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Review Article

A Review of Applications of Spatial Statistics in the Study of COVID-19 Pandemic in Vietnam

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ABSTRACT

The spread of the 2019 novel coronavirus disease (COVID-19) in Wuhan city, China, caused by the emergence of severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2), spreads rapidly across the world and has negatively affected almost all countries. The Covid-19 pandemic has engulfed the world with a rapid, unexpected, and far-reaching global crisis. In the study of COVID-19 pandemic, spatial statistics have played an important role in many aspects, especially in the study of the clustering of COVID-19 pandemic. This paper summarises 24 scientific papers on applications of spatial statistics including the local Moran's I and Getis-Ord's G_i^* statistics on studies of the COVID-19 pandemic in Vietnam. The findings of this study provide insight into not only how to apply spatial clustring in spatial statistics to analyze the clustering of the COVID-19 pandemic, but also preventing the COVID-19 spread across the world.

Keywords: Applications, Spatial statistics, spatial clustering, local Moran's I and Getis-Ord's G statistics, the COVID-19 pandemic.

INTRODUCTION

The 2019 novel coronavirus disease (COVID-19) is an epidemic illness that was discovered in Wuhan of China at the end of 2019 (1). The COVID-19 epidemic quickly spreads worldwide rapidly to emerge as a global public health concern (2). It has been reported as a social, human, and economic crisis (3). The latest data shows that, globally, as of 5:56 PM CEST, 28 June 2023, there have been 767,518,723 confirmed cases of COVID-19, including 6,947,192 deaths, reported to World Health Organization (4). The COVID-19 pandemic has been described as a social, human, and economic crisis. Recently, it has been revealed that the assessment of the scale of the COVID-19 pandemic from a geographical perspective that can offer a better understanding of the spatial distribution, better manage the COVID-19 infection, and effectively study its impacts (5). This assessment can be done with the help of spatial clustering analysis in spatial statistics. It is, therefore, the use of spatial statistics to have more understanding of the spatial distribution of the COVID pandemic in general, and of the spatial clustering in particular, plays an important role in the fight of COVID-19 (1).

COVID-19-related data such as the geographical locations of (visited) COVID-19 cases which have a spatial and geographic dimension can be considered a type of spatial object and can be studied with the help of a Geographic Information System (GIS) and spatial statistics (6). A GIS is an essential tool to examine the spatial distribution of spatial objects (5). Whereas, spatial statistics is an area of study devoted to the statistical analysis of data that have a spatial label associated with them (7). Spatial statistics is tied to Tobler's First Law of Geography (8). Following this idea, widely used statistics for spatial auto-correlation analysis such as global spatial statistics (Moran's I, Getis-Ord G* and Geary's C) and local indicators of spatial association have been successfully employed in epidemiological studies (9–12) in general, and in the study of COVID-19 spread in particular (13–15). Using spatial statistics, (16) carried out a study on spatiotemporal analysis and hotspots detection of COVID-19 using GIS (March and April, 2020). In this study, hot spot analysis and Anselin local Moran's I indices were then applied to accurately locate high and low-risk clusters of COVID-19 globally. The results showed that southern, northern and western Europe were detected in the high-high clusters demonstrating an increased risk of COVID-19 in these regions and also the surrounding areas (16). Also with the help of GIS techniques, spatio-temporal COVID-19 spread over Oman was also successfully assessed (17). In this study, the assessment was made using five geospatial techniques within a GIS context, including a weighted mean centre, standard deviational ellipses, Moran's I autocorrelation coefficient, Getis-Ord General-G high/low clustering, and Getis-Ord Getis-Ord's G_i^* statistic. These geospatial techniques successfully indicated that the directional pattern of COVID-19 cases has moved from northeast to northwest and southwest of Oman. Most recently, it has also been shown that many COVID-19-related data such as the locations of (visited) COVID-19 cases can be considered a type of spatial object which has a spatial dimension and can be mapped by a GIS (5).

According to the Ministry of Health of Vietnam (18), as of 1st July 2023, the COVID-19 pandemic in Vietnam resulted in a total of 11,6 million confirmed cases and 43.206 deaths. A recent study indicated that very little attention has been paid to the role of spatial statistics such as geographical methods in the study of COVID-19 in Vietnam (6). It is, therefore, this study aims to summarises applications of spatial statistics such as the local Moran's I and Getis-Ord's G_i^* statistics in the study of the COVID-19 pandemic in Vietnam.

MATERIALS & METHODS

Materials

A total of 24 scientific papers collected from Google scholar, Web of Science and SCOPUS databases was used in this study. These references were selected based on the criteria of high number of citations and published in recent years.

Methods

The references were first searched from Google scholar, Web of Science and SCOPUS databases based on important keywords of applications, Spatial statistics, spatial clustering, Moran's I and Getis-Ord's G statistics and the COVID-19 pandemic. Based on the above two criterias for selecting documents, these references were then downloaded for serving the process of analyzing, evaluating and synthesizing the applicability of spatial statistics in the study of COVID pandemic around the world, in general, and in Vietnam, in particular.

RESULTS AND DISCUSSIONS

Applications of classical statistics in the study of the COVID-19 pandemic

Although, a lot of efforts have been put into the study of the COVID-19 pandemic in Vietnam using classical statistics (19–23), so far, very little attention has been taken into account the important role of spatial statistics (1,6). The pattern of the COVID-19 epidemic in Vietnam was successfully analyzed using descriptive statistics (means, median, standard deviation and interquartile of continuous variables) from a dataset of 32416 COVID-19 cases in four cities and provinces in the first phase (20). Later, when assessing the spatiotemporal distribution of COVID-19 during the first 7 months of the epidemic in Vietnam, a dataset of COVID-19 cases from 23 January to 31 July 2020 in Vietnam was used to assess geographical distribution of COVID-19 via the number of cases in each province along with their timelines (24). It was found that a spatial cluster in phase 1 was detected in Vinh Phuc Province. In phase 2, primary spatial clusters were identified in the areas of Hanoi and Ha

Nam Province. In phase 4, a spatial cluster was detected in Da Nang, a popular coastal tourist destination (24). This study also came to a conclusion that spatial disease clustering of COVID-19 in Vietnam was associated with large cities, tourist destinations, people's mobility, and the occurrence of nosocomial infections. However, the main disadvantage of the above-mentioned studies is the lack of spatial statistics.

Applications of Moran's I statistics in the study of spatial clustering of COVID-19 cases

To overcome the limitation in studies in Vietnam, most recently, with the aim of identifying the spatio-temporal clustering of COVID-19 patterns in Vietnam. The local Moran's I spatial statistic and Moran scatterplot were successfully employed to identify high-high and low-low clusters and low-high and high-low outliers of COVID-19 cases from a dataset of 10,742 locally transmitted cases in four COVID-19 waves in 63 prefecture-level cities/provinces in Vietnam (6). It was found that significant low-high spatial outliers of COVID-19 cases were first detected in the north-eastern region in the first wave and in the central region in the second wave in Vietnam. Whereas, spatial clustering of high-high, low-high, and high-low was mainly found in the north-eastern region in the last two waves in Vietnam. More specifically, in the first COVID-19 wave, a total of seven low-high spatial outliers of COVID-19 cases were detected by local Moran's I statistic in provinces of north-eastern Vietnam. In the second COVID-19 wave in Vietnam, spatial clustering of COVID-19 cases was mainly detected in the central region of Vietnam (6). In the third COVID-19 wave, we identified spatial clustering of COVID-19 cases in provinces and cities in the north eastern region. Two high-low outliers were detected in Hai Duong (575 cases) and Vinh Long (27 cases), a high-high cluster was found in Quang Ninh province (60 cases). Whereas, five low-high outliers in cities/provinces of Bac Ninh (5 cases), Hung Yen and Bac Giang (2 cases), Hai Phong (1 case), and Thai Binh (1 case) were also successfully discovered (6). Finally, in the fourth COVID-19 wave, local Moran's I statistic successfully identified three high-high clusters in Bac Giang (5,083 cases), Bac Ninh (1,407 cases) and Hanoi (464 cases); and nine low-low clusters including Ninh Thuan (12 cases), Binh Thuan (11 cases), Dak Lak (6 cases) in south-central region (6). It can be seen that spatial clustering of COVID-19 casses in this wave was mainly high-high clusters and low-high outliers in the north-eastern provinces of Vietnam including areas of huge population density as industrial parks in Bac Giang and Bac Ninh provinces.

Later, when analyzing the spatial clustering of the COVID-19 pandemic using spatial auto-correlation analysis. Spatial clustering including spatial clusters (high-high and low-low), spatial outliers (low-high and high-low), and hotspots of the COVID-19 pandemic in Vietnam successfully detected and explored using the local Moran's I statistics (1). In this study, the local Moran's I and Moran scatterplot were first employed to identify spatial clusters and spatial outliers of COVID-19 from a dataset of 86,277 locally transmitted cases confirmed in two phases of the fourth COVID-19 wave in Vietnam. This study results showed that significant low-high spatial outliers and hotspots of COVID-19 were first detected in the north-eastern region in the first phase, whereas, high-high clusters and low-high outliers were then detected in the southern region of Vietnam (1). This study revealed that a total of three high-high clusters in Bac Giang (5,083 cases), Bac Ninh (1,407 cases) and Hanoi (464 cases); and nine low-low clusters including Ninh Thuan (12 cases), Binh Thuan (11 cases), Dak Lak (6 cases) in south-central region was successfully identified in the first phase of the fourth wave of the COVID-19 pandemic in Vietnam. Whereas, in the second phase of the fourth wave of the COVID-19 pandemic in Vietnam, five high-high clusters in Ho Chi Minh city (52,913 cases) and in the southern provinces of Binh Duong (6,146 cases), Long An (2,178 cases) and Dong Nai (1,778 cases), and Tien Giang (1,245 cases) were detected by the local Moran's I statistics. In addition, two low-high outliers were also successfully detected in provinces of Ba Ria - Vung Tau (471 cases) and Tay Ninh (204 cases) in this phrase (1).

Applications of Getis-Ord's G statistics in the study of hotspots and coldspots of COVID-19 cases

To identify the spatio-temporal clustering of COVID-19 hot spots and cold spots in Vietnam using spatial statistics. The local Getis-Ord's G_i^* statistic was successfully applied to detect hotspots and coldspots of COVID-19 cases in four waves in Vietnam (6). The results showed that seven hotspots of COVID-19 cases in provinces were detected in areas of high population density in the north-eastern region of Vietnam including Ha Nam, Bac Giang, Hung Yen, Bac Ninh, Thai Nguyen, Phu Tho, and Hoa Binh in the first wave of the COVID-19 pandemic. Whereas, hotspots of confirmed COVID-19 cases were mainly discovered in three cities/provinces with high population density in the central region including Da Nang (353 cases), Quang Nam (124 cases), and Thua Thien Hue (3 cases) in the second COVID-19 wave (6). In the last two COVID-19 waves in 2022 a total of seven COVID-19 hotspots was identified in the north-eastern region of Vietnam, including Bac Giang (5,083 cases), Bac Ninh (1,470 cases), Hanoi (464 cases), Hai Duong (51 cases), Thai Nguyen (7 cases), and Quang Ninh (1 case). Bac Giang (5,083 cases) and Bac Ninh (1,407 cases) have also been reported as two provinces having the highest number of new COVID-19 cases (6).

When analyzing the spatial clustering of the COVID-19 pandemic using spatial auto-correlation analysis in two phases of the fourth COVID-19 wave in Vietnam, the Getis-Ord's G_i^* statistics were also used to detect hotspots of COVID-19 from 86,277 locally transmitted cases (6). Similar to those obtained from the the local Moran's I statistics and Moran scatterplot, hotspots of COVID-19 cases were also first identified in the north-eastern region in the first phase, whereas, hotspots were then detected in the southern region of Vietnam. More specifically, the local Getis-Ord's G_i^* statistic successfully detected a total of six COVID-19 hotspots in the north-eastern region of Vietnam, including Bac Giang (5,083 cases), Bac Ninh (1,470 cases), Hanoi (464 cases), Hai Duong (51 cases), Thai Nguyen (7 cases), and Quang Ninh (1 case) in the first phase of the fourth COVID-19 wave. Whereas, in the second phase, the local Getis-Ord's G_i^* statistic also successfully detected seven COVID-19 hotspots in the southern region of Vietnam and 11 coldspots in the north-western cities/provinces (6).

CONCLUSION

This review summarises 24 scientific papers on applications of spatial statistics including the local Moran's I and Getis-Ord's G_i^* statistics on studies of the COVID-19 pandemic in Vietnam. Three themes about the applications of classical statistics, the local Moran's I and Getis-Ord's G_i^* statistics in the study of COVID-19 have been fully discussed. The findings of this study provide insight into not only how to apply spatial statistics on the analyis of the spatial clustering of the COVID-19 pandemic, but also can help prevent the COVID-19 spread across the world. It can be concluded that Getis-Ord's G_i^* statistic-based hot spot analysis coupled with Anselin local Moran's I provides a scrupulous and objective approach to identify the locations of statistically significant spatial clustering or spatial outliers of COVID-19 cases. Spatial statistics not only plays an important role in the study of spatial clustering of COVID-19 cases, but also in the fight against the COVID-19 pandemic.

Declaration by Authors

Ethical Approval: Not Applicable

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REFERENCES

1. Vu D-T, Nguyen T-T, Hoang A-H. Spatial clustering analysis of the COVID-19 pandemic: A case study of the fourth wave in Vietnam. Geogr Environ Sustain. 2021;14(4).
2. Das A, Ghosh S, Das K, Basu T, Dutta I, Das M. Living environment matters: Unravelling the spatial clustering of COVID-19 hotspots in Kolkata megacity, India. Sustain Cities Soc. 2021;65:102577.
3. Nations U. The Social Impact of COVID-19 [Internet]. 2020 [cited 2007 Mar 20]. Available from: https://www.un.org/development/desa/dspd/2020/04/social-impact-of-covid-19/
4. WHO. WHO Coronavirus (COVID-19) Dashboard [Internet]. 2023. Available from: https://covid19.who.int/
5. Kieu Q-L, Nguyen T-T, Hoang A-H. GIS and remote sensing: a review of applications to the study of the COVID-19 pandemic. Geogr Environ Sustain. 2021;14(4).
6. Hoang A, Nguyen T. Identifying Spatio-Temporal Clustering of the COVID-19 Patterns Using Spatial Statistics: Case Studies of Four Waves in Vietnam. Int J Appl Geospatial Res. 2022;13(1):1–15.
7. Cressie N, Moores MT. Spatial statistics. In: Encyclopedia of Mathematical Geosciences. Springer; 2022. p. 1–11.
8. Tobler W. On the first law of geography: A reply. Ann Assoc Am Geogr. 2004;94(2):304–10.
9. Gonzalez-Rubio J, Najera A, Arribas E. Comprehensive personal RF-EMF exposure map and its potential use in epidemiological studies. Environ Res. 2016;149:105–12.
10. Fecht D, Hansell AL, Morley D, Dajnak D, Vienneau D, Beevers S, et al. Spatial and temporal associations of road traffic noise and air pollution in London: Implications for epidemiological studies. Environ Int. 2016;88:235–42.
11. Alves JD, Abade AS, Peres WP, Borges JE, Santos SM, Scholze AR. Impact of COVID-19 on the indigenous population of Brazil: A geo-epidemiological study. Epidemiol Infect. 2021;149:e185.
12. Şener R, Türk T. Spatiotemporal analysis of cardiovascular disease mortality with geographical information systems. Appl Spat Anal Policy. 2021;14(4):929–45.
13. Xie Z, Qin Y, Li Y, Shen W, Zheng Z, Liu S. Spatial and temporal differentiation of COVID-19 epidemic spread in mainland China and its influencing factors. Sci Total Environ. 2020;744:140929.
14. Aral N, Bakır H. Spatiotemporal pattern of Covid-19 outbreak in Turkey. GeoJournal. 2023;88(2):1305–16.
15. Zhang P, Yang S, Dai S, Aik DHJ, Yang S, Jia P. Global spreading of Omicron variant of COVID-19. Geospat Health. 2022;17(s1).
16. Shariati M, Mesgari T, Kasraee M, Jahangiri-Rad M. Spatiotemporal analysis and hotspots detection of COVID-19 using geographic information system (March and April, 2020). J Environ Heal Sci Eng. 2020;18:1499–507.
17. Al-Kindi KM, Alkharusi A, Alshukaili D, Al Nasiri N, Al-Awadhi T, Charabi Y, et al. Spatiotemporal assessment of COVID-19 spread over Oman using GIS techniques. Earth Syst Environ. 2020;4:797–811.
18. MHV. COVD-19 Information Website of Ministry of Health, Vietnam [Internet]. vaMinistry of Health of Vietnam. 2023 [cited 2007 Mar 20]. Available from: https://ncov.moh.gov.vn/
19. Duy C, Nong VM, Van Ngo A, Doan TT, Nguyen TQ, Truong PT, et al. Nosocomial Coronavirus Disease Outbreak Containment, Hanoi, Vietnam, March–April 2020. Emerg Infect Dis. 2021;27(1):10.
20. Hoang VM, Hoang HH, Khuong QL, La NQ, Tran TTH. Describing the pattern of the COVID-19 epidemic in Vietnam. Glob Health Action. 2020;13(1):1776526.
21. Nguyen THD, Vu DC. Summary of the COVID-19 outbreak in Vietnam–Lessons and suggestions. Travel Med Infect Dis. 2020;37:101651.
22. La V-P, Pham T-H, Ho M-T, Nguyen M-H, P. Nguyen K-L, Vuong T-T, et al. Policy response, social media and science journalism for the sustainability of the public health system amid the COVID-19 outbreak: the Vietnam lessons. Sustainability. 2020;12(7):2931.
23. Thanh HN, Van TN, Thu HNT, Van BN, Thanh BD, Thu HPT, et al. Outbreak investigation for COVID-19 in northern

Vietnam. Lancet Infect Dis. 2020;20(5):535–6.
24. Manabe T, Phan D, Nohara Y, Kambayashi D, Nguyen TH, Van Do T, et al. Spatiotemporal distribution of COVID-19 during the first 7 months of the epidemic in Vietnam. BMC Infect Dis. 2021;21(1):1–8.

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