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Spatial distribution and autocorrelation of infant mortality for three cities in Paraná state, Brazil

Rosana Rosseto de Oliveira, Josane Rosenilda da Costa, Thais Aidar de Freitas Mathias

State University of Maringá, Paraná State, Brazil

Abstract. Infant mortality (IM), defined as deaths among children one year of age or younger, is an indicator of quality of life and of the organisation and quality of health services. IM reduction is one of the main goals of healthcare and improvements in this area would demonstrate an impact of public services and improved living conditions. Knowledge of the geographic distribution of IM can provide support for prevention and health maintenance decisions. The objective of this study was to analyse the spatial distribution and autocorrelation of IM in Maringá, Sarandi and Paiçandu, three cities in the Maringá metropolitan area, Paraná state, Brazil. The coefficients ranged between 6.5 and 18.2, with the highest rates found in the outskirts of the fused cities, particularly in the demographic expansion areas (DEAs) in Sarandi, with a "high-high" correlation for DEAs no. 18 and 19 and a "low-high" for DEA no. 16. In the central area of Maringá, represented by DEAs no. 3, 6 and 7, the correlation was "low-low". Peripheral DEAs generally show inferior socioeconomic and healthcare conditions. These observations make it possible to analyse programme coverage, set priorities, define goals and follow-up future changes.

Keywords: infant mortality, geographical information system, residence characteristics, Brazil.

Introduction

Infant mortality (IM), defined as the number of deaths among children one year of age or younger, is an avoidable event that reflects poor socioeconomic conditions. Apart from indicating the quality of life, IM functions as a measure of the quality of healthcare services and the prenatal care offered (Brazil, 2006a). IM is divided into neonatal death (<28 days of age) and post-neonatal death (between 28 and 364 days). The latter can be subdivided into early neonatal death, comprising the first six days of life and late neonatal death, covering 7-27 days of life (Brazil, 2009).

Efforts aimed at reducing IM, one of the main goals of healthcare in several countries, have resulted in markedly reduced rates, particularly in the post-neonatal period (Ventura et al., 2008). In Brazil, the continuous decline in IM rates has mainly come about as a result of improved sanitation, expanded access to prenatal and childbirth care, as well as reduced birth rates (Ventura et al., 2008; Mathias, 2010). In 1990, the IM rate in Brazil was 47.1 per 1,000 live births (LBs); by 2009, it had fallen to 22.5 per 1,000 LBs (Brazil, 2009; Brazilian Institute of Geography and Statistics (IBGE), 2010). In the state of Paraná, IM has also shown decreasing trends in recent years. In 2001, the rate was 17.4 per 1,000 LBs, falling to 13.1 per 1,000 LBs in 2008, a reduction of 24.8% (Brazil, 2008).

The distribution of morbidity and mortality patterns can be obtained by georeferencing techniques, which facilitate the allocation of services that determine accessibility to healthcare (Barcellos et al., 2008). Considering the need for ongoing regional IM studies, still little explored with regard to spatial distribution, a study of the spatial IM distribution based on the variables contained in the Brazilian Information System on LBs (SINASC) and the Information System on Mortality (SIM) should be able to identify homogenous areas. A clear recognition of such areas would allow improved support for programmes or policies aiming at improved health services, increase use of public resources for areas at risk, prioritize health actions and assist reducing inequalities (Brazil, 2006b).

The objective of this study was to analyse the spatial distribution and autocorrelation of IM coefficients (IMCs) by period of death according to the demographic expansion area (DEA) in three cities of the Maringá metropolitan area, Paraná state, Brazil.

Materials and methods

Study area

Paraná is one of Brazil's 26 states, located in the country's southern region (Fig. 1) The basic informa-

Corresponding author:
Thais Aidar de Freitas Mathias
State University of Maringá
Avenida Colombo, 5.790, CEP 87020-900
Maringá, Paraná state, Brazil
Tel./Fax +44 3011 - 4494
E-mail: tafmathias@uem.br

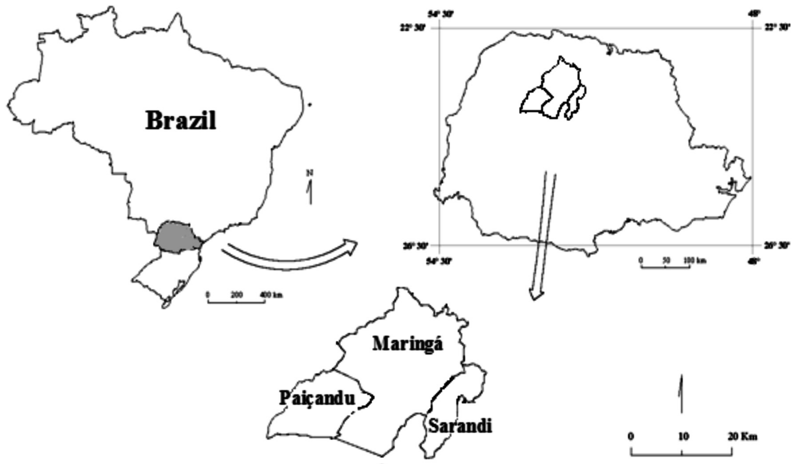

Fig. 1. Map of Brazil highlighting the location of the Paraná state and the cities Maringá, Sarandi and Paiçandu.

tion below for the study area comes from Instituto Paranaense de Desenvolvimento Economico e Social (IPARDES) (http://www.ipardes.gov.br/).

Maringá, with a population of 357,077 in 2010 and a density of 734.1 inhabitants per km^2, is a medium-sized city in northwestern Paraná. It features a 98.2% urbanization rate and has a human development index (HDI) of 0.84 for the year 2000, ranking sixth statewide and 65th in Brazil.

Sarandi, bordering Maringá to the east, had a population of 82,847 in 2010. With 799.0 inhabitants per km^2, Sarandi has the highest population density of the cities in the study. With an urbanization rate of 99.1% and a HDI of 0.76 in 2000, it is regarded as of medium human development.

Paiçandu, fused with Maringá to the west, featured a total population of 35,936 in 2010 with a density of 210.2 inhabitants per km^2, an urbanization rate of 98.6% and a HDI of 0.74 in 2000.

Data

The study covered all IMs in the three study cities between January 2004 and December 2008. These cities are highly integrated with inter-municipal flow, functional complementation and socioeconomic integration (Santana et al., 2010). The SIM and SINASC databases were linked using the Live Birth Declaration (LBD) number as the identifying variable. This study used the "mother's residence address" from SINASC for spatial distribution and autocorrelation. This type of data is important as locates all study events in space. Of the 29,272 births recorded, 21,258 were residents of Maringá (72.6%), 5,809 were from Sarandi (19.8%) and 2,205 from Paiçandu (7.6%). A total of 3,413 records were found without "neighbourhood" and "street of residence" and 965 records had left the street name blank. A detailed search was carried out to reduce the possibility of invalid records. Still, 133 birth records had to be discarded, 31 from Sarandi and 102 from Maringá. Once this had been done, each birth was joined with a DEA. For Paiçandu, this was not necessary as that city consists of a single DEA. The total loss records represented 0.4% of the combined database.

The IM was analysed in total and according to its subdivisions as defined before. The DEAs, the analysis units used as "weighted areas", were defined by the IBGE based on the 2000 census with the objective of publishing data by areas formed by a reunion of census sectors. This gives these areas a very consistent character, both statistically and sociologically (Santana et al., 2010). The study included 19 DEAs defined by Santana et al. (2010), 14 in Maringá, four in Sarandi and one in Paiçandu.

Statistical approach

The analysis of spatial autocorrelation was carried out using Moran's local indicator of spatial association (LISA), which facilitates identification of area clusters with significant patterns of spatial association. This analysis makes it possible to identify and compare the values of each specific DEA with the values of neighbouring DEAs. A non-significant autocorrelation occurs when the spatial pattern that differs from that observed for the group is not identified (Anselin, 1994).

For the analysis of spatial distribution, the coefficients are presented in quartiles, according to maxi-

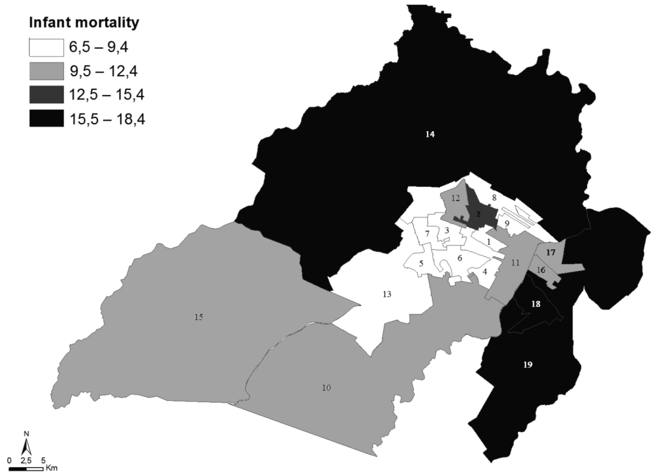

Fig. 2. Spatial distribution of infant mortality coefficients, stratified by DEA, Maringá, Sarandi and Paiçandu, 2004 to 2008.

mum and minimum number; gray-shades were used in the maps with white representing the "best" values (the lowest coefficients) and black for the "worst" (the highest coefficients).

Results

The spatial distribution of the coefficients showed low values in central Maringá (DEAs 1, 3, 4, 5, 6, 7, 8, 9 and 13) and DEAs 18 and 19 in Sarandi (Fig. 2). The highest coefficients, both for IM and neonatal mortality (18.2 and 14.9 deaths per 1,000 live births, respectively), was found in DEA 14 in Maringá. It was observed that, even when analysing deaths by discriminating within the reality of each specific DEA, the neonatal mortality is still higher than the post-neonatal (Table 1).

For the neonatal deaths, without subdividing the coefficients further, Maringá has the "best" results with only four DEAs showing double-digit coefficients (DEAs 2, 11, 12 and 14) (Table 1 and Figure 3). There

Table 1. Distribution of the infant mortality coefficient, according to period of death, by DEA, Maringá, Sarandi and Paiçandu, 2004 to 2008

DEA	Neighbourhood	<1 year	Neonatal	Early	Late	Post-neo
1	Maringá Vila Morangueira	7.9	5.6	4.5	1.1	2.3
2	Maringá Jd. Alvorada	14.0	12.0	9.3	2.7	2.0
3	Maringá Zona 7	8.9	8.9	7.2	1.8	-
4	Maringá Zona 8	8.0	6.8	4.6	2.3	1.1
5	Maringá Zonas 5 and 6	7.0	4.2	2.8	1.4	2.8
6	Maringá Zonas 1, 2, 3 and 4	7.9	6.1	3.0	3.0	1.8
7	Maringá Av. Mandacaru	8.9	6.4	3.8	2.5	2.5
8	Maringá Contorno Norte	7.1	4.7	2.4	2.4	2.4
9	Maringá Conjunto Requião	6.5	4.1	2.8	1.2	2.4
10	Maringá Cidade Alta	9.9	7.1	6.0	1.1	2.8
11	Maringá Liberdade-Aeroporto	11.2	10.2	9.2	1.0	1.0
12	Maringá Jd. Imperial-Pq Grv.	10.2	8.2	7.2	1.0	2.0
13	Maringá Zona Industrial	8.3	5.0	2.5	2.5	3.3
14	Maringá Olímpico	18.2	14.9	11.0	3.9	3.2
15	Paiçandu	10.9	9.1	7.7	1.4	1.8
16	Sarandi Centro	11.0	6.6	4.9	1.6	4.4
17	Sarandi Jd. Independência	10.7	8.3	7.2	1.2	2.4
18	Sarandi Parque Alvamar	15.8	12.4	8.3	4.1	3.4
19	Sarandi Linha do Trem	16.8	9.6	6.6	3.0	7.2

Source: SINASC and SIM.

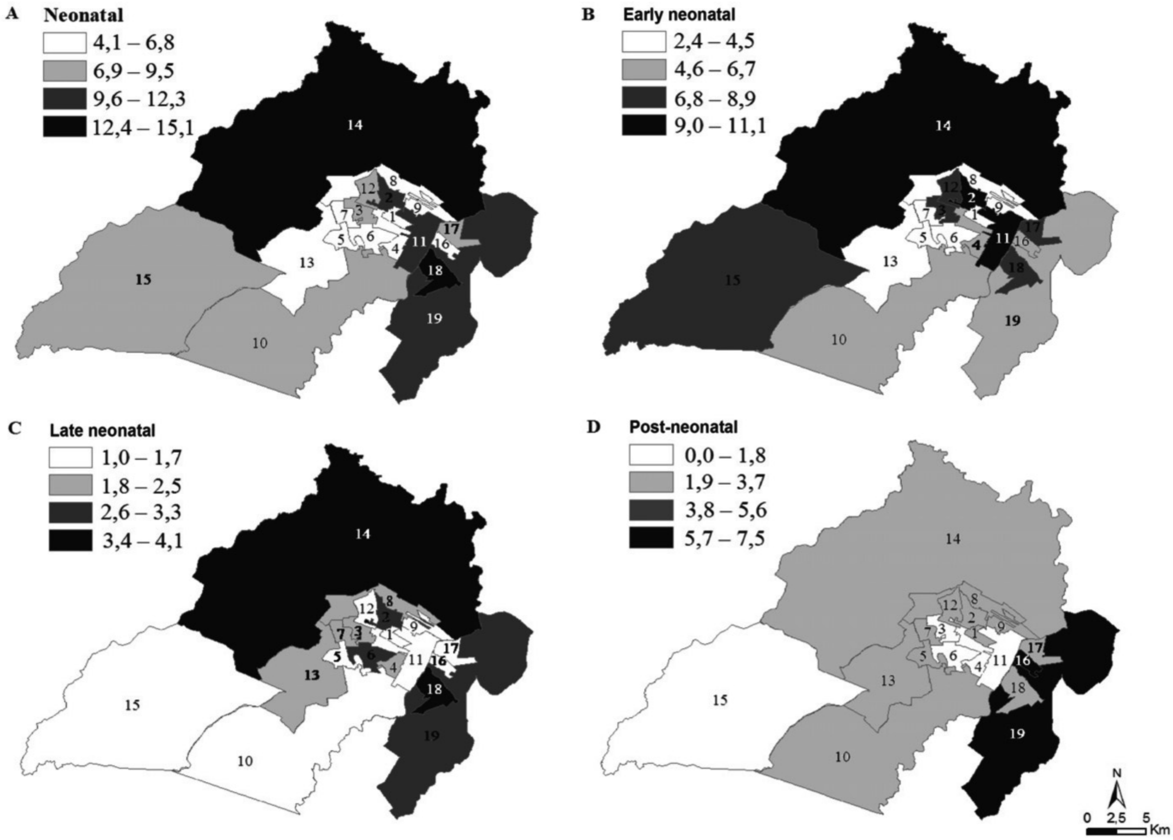

Fig. 3. (A) Spatial distribution of the total neonatal coefficient, (B) early neonatal coefficient, (C) late neonatal coefficient, (D) post-neonatal coefficient. Maringá, Sarandi and Paiçandu 2004 to 2008.

was a significant "high-high" spatial autocorrelation in DEAs 18 and 19, located in Sarandi; a "low-low" correlation in DEAs 3, 6 and 7, in the central area of Maringá; and a "low-high" correlation in DEA 16 in Sarandi.

The correlation results for the IM periods indicate that neonatal mortality showed "low-low" autocorrelation only in DEA 8, which comprises the central region of the study area. Early neonatal mortality kept a similar trend, with "low-low" correlation only in the cluster formed by DEAs 5, 7 and 8 (Fig. 5), which constitute the central region of Maringá. There was a significant "high-high" correlation in DEA 5 and a "high-low" one in DEA 2 for the late

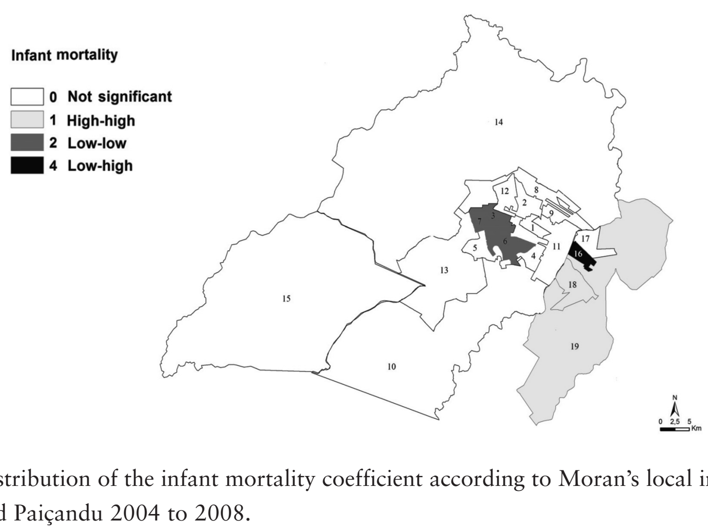

Fig. 4. Map of the distribution of the infant mortality coefficient according to Moran's local indicator of spatial association (LISA), Maringá, Sarandi and Paiçandu 2004 to 2008.

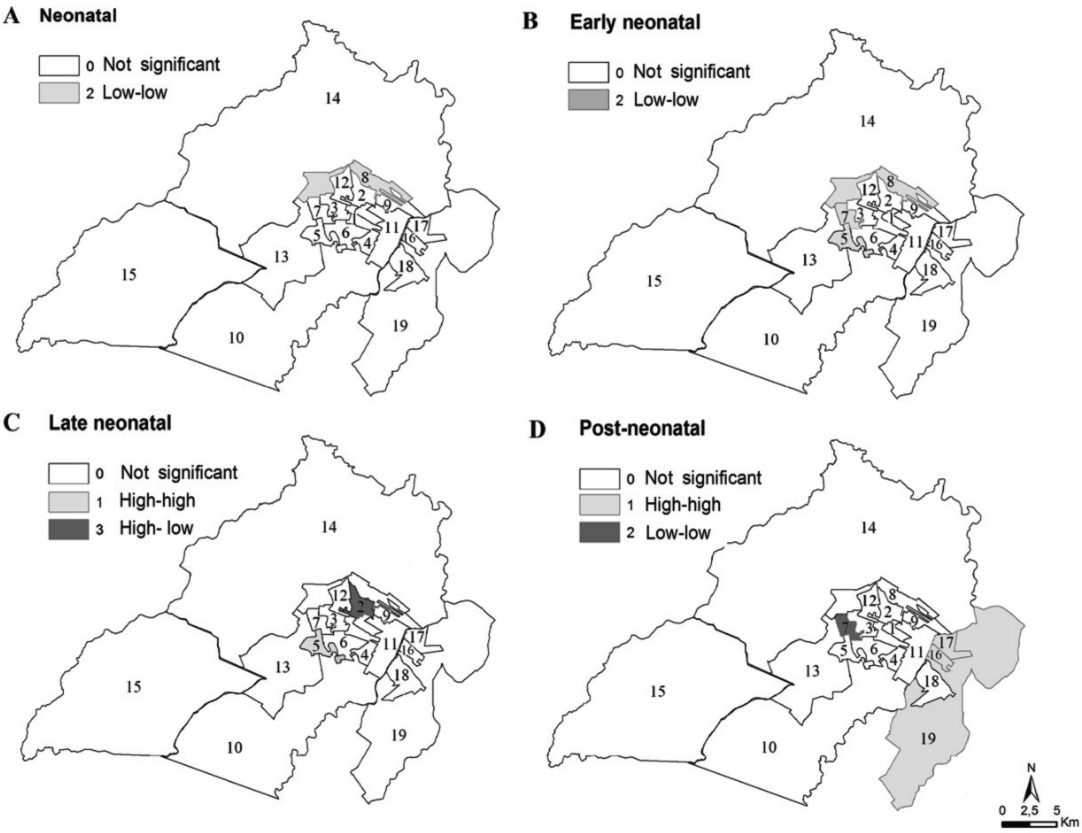

Fig. 5. (A) Spatial distribution of the neonatal coefficient, (B) early neonatal coefficient, (C) late neonatal coefficient, (D) post-neonatal coefficient, by DEA, according to Moran's local indicator of spatial association (LISA), Maringá, Sarandi and Paiçandu 2004 to 2008.

neonatal coefficient. With regard to post-neonatal death, a "high-high" correlation in DEAs 16, 17 and 19 was observed and a "low-low" correlation in DEA 7 (Fig. 5).

Discussion

The distribution of the IMC clusters identified corroborates the nucleus-periphery model with the lowest values seen in central Maringá and Sarandi. Incidently, the outskirts of Sarandi had the worst IMCs of any of the cities (Fig. 2). These results are in accordance with the HDI values for the investigated cities, with Maringá showing a high HDI of 0.84 and Sarandi and Paiçandu having considerably lower values of 0.76 and 0.74, respectively (IPARDES, 2011).

Our results highlight the area located in the western region of Maringá with the highest IM value (18.2 deaths per 1,000 LBs) of all the areas investigated. That neighbourhood, regarded as less developed and characterised by poor economic conditions, is comprised by semi-urban and rural areas (Santana et al., 2010). The analysis of IMCs by period of death shows that social inequalities, combined with precarious living conditions, represent the main obstacle to improving the population's health situation. This was exemplified when the subdivisions of the IM were analysed with respect to the various homogenous areas. For example, neonatal mortality reached values up to 14.9 deaths per 1,000 LBs in DEA 14 and amounted to 11.0 in the early neonatal period for the same DEA.

Since IM remains yet another manifestation of the contradictions between social classes, identified in workplace inclusion, living conditions, access to education and health (Ventura et al., 2008), the challenge is to restructure the healthcare assistance model to guarantee access and quality services to those who currently have the least access to these services, i.e. in Sarandi and Paiçandu as well as in the western region of Maringá according the current study.

Few regions showed significant correlation with neighbouring areas. This result may be due to the fact that the neighbouring areas tend to show more similarities than regions further away and that average values become similar and lose their power of spatial discrimination as access to sanitation and education improves (Bezerra Filho et al., 2007).

Even if there were no significant correlation for any

IM subdivisions, the autocorrelation analysis showed some areas with similarities and differences, e.g. the "high-high" autocorrelation in DEAs 18 and 19 in Sarandi (Fig. 4). This indicates that the neighbourhoods that make up those areas are surrounded by others with the same characteristics. The significant "low-low" correlation in areas in the central region of Maringá indicates that these neighbourhoods and adjacent areas have low coefficients. Finally, the central region of Sarandi showed a significant "low-high" correlation demonstrating that this area, although it has a low coefficient, is surrounded by neighbourhoods with high IM coefficients. The results of this analysis also highlight homogenous areas with low coefficients in the central areas of Maringá.

A previous study (Predebon et al., 2010) provided evidence for a concentration of lower percentages of unfavourable indicators in areas with significant spatial autocorrelation, such as those with teenage mothers, mothers with low education (<8 years of schooling), insufficient number of prenatal appointments (<4 consultations), and children with low newborn vitality. These results indicate that areas, vulnerable according to socio-demographic variables, concur with areas found to have higher coefficients, both with respect to IM and its subdivisions.

This study further showed the functionality of the use of DEAs as units for spatial analysis of IM, as they are aggregates of census sectors with representation as well as a sociologically consistent character. However, a difficulty of the methodology regarding the georeferencing of data from rural areas should be noted. In addition, location is more difficult in rural areas, since there are no nationwide standards for address data unlike in urban areas.

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