely to contain a centrality that plays a functional role closer to what is understood as a "medium city", considering all the conceptual complexity inlaid in the term. Thus, 23 municipalities presented a high g_{ik} in Profile 1. They include all the state capitals of the Legal Amazon, which were qualified as being pure Profile 1 types. Considering that a state capital, even a demographically middle-sized one, is generally on the top of the regional hierarchy and, therefore, would not be qualified as a medium city, it is noteworthy that, in this discussion applied to the Amazon, the municipalities of Ji-Paraná, Araguaína, Imperatriz, Barra do Garças, Rondonópolis, Tangará da Serra, Várzea Grande, Ariquemes, Sinop, Gurupi, Castanhal, and Vilhena stand out due to the high compatibility with Profile 1, which is characterized by a medium/large population size, high degree of urbanization, high functional diversification, and medium/high GDP (Gross Domestic Product).

The GoM demonstrated that some municipalities that contain cities of expressive population contingent in the inner region of the Amazon (not the capitals) do not present a high compatibility with Profile 1, which is an evidence of the existing needs in part of the medium-sized municipalities in the region, such as in Santarém—the largest city in the inner region of the Amazon—,Marabá, Itaituba, Parauapebas, Abaetetuba, and Parintins.

The GoM also permits evaluating the existence of differentiated patterns in the location's influence (highway – border areas / rivers – countryside) regarding model variables, since the description and spatialization of the municipalities with a high compatibility with Profiles 2 and 3 shows this very clearly.

Profile 2, characterized by its medium to high urbanization degree (between 70% and 90%), by medium-sized population (30,000 to 100,000) and low to medium GDP (from R$ 500,000,000 to R$ 1,500,000,000), encompasses a group of municipalities found predominantly in the "archway" that cuts through all the southern portion of the region. Profile 3 is characterized by a medium urbanization degree (from 50% to 70%), by a medium-sized population (30,000 to 100,000 people) and GDP lower than R$ 500,000,000, and includes municipalities located in a dispersed manner through the forest, and, mainly, near the main rivers of the region. It is noteworthy that, in this case, the population, when analyzed alone, does not help to differentiate Profile 2 from 3.

Thus, it seems evident that spatial and functional variables exert an influence on

the model's final result. Understanding the differences and particularities of the isolated cities and the road arch cities seems to be an interesting exercise, since the urban hierarchy model suggests differences that interact with the urban nature and the regional urban net dynamics.

Profile 4 is characterized by small municipalities that are little urbanized (from 10 to 50%), by a small-sized population (between 20,000 and 30,000 inhabitants), by a GDP lower than R$ 50,000,000 and by high proportion of poor people in the year 2000, between 64.92% and 79.6%. These municipalities are not located along the main roads of the region, but instead they are found near rivers and secondary roads, especially in the states of Pará and Maranhão.

Furthermore, GoM used two variables that aimed to make the model more reliable: the Functionality Indicator and the Centrality Indicator. With this methodological novelty, the analysis of the hierarchical patterns represented in the model by the 4 profiles were closer to what could be understood as a "methodological ideal", difficult to be applied empirically due to the complexity of the subject, but included in studies theoretically based. As for future studies, which will seek to understand the hierarchical urban organization of other regions of the country and of the world, these indicators may be incorporated if adapted to the regional reality.

Understanding the hierarchical organization of the cities in the Amazon seems to be a very important exercise in order to comprehend the dynamics and specific characteristics of regional urban nets. In this way, it is evident that policies which stimulate the establishment of more structured urban nets in the Amazon are needed. A more balanced population distribution throughout the territory could bring a series of benefits, especially when it comes to the offer and access to all different sorts of services.

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Resumo

A hierarquia urbana na Amazônia

O modelo Grade of Membership (GoM) é utilizado para delinear perfis, com base em um banco de dados heterogêneo e multidimensional, o que permite identificar grupos (*clusters*) e descrever as diferenças entre os mesmos. Neste trabalho, o GoM utiliza diversos tipos de variáveis, que objetivam uma maior compreensão da grandeza e da capacidade de influência das cidades amazônicas. Para cumprir tal tarefa, propõe-se um modelo que considera uma diversidade de aspectos que extrapolam as análises de ordem puramente econômica ou demográfica. Entender a organização hierárquica das cidades na Amazônia parece ser um exercício de grande importância para a compreensão do dinamismo e das especificidades das redes urbanas na região. Nesse sentido, parece evidente a necessidade de políticas que incentivem o estabelecimento de redes urbanas mais estruturadas na Amazônia. Uma distribuição mais equilibrada da população ao longo do território amazônico poderia trazer uma série de ganhos, sobretudo no que se refere à oferta e ao acesso a serviços de diversos tipos e níveis de sofisticação.

Palavras-chave: Amazônia. Distribuição espacial da população. Hierarquia urbana. Grade of Membership (GoM).

Resumen

La jerarquía urbana en la Amazonia

El modelo Grade of Membership (GoM) se utiliza para trazar perfiles, en base a un banco de datos heterogéneo y multidimensional, lo que permite identificar grupos (*clusters*) y describir las diferencias entre los mismos. En este trabajo, el GoM utiliza diversos tipos de variables, que tienen como objetivo una mayor comprensión de la grandeza y de la capacidad de influencia de las ciudades amazónicas. Para cumplir tal tarea, se propone un modelo que considera una diversidad de aspectos que extrapolan los análisis de orden puramente económico o demográfico. Entender la organización jerárquica de las ciudades en la Amazonia parece ser un ejercicio de gran importancia para la comprensión del dinamismo y de las especificidades de las redes urbanas en la región. En este sentido, parece evidente la necesidad de políticas que incentiven el establecimiento de redes urbanas más estructuradas en la Amazonia. Una distribución más equilibrada de la población a lo largo del territorio amazónico podría proporcionar una serie de beneficios, sobre todo en lo que se refiere a la oferta y acceso a servicios de diversos tipos y niveles de sofisticación.

Palabras-clave: Amazonia. Distribución espacial de la población. Jerarquía urbana. Grade of Membership (GoM).

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