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COVID-19 Pandemic in Urban Environment and Household Population: An Exploratory Spatial Risk Analysis in Selangor, Malaysia

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Abstract

Malaysia faced the COVID-19 epidemic which had a huge impact on the community and environmental health in 2020. This paper was conducted to perform exploratory analysis on the feasible factors influencing the COVID-19 pandemic in Selangor using Geographical Information System (GIS) techniques. Two central objectives were carried out, specifically: i) to analyse the spatial-temporal distribution of COVID-19 cases by months and districts in the state; and ii) to identify the environmental factors that contribute to the increase of COVID-19 cases, including population, housing, urbanisation, gradient, and industrial area. Natural break classification method in ArcGIS was used to produce the COVID-19 map and analysis, followed by the possible correlation between the cases, and selected risk factors were determined using correlation analysis. Every district had experienced the pandemic, especially in the populous and urbanised district of Petaling and Klang. The cases rose in the last three months of 2020 namely October, November, and December. Although there were no dominant factors shaping the increasing cases as the correlation strength was mostly moderate and low trends, the number of population was suggested as the main local factor as there was a moderately strong correlation (r=0.56) due to uncontrolled human movements and crowded conditions in certain areas. GIS has also demonstrated its methodological capabilities and responsive planning to spot the spatial distribution and correlation of COVID-19 cases with the potential risk factors.

Keywords: COVID-19, spatial environment, urban population, correlation risk analysis, GIS

1.0 INTRODUCTION

Coronavirus disease (COVID-19) is a newly found coronavirus-based viral disease. For the most part, patients who were infected with COVID-19 have mild to severe respiratory symptoms. There is a greater risk of developing a major illness in the elderly and people with comorbidities such as cardiovascular disease, diabetes, chronic respiratory disease, and cancer (WHO, 2021). Nowadays, the global distribution pattern across continents indicated a steady rise in the sequence of America, Europe, Asia, Africa, and Oceania (Ali et al., 2021).

A great way to avert and slow down transferral is to be alert about the COVID-19 virus, its origin, and how it extends. Hand hygiene practices such as washing hands or using a sanitizer regularly, and not touching your face are also deemed essential. Previously, specific vaccines or treatments for COVID-19 have not been found yet. However, there are several clinical trials in progress to evaluate possible treatments. World Health Organization (WHO) continues to provide updated news as soon as clinical findings were obtained. At the end of 2019, Wuhan faced an outbreak of a novel coronavirus that snatched more than 118 lives and infected over 70,000 individuals within the first 50 days of the epidemic. Chinese researchers termed the novel virus Wuhan coronavirus or 2019 novel coronavirus (2019-nCov). According to the International Committee on Virus Taxonomy, SARS-CoV-2 is the virus, and COVID-19 is the disease (WHO, 2020).

The flare-up of COVID-19 sickness 2019 in Malaysia started in January 2020, when COVID-19 was first detected on 25 January among visitors originated from China that showed up from Singapore. Revealed cases remained generally low and to a great extent, minimal to imported cases until confined clusters started to rise in March. The largest group was associated with a Tabligh Jumaat stringent social occasion conducted in late February and early March in Sri Petaling, Kuala Lumpur (Babulal & Othman, 2020). The congregation caused tremendous rises in cases as well as the exportation of cases to neighbouring areas. Malaysia had the most confirmed

COVID-19 instances in Southeast Asia within half a month and had surpassed 2,000 imprints in active cases by the end of March, up from less than 30 at the start of the month (Babulal & Othman, 2020).

COVID-19, much like the flu, can be passed from one person to another by direct contact. Coughing, sneezing, and talking to a COVID-19-infected person might transfer the virus to nearby surfaces (Islam et al., 2020; Li et al., 2020; Wang et al., 2020). This airborne virus is a zoonotic disease that is exacerbated by a variety of environmental conditions (Rume & Islam, 2020; Shakil et al., 2020). Human congestion, mobility, poverty, social work, and weather are also conditions that could impact the spread of this pandemic (Thoradeniya & Jayasinghe, 2021). Shakil et al. (2020) also discovered a positive correlation between climatic factors such as temperature, due point, humidity, wind speed, rainfall, and COVID-19 transmissions, but the researchers have also recommended that the study should focus on other factors including environmental degradation, air pollution, climate/metrological factors, and temperature using a spatial approach.

Consequently, the human and environmental factors in urban areas seem to be closely related to the spread of the pandemic. Precautionary measures were also even taken by implementing human movement control order (MCO) to overcome this situation and the public was advised to practice physical distancing in public areas. This study has seen the significance of exploring the spatial distribution of the disease in order to identify the spatial variation of the cases in selected areas and possible risk factors of Selangor, Malaysia. Two main objectives of the study are: i) to analyse the general spatial-temporal distribution of COVID-19 cases; and ii) to identify the environmental factors that potentially contribute to the increase of COVID-19 cases.

2.0 LITERATURE REVIEW

2.1 Coronavirus Disease (COVID-19)

Coronaviruses are a type of virus that can cause lung illness in humans. The word "corona" comes from the virus's many crown-like spikes on its surface. Shereen et al. (2020) stated that coronaviruses cause human illness, including severe acute respiratory syndrome (SARS), Middle East respiratory disease (MERS), and cold symptoms. COVID-19, the most recent coronavirus strain, was discovered in December 2019 in Wuhan, China. Since then, the sickness has spread to every continent, except Antarctica (Shereen et al., 2020).

Starting on 31 December 2019, China's Wuhan City was the epicentre of an outbreak of an unnamed virus that spread to Thailand, Korea, Japan, United States, Vietnam, and Malaysia, as well as other countries across the world (Babulal & Othman, 2020). Coronavirus disease-2019 was listed as extreme pneumonia with novel pathogens by Taiwan's CDC, Ministry of Health, on 15 January 2019, and is a notifiable communicable disease of the fifth group. There is a low to moderate mortality risk associated with COVID-19 that is estimated at 2 percent to 5 percent (WHO, 2020).

Person-to-person transmission can occur through the transfer of droplets or by touch, which might endanger first-line health workers if there is ineffective infection monitoring or if suitable protective equipment is not available. When people are in close proximity, the virus travels mostly through the air, especially when people smoke, cough, sneeze, or converse; then exits an infected entity and penetrates another individual through their eyes, mouth, or nose. It can also spread through diseased surfaces. For up to two weeks, individuals are infected, and may transmit the infection even though they do not exhibit symptoms (Babulal & Othman, 2020).

In terms of social aspects, the rate of COVID-19 infection was found to be both positively associated with population density and negatively correlated with the rate of social isolation, thereby suggesting that social distancing is successful in reducing the transmission of COVID-19. To provide insights into the distribution of COVID-19 across the enlarged metropolitan region, a spatial analysis was performed in order to determine social factors and environmental variables that could impact the occurrence of COVID-19, particularly mutual travel and contact of people in metropolitan or urban areas as suggested by Franch-Pardo et al. (2020).

2.2 Geographical Distribution of COVID-19

The epidemic of the deadly COVID-19 that had first originated in China spread rapidly across the world. The trend of global distribution across continents has shown in the order of America, Europe, Asia, Africa, and Oceania have risen steadily. Scientists have already made considerable strides in managing the spread of the novel coronavirus, although further experimental experiments need solid evidence. Though queries remain vague, and there is an immediate need for further reports to investigate the rate of infection, the production of vaccines and therapeutics to deter further proliferation, providing the foundation for potential research (WHO, 2021).

In a global view, according to WHO (2021), COVID-19 status report on 18 December 2020, 75,641,366 confirmed instances of COVID-19 infection were detected worldwide, with 1,674,733 fatalities and 53,089,262 recoveries. United States of America recorded 17,669,508 cases, India (9,989,130), Brazil (7,120,103), Russia (2,791,220), France (2,427,316), Turkey (1,955,680), United Kingdom (1,948,660), Italy (1,906,377), Spain (1,805,633), and Argentina are the top-10 countries with the largest burden of infection (1,524,372). The Americas region has the largest number of confirmed cases (31,573,039), with the lowest number of COVID-19 infections in the Western Pacific region (991,931).

The Malaysian Ministry of Health (MOH) reported 5,251 COVID-19 cases as of 17 April 2020, including 86 deaths and 2,967 recovery cases. COVID-19 has been confirmed in 1,338 people in Selangor, making it the state with the most confirmed cases. The districts of Lembah Pantai, Hulu Langat, Petaling Jaya, Seremban, Kuching, and Kluang have been designated as red zones due to the large number of positive cases. On 25 January 2020, the first case of COVID-19 was detected in Malaysia, and it was connected back to three Chinese citizens who had personal contact with an infected person in Singapore. On 24 January 2020, they travelled from Singapore to Malaysia. They were hospitalized at Selangor's Sungai Buloh Hospital, Tuanku Jaafar Hospital, Sungai Buloh Hospital, and Kuala Lumpur Hospital, and various other hospitals throughout the country (Babulal & Othman, 2020).

In Malaysia, this was the first case of COVID-19 recovery. On 6 February 2020, a 40-year-old Malaysian woman was tested positive for COVID-19. Although her trip history was normal, she was the younger sister of a 41-year-old man detected positive with the virus on 4 February 2020. She was the very first COVID-19 patient in Malaysia who caught the virus through local spread. Monitoring has been made from time to time. Several parties were doing their very best to avert any dissemination. Starting from 15 March, Malaysia saw an outstanding increase in active cases. The Malaysian Prime Minister held a live broadcast to announce the implementation of the Movement Control Order (MCO). The order was extended to 14 April on 25 March, and further extended till 28 April. Several limitations were enforced: i) large-scale gatherings and events, such as sporting, social, and social activities are prohibited in public; ii) all kindergartens, government and private schools, especially daily schools and boarding schools, international schools, and other primary, secondary, and pre-university institutions, as well as *tahfiz* centres, have been ordered closed by the government; and iii) All open and private advanced education foundations (IPTs) and aptitude preparing establishments are requested to close.

All government and private premises were closed down except for fundamental administrations. In Selangor, all nine districts in the state now were declared as red zones after recording 697 new COVID-19 cases at the end of December. All the cases recorded also involved local infections. Through graphic info uploaded on the Facebook page of the COVID-19 Selangor Prevention Task Force (STFC), the nine districts involved were Hulu Langat (328 cases), Klang (157 cases), Petaling (89 cases), Kuala Selangor (43 cases), Gombak (40 cases), Sepang (13 cases), Kuala Langat (12 cases), Sabak Bernam (8 cases) and Hulu Selangor (7 cases). To date, Selangor has recorded a total of 29,969 COVID-19 cases in total. Based on the latest statistics, a total of 1,594 new COVID-19 cases were recorded across Malaysia on 28 December with a total of 1,181 recovery cases.

2.3 COVID-19 and Urban Environment

The region around a city, town, or suburb is referred to as urban area. This includes the environment of a person, animal, or plant lives or operates. The urban area is generally indicated through the density of human structures such as residences, commercial buildings, roads, bridges, and high transportation systems. In many nations, rapid urbanisation combined with rapid rise in living standards is straining natural resources and posing a threat to environmental quality. These urban environmental concerns led to the contamination of air, water, and soil that impact human health (Vardoulakis et al., 2016).

In the context of COVID-19, the disease is predominantly spread through direct interaction with mammals, respiratory droplets, fomites, and infected surfaces produced by coughing, sneezing, and talking (Islam et al., 2020; Li et al., 2020; Wang et al., 2020). A 1-m physical distancing protocol was adapted by WHO, based primarily on the premise that the virus is spread within this range by mostly isolated droplets. The probability of airborne transmission by airborne particles with diameters of less than 5 μm has, however, been proposed. The global outbreak COVID-19 has affected every part of human life, including the environment (Aabed & Lashin, 2021; Rume & Islam, 2020; Shakil et al., 2020) determined the associations between COVID-19 and environmental parameters were not affected by potentially confounding factors such as air pollution, sea level, or population. In Malaysia, the study identified the relationship between COVID-19 cases with air pollution (Othman & Latif, 2021) and population density (Aw et al., 2021).

In the transmission of COVID-19 between people, many variables are involved, including the climate in buildings and human actions. Finger contact with virus-contaminated surfaces and facial membranes are possible exposure processes for COVID-19 infection, similar to the transmission routes of other respiratory viruses such as influenza, inhalation of the virus kept in airborne particles exhaled from coughing or vocalisation, and droplet spray, direct projection to the virus's facial membranes.

Therefore, environmental conditions in buildings, such as temperature, humidity, fomite stability, ventilation, and filtration systems, such as in public spaces, health centres, restaurants, hotels, leisure facilities or residential buildings where people are close together, could have a direct effect on the infection. In order to determine the dissemination of COVID-19, effective regulation of these environmental factors and proper human actions in compliance with these environmental conditions play a significant role. It is important to consider the possible transmission dynamics of COVID-19 within a house, the spatial dynamics, and the building operational variables that theoretically facilitate and reduce the transmission and dissemination of COVID-19, since most people spend more than 90 percent of their daily lives inside buildings.

2.3.1 Housing

The housing conditions of people have influenced their ability to protect against COVID-19. People have been advised to remain in their homes, but replication within the household has played a serious role in the dissemination of the virus. Overcrowding, which grew in the years preceding the pandemic, makes it more difficult to separate and shield oneself, which may have led to higher mortality rates in poorer regions (Kadi & Khelfaoui, 2020; Yaakub et al., 2020).

Contrary to the former entitlement that covered a one-bedroom apartment from the age of 25, a program that now provides rental insurance for those in a shared home before the age of 35 has resulted in more people staying in shared accommodation. In a household with communal kitchen and bathroom facilities, it is harder to effectively self-isolate. The existence of shared housing has caused a mass migration to other areas of the nation and encourage individuals during lockdown to live in higher quality housing, which may also have helped to spread the virus.

2.3.2 Population

Population density has a major influence on the pandemic's distribution (Aabed & Lashin, 2021; Kadi & Khelfaoui, 2020; Yaakub et al., 2020). Population density is defined as the total number of residents per unit of geographical area, and overcrowding is creating a rise in air pollution (Liu et al., 2020). The higher the density of the population, the further it will transmit the diseases (Ganasegeran et al., 2021).

Population density is undoubtedly one of the main variables that decide a given location's exposure to the virus. COVID-19 has taken hold and struck hard at many forms of sites around the world.

However, in India, Bhadra et al. (2021) found that at the district level, only a minor correlation between the spread of COVID-19 and density of population utilizing correlation and regression. Sizeable, dense, powerhouse cities such as New York and London are typified by one kind, with massive flows of visitors and tourists, varied global communities, and dense residential neighbourhoods. A second type consists of industrial centres linked by supply lines, such as Wuhan, Detroit, and Northern Italy. Third, there are global tourist meccas such as the ski slopes of Italy, Switzerland, and France, as well as their Colorado Rockies counterpart. The pandemic has attacked nursing homes and funeral parlours in smaller areas and, of course, cruise ships, which are similar to dense little towns at sea (Florida, 2020).

2.3.3 Urbanisation

Cities around the world have been affected by the COVID-19 crisis. The worst consequences of the epidemic are closely related to urban areas, where mortality rates appear to be higher due to a dynamic mix of causes, including population growth, national and international access, and response to public health. For example, large urban centres in the United Kingdom and USA have higher mortality rates than other settlement types, and community size has also shown to play an important role in deciding infection rates.

Nowadays, a plurality of urban organisms has risen new problems and threats to urban planning, transit networks, and reaction to evolving infectious disease outbreaks (Connolly et al., 2020; Wolf, 2016). These trends have been brought to a sharper perspective by the COVID-19 pandemic, particularly with the fast spread of urban processes and forms into previously unurbanized regions, as well as improved inter-urban communication. Many of these expansions have occurred in Asia and Africa, resulting in the emergence of novel diseases in West Africa and the Democratic Republic of the Congo, including Ebola virus disease (EVD) (Centers for Disease Control and Prevention, 2021). We are now seeing a wider network of cities, more peri-urban and geographical links that make it much harder to control epidemic outbreaks.

2.4 GIS and Spatial Analysis for COVID-19 Cases

There are several ways to use GIS methods in dealing with pandemics or disease outbreaks, considering the restricted GIS implementations in understanding the essence and spatio-temporal trend of this raging pandemic (Azewan & Rasam, 2020; Franch-Pardo et al., 2020; Omar et al., 2021; Rasam et al., 2011; Ridzuan et al., 2021). For, example, the use of spatial analysis and GIS will greatly change how the COVID-19 pandemic is perceived, as well as how underserved population populations and societies are treated. GIS and Maps are used to store and understand data. As a geographical information science, GIS includes a variety of data sources and analysis of spatial positions and assembles layers of information into visualizations using maps and 3D scenarios. With this special function, GIS exposes finer insights into data, such as habits, interactions, and circumstances, which help developers to make better judgments about their projects.

Franch-Pardo et al. (2020) have reviewed the capabilities of GIS for COVID-19 locations and propagation patterns through disease mapping, such as spatial-temporal analysis, social health cartography, environmental factors, data mining, and web-based visualization. This aim is to illustrate existing geospatial-analytical approaches in the understanding of COVID-19's environmental causes and consequences, to consider its socio-demographic ramifications, and the role of big data mining and spatial analysis and representation based on the site (Zhou et al., 2020) The various therapies used in COVID-19 patients were explored by Tobaiqy et al. (2020), whereas Pham et al. (2020) systematised existing data science activities in this region by discussing the application of artificial intelligence and big data to explore and mitigate the effects of the virus.

In decision-making and more specifically, civic mobilization and group reactions, COVID-19 experiments with GIS may be useful instruments for health geography. Health geography therefore has a particularly important vital social viewpoint, such that all sectors of society will be accountable for political choices, potentially minimizing the regularity in which vulnerable groups are sacrificed or left unprotected. Users can utilise GIS and spatial insights to react to this, to diminish the pestilence over logical data, find spatial connections with different factors, and decide transmission elements.

In Malaysia, a GIS approach has been widely used for disease data management and analysis (Mahsin et al., 2021; Monir et al., 2021; Rasam et al., 2016), including for spatial COVID-19 data analysis (Ullah et al., 2021). The Selangor State Health Department has also used GIS and mapping tool to control and manage the disease comprehensively through a monitoring system (Noh, 2020; Shari, 2020). Monitoring, analysing, and strategizing with geospatial analysis are critical for controlling the transmission of COVID-19 throughout the country (Yahya et al., 2020). Ahasan et al. (2021) have demonstrated how both researchers and practitioners may use GIS to extract relevant information in order to make educated long-term decisions. As a result, GIS can be used by policymakers and researchers to control the spread of COVID-19 for a realistic decision-making, response planning, and community action (Ismail et al., 2021; Lim et al., 2021; Ullah et al., 2021; Zakaria et al., 2021).

3.0 MATERIALS AND METHODS

Figure 1 shows the flowchart of methodology used in this study. The study includes a review of literature on the factors, method, and software used in the study. This was followed by data acquisition, data processing, and data analysis. The final stage was the visualisation of the distribution map and risk factors of the COVID-19 cases in Selangor.

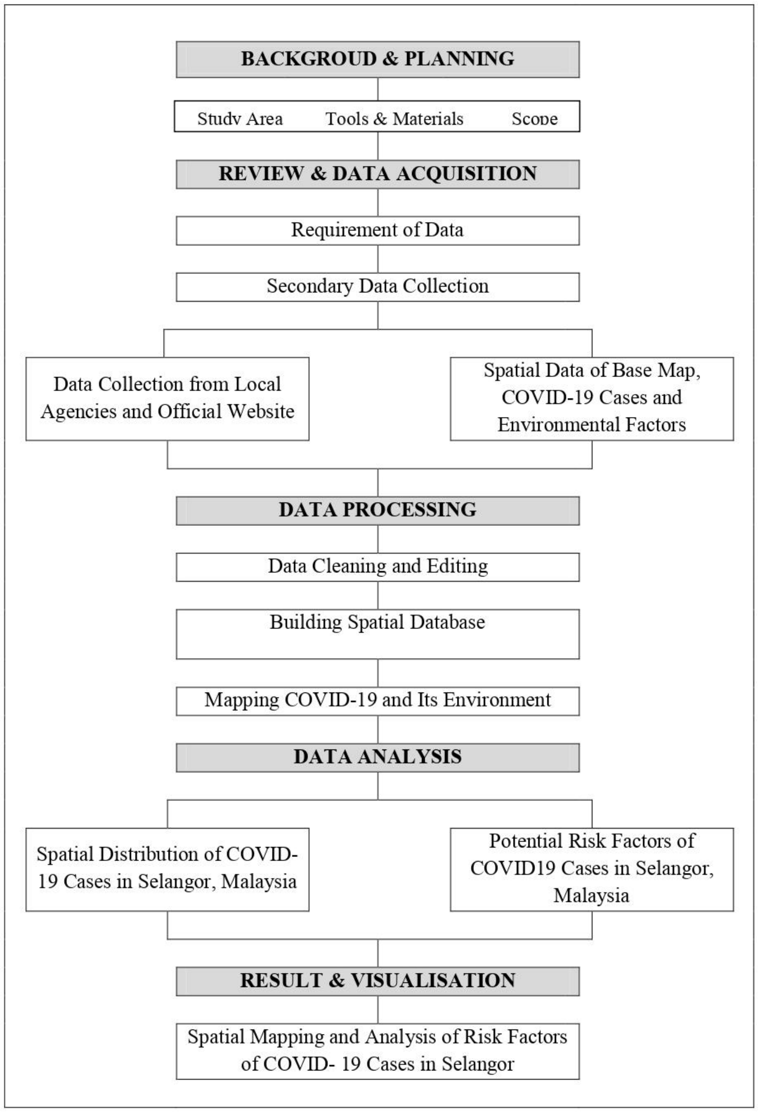


Figure 1 Research methodology

3.1 Planning and Limitation of the Study

This study was conducted in Selangor as shown in Figure 2. It is on the west coast of Peninsular Malaysia. The state capital is Shah Alam, but the royal capital is Klang. Subang Jaya was granted city status in 2006, and Petaling Jaya in 2019. There are four states in Malaysia that have more than one official city, including Selangor, Sarawak, Johor, and Penang. The software used in this study was ArcGIS version 10.8.1. This software was used for producing the final product of the disease mapping and its risk factor analysis. Microsoft Excel was also applied that offers all spreadsheets' fundamental capabilities for correlation, employing a grid of cells structured in numbered rows and letter-named columns to manage data operations such as arithmetic calculations. The main data sources utilised include public sources of COVID-19 cases. This exploratory study only emphasized the district level of COVID-19 cases in 2020 and selected risk factors, including population, housing, urbanisation, gradient, and industrial area.

Figure 2 The state of Selangor with the nine districts in Malaysia (Source: Google Map)

3.2 Data Acquisition

Two main datasets were run in the whole process of the study, namely spatial data from Open Street Map for Selangor, and COVID-19 data from MOH. This process is the 1st phase before continued with another phase which consists of four processes in total. The cases were collected through walk-in method by collecting the data from their main office, and the data were also requested through the official portal. The disease data were captured from their official info graphic or website released by MOH and the COVID-19 Selangor Prevention Task Force (STFC). Data were retrieved and converted in excel format where the data contained the date, place name, and number of cases. Data were taken from March to December 2020 to show an increase in the number of cases.

The spatial dataset for the polygon of the study area were freely downloaded from the open street map (OSM). The polygon was downloaded in a shapefile format, making it easier for the data to be processed and used in ArcGIS environment. However, to ensure its validity, it is imported into Google Earth to cross-check its boundaries. Only then it is decided that the data can be used for this study. Estimated data of five possible risk factors were collected from the annual reports of the Selangor Town and Country Planning Department (Kajian Semula Rancangan Struktur Negeri Selangor 2035 - http://jpbdselangor.gov.my/Laporan/RSN_Selangor/RSN_Selangor_2035.pdf), including population, housing, urban area, industrial area, and gradient. Population is represented in people, housing by unit, gradient is shown in degree unit, while industrial and urban areas are displayed in hectares. Urban areas include residential, industry, business, community facilities, sports, open and recreational land mines / quarry area, transportation, infrastructure, and utilities.

3.3 Data Processing and Analysis

Data processing involved several processes such as data editing, cleaning, and data intersection process to ensure that all data are in an ArcGIS compliance format. The data was converted to either a comma-separated values (.csv) (for table) or shapefile (.shp) (for spatial data). The statistical data were shown in attribute table which is in a .csv format and were also standardized in similar map projection to ensure uniformity. By using an ArcMap Arc Toolbox, Analysis Tool was utilised to intersect the COVID-19 layer with other layers. This intersect function was used to compute the geometric intersection of an input feature.

GIS mapping and analysis were applied to discover the pattern in geographic data, and the relationship between features factors of the cases. The process can be either very simple by creating a map, or very complex by involving many data layers. The correlation analysis in M. Excel is conducted the strength and direction of a relationship between two variables (equation 1). The coefficient value is between -1 and 1, indicating the degree as well as the direction of the linear relationship between the variables. A scale of weak, moderate, and strong associations is represented by values ranging from 0 to +1/-1. As r approaches -1 or 1, the strength of the link grows. A coefficient of 0 shows that the variables do not have a linear connection. This is what two sets of random numbers are likely to produce.

$$\mathbf{r} = \frac{\mathbf{n}(\sum \mathbf{xy}) - (\sum \mathbf{x})(\sum \mathbf{y})}{\sqrt{[\mathbf{n}\sum \mathbf{x}^2 - (\sum \mathbf{x})^2][\mathbf{n}\sum \mathbf{y}^2 - (\sum \mathbf{y})^2]}} \quad \text{.........................(1)}$$

Where,

r = Pearson Coefficient
n= number of the pairs of the stock
$\sum xy$ = sum of products of the paired stocks
$\sum x$ = sum of the x scores
$\sum y$= sum of the y scores
$\sum x^2$ = sum of the squared x scores
$\sum y^2$ = sum of the squared y scores

4.0 RESULTS AND DISCUSSION

4.1 Spatial Distribution of COVID-19 Cases in Selangor (Overall Cases in 2020)

Figure 3 shows the total number of COVID-19 cases in Selangor for year 2020. The total number of cases is divided into 3 classes, illustrating the different zones of each district. Green zone is for low number of cases, yellow is for medium, and red is for high number of cases (3 classes for overall cases in 2020 in the State). Map classifications has been created based on manual natural breaks method, since there is no specific range classification for yearly cases introduced by MOH for the district level of the country. The lowest cases are in Sabak Bernam, and the highest is recorded by Klang with the total number of cases are 115 and 14,907, respectively. It is also identified that Klang is consistent in the red zone area throughout the year.

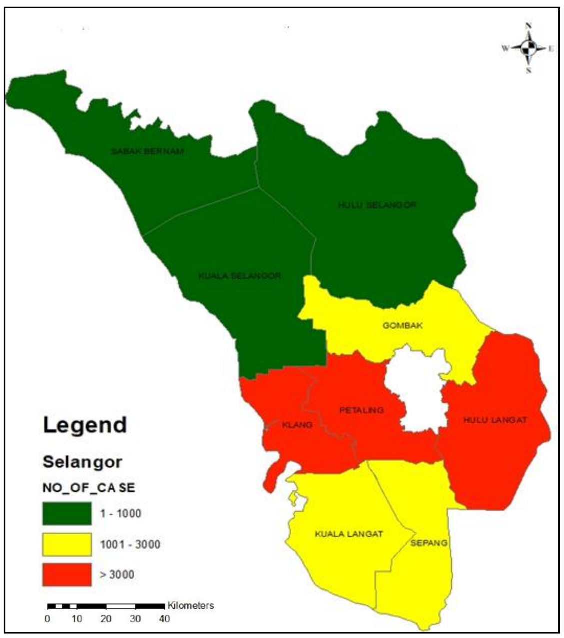


Figure 3 The total cases of COVID-19 in Selangor, 2020

Population or human factors are the main reason why Petaling, Klang, and Hulu Langat have recorded the highest cases of COVID-19 in comparison to other districts. For example, Petaling identified 105 positive COVID-19 cases in October that found in the Utama cluster. Among those who tested positive were 79 security guards, 8 mall outlet employees, and 18 cleaners. Nonetheless, the management of the 1 Utama Shopping Centre disputed that all COVID-19 instances were originated from the mall, as reported in an early announcement from the Petaling disaster management committee.

The mall even reported, implying that all instances included in the study came from 1 Utama was inaccurate because no index case was recognised as coming from the mall. Meanwhile, the Tropicana cluster reported 18 new COVID-19 positive patients, bringing the total to 25. 16 of the incidents involved residents of the Asrama Tropicana staff hostel, with the remainder being outsiders. COVID-19 screening was performed on 350 dormitory staff members.

The other instance is that the recent increase in COVID-19 cases in Klang was due to an increase in workplace-related cases. This is because the state is the focus of workers. This population density could be also one of the risk factors contributing to the increasing rate of infection of the disease. 31 cases in which 14 cases in the Klang district, namely eight close contact screenings in Klang sub-district, four cases of Jalan Meru Cluster screening in Klang sub-district, one case of Jalan Meru Cluster screening in Kapar sub-district, one screening case returning from Sabah in Klang sub-district. In November, the highest cumulative cases were recorded in the Klang district with 2,015 cases, Mukim Kapar recorded 1,330 cases, while Klang with 685 cases.

4.2 Temporal Distribution of COVID-19 Cases in Selangor (Monthly Cases)

The monthly cases pattern of COVID-19 in Selangor showed an increasing trend for each district as shown in Figure 4. It revealed that December is the month in which many cases were recorded, while no cases were recorded in January and February of 2020. This is a series of cases involving the Sabah State Election (PRN) at the end of September 2020 (Yazid, 2020). The cases began to rise sharply in early October and continued to rise until December where in just three months; most districts were almost categorized as red zones.

One of the factors that contributed to the rising cases was that most of the residents who returned from the campaign in Sabah PRN settled in Selangor. Furthermore, the increase in cases occurred because they were not instructed to quarantine themselves upon returning from Sabah. Due to the high and alarming number of cases, Selangor was instructed to undergo Conditional Movement Control Order (CMCO) in middle of December until further notice.

In the context of temporal distribution, Figure 5 illustrates the difference results of COVID-19 cases by month in four classes (green, yellow, orange, and red). In October, the number of cases had increased rapidly. Then, the cases increased sharply in October, and continued to rise until December. A study was conducted and concluded that the increasing number of cases in October were attributable from Sabah PRN held at the end of September 2020. The arrival of supporters and political assistant in Sabah caused the cases to increase as they were only instructed to quarantine after a week of returning from Sabah, which was no longer relevant. However, the other factors influencing the cases in Klang were also due to the screening of foreign workers, as well as targeted screening programs implemented by employers and government agencies, namely the 'Seruling' cluster.

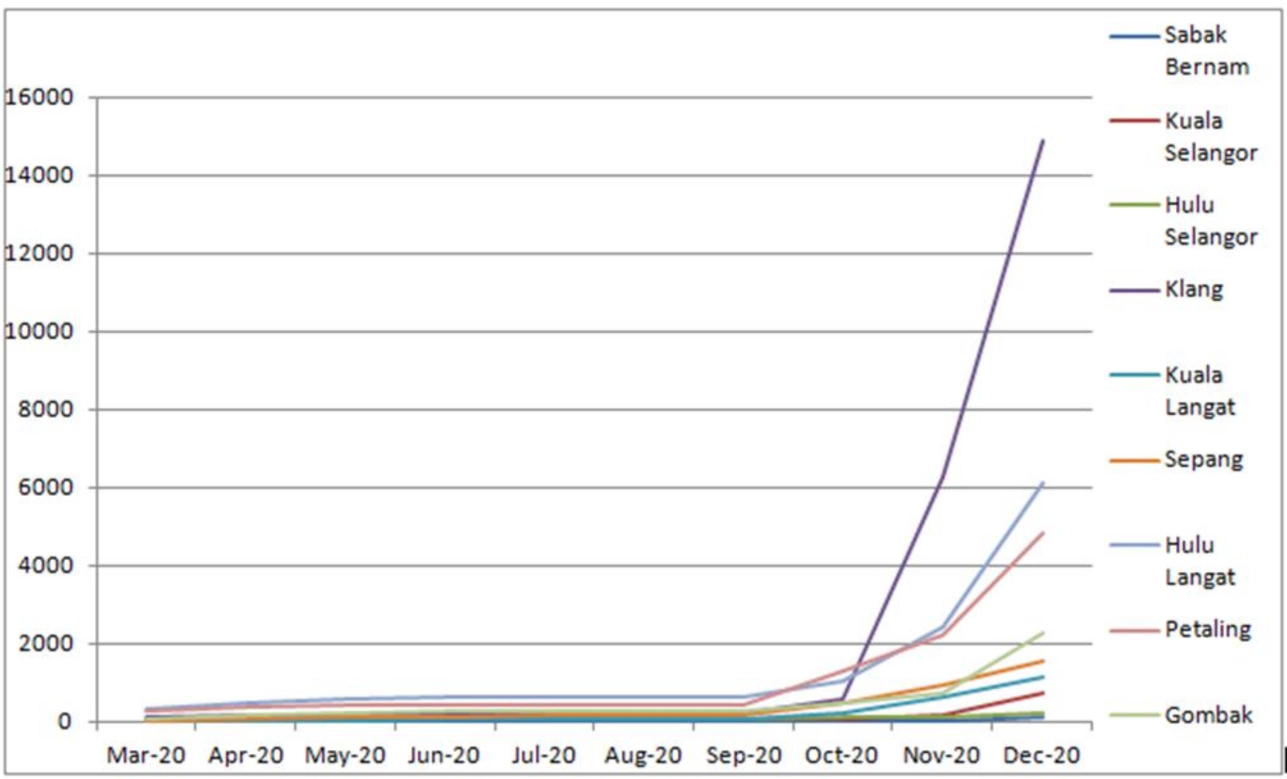
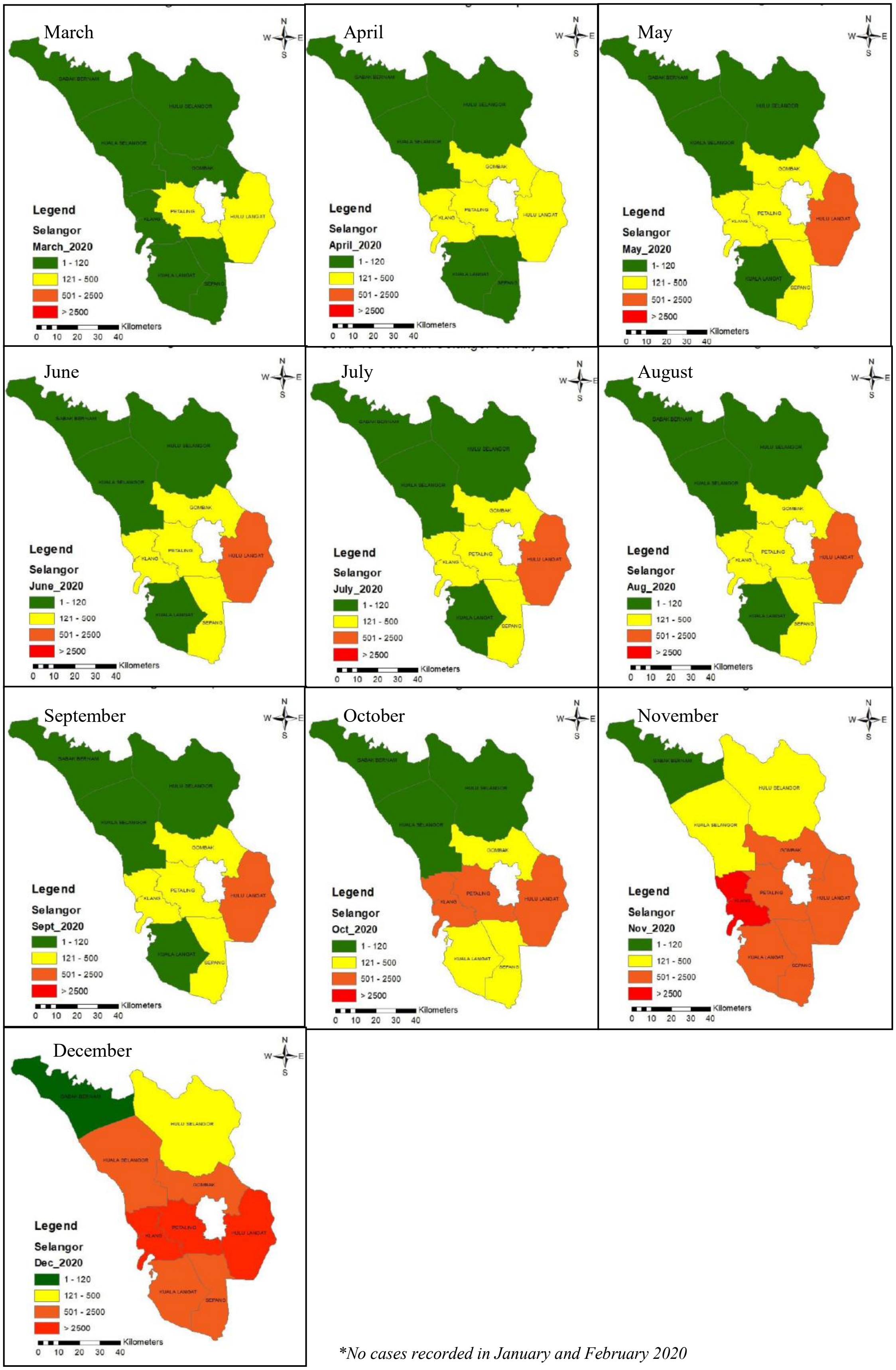


Figure 4 Line chart of COVID-19 cases in Selangor by month



**No cases recorded in January and February 2020*

Figure 5 Map of COVID-19 cases by month in Selangor for 2020

4.3 Environmental Risk Factors of COVID-19 Cases in Selangor

Table 1 exhibits the correlation between number of cases of COVID-19 and the selected risk factors using Correlation Coefficients (r). r is a correlation coefficient of 1 (red), indicating that for every positive rise in one variable, there is a fixed substantial increase in the other. Zero (dark green) indicates that there is no positive or negative rise for every increase. The two are not linked since there is no correlation between gradient surface of the earth and number of the cases (r=0).

Table 1 Correlation between number of COVID-19 cases and the selected risk factors by district in Selangor

District	NO_OF_CASE	NO_OF_POP	HOUSING	URBAN	GRADIENT	INDUSTRIAL
Sabak Bernam	115	137600	29004	9165.69	12	143.3
Kuala Selangor	740	268300	54599	12038.5	12	571.3
Hulu Selangor	258	275200	54658	13809.7	25	2198.8
Klang	14907	1073400	230078	20771	12	3116.9
Kuala Langat	1156	323400	58590	8894.07	12	1621.2
Sepang	1552	337200	57780	24675.5	12	1003.4
Hulu Langat	6131	1431200	324083	24011.5	25	3133.3
Petaling	4838	2091700	533667	40116.3	25	5882.1
Gombak	2286	642600	191009	14472.1	25	1890.7
	Correlation, R	0.56	0.50	0.39	0.0	0.51
	Strength	Medium	Medium	Weak	No	Medium
	Variables	Cases Vs Pop	Cases Vs Hou	Cases Vs Urban	Cases Vs Grad	Cases Vs Indus

In terms of map visualization, Figure 6 to Figure 10 reveal the relationship between COVID-19 cases and population (people), housing (unit), urbanization (area, km), and gradient (degree). Value of correlation shows a various relationship for number of cases, and the risk factors as the correlation value indicated are not the same. There are four different classification colours to differentiate the relationship status between selected risk factors and the overall number of cases. Green colour is for a weak relationship, yellow is for a moderate relationship, orange for a strong relationship, and red is for very strong relationship. The gradient of colour used for each risk factors are also used to identify number of factors in each district. Mostly, the highest number of cases lies in high density areas as the value of risk factors influences the number of cases to increase.

With regard to correlation COVID-19 cases with population (Figure 6), the relationship between population and number of cases is quite strong correlation. The population size affects the number of cases, where the higher the population, the higher the number of cases. Therefore, orange colour is used to indicate the relationship status between these two variables. Population density is merely one of the major factors that determine a location's virus exposure (Liu et al., 2020).

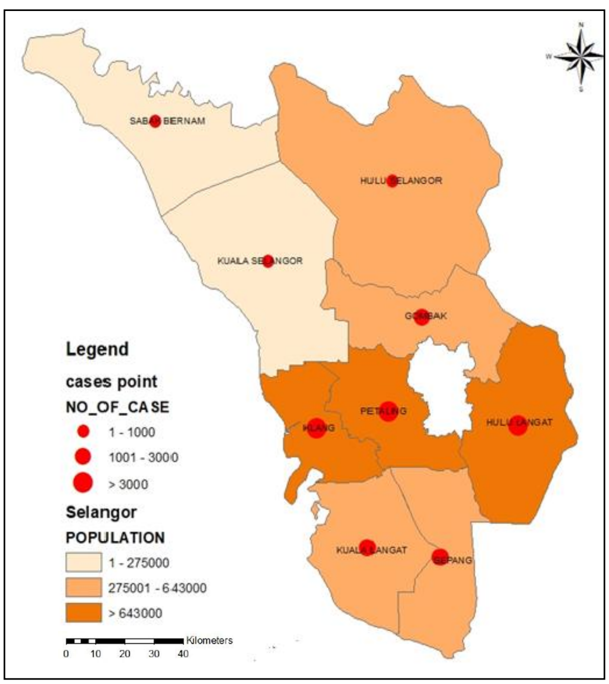


Figure 6 Map of COVID-19 cases versus population

COVID-19 cases have also a possible relationship to housing, and in this study has proven that the cases have a moderate correlation with the residential areas (Figure 7). The amount of housing in certain areas does not really determine the number of cases as it is related to the number of members in the house. This situation shows that a high number of housings can be potentially a factor in the increase in the number of cases, but with a small implication. This implication may not contribute much to the increase in the number of cases. However, housing areas with overcrowding, which grew in the years preceding the pandemic, makes it more difficult to separate and shield oneself. This may have led to higher mortality rates in poorer areas in the state.

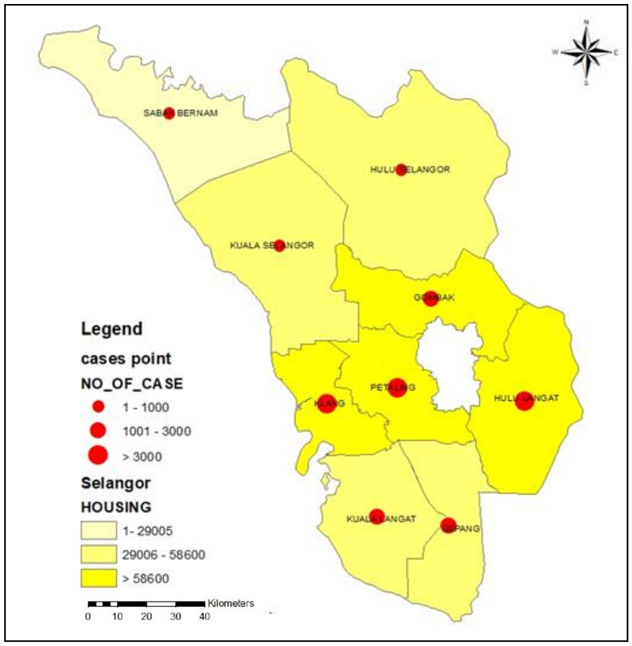


Figure 7 Map of COVID-19 cases versus housing

In theory, urbanisation has a correlation with COVID-19 cases, but the status of urban areas in the state has only shown a medium-weak relationship with a value of r= 0.39 (Figure 8). The urban areas can affect the number of cases as the people complied with the government’s order to limit movement outside the home, thus the high number of urban areas may not significantly affect the number of cases. Nevertheless, the worst consequences of the epidemic are not only closely related to urban areas, but the mortality rates appeared to be higher due to a dynamic mix or combination of the factors, including population growth, national and international access, and response to public health. Therefore, the residents in urban areas need to be careful with this disease because the infection will be more dangerous if they stay in crowded and populous areas or other local factors.

This result is consistent with the study found by Aw et al. (2021), where in Malaysia, population concentration was found to have a relatively substantial correlation with overall COVID-19 cases (R^2=0.415). Up until 31 December 2020, districts with dense populations had larger COVID-19 infection rates and overall COVID-19 cases. In general, urban areas concentrated a large population in a relatively small space where they communicate, live, and work. The urban areas were the initial origins of COVID-19 epidemics in Malaysia and other nations. In places that are strongly integrated economically and industrially, illness spread to neighbouring districts is stronger than in isolated localities with interconnection concerns.

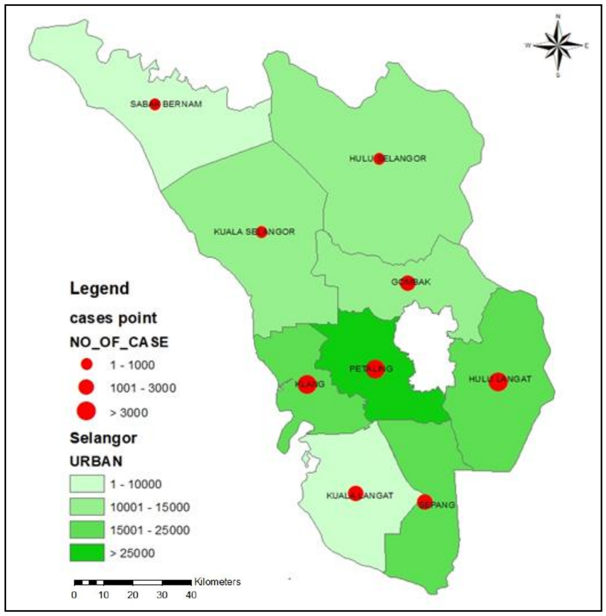


Figure 8 COVID-19 cases versus urbanization

Another factor related to COVID-19 cases is the industrial area. This study has exposed those industrial areas affected the number of cases moderately as the industrial sector was stopped during the pandemic (Figure 9). If the industrial sector had continued, many workers would have to work in crowded and congested areas, causing the number of cases to increase, which in turn will change the status of strong relations between industrial area and the number of cases.

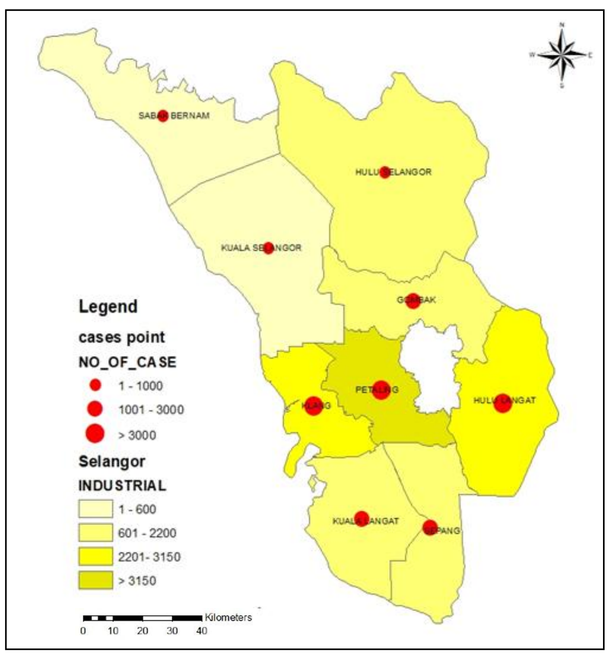


Figure 9 Map of COVID-19 cases versus industrial area

Gradient of the earth is also examined in this study on its possible relationship with the COVID-19 cases. Gradient (or slope) of the ground surface is one of the most basic topographic observations used to help visualize earth surface. However, the gradient indicates a no relationship status by using green colour with a correlation value of 0 because the gradient value does not affect the number of cases (Figure 10). The gradient does not affect the number of cases due to the number of land use, where even areas with low gradient do not affect the number of cases to increase.

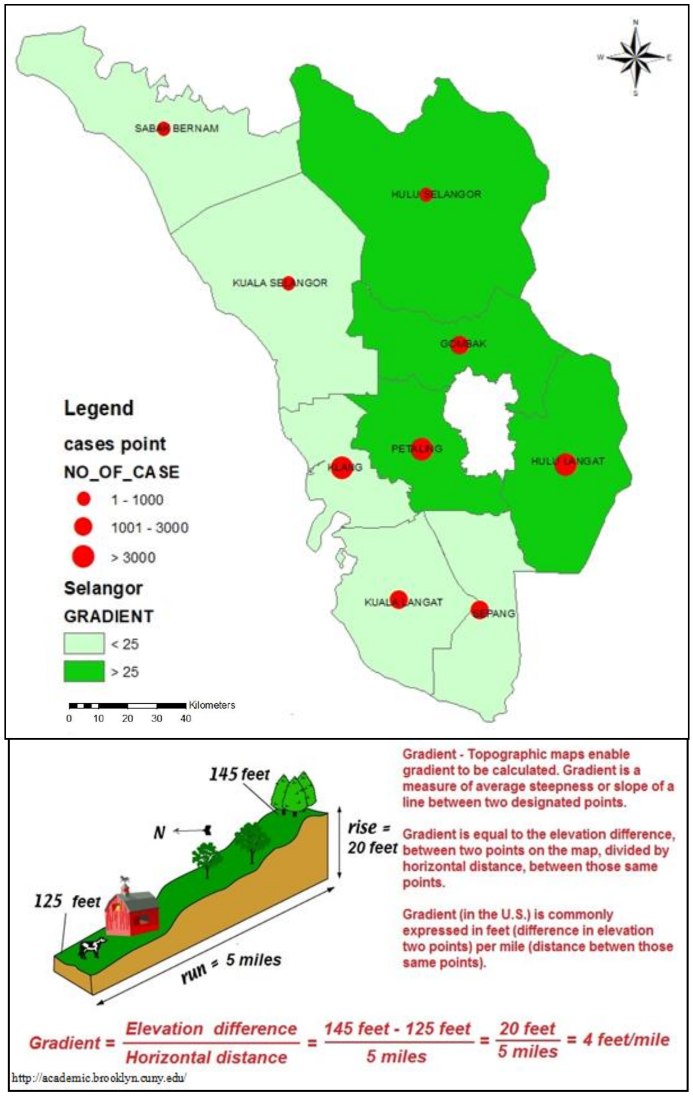


Figure 10 Map of COVID-19 cases versus gradient

There are several social and geographical elements that contribute to the propagation of the lethal virus. Based on this analysis, among the main factors influencing the increase in the number of COVID-19 cases is population. This is due to the density of these factors in an area. Specifically, the dense and congested areas affect the increase in the number of cases. With the growing number of humans, the transmission of a lethal virus may be increased. It is therefore necessary to understand the transmission of COVID-19 with regards to the size of the population of a geographical region. The main concern about the dissemination of COVID-19 is the transmission from humans to humans. The experience of pandemics shows that in a small population, the epidemic will cross international borders.

Several statistical analyses have revealed that climatic conditions have an inescapable influence on this COVID-19 cases. Local meteorology, as well as geographical location and population, may account for the variation in the spatial occurrence of diseases. However, no single quality can adequately describe the nature of transmission., and it is therefore, the other factors need to be considered in this study mainly outdoor air pollution, or sea level and indoor buildings factors such as temperature, humidity, fomite stability, and ventilation and filtration systems (Aabed & Lashin, 2021; Rume & Islam, 2020; Shakil et al., 2020).

5.0 CONCLUSION

The Malaysian Ministry of Health in 2020 reported that nearly half the new COVID-19 cases were concentrated in Selangor. It is known that the disease spread via droplets in the air, but environmental factors can also affect the rate of the infectious transmission among the population. This study was carried out to analyse the spatial exploratory pattern and risk factors of COVID-19 cases in the state. The districts in the state experienced the epidemics with high cases in the last three months of 2020. There was no dominant correlation of the selected environmental factors that affect the increasing of COVID-19 cases as the correlation strength is mostly moderate, including population, housing, as well as urban and industrial areas. However, certain factors may potentially influence the increase of COVID-19 cases. Population is the influential factor of the increase in the number of cases because by the end of 2020, in which the government no longer need to continue MCO. The urban citizens started to move freely and perform activities in crowded places. Most community may also start to feel comfortable and forget about the precaution from being infected such as physical distancing and wearing face masks. In addition, GIS has demonstrated its capacities to analyse the distribution and correlation of COVID-19 cases, as well as the potential risk factors towards responsive decision-making and community action planning of the pandemic. For further study, it is suggested that the specific epidemiology of the local COVID-19 cases needs to be explored with high geospatial dataset quality and advanced analytical methods. Human mobility and environmental conditions such as outdoor air pollution or sea level and indoor buildings factors (e.g., temperature, humidity, fomite stability, and ventilation and filtration systems) could be also taken consideration.

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