SPATIAL CLUSTERING PHENOMENA OF COVID-19 CASES IN SELANGOR: A HOTSPOT ANALYSIS AND ORDINARY LEAST SQUARES METHOD

Nur Syuhadah Mohammad[1], Abdul Rauf Abdul Rasam[1*], Rosmadi Ghazali[1], Roslina Idris[1], Rabieahtul Abu Bakar[1]
[1]Centre of Studies for Surveying Science and Geomatics
College of Built Environment
Universiti Teknologi MARA, Shah Alam, Selangor, Malaysia

Corresponding Author: rauf@uitm.edu.my*

Commission IV, WG 7

KEY WORDS: COVID-19, Ordinary Least Squares (OLS), Hotspot Analysis, Spatial Cluster Analysis, GIS.

ABSTRACT:

An increase in number of Coronavirus disease 2019 (COVID-19) cases will lead to more cluster discovery in Malaysia. Furthermore, with the increasing population, city growth, workplace income needs, high-risk groups, and other relevant factors can contribute to the formation of the new clusters. The cluster distribution of the disease could be seen by mapping and spatial analysis to understand their spatial phenomena of the disease dynamics. The purpose of the study is to analyse the spatial distribution of COVID-19 cluster cases in Selangor for year 2020. Two objectives of the study are i) to determine the hotspot location of the COVID- 19 cluster, and ii) to examine the spatial distribution of the factors affecting the COVID-19 cluster. The data processing was conducted using hotspot analysis and ordinary least squares (OLS) in ArcGIS Pro and Microsoft Excel to explore the local disease phenomena. The COVID-19 cases was most prevalent in the Petaling district, followed by Hulu Langat and Klang. The virus had the least impact in Sabak Bernam, Hulu Selangor, Kuala Selangor, Sepang, Kuala Langat, and Gombak. Three environmental factors of population density, the effects of urbanisation, and workplace cases were influential variables at the local clusters. These findings could help the local agencies to facilitate and control the spread mode of the virus in a spatial human environment.

1. INTRODUCTION

COVID-19 is a contagious disease caused by SARS-CoV-2 which triggered the respiratory illness. The first case was with a 55-year-old resident found in Wuhan, Hubei Province, China and was reported to the hospital on 17 November 2019 (Bryner, 2020). This was when the Wuhan Municipal Health Commission from China reported a cluster of Pneumonia cases in the Province on 31 Dec 2019. People believe that the virus originated from bats. However, scientists believe that the virus transferred to human via intermediate animal which can be in form of domestic animal, wild animal, or food animal. The exact media is not exactly found yet (WHO, 2021). The infected person will usually be suffering with a few symptoms, however, the most common symptoms suffered by the patients are fever, loss of taste and smell, tiredness, and cough (WHO, 2022).

In Malaysia, COVID-19 was the second big pandemic faced by the locals after Nipah Virus in 1999. The first COVID-19 case was reported on 25 January 2020 when three citizens of China travelled to Malaysia from Singapore. Ever since then, Malaysia had undergone a few series of lockdown and had affected many people from many perspectives. Businesses were closed. Kids are unable to go to school, people are prohibited from going to work, family are separated and the worst for many people, everyone is obliged to stay at home. Everyone was surrounded with fear and break down within the two years' period. Even when the first vaccine arrived in Malaysia on 24 February 2021 and the former prime minister of Malaysia, Tan Sri Muhyiddin Yassin, became the first to receive the first dose of COVID- 19 vaccine (Anand, 2021) things are not getting better. Up until November 2021, Malaysia has reported a total 2,451,216 of cumulative cases since the first case was reported more than a year ago (MOH, 2022).

COVID-19 cases have been rising all throughout Malaysia. If taken a closer look, the Petaling district alone, has reported a high number of daily cases from time to time. This is probably because of the large number of populations, approximately at a total of 2.16 million in 2020 (Bernama, 2021). The concentration of cases in the same area at the same time resulted in the formulation of clusters (Public Health Madison & Dane Country, 2022). Clusters, as defined by the Public Health Madison and Dane County, is formed when two or more cases occur at the same location, group, or event at the same period. Malaysia's deadliest cluster was the one in Sri Petaling which branched many sub clusters with over 3,370 cases (Edinur & Safuan, 2020). It took about four months until there were no newcases reported from the Sri Petaling cluster. Another significant cluster discovered in November 2020, was the Teratai cluster which involved Klang, Kuala Selangor, Petaling and Hulu Langat. This cluster was linked to Top Glove Corp Bhd and resulted in over 6000 cases (Birruntha, 2021)

Several research have investigated the spatial clustering analysis of COVID-19 and its associated variables utilising GIS techniques (Liu et al., 2021; Ullah et al., 2020; Fonseca-Rodríguez et al., 2021; Santos et al., 2022). The results of the investigations indicated that the COVID-19 transmission was significantly influenced by the population outflow. (Liu et al., 2021; Fonseca-Rodríguez et al., 2021) such as population in with higher social socioeconomic inequality (Santos et al., 2022) and the proportion of immigrants senior citizens (Fonseca-Rodríguez et al., 2021). SARS-CoV-2 may also disseminate in environment with high levels of inbound movement or travel, poor ventilation, high humidity or heavy rains, low temperatures, and high levels of air pollution. (Liu et al., 2021)

https://doi.org/10.5194/isprs-archives-XLVIII-4-W6-2022-237-2023

Therefore, by identifying the spatial clustering of the disease, it can be beneficial to guide control authorities on prioritizing locations for targeted interventions or mass immunisation programme and other the disease control activities (Ullah et al., 2020; Santos et al., 2022). For example, for the control and prevention of COVID-19, it may be beneficial to implement the proper lockdown procedures and travel restrictions, improve the ventilation of living and working spaces, manage air pollution, and make adequate preparations for a potential second wave in the relatively cold autumn and winter months (Liu et al., 2021). These spatial results can be also applied to stop the spread of the disease (Ullah et al., 2020) such as the initiatives can enhance ongoing and future disease prevention and optimise budget allocation (Fonseca-Rodríguez et al., 2021)

Interestingly, these finding can be also benefited to other cases than COVID-19 control programme such as mental disorders (Sergeant et al., 2020), emerging viral diseases (Wilder-Smith (2021) and tuberculosis (TB) (Song et al., 2021; Gao et al., 2021). Sergeant et al. (2020) has suggested the information gathered could help future intervention healthcare policies, particularly in regards to the possible effects of the present pandemic disruption of healthcare services on mental health. Wilder-Smith (2021) has shown that the COVID-19 pandemic in China is the worst in terms of scope and speed of this century and is linked to the greatest number of viral deaths worldwide. Thus, combatting the COVID-19 will necessitate an all-society and all-government strategy.

COVID-19 and TB coinfection also makes the situation worse (Gao et al., 2021), and consequently, in nations with high TB prevalence, routine TB screening may be advised among suspected or confirmed COVID-19 cases (Song et al., 2021). To ensure that particular effective global preventative programmes for TB patients (Gao et al., 2021), utilising GIS and spatial approaches is an other relevant strategy (Ramli et al., 2022, Abdul Jalil and Abdul Rasam, 2021; Monir et al., 2021; Ridzuan et al., 2021; Rasam et al., 2019; Abdul Rasam et al., 2016) especially for creating a TB risk mapping and planning an effective control programme (Rosmadi et al., 2021; Abdul Rasam et al, 2020; Rajab et al., 2020; Abdul Rauf & Mohd Shariff, 2019).

As a result, scientists are forecasting that there will be an escalation of number of positive cases reported in many countries (WHO, 2020) by applying geospatial approaches. An increase in number of cases will lead to more cluster discovery in Malaysia. The rise in number of cases and cluster will make it hard for the authority to control the spread of the disease. Furthermore, with the increasing population (birth rate increase), city growth, workplace income needs, high-risk groups, and other relevant factors that contribute to the formation of the new cluster. A study need to be conducted to identify the factors causing the rise in this COVID-19 epidemic cluster.

In order to elucidate these spatial problems, GIS mapping and spatial analysis conducted in this study that would aid in envisioning the cluster distribution of COVID-19 cases cluster and their factors in Selangor. GIS hotspot analysis is a spatial mapping technique that is engaged in the classification of spatial phenomenon clustering, while OLS is a common method used for determining the connection between one or more independent numerical variables and a dependent variable, such as COVID-19 risk factors.

2. METHODOLOGY

2.1 Study Area

The study was carried throughout Selangor, Malaysia (3.0738° N, 101.5183° E) which has been impacted by the virus of COVID-19 and higher population density (Figure 1). It is located in Peninsular Malaysia'swest coast, bordered by Perak to the north, Pahang to the east, Negeri Sembilan to the south, and the Malacca Strait to the west. Selangor encircles the federal territories of Kuala Lumpur and Putrajaya, which were previously included in it (Citypopulation, 2022). Selangor's state capital is Shah Alam, and its royal capital is Klang. Selangor is one of four Malaysian states with multiple cities with official city status, the others being Sarawak, Johor, and Penang. Selangor has a population of approximately 5.4 million people and contributes significantly to the country's economy, primarily through agriculture and commerce.

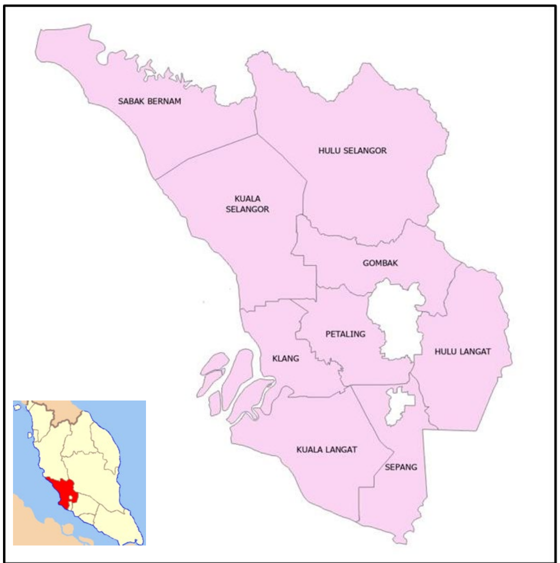

Figure 1. The study area

2.2 Data Collection

Relevant data were collected from difference official websites. The Ministry of Health Malaysia (MOHM) has provided information needed for the study area. This study used an open- source data from GitHub website for conducting the data processing and analysis of spatial clustering of the COVID-19 cases.

2.3 Key Spatial Distribution and Hot Spot Analysis (Getis Ord-G*)

This procedure is necessary to shed light on the analysis strategy used to pinpoint Selangor's red zone area and spatial distribution. This method is implemented in ArcGIS software using district data (prevalence value) and the number of cluster cases. Natural breaks were used as the classification method for COVID-19 cases (Jenks).

The hotspot map displays the locations of high and low occurrences. The location of the statistically significant hot spot and cold spot areas of the COVID-19 cluster cases will be determined using this technique. Using the Getis-Ord Gi* statistic and the incident points, a map of statistically significant hotand cold spots is then produced. The prevalence of COVID-19 cluster cases is examined by the hot spot analysis tool, as well as the likelihood of an infected hot spot area in Selangor. This technique distinguishes between cold spot clusters with high values and statistically significant hot spot clusters. For each feature in the input feature class, a Getis-Ord Gi* confidence level, a z-score, and a p-value are provided in the output class. This tool is suitable for this analysis because it enables automated parameter selection for hot spot results. As a result, this tool could be used to identify COVID-19 cluster cases breakdown hot spot areas that contribute to the infection factors.

2.4 Explanatory Regression

It is necessary to use the exploratory regression tool to determine whether the factors and COVID-19 cluster cases are linearly related to one another. The result of OLS could be run and mapped. The COVID-19 cluster cases are the independent variables, while the factors influencing COVID-19 clusters are the dependent variables (population, impact of urbanization and workplace). The data were put through a spatial autocorrelation tool to identify which dependent and independent variables are correlated in order to complete the third goal.

2.5 Ordinary Least Squares (OLS)

One of the Geoprocessing Analysis tools in ArcGIS is called Ordinary Least Square (OLS), and it was used to conduct the analysis in the study. This tool makes it possible to analyses the connections between COVID- 19 cluster cases and the contributing factors (population density, urbanization impact and workplace cases). The OLS aids in both report generation and data visualization. This analysis tool was used with COVID-19 cluster cases as the dependent variable and population, urbanization impact, and workplace as the explanatory or independent variables. Finding the correlation (r) between these factors is the goal of the analysis. A scatter plot and map were then made using the results of the three data. The data analysis was distinguished using the scatter plot.

3. RESULTS AND ANALYSIS

This section goes over the results by analysing the distribution by measuring spatial hot spots analysis based on both feature locations and feature values at the same time. Statistical analysis using OLS verification is also discussed in this section to estimate the factors that influence the COVID-19 cluster cases are mapped and analysed.

3.1 Hot Spot Areas in Selangor

The production of the hotspot map for this study is because to detect the hot spot areas of COVID-19 cluster in Selangor. From this analysis, the location with the highest rate of cases was identified. The hotspot was determined using GIS Spatial Statistics Tools on the layer containing event rate information. The heat map of COVID-19 clusters cases in Selangor in 2020 is depicted in Figure 2. The hot spot was indicated by a yellow colour, whereas the cold spot is indicated by a dusty purple colour. The hotspot locations were tabulated based on the number of cases in each cluster.

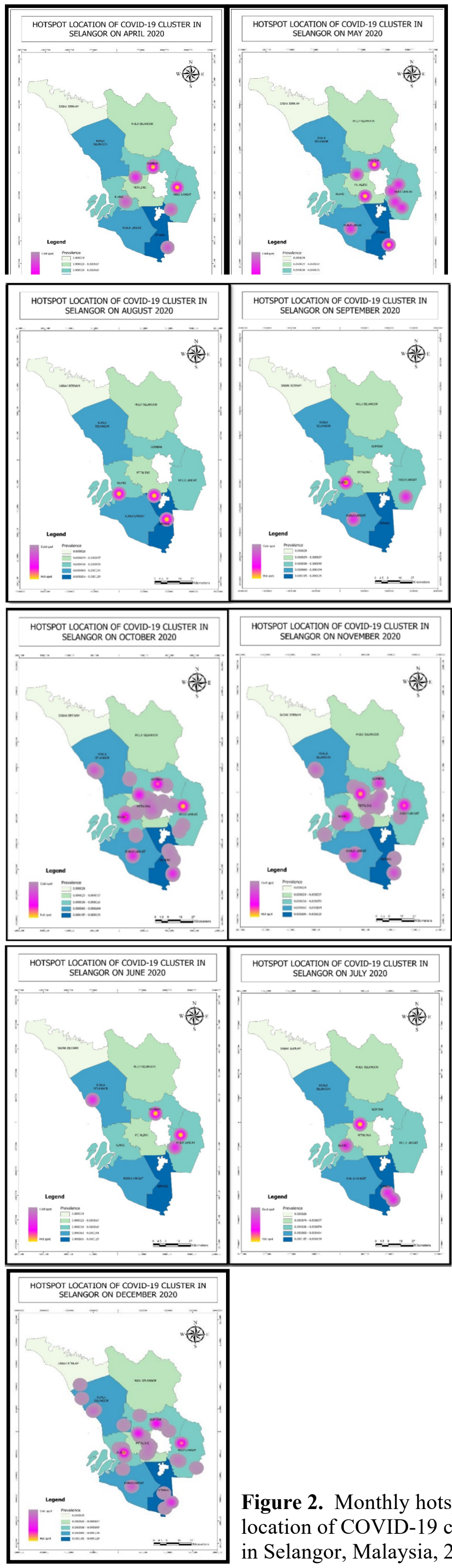

Figure 2. Monthly hotspot location of COVID-19 cluster in Selangor, Malaysia, 2020

Figure 2 depicts the COVID-19 cluster case hotspot areas from April until December 2020. To more clearly see the change in the location of the hot spot, COVID-19 cases were divided by month. This is so that the study's goal, which is to locate the

COVID-19 cluster's hotspot, could be achieved. With the breakdown by this month, locations with a high number of cases and factors contributing to the epidemic's spread could be also determined.

April and May show an increase in COVID-19 cluster cases in several districts namely Petaling, Hulu Langat, Klang and Sepang. This is because, MOHM has conducted a large-scale COVID-19 detection test to detect infection carriers from the Tabligh Sri Petaling cluster which recorded the highest cluster cases and the first cluster in Malaysia. Hulu Langat shows many hot spots as a result of the screening. In Kampung Sungai Lui, 210 cases were recorded, 25 of which were linked to the Seri Petaling cluster. Datuk Dr Noor Hisham Abdullah, Director-General of Health, stated that some of those found to be positive in the district were caught attending a tabligh gathering at Masjid Jamek Seri Petaling last month (Mat Ruzli, 2020).

From June to September, cases of infection and new clusters decreased. This is because, all those involved with the Seri Petaling cluster have been screened and there are no more active cases. In addition, the MCO was enacted on 4 May 2020 has curbed the spread of the epidemic.

Cases of infection and new clusters fell from June to September. This is due to the fact that everyone linked to the Seri Petaling cluster has undergone screening, and there are no longer any active cases. The Movement Control Order (MCO), which went into effect on May 4, 2020, has also prevented the epidemic from spreading. As the number of daily active cases decreased, MOHM decided to be lenientand issued a Rehabilitation Movement Control Order (RMCO) on June 10, 2020.

However, in October, November and December, the number of clusters has increased dramatically. This increase was termed as the third wave to hit Malaysia. More workplace clusters have emerged as a result of the epidemic's third wave spread. The Lotus cluster was one of the clusters that produced the most cases. These clusters result from workplace sprawl. Except for Sabak Bernam, almost every districtin Selangor has this cluster.

3.2 Relationship between COVID-19 Cluster Cases and Population Density

The analysis of linear regression between the population density and the number of COVID-19 cluster cases is shown in Figure 3. With two possible outliers in the data, it displays a strong linear trend. When the population is growing along with the number of COVID-19 cluster cases, a positive relationship between the two can be seen. The dots are reasonably close to the estimated values, indicating a strong correlation between the variables. The number of COVID-19 cluster cases in the population explains 75% of the variation in the population according to the model. The correlation r is close to 1, which indicates a strong relationship, at 0.885.

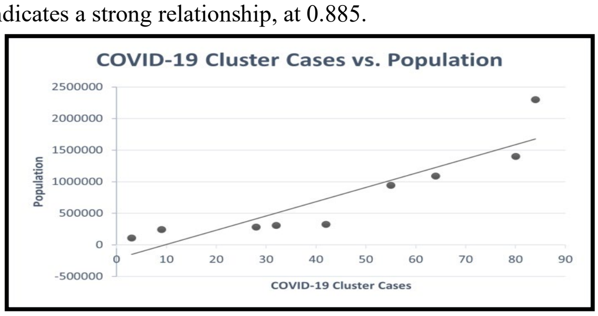

Figure 3. Scatter plot between the number of COVID-19 cluster cases and population density.

The OLS analysis result between the number of COVID-19 cluster cases and the population density is summarised in Table 1. The analysis yielded a p-value of 0.006711, and less than 0.05. The results of the analysis showed a correlation between the two variables. This shows that there is a correlation with r = 0.885 from the analysis and the p-value is 0.006711 and shows that the null hypothesis that there is no relationship between the two variables can be rejected. The coefficient value describes the value that a one-unit change in the independent variable affects the result of the dependent variable while keeping all other model variables constant. The population's obtained coefficient is 0.000036.

Variable	Coefficient (a)	StdError	t-Statistic	Probability (b)	Robust_SE	Robust_t	Robust_Pr (b)
Intercept	16.197761	6.783506	2.387815	0.048172	6.487782	2.496656	0.041045
Population	0.000036	0.000007	5.487387	0.000988	0.000007	5.272355	0.001248

Table 1. Summary of OLS results between the number of COVID-19 cluster cases and population density

The number of COVID-19 cluster cases and population density are analysed, and the results show a strong correlation between the two variables. Despite the presence of two potential outliers, the scatter plot clearly demonstrates a positive relationship. The ordinary least squares analysis also yields positive results with a correlation r = 0.885 and 0.006711 p-value, which helps to strengthen the correlation analysis. This study conclude that the COVID-19 cluster cases and population density are significantly correlated. The relationship between the number of COVID-19 cluster cases and the population density in each district is shown in Figure 4.

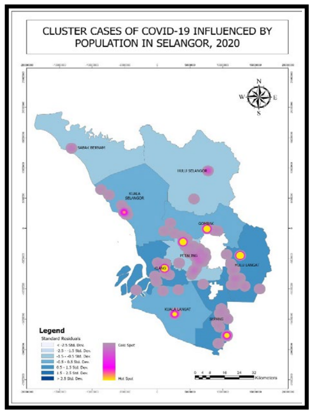

Figure 4. Cluster cases of COVID-19 influenced by population density map, Selangor, 2020

3.3 Relationship between COVID-19 Cluster Cases and Impact of Urbanization

The analysis of linear regression between the number of COVID-19 cluster cases and urbanisation is shown in Figure 5. It demonstrates a positive association between the number of COVID- 19 cluster cases and the effects of urbanisation, with no discernible outlier. The dots are reasonably close to the estimated values, indicating a strong correlation between the variables. The data clearly demonstrates a positive relationship between the growth of an urbanisation and the rise in COVID-19 cluster cases. The number of COVID-19 cluster cases in the model accounts for 50% of the variation in the impact of urbanisation. The correlation r is close to 1, which indicates a strong relationship, at 0.899.

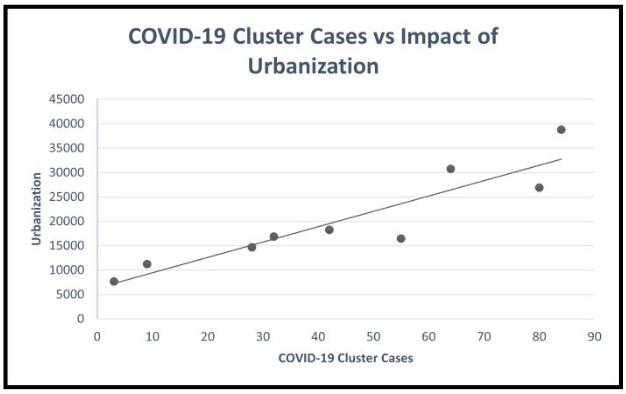

Figure 5. Scatter plot between the number of COVID-19 cluster cases and impact of urbanization.

The OLS analysis result between the number of COVID-19 cluster cases and the effect of urbanisation is summarised in Table 2. The study indicated a p-value of 0.004717, and less than 0.05. This shows that there is a correlation with R = 0.899 from the analysis and the p-value being less than 0.05 and that the null hypothesis that there is no relationship between the two variables can be rejected. This demonstrates that the COVID-19 cluster cases will rise by 0.912 if urbanisation has an increasing impact of 1.

Variable	Coefficient (a)	StdError	t-Statistic	Probability (b)	Robust_SE	Robust_t	Robust_Pr (b)
Intercept	-9.333184	10.006290	-0.932732	0.382018	7.716774	-1.209467	0.265883
Urbanization	0.002648	0.000449	5.894069	0.000631	0.000353	7.511414	0.000071

Table 2. Summary of OLS Results between the Number of COVID-19 Cluster Cases and Impact of Urbanization

To summarize the result and analysis from the number of COVID-19 cluster cases and impact of urbanization, it can be seen there is a positive correlation between these two variables. The pattern can be seen from the scatter plot clearly. To strengthen the correlation analysis, the ordinary least square analysis also produces positive results of correlation r = 0.899 and 0.004717 p-value thus rejecting the null hypothesis. Figure 6 display the map of the relationship of number of COVID-19 cluster cases and the impact of urbanization in each district of the state.

Variable	Coefficient (a)	StdError	t-Statistic	Probability (b)	Robust_SE	Robust_t	Robust_Pr (b)
Intercept	-2.079199	2.808382	-0.740355	0.483066	2.061133	-1.008765	0.346739
Workplace	1.807447	0.094802	19.065436	0.000000	0.068306	26.461177	0.000000

Table 3. Summary of OLS Results between the Number of COVID-19 Cluster Cases and Workplace Cases

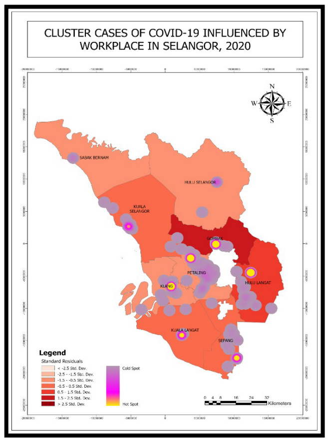

Figure 6. Cluster cases of COVID-19 influenced by the impact of urbanization Map, Selangor, 2020

3.4 Relationship between COVID-19 Cluster Cases and Working Places

The linear regression from Figure 7 illustrates a positive trend between the two variables. It also shows a strong linear association without any significant outlier between the number of COVID-19 cluster cases and the number of workplace cases. The positive relationship can be seen where the increasing of workplace cases is in line with the increasing number of COVID-19 cluster cases. The R-squared obtained is 0.978 which this model explains 100% of the variation in the number of workplace cases is explained by the number of COVID-19 cluster cases. The correlation r is 0.989 which shows there is a strong relationship as it near to 1.

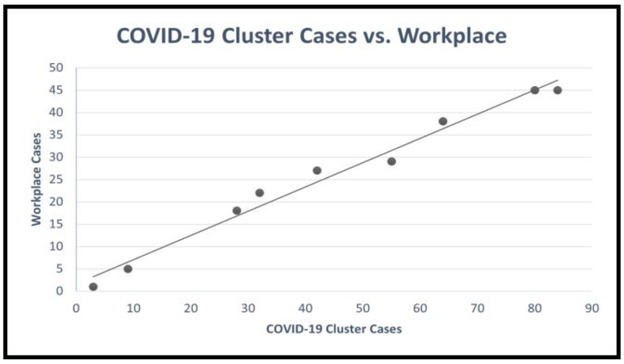

Figure 7. Scatter plot between the number of COVID-19 cluster cases and the number of workplace cases.

Table 3 shows the summary of the OLS analysis result between the number of COVID-19 cluster cases and the number of workplace cases. The p-value obtained from analysis is 0.000007 which is < 0.05. This indicates that the null hypothesis of there is no relation between the two variables can be rejected showing the p-value = 0.000007 and correlation r = 0.989 from the analysis proving there are relations between the two variables. The coefficient value signifies how much the mean of the dependent variable changes given a one-unit shift in the independent variable while holding other variables in the model constant. The coefficient obtained for the workplace is 1.807.

To sum up the result and analysis from the number of COVID-19 cluster cases and workplace cases, it can be seen there is a positive correlation between these two variables. The positive relation can be seen from the scatter plot clearly. To strengthen the correlation analysis, the ordinary least square analysis also produces positive results of correlation r = 0.989 and 0.000007 p-value. It can be concluded that there is significant relationship between the COVID-19 cluster cases and workplace. Figure 8 displays the map of the relationship of number of COVID-19 cluster cases and the number of workplace cases in the districts of Selangor.

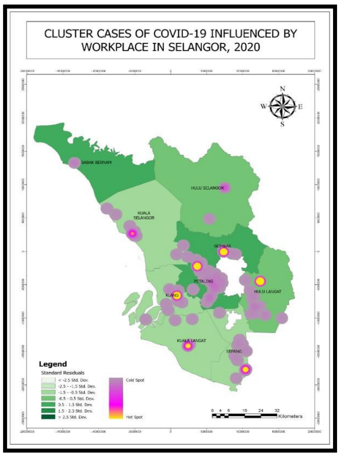

Figure 8. Cluster cases of COVID-19 influenced by workplace cases map, Selangor, 2020

4.0 Conclusions

This study is conducted to analyse the spatial pattern of COVID-19 cluster cases in Selangor Malaysia using hotspot analysis and OLS method. Based on the distribution map for the year 2020, the major finding revealed that Petaling and Hulu Langat were the two districts most badly affected by the COVID-19 cluster, with 84 and 80 accumulative cases respectively. The location of hot spots varied by month with three patterns in the hot spot areas. For the first pattern, which occurred in April and May. Then, due to MCO, the pattern decreased from June to September. Finally, as the third wave hit Malaysia in October, the hot spot area dramatically increased until December. In regard to the correlation of the COVID-19 cluster cases with the three factors (population density, the effect of urbanisation, and workplace cases). It demonstrated that the p-value for each of the three is less than 0.05 and rejects the null hypothesis that the variables are not significantly related. The most correlated factors were workplace and followed by urbanization impact and population density. This could be seen by the adjusted R-squared value was near to value 1 which were 0.989, 0.899 and 0.885 correspondingly. These findings are beneficial to the local health agencies in controlling the potential triggers that could exacerbate the spread of this epidemic, and then will prompt appropriate action, saving more lives in the future. It is also recommended to apply directly to the relevant agency in order to obtain the raw data of the cases for advanced processing techniques such as geographical weighted regression (GWR) and other geospatial big data approaches. Since COVID-19 has coinfection with other diseases, thus a future in-depth study on this matter need to be conducted.

ACKNOWLEDGEMENTS

The authors gratefully acknowledge the assistance of the Research Nexus UiTM (ReNeU), Office of Deputy Vice Chancellor (Research and Innovation) UiTM Selangor for providing a financial support for this conference paper fee payment through Pembiayaan Penerbitan Yuran Prosiding Berindeks (PYPB).

REFERENCES

Abdul Jalil, I., Abdul Rasam, A. R., 2021. Social Network Analysis of Spatial Human Mobility Behaviour in Infectious Disease Interaction: An Exploratory Evidence Of Tuberculosis In Malaysia. Int. Arch. Photogramm. Remote Sens. Spatial Inf. Sci. XLIII-B4-2021, 55–61, https://doi.org/10.5194/isprs-archives-XLIII-B4- 2021-55-2021

Abdul Rasam, A. R., Shariff, N. M, Dony, J. F., 2016. Identifying High-Risk Populations of Tuberculosis Using Environmental Factors and GIS Based Multi- Criteria Decision Making Method, ISPRS - International Archives of the Photogrammetry, Remote
Sensing and Spatial Information Sciences, XLII-4/W1, 9-13.

Abdul Rasam, A.R., Shariff, N.M., Dony, J.F., A. Misni., 2018. Socio-Environmental Factors and Tuberculosis: An Exploratory Spatial Analysis in Peninsular Malaysia, International Journal of Engineering & Technology., 7(3.11). 187- 192. doi:10.14419/ijet. v7i3.11.15958

Abdul Rasam, A. R. ., Mohd Shariff, N. ., Dony, J., 2020. The Invention of Geospatial Decision Support System for Malaysian Tuberculosis Surveillance Data Management. Environment-Behaviour Proceedings Journal, 5(SI3), 269-274. https://doi.org/10.21834/ebpj.v5iSI3.2564

Anand, R. PM Muhyiddin receives first Covid-19 vaccine as Malaysia kicks off mass inoculation campaign. https://www.straitstimes.com/asia/se-asia/pm-muhyiddin-receives-first-covid-19-vaccine-as- malaysia-kicks-off-mass-inoculation (2021, February 24).

Bernama. Petaling district records highest population in 2020 - stats department. https://www.malaysiakini.com/news/596845. . (2021, October 26)

Birruntha, S. Six biggest Covid-19 clusters in Malaysia. https://themalaysianreserve.com/2021/01/04/six-biggest-covid-19- clusters-in-malaysia/ (2021, January 4)

Bryner, J. 1st known case of coronavirus traced back to November in China. https://www.livescience.com/first-case-coronavirus- found.html (2020, March 14)

Edinur, H., & Safuan, Sri Petaling COVID-19 cluster in Malaysia: challenges and the mitigation strategies. https://www.ncbi.nlm.nih.gov/pmc/articles/PMC7927555/ S. (2020, November 10).

Fonseca-Rodríguez, O., Gustafsson, P,E., San Sebastián, M., 2021. Spatial clustering and contextual factors associated with hospitalisation and deaths due to COVID-19 in Sweden: a geospatial nationwide ecological study BMJ Global Health. 6:e006247.

Citypopulation. Selangor: https://www.citypopulation.de/en/malaysia/admin/10 selangor/ (2022, March 1)\

Liu, M., Liu, M., Li, Z., Zhu, Y., Liu, Y., Wang, X., Tao, L., Guo, X., 2021. The spatial clustering analysis of COVID-19 and its associated factors in mainland China at the prefecture level. Sci Total Environ. 2021 Jul 10;777:145992. doi: 10.1016/j.scitotenv.2021.145992.

MOH. COVID-19 Cases in Malaysia. https://covidnow.moh.gov.my/cases/ (2022).

Monir, N., Abdul Rasam, A., Ghazali, R., Suhandri, H., Cahyono, A., 2021. Address Geocoding Services in Geospatial-based Epidemiological Analysis: A Comparative Reliability for Domestic Disease Mapping. International Journal of Geoinformatics, 17(5), 156–166. https://doi.org/10.52939/ijg.v17i5.2029

Public Heatlh Madison & & Dane Country. Understanding ‘Clusters’.. https://publichealthmdc.com/blog/understanding-clusters (2020, October 20)

Rajab, N.A., Hashim, N., Rasam, A. R. A., 2020.Spatial Mapping and Analysis of Tuberculosis Cases in Kuala Lumpur, Malaysia. 2020 IEEE 1th International Conference on System Engineering and Technology (ICSET), 38-43, doi: 10.1109/ICSET51301.2020.9265385.

Ramli, M. N., Abdul Rasam, A. R., Rosly, M. A. Cartography and Mapping For Precision Health: Review Of Essential Elements For Disease Mapping, Int. Arch. Photogramm. Remote Sens. Spatial Inf. Sci., XLVI-4/W3-2021, 273–280, https://doi.org/10.5194/isprs-archives-XLVI-4-W3-2021-273-2022, 2022.

Rasam, A.R.A., Mohd Shariff, N., Dony, J.F., Maheswaran, P., 2017. Mapping risk areas of tuberculosis using knowledge-driven GIS model in Shah Alam. Malaysia. Pertanika J Soc Sci HumIties 2:135–144.

Rasam, A.R.A., Shariff, N.M., Dony, J.F, Othman, F., 2019. Spatial and Statistics for profiling risk factors of diseases: a case study of tuberculosis in Malaysia. IOP Conf Ser Earth Environ Sci. 385(1): 012037.

Rasam, A. R. A., Mohd Shariff, N., 2019. Disease Mapping and Spatial Landscape Characterization of Tuberculosis Ecology in Malaysia. Abstracts of the ICA, 1, NA. https://link.gale.com/apps/doc/A616977728/AONE?u=anon~623c752d&sid=googleScholar&xid=c1f32b2e

Ridzuan, N., Abdul Rasam, A., Isa, M., Shafie, F. 2021. Spatial Interaction between Lifestyles and Tuberculosis: An Expert and Public Participatory GIS in Malaysia. International Journal of Geoinformatics, 17(5), 178–192. https://doi.org/10.52939/ijg.v17i5.2033

Rosmadi, M. A., Rasam, A. R. A., Ismail, H., Hasim, M. S., Halil, F. M., Ghazali, R., 2021. Mobile Health Applications And Disease Hotspot Tracking System: A Proposed Spatial Assessment Tool For Tuberculosis Contact Tracing In Malaysia. Turkish Journal of Physiotherapy and Rehabilitation, 32, 2.

Santos, V, S., Siqueira, T, S., Atienzar, A, C., Filho, P.M., Cuevas., L, E., Gurgel, R Q., 2022. Spatial clusters, social determinants of health and risk of COVID-19 mortality in Brazilian children and adolescents: A nationwide population-based ecological study The Lancet Regional Health - Americas 2022;13: 100311. https://doi.org/10.1016/j. lana.2022.100311

Sergeant, A., van Reekum, E,A., Sanger, N, 2020. Impact of COVID-19 and other pandemics and epidemics on people with pre-existing mental disorders: a systematic review protocol and suggestions for clinical care. BMJ Open. 10:e040229. doi: 10.1136/bmjopen-2020-040229

Song W,-M., Zhao, J-Y., Zhang, Q-Y., Liu, S-Q, Zhu X-H., An, Q-Q., Xu, T-T., Li, S-j, Liu, J-Y., Tao, N-N., Liu, Y, Li, Y-F., Li, H-C., 2021. COVID-19 and Tuberculosis Coinfection: An Overview of Case Reports/Case Series and Meta-Analysis. Front. Med. 8, 657006. doi: 10.3389/fmed.2021.657006

Ullah, S., Mohd Nor, N. H. ., Daud, H., Zainuddin, N., Gandapur, M. S. J., Ali, I., Khalil, A., 2021. Spatial cluster analysis of COVID-19 in Malaysia. Geospatial Health, 16(1). https://doi.org/10.4081/gh.2021.961

WHO (2022). Coronavirus disease (COVID-19). https://www.who.int/health-topics/coronavirus#tab=tab_3

WHO. (2021). Coronavirus disease (COVID-19) pandemic. https://www.euro.who.int/en/health-topics/health-emergencies/coronavirus- covid-19/novel-coronavirus-2019-ncov

WHO (2020). Coronavirus disease 2019 (COVID-19) Situation Report - 32. World Health Organization.

WHO. (2020). WHO Coronavirus Disease (COVID-19) Dashboard. https://covid19.who.int/

Wilder-Smith, A., 2021. COVID-19 in comparison with other emerging viral diseases: risk of geographic spread via travel. Trop Dis Travel Med Vaccines. 7, 3 (2021). https://doi.org/10.1186/s40794-020-00129-9