2: Spatially Explicit Demographic Projections for Brazilian Metropolitan Areas by 2020 and 2030

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Short Abstract

Simulation models coupled with Geographic Information Systems are now applied to several areas and have great potential for demographic studies. Demographic projections can tell us “how much we will be”, but when coupled with GIS tools these projections can add the ability to show “where we will be”. This paper simulates the growth of urban areas, the resident population, and their households for the Brazilian Metropolitan Regions of São Paulo, Rio de Janeiro, Belo Horizonte, Brasilia, and Belém for 2020 and 2030. Based on demographic data measured between 2000 and 2010, and the mapping of urban areas through satellite images between 2000 and 2016, we used cellular automata models coupled with GIS to simulate future scenarios of population and urban growth. Our results suggest a decrease in the growth rate of urban areas despite the population and household growth in the coming decades. These trends are indicative of increasing intra-urban density, possibly reflected in the increase in building verticalization. Population is projected to grow at a slower pace than households, reflecting a decrease in the number of inhabitants per household in the study areas.

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Spatially Explicit Demographic Projections for Brazilian Metropolitan Areas by 2020 and 2030

Abstract Simulation models coupled with Geographic Information Systems are now applied to several areas and have great potential for demographic studies. Demographic projections can tell us "how much we will be", but when coupled with GIS tools these projections can add the ability to show "where we will be". This paper simulates the growth of urban areas, the resident population, and their households for the Brazilian Metropolitan Regions of São Paulo, Rio de Janeiro, Belo Horizonte, Brasilia, and Belém for 2020 and 2030. Based on demographic data measured between 2000 and 2010, and the mapping of urban areas through satellite images between 2000 and 2016, we used cellular automata models coupled with GIS to simulate future scenarios of population and urban growth. Our results suggest a decrease in the growth rate of urban areas despite the population and household growth in the coming decades. These trends are indicative of increasing intra-urban density, possibly reflected in the increase in building verticalization. Population is projected to grow at a slower pace than households, reflecting a decrease in the number of inhabitants per household in the study areas.

Keywords: Urban sprawl, geotechnology, cellular automata, simulation models, metropolitan areas in Brazil

Introduction

There has been an increasing demand for spatially explicit demographic projections. The planning of public housing policies, housing support services, infrastructure, and community services are the main drivers of this increasing demand (UNFPA 2011, Umbelino, 2012, UN, 2014). The chapter "Planning in advance the growth of cities", from the UNFPA Report on the Situation of World Population (UNFPA, 2011), calls for methodological initiatives that explicitly use spatial information for population projections. This is especially relevant for Latin America, where its urban population is expected to reach 536 million people by 2020 (UN, 2014).

Since the 1990's rapid development of spatially explicit demographic data and, more generally, the increase in georeferenced data on urban equipment and infrastructure opened a new avenue of research for putting together people and places. Many studies have been conducted exploring current and past trends and their spatial patterns. This knowledge can now be incorporated into future scenarios with the aid of Geographic Information Systems (GIS) coupled with models based on cellular automata (CAs), which have a relevant applicability in simulations of urban expansion and densification (White and Engelen, 1997; Batty, 2005). Based on these methodological advances, this work

simulates the future development of population and household growth in the Brazilian Metropolitan Regions of São Paulo, Rio de Janeiro, Belo Horizonte, Brasilia and Belém, for the years 2020 and 2030. Giving the past and current trends of rapid urbanization and verticalization of metropolitan areas in Latin America, and Brazil is not an exception, it is key to understand how and if these trends will continue in the near future. This information is key for urban planners when dealing with urban flow, housing demand, and the most efficient positioning of urban equipment.

Material and Methods

In order to obtain spatially explicit projects we follow five stages. In the first stage, the evolution of the urban areas pertained to the metropolitan regions of São Paulo, Rio de Janeiro, Belo Horizonte, Belém and Brasília is identified and mapped. For that, satellite images from the year 2000 were used. In the second stage, the growth of the urban areas for 2020 and 2030 are simulated by integrating Geographic Information Systems (GIS) to dynamic models that use cellular automata (CAs). These coupled models enable the simulation of changes in land use and land cover simultaneously to changes in demographic and socioeconomic characteristics of the population within the area. Information on municipal legislation about land use and cover is also used as spatial rules (UMBELINO, 2012).

The demographic parameters were measured in 2000 and 2010, while urban areas growth was measured between 2000 and 2016. These were the base scenarios for the simulation of population increase and households from 2016 and urban area growth in 2020 and 2030. For the simulation of urban occupation in 2020 and 2030, digital bases were processed in the Land Change Modeler (LCM) module of IDRISI 16, where a scenario of horizontal expansion of the urban areas in 2020 and 2030 was created according to its evolution in the period 2000-2010-2016. The simulated results was submitted to a calibration process, which consists of scenario adjustments so it approximates the real urban area verified in 2016 by the satellite images. This calibration refine the precision of the simulated probability of the pixels becoming urban by 2020 and 2030 (EASTMAN, 2009, UMBELINO, 2012).

Preliminary Findings

Current and past trends suggest that all main Brazilian metropolitan areas are under a process of urban expansion, but will follow a slower pace than population growth in these areas. Analyzing the Geometric Growth Rate (GGR) of the urban population and the urban areas in the period 2000-2010, these urban areas expanded at a rate between 1.71% and 4.07% per year (Table 1), while the urban population grew at a rate between 0.27% and 1.09% per year (Table 2). The number of households also increased above population growth (Table 3), with rates ranging from 0.71% to 1.36%. These figures combined

translate into a general decrease in the number of inhabitants per household (Table 4).. For the projected figures for the period 2010-2020 and 2020-2030 (Table 1), population and household are expected to increase faster than the urban areas, pointing to a tendency of increase in intra-urban density. This process can result in how and where people will locate in the metropolitan regions, with a likely tendency towards increasing verticalization of buildings.

Table 1 - Total Urbanized area measured (2000-2016) and projected (2020-2030) for the main Brazilian Metropolitan Regions

Metropolitan Region	Metropolitan Total Area (km²)	Urbanized Area (km²)							
		2000	2010	2016	2020	2030	2000-10	2010-20	2020-30
Brasília	19,916.1	521.3	822.7	867.9	935.3	1,034.9	4.67	1.29	1.02
Belém	1,291.0	199.0	235.8	247.7	287.4	335.2	1.71	2.00	1.55
Belo Horizonte	9,495.2	869.1	1,195.7	1,278.4	1,536.4	1,759.4	3.24	2.54	1.36
Rio de Janeiro	4,673.6	1,131.3	1,431.6	1,458.3	1,473.8	1,575.8	2.38	0.29	0.67
São Paulo	7,967.6	1,759.8	2,300.0	2,342.4	2,355.7	2,378.2	2.71	0.24	0.10

Source: IBGE, 2010; Google Earth, 2000, 2010, 2016; Landsat, 2000, 2010, 2016; Umbelino, 2012; Cedeplar, 2014.

Table 2 - Total population measured (2000-2010) and projected (2016-2030) for the main Brazilian Metropolitan Regions

Metropolitan Area	Population Total						Geometric growth rate		
	2000	2010	2016	2017	2020	2030	2000-10	2010-20	2020-30
Brasília	2,689,389	3,401,773	3,792,343	3,843,003	3,999,596	4,417,646	1.09	1.63	1.00
Belém	1,795,536	2,042,417	2,239,860	2,265,246	2,343,548	2,492,378	0.93	1.38	0.62
Belo Horizonte	4,357,942	4,883,970	5,271,322	5,311,249	5,432,906	5,658,278	0.77	1.07	0.41
Rio de Janeiro	10,710,515	11,599,156	11,918,723	11,949,941	12,046,345	12,096,968	0.27	0.38	0.04
São Paulo	17,878,703	19,683,975	21,175,749	21,297,969	21,671,082	22,332,818	0.73	0.97	0.30

Source: IBGE, 2010; Google Earth, 2000, 2010, 2016; Landsat, 2000, 2010, 2016; Umbelino, 2012; Cedeplar, 2014.

Table 3 - Number of households measured (2000-2010) and projected (2016-2030) for the main Brazilian Metropolitan Regions

Metropolitan Area	Households Total						Geometric growth rate		
	2000	2010	2016	2017	2020	2030	2000-10	2010-20	2020-30
Brasília	709,551	1,011,331	1,177,241	1,202,535	1,291,100	1,557,917	1.53	2.47	1.90
Belém	416,305	540,159	618,540	630,568	672,987	781,910	1.36	2.22	1.51
Belo Horizonte	1,175,508	1,505,073	1,696,188	1,722,742	1,817,910	2,068,399	1.20	1.91	1.30
Rio de Janeiro	3,200,435	3,829,185	4,108,464	4,152,263	4,318,083	4,737,203	0.71	1.21	0.93
São Paulo	4,994,933	6,089,847	6,840,726	6,935,390	7,279,975	8,196,012	1.17	1.80	1.19

Source: IBGE, 2010; Google Earth, 2000, 2010, 2016; Landsat, 2000, 2010, 2016; Umbelino, 2012; Cedeplar, 2014.

Table 4 - Household density measured (2000-2010) and projected (2016-2030) for the main Brazilian Metropolitan Regions

Metropolitan Area	2000	2010	2016	2017	2020	2030
Brasília	3.79	3.36	3.22	3.20	3.10	2.84
Belém	4.31	3.78	3.62	3.59	3.48	3.19
Belo Horizonte	3.71	3.25	3.11	3.08	2.99	2.74
Rio de Janeiro	3.35	3.03	2.90	2.88	2.79	2.55
São Paulo	3.58	3.23	3.10	3.07	2.98	2.72

Source: IBGE, 2010; Google Earth, 2000, 2010, 2016; Landsat, 2000, 2010, 2016; Umbelino, 2012; Cedeplar, 2014.

The dynamic modeling via CAs allowed us to identify which possible areas within the studied metropolitan areas will grow by spatializing where population will grow faster. Studies of spatial growth and spatially explicit demographic projections as the ones undertaken in this study are an important urban planning instrument for it simulates the dynamics of urban occupation and household occupation (UNFPA, 2011, Umbelino, 2012, Seto et al., 2015). This methodological strategy increases precision in how much and where people will be in a specific area and provides insights on the shape of urban expansion. Many immediate applications can derive from this type of analysis: from insights on urban sprawl or verticalization to the overlap between urban growth and environmentally protected areas. In the final version of this study, we will provide an example of spatial overlap between urbanization, population grow and protected areas in the metropolitan regions under study.

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