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A DEMOGRAPHIC DYNAMICS SYSTEM FOR BRAZILIAN AMAZON MUNICIPALITIES

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ABSTRACT

Population growth and migration represent an important underlying cause of deforestation in the Brazilian Amazon. Models designed to simulate deforestation should therefore incorporate a demographic dynamics system to help project the influence of these variables on the location and rates of deforestation across the basin. We present a demographic model that projects population at municipality level by computing migratory movements among Brazilian Amazon municipalities, both in and out of the region, as well as their crude birth and mortality rates. The annual projections from 1995 to 2035 are based mainly on mortality, fertility, and migration data from the 1991 and 2000 IBGE censuses. The model assumes a logistic curve to project the municipalities' crude birth and mortality rates, which are obtained using specific functions of fertility and mortality by age. The migratory movements were determined by establishing an origin-destination matrix for all the Brazilian Amazon municipalities and Brazilian states from 1995 to 2000. Vensim, a system-thinking software which allows for the solution of simultaneous equations for the 810 defined spatial units by employing integration techniques, such as the Runge-Kutta method, is used to implement the simulation model. Validation was performed comparing the model output with 2000 IBGE municipality census data. The model is designed to handle various scenarios of regional migration to expand infrastructure across the Brazilian Amazon region.

Keywords: demographic model; regional migration; Brazilian Amazon.

JEL: R19

1. Introduction

The Brazilian population has experienced, over the last decades, an extreme change in its demographic profile, such as the rapid decline of fertility and the acute increase in longevity even though mortality has risen due to a sharp increase in violence.

Although the overall growth of the Brazilian population is decelerating, large internal migrations still continue to shape its territorial distribution, especially across the Brazilian Amazon region, where large fluxes of people seeking better life opportunities help push the agricultural frontier forward, driving deforestation to inner fronts. Thus, the Brazilian socio-economic dynamic has been one of the major drivers of the large environmental changes which have recently affected the Brazilian Amazon region. Therefore, studies of land-use planning should incorporate the analysis of population movements over time and space to assess their current and future potential for environmental change. In this way, population projections for relatively small spatial units, such as the municipalities, should provide insights, both in the short and long terms, regarding the likely anthropic pressure on a region's natural resources (Monteiro and Sawyer, 2001).

Methods for population projections of small areas generally use a way to calculate the population of small areas, which compose a larger area, based upon the population projected for larger areas. Studies which employ and compare these methods are, however, scarce in present literature. The most widely used in Brazil include the c*oefficients* and the *cohort relation* methods. Proposed by Pickard (1959), the so-called "Apportionment Method", consists of projecting the population of smaller areas based on their contribution to the absolute population growth expected for a said region which encompasses all of the small areas in question (Waldvogel, 1998). In Brazil, Madeira & Simões (1972) were pioneers in applying their so-called "coefficients method" to estimate the urban and rural populations of the Brazilian states from 1960 to 1980. The *cohort relation*, by contrast, was proposed by Duchesne (1989) and requires, as basic data, the population composition by sex and age for the smaller areas that make up the region as a whole in addition to the population data projected for the entire region. This method has the advantage of taking into account the age structure of the population and changes in its demographic components: mortality, fertility, and migration.

In Brazil, population projections for small areas involve problems of various natures, such as the inappropriateness of traditional analytical methods; the inaccuracy of basic data, such as the initial population; and the difficulty of including migratory movements in sufficient detail. There are, however, some studies developed to improve these projections, among these Waldwogel (1998), Freire & Assunção (2000), Assunção (2000), and Jannuzzi (2000) stand out. It is within this context that the present study has developed a system to simulate the demographic dynamics among the Brazilian Amazon municipalities and the remainder of Brazil. To build the model, we derived functions of mortality and fertility and net rates of migration for each municipality, as well as a matrix of all migratory movements, using data from 1991 and 2000 Demographic Censuses, among other sources. Also, to apply the system for projections up to 2035, we have made hypotheses regarding the future evolution of these components.

Therefore, the designed system allows one to estimate the evolution of the rural and urban population of the Brazilian Amazon municipalities via three fundamental components of demographic dynamics: mortality, fertility, and migration. As a result, the simulation system can be used to handle various scenarios of migration and their impact on the regional patterns of land-use change, such as deforestation, across the Brazilian Amazon.

2. *Methods*

This work is divided into the following methodological steps: (1) Matching the Brazilian Census Sectors of 1991 and 2000; (2) estimating the local population by sex and age for the years of 1990, 1995, and 2000, according to the network of Brazilian municipalities from 2000; (3) estimating crude death rates (CDR), crude birth rates (CBR), crude rates of out-migration (CROM), and urbanization rates (UR) for the Brazilian Amazon municipalities and Brazilian states outside the Brazilian Amazon region; (4) determining the origin-destination matrix for the migratory movement among the locations; (5) implementing the dynamic system; (6) validating of the model; (7) Projecting Mortality (CDR), Birth (CBR), Emigration (CROM), and Urbanization (UR) up to 2035.

Matching the Brazilian Census Sectors of 1991 and 2000

Firstly, to derive the data needed to set up the system, it is necessary to deal with the changes which occurred within the Brazilian municipality network between 1991 and 2000. According to the Brazilian Institute of Geography and Statistics (IBGE), in 1970, Brazil consisted of a total of 3,950 municipalities plus the Federal District. This number remained practically unchanged throughout the 70's. After 1980, the number of municipalities has virtually proliferated with the appearance of 1,516 new municipalities by 2000, when Brazil had a total of 5,560 municipalities plus the Federal District. This represents a 40 %increase over nearly three decades.

The dismembering of larger municipalities into two or more smaller ones creates great obstacles to the direct application of population projection methods since one would need to reassemble the municipality data for comparison purposes. Thus, for the appropriate application of the population projection methods, discussed later in this text, one needs either to compile the past census data in such a way as to reconstruct the current territorial units or to break down the data of current territorial units into its former units.

So as to obtain information about a location that had not been emancipated at a given time, it was necessary to break down the information prior to that time into smaller geographic units of interest and re-arrange them according to a new desired configuration. The census sector is the smallest geographic unit. Each municipality is made up of a group of census sectors. Thus, it is necessary to access the census data at the sector level in two consecutive Demographic Censuses in order to estimate, in the first census, the population of a municipality that was created between the two censuses. This would be true provided the census sectors had undergone no dismemberment, analogous to that of the municipalities, from one census to another. The definition of census sectors obeys specific criteria, such as: average number of homes, local population, rural establishments, etc. Thus, it is natural for these areas to change over time. Fortunately, the dismembering of border sectors represents few exceptions.

Once census sectors of both censuses have been matched, accurate estimates of the local population of the 795 locations, which constituted the Brazilian Amazon municipality network in 2000, were obtained for 1991, compiling demographic census tract data.

Estimates of the local population in 1990 and 1995

As a next step, population by sex of each municipality, conserving the age structure observed in 1991, was extrapolated retroactively to 1990 by using the annual growth rates observed from 1991 to 2000. Since the majority of Demographic Censuses are carried out within a ten year period, Duchesne (1989) proposes an algorithm for the estimation of the local population at the end of the first five year period, using data from the two encompassing Demographic Censuses. The procedure was adapted by Garcia & Carvalho (2005), who made slight modifications to the original method, such as the application of the *woman child ratio*, proposed by Lee (1957), to estimate the population between zero and four years old.

As a result of the application of the aforementioned method, population estimates by sex and age were obtained for 1990 and 1995 for all existing Brazilian Amazon municipalities in 2000, plus the 18 remaining Brazilian states. This allowed for the calculation of crude birth and mortality rates, based on the specific rates of fertility and death, as explained below.

Estimates of crude mortality rates

Crude mortality rates were obtained via estimation of age specific probabilities of death, which were calculated using a logit adjustment on the parameters of the standard curve of probability of death published in the 1991 and 2000 Atlas of Human Development (FJP, 2003). The logit adjustment is expressed as follows:

$$Y_x = a + bY_x^s$$

where

$$Y_x = 0{,}5\ln^{[(1-q_x)/q_x]} \text{ e } Y_x^s = 0{,}5\ln^{[(1-q_x)/q_x^s]}$$

in which q_x and q_x^s are, respectively, the probability of death *q,* at age *x*, published and standard. Once the functions of the age specific mortality rates (EMR) had been obtained, the Crude mortality rate (CDR) was calculated according to:

$$CDR_J^A = \frac{\sum_J EMR_x^A \, {}_J P_x^A}{\sum_J P_x^A}$$

in which ${}_{J}EMR_{x}^{A}$ is the specific mortality rate at age x, in year A, for location J and ${}_{j}P_{x}^{A}$ is the population in year A of age x in location J.

Estimates of crude birth rates

Crude birth rates of the Brazilian Amazon municipalities were obtained via estimates of age specific fertility rates, calculated through the ratio of the total fertility rate (TFT) observed in the demographic census data and those published by the Atlas of Human Development from the João Pinheiro Foundation (FJP, 2003), for the years of 1992 and 2000. This adjustment was denoted as follows:

$$CBR_{J}^{A}=\frac{\sum {}_{J}f_{x}^{A}\left({}_{J}TFR_{c}^{A} \Big/ {}_{J}TFR_{s}^{A} \right)}{\sum {}_{J}P_{x}^{A}}$$

in which a CBR_{J}^{A} is the crude birth rate in year A, at location J ; ${}_{j}P_{x}^{A}$ is the population at age x, in year A, at location J; ${}_{j}f_{x}^{A}$ is the female population at age x, in year A, at location J, who declared to have had a ever born child within the 12 months that preceded the research; ${}_{J}TFR_{c}^{A}$ and ${}_{J}TFR_{s}^{A}$ correspond to the total fertility rates, in year A, at location J, taken, respectively, from the demographic censuses (c) and from that published by FJP (s).

Estimates of annual urbanization rates

The annual urbanization rates were calculated from the variation in degree of urbanization from 1991 to 2000. The degree of urbanization corresponds to the percentage of urban population divided by the total population:

$$TU_{J}^{a}=\left(\frac{{}^{u}P_{J}^{A} \Big/ {}^{t}P_{J}^{A}}{{}^{u}P_{J}^{A-x} \Big/ {}^{t}P_{J}^{A-x}}\right)^{1/x}-1$$

in which ${}^{u}P_{J}^{A}$ is the urban population in year A and ${}^{t}P_{J}^{A}$ is the total population in year A.

Estimates of annual emigration rates

Once the averages of crude birth and mortality rates had been obtained, it was possible to calculate the crude rates of natural increase (CRNI) in the 792 municipalities that make up the Brazilian Amazon region plus 18 remaining Brazilian states, during the 1990's, according to the following equation:

$$CRNI_{J}^{m}=CBR_{J}^{m}-CDR_{J}^{m}$$

With this, a proxy of the net migration rate (MR) could be calculated by subtracting the crude rates of natural increase (CRNI) from the total growth rate (TGR):

$$TM_J^m = TGR_J^m - CRNI_J^m$$

As a result, the emigration rate was obtained through an adjustment between the net migration rates obtained directly from the 2000 Demographic Census data and TM's calculated by the aforementioned procedure, based on expected populations without migration, at the end of the period of reference, in such a way that:

$$\overline{P}_J^A = P_J^{A-X}(1 + CRNI_J^m)^X$$

for X = 0, 1, 2, 3 e 4.

$$\overline{P}_J^A = P_J^A + E_J^{d.f.} - I_J^{d.f.}$$

in which $\overline{P}_J^A$ is the expected population, in year A (A = 2000), without migration, at location J; $E_J^{d.f.}$ and $I_J^{d.f.}$ are, respectively, the out-migrants and in-migrants of fixed data from the 2000 Demographic Census plus its indirect effects.

Once the total number of emigrants has been corrected for the period between 1995 and 2000, for all municipalities and states, one need only calculate the annual crude rates of out-migration, according to the following equation:

$$CROM_J^a = \left(\frac{\overline{P}_J^A - E_J^a}{P_J^{A-5}} \right)^{1/5} - 1$$

in which $CROM_J^a$ is the annual crude rates of out-migration, for the period of 1995-2000, for location J.

The origin-destination matrix of recent migratory movement

After estimating the annual out-migration rates, the next step consists of identifying the percentage of migrants received by each location. For this purpose, the 1991 and 2000 Brazilian Demographic Census micro-data provide information regarding where each person was residing exactly five years prior to the census survey. This allowed us to identify the contribution of emigrants from one location to another during the five years preceding each census, i.e. 1986 to 1991, for the 1991 Census, and 1995 to 2000 for the 2000 Census. Since no major changes in migration trends occurred from one census to the other, we adopted the 1995-2000 migration matrix. Out-migrants (E_{IJ}^A) originating from location I and heading for location J – or, in other words, the in-migrants in location J who had come from location I – were calculated, for year A, in the following manner:

$$E_{IJ}^A = P_I^{A-1}(1 + (CBR_I^m - CDR_I^m)(CROM_I^a)Q_{IJ})$$

Fig. 1 illustrates part of the 810X810 migration matrix obtained from the 2000 Demographic Census micro-data, which informs the location of residence of the Brazilian population on August 1, 1995.

Figure 1.

Migration matrix (Q)

Residence in 2000 **out-migrants** →

Residence in 1995

in-migrants ↓

	Município de Residência em 2000																
Código do município		1100015	1100023	1100031	1100049	1100056	1100064	1100072	1100080	1100098	1100106	1100114	1100122	1100130	1100148	1100155	110018
	Nome do município	Alta Flores	Ariquemes	Cabixi	Cacoal	Cerejeiras	Colorado d	Corumbiar	Costa Mar	Espigão D	Guajará-M	Jaru	Ji-Paraná	Machadinh	Nova Brasi	Ouro Pretc	Pimenta
Município de Residência em 1995	1100015 Alta Floresta D'Oeste	0	0	0	183	13	0	0	0	0	0	0	44	0	61	0	3
	1100023 Ariquemes	48	0	12	150	20	0	0	10	24	59	253	636	714	29	126	2
	1100031 Cabixi	0	0	0	0	103	78	16	0	0	0	0	0	0	0	0	
	1100049 Cacoal	144	232	0	0	0	11	7	146	279	0	83	480	224	212	121	32
	1100056 Cerejeiras	0	28	100	117	0	98	504	20	0	0	43	47	7	39	0	5
	1100064 Colorado do Oeste	21	57	295	126	243	0	272	39	10	0	28	56	14	0	55	3
	1100072 Corumbiara	0	0	0	0	434	94	0	0	0	0	0	0	0	0	10	1
	1100080 Costa Marques	9	9	0	0	0	72	0	0	0	286	0	151	0	0	119	1
	1100098 Espigão D'Oeste	105	44	0	366	33	0	0	19	0	0	11	26	0	0	47	15
	1100106 Guajará-Mirim	47	97	0	152	27	0	0	147	0	0	12	63	69	11	10	3
	1100114 Jaru	64	851	0	149	0	0	0	7	7	75	0	337	903	54	281	3
	1100122 Ji-Paraná	22	963	4	460	34	12	0	158	67	78	340	0	709	186	488	3
	1100130 Machadinho D'Oeste	0	384	30	0	0	31	0	0	0	20	125	105	0	0	142	
	1100148 Nova Brasilândia D'Oeste	99	0	0	28	0	0	0	0	0	0	0	8	16	0	23	
	1100155 Ouro Preto do Oeste	7	286	2	71	0	0	0	29	0	30	741	643	393	5	0	
	1100189 Pimenta Bueno	173	150	19	576	14	43	0	62	507	0	11	237	0	0	36	
	1100205 Porto Velho	64	1063	4	476	56	111	0	85	31	991	180	1179	95	34	207	12
	1100254 Presidente Médici	52	83	4	172	8	6	0	83	46	0	0	335	153	121	61	4
	1100262 Rio Crespo	0	0	0	0	0	0	0	0	0	0	0	14	49	0	0	
	1100288 Rolim de Moura	317	185	0	486	36	0	0	77	89	13	51	610	73	487	15	23
	1100296 Santa Luzia D'Oeste	303	0	0	69	0	0	23	27	9	0	0	0	0	6	34	11
	1100304 Vilhena	0	154	96	353	270	123	64	6	87	99	110	268	68	0	81	4
	1100320 São Miguel do Guaporé	0	43	0	161	10	0	2	7	39	0	0	184	0	113	57	4
	1100338 Nova Mamoré	0	60	0	29	0	0	0	0	0	133	21	0	0	0	0	
	1100346 Alvorada D'Oeste	25	11	0	155	0	0	0	63	56	0	22	449	37	197	136	
	1100379 Alto Alegre dos Parecis	121	68	0	77	0	0	0	0	0	0	0	22	0	0	0	
	1100403 Alto Paraíso	0	183	0	0	0	0	0	0	0	0	18	31	49	0	14	
	1100452 Buritis	0	32	0	48	23	0	20	0	0	0	0	45	0	17	26	
	1100502 Novo Horizonte do Oeste	38	0	0	49	0	0	0	0	0	0	0	0	0	21	0	
	1100601 Cacaulândia	0	183	0	0	0	0	0	0	0	0	66	0	20	0	0	
	1100700 Campo Novo de Rondônia	0	97	0	0	65	0	0	0	0	0	24	28	0	0	0	
	1100809 Candeias do Jamari	0	53	0	0	0	0	0	0	0	0	37	52	0	0	74	
	1100908 Castanheiras	0	0	0	12	0	0	0	0	0	0	0	0	0	0	0	1
	1100924 Chupinguaia	9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
	1100940 Cujubim	0	159	0	0	0	0	0	0	0	0	0	0	24	0	0	
	1101005 Governador Jorge Teixeira	0	0	0	11	0	0	0	0	0	0	116	0	0	0	0	
	1101104 Itapuã do Oeste	0	31	0	0	0	0	0	0	0	0	0	0	0	0	0	
	1101203 Ministro Andreazza	0	0	0	355	0	0	0	0	0	0	0	0	0	0	0	
	1101302 Mirante da Serra	0	140	12	11	0	0	0	0	0	0	118	135	28	0	307	
	1101401 Monte Negro	0	153	0	0	26	0	0	0	0	0	0	50	38	13	0	
	1101435 Nova União	0	12	0	4	0	0	0	0	0	0	0	9	0	0	97	
	1101450 Parecis	0	0	0	0	0	0	0	0	11	0	0	0	0	33	10	3
	1101468 Pimenteiras do Oeste	0	0	0	0	0	0	0	3	0	0	0	0	0	0	0	
	1101476 Primavera de Rondônia	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5
	1101484 São Felipe D'Oeste	0	0	0	46	0	0	0	0	0	0	0	0	0	0	0	9
	1101492 São Francisco do Guaporé	0	0	0	0	0	0	0	73	33	10	0	70	0	52	0	2

Validation of the population projections

The equations below calculate population at a time *t* as a function of population at time *t-1*. All estimates refer to the period of one year, and the population growth equations were represented in their discreet form (PRESTON, HEUVELINE & GUILLOT, 2001, p. 03-20)**.** This is, in fact, a discreet version of the model equation, which is solved simultaneously by using the Runge-Kutta integration techniques implemented in Vensim (Ventana Systems, 2005).

$$P_J^{1996} = P_J^{1995}(1+(CBR_J^m - CDR_J^m - CROM_J^a)) + \sum P_I^{1995}(1+(CBR_I^m - CDR_I^m)(CROM_I^a))Q_{IJ}$$

in which P_J^{1995} is the population in 1995 and Q_{IJ} is the percentage of migration from location *I* to location *J* during the period of 1995-1996.

Fig. 2 depicts the system structure for the simulation of population growth, designed using a Vensim graphic interface. Arrows indicate the relationships between each pair of system elements. In this manner, one can quickly access information from rural, urban, or total population contingents to the number of deaths in a given municipality, for each year during the period of simulation.

The comparison between the data estimated by the system of equations and that observed directly in the 2000 Demographic Census data is illustrated in Fig. 3. For the purpose of public policy orientation, the IBGE annually publishes population estimates for all Brazilian municipalities. In this manner, it was also possible to compare the results obtained with those divulged by the FJP for 2004 (Fig. 4).

Figure 2. Population system dynamics as implemented in Vensim.

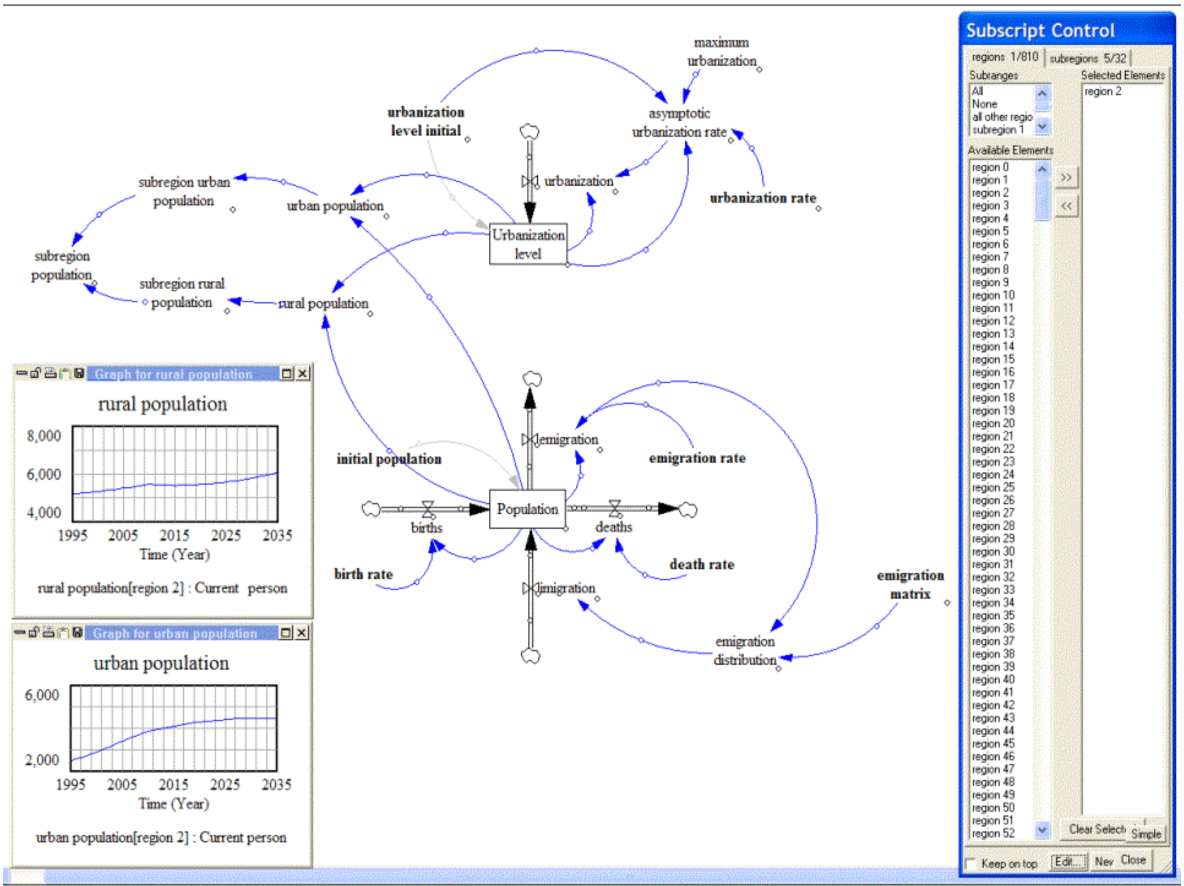
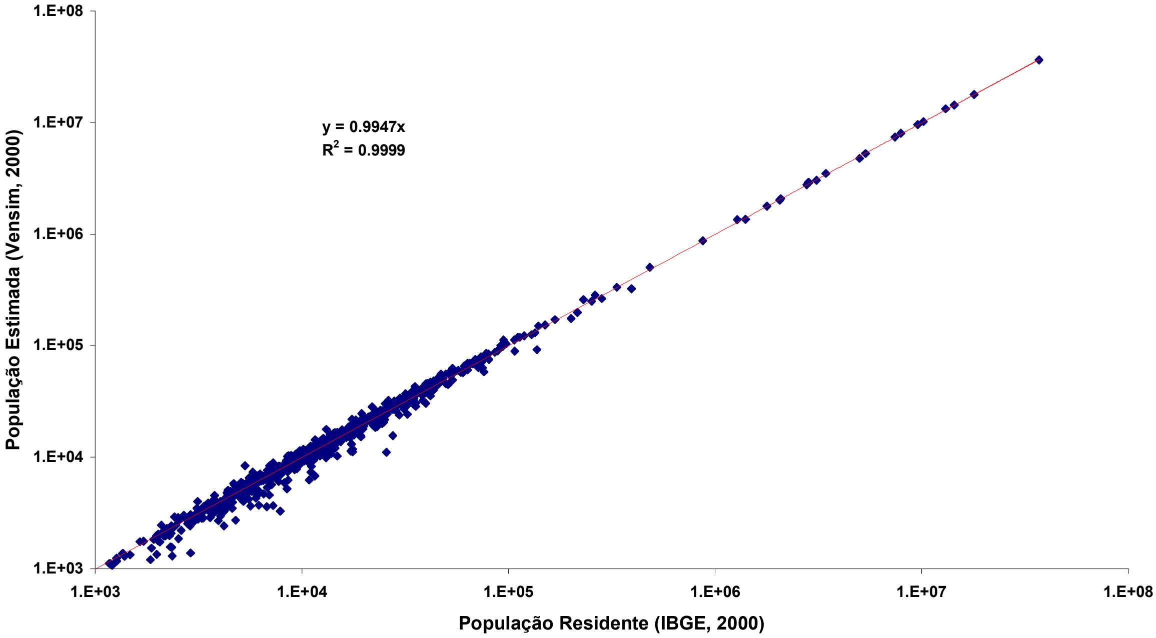
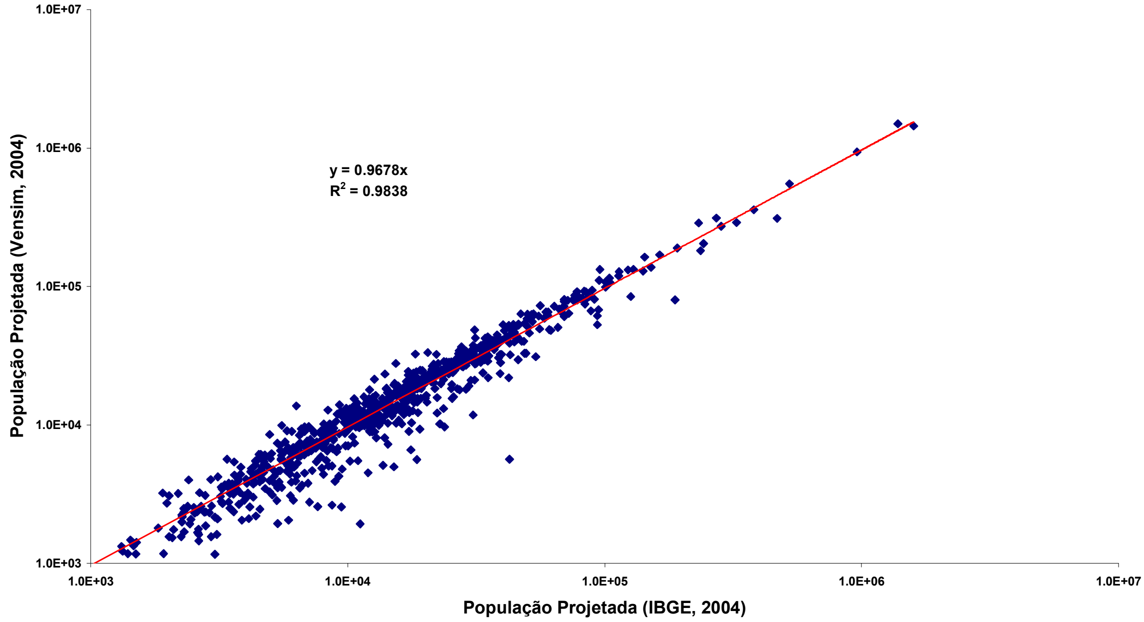


Figure 3. Validation of the Demographic Dynamics System of Brazilian Amazon municipalities. Total local population in 2000 (IBGE) versus estimated population.



Source: IBGE. 2000 Demographic Census and own estimations.

Figure 4. Validation of the Demographic Dynamics System of Brazilian Amazon municipalities. Total projected population in 2004 (IBGE) versus estimated population (Vensim).



Source: IBGE. Estimates of population – Revision 2004 and own estimates.

The analysis of the above graphics suggests that there was a great adherence between the population estimates stemming from the system of equations and those from the 2000 Demographic Census (R^2= 0,9999), which, in turn, suggests a high internal coherence from the proposed population simulation model. The same degree of adjustment, however, was not found between the IBGE estimates regarding local population and those simulated by Vensim even though a very high adherence level was found between them (0,9838). This indicates differences in hypotheses regarding the future evolution of demographic components adopted in the calculations of these population estimates. This outcome was expected since, in the system proposed herein, the migration component remained constant, as explained below.

Projection of estimates of mortality and fertility through logit adjustment

Once the parameters of the model equations had been validated, the next step was to develop projections of mortality, fertility, and urbanization rates. At this stage, the emigration rates and the origin-destination matrix remained unaltered. For future estimates of these rates, a logistic function, whose upper and lower asymptote, as well as the speed of increase, were calculated, interactively, in such a way as to reproduce, as quickly as possible, the values referent to the years of 1991, 1995, and 2000. The following equation represents the logistics curve adopted.

$$Y_t = Y_i + \left(\frac{Y_s - Y_i}{1 + e^{-w(t-k)}} \right)$$

where: Y_s represents the upper asymptote; Y_i, the lower asymptote; *w,* the speed of increase; and *K,* the inflection point.

3. *Results*

Simulation of the Annual Population Growth of Brazilian Amazon Municipalities: evolution of crude mortality and fertility rates and degree of urbanization

As aforementioned, the population growth of one location is dependent upon the behavior of its birth, mortality, and migration rates. In the case of Brazilian Amazon municipalities specified herein, their growth may vary depending upon the scenario adopted regarding the evolution of their crude birth, death, and emigration rates, as well as the evolution of their urbanization rates, between 1995 and 2035.

As the emigration rates for all locations input in the Vensim system remained constant as compared to those of the period between 1995 and 2000, population estimates were developed, considering the estimate of annual evolution of crude death and birth rates for all locations and urbanization rates only for the Brazilian Amazon municipalities between 1995 and 2035.

According to these estimates, the percentage of highly urbanized municipalities, or those with a degree of urbanization greater than 80%, will increase from 11.6%, in 2000, to

32.1%, in 2035, while those that present a degree of urbanization of less than 20% will fall from 5.3% to 3.7%, during the same period, as can be observed in Table 1.

Table 1. Brazilian Amazon Region: 2000. Number of Brazilian Amazon municipalities, according to degree of urbanization and crude birth and death rates in 2000 and 2035.

Degree of Urbanization (%)	Municipalities			
	Year			
	2000		2035	
	n	%	n	%
80 - 100	92	11.6	278	35.1
60 - 80	186	23.5	157	19.8
40 - 60	257	32.4	209	26.4
20 - 40	215	27.1	119	15.0
< 20	42	5.3	29	3.7
Total	792	100	792	100

Crude Birth Rate (‰)	Municipalities			
	Year			
	2000		2030	
	n	%	n	%
80 - 100	0	0.0	1	0.1
60 - 80	1	0.1	1	0.1
40 - 60	31	3.9	23	2.9
20 - 40	746	94.2	573	72.3
0 - 20	0	0.0	194	24.5
Total	778	100	792	100

Crude Death Rate (‰)	Municipalities			
	Year			
	2000		2030	
	n	%	n	%
40 - 70	1	0.1	9	1.1
30 - 40	195	24.6	55	6.9
20 - 30	345	43.6	238	30.1
10 - 20	251	31.7	395	49.9
0 - 10	0	0.0	95	12.0
Total	792	100	792	100

Source: IBGE. 2000 Demographic Census; FJP, 2003 and own estimates.

In 2000, the great majority of the Brazilian Amazon municipalities (94.2%) present crude birth rates of less than 40 births per one thousand inhabitants; however, no municipality presents birth rates of less than 20 births per one thousand inhabitants. For 2035, the model projects that the percentage of Brazilian Amazon municipalities with birth rates of less than 40 per one thousand inhabitants will be approximately 97%, while birth rates of less than 20 per one thousand inhabitants will be 24.5% (Table 1).

Likewise, the majority of these municipalities (75.3%) present crude mortality rates of less than 30 deaths per one thousand inhabitants in 2000; however, no municipality presents mortality rates of less than 10 deaths per one thousand inhabitants. For 2035, the model projects that the percentage of Brazilian Amazon municipalities with mortality rates of less than 30 per one thousand inhabitants will be approximately 98%, while the percentage of mortality rates of less than 10 per one thousand inhabitants will be 12.0% (Table 1). Figures 5, 6, and 7 show the spatial evolution of these estimates between 2000 and 2035.

In the scenarios of current migratory movements, the population projection indicates that, while in 2000, of the total 792 municipalities, 19.3% had a population volume of less than 5,000 people and 31.6% had a population volume of greater than 20,000 people, in 2035, these figures will change to 18.3% and 42.4%, respectively. The percentage of municipalities with a rural population of greater than 20,000 people will increase from 14.8% to 27.1% between 2000 and 2035, and those municipalities with an urban population of greater than 20,000 people will increase from 8.1% to 13.6% over the same time period, as can be observed in Table 2.

Table 2. Amazon Region: 2000 and 2035. Number of Amazonian municipalities, according to population size and housing situation in selected years.

Local Population	Municipalities											
	Total				Rural				Urban			
	2000		2035		2000		2035		2000		2035	
	n	%	n	%	n	%	n	%	n	%	n	%
> 20 000	250	31.6	336	42.4	117	14.8	215	27.1	64	8.1	108	13.6
15 000 - 20 000	81	10.2	72	9.1	40	5.1	64	8.1	67	8.5	47	5.9
10 000 - 15 000	142	17.9	112	14.1	83	10.5	95	12.0	96	12.1	78	9.8
5 000 - 10 000	166	21.0	127	16.0	175	22.1	159	20.1	214	27.0	141	17.8
< 5 000	153	19.3	145	18.3	377	47.6	259	32.7	351	44.3	418	52.8
Total	792	100	792	100	792	100	792	100	792	100	792	100

Source: IBGE. 2000 Demographic Census and own estimates.

As a result, Table 3 illustrates the local population contingent in the Brazilian Amazon region in 2000 and 2035. Within 35 years, the population of the Brazilian Amazon will grow by 43%, passing from 21.1 million to 30.2 million inhabitants. However, the relative weight of the rural population will fall from 31.6% in 2000 to approximately 30% in 2035.

Table 3. Amazon Region: 2000 and 2035. Population size according to housing situation in selected years

Brasilian Amazon	2000		2035	
	N	%	N	%
Rural	6 713 877	31.82	7 548 825	24.95
Urban	14 387 094	68.18	22 706 841	75.05
Total	21 100 971	100.0	30 255 666	100.0

Source: IBGE. 2000 Demographic Census and own estimates.

Fig. 8 shows both the rural and urban population growth in the Brazilian Amazon region between the years of 2000 and 2035. To facilitate the understanding of these results, they were aggregated to the regions of socio-economic influence from economic poles of the Brazilian Amazon region, as proposed by Garcia, Soares & Sawyer (2004).

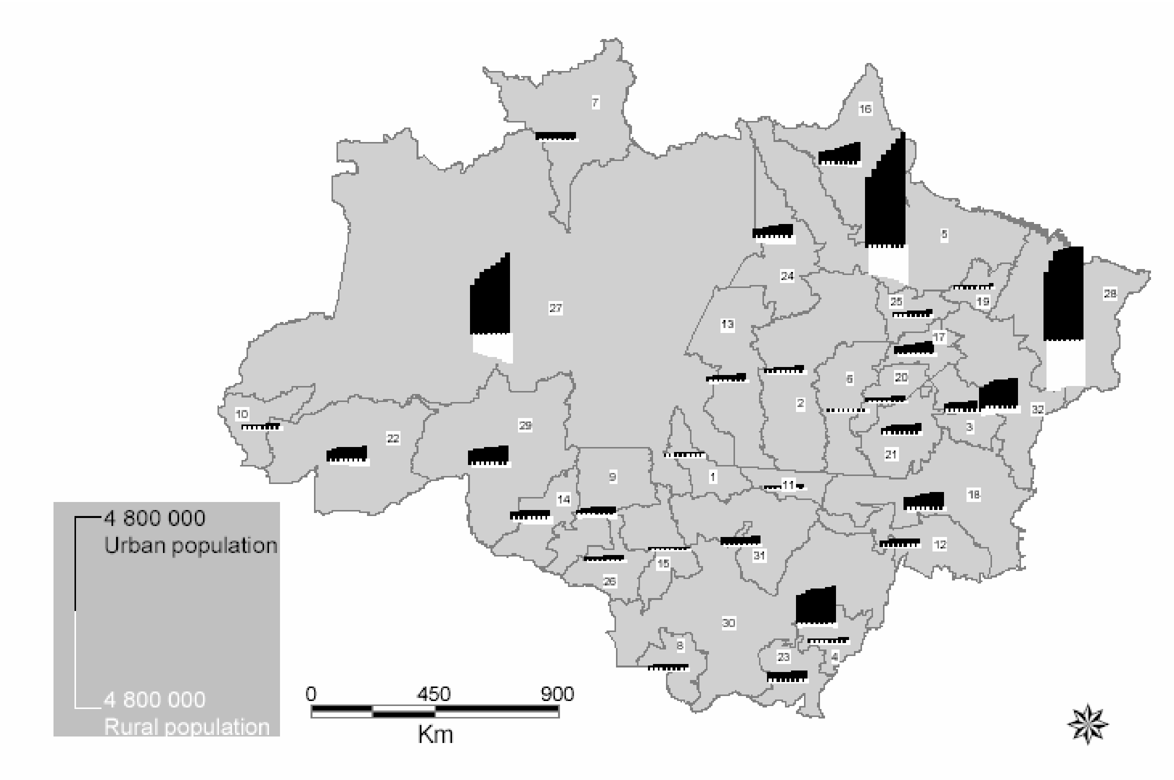


Figure 5. Annual evolution of the local population in Brazilian Amazon municipalities, according to housing situation, between 1995 and 2035. Results aggregated in sub-regions.

Source: IBGE. 2000 Demographic Census and own estimates.

4. Final Considerations

Our goal was to set up a demographic dynamics system to investigate scenarios of future population movement. The model was designed to take into account the evolution of crude mortality, fertility, and emigration rates and thus set up a system capable of simulating the population growth of small areas in an integrated and analytical manner. Such a model, therefore, resembles the classic methods of multi-regional projections, since it also allows one to deal with population movements among all areas considered.

In this manner, the proposed system brings advantages with respect to the two other methods of projection of small areas mentioned above (the c*oefficients* and the *cohort relation* methods), as it allows for the control of the input variables, CBR, CDR, OMR, as well as of others not considered in the model.

The results of the model, when compared to the official IBGE data, suggest that the system is capable of providing reliable estimates regarding all of its components. This suggests that there is a consistency maintained between the municipal matrix of migration obtained from the Demographic Censuses and the inter-municipal migratory movement. This further instigates an interesting field of analysis of the interrelations between economic development and population movement in small areas and their impacts on the environment and surrounding regions. This study took a small step in this direction.

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