

# Geographical Analysis of COVID-19 Epidemiology: A Review

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## ABSTRACT

**Background:** Since coronavirus disease 2019 (Covid-19) emerged in Wuhan city and rapidly spread throughout China in December 2019, many methods have been proposed for COVID-19 studies.

**Methods:** In this study, we reviewed the geographical analysis-based methodological approaches in COVID-19 epidemiological studies. Three different issues related to applications of geographical analysis in the COVID-19 epidemiology are presented under three sub-sections; namely (1) assessing the spatial distribution of the COVID-19 pandemic at different scales, (2) WebGIS-based mapping the COVID-19 pandemic, and (3) the assessment of impacts of socio-economic factors on the transmission of the COVID-19 pandemic. A systematic literature search of geographical studies of COVID-19 published in English.

**Results:** It was found that geographical analysis can effectively help to study the COVID-19 epidemiology.

**Conclusion:** The study contributes to current research on the spread and social-economic impacts of the COVID-19 pandemic.

**Keywords:** Geographical analysis, COVID-19, Spatial statistics, Epidemiology, Review.

## INTRODUCTION

Coronavirus disease 2019 (COVID-19) is a highly transmittable and pathogenic viral infection caused by severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) (1). The COVID-19 pandemic has caused a global pandemic and has contributed to many deaths worldwide, posing a massive threat to global public health and the economy that may take several years to recover (2).

Globally, as of 8:14am CEST, 26 July 2023, there have been 768,560,727 confirmed cases of COVID-19, including 6,952,522 deaths, reported to World Health Organization (3). It is therefore, COVID-19 epidemiology including the identification of the source of the outbreak, monitoring and tracking the disease, and studying the disease play a vital role in the against the COVID-19 pandemic.

Geographical analysis is defined as the process of analyzing data to identify geographic relationships, patterns, and trends. Geographical analysis is also a powerful automated system for the analysis of spatial data. Methods for geographical analysis including spatial analytical methods and geographic information systems has been widely used in health research (4,5) and epidemiology (5). Geographical analysis has been successfully applied to study the distribution of specific diseases such as lung cancer (6,7), heart attack mortality rate (8,9), cardiovascular diseases (10), and particularly respiratory diseases (11–15).

This paper aims to give an overview of applications of geographical analysis in the study of COVID-19 epidemiology. The content is presented under three sub-sections; namely (1) assessing the spatial distribution of the COVID-19 pandemic at different scales, (2) WebGIS-based mapping the COVID-19 pandemic, and (3) the assessment of impacts of socio-economic factors on the transmission of the COVID-19 pandemic.

## **MATERIALS & METHODS**

### **Materials**

A total of 61 scientific papers collected mainly from Web of Science, SCOPUS, and Google scholar databases was used in this review. These papers were mainly published in recent years after the COVID-19 outbreak in Wuhan city, China. They were selected based on their high number of citations and the high degree of relevance with the research topic.

### **Methods**

We conducted a systematic literature search of geographical analysis of COVID-19 epidemiology published in English from Web of Science, Google Scholar, and SCOPUS databases from 1 January 2019 to 30 July 2023. We queried these databases with different combinations of keywords including ‘applications’, ‘geographical analysis’, ‘COVID-19’, ‘spatial statistics’, ‘epidemiology’ and ‘review’ or ‘overview’. Three different sub-topics was then identified based on applications of geographical analysis-based methods in the study of the COVID-19 epidemiology. Based on search results, search terms were refined to get more specific results for each topic, e.g., ‘the spatial distribution of the COVID-19’, ‘WebGIS-based mapping the COVID-19’, and ‘impacts of socio-economic factors on the transmission of the COVID-19’. Finally, applications of geographical analysis in studies of the COVID-19 epidemiology were summarised and discussed.

## **RESULTS AND DISCUSSIONS**

### **Assessing the spatial distribution of the COVID-19 pandemic at different scales**

Geographical analysis has been widely applied to study the spatial distribution and the spread of the COVID-19 epidemic at different scales such as the global scale (16–18), regional scale (19,20) and the country or state scale (21,22). A typical study at the global scale was carried out when a sample of 186 countries divided into four main regions, notably: Asia-Pacific and the Middle East, Europe, Africa and America

was used successfully to study the effectiveness and consequences of Covid-19 measures (16). As for regional scale, a geographical information system model was employed to define COVID-19 problem areas with an analysis in the socio-economic context at the regional scale in the North of Spain (19). At the country scale, many studies have also been applied geographical analysis to study the spread of the COVID-19 pandemic over the world. When extracting data regarding 1099 patients with laboratory-confirmed Covid-19 from 552 hospitals in 30 provinces, autonomous regions, and municipalities in mainland China through January 29, 2020, geographical analysis has been successfully applied to map COVID-19 pandemic in mainland China (23). Also in China, ArcGIS software and the Bayesian space-time model have been employed to analyzed the distribution of the COVID-19 epidemic and correlation with population emigration from Wuhan, Hubei province (24). It was concluded that the population that emigrated from Wuhan was the main infection source in other cities and provinces (24). After the COVID-19 pandemic rapidly spread across over the world, attempts have been put on the use of geographical analysis to detect the spatio-temporal changes in many countries, especially in the worst-affected countries (25).

Using spatial and space-time scan statistics and the Joinpoint analysis, a study in the United States has indicated that higher risks of clustering and incidence of COVID-19 were consistently observed in metropolitan versus rural counties, counties closest to core airports, the most populous counties, and counties with the highest proportion of racial/ethnic minorities (26). Also in the United States, a study on the application of geographical analysis on characterizing spatio-temporal transmission of COVID-19 and its mitigation strategies was also carried out (27). Geographic differences in COVID-19 cases, deaths, and incidence in the United States, February 12–April 7, 2020 have been also investigated with the help of GIS (28).

The study of (28) has described the geographic distribution of laboratory-confirmed COVID-19 cases and related deaths reported by each U.S. state, each territory and freely associated state (28). Additionally, the spatio-temporal multivariate time-series model has been successfully used for analyzing the spread of COVID-19 in the USA (29).

England is one of the worst affected countries in Europe. In the early stages of the COVID-19 pandemic between January and June 2020 in England, spatial and spatio-temporal kernel estimates have been used to discover the spatio-temporal distribution of COVID-19 infection (30). Also in England, studies on the geography of the COVID-19 crisis along three dimensions: health, jobs and families in England has been documented (31). In Brazil, daily data on reported cases and deaths has been used to understand, measure, and compare the spatio-temporal pattern of the spread across municipalities (32). In Italy, the geography of COVID-19 spread and implications for the relaxation of confinement measures was also studied (33). A part from these countries, geographical analysis has also been successfully applied in many studies in other countries, such as South Korea (34), Iran (35), India (36,37) and Spain (38).

### **WebGIS-based mapping the COVID-19 pandemic**

WebGIS is defined as a complex system with access to the Internet, for capturing, storing, integrating, manipulating, analyzing and displaying data related to locations without the need of having proprietary GIS software (39). WebGIS provides end-users a cost-saving solution to access up-to-date spatial datasets and information (39,40). WebGIS can be customized to provide specific data and information and/or services to end-users (41). In this paper we present WebGIS applications customized for mapping the COVID-19 pandemic.

Web-GIS maps have been widely used for delivering public information on this fast-moving, epidemiologically complex, and

geographically unbounded process (42). In line with those reported in the study of (42). WebGIS-based mapping has also shown the importance in the dissemination and provision of (official) information on COVID-19, especially for the spatial representation of the pandemic and its evolution (43). When investigating geographical tracking and mapping of coronavirus disease COVID-19/ SARS-CoV-2 epidemic and associated events around the world, different types of WebGIS-based mapping such as practical online/mobile GIS and mapping dashboards have been successfully used for tracking the 2019/2020 coronavirus epidemic (44). Based on WebGIS, a visualization system for COVID-19 simulation has also been designed and developed (45). The most international information compiled, the most widely referenced viewer, and the first to go online out is an interactive WebGIS-based dashboard to track COVID-19 in real-time developed by John Hopkins University (43). The web-based was also successfully used for the study of epidemics and design of the web maps on COVID-19. It was found that participatory GIS, Volunteered Geographic Information communities as OpenStreetMap, Virtual Globes, online live tracking dashboards and other computer-assisted applications made it possible to translate datasets from different sources and users into maps easily understandable from the public. The use of these tools in geospatial health has been firmly established as a useful tool for collating, exploring, visualizing and graphically analyzing such health data as the COVID-19 pandemic (46). Since then, more WebGIS-based applications for mapping the COVID-19 pandemic have been employed in many studies in many countries. In Germany, a Web GIS was developed for small-scale detection and analysis of COVID-19 (SARS-CoV-2) cases based on volunteered geographic information for the city of Cologne (47). In Italy, the construction of a digital cartography tool as a WebGIS to allow local communities understanding of

epidemiological spread is presented (48). In India, a user interactive webgis webpage was designed for decision making and resource allocation during COVID in the Solapur City, Maharashtra, India (49), etc.

### **Assessment of impacts of socio-economic factors on the transmission of the COVID-19 pandemic**

The impacts of socio-economic factors on the transmission of the COVID-19 pandemic have been investigated in many studies. A study on the analysis of the correlation between confirmed cases of COVID-19 and several geographic, meteorological, and socio-economic variables at the province level in Spain has indicated that there is a strong and robust negative relationship between average temperature and the rate of cases of COVID-19 (50). GIS-based spatial modeling of COVID-19 incidence rate was carried out to explore relationship between 35 environmental, socioeconomic, and demographic variables and COVID-19 incidence in US in the continental United States (51). It was found that multiscale geographically weighted regression could explain 68.1% of the total variations of COVID-19 incidence in US (51).

The correlation between the geographic spread of COVID-19 and the structure of social networks as measured by Facebook was investigated in US (52). This study revealed that a social connectivity index can help epidemiologists predict the spread of communicable diseases (52). A geographically weighted regression was successfully employed to explore the spatial-temporal varying impacts of social, economic, and environmental multiple facets on COVID-19 cumulative case in Texas, USA (53). When analyzing the risk to COVID-19 infection using remote sensing and GIS, geographical analysis-based proximity analysis and census data of Jaipur city and socioeconomic parameters (population, population density, percentage of main workers, and percentages of literates) have been employed to identify the risk to COVID-19 infection. Also in India,

with the aim of dealing with an in-depth analysis of riskness associated with COVID-19 infections in Kolkata Municipal Corporation at the subcity level, the areas with high or low risk of infections using GIS-based geostatistical approach was identified in this area (54). The study results of (54) has shown that the highest risk areas were located in the eastern and western part of the city, to a great extent overlapped with wards containing larger share of population living in slums and/or below poverty level (54). Impacts of social and economic factors on the transmission of COVID-19 was also assessed in China (55). Additionally, geographical analysis has been widely applied to study the impacts of the COVID-19 pandemic on socio-economic factors in other countries such as Japan (56), Peru (57), Bangladesh (58,59), Thailand (60) and Indonesia (61), etc.

### **CONCLUSION**

This study aims to review the geographical analysis-based methodological approaches in COVID-19 epidemiological studies. Three different issues related to applications of geographical analysis in the COVID-19 epidemiology are presented under three subsections. First, based on a literature review, we discussed the applications of geographical analysis on assessing the spatial distribution of the COVID-19 pandemic at different scales. Then, WebGIS-based mapping the COVID-19 pandemic was reviewed. Finally, the assessment of impacts of socio-economic factors on the transmission of the COVID-19 pandemic was discussed. A systematic literature search of geographical studies of COVID-19 published in English. The results of this review indicate that geographical analysis has proved its effectiveness in the study the COVID-19 epidemiology. The study is significant which contributes to current research on the spread and social-economic impacts of the COVID-19 pandemic.

### **Declaration by Authors**

**Ethical Approval:** Not Applicable



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