pagepress

Geospatial Health 2022; volume 17:1101

Spatial variability of mother-to-child human immunodeficiency virus transmission in a province in the Brazilian Rainforest: An ecological study

Marcus Matheus Quadros Santos,* Bianca Alessandra Gomes do Carmo,* Taymara Barbosa Rodrigues, Bruna Rafaela Leite Dias, Cleyton Abreu Martins, Glenda Roberta Oliveira Naiff Ferreira, Andressa Tavares Parente, Cíntia Yollete Urbano Pauxis Aben-Athar, Sandra Helena Isse Polaro, Eliã Pinheiro Botelho

Graduate Nursing Program, Federal University of Pará, Complexo da Saúde - Guamá, Belém, Pará, Brazil

**The first two authors shared the first authorship*

Abstract

The mother-to-child transmission (MTCT) of the human immunodeficiency virus (HIV) remains a serious public health problem in the Brazilian Rainforest. This study aimed to spatially analyze this type of infection between 2007 and 2018 in Pará, which is the second-largest Brazilian state in the Brazilian Rainforest and also has the highest MTCT of HIV in Brazil. We analyzed the incidence rates of HIV (including the acquired immunodeficiency syndrome (AIDS) by MTCT as the main route of infection in children younger than 13 years old and whose mothers live in Pará. We employed spatial autocorrelation, spatial scanning, and geographic-weighted spatial regression techniques. In the period of this study, 389 new HIV/AIDS were noted, with territorial expansion of the incidence rates in the municipalities in northern and southern Pará having the highest rates. São Francisco do Pará had high spatial risk and high-spatiotemporal risk clusters comprising municipalities in western and south-western Pará between 2013 and 2016. The spatial variability of HIV/AIDS incidence rates was found to be common in the number of men and women with formal jobs; unemployed ≥18 years old people; elementary school pupils; and families enrolled in the "Single Registry for Social Programs". The social equity approach in Pará guarantee pregnant women access to preventive, diagnostic and treatment health services and their children should be supported to eliminate the MTCT of HIV in Pará.

Correspondence:Eliã Pinheiro Botelho, Graduate Nursing Program, Federal University of Pará, Rua Augusto Correia, 01 Campus III, Complexo da Saúde - Guamá, Belém Pará, 66.075.110 Brazil.
E-mail: ebotelho@ufpa.br

Key words: Spatial analysis; mother-to-child HIV transmission; HIV AIDS; social determinants of health; Brazil.

Funding: This study was supported by the Coordenação de Aperfeicoamento de Pessoal de Nível Superior under grant number 88881.200527/2018-01, PROCAD-AM.

Acknowledgments: The authors are thankful to the Secretaria de Saúde do Pará for releasing the epidemiological data which made this study possible.

Conflict of interest: The Authors declare no conflict of interest.

Received for publication: 20 April 2022.
Revision received: 19 June 2022.
Accepted for publication: 10 September 2022.

Geospatial Health 2022; 17:1101
doi:10.4081/gh.2022.1101

Introduction

In 2011, the Joint United Nations Programme on HIV/AIDS (UNAIDS) launched the "Global Plan towards the Elimination of New HIV Infections among Children and Keeping their Mothers Alive", with the main goal of the elimination of the mother-to-child transmission (MTCT) of HIV by 2015 (UNAIDS, 2011). However, although the number of HIV cases reported since 2010 has decreased by 52% (2010: 310,000 cases, 2020: 160,000 cases), MTCT of HIV remains a problem in several countries even if, according to the United Nations Children's Fund (UNICEF), Cuba, Thailand, Armenia, Belarus, Anguilla, Montserrat, the Cayman Islands, Bermuda, Antigua, Barbuda and Saint Kitts and Nevis were certified in 2017 to have eliminated MTCT of HIV (UNICEF, 2021).

In Brazil, a decrease of 70% in the AIDS detection rate in children younger than five years was observed in the last decade (2010: 4.0; 2020: 1.2; ×100,000 inhabitants). However, Brazilian regional discrepancies were observed when considering the decreasing MTCT of HIV. The northern region had the smallest decrease among the regions (Midwest: 82.6%, South: 77.1%, Southeast: 68.6%, Northeast: 68.5%, North: 61.2%) (Brasil Ministry of Health, 2021). The Brazilian Ministry of Health has implemented several policies to promote women's sexual and reproductive health, such as the Stork Network Program that pro-

motes HIV screening at least twice during antenatal care and birth, clinical protocols; and the Option B+ Program, which offers free antiretroviral therapy to pregnant women diagnosed with HIV regardless of the CD4 blood cell count. In addition, mothers receive a drug to inhibit lactation, a special formula to feed their babies and antiretroviral therapy (ART) for babies' prophylaxis for four weeks (Miranda et al., 2021). However, a recent national study in Brazil with pregnant women living with HIV showed missed opportunities to fight the MTCT of the virus, with 24.1% not treated by ART; 16% not showing a positive HIV diagnosis; 19.3% not receiving ART following childbirth; and 22.9% not receiving adequate care during childbirth. Approximately 13.2% of newborns do not receive ART in the first 24 h after birth, and 2.8% are breastfed (Domingues *et al.,* 2022).

The comprehension of how social determinants of health (SDHs) influence the MTCT of HIV is crucial with regard to its elimination. SDHs influence the health outcomes as they are the conditions under which people are born, grow up and live (Aagaard-Hansen and Chaignat, 2010). In this way, spatial analytic techniques are helpful as they permit the correlation of the studied problem with territorial SDHs (Momenyan *et al.,* 2018). However, studies employing spatial analysis to study the MTCT of HIV remain scarce (McCoy *et al.,* 2016; Waruru *et al.,* 2018). This work is the first study to analyze the MTCT of HIV spatially in the Brazilian Rainforest region, which has the highest HIV/AIDS rate detected in children younger than five years among all Brazilian regions, *i.e.* 2.0 per 100,000 inhabitants.

Several policies to fight HIV by MTCT have been implemented. In 2011, the Brazilian Ministry of Health launched the Stork Network Program, which aimed to strengthen the UNAIDS plan to eliminate HIV infection by MTCT by focusing on women's reproductive health and children's health during their first two years of life (Guimarães *et al.*, 2019; Miranda et al., 2021). In 2012, HIV testing was implemented during the 1st and 3rd trimesters of pregnancy in mothers giving birth and in newborns. In 2013, the Option B+ program was launched, with all pregnant women receiving free ART regardless of their CD4 cell status and clinical stage of the disease. However, between 2010 and 2017, 2,400 HIV/AIDS cases were reported in pregnant women in Pará, with 67% of them discovering their HIV status in the third trimester of pregnancy and 16.5% during delivery and with only 68.8% receiving ART (Trindade *et al.,* 2021). Furthermore, the World Health Organization (WHO) recommends 95% coverage or superiority of antenatal care, HIV screening and ART for at least two years in all pregnant women living with HIV to eliminate MTCT (Goga *et al.,* 2019). However, in most municipalities in Pará, pregnant women attend fewer than seven consultations (FAPESPA, 2021).

The state of Pará, which is located in the Brazilian Rainforest and its capital Belém have the highest HIV/AIDS rates (2.8 and 9.7, respectively, ×100,000 inhabitants) among the Brazilian states and capitals. In addition, in this region, the HIV rate detected in pregnant women increased by 111.3% between 2010 and 2020 (Brasil Ministry of Health, 2021). São Franciso do Pará and Novo Progresso are two high-risk municipalities. Although both have 100% coverage by the Primary Health System, the proportions of pregnant women attending at least seven consultations for antenatal care there in 2018 are only 57.21% and 70.25%, respectively (FAPESPA, 2021). In addition, these cities have no resources for specialized hospitals to follow-up infected pregnant women and newborns with HIV during the antenatal, birthing, and postpartum periods. Novo Progresso was founded in 1993 and had a rapid growth promoted by illegal mining, road construction, livestock and illegal land occupation leading to a population boom that promoted increase social inequity, violence and prostitution. In 2009, the Edson Royer Institute was created in Novo Progresso to combat violence and prostitution of children and adolescents, pregnancy among adolescent girls and youth employment in drug trafficking (IER, 2022). São Francisco has only about 7% of its population employed in formal jobs and receiving a monthly income of R$ 2,302.08 (USD 490.00), with most of the people having low school level degrees (IBGE, 2021). These unfavourable social conditions have already been identified as favouring the HIV by MTCT. In Southern Brazil, pregnant women that had their babies exposed to HIV are poor, with low schooling levels and receiving low monthly incomes (Bick *et al.,* 2018).

This study aimed to study the spatial variability of MTCT of HIV in the state of Pará. We analyzed the spatial distribution and autocorrelation of HIV/AIDS incidence rates in children younger than 13 years who had become HIV-infected by the MTCT route.

Materials and Methods

This work is an ecological study, which are characterized by analysing data at the population level and they are ideal to monitor the population health and to provide subsidies to health authorities to implement efficient public policies to fight health problems under study (Levin, 2006).

Study site

The study took place in Pará, the second-largest Brazilian state, with a territorial area of 1,245,870,707 km^2, which is located in the North of Brazil. Pará is divided into 144 municipalities and has a population of 8,690,745 (Figure 1). According to the Brazilian Institute of Geography and Statistics (Instituto Brasileiro de Geografia e Estatistica or IBGE), Pará is the third-poorest state in Brazil [human development index (HDI) = 0.698] with a high-income inequality distribution (Gini index = 0.53) (IBGE, 2021). The state has in addition a low coverage of primary health care facilities (59.1%), most of which in urban zones (68.2%). These factors are associated with socioeconomic and geographic barriers (e.g., remarkable distances, densely forested areas and rainy climate with some places only accessible by boat), which all are challenges with respect to health services for people living in the rural zones (Garnelo *et al.,* 2018).

Pará has minimal resources to combat HIV. For all its 144 municipalities, only two pre-exposure prophylaxis (PrEP) units, 33 ART-dispensing units, 7 specialized HIV/AIDS care centers (SICLOM, 2019; Brasil Ministry of Health, 2022) and two HIV/AIDS hospitals exist in the capital. These hospitals (Unidade de Referência Materno Infantil e Adolescente and Fundação Santa Casa de Misericórdia) specialize in antenatal care of pregnant women living with HIV and in follow-up of newborns exposed to HIV (SESPA, 2022).

Study subjects

This study's population was composed of all HIV/AIDS cases in children younger than 13 years between 2007 and 2018 who had been reported to the Information System for Notifiable Diseases. These data were provided by the State Department of Public Health in Pará. However, we included only notifications of chil-

dren who had been infected by HIV through the MTCT route and whose mothers lived in Pará. The variables collected for the children were i) age; and ii) the year of HIV diagnosis. For the mother they were i) age; ii) race; iii) schooling; iv) occupation; and v) city of residence of the mother. The data were double-checked and all inconsistencies removed.

Data analysis

Descriptive analysis was performed employing Microsoft Office Excel 365® software, version 2019 (Microsoft Corporation, Santa Rosa, CA, USA), with results expressed as absolute values (*n*) and relative frequencies (%). To avoid annual variation in the spatial analysis, the HIV/AIDS incidence rate in each municipality was calculated by quadrennia (2007–2010, 2011–2014 and 2015–2018) and also for the entire period (2007–2018). Calculations were performed by dividing the number of cases in the municipality by the average number of inhabitants in the specific age range for each study period. The results were then multiplied by 100,000. To reduce the variability in incidence rates calculated for small areas, we employed global empirical Bayesian smoothing by TerraView® software, version 4.2.2 (INPE, São José dos Campos, SP, BR). The smoothed incidence rates were analyzed using the spatial distribution and the spatial autocorrelation techniques through ArcMap of ArcGis® software, version 10.6.1 (ESRI, Redlands, CA, USA). For the spatial autocorrelation analysis, we employed Global Moran's *I* followed by the local indicator of local indicator spatial autocorrelation maps (LISA maps). Here, a queen-type W-contiguity matrix with 999 permutations was employed, with municipalities sharing borders and nodes considered as neighbours. A value of $p \leq 0.05$ was considered statistically significant.

To identify the spatial and spatiotemporal risk zones for MTCT of HIV, we used SatScan software, version 9.7 (Kulldorf, Cambridge, MA, USA). This analysis was based on the discrete Poisson model. The following criteria for the spatial risk were considered: non-overlapping clusters with a maximum size of 50% of the population at risk and 999 replications. The same criteria were used for the spatiotemporal analysis except that the maximum size of the temporal cluster was equal to 50% of the study period. Risk zones were those with relative risk ≥1 and $p \leq 0.05$.

To analyze the influence of the SDHs on the spatial variability of the HIV epidemic in children in Pará younger than 13 years, we employed geographically weighted regression (GWR) analysis technique. The SDHs were obtained from a Brazilian business management system (Sistema de gestãoempresarial or e-GESTOR) – Infomação da Atenção Básica in the Fundação Paraense de Amparo a Pesquisa (FAPESPA) and Atlas da Vulnerabiliada Social – Instituto de Pesquisa de Economia Aplicada websites. The variables were categorized as follows: i) HDI: municipal HDI; and HDI - education; ii) Economy: Gini coefficient; gross domestic product; gross domestic product per capita; women with formal jobs; men with formal jobs; average wages of men with formal jobs; average wages of women with formal jobs; percentage of illiterate, unemployed people aged between 15 and 24 years with a per capita income ≤ half the minimum wage; proportion of people with a per capita income equal to or less than half the minimum wage; unemployment rate of the population aged ≥18 years; percentage of people ≥18 years without having completed elementary school and in informal employment; unemployment rate of the population ≥18 years; percentage of people ≥18 years without complete elementary school and in informal occupations; percentage of people in households with a per capita income of less than half the minimum wage and dependent on elderly people; percentage of people living in households with per capita income of less than half the minimum wage and spending more than an hour commuting to work; and activity rate of people aged between 10 and 14 years; iii) Education: illiteracy rate of the population aged ≥15 years; percentage of children living in households where none of the residents has completed elementary school; percentage of people aged ≥18 years who completed elementary school; elementary school pass rate; high school pass rate; elementary school dropout rate; preschool enrolment; number of enrolments in elementary school; number of enrolments in high school; Basic Education Development Index (IDEB) - public school to 5th grade; IDEB - public school to 9th grade; and sub-index of school attendance; iv) Health: Family health strategy coverage; percentage of live births with 7 or more prenatal consultations; infant mortality rate; birth rate; number of healthcare facilities per 10 thousand inhabitants; doctors per 10,000 inhabitants; percentage of live births by vaginal delivery; percentage of live births by caesarean section; and percentage of live births to mothers aged 10–19 years; v) General infrastructure: percentage of people in households with an inadequate water supply and sanitation;and percentage of the population living in urban households without garbage collection service; and vi) Social infrastructure: 1families assisted by Family Allowance (Bolsa Família Program); total families enrolled in the Single Registry for Social Programs; total families enrolled in the Single Registry for Social Programs with a per capita family income of up to half of the minimum wage; social vulnerability index; percentage of women between 10 and 17 years who have had children; and percentage of mothers who are heads of household without completing elementary school and with children younger than 15 years.

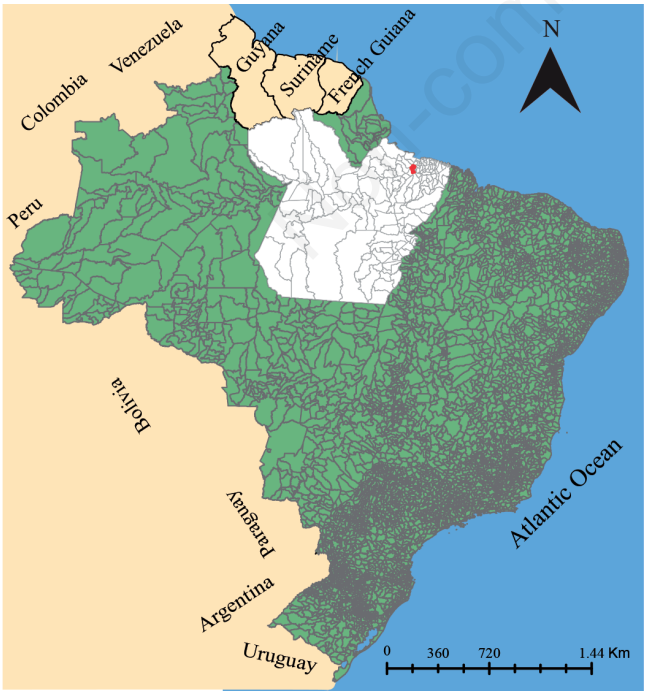

Figure 1. The study area in Brazil. Brazil (green); Pará (white); location of the state capital Belém (red polygon).

We analyzed the association between the dependent (incidence rate) and independent SDH variables, and the association with $p \leq 0.05$ were analyzed with an ordinary least-squares (OLS) regression model in the "stepwise" model technique using GeoDa® software, version 1.14.0 (University of Chicago, Chicago, IL, USA). Models with variance inflation factors (VIFs)<10 were considered. The best model was that with the lowest Akaike information criterion (AIC) and VIF values and high R^2 and adjusted R^2. The residuals of the chosen model in terms of their spatial independence were analyzed by applying Global Moran's *I*.

After discarding the spatial dependency of the residuals, GWR was applied using ArcGis® software, version 10.6.1. For this study, the adaptive kernel band was chosen on the basis of the value of the smallest corrected AIC (AICc) (adaptive band: AICc = 226.96; fixed band: AICc = 228.44). Finally, GWR residuals were tested to discard the spatial dependence. OLS and GWR models were compared using the AIC, AICc, R and R^2 values. Thematic maps were created in ArcMap in ArcGis® software, version 10.6.1, using the SIRGAS-2000 Horizontal Datum and the Longlat EPSG 4674 projection system in the geographic coordinate system.

Results

Between 2007 and 2018, 389 new HIV/AIDS cases infected through the MTCT route were reported in children younger than 13 years in Pará: 31.7% were 2–3 years; 53.2% were female; and 79.9% were brown race/skin color (Table 1). The characteristics of the children's mothers were the following: 50.1% were 15–29 years; 78.4% lived in urban areas; 75.1% were brown race/skin color; 48.8% had complete/incomplete elementary schooling; and 39.1% had complete/incomplete elementary schooling and were homemakers (Table 1).

A total of 86 municipalities reported HIV/AIDS cases, and during the study period, an increase of 250% was observed in the number of notifications between 2007 and 2018 (2007: 12 cases, 2018: 42 cases). Higher incidence rates were identified between 2011 and 2014. Figures 2A, 2C and 2E show the spatial distribution of the crude HIV/AIDS incidence rate in children younger than13 years old. Figures 2B, 2D and 2F show the Bayesian smoothed incidence. Although a territorial expansion of the cases was possibly noted between 2011 and 2014, a large number of municipalities reported HIV/AIDS cases in children. In addition, the territorial expansion of the HIV epidemic in children was predominantly in the northern and southern parts of Pará.

Global Moran's I was only statistically significant for the period of 2011–2014 (2007–2010: I = 0.04 at p = 0.25; 2011–2014: I = 0.10 at p = 0.00; 2015–2018: I = 0.01 at p = 0.63), and the LISA map showed high-high (HH) and low-low (LL) clusters. Figures 3A, 3C and 3E show the LISA map of the crude HIV/AIDS incidence and Figures 3B, 3D and 3F show the Bayesian incidence rates. The smoothing process did not influence the results. The HH cluster comprised the municipalities of Castanhal, São Francisco do Pará, Igarapé-Açu and Santa Maria do Pará, and the LL one comprised Curralinho, São Sebastião da Boa Vista, Limoeiro do Ajuru, Igarapé-Miri, Cametá e Mocajuba (Figure 3D).

Figure 4A shows the spatial risk zones for the HIV by MTCT, with the highest risk in the municipality of São Francisco do Pará, followed by Novo Progresso. Figure 4B shows two different spatiotemporal risk clusters, with the higher risk noticed in the cluster

Table 1. Sociodeomografic profile of children and pregnant mothers in Pará, Brazil diagnosed with HIV in Pará, Brazil 2007-2018.

Variable	Absolute frequency (n=389)	Relative frequency (%)
CHILD		
Age (years)		
<2	113	29.1
2-3	123	31.7
4-5	58	14.9
6-7	34	8.8
8-9	31	8.0
10-12	30	7.8
Sex		
Female	203	53.2%
Male	186	47.8%
Race/skin color		
Yellow	1	0.3
White	29	7.7
Blown	311	79.9
Black	6	1.5
Not given	42	10.8
MOTHER		
Age (years)		
15-19	27	6.9
20-24	77	19.8
25-29	91	23.4
30-34	60	15.4
35-39	38	9.8
>40	13	3.4
Not given	83	21.4
Skin colour		
Yellow	2	0.5
White	18	4.6
Blown	292	75.1
Black	16	4.1
Not given	61	15.7
Schooling		
Illiterate	5	1.3
Elementary complete/incomplete	190	48.8
High school complete/incomplete	58	15.4
University	1	0.3
Not given	135	34.7
Occupation		
Unemployed	4	1.0
Student	3	0.8
Formal job	15	3.86
Informal job	5	1.3
Agriculture	6	1.54
Fisherman	2	0.5
Housewife	152	39.1
Not given	202	51.9
Residency zone		
Urban	305	78.4
Peri-urban	3	0.8
Rural	65	16.7

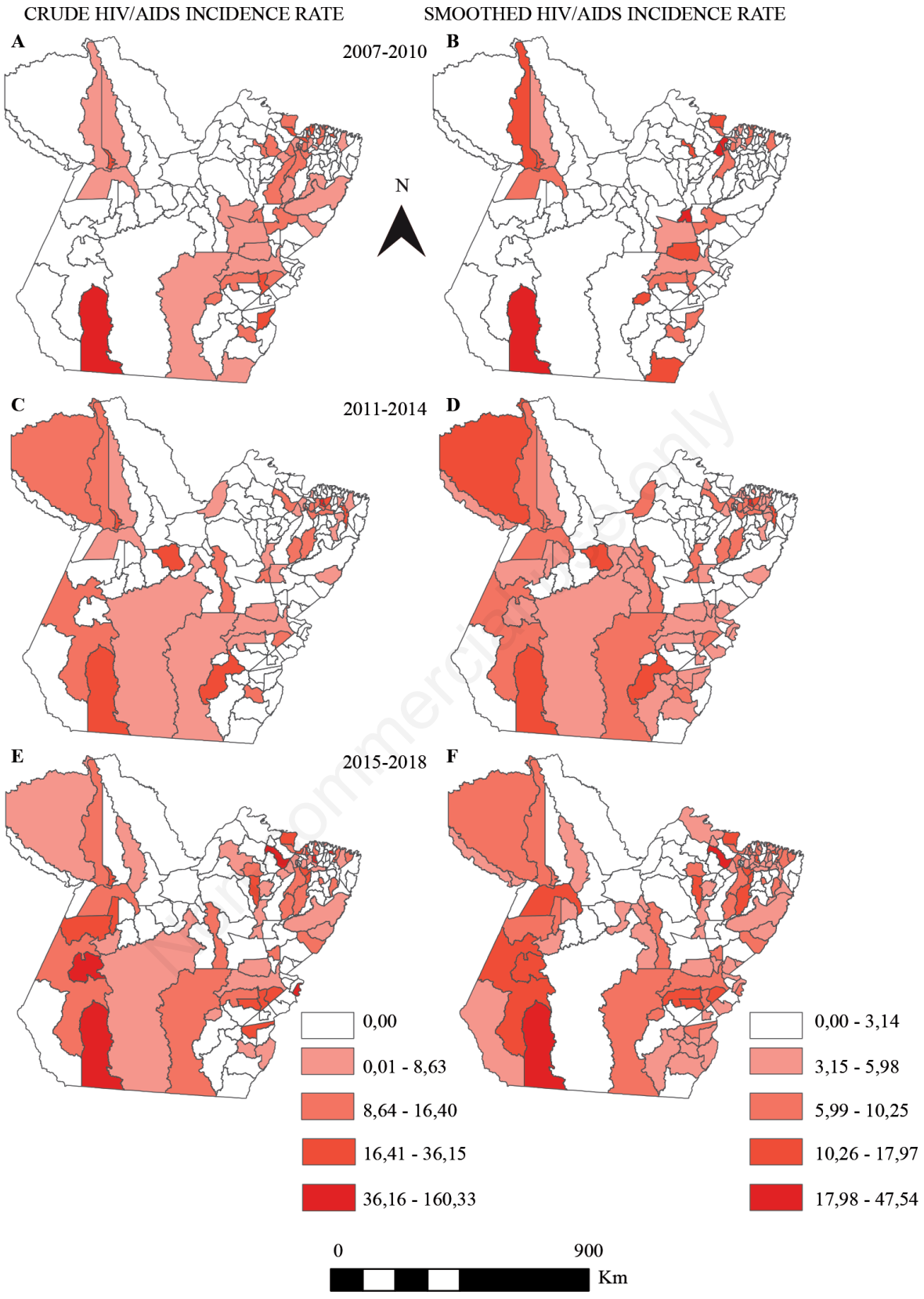

Figure 2. Spatial distribution of crude and Bayesian HIV/AIDS smoothed incidence rates in children less than 13 years in Pará, Brazil 2007-2018. A, C and E show the crude incidence rates; B, D and F show the Bayesian smoothed incidence rates (Figure 2B, 2D and 2F); A and B show the 2007-2010 period; C and D the 2011-2014 period; E and F the 2015-2018 period.).

comprising municipalities in western and south-western Pará between 2013 and 2016 and the other cluster comprising municipalities of northern and north-eastern Pará between 2014 and 2019.

Regarding the influence of SDHs on HIV infection by MTCT, the best model was revealed by OLS (Table 2). After discarding the spatial dependency of the models' residues ($I = 0.029$ at p=0.081), the variables were then analyzed in the GWR, which was better fitted in GWR ($R^2 = 0.33$, R^2 adjusted = 0.26, AICc = 226.96) as compared to OLS ($R^2 = 0.16$, R^2 adjusted = 0.13, AIC = 242.18). No spatial dependency of the GWR model's residues was noted (I = 0.06 at p = 0.17).

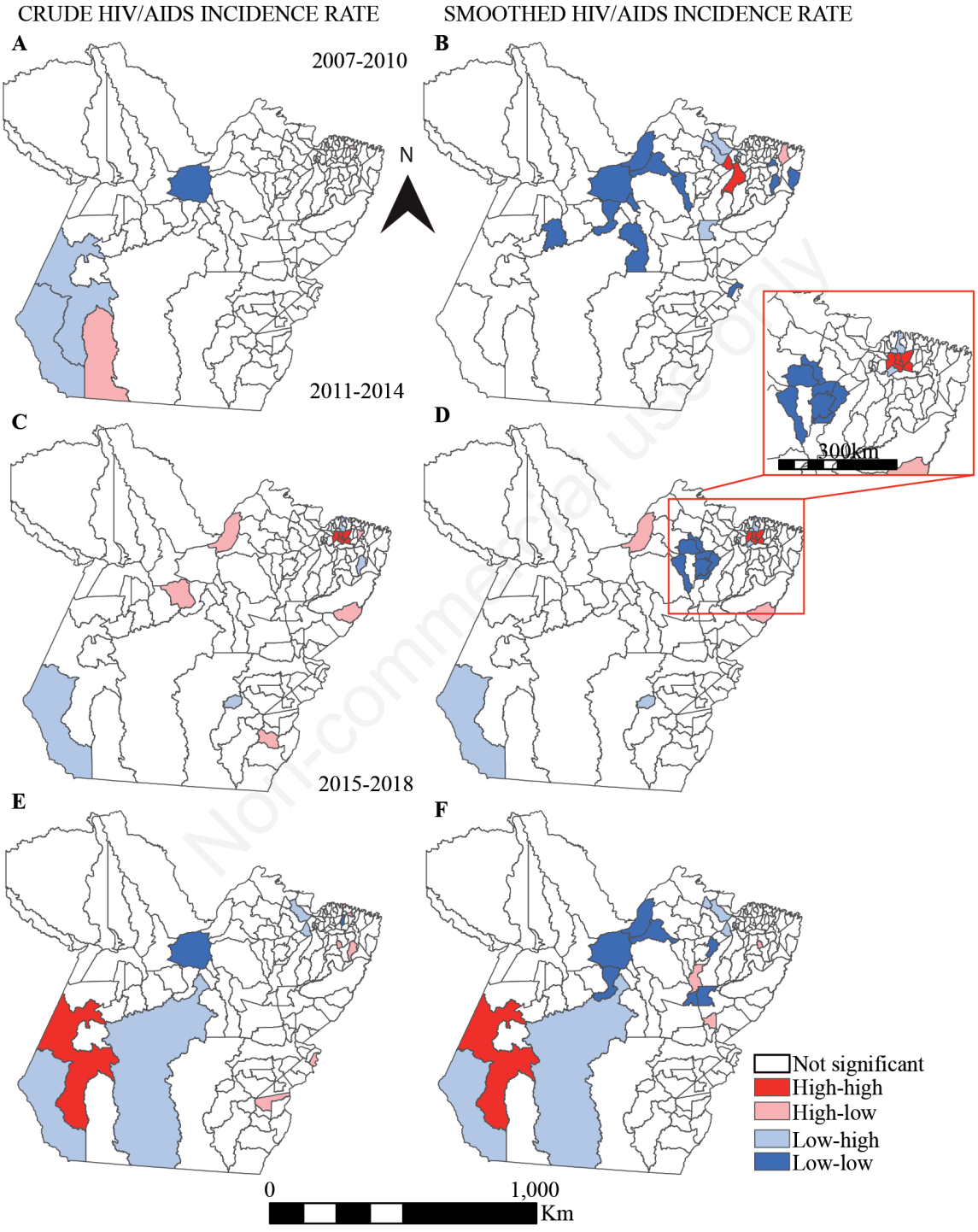

Figure 3. LISA maps of crude and Bayesian HIV/AIDS smoothed incidence rates in children less than 13 years old in Pará, Brazil 2007-2018. A, C and E show the LISA maps of the crude incidence rates; B, D and F show the LISA maps of Bayesian smoothed incidence rates; A and B show the 2007-2010 period; C and D the 2011-2014 period; E and F the 2015-2018 period.

Table 2. OLS explicative model for SDHs influence in HIV by mother to child transmission in Pará, Brazil, 2007–2018.

Variable (number)	Estimated	Standard error	p
(Constant)	0.209	0.133	0.119
Men with formal job	1.430	8.205	0.083
Women with formal job	-3.601	1.040	0.0007
Unemployed people aged ≥18 years old	-0.028	0.014	0.053
People enrolled in the elementary school	5.524	7.367	0.454
Families enrolled in the Single Register for Social Program	1.124	6.024	0.041

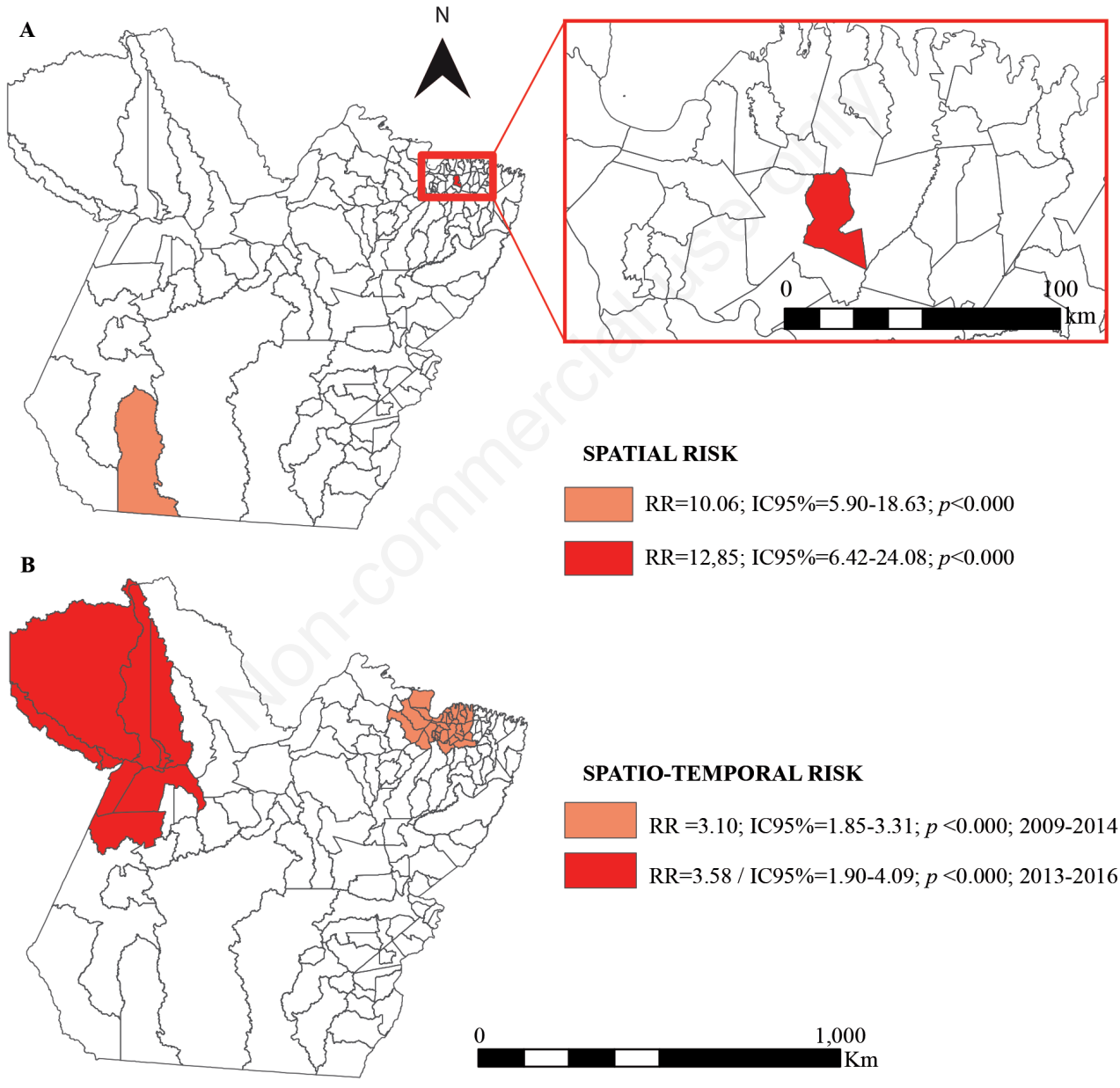

Figure 4. Spatial and spatio-temporal risks zones for HIV/AIDS in children less than 13 years old in Pará, Brazil 2007-2018. A shows the spatial risk zones, and B the spatio-temporal risks zones. The higher-risk cluster comprises municipalities in western Pará between 2013 and 2016 and the other municipalities in north-eastern Pará between 2014 and 2019.

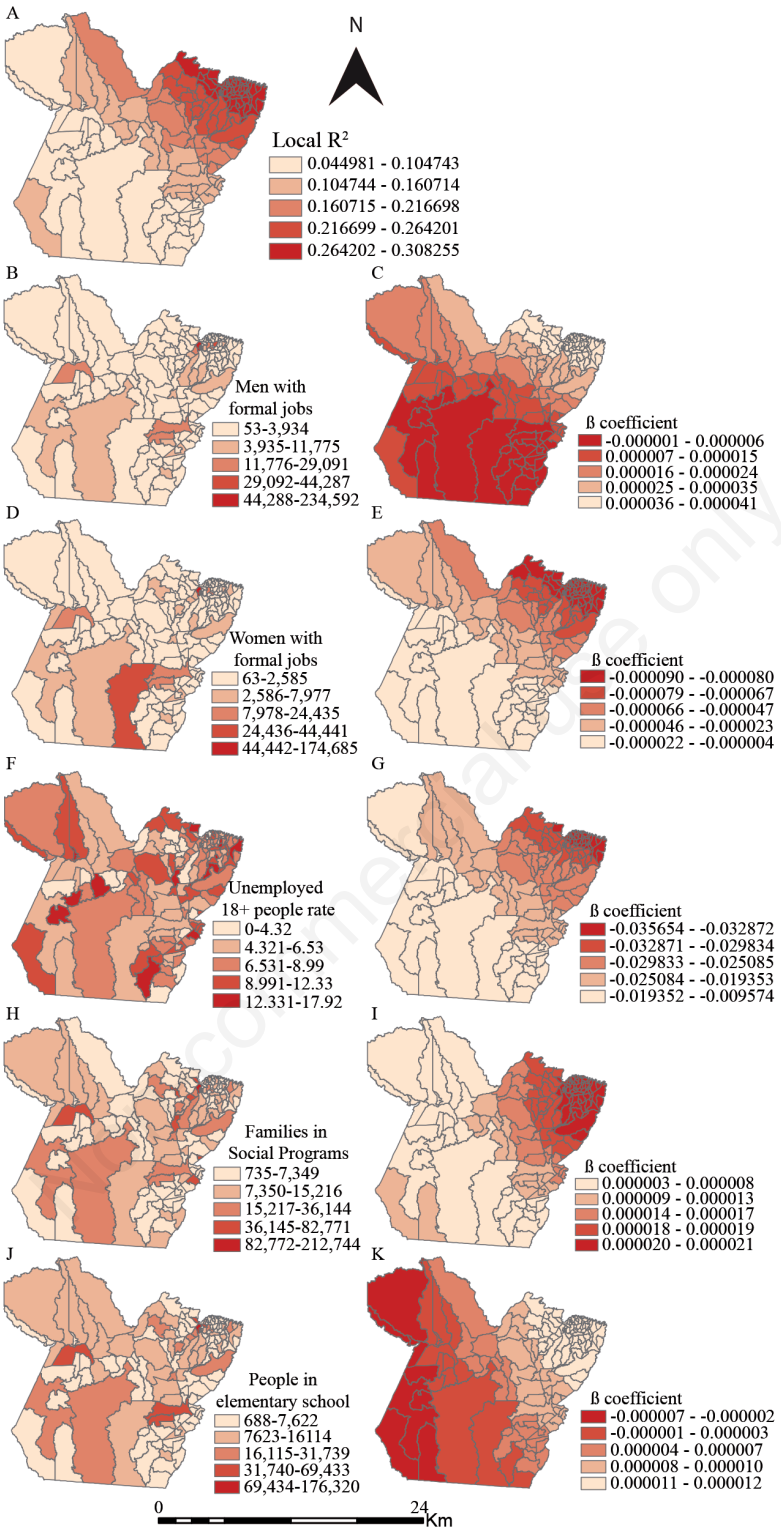

Figure 5. Spatial mapping by geographic weighted regression of social determinants of health influences on MTCT of HIV in Pará. A shows the local R2; B and D the spatial distribution of number of men and women with formal jobs; F the number of unemployed ≥18-year olds; H the number of families enrolled in the Single Registry for Social Programs; J the number of people in elementary schools; C and E the β coefficient of the spatial distribution of the number of men and women with formal jobs; G the β coefficient of the number unemployed ≥18-year olds, I the β coefficient of the number of families enrolled in the Single Registry for Social Programs; and K the β coefficient of the number of people in elementary schools.

Figures 5B, 5D, 5F, 5H and 5J show the spatial distribution of SDHs in the GWR model, and figures 5C, 5E, 5G, 5I and 5K the β coefficient of the impact of the corresponding SDH on the HIV by MTCT occurrence in Pará. Although the SDHs in the model conferred only a small risk to HIV-infection by MTCT in the municipalities of Pará, they still influenced the spatial variability of the HIV epidemic. The risk of HIV by MTCT was lower in municipalities where a greater number of men have formal jobs (Figure 5C). This was also the case in northern and north-eastern Pará where only a small number of women have formal jobs (Figure 5E) and the number of unemployed people ≥18 years is high (Figure 5G). The risk of becoming HIV by MTCT was also lower in the municipalities in the North, Northeast and Southeast Pará, where there is a greater number of families enrolled in the Single Recording for the Social Program, and in south-eastern and western meridionals, where most municipalities have a greater number of people in elementary school (Figure 5K).

Discussion

Our results showed a territorial expansion between 2007 and 2018 of the HIV/AIDS detection rates in Pará in children aged younger than 13 years old, with MTCT as route of virus transmission. High HIV/AIDS incidence rates in children were noticed between 2011 and 2014, and municipalities in northern and southern parts of Pará were found to be particularly affected by this HIV epidemic in children. Several spatiotemporal risk clusters were identified and the spatial variation of HIV rate incidence rate due MTCT was understood as promoted by the numbers of men and women with formal jobs, unemployed people ≥18 years old, people in elementary schools, and families enrolled in the Single Registry for Social Program. However, our study was limited by underreported cases of HIV in children younger than 13 years. In addition, the qualities of the processed information depended exclusively on the responsible professionals for the notifications, which was beyond the control of the researchers. Furthermore, considering that this work is an ecological study, we did not infer the causalities as only due to the study subjects themselves. In addition, we used secondary data. Although these limitations did not compromise the analysis, future studies are necessary to evaluate the effect of the COVID-19 pandemic of HIV caused by MTCT.

The two different time periods, 2009–2013 and 2013–2016, noted in the spatiotemporal clusters in the North and West of Pará, respectively, could be due to the high latency of implementing the Stork Network Program and other policies in municipalities far from the capital. This program was implemented in 2011 in the North of Pará and in 2015 also in the West (SESPA, 2012). The dismantling of this network by the Brazilian Ministry of Health through ordinance MS 715/2022 raises concerns about a possible increase in HIV by MTCT, mainly in regions with low physician coverage.

The risk of HIV by MTCT in the municipalities of southern Pará is indirectly associated with the number of men with formal jobs. Southern Pará has the highest economic growth among all parts of the state due to the expansion of the mineral extraction industries and hydroelectric construction, resulting in generating jobs and hiring of qualified people. A study in Nigeria showed that men with high school educations were more involved in prevention of MTCT (Belato *et al.,* 2017; Lliyasu *et al.,* 2020). However, in the same region, the risk of HIV by MTCT was higher in municipalities with a large number of women with formal jobs and a larger number of unemployed people ≥18years. This finding could be due to the geographic barriers to these women accessing health care centres specialized in prevention of MTCT. Among its 144 municipalities, the only two health care centres attending pregnant women living with HIV are in Belém, and women living in southern Pará must travel more than 12 hours by bus to reach these services. In Rio de Janeiro, HIV by MTCT is associated with mothers living with HIV and attending prenatal consults at low frequencies (Lovero *et al.,* 2018). Even though Brazil is a signatory of the Option B+ Program, MTCT is still a problem, particularly in Pará, which may be due to the minimal resources allocated for prevention of MTCT. In Kenya, the Option B Program reduced the HIV by MTCT from 19.7 in 2007 to 7.0 in 2013 (Waruru *et al.,* 2018).

São Francisco and Novo Progresso represent municipalities with a high spatial HIV risk. Two spatiotemporal risk clusters for MTCT of HIV were found in northern and western Pará, and the latency on the policy implementation against HIV by MTCT explains the time difference found between the two clusters, 2009–2013 vs. 2013–2016. The spatial variation in incidence rates is promoted by the numbers of men and women with formal jobs, unemployed people aged ≥18 years, people in elementary school, and families enrolled in the Single Registry for Social Programs.

In Northern Pará, the risk of HIV by MTCT is directly associated with the number of families enrolled in Single Registry for Social Programs and people having less than an elementary schooling level. In India and Tanzania, poor pregnant women living with HIV had low adherence to antenatal care and follow-up treatment of their babies (Rebnord *et al.,* 2017; Suryavanshi *et al.,* 2018). In Africa, pregnant women with high schooling levels were more aware of prevention of HIV by MTCT during antenatal care, postpartum and during breastfeeding (Dlamini and Mokoboto-Zwane, 2019; Darteh *et al.,* 2021). On the other hand, although pregnant women in Tanzania who lived with HIV had a high level of knowledge about prevention of HIV by MTCT, stigma and social prejudice were associated with low prenatal frequency and ART adherence (Rebnord *et al.,* 2017). Thus, much more than to promote health accessibility equity to combat HIV by MTCT, it is necessary to fight the stigma and social prejudice against people living with HIV.

Conclusions

Our results showed a 250% expansion of the incidence rate of HIV in children due to MTCT of HIV. The municipalities with a significant effect on HIV by MTCT were mainly seen in southern Pará. Fighting the stigma should be reinforced, and access to preventive, diagnosis, and treatment health care places provided to all women to decrease HIV by MTCT. Furthermore, considering the sizeable territorial area of Pará and the poor socioeconomic conditions of people, the specialized centres for pregnant women living with HIV and newborns' follow-up treatment should be expanded. In addition, health education should be promoted among women living with HIV and told about the importance of preventing HIV by MTCT.

References

Aagaard-Hansen J, Chaignat CL, 2010. Neglected tropical diseases: equity and social determinants in Equity, social determinants and public health programmes, Blass E, Kurup AS, editors. Geneva: World Health Organization, 291 pp.

Belato DT, Mekiso AB, Begashaw B, 2017. Male Partners Involvement in Prevention of Mother-to-Child Transmission of HIV Services in Southern Central Ethiopia: In Case of Lemo District, Hadiya Zone. AIDS Res Treat, 1-8.

Bick MA, Ferreira T, Sampaio CO, Padoin SMM, Paula CC, 2018. Profile of infected pregnant women and children exposed to HIV at a specialized service in the South of Brazil. Rev Bras Saúde Mater Infant 18:791-801.

Brasil Ministry of Health, 2021. Ministério da Saúde. Secretária de VigilânciaemSaúde. BoletimEpidemiológico: HIV/Aids. Brasília: Ministério da Saúde. Available from: http://www.aids.gov.br/pt-br/pub/2021/boletim-epidemiologico-hivaids-2021

Brasil Ministry of Health, 2022. Ministério da Saúde do Brasil - PORTARIA GM/MS Nº 715, DE 4 DE ABRIL DE 2022. Available from: https://www.in.gov.br/web/dou/-/portaria-gm/ms-n-715-de-4-de-abril-de-2022-391070559

Brasil Ministry of Health. Ministério da Saúde. Departamento de Doenças de Condições Crônicas e Infecções Sexualmente Transmissíveis, 2022. Available from: http://www.aids.gov.br/pt-br/acesso_a_informacao/servicos-de-saude?field_end_servicos_disponiveis_tid=All& field_endereco_tipo_tid=All& province=PA

Darteh EKM, Abraham SA, Seidu AA, Chattu VK, Yaya S, 2021. Knowledge and determinants of women's knowledge on vertical transmission of HIV and AIDS in South Africa. AIDS Res Ther 18:40.

Dlamini P, Mokoboto-Zwane TS, 2019. Knowledge, attitudes, and practices associated with post-natal PMTCT in breastfeeding mothers living with HIV. Int J Afr Nurs Sci 11:100150.

Domingues RMSM, Saraceni V, do Carmo Leal M, 2018. Mother to child transmission of HIV in Brazil: Data from the "Birth in Brazil study", a national hospital-based study. PLoS One 13:e0192985.

FAPESPA, 2021. Anuário Estatístico do Pará 2021. Available from: https://www.fapespa.pa.gov.br/sistemas/anuario2021/tabelas/social/5.5-saude/tab-5.5.11-percentual-de-nascidos-vivos-com-7-ou-mais-consultas-pre-natal-2016-a-2020.htm

Garnelo L, Lima JG, Soares E, Rocha C, Herkrath FJ, 2018. Access and coverage of Primary Health Care for rural and urban populations in the northern region of Brazil. Saúde Debate 42:81–99.

Goga A, Singh Y, Jackson D, Pillay Y, Bhardwaj S, Chirinda W, Hayashi C, Essajee S. 2019. Is elimination of

vertical transmission of HIV in high prevalence settings achievable? BMJ 364:1687.

Guimarães MF, Lovero KL, de Avelar JG, Pires LL, de Oliveira GRT, Cosme EM, Salviato CM, Oliveira TRD, Cabrera NB, Cardoso CAA, 2019. Review of the missed opportunities for the prevention of vertical transmission of HIV in Brazil. Clinics 74:e318.

IBGE, 2021. Instituto Brasileiro de Geografia e Estatística – Cidades – Pará, 2010. Available from: https://cidades.ibge.gov.br/brasil/pa/panorama

IER. Instituto Edson Royer, 2022. Available from: https://prosas.com.br/empreendedores/52946-instituto-edson-royer?locale=en

Levin KA, 2006. Study design VI – Ecological studies. Evid Based Dentist 7:108.

Lliyasu Z, Galadanci HS, Muhammad B, Yadudu FZ, Kwaku AA, Salihu HM, Alyiu MH, 2020. Correlates of HIV-Positive Fathers' Involvement in Prevention of Mother-to-child Transmission Programs in Northern Nigeria. Curr HIV Res 18:443-457.

Lovero, KL,OliveiraTRD,Cosme EM, Cabrera NB, Guimarães MF, Avelar JG, Oliveira GRT, Salviato CM, Douglass-Jaimes G, Cruz MLS, João EC, Barros ACMW, Pone MVS, Gomes IM, Riley LW, Cardoso CAA, 2018. Retrospective analysis of risk factors and gaps in prevention strategies for mother- to-child HIV transmission in Rio de Janeiro, Brazil. BMC Public Health 18:1110.

McCoy SI, Fahey C, Buzdugan R, Mushavi A, Mahomva A, Padian NS, Cowan FM, 2016 Targeting elimination of mother-to-child HIV transmission efforts using geospatial analysis of mother-to-child HIV transmission in Zimbabwe. AIDS 30:1829–37.

Miranda AE, Freitas FLS, Passos MRL de, Lopez MAA, Pereira GFM, 2021. [Políticas pública seminfecções sexualmente transmissíveis no Brasil]. [Article in Portuguese] Epidemiol Serv Saúde 30:e2020611.

Momenyan S, Kavousi A, Poorolajal J, Momenyan N, 2018. Spatial inequalities and predictors of HIV/AIDS mortality risk in Hamadan, Iran: a retrospective cohort study. Epidemiol Health 40:e2018038.

Rebnord T, Østbye T, Mmbaga BT, chome B, Lie RT, Daltveit AK, 2017. Time trends in management of HIV-positive pregnant women in Northern Tanzania: A registry-based study. PLOS One 12:e0184362.

SESPA. Secretaria de Saúde do Pará. Agência Pará. Available from: https://agenciapara.com.br/noticia/21505/.

SESPA. Secretaria de Saúde do Pará – Plano de Ação Rede Cegonha 2011 – 2014. Available from: http://www.sopape.com.br/data/conteudo/arquivos/z65PlanodeAcaoRedeCegonha.pdf

SICLOM. Sistema De Controle Logístico De Medicamentos, 2022. Available from: http://azt.aids.gov.br

Suryavanshi N, Kadam A, Kanda S, Sivalenka S, Kumar VS, Harvey P, Gupta R, Hegde A, Gupte N, Gupta A, Bollinger RC, Shankar A, 2018. Challenges and opportunities for outreach workers in the Prevention of Mother to Child Transmission of HIV (PMTCT) program in India. PLOS One 13:e0203425.

Trindade LNM, Nogueira LMV, Rodrigues ILA, Ferreira AMR, Corrêa GM, Andrade NCO, 2021. HIV infection in pregnant women and its challenges for the prenatal care. Rev Bras Enferm 74:e20190784.

UNAIDS, 2011. Global plan towards the elimination of new infections in children by 2015 and keeping mothers alive: 2011–2015. Available from: http://www.zero-hiv.org/wp-content/uploads/2014/06/Global-Plan-Elimination-HIV-Children-Eng.pdf

UNICEF, 2021. Elimination of mother-to-child transmission. Available from: https://data.unicef.org/topic/hivaids/emtct/

Waruru A, Achia TNO, Muttai H, Ng'ang'a L, Zielinski-Guttierrez E, Ochanda B, Katana A, Young PW, Tobias JL, Juma P, Cock KM, Tylleskär T, 2018. Spatio-temporal trend for mother-to-child transmission of HIV up to infancy and during pre-Option B+ in Western Kenya, 2017-13. PeerJ 6:e4427.