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GIS-BASED AND GEOSPATIAL ANALYSIS: MAPPING AND VISUALIZING THE TREND OF COVID-19 DATA IN SELECTED ASIAN COUNTRIES

(Analisis Berasaskan GIS dan Geospatial: Pemetaan dan Visualiasi Trend Data COVID-19 di Negara-negara Asia Terpilih)

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ABSTRACT

The outbreak of COVID-19 has caused many losses, unprecedented threats, and a change of life in many ways. The daily records of cases and other related data contain important information to reflect the severity, trend, and risk level of each country over time. Thus, this study aims to examine the trend, severity, and change of the pandemic situation in Asia over four periods. In this study, the data are collected from 48 Asian countries. The four periods are selected to represent different stages of the outbreak based on the daily records for comparison. The four periods are 6th January 2020, 6th January 2021, 6th July 2021, and 6th June 2022. The data include the daily record of confirmed cases, the number of deaths, the number of vaccinations, and the number of recoveries. Besides, this study also examines the accumulated cases up to 6th July 2022. The accumulated data includes the four data points mentioned and the severity index. The Local Indicators of Spatial Association (LISA) is applied to detect the clustering pattern and hotspot area as well as the existence of spatial effects in the data. The GIS mapping reveals that China has the most severe situation in Period 1. Nevertheless, from Periods 2 to 3, the pandemic is spreading speedily and widely over the Asian region. The deadly situation (confirmed cases, high fatality, and vaccination) is centred around Southeast Asia and West Asia. Nonetheless, with the exception of China, the situation is improving in Period 4.

Keywords: COVID-19; GIS; spatial effect; clustering; Asia; severity

ABSTRAK

Wabak COVID-19 telah menyebabkan banyak kerugian, ancaman-ancaman yang tidak pernah berlaku sebelumnya, dan perubahan corak kehidupan dalam pelbagai cara. Rekod-rekod kes harian dan data lain yang berkaitan mengandungi maklumat penting untuk mencerminkan tahap keterukan, arah aliran dan risiko setiap negara dari semasa ke semasa. Oleh itu, kajian ini bertujuan untuk mengkaji trend, keterukan, dan perubahan situasi pandemik di Asia dalam empat tempoh. Dalam kajian ini, data dikumpul daripada 48 negara-negara Asia. Empat tempoh telah dipilih untuk mewakili peringkat-peringkat wabak yang berbeza berdasarkan rekod-rekod harian untuk perbandingan. Empat tempoh tersebut ialah 6 Januari 2020, 6 Januari 2021, 6 Julai 2021, dan 6 Jun 2022. Data tersebut termasuk rekod kes harian yang disahkan, jumlah kematian, jumlah vaksinasi, dan jumlah pemulihan. Selain itu, kajian ini juga mengkaji kes-kes terkumpul sehingga 6 Julai 2022. Data terkumpul termasuk empat titik data yang dinyatakan dan indeks keterukan. Local Indicators of Spatial Association (LISA) telah digunakan untuk mengesan corak kluster dan kawasan hotspot serta kewujudan kesan-kesan spatial dalam data. Pemetaan GIS mendedahkan bahawa keadaan yang paling teruk dalam Tempoh 1 adalah di China. Walau bagaimanapun, wabak itu merebak dengan pantas dan meluas di seluruh rantau Asia dari Tempoh 2 hingga Tempoh 3. Keadaan yang teruk (kematian yang tinggi, kes yang disahkan dan vaksinasi) berkumpul di sekitar Asia Barat dan Asia Tenggara. Namun begitu, keadaan itu menjadi semakin baik dalam Tempoh 4 kecuali untuk negara China.

Kata kunci: COVID-19; GIS; kesan spatial; pengelompokan; Asia; keterukan

1. Introduction

Coronavirus disease 2019 (i.e., COVID-19), according to the World Health Organization (WHO), is an infectious illness triggered by the virus of severe acute respiratory syndrome coronavirus 2, or SARS-CoV-2. The first occurrence was found in Wuhan. The WHO and Chinese officials both identified human-to-human transmission. Due to the rapid spread of the disease, the WHO declared COVID-19 a Public Health Emergency of International Concern on January 30. Then, by March 11, 2020, COVID-19 has declared to be a global pandemic by the WHO. When the pandemic was declared, there were 118,000 cases reported in 114 countries, which involved 4,291 death cases (World Health Organization 2020). COVID-19 has caused many losses, deaths, and the collapse of economies. As of August 10, 2020, a total of 19,718,030 cases have been registered globally, with 728,013 deaths. According to the WHO, the United States had 14,960 confirmed cases per 1 million population and 486 fatalities per million, Peru had 14,285 confirmed cases and 632 fatalities per million, and Brazil had 14,172 confirmed cases and 472 fatalities per million (Thompson *et al.* 2020). By March 6, 2023, the confirmed cases were 680,690,503. The confirmed deaths were 6,805,280 (Worldometer 2023b).

No single country could escape from the influences of COVID-19. The top 10 confirmed COVID-19 cases by country include United States, India, Brazil, United Kingdom, Russia, France, Turkey, Germany, Spain, and Iran (CovidNow 2022). Besides, the top 10 confirmed COVID-19 deaths consist of United States, Brazil, India, Russia, Mexico, Africa, Peru, United Kingdom, Indonesia, and Italy (Mathieu *et al.* 2021). The harmful effect of COVID-19 is not limited to the loss of lives but the long-term effect on the socio-economy throughout the world (Dyvik 2024). The second-largest economy, China, also recorded a decline in the first quarter of 6.8%. Along with increasing telework and telecommuting, halting operations, and limiting supply and demand, lockdown measures have also been used (Shrestha *et al.* 2020). The negative effects of COVID-19 are reported through plenty of research and empirical studies on economic indicators, including employment, poverty, GDP growth, government expenditure, and budget deficits (International Labor Organization 2020; Nicola *et al.* 2020; Sumner *et al.* 2020). As reported by Statista Research Department, Aug 25, 2022, United Kingdom was the country that received the largest hit from COVID-19. The GDP growth was reported to be -7.7% during the third quarter of 2020, while that of India and Japan was reported as -5.3%. However, the largest economies started to gain recovery in 2021.

The pandemic has not yet come to an end, and it is hard to tell when COVID-19 will disappear as medication to kill the virus has not yet been found. Hence, we have to adapt to the new live style with the pandemic. It is also a long-term effort to fight COVID-19. In this study, the main focus is to utilize the geographic information system (GIS) mapping approach to visualize trends and changes in indicators related to COVID-19 in the region of Asia. The spatial analysis is also applied to detect the spatial dependence among countries and how such a relationship might affect the behaviour of the variables examined. This study may reveal the evolution and transition of COVID-19 in Asia in determining the behaviour of indicators, the relationship among variables, and the patterns that changed over time. This research provides new insights into the factors contributing to the outbreak of the COVID-19 pandemic and raises the public's awareness of the need for preventive actions.

The focus is on the region of Asia, as the first case was found in China. Besides, the large economies in Asia, such as China, India, Japan, and South Korea, are among the top countries with high confirmed cases. These economies are also badly affected by COVID-19. The neighbouring countries in Asia have a high connection with these large economies through trades and investments. Hence, the outbreak of COVID-19 might spillover to other countries.

By considering the spatial dependence among countries, the study might reveal the deep connection among countries in determining the indicators examined.

2. Review of COVID-19 Influences in Asia

Sawada and Sumulong (2021) discussed the macroeconomic impacts of COVID-19 in developing Asia. As they stated, COVID-19 has afflicted almost 200 million people, with fatality over 4.2 million as dated 31 July 2021. By the end of July 2021, developing Asia has accounted for 23%, Europe for 29%, and the United States for 18%. While within developing Asia, South Asia showed the greatest share of infected occurrences. This was followed by Southeast Asia, Central Asia, East Asia, and the Pacific. In terms of economic losses, ADB's assessment via Multi-Regional Input-Output Tables (MYRIOT) released in December 2020 suggested a loss of 5.5-8.7% of global GDP in 2020 and 3.6-6.3% in 2021. The estimated losses for developing Asia are 6.0-9.5% and 3.6-6.3% of GDP in 2020 and 2021, respectively (Abiad *et al.* 2020). By subregion, East Asia and the Pacific received smaller hits from the outbreaks, while South Asia and those tourism-dependent economies received the largest hits as the pandemic induced sharp declines in domestic demand and tourism demand (Sawada & Sumulong 2021). In terms of job losses, Park *et al.* (2020) estimated that developing Asia accounted for nearly 70% of total losses in employment globally, which involved a drop of 109 million – 166 million jobs. The pandemic also increased the number of poor in developing Asia. As indicated by Bulan *et al.* (2020), the pandemic caused an increase of 162 million and 78 million under the international poverty lines of $3.20 and $1.90 per day, respectively, in the year 2020.

3. Data

In this study, the aim is to investigate the outbreak of COVID-19 in Asian countries. This involves 48 Asian countries (see Table 1). Following the definition of Worldometer and United Nations, there are 48 countries of Asia. This classification does not include the dependent territories. Hence, Hong Kong, Macau and Taiwan are excluded. Russia is not in the list of Asia under this classification. Most Russians live on the European continent, although most Russian territory is in Asia (Worldometer 2023a).

The data are in cross-section units. To study the changes in the pandemic-related indicators, the data are classified into four main periods, which are 6th January 2020 (Period 1), 6th January 2021 (Period 2), 6th July 2021 (Period 3), and 6th June 2022 (Period 4). 6th June 2022 is the most recent COVID-19 data up to the date of this study.

Table 1: List of Asia countries involved

Country	Country	Country	Country
Afghanistan	Indonesia	Maldives	South Korea
Armenia	Iran	Mongolia	Sri Lanka
Azerbaijan	Iraq	Myanmar	Syria
Bahrain	Israel	Nepal	Tajikistan
Bangladesh	Japan	North Korea	Thailand
Bhutan	Jordan	Oman	East Timor
Brunei	Kazakhstan	Pakistan	Turkey
Cambodia	Kuwait	Palestine	Turkmenistan
China	Kyrgyzstan	Philippines	United Arab Emirates
Cyprus	Laos	Qatar	Uzbekistan
Georgia	Lebanon	Saudi Arabia	Vietnam
India	Malaysia	Singapore	Yemen

The variables involved include daily confirmed cases, daily confirmed deaths, daily recovery cases, and daily vaccinated individuals. These data are collected from various websites, namely the World Health Organization (WHO) official website, Worldometer and the Our World in Data organization website. Apart from the above-mentioned data, accumulated data is also collected. These data show the accumulated cases reported from the first day the pandemic was reported until the most recent (12th June 2022). These data include accumulated confirmed cases, accumulated confirmed deaths, and full vaccination rates (see Table 2).

Table 2: Summary of variables

Variable	Description	Measurement unit
Confirmed cases (CC)	Daily confirmed COVID-19 cases	No. of cases
Death cases (DC)	Daily confirmed death cases due to COVID-19	No. of cases
Recovery cases (RC)	Daily recovery cases from COVID-19	No. of cases
Vaccination cases (VC)	Daily COVID-19 vaccination cases	No. of cases
Accumulated cases (AC)	The confirmed COVID-19 cases from January 2020 until 12 June 2022.	Accumulated cases
Accumulated deaths (AD)	The confirmed deaths due to COVID-19 from January 2020 until 12 June 2022.	Accumulated cases
Fully vaccination rate (FV)	The vaccination rate of taking 3 doses of vaccine including booster until 11 June 2022.	Percent

4. Methodology

4.1. *GIS mapping*

A geographic information system (GIS) is a system that captures, stores, analyses, and displays various forms of geographical data. GIS is applied to visualize the data in a spatial environment and for problem-solving as well as decision-making processes. GIS can be employed to map the spatial location of real-world elements as well as visualize their spatial associations. Besides, GIS can be adopted to map quantities and densities to look at the relationships of the variables. Moreover, the features of the location inside a region or within a set of distance by mapping what is nearby can be determined. In addition, the change in a specific geographic area can be mapped to forecast future circumstances and undertake action or policy with evaluation. Examples include country boundaries and the position of roads and railways using lines. In this project, the format used is Shapefile (SHP). The ESRI Shapefile has evolved into an industry-standard geospatial data format, which is practically compatible with all lately released GIS software (DiBiase 2014). However, in this study, there is no shapefile available for the Asia countries. Hence, the world shapefile is edited to remove the unrelated countries. The world shapefile is obtained from World Bank Group (2022). Hence, the shapefile contains the geographical location and administrative area as defined by the World Bank.

4.1.1. *Spatial data analysis*

There are two types of spatial effects, namely spatial dependence and spatial autocorrelation. Spatial autocorrelation helps us measure the degree of similarity (correlation) of an object to nearby areas. Spatial randomness means that there is no spatial pattern observed in the data. In other words, the value observed in the spatial unit is as probable as the spatial unit seen in another. Spatial randomness is vital since it forms the null hypothesis. However, there is evidence of spatial structure if it is rejected. Spatial autocorrelation may be written in Eq. (1) as follows:

$$Cov(y_i, y_j) = E(y_i y_j) - E(y_i)E(y_j); i \neq j, \quad (1)$$

where y_i and y_j represent observations on a random variable at locations i and j in space. The i, j can be points or areal units. Thus, if the covariance between feature attribute values at locations i and j is nonzero, there is a nonzero spatial autocorrelation between those points (Sarrias 2020).

Assume that n is the number of spatial units. The spatial weight matrix, **W**, is a $n \times n$ non-stochastic positive symmetric matrix with element w_{ij} at location i, j. The values of w_{ij} or the weights for each pair of locations are allocated by certain predefined criteria that specify the spatial relationships between them. By convention, $w_{ij} = 0$ for the diagonal elements (Sarrias 2020).

$$\mathbf{W} = \begin{bmatrix} w_{11} & \cdots & w_{1n} \\ \vdots & \ddots & \vdots \\ w_{n1} & \cdots & w_{nn} \end{bmatrix}.$$

There are two essential conditions for w_{ij}. The first type forms a link based on shared boundaries or vertices of lattice or irregular polygon data (contiguity). The other type forms a connection based on the distance between locations. Contiguity is best suited for geographic data defined as polygons or areal units, whereas distance is appropriate for point data; however, this distinction is not absolute in practise. In terms of contiguity, Rook and Queen contiguity are the most widely used. A common specification of the contiguity relation in the spatial weight matrix is as follows:

$$w_{ij} \begin{cases} 1 & \text{if } i \text{ and } j \text{ are contiguous} \\ 0 & \text{if } i \text{ and } j \text{ are not contiguous} \end{cases}.$$

In this study, queen contiguity is used for the data analysis. Queen contiguity refers to the neighbour consists of any region that touches the boundary of region i, whether on a side or a single point. By using this reasoning, the neighbours of 5 will be 1, 2, 3, 4, 6, 7, 8, and 9 as shown in Figure 1 (Sarrias 2020).

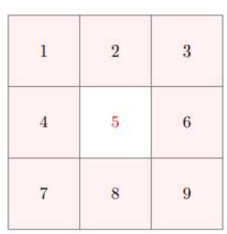

Figure 1: Queen Contiguity (Sarrias 2020)

4.2. *Local Moran's I*

Local Moran's I categorises the spatial autocorrelation into four quadrants based on the concept of a local indicator of spatial association (LISA) introduced by Anselin (1995). The four quadrants are High-High (HH), Low-Low (LL), High-Low (HL), and Low-High (LH) clustering. HH and LL quadrants are examples of a positive local association, I>0, while HL and LH quadrants belong to the negative local association, I<0. HH (LL) indicates that the individual country with a high (low) value is surrounded by neighbours with high (low) values. LH refers to the condition of a low individual value is surrounded by high values, and HL denotes a high individual value is surrounded by neighbours with low values (Anselin 1995). The local Moran's I statistic is given by the following formula:

$$I_i = \frac{(x_i - \bar{x}) \sum_{j=1}^{n} w_{ij}(x_j - \bar{x})}{\frac{1}{n}\sum_{j=1}^{n}(x_j - \bar{x})^2},$$

where *N* is the number of spatial units indexed by i and j, x is the variable of interest, $\bar{x}$ is the mean of x, and w_{ij} is the matrix of spatial weights with zeros on the diagonal as $w_{ii} = 0$ (Rios 2019).

5. Results

5.1. *Daily data – Four periods*

The results of GIS mapping for the four periods of daily cases are displayed in Figure 2 and Figure 3. By comparing the region of Asia, the only affected country for the confirmed cases in the early stage (Period 1) was China. It was due to the discovery of the COVID-19 virus in Wuhan, China. Since January 2020, the cumulative confirmed cases in Wuhan alone have reached over 89,000 (Xu *et al.* 2020). COVID-19 is spreading fast, as can be seen from Period 2. The West and Southeast Asian countries like Japan, South Korea, Singapore, Bangladesh, Iran, India, Indonesia, and Pakistan are more severe in the number of COVID-19 cases as the colours of the region on the maps are getting darker. The critical condition remains until Period 3. In Period 4, the conditions in some countries were getting better. However, China was experiencing an increasing rate.

In terms of death cases, the conditions vary across countries. China exhibited very low death cases from Period 1 to Period 3 but experienced a drastic spike in death in Period 4 due to the contagion of Delta and Omicron in the second quarter of 2022. India, on the other hand, experienced critical death cases in all four periods. As quoted by Soutik Biswas (2022) from BBC News, India has officially recorded more than half a million deaths due to the novel coronavirus until now. It reported 481,000 deaths due to COVID-19 between 1 January 2020 and 31 December 2021, but the WHO's estimates put the figure at nearly ten times as many.

The number of death cases was initially high in Pakistan for Period 1 but decreased across the period until Period 4. Indonesia initially showed an increasing number of deaths from Period 1 to Period 3 (6th July 2021) but then decreased to zero in Period 4. The West Asian countries also exhibited a serious condition with high fatalities due to COVID-19 from Periods 1 to 3, but the condition improved in Period 4. The Southeast Asian countries experienced high fatalities in Periods 2 and 3, but the condition improved in Period 4. The safest country was Laos because zero deaths were recorded across four periods.

In terms of recovery cases, the trend does not change much from Periods 2 to 3, where the high recovery cases are found in those countries with high confirmed cases, especially in India and West Asian countries. Indonesia also exhibits high recovery cases due to its high confirmed cases from Periods 2 to 3, but the recovery rate is lower in Period 4. China shows low recovery cases from Periods 2 to 3 but a drastic increment in Period 4 due to the re-surge of COVID-19 in Quarter 2, 2022.

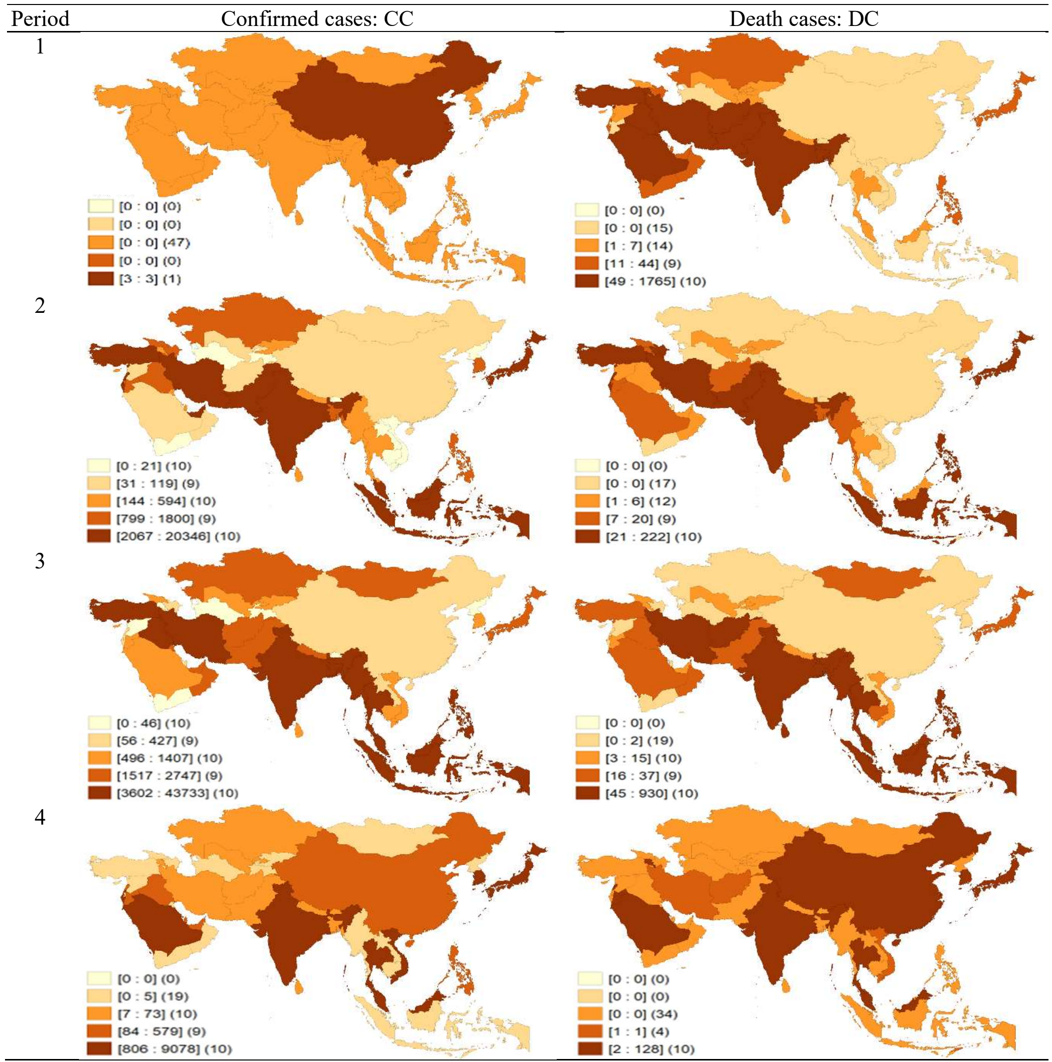

Figure 2: GIS maps for confirmed cases (CC) and death cases (DC)

The vaccination cases are zero in Period 1 as the vaccination has not started yet. In Period 2, only a few countries start vaccination. In Period 3 and Period 4, many countries have increasing vaccination cases. China has the highest vaccination cases due to its large population. North Korea has zero vaccination cases as North Korea has not started the vaccination campaign.

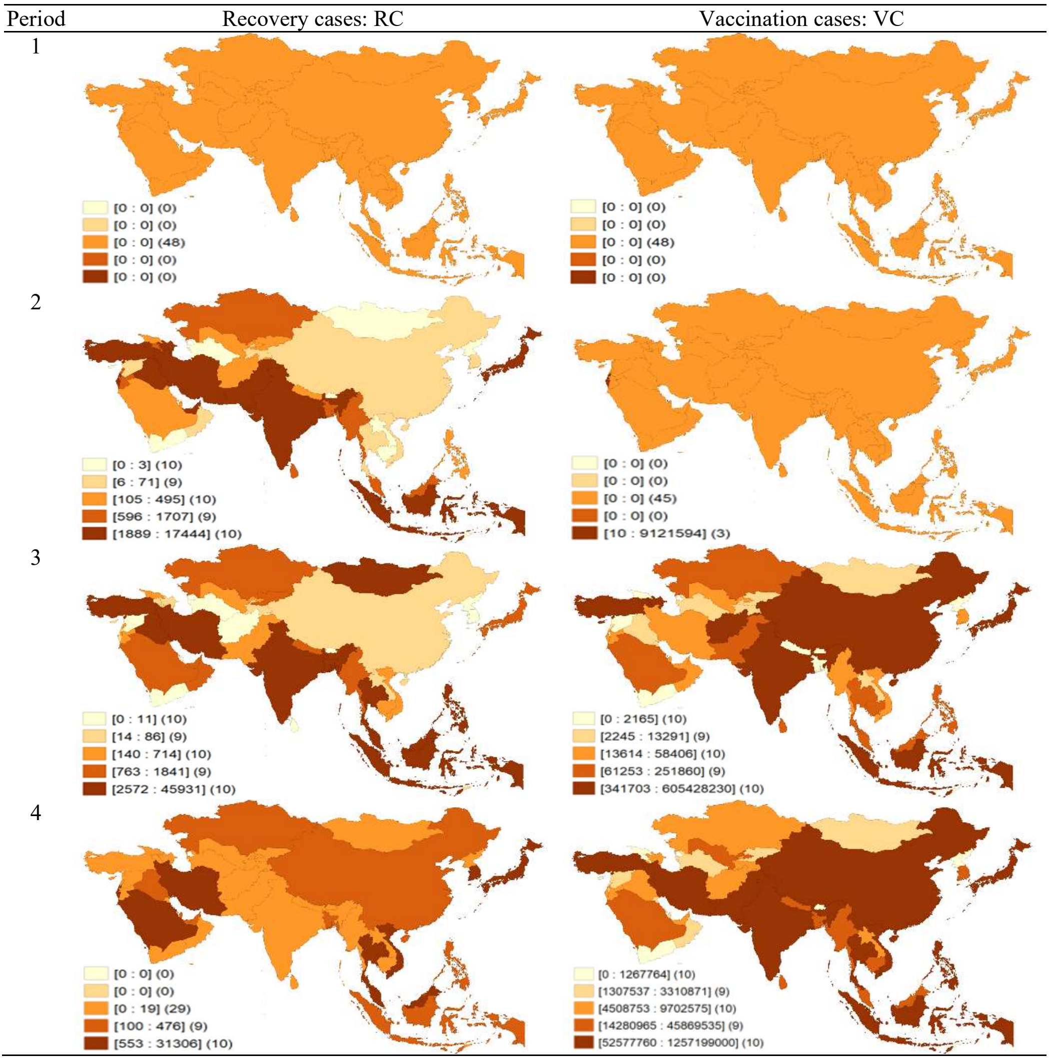

Figure 3: GIS Maps for recovery cases (RC) and vaccination cases (VC)

5.2. *Accumulated data*

The GIS maps (Figure 4) show that the countries with high confirmed cases are also having high death cases. These countries are mainly from Southeast Asia and West Asia. In terms of Vaccination rate, United Arab Emirates, Bhutan, Brunei, Cambodia, China, South Korea, Malaysia, Qatar, and Singapore show high vaccination rates. North Korea is undefined as the vaccination rate is zero. The distribution of countries for AC, AD, and FV can also refer to Moran's I quadrants plots, which classify the countries into four main quadrants: HH, LL (positive relationship) and HL, LH (negative relationship).

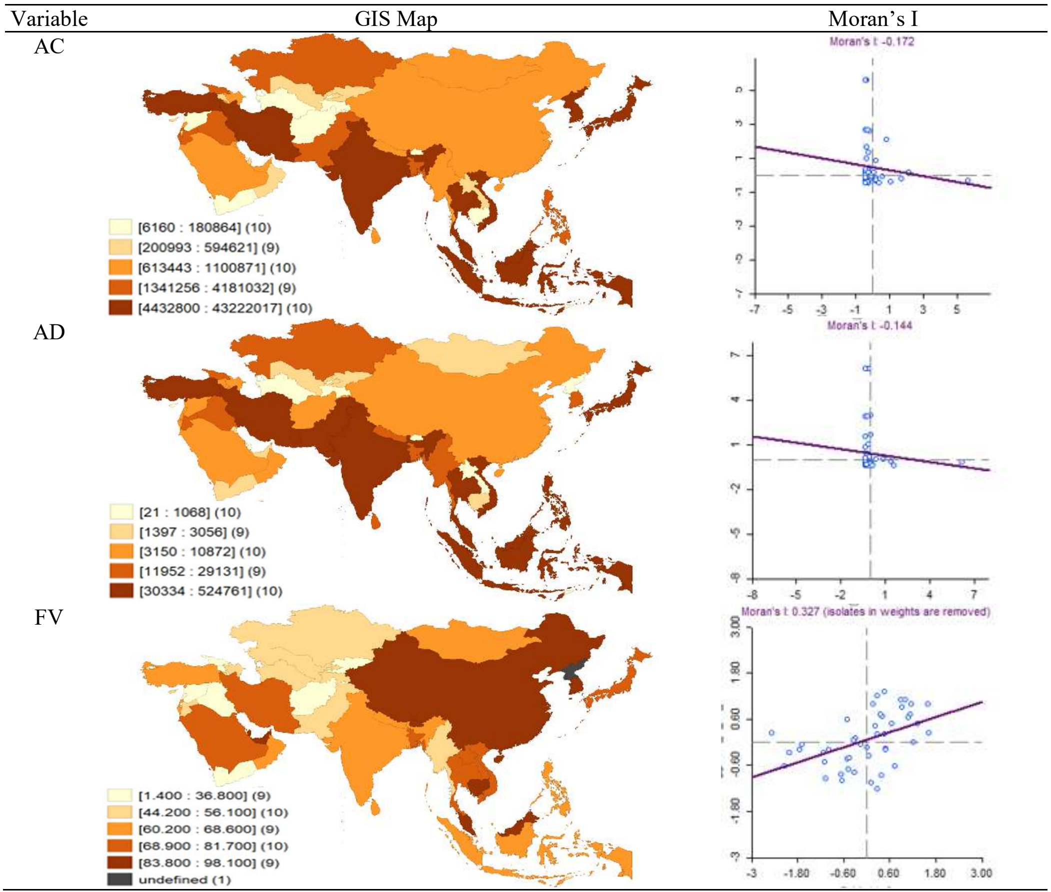

Figure 4: GIS maps for accumulated cases (AC), accumulated death (AC) and fully vaccination rate (FV)

Table 3: LISA patterns for accumulated data

Variable	Moran's I	Clustering of countries according to quadrant			
		Quadrant I (HH)	Quadrant II (LH)	Quadrant III (LL)	Quadrant IV(HL)
AC	-0.172**	Japan**	Bangladesh** Bhutan** Sri Lanka*** Cyprus** Maldives*** Nepal** Pakistan**	Kazakhstan** Tajikistan** Uzbekistan**	-
AD	-0.144**	Pakistan***	Bangladesh** Myanmar** Bhutan** Sri Lanka*** Maldives*** Nepal** East Timor**	Kazakhstan**	-
FV	0.327***	Laos** Malaysia** Vietnam**	-	Jordan** Uzbekistan**	Iran** Israel** Turkey***

Note: * significant at 10%; ** significant at 5% and *** significant at 1%

The list of countries under each quadrant is summarised in Table 3. The degree of connectivity according to Moran's I is also given. The values of connectivity are negative for AC and AD but are positive for FV. All are significant at either 5% or 1% levels. The negative Moran's I for AC and AD is due to the majority of countries being grouped under LH, in which an individual country with low AC or AD is surrounded by neighbours with high AC or AD. The positive Moran's I for FV is because HH and LL are the dominant groups, where an individual country with a high (low) vaccination rate is surrounded by neighbours with the same or similar trends and conditions.

6. Conclusion

In this study, the GIS mapping approach and spatial statistics are applied to examine the condition of COVID-19 in the region of Asia. The variables examined include the confirmed cases, recovery cases, death cases, and vaccination rate by comparing four main periods: 6th January 2020 (Period 1), 6th January 2021 (Period 2), 6th July 2021 (Period 3), and 6th June 2022 (Period 4). In addition, the accumulated cases, accumulated deaths, and accumulated vaccination rates up to 12th June 2022 are further examined using the LISA approach in detecting the clustering spatial effect. Our results reveal that the pandemic has a strong spreading power, as the majority of countries experienced an increment in the severity with higher confirmed and death cases, but the recovery rate was also high. The most impacted countries are the West and South of Asia. However, the results are subject to the availability and accuracy of data reported by the authorities. Hence, readers should interpret the results carefully. Besides, the data is only available in daily of number cases reported, i.e. the daily recovery and vaccination cases without distinguishing if the recovery is due to repeated or first time infected cases and the vaccination is due to first or repeated vaccines. Despite these limitations, the GIS mapping provides a good visualization on detecting the change in pattern of variables over time. The analysis of LISA on accumulated cases also detected the clustering spatial effect. The negative spatial effect was detected in accumulated cases and accumulated deaths, while the positive spatial effect was found in accumulated vaccinations. This tells us that geographical location matters, as a country might receive stronger impacts from its nearest neighbours. Further analysis by considering the spatial effect is crucial to reveal the information to fight against the pandemic, as well as to monitor the outbreak of COVID-19 among members of Asia. The analysis can be extended to spatial regression modelling, which considers spatial correlation among neighbour countries in the regression since spatial correlation is evident.

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