Severe Acute Respiratory Syndrome and COVID-19 Under the Urban Hierarchy of Municipalities in the State of Rondônia (Western Amazon)

Síndrome Respiratorio Agudo Severo y COVID-19 Bajo la Jerarquía Urbana de los Municipios del Estado de Rondônia (Amazonia Occidental)

Síndrome Respiratória Aguda Grave e COVID-19 sob a Hierarquia Urbana dos Municípios do Estado de Rondônia (Amazônia Ocidental)

Mário Alves
Reinaldo Souza-Santos
Ana Lúcia Escobar
Marina Atanaka

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Abstract

Analyzing the SARS data can provide insights into the severe form of COVID-19, contributing to short, medium, and long-term pandemic response planning. The virus entered Brazilian through air travel, spreading via airport connections. The spatial diffusion of COVID-19 transmission is linked to the territorial division of labor (referring to characteristic daily activities), as reflected in the urban hierarchical network, which serves as a framework for analyzing COVID-19 transmission. This analysis covers mobility aspects such as density, connectivity and the movement of people at different scales. The objective is to evaluate the transmission of SARS and COVID-19 in the state of Rondônia, Western Amazon, between 2020 and 2021, using geoprocessing techniques for spatiotemporal analysis. Maps depicting the urban hierarchy (understood as cities organized by size, from smallest to largest) of the municipalities of Rondônia, along with SARS incidence rates and their standard deviation, were created using QGIS program, version 2.18.20. Spatiotemporal analysis was conducted using Kulldorff statistics to identify clusters of SARS cases in each

Mário Alves. Universidade do Estado do Rio de Janeiro. ORCID: https://orcid.org/0000-0003-3665-6821 E-mail: malvesgeo@gmail.com
Reinaldo Souza-Santos. Fundação Oswaldo Cruz. ORCID: https://orcid.org/0000-0003-2387-6999 E-mail: rssantos@ensp.fiocruz.br
Ana Lúcia Escobar. Universidade Federal de Rondônia. ORCID: https://orcid.org/0000-0003-4386-0863 E-mail: ana@unir.br
Marina Atanaka. Universidade Federal de Mato Grosso. ORCID: https://orcid.org/orcid.org/0000-0003-3543-3837 E-mail: marina.atanaka@gmail.com

municipality. A higher concentration of SARS rates was observed in municipalities in the northwestern part of the state. Six spatiotemporal clusters were identified, but no clear pattern of spatial distribution was observed. The spatial diffusion of COVID-19 transmission is linked to the territorial division of labor (i.e., the spatial classification based on the predominant economic activity in each area), as evidenced by the urban hierarchical network, which serves as a reference for analyzing COVID-19 transmission.

Keywords: COVID-19, pandemics, spatial analysis, urban population

Resumen

El análisis de los datos del SARS puede ayudar a comprender el escenario de la COVID-19 en su forma grave, contribuyendo a la planificación en relación con la lucha contra la pandemia a corto, medio y largo plazo. El virus ingresó al territorio brasileño por el espacio aéreo, transmitiéndose a través de conexiones vía aeropuertos. La difusión espacial de la transmisión de la COVID-19 está relacionada con la división territorial del trabajo (refiriéndose al trabajo característico del día a día), evidenciada por la red jerárquica urbana, que se configura como un referente para analizar la transmisión de la COVID-19. , cubriendo aspectos de la movilidad (densidad, conectividad y movimiento de personas) a diferentes escalas. El objetivo es evaluar la transmisión del SARS y del COVID-19 en el estado de Rondônia, Amazonía Occidental, entre 2020 y 2021, con técnicas de geoprocesamiento para análisis espaciotemporal. Los mapas referentes a la jerarquía urbana (entendida como sinónimo de ciudades organizadas por tamaño, de menor a mayor) de los municipios de Rondônia, tasas de incidencia de SARS y desviación estándar de las tasas de incidencia de SARS fueron elaborados en el Programa QGIS, versión 2.18. 20. También se realizó un análisis espacio-temporal utilizando estadísticas de Kulldorff para identificar grupos de casos de SARS para cada municipio. Una concentración de valores más altos de tasas de SARS se observó en los municipios ubicados en la zona noroeste del estado. Se obtuvieron seis grupos espaciotemporales y no se observó ningún patrón de distribución espacial. La difusión espacial de la transmisión del COVID-19 está relacionada con la división territorial del trabajo (es decir, la clasificación espacial por la actividad económica propia de cada territorio), evidenciada por la red jerárquica urbana, siendo un referente para analizar la transmisión del COVID-19.

Palabras clave: Covid-19, pandemia, analisis espacial, poblacion urbana

Resumo

A análise dos dados da SARS pode ajudar a compreender o cenário da COVID-19 na sua forma grave, contribuindo para o planejamento em relação ao combate à pandemia no curto, médio e longo prazo. O vírus entrou em território brasileiro pelo espaço aéreo, transmitindo-se por meio de conexões via aeroportos. A difusão espacial da transmissão da COVID-19 está relacionada à divisão territorial do trabalho (referente ao cotidiano característico do trabalho), evidenciada pela rede hierárquica urbana, que se configura como referência para analisar a transmissão da COVID-19 , abrangendo aspectos de mobilidade (densidade, conectividade e circulação de pessoas) em diferentes escalas. O objetivo é avaliar a transmissão da SARS e da COVID-19 no estado de Rondônia, Amazônia Ocidental, entre 2020 e 2021, com técnicas de geoprocessamento para análise espaço-temporal. Os mapas referentes à hierarquia urbana (entendida como sinônimo de cidades organizadas por tamanho, indo do menor para o maior) dos municípios de Rondônia, taxas de incidência de SRAG e desvio padrão das taxas de incidência de SRAG foram elaborados no Programa QGIS, versão 2.18. 20. A análise espaço-temporal também foi realizada utilizando estatísticas de Kulldorff para identificar agrupamentos de casos de SRAG para cada município. Observou-se concentração de valores mais elevados de taxas de SRAG em municípios localizados na região noroeste do estado. Foram obtidos seis aglomerados espaçotemporais e nenhum padrão de distribuição espacial foi observado. A difusão espacial da transmissão da COVID-19 está relacionada à divisão territorial do trabalho (ou seja, à classificação espacial pela atividade econômica característica de cada território), evidenciada pela rede hierárquica urbana, sendo uma referência para analisar a transmissão da COVID-19.

Palavras-chave: COVID-19, Pandemia, Análise Espacial, População Urbana

Introduction

In December 2019, a new coronavirus (SARS-CoV-2) was identified in Wuhan (province of China), causing COVID-19, a disease that has been transmitted from person to person and can cause from asymptomatic infections to severe pneumonia (Li et al., 2020).

The Ministry of Health, from the Health Surveillance Secretariat, has implemented a Severe Acute Respiratory Syndrome (SARS) surveillance system since the Influenza A(H1N1) pdm09 pandemic in 2009. In 2020, COVID-19 surveillance was incorporated into the Influenza and other respiratory viruses surveillance network (Brasil, 2021a).

Updated data (06/24/2021) from the Ministry of Health reveal 18,243,483 cases of COVID-19 in Brazil, with an incidence of 8,681.3 per 100,000 inhabitants. Of this total of cases, 16,511,701 were recovered. There were 509,141 deaths, with a lethality rate of 2.8% and a mortality rate of 242.3 per 100,000 inhabitants. In the state of Rondônia, there were 245,752 cases (the third highest number among the northern states), with an incidence of 13,827.8 per 100,000 inhabitants and 6,092 deaths, with a mortality of 342.8 per 100,000 inhabitants (Brasil, 2021b).

Studies that compared the occurrence of SARS before and during the COVID-19 pandemic (Silva, et al., 2020; Bastos et al., 2020) showed a significant increase in notifications (even with possible underreporting), possibly explained by the detection of severe cases of disease by SARS surveillance, as more serious cases would make people seek health services more, leading to an increase in the number of notifications. We highlight the importance of spatial analyses techniques to understand SARS data, especially in the analysis of severe forms of COVID-19 and how this understanding may contribute to planning in relation to fighting the pandemic in the short, medium and long term.

According to the above, our research aims to evaluate the transmission of SARS and COVID-19 in the state of Rondônia, Western Amazon, between 2020 and 2021. Support was sought in geoprocessing techniques for spatiotemporal analysis of disease diffusion (that is, the relationship, in time and space, of the transmission of the disease throughout the hierarchy of cities in Rondônia) in the state throughout the study period, relating it to the urban hierarchy of its municipalities.

Subjects and methods

Design and study area

This is a retrospective and descriptive study, using secondary data (official, publicly accessible databases) from the Ministry of Health (Brasil, 2021b). Data on Severe Acute Respiratory Syndrome (SARS) were collected, including data from COVID-19 (associated to a COVID-19 diagnosis), for the period from 01/05/2020 to 06/06/2021.

The state of Rondônia belongs to the northern region of Brazil and composes the Western Amazon together with the states of Acre, Amazonas and Roraima (Brasil, 2021c). It is made up of 52 municipalities, with Porto Velho as the capital (539,354 inhabitants) (IBGE, 2018a). Data (official registries) from 2021 indicate a projected population of 1,815,278 inhabitants (IBGE, 2021). According to the urban hierarchy of its municipalities (defined by a Brazilian federal institution, also responsible for the national Census), the state has two Regional B Capitals (Porto Velho and Candeias do Jamari, which make up the Porto Velho Population Arrangement), two Regional C Capitals (Cacoal and Ji-Paraná), two Subregional A Centers (Ariquemes and Vilhena), five Subregional B Centers (Guajará-Mirim, Jaru, Ouro Preto do Oeste, Pimenta Bueno and Rolim de Moura) and three Zone B Centers (Cerejeiras, Colorado do Oeste and Machadinho D'Oeste). The other municipalities are classified as Local Centers (IBGE, 2018b) (Figure 1).

Estimated population data for the year 2020 were obtained from the Ministry of Health (Brasil, 2020a). The digital grid for the municipalities in Rondônia was taken from the Brazilian Institute of Geography and Statistics (IBGE) (IBGE, 2015).

Data from weekly notification of SARS cases in Rondonia residents were selected and organized by municipalities and in four periods: from January to April 2020 (period 1), from May to August 2020 (period 2), from September to December 2020 (period 3) and from January to June 2021 (period 4). Incidence rates were calculated for each study period by dividing cases of SARS by period by the estimated population, multiplied by 100,000. Subsequently, a standard deviation map was prepared, taking as the reference value the incidence rate for all municipalities in the state of Rondonia for the same study periods, and comparing it with each municipality, for the same study periods. Municipalities with higher standard deviations represent higher rates of SARS in relation to the average rate for the entire state of Rondônia; those with lower standard deviation values represent rates of values close to the average rate (Figure 2).

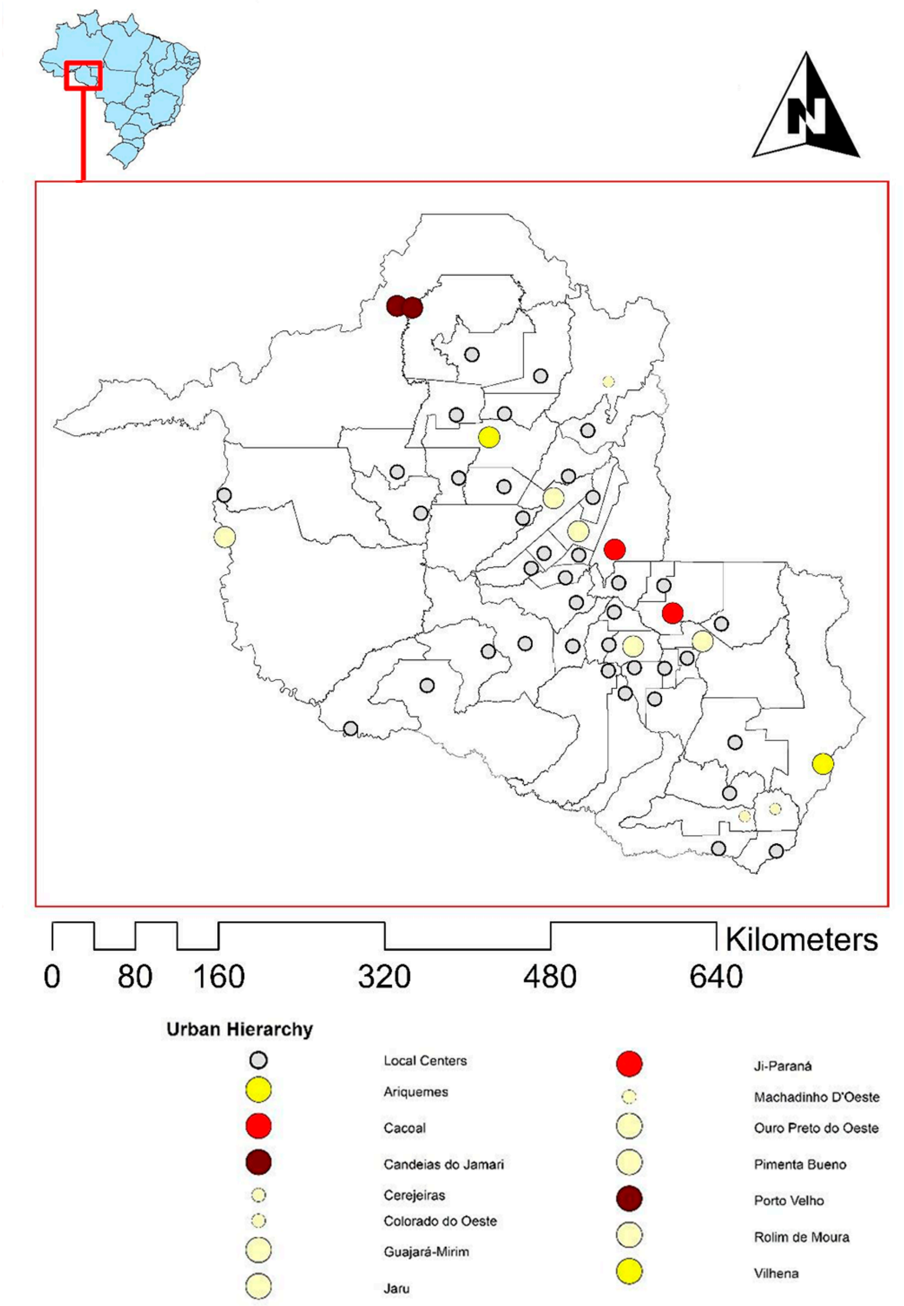

Figure 1. Location of the state of Rondônia (Western Amazon) and urban hierarchy of its main municipalities

Spatio-temporal analysis was also performed using Kulldorff statistics to identify clusters of SARS cases for each municipality. For this step, SARS cases were organized by notification week. A circular spatial window with a discrete Poisson distribution with a radius of 120 kilometers was used (after successive attempts with different radii, this one demonstrated the best results), identifying high-risk clusters based on the comparison between the number of observed and expected cases (Kulldorff, 2018). Relative Risk (RR) and Log Neighborhood Rate (LLR) per cluster were also calculated, being evaluative parameters of the spread of the disease over space and time. There was no geographic overlap. Initially, seven spatiotemporal clusters were observed; however, one was not statistically significant and was excluded. This scanning process was performed in the SaTScan Program (version 9.6).

The maps referring to the urban hierarchy of the municipalities of Rondônia, SARS incidence rates and standard deviation of SARS incidence rates were made in the QGIS Program, version 2.18.20.

Results

Regarding SARS incidence rates (number of new cases per 100,000 population), a concentration of higher SARS incidence rates was observed in municipalities located in the northwestern part of the state. In general, there was an increase in values from the first to the second periods, followed by a decrease in the third and fourth periods. In the first period, the highest incidence rate was observed in the municipality of Vilhena (72.40), being the only one belonging to the stratum of 50.01 to 100.00. In the second period, an increase in SARS rates was observed in all municipalities of Rondônia (except for the municipality of Seringueiras), with the highest values observed in Guajará-Mirim (459.66), Porto Velho (407.52), Jaru (364.20), Ariquemes (334.18), Nova Mamoré (242.10), São Francisco do Guaporé (217.59), Buritis (215.58), Ji-Paraná (208.45) and Candeias do Jamari (200.82). Subsequently, there was an increase in SARS rates in Vale do Paraíso (270.43) and maintenance of its values in Ji-Paraná (208.45). A reduction in SARS incidence rates was mostly observed in: Porto Velho (232.5), Ouro Preto do Oeste (209.87), Ji-Paraná (208.45) and Nova Mamoré (200.69). In the last study period, only one rate was observed in the stratum of values between 100.01 and 200.00 (Porto Velho, with 149.81). The other two highest incidence rates were observed in Nova Mamoré (89.19) and Candeias do Jamari (54.77) (Figure 2).

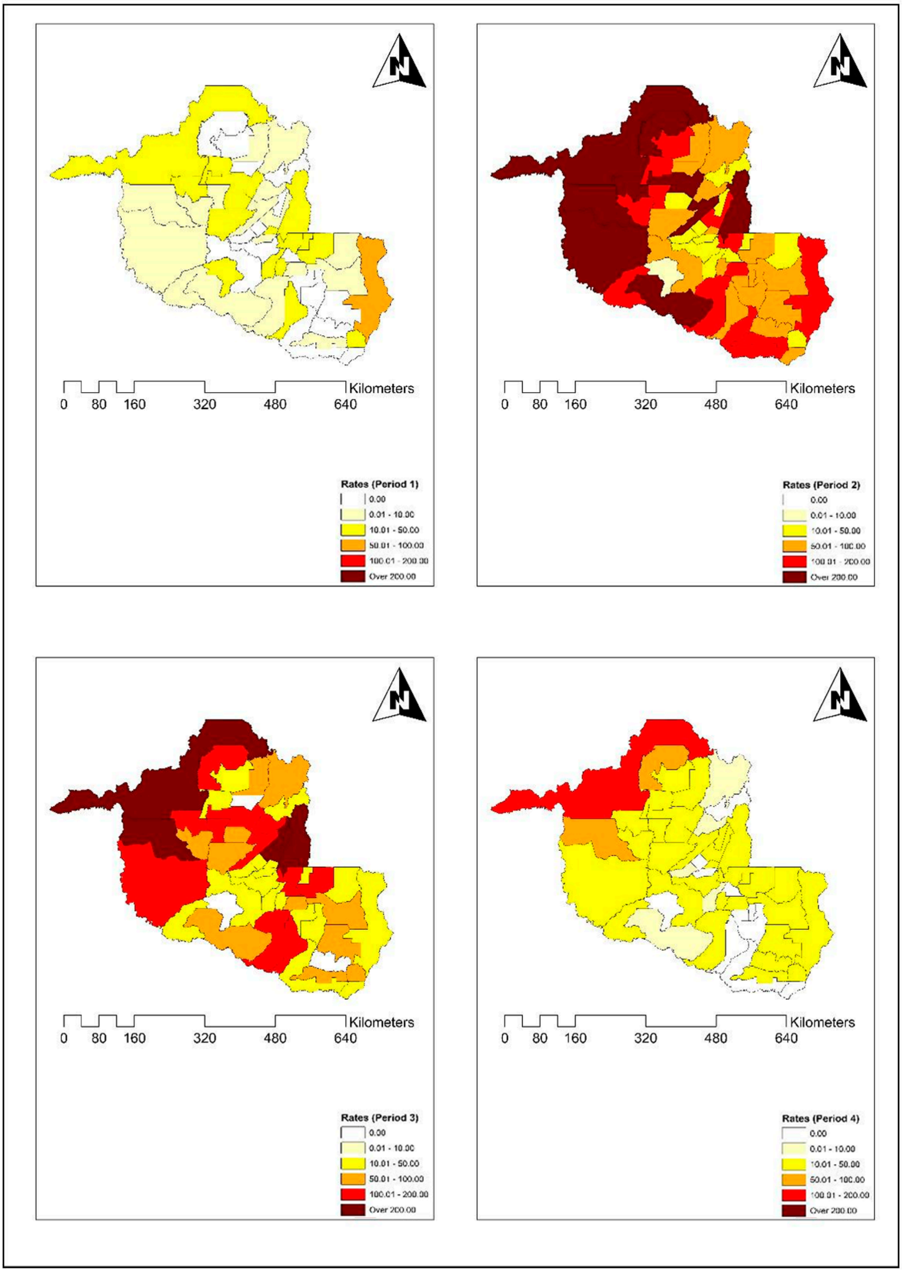

Figure 2. Severe Acute Respiratory Syndrome Rates (cases per 100,000 population) by municipalities in the state of Rondônia (Western Amazon)

As for the standard deviation of SARS incidence rates, a spatial distribution similar to the values of SARS incidence rates was observed, as there were higher values of incidence rates in municipalities in the northwestern part of the state, especially Ariquemes and Vilhena (first period, with values above 32, 72), Ariquemes, Guajará-Mirim, Jaru and Porto Velho (second period, values above 318.62), Porto Velho and Vale do Paraíso (values above 220.11 and 75.77, respectively for third and fourth periods) (Figure 3).

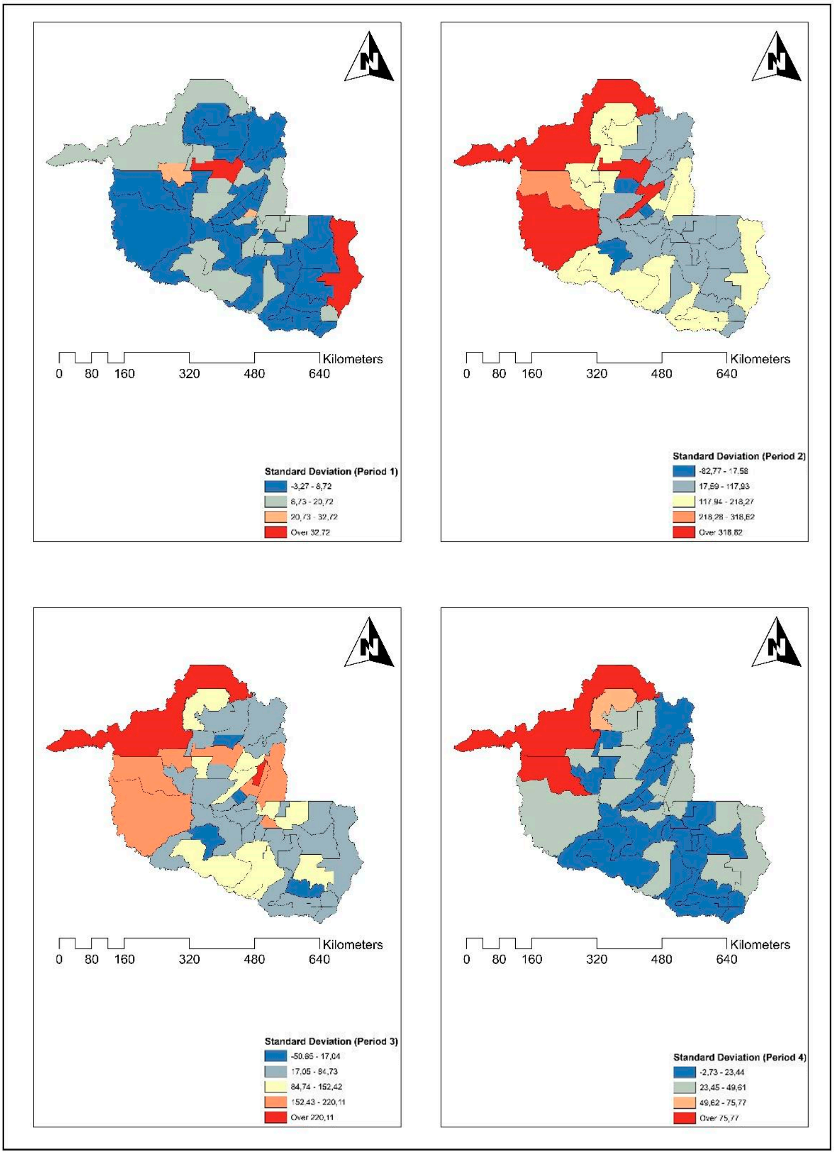

Figure 3. Standard deviation of Severe Acute Respiratory Syndrome rates by municipalities in the state of Rondônia (Western Amazon)

With regard to spatiotemporal clusters, six clusters were obtained. No pattern of spatial distribution was observed, as they were located in different parts of the state. Longer duration (35 weeks) and longer LLR (2089.66) were observed in Cluster 1 (Alto Paraíso, Ariquemes, Candeias do Jamari, Cujubim, Itapuã do Oeste, Monte Negro, Porto Velho and Rio Crespo). The second longest temporal duration (31 weeks) was observed in Cluster 2 (Jaru, Ji-Paraná, Nova União, Ouro Preto do Oeste, Teixeirópolis and Vale do Paraíso), although the lowest values of RR (2.27) and of ratio of observed and expected cases (2,12). In Cluster 3 (Guajará-Mirim and Nova Mamoré), the third highest ratio of cases (3.20) was observed, in addition to having started in week 19. Cluster 4 (Vilhena) was the first cluster to have started (week 18) and also the first to finish (week 21), having the second highest values of RR (5.21) and ratio of cases (5.14). Although it lasted only two weeks (32 and 33), Cluster 5 (São Francisco do Guaporé) had higher RR (13.24) and case ratio (13.19) values. Comprised of three municipalities (Alta Floresta d'Oeste, Alto Alegre dos Parecis and Santa Luzia d'Oeste), Cluster 6 was the penultimate to be formed (week 31), with RR values (2.58) and ratio of cases (2.57) only larger than those in Cluster 2 (Figure 4) (Table 1).

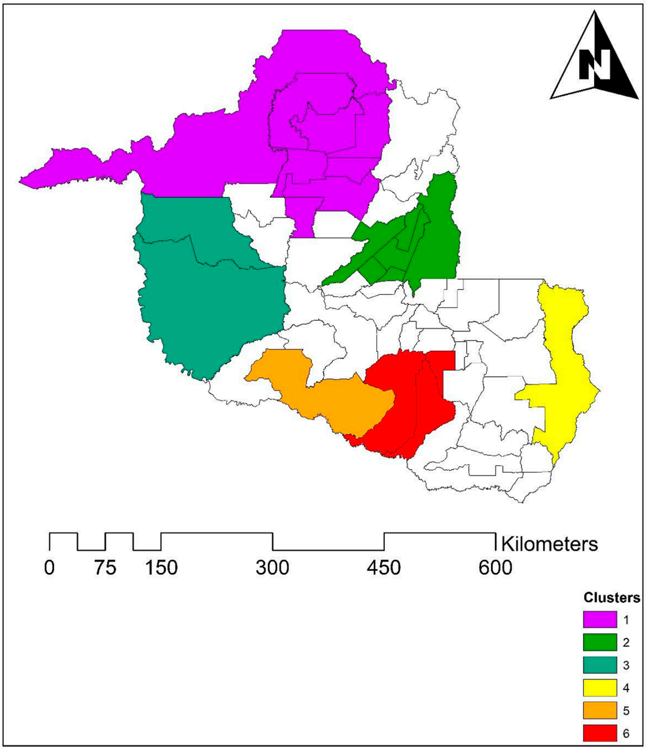

Figure 4. Spatiotemporal clusters of Severe Acute Respiratory Syndrome rates by municipalities in the state of Rondônia (Western Amazon)

Table 1. Characteristics of spatiotemporal clusters of Severe Acute Respiratory Syndrome rates by municipalities in the state of Rondônia (Western Amazon)

	Log Neighborhood Rate (LLR)	Relative Risk (RR)	Period (for weeks)	Cases observed / expected	Number of municipalities (by cluster)
Cluster 1	2089.66	4.32	20 to 54	2.62	8
Cluster 2	233.27	2.27	24 to 54	2.12	6
Cluster 3	166.13	3.29	19 to 40	3.20	2
Cluster 4	109.67	5.21	18 to 21	5.14	1
Cluster 5	56.35	13.24	32 to 33	13.19	1
Cluster 6	18.02	2.58	31 to 38	2.57	3

Discussion

The COVID-19 pandemic has become a challenge to be faced today. As it is a new problem, a new look is needed to understand it (Guimarães et al., 2020). Following Brazil's urban hierarchy, the virus entered national territory via airspace, transmitting itself through connections between the middle and upper classes via airports. Since then, its transmission has also taken place by road transport (such as private cars, trailers and motorcycles) and closer labor relationships (as activities linked to commerce and the provision of services, including commuting) (Silveira et al., 2020).

Several studies have addressed the process of internalization and the transmission of disease in different states of Brazil (Souza et al., 2020; Andrade et al., 2020; Bessa and Luz, 2020), including those processes affecting indigenous populations and quilombola communities in the Amazon region (Escobar, 2020). At the beginning of the pandemic (April 2020), at the beginning of the pandemic, the analysis of the weekly evolution of cases, showed a hierarchical pattern of diffusion, initially reaching the most populated and distant cities and later smaller and closer cities, demonstrating a trend of internalization of the transmission of COVID-19, which arrived in an accelerated form in smaller Brazilian municipalities (there are already cases in municipalities with a population of up to 10 thousand inhabitants) (Brasil, 2020b).

These findings corroborate our results, as although the first case of SARS from Rondônia in 2020 (01/05/2020) was registered in Cacoal (from a resident of Rolim de Moura) and Cluster 4 was formed first, the Cluster 1 (of which Porto Velho is part) was the one with the longest temporal duration and the largest LLR (the cluster being less likely to have occurred by chance) (Kulldorff, 2018) in the study period, in addition to covering the largest number of municipalities. This can be explained by the fact that Cluster 1 is formed by prominent cities in the urban hierarchy of Rondônia, such as Ariquemes (Subregional A Center), Candeias do Jamari (Regional B Capital) and Porto Velho (Regional B Capital) (IBGE, 2018b). Higher values for SARS incidence rates and its standard deviation were also observed in these municipalities, which, in addition to being hierarchically relevant (by position of cities, interconnectedness with other networks), are also the most populous in Rondônia: Porto Velho (539,354 inhabitants), Ji-Paraná (130,009), Ariquemes (109,523), Vilhena (102,211), Cacoal (85,893), Jaru (51,620), Guajará-Mirim (46,556), Buritis (40,356), Ouro Preto do Oeste (35,737), Nova Mamoré (31,392) and Candeias do Jamari (27,388) (IBGE, 2018a).

The relevance of Porto Velho as a capital is highlighted in the face of the dissemination of SARS-CoV-2 transmission, since, as observed in the state of Ceará, in a disjointed urban network (with irregular and disproportionate degrees of centrality), it tends to overload the few centers of greater expression, tending to the convergence of the population affected by the disease. Added to this is the socioeconomic polarity (the state's main economic activities are concentrated in a few cities) based on greater dynamism in trade and services, in addition to the daily agglomeration of people, tending to concentrate the virus contamination in these urban centers, which are configured as "nodes" of attraction/diffusion of the disease (Pereira Júnior, Sampaio and Gomes, 2020).

As COVID-19 is transmitted through social contacts, it is assumed that urban centers with larger populations would tend to be more affected over time (Santos, 2020). Those municipalities with a large population are places of great movement of people, also contributing to the circulation of SARS-CoV-2, since the space of the regional urban network is formed by relationships that are established around centers of regional influence , sub-regional, micro-regional and local, which have a geographic position in these networks, in addition to being close to centers with a greater offer of urban functions (cities with important economic activities for Rondônia, compensating for their inability to offer goods and services) (Bessa and Luz, 2020), where the constant movement of people makes means of transport mechanisms in the contamination network (Pereira Júnior et al., 2020). As observed in Tocantins, as in the urban profile of numerous small centers, its urban functions do not meet the population's demand, causing people to travel to other locations (even outside the state) based on complementary and hierarchical solidarity between these cities, reinforcing the conditions for the dissemination of COVID-19 (Bessa and Luz, 2020). Reinforcing our results, studies show that initial cases occurred predominantly in larger urban centers and that with community transmission, the disease spread to municipalities with intense commercial activity and inter-municipal mobility (Andrade et al., 2020; Nascimento et al., 2020).

When analyzing the last study period of this work, a decrease in SARS incidence rates and its standard deviation can be observed, although data from Johns Hopkins University show an increase in the registration of COVID-19 cases during this period: in January 2021, 270 new cases were registered (average of 7 days of 517 cases) and on March 21st, 1,140 new cases (average of 7 days of 1,393 cases) (JHU CSSE, 2021). This can be explained by the underreporting of SARS cases, since in Brazil there is little testing per inhabitant, with lower rates than other South American countries such as Chile, Uruguay, Paraguay and Argentina (Our World in Data, 2021). Another possible explanation is the insufficient capacity for clinical and laboratory diagnosis, which tends to be even lower in smaller cities (which have less availability of health services), as observed in some states where there has been a decrease in the number of cases and deaths due to COVID-19 (Brasil, 2020b). As observed in Pernambuco, inland municipalities generally have less availability of medical resources (Souza et al., 2020), with limited health technologies for treating the disease, such as mechanical ventilation equipment and ICU beds (Noronha et al., 2020).

Another worrying issue is that small urban centers generally have deficient sanitation and housing infrastructures, aggravated by the unequal conditions of the health system in absorbing the consequences of COVID-19 cases within the urban network (Gomes and Caldeira, 2020), contributing to the spread of SARS-CoV-2 in these locations. As an example, only 2.51% of Porto Velho's population has sewage treatment and 35.26% has water supply (Giatti, 2007), a scenario that is even more critical in hierarchically smaller cities.

The spatial diffusion of COVID-19 transmission is related to the territorial division of labor, evidenced by the urban hierarchical network, which is configured as a reference to analyze the transmission of COVID-19, covering aspects of mobility (density, connectivity and movement of people) at different scales, allowing an understanding of the spread of the virus (Pereira Júnior, Sampaio and Gomes, 2020). Thus, it is essential to knowledge about the spatial evolution of a disease to stop its transmission, reducing contacts and treating patients (Silveira et al., 2020).

We highlight the application of geoprocessing techniques, which enable the identification of risk areas for communicable diseases through clusters (Resendes et al., 2010), strengthening epidemiological surveillance systems and facilitating decision-making by agents of health in both the predictive and preventive fields (Barcellos and Bastos, 1996).

This work aimed to analyze the diffusion of SARS and COVID-19 transmission in Rondônia, considering the urban hierarchy of their municipalities, identifying priority areas for control. As possible limitations, we emphasize that the possible underreporting of cases may bias the findings of this study. The ecological study design itself can generate aggregation bias, as aggregated data do not allow inferences of risk at individual levels.

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