



EVALUATION OF SPATIAL DISTRIBUTION OF TUBERCULOSIS

AVALIAÇÃO DA DISTRIBUIÇÃO ESPACIAL DA TUBERCULOSE

EVALUACIÓN DE DISTRIBUCIÓN ESPACIAL DE LA TUBERCULOSIS

Frederico Fávaro Ribeiro¹, Joabson Gomes Rodrigues², Rodrigo Pinheiro de Toledo Vianna³, Ronei Marcos de Moraes⁴

ABSTRACT

Objective: identifying significant spatial clusters of tuberculosis. **Method:** an ecological study, making use of secondary data, concerning cases of tuberculosis of residents in the city of João Pessoa, Paraíba; diagnosed from January 2002 to December 2012. Relative risk maps and spatial scan were generated for all months in the study. **Results:** in almost all months there was detected clusters of high risk in the North region; thus, indicating the existence of a geographical or socioeconomic barrier in the region. **Conclusion:** a spatial analysis was able to detect spatial clusters of high risk in João Pessoa, which can assist managers in directing actions to control tuberculosis in the city. **Descriptors:** Tuberculosis; Relative Risk; Space Scan.

RESUMO

Objetivo: identificar conglomerados espaciais significativos de tuberculose. **Método:** estudo ecológico, fazendo uso de dados secundários, referentes aos casos de tuberculose, de residentes no município de João Pessoa/PB, diagnosticados no período de janeiro de 2002 a dezembro de 2012. Mapas de risco relativo e Scan espacial foram gerados para todos os meses em estudo. **Resultados:** em praticamente todos os meses, foi detectado conglomerados de alto risco na região Norte, indicando assim, a existência de uma barreira geográfica ou socioeconômica na região. **Conclusão:** a análise espacial foi capaz de detectar conglomerados espaciais de alto risco em João Pessoa, o que pode auxiliar os gestores no direcionamento das ações para controle da tuberculose no município. **Descritores:** Tuberculose; Risco Relativo; Scan Espacial.

RESUMEN

Objetivo: identificar agrupaciones espaciales significativas de tuberculosis. **Método:** un estudio ecológico a partir de datos secundarios sobre los casos de tuberculosis en los residentes de la ciudad de João Pessoa, Paraíba; diagnosticados desde enero de 2002 a diciembre de 2012; los mapas de riesgos relativos y exploración espaciales fueron generados para todos meses en el estudio. **Resultados:** en casi todos los meses, se detectó grupos de alto riesgo en la región Norte, lo que indica la existencia de unas barreras geográficas o socioeconómicas de la región. **Conclusión:** un análisis espacial fue capaz de detectar agrupaciones espaciales de alto riesgo en João Pessoa, que puede ayudar a los administradores en la dirección de las acciones de control de la tuberculosis en la ciudad. **Descriptores:** Tuberculosis; Riesgo Relativo; Exploración Espacial.

¹Biologist, Doctoral student of Therapeutic Innovation, Federal University of Pernambuco / PPGIT / UFPE. Recife (PE), Brazil. Email: fredericofavaro@gmail.com; ²Graduating in Statistics, Federal University of Paraíba. João Pessoa (PB), Brazil. Email: joabson.rccpb@hotmail.com; ³Food engineer, Doctorate in Public Health, Federal University of Paraíba / PPGMDS / UFPB. João Pessoa (PB), Brazil. Email: vianna@ccs.ufpb.br; ⁴Statistician, Doctorate in Applied Computing, Federal University of Paraíba / PPGMDS / UFPB. João Pessoa (PB), Brazil. Email: ronei@de.ufpb.br

INTRODUCTION

Although it can be prevented and treated efficiently, tuberculosis has worldwide distribution, with high incidence and mortality. This situation is a result of noncompliance with the treatment, the emergence of resistant strains of the HIV epidemic and unfavorable socioeconomic conditions, which act hampering tuberculosis control, harm the increasing susceptibility and vulnerability.¹⁻³

Brazil, together with 21 countries, is responsible for 80% of all TB cases worldwide. It is estimated that in Brazil more than 50 million people are infected, occurring 80 000 new cases and from 4 to 5 thousand deaths per year. Regarding this situation, tuberculosis is seen as a priority in governmental policies of the country's health.^{1-2,4}

According to data obtained from the Information System of Disease Notification,⁵ during the period from 2007 to 2011, the State of Paraíba was in the 18th position in the rankings of the Brazilian states most affected by tuberculosis, with a total of 6803 reported cases, of which 195 they had died, representing an incidence rate of 36,34 cases per 100,000 inhabitants and a mortality rate of 1,04 deaths per 100,000 inhabitants. The Ministry of Health rated six municipalities as a priority for TB control, namely: Cajazeiras, Patos, Campina Grande, Santa Rita, Bayeux and João Pessoa, especially the latter not only as the capital of the State, but concentrate the largest number of cases of tuberculosis among the municipalities of Paraíba in the last 10 years.⁶

Geoprocessing techniques are important tools for epidemiological evaluations. It enables the researcher to build maps of epidemiological indicators, to measure the association between health indicators, relate data layers on environment and health, detect clusters from the identification of areas of greatest incidence, evaluate the evolution of the spatial distribution of disease in time and analyze health care networks, and thus assisting the managers in the decision-making process in health.⁷ Based on the current situation of tuberculosis, the advantages of using Geoprocessing techniques in epidemiological studies and the need to enhancing health actions in order to achieve effective control of the disease, the current study aims to identifying significant spatial clusters of tuberculosis.

OBJECTIVE

- Identifying significant spatial clusters of tuberculosis.

METHOD

A quantitative and ecological study, making use of secondary data concerning cases of tuberculosis of residing in the city of João Pessoa, Paraíba, diagnosed from January 2002 to December 2012.

The city of João Pessoa, being located in the Northeast region of Brazil has a total area of 211,475 km² and is bordered to the north with the municipality of Cabedelo, to the south with the municipality of Conde, on the east by the Atlantic Ocean and west to the towns of Bayeux and Santa Rita. It has a total population of 723,515 inhabitants and a population density of 3.421,30 inhabitants per km², being considered by the Ministry of Health as one of the 6 priority municipalities for the National Plan for Tuberculosis Control in the State of Paraíba. By the year 2006 consisted of 66 districts, however, after policy reform in the geographical conformation of some neighborhoods, in 2007 the city started to be formed by 64 districts, due to this, two digital meshes of the municipality were used in spatial analyzes performed in this research.^{6,8}

To have access to the data, the project was subjected to review by the Department of Health Education (GES) of the Municipal Health Department, under case number 20.297/2013. The data reporting cases of tuberculosis were obtained from the Health Inspectors of Municipal Health Secretariat, from the investigation files of the Notifiable Diseases Information System (SINAN) for cases of tuberculosis residing in the city of João Pessoa, diagnosed during the study period. There were considered, for the study, only the notifications containing the home district and the date of diagnosis. As for living in the city during the study population it was obtained from the estimates generated by the Brazilian Institute of Geography and Statistics (IBGE).

The Lilliefors test was used to verifying whether the data were normally distributed. This test is a derivation of the Kolmogorov-Smirnov grip that weighs the central and extreme values of the distribution test. The test evaluates the level of correlation between the distribution of a set of sample values and the test statistic based on level of significance, in which case was of 5%.⁹

The first spatial analysis used was to draw up maps of relative risk (RR), which assesses

the intensity of tuberculosis in the neighborhoods of João Pessoa. Monthly RR of each neighborhood was calculated from the

$$RR = \frac{\textit{incidence rate of tuberculosis of the neighborhood}}{\textit{incidence rate of the municipality}}$$

The RR values obtained were plotted in choropleth maps with class intervals regarding the RR values obtained. Each interval was linked a color map representing the RR of each district, enabling better visualization and interpretation of results.

In order to identifying the existence of statistically significant spatial clusters, it was used the method proposed by Kulldorff and Nagarwalla¹¹, the spatial Scan. A conglomerate consists of a set of areas that have a high risk in relation to the other, regarding the occurrence of an event, in this case, tuberculosis.¹² To performing the spatial scan method, it was associated with each neighborhood area in one study centroid and he the number of diagnosed cases of tuberculosis as well as population size. About each centroid there are positioned circles that had its radius increased continuously, so you can engage neighboring centroids, to include a total of 10% of the population. Concomitant

ratio of the incidence rate of tuberculosis in the neighborhood and the incidence rate for the entire municipality.¹⁰

with the increase in radius, is tested the null hypothesis of no conglomerate from a significance test, determining whether the area bounded by the circle it is or not a conglomerate.^{11,13}

By assuming that the probability distribution of the data follow a Poisson model, we have as a parameter the triple $(z,p(z),r(z))$, where z consists of the circle positioned on the centroid belonging to Z , which is the set of all circles, $p(z)$ is the probability that any one individual in z is a case, and $r(z)$ the probability of any individual out of z is one case.^{11,13} In spatial scanning method, the rays of the circles are calculated so that the estimated values of $p(z)$ and $q(z)$, $\hat{p}(z)$ and $\hat{q}(z)$, maximize the maximum likelihood function based on total cases observed. When z is admitted as a candidate to conglomerate, it is considered the statistical KN defined by the equation:¹⁴

$$KN = \max_{z \in Z} \frac{L(z,\hat{p}(z),\hat{q}(z))}{L_0},$$

where L_0 is defined by:

$$L_0 = \frac{C^C(M-C)^{M-C}}{M^M},$$

where C is the total of cases observed in the considered region and M the total

population under the whole region of the study. $L(z,\hat{p}(z),\hat{q}(z))$ is defined by:

$$L(z,\hat{p}(z),\hat{q}(z)) = \frac{\exp[-p(z).n_z - q(z)(M - n_z)]}{C!} p(z)^{c_z} q(z)^{C - c_z} \prod_i c_i,$$

and wherein c_z and c_i are, respectively, the number of cases in the circle in the z circle, ie n_z is the number of at-risk individuals in the circle z . In the end the greatest value of KN is logged and the significance of the result is calculated from the Monte Carlo simulation.^{13,15}

RESULTS

During the period 2002 to 2012 were diagnosed a total of 4358 cases of tuberculosis in the city of João Pessoa. The number of diagnoses varied greatly over the months, when the largest number of cases occurred in August 2012, with 53 cases diagnosed, while in the month of December 2011, there was the lowest amount recorded in the period, 8 patients; corresponding, respectively, to the

incidence rates of 0,69 and 0,11 cases per 10,000 inhabitants.

The spatial analysis was performed based on the correlation between risk maps and spatial analysis Scan for each month of the study period, a total of 132 maps for each analysis. During all months of 2002, we observed a clear spatial pattern, where the neighborhoods that had higher RR were almost exclusively in the north of the city, especially the downtown neighborhoods (1), Varadouro (2) Róger (3), Padre Zé (4) and Mandacaru (5), which in almost all months presented high RR. A similar result was obtained in the spatial analysis scan, which revealed that most of the districts have also formed RR statistically significant spatial clusters (Figure 1).

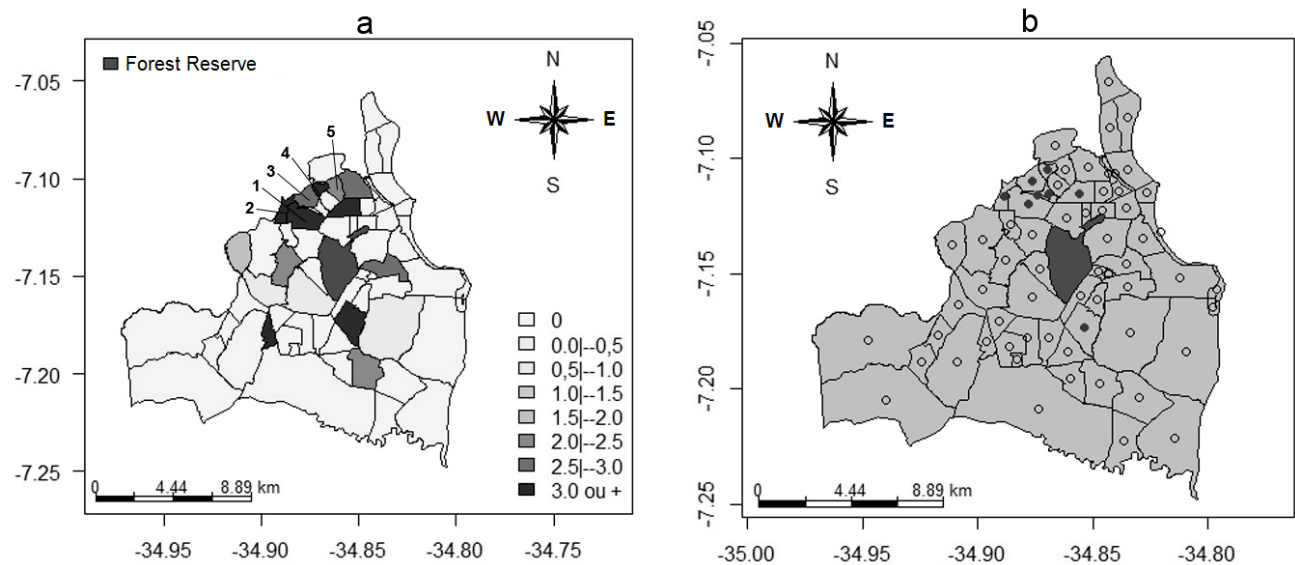


Figure 1: Map of relative risk (a) and spatial Scan (b) for the municipality of João Pessoa in January 2002. Caption: The fulfilled circles represent significant conglomerates.

In 2003 the results were similar to those observed in 2002, with the downtown neighborhoods, Varadouro, Roger and Mandacaru keeping up with higher risks and greater concentration of significant clusters of high risk located in the northern region.

Months in 2004, neighborhoods located in the south of João Pessoa began presenting

high RR, as was the case of the neighborhoods of Bancários (1), Mangabeira (2), Valentina (3) and Grotão (4). The downtown neighborhoods (6), Varadouro (5) Roger (7) and Mandacaru (8), continued showing high RR, however, the spatial scan analysis revealed a higher frequency of significant concentration of conglomerates in the south (Figure 2).

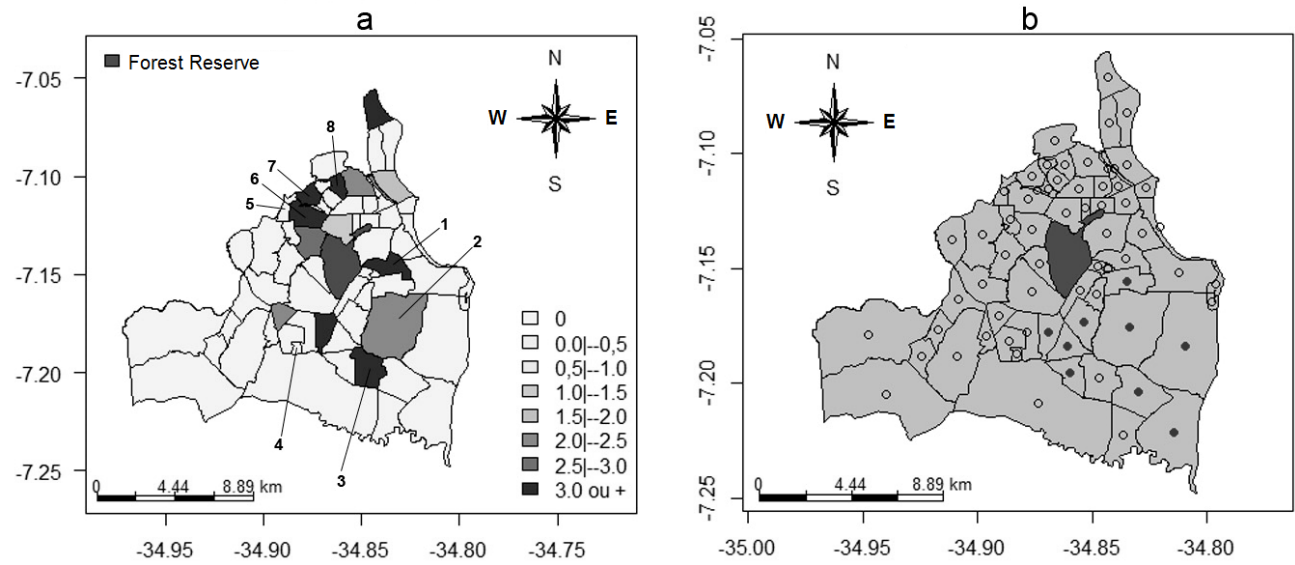


Figure 2: Relative risk map (a) and (b) spatial Scan for the municipality of João Pessoa in July 2004. Caption: The fulfilled circles represent significant conglomerates.

For months in 2005, the distribution of neighborhoods with higher RR concentrated in the north and west of João Pessoa, where neighborhoods were most prominent, Centro (1), Roger (2), Padre Zé (3), Jaguaribe (4),

Rangel (5) and Bessa (6). During almost every month statistically significant clusters were also located in the northern and western regions of the city, as can be seen in Figure

3.

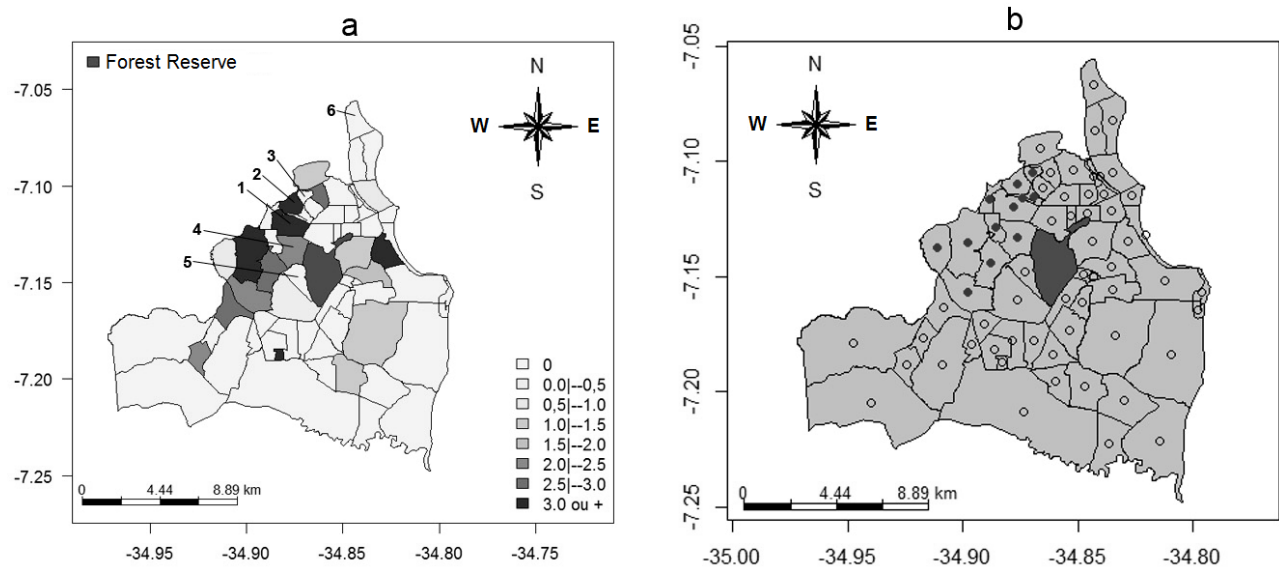


Figure 3: Map of relative risk (a) and Scan spatial (b) for the municipality of João Pessoa in August 2005.
Caption: The fulfilled circles represent significant conglomerates.

In 2006, the districts of Roger, Mandacaru, Bancários, Mangabeira, Valentina and Costa e Silva had elevated RR during the months, demonstrating that high-risk areas are scattered throughout the municipality. However the scan analysis obtained similar results to those observed in the months of 2005, with significant spatial clusters, mainly in the north and the west of João Pessoa.

Despite the neighborhoods of Bancários and Valentina are consistently high RR in 2007, the spatial pattern of RR of TB was focused on the northern region of the city. Similar average was obtained in the analysis of spatial scan, where only the months of March and August were the focus of significant clusters in the south, in the remaining months the clusters were concentrated in the northern region.

For 2008, once again the focus of neighborhoods with higher RR in the north of the city is observed, highlighting the

downtown neighborhoods, Varadouro, Roger, Padre Zé and Mandacaru, where for all months, significant spatial clusters were located almost exclusively north of João Pessoa.

Months in 2009, the districts with the highest RR were concentrated to the north and west of the city, with the center (1), Varadouro (2) Roger (3), Padre Zé (4), Mandacaru (5), Cruz das Armas (6) and Ilha do Bispo (7) neighborhoods with higher RR. Statistically significant clusters coincided with areas that had neighborhoods with high RR, ie, located to the north and west, with the exception of August when the clusters were located further south (Figure 4).

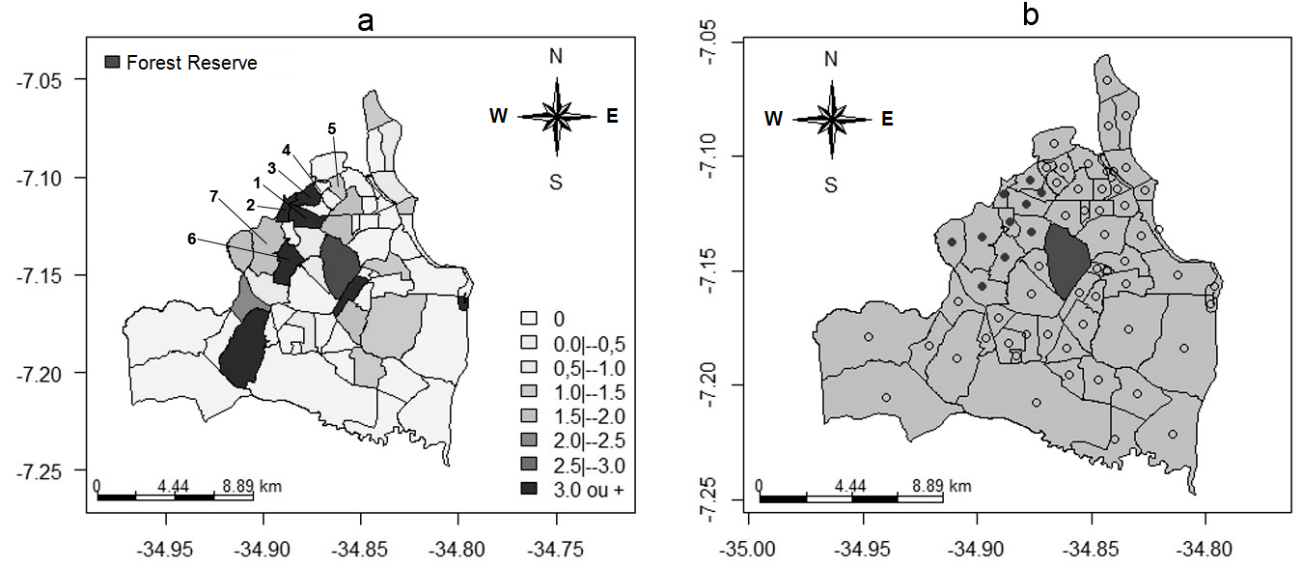


Figure 4: Relative risk map (a) and Scan spatial (b) for the municipality of João Pessoa, in October 2009.
Caption: The fulfilled circles represent significant conglomerates.

Similar to 2009 spatial pattern was observed from 2010 where the neighborhoods located to the north and west were those with the highest RR. The neighborhoods of Bancários and Mangabeira, located to the

south, also had a high RR. The spatial scan analysis detected statistically significant spatial clusters mainly located in the northern region, but in the months of March, April,

September and December conglomerates were mostly south of João Pessoa.

For the year 2011, was observed once again focused to the north of the county, with higher RR in the downtown neighborhoods (1), Varadouro (2) Roger (3), Padre Zé (4) Rangel and spatial pattern (6). However, in the months of November and December only the

downtown neighborhoods (1), Varadouro (2) Roger (3), Padre Zé (4), Mandacaru (5), Torre (7), Ernesto Geisel (8), Cidade dos Colibris (9), Bancários (10) and Valentina (11) had a nonzero RR, and high values. Spatial clusters were detected mainly north and west of João Pessoa, including neighborhoods with higher RR (Figure 5).

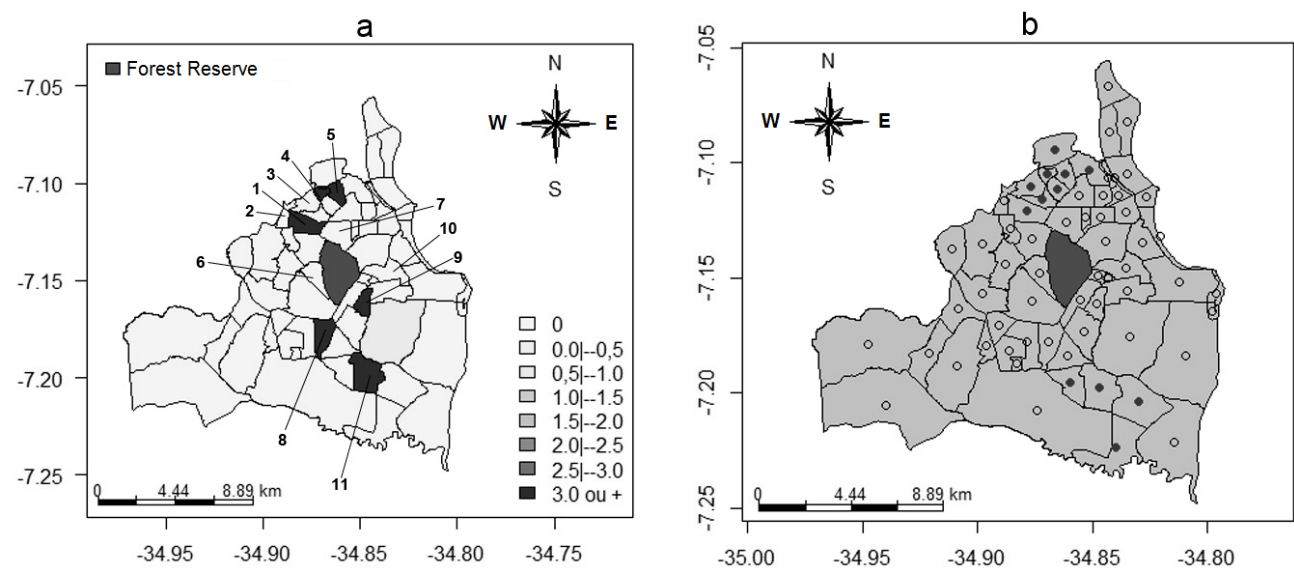


Figure 5: Relative risk map (a) and Scan spatial (b) for the municipality of João Pessoa, in November 2011. Caption: The filled circles represent significant conglomerates.

During the year 2012, the largest concentration of neighborhoods with high RR in the northern and western region occurred, except in the month of May in which this concentration occurred south of João Pessoa. The downtown neighborhoods, Varadouro, Roger, Padre Zé, Mandacaru remain among the neighborhoods with higher RR. In all months of significant spatial clusters in the northern and western region were detected, however, in February and May there was a greater concentration south of the city of João Pessoa.

DISCUSSION

As the spatial analysis, it was observed that in almost all months, the districts located in the northern region of the municipality presented the highest values of RR, a situation that is compounded by the results of spatial analysis scan, which considered these neighborhoods as clusters statistically significant. It stood out in the spatial analysis the downtown neighborhoods, Varadouro, Roger, Padre Zé and Mandacaru, for showing up in most months with very high risk and thus forming clusters of high risk.

A similar result was obtained in the study by Silva and Moraes¹⁶ to evaluate the spatial distribution of tuberculosis in João Pessoa, during the years 2007 and 2008, using maps of relative risk and the method of detection of spatial clusters of Besag and Newell, detecting the greatest risk in the north and south of the city, especially the downtown neighborhoods,

Varadouro, Mandacaru Mangabeira and with greater concentration of significant spatial clusters in the northern region.

The results obtained in this study indicate the existence of a geographical barrier in the neighborhoods of the north, which would be providing the necessary conditions for the development of tuberculosis conditions, requiring better research to determine what factors are contributing to this.

CONCLUSION

A monthly analysis of RR maps identified that neighborhoods with higher values of RR were concentrated almost exclusively in the north of the city, especially the downtown neighborhoods, Varadouro, Roger, Padre Zé and Mandacaru. When compared with the results of spatial analysis Scan, neighborhoods with high RR were also classified as statistically significant clusters, and due to this the highest concentration of clusters were located in the north of the city.

The observation of this spatial pattern during the study period should be considered by managers to assist in the preparation of action plans for the control of tuberculosis in the city, as it enables the targeting of these actions.

REFERENCES

1. Ministério da Saúde, Secretaria de Vigilância em saúde [Internet]. Guia de Vigilância Epidemiológica. 7th ed. Brasília: Ministério da Saúde; 2009 [cited 2013 Dec 15].

Available from:
http://bvsmis.saude.gov.br/bvs/publicacoes/guia_vig_epid_novo2.pdf

2. Ferreira AA, Gonçalves MJF. Fatores associados à internação de pacientes com tuberculose: Revisão de literatura. J Nurs UFPE on line [Internet]. 2012 Dec [cited 2014 Jan 10];6(12):3051-63. Available from: <http://www.revista.ufpe.br/revistaenfermagem/index.php/revista/article/download/2595/4902>

3. Vendramini SHF, Santos NSGM, Santos MLSG, Chiaravalloti-Neto F, Ponce MAZ, Gazetta CE, et al. Análise espacial da co-infecção tuberculose/HIV: relação com níveis socioeconômicos em município do sudeste do Brasil. Soc Bras Med Trop [Internet]. 2010 Sept/Oct [cited 2013 Nov 22];43(5):536-541. Available from: <http://www.scielo.br/pdf/rsbmt/v43n5/v43n5a13.pdf>

4. Oliveira IC, Jesus GJ, Pinto FPS, Balderrama P, Cury MRCO, Vendramini SHF. Controle da tuberculose: Avaliação da equipe de enfermagem sobre a estrutura de serviços de saúde. J Nurs UFPE on line [Internet]. 2012 Sept [cited 2014 Jan 10];6(9):2145-53. Available from: http://www.revista.ufpe.br/revistaenfermagem/index.php/revista/article/viewFile/2580/pdf_1451

5. SINAN, Sistema de Informação de Agravos de notificação [cited 2013 Nov 17]. Available from: <http://dtr2004.saude.gov.br/sinanweb>

6. Ruffino-Neto A, Villa TCS. Tuberculose: Implantação do DOTS em algumas regiões do Brasil histórico e peculiaridades regionais. Instituto do Milênio REDE TB; 2006 [cited 2014 Jan 15]. Available from: http://www.eerp.usp.br/geotb/Doc/livro_DOTST.pdf

7. BRASIL. Ministério da Saúde. **Abordagens espaciais na saúde pública** [Internet]. Brasília (DF): Ministério da Saúde; 2006 [cited 2014 April 8]. 136 p. Available from: http://www.escoladesaude.pr.gov.br/arquivos/File/TEXTOS_CURSO_VIGILANCIA/serie_geoproc_vol_1.pdf

8. IBGE, Instituto Brasileiro de Geografia e Estatística [cited 2013 Nov 28]. Available from: <http://cidades.ibge.gov.br/xtras/perfil.php?codmun=250750&search=paraiba|joao-pessoa>

9. Siegel S. Estatística não-Paramétrica para as ciências do comportamento. 2nd ed. São Paulo: Bookman; 2006

10. Medronho RA. Epidemiologia. 2nd ed. São Paulo: Atheneu; 2008 [cited 2014 Jan 15].

11. Kulldorff M, Nagarwalla N. Spatial disease clusters: detection and inference. Statistic in Medicine [Internet]. 1995 April [Cited 2013 Dec 1];14(8):799-810. Available from: <http://onlinelibrary.wiley.com/doi/10.1002/sim.4780140809/abstract>.

12. Knox EG. Detection of clusters. In: Methodology of enquiries into disease clustering. ELLIOTT, P. London: Small Area Health Statistics Unit; 1989.

13. Costa MA, Assunção, RM. A fair comparison between the spatial Scan and the Besag-Newell Disease clustering tests. Environ Ecol Stat [Internet]. 2005 Sept [cited 2013 Nov 28];12(3):301-19. Available from: http://download.springer.com/static/pdf/931/art%253A10.1007%252Fs10651-005-1515-6.pdf?auth66=1391782287_21269fee4c9578fcabfcc1b96fd2885c&ext=.pdf

14. Gómez-Rubio V, Ferrándiz-Ferragud J, López-Quílez A. Detecting clusters of disease with R. J Geogr Syst [Internet]. 2005 June [cited 2013 Nov 28];7(2):189-206. Available from: <http://www.r-project.org/conferences/DSC-2003/Proceedings/GomezRubioEtAl.pdf>

15. Costa MA, Scherrer LR, Assunção RM. Detecção de Conglomerados Espaciais com Geometria Arbitrária. Informática Pública [Internet]. 2005 [cited 2013 Nov 28];8(1):23-34. Available from: http://www.ip.pbh.gov.br/ANO8_N1_PDF/ANO8N1_Marcelo.pdf

16. Silva AHA, Moraes RM. Aplicação do método de Besag & Newell modificado para detecção de conglomerados espaciais de Tuberculose no município de João Pessoa nos anos de 2007 e 2008. Anais do XIX Simpósio Nacional de Probabilidade e Estatística. 2010 [cited 2013 Nov 28]. Available from: http://www.de.ufpb.br/~ronei/AnaHerm_SINAPE2010.pdf

Submission: 2013/02/06

Accepted: 2014/06/04

Publishing: 2014/07/15

Corresponding Address

Frederico Fávaro Ribeiro
 Rua Sidney Clemente Dore, 100 / Ap. 201
 Bairro Tambaú
 CEP 58039-230 – João Pessoa (PB), Brazil