Journal of Sustainability Science and Management *eISSN: 2672-7226*
Volume 17 Number 12, December 2022: 2-12 *© Penerbit UMT*

EVALUATION OF THE EFFECT OF RAINFALL ON COVID-19 TRANSMISSION IN TERENGGANU, MALAYSIA

NUR FATIN AUNI MOHAMED NAWI[1], NAZRI CHE DOM[1,2,3]*, RAHMAT DAPARI[4], HASBER SALIM[5] AND NOPADOL PRECHA[6]

[1]Centre of Environmental Health and Safety, Faculty of Health Sciences, Universiti Teknologi MARA, UiTM Cawangan Selangor, 42300 Puncak Alam, Selangor, Malaysia. [2]Integrated Mosquito Research Group (I-MeRGe), Universiti Teknologi MARA, UiTM Cawangan Selangor, 42300 Puncak Alam, Selangor, Malaysia. [3]Institute for Biodiversity and Sustainable Development (IBSD), Universiti Teknologi MARA, 40450 Shah Alam, Selangor, Malaysia. [4]Faculty of Medicine and Health Sciences, Universiti Putra Malaysia, 43400 Serdang, Selangor, Malaysia. [5]School of Biological Sciences, Universiti Sains Malaysia, 11800 USM Penang, Pulau Pinang, Malaysia. [6]Department of Environmental Health & Technology, School of Public Health, Walailak University, Nakhon Si Thammarat, Thailand.

**Corresponding author: nazricd@uitm.edu.my*
Submitted final draft: 6 August 2022 *Accepted: 8 August 2022* http://doi.org/10.46754/jssm.2022.12.002

Abstract: One of the variables leading to the global spread of COVID-19 cases is the weather, which includes temperature and air quality. In this study, an investigation of the association between precipitation and COVID-19 cases was conducted to provide useful information on the possibility of this climate factor (precipitation) on the progression of COVID-19 cases for an appropriate management strategy. Secondary COVID-19 and rainfall data obtained from the Ministry of Health and the Meteorological Department in Malaysia were used for the study. The collected data were subjected to Pearson correlation analysis. The results of this study showed that both rainy days and rainfall amount were insignificant to COVID-19 cases, indicating that rainfall amount was not associated with COVID-19 transmission in Terengganu, Malaysia. Thus, this discovery could be used to inform individual and COVID-19 supervisors and the government as it prepares for the new weather season.

Keywords: COVID-19 cases, rainfall variables, cluster, correlation.

Introduction

SARS-coronavirus CoV-2 (also known as COVID-19) is a newly identified coronavirus that causes an infectious zoonotic disease (Kerr *et al*., 2021; Lim *et al*., 2021). The outbreak started spreading from person to person through intimate contact as close as one metre in Wuhan, China in December 2019 (Chien & Chen, 2020). The World Health Organization (WHO, 2020) designated COVID-19 as a worldwide pandemic infection in March of that year. Although it is well-accepted that the virus is transferred by human droplets in the air we breathe and by direct touch, the capability of COVID-19 aerosol transmission and the role of weather conditions are frequently debated (Makama & Lim, 2021; Beggs & Avital, 2021; Makama & Lim, 2021).

In Malaysia, the COVID-19 epidemic began as a small wave of 22 imported cases in January 2020 and now the total of COVID-19 cases has exceeded one million cases in September 2021 since the first case was identified on 24 January 2020 (Hashim *et al*., 2021; Aw *et al*., 2021; Rahim *et al*., 2021). Since then, the daily cases of COVID-19 have continued to arise and created numerous clusters with the emergence of new variants. In early 2021, Terengganu, one of the states with a small number of cases also recorded an increase in COVID-19 cases due to the delta variant. The easing of Movement Control Order (MCO) 3.0 as well as the economic sectors that are opened regularly, as well as the celebration of Eid al-Fitr that have seen cross-state movements have caused this variant to spread rapidly and increase daily cases in the country (Aw *et al*., 2021).

It has also been noted that environmental conditions may have an impact on a virus' ability to survive (Bherwani *et al*., 2020; Hakil *et al*., 2020; Briz-Redón & Serrano-Aroca, 2020;

Kanniah *et al*., 2020; Alam & Sultana, 2021; Brohan *et al*., 2021). The average temperature, relative humidity, wind speed and absolute humidity all had strong positive correlations with the number of confirmed COVID-19 cases, according to recent research on the effects of weather in Bangladesh (Chiyomaru & Takemoto, 2020). Governments around the world have implemented travel restrictions, business closures and social distancing measures in the hopes of flattening the outbreak curve and preventing new cases from overwhelming the health system due to COVID-19's high reproduction and mortality rates, lack of a vaccine and herd immunity (Chien & Chen, 2020).

In order to identify outbreaks of COVID-19, knowledge of its temporal and geographical distribution is essential. The spatial distribution of COVID-19 can be better understood to help with intervention programmes and health resource allocation (Tosepu *et al*., 2020; Scarpone *et al*., 2020). In addition, in locations with a high number of cases, cluster detection can help with more in-depth epidemiological surveillance which can improve the efficacy of control efforts. This study aims to determine the pattern of COVID-19 transmission in Terengganu, the pattern of rainfall in Terengganu and the association between the distribution of COVID-19 cases and weather variables.

Materials and Methods

Study Site and Study Population

Terengganu is a Malaysian state bordered by Kelantan (north and northwest) and Pahang (south and southwest), located on Peninsular's East Coast with latitude longitude coordinates 5°19'48.72"N, 103°8'26.88"E, with a total area of 13,035 km^2 and a population of 1.25 million people. The average temperature of 28°C to 30°C during the day and slightly milder after night. The districts receive heavy rainfall from November to January when the northeast monsoon blows. The capital of Terengganu has eight main districts: Besut, Setiu, Kuala Nerus, Kuala Terengganu, Hulu Terengganu, Marang, Dungun and Kemaman. The local communities are mostly farmers and fishermen because of associated rivers. Terengganu was selected for this study because of its low COVID-19 cases compared to other regions of Malaysia (Figure 1).

Study Design

A cross-sectional design with an integrated epidemiological survey was used to assess the effect of rainfall on COVID-19 cases. From August 2020 to July 2021, data on COVID-19 cases and rainfall within 53 weeks of the year were obtained from the Ministry of Health and the Meteorological Department of Technology and Innovation, and privacy and confidentiality were maintained throughout the study. The collected data were reviewed weekly and ongoing to help stakeholders, public health epidemiologists and health workers understand the prevalence of COVID-19 in their area of

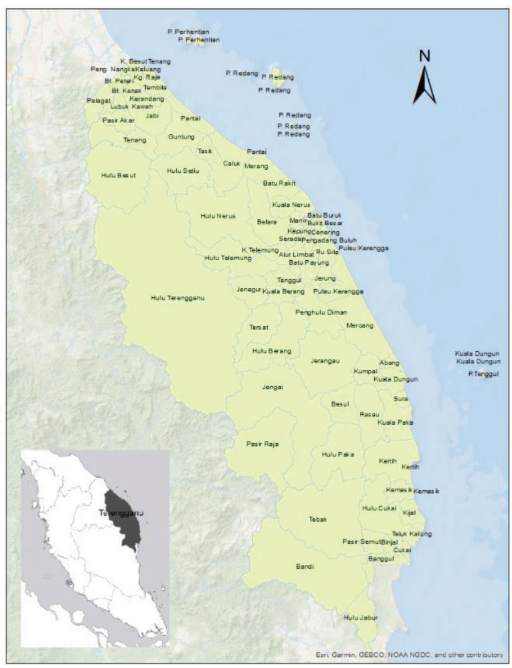


Figure 1: The geographical representation of the area of interest in the Terengganu map based on sub-district

responsibility. Furthermore, this data will be used to build a COVID-19 model to predict future outbreaks.

Data Collection and Analysis

As part of the prevention and control of infectious diseases (PCIDs) Act 1988, all registered medical practitioners reported confirmed cases of COVID-19 to the nearest district health office within 24 hours (Act 342). The COVID-19 cases that were collected were notified in the *e-notifikasi* system (Communicable Disease Control Information System) and submitted in the Notification Form (NF). A health official evaluated the alerted cases and the records were recorded into a database before being submitted to the state and national levels for surveillance reasons. The collected data on COVID-19 cases was analysed weekly based on an epidemiological survey for each district. For the rainfall variable (rain days and rain volumes), four different weather stations viz; Kuala Terengganu, Kerteh, MARDI Jerangau and FELDA Belara provided the records of the daily distributions which were measured in millimetres (mm) and converted to weekly basis as indicated in (Table 1).

Statistical Analysis

A descriptive analysis of the cumulative instances of the epidemiological 53-week period was performed for the COVID-19 cases using Origin version 2021 (OV-2021) software and a 3D waterfall colour map was generated as a result. Moran's I statistic was used to identify spatial autocorrelation and disease hotspots. The package provides a continuous index value that may indicate a random distribution (value of zero or close to zero), a clustered distribution (value close to +1.0) or a scattered but organised distribution (value close to -1.0). There are four types of clusters in the LISA values: High-high, low-low, high-low and low-high. Low-low clusters are related to low IR areas (cold spots) while high-high clusters refer to high IR areas (hot spots). Outliers are detected in the high-

Table 1: Dataset and their attributes

Datasets	Sources	Specifications	Attributes	Value	Being Pre-processed
COVID-19 cases data	Ministry of Health Malaysia	Weekly and monthly aggregated data: • Dates • District • Sub-district	Data time interval	August 2020-July 2021	Weekly based was converted
			Size	Districts in Terengganu	8 main districts
			Week	1-53	
			District Sub-districts	8 85	
			Types of disease	Infectious disease	COVID-19
Weather data	Malaysian Metrological Department, Ministry of Science, Technology	Information includes: • Weekly average values of the rainy day and volume variables	Data time interval	January-December 2021	
			Station	Kuala Terengganu, Kerteh, MARDI Jerangau and FELDA Belara	FELDA Belara, Kerteh, Kuala Terengganu, MARDI Jerangau
			Rainfall	mm	Weekly based was converted

low and low-high categories. GeoDa software version 1.14 was used to perform the global and local Moran's I tests. A first-order spatial weight matrix was created for subsequent analysis to define sub-districts with common boundaries and vertices as neighbours. Data visualisation was performed using ArcMap software version 10.8.

A scatterplot for the total data of a year, depending on the epidemiological week was developed to comprehend the pattern of rainfall variables better. This scatterplot graph used in this study was created in Origin software version 2021 to fully visualise the diverse rainfall patterns in Terengganu's high-high and low-low clusters. The volume data were averaged based on the epic week to determine the linear association between rainfall data and COVID-19 case data. The data collected from the Malaysia Meteorological Department was recorded in Microsoft Excel 2018 software before being transferred into Origin software version 2021 for correlation analysis. Aside from that, data on rainy days and rainfall volume were displayed in column graphs and line graphs with a 5% error band and a double y-axis to detect the temporal pattern between COVID-19 instances and rainfall data based on the epic week. The graph was made using the Origin software version 2021 function.

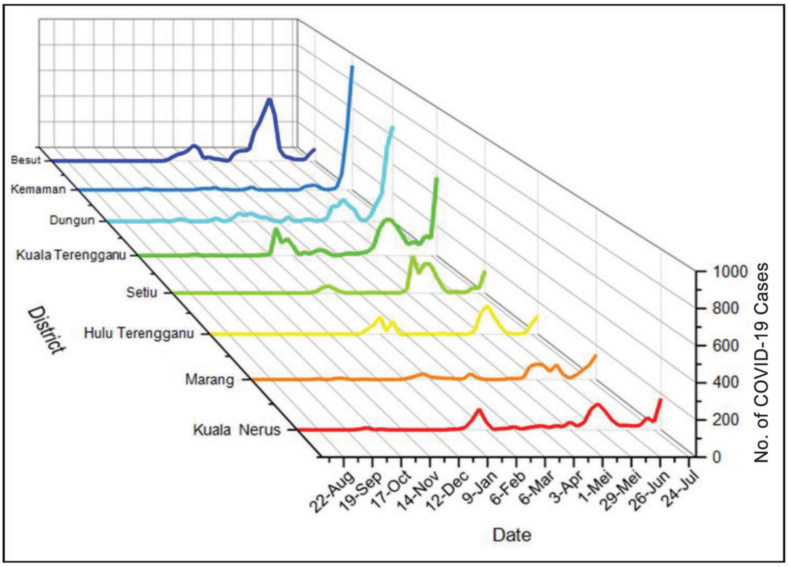
The data were gathered in Microsoft Excel to establish the association between COVID-19 case distributions and rainfall, and the Pearson correlation test was performed to confirm the correlation in SPSS version 25. Finally, the degree of association between COVID-19 case data and rainfall over time was determined using descriptive analysis. A cross-correlation function (CCFs) graph was created to visualise the relationship between the rainfall variable and COVID-19 cases from lag 1 to lag 14.

Results

Figure 2 (A) depicts the outcome of the COVID-19 transmission dispersion pattern in Terengganu's eight major districts [Figure 2 (A)]. The 3D waterfall plot graph of COVID-19 transmission from August 2020 to July 2021 concerning epidemiological weeks (53 weeks) revealed that COVID-19 transmission occurred in the following order of decreasing prevalence: Kemaman 900 cases > Dungun 600 cases > Kuala Terengganu 500 cases > Setiu 200 cases > Hulu Terengganu, Marang, Kuala Nerus and Besut 130 cases throughout the study periods. The result of the descriptive analysis of the COVID-19 transmission in eight main districts in Terengganu is detailed in [Figure 2 (B)]. From the population of 1.25 million inhabitants of Terengganu districts, the descriptive result revealed that Kemaman had the highest COVID-19 with maximum cases of 913 and a mean of (57.379) with a population of 166,750 people. In contrast, the lowest number of COVID-19 cases was recorded for Marang, with a case value of 145 and a mean of (31.690) with a population of 99,775 people. These highest and lowest cases of COVID-19 substantially differed from the recorded COVID-19 cases in the remaining districts that includes Dungun, Kuala Terengganu, Besut, Setiu, Hulu Terengganu and Kuala Nerus with COVID-19 cases of 669, 526, 479, 241, 176 and 173, respectively, in the population of 798,041 people of Terengganu districts.

Figure 3 demonstrates the result of the spatial, temporal pattern of COVID-19 cases in Terengganu's sub-districts. The result indicated that in every month, the major peak of seasonal cases was between May 2021 and July 2021 while in August and September 2020, there were no cases in any sub-district and the incidence rate for these two months was low. Generally, many areas recorded COVID-19 cases ranging from 1 to 17 cases in October 2020, with only one sub-district, Kuala Nerus being a yellow area with average cases ranging from 17 to 36 cases. The cases of COVID-19 increased from January 2021 as many areas recorded more than 17 cases per month. This increase in COVID-19 cases in early 2021 was due to the third wave of contagion that hit the country. In July 2021, more sub-district became red zone due to cases exceeding 113 cases per month and only 4 sub-

(A)



(B)

District	Min	Max	Mean	Standard Deviation	Population
Kuala Nerus	2	173	43.724	44.647	17,8100
Marang	1	145	31.690	37.343	9,9775
Hulu Terengganu	1	176	34.138	50.200	70,800
Setiu	1	241	43.483	67.420	54,563
Kuala Terengganu	1	526	94.311	110.689	214,584
Dungun	1	669	85.379	151.769	145,454
Kemaman	1	913	57.379	183.631	166,750
Besut	1	479	99.621	124.441	134,540

Figure 2: (A) The cumulative cases of COVID-19 in Terengganu district from August 2020 until July 2021, (B) Descriptive analysis of COVID-19 cases

districts with zero cases: Hulu Terengganu, Tersat, Kumpal and Pasir Raja. Based on this, the highest incidence of COVID-19 transmission is in the southern region of Terengganu, many areas in this region have become red zone.

The spatial autocorrelation of distributions and disease foci (hot spot and cold spot) in Terengganu were classified based on the spatial clusters of COVID-19 transmission (Figure 4). The studied area had a highly significant, positive spatial autocorrelation (Global Moran's I= 0.228, $p > 0.001$, Z-score=3.343). This suggests that COVID-19 incidence in Terengganu is spatially dependent and clustered. In 85 smaller districts, the local Moran's I test found statistically significant hotspots or substantial spatial clusters. Lubuk Kawah, Bt. Kenak, Kuala Nerus, Kuala Dungun, Sura, Kuala Paka and Manir were identified as high-high clusters (hotspots). With only 133 cases and a Lisa index of 0.05, a cold spot (low spatial cluster) in Hulu Besut was identified. High and low spatial clusters were identified in three sub-districts, namely Kumpal, Belara and Pasir Akar [Figure 4 (B)]. These three sub-districts are spread across several districts. Although Kumpal had no COVID-19 cases, it was surrounded by high-incidence sub-districts such as Kuala Dungun, Sura and Kuala Paka, making it a low-high cluster that could be affected in the future.

Figure 5 demonstrates the relationship between the COVID-19 case distribution and the rainfall. Rain days and rain amounts lagged from 0 to 14 days with COVID-19 confirmed cases revealed that only positive lags might be evaluated, as a positive value suggests that climatic factors may influence COVID-19 confirmed cases in the future. Except for lag 13, negative correlations were found between COVID-19 cases and rainy days for the cluster "High-high" while a negative correlation was found between COVID-19 cases and rainfall from lag 0 to lag 14.

Furthermore, rainy days had a significant negative correlation with COVID-19 instances in the low-low cluster from lag 3 to lag 10 but they used to have a positive correlation (at lag 0, lag 1, lag 2, lag 12 and lag 13). Except for lags 5 and 6, there is a negative correlation between COVID-19 cases and rainfall volume. According to this cross-correlation function graph, lags 5 and 6 impacted COVID-19 transmission with a volume of rainfall from a low-low cluster, implying that rainfall values from 5 and 6 days ago may influence today's COVID-19 confirmed cases.

Discussion

The degree of the influence of weather conditions in suppressing SARS-CoV-2 virus transmission is uncertain. The measured rainfall variable (rainy day and rainfall amount) was not found to be significantly ($p > 0.05$) related to COVID-19 cases in this study. In Terengganu, rainy days and rainfall amounts are adversely linked with COVID-19 instances. Rainfall and COVID-19 cases have a negative relationship because people avoid leaving their homes on rainy days (Menebo, 2020; Chiyomaru &

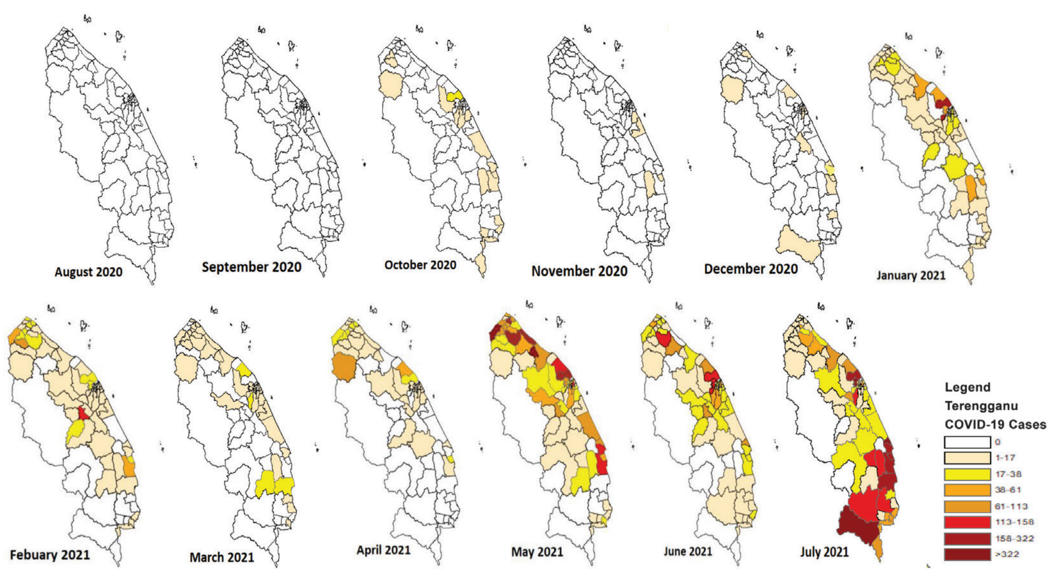
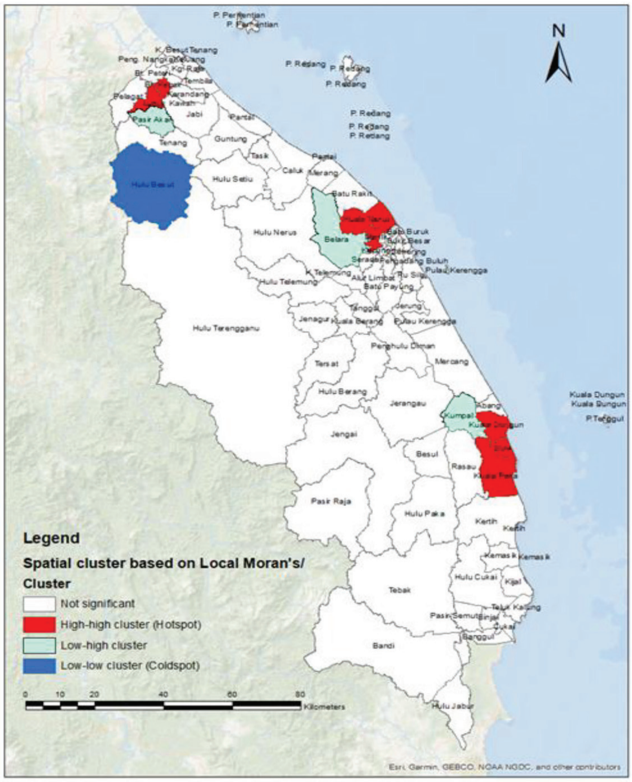


Figure 3: Spatial-temporal distributions of COVID-19 cases in the Terengganu sub-district from August 2020 until July 2021

(A)



(B)

Cluster Type	Sub-district	District	IR	Number of Cases	LISA Index	p-value
High-high (hotspots)	Lubuk Kawah	Besut	24.09	214	0.40	0.05
	Bt. Kenak		17.67	170	0.13	0.05
	Kuala Nerus	Kuala Nerus	10.06	843	6.25	0.01
	Kuala Dungun	Dungun	12.12	415	0.00	0.01
	Sura		14.07	550	4.24	0.05
	Kuala Paka		15.17	470	1.66	0.05
	Manir	Kuala Terengganu	25.08	713	2.37	0.05
Low-high	Kumpal	Dungun	0	0	-0.76	0.05
	Belara	Kuala Terengganu	3.91	69	-0.61	0.01
	Pasir Akar	Besut	24.05	136	-0.06	0.05
Low-low (cold spots)	Hulu Besut	Besut	28.91	133	0.05	0.05

Figure 4: (A) COVID-19 spatial cluster from August 2020 to July 2021: A spatial hotspot and coldspot analysis at the sub-district level, (B) Geographic clusters of COVID-19 cases at the sub-district level that are statistically significant based on Incidence Rate (IR)

Takemoto, 2020). People who do not leave their homes are less likely than those who do to contract an infectious disease. This is due to the lack of direct contact between people (Palialol *et al*., 2020; Abraham *et al*., 2021).

The occurrence of COVID-19 in Malaysia is depicted by the climatic pattern observed in this study. Early research has found that low rainfall (rainfall) is associated with the occurrence of COVID-19. One possibility is that when the sun shines outside, people are more likely to break the "staying indoors" rule and thus, contract the virus (Menebo, 2020; Hossain *et al*., 2021). High mobility, high population density and poor housing conditions are all characteristics that are likely to have a role in the spread of COVID-19, especially in large cities, regardless of the weather (Azuma *et al*., 2020; Naing *et al*., 2020; Rosario *et al*., 2020; Yatim *et al*., 2021; Aune *et al*., 2021). Aerosols and microbiological bioaerosols (fungi, bacteria, viruses) may be accumulated and dispersed by precipitation, suggesting that viruses do not have a long residence time in ambient air and cannot propagate further (Hossain *et al.,* 2021). This study has some limitations that should be noted. Rainfall data from meteorological stations do not cover all districts in Terengganu because only four stations have data.

This research sheds new light on the association between rainfall and new COVID-19 cases, which could benefit local policy development. The test data (daily Corona cases) in this study may not exactly match the infection data (or virus transmission data). It is possible that the incubation period has been extended

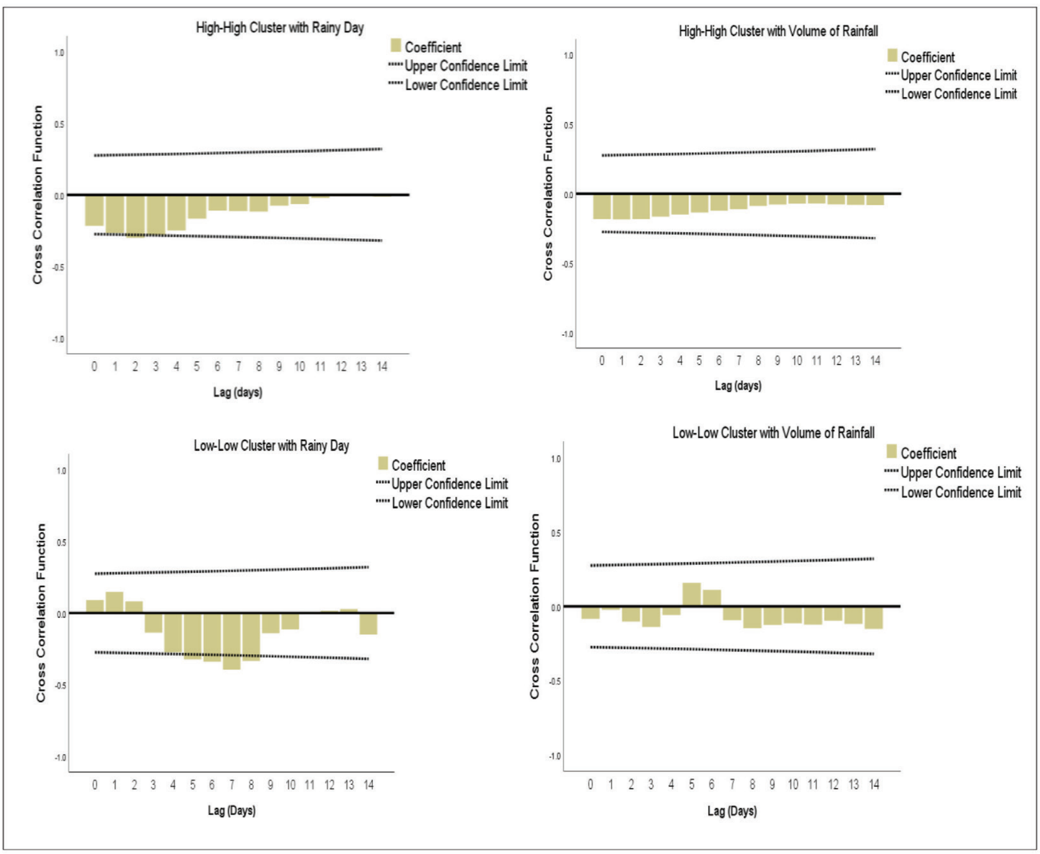


Figure 5: Analysis of cross-correlation between COVID-19 cases and rainfall variables in Terengganu from lag 0 to 14 (rainy day and volume)

or the infection date is the same for each of the daily Corona cases reported on the test dates. As a result, another limitation of this study is the insufficient selection of weather forecast data to match the daily new cases. The relevance of the link between precipitation (mm) and COVID-19 cases remains unchanged between the two scenarios.

Conclusion

This study's significant results suggest that the amount of rainfall is inversely related to the spread of COVID-19 in Terengganu. Rainy days and the amount of rainfall were very weakly linked with COVID-19 incidence in both hotspot and coldspot regions. This study proves a hypothesis: Rainfall reinforces the "stay at home" rule. Outdoor activities can have an impact on virus transmission and this needs to be considered when developing a new management strategy. Meteorological and environmental factors play an important role in predicting infectious diseases. It is proposed that an additional study be conducted to strengthen the association between meteorological and environmental conditions and COVID-19 transmission.

Acknowledgements

The authors sincerely thank the Ministry of Health, Malaysia and the Department of Environment (DOE) for providing ground data for this research work. This study has received funding from the Young Talent Research (YTR), Universiti Teknologi MARA (600-RMC/YTR/5/3 (007/2021).

References

Abraham, J., Turville, C., Dowling, K., & Florentine, S. (2021). Does climate play any role in COVID-19 spreading? — An Australian perspective. *International Journal of Environmental Research and Public Health, 18*(17), 9086.

Alam, M. S., & Sultana, R. (2021). Influences of climatic and non-climatic factors on COVID-19 outbreak: A review of existing literature. *Environmental Challenges*, *5*, 100255.

Aune, K. T., Davis, M. F., & Smith, G. S. (2021). Extreme precipitation events and infectious disease risk: A scoping review and framework for infectious respiratory viruses. *International Journal of Environmental Research and Public Health*, *19*(1), 165.

Aw, S. B., Teh, B. T., Ling, G. H. T., Leng, P. C., Chan, W. H. & Ahmad, M. H. (2021). The COVID-19 pandemic situation in Malaysia: Lessons learned from the perspective of population density. *International Journal of Environment Research and Public Health*, *18*(12), 6566.

Azuma, K., Yanagi, U., Kagi, N., Kim, H., Ogata, M., & Hayashi, M. (2020). Environmental factors involved in SARS-CoV-2 transmission: Effect and role of indoor environmental quality in the strategy for COVID-19 infection control. *Environmental Health and Preventive Medicine, 25*(66). https://doi.org/10.1186/s12199-020-00904-2

Beggs C. B. & Avital E. J. (2021). A psychrometric model to assess the biological decay of the SARS-CoV-2 virus in aerosols. *PeerJ,* 9, 1-22.

Bherwani, H., Gupta, A., Anjum, S., Anshul, A., & Kumar, R. (2020). Exploring dependence of COVID-19 on environmental factors and spread prediction in India. *NPJ Climate Atmospheric Science*, *3*(38), 1-13. https://doi.org/10.1038/s41612-020-00142-x

Briz-Redón, Á., & Serrano-Aroca, Á. (2020). The effect of climate on the spread of the COVID-19 pandemic: A review of findings, and statistical and modelling techniques. *Progress in Physical Geography: Earth and Environment*, *44*(5), 591-604.

Brohan, M.A., Dom, N.C., Ishak, A.R., Abdullah, S., Salim, H., Ismail, S.N.S., &

Precha. (2021). An analysis on the effect of Coronavirus (COVID-19) pandemic Movement Control Order (MCOS) on the solid waste generation in Peninsular Malaysia. *Environmental Science and Pollution Research*, *28*(46), 66501-66509.

Chien, L., & Chen, L. (2020). Meteorological impacts on the incidence of COVID-19 in the U.S. *Stochastic Environmental Research and Risk Assessment*, *34*(10),1675-1680.

Chiyomaru, K., & Takemoto, K. (2020). Global COVID-19 transmission rate is influenced by precipitation seasonality and the speed of climate temperature warming.

Hashim, J.H., Adman, M.A., Hashim, Z., Mohd Radi, M.F., Kwan, S.C. (2021). COVID-19 Epidemic in Malaysia: Epidemic Progression, Challenges and Response. *Frontiers in Public Health,* 9, 560592.

Hossain, M. S., Ahmed, S., & Uddin, M. J. (2021). Impact of weather on COVID-19 transmission in South Asian countries: An application of the ARIMAX model. *Science of the Total Environment*, *761*, 143315.

Kanniah, K. D., Kamarul Zaman, N. A., Kaskaoutis, D. G., & Latif, M. T. (2020). COVID-19's impact on the atmospheric environment in the Southeast Asia Region. *Science of the Total Environment*, *736*, 139658.

Kerr, G. H., Badr, H. S., Gardner, L. M., Perez-Saez, J., & Zaitchik, B. F. (2021). Associations between meteorology and COVID-19 in early studies: Inconsistencies, uncertainties, and recommendations. *One Health*, *12*, 100225.

Lim, Y. K., Kweon, O. J., Kim, H. R., Kim, T.-H., & Lee, M.-K. (2021). The impact of environmental variables on the spread of COVID-19 in the Republic of Korea. *Scientific Reports, 11*(1). https://doi.org/10.1038/s41598-021-85493-y

Makama, E. K., & Lim, H. S. (2021). Effects of Location-Specific Meteorological Factors on COVID-19 daily infection in a tropical climate: A case of Kuala Lumpur, Malaysia. *Advances in Meteorology*, *2021*, 1-10.

Menebo, M. M. (2020). Temperature and precipitation associate with COVID-19 new daily cases: A correlation study between weather and COVID-19 pandemic in Oslo, Norway. *Science of the Total Environment*, *737*, 139659.

Naing, C., Ni, H., Aung, H. H., Chan, E., & Mak, J. W. (2020). The influence of climate factors on COVID-19 transmission in Malaysia: An autoregressive integrated moving average (ARIMA) model. medRxiv.

Palialol, B., Pereda, P., & Azzoni, C. (2020). Does weather influence COVID-19 transmission? *Regional Science Policy & Practice, 12*(6), 981-1004.

Rahim, M. H., Dom, N. C., Ismail, S.N.S., Abd Mulud, Z., Abdullah, S., & Pradhan, B., (2021). The Impact of Novel Coronovirus (2019-*n*CoV) pandemic Movement Control Order (MCO) on dengue cases in Peninsular Malaysia. *One Health*, *12*, 100222.

Rosario, D. K. A., Mutz, Y. S., Bernardes, P. C., & Conte-Junior, C. A. (2020). Relationship between COVID-19 and weather: Case study in a tropical country. *International Journal of Hygiene and Environmental Health*, *229*, 113587.

Sarkodie, S. A., & Owusu, P. A. (2020). Impact of meteorological factors on COVID-19 pandemic: Evidence from top 20 countries with confirmed cases. *Environmental Research*, *191*, 110101.

Scarpone, C., Brinkmann, S. T., Große, T., Sonnenwald, D., Fuchs, M., & Walker, B. B. (2020). A multimethod approach for County-scale geospatial analysis of emerging infectious diseases: A cross sectional case study of COVID-19 incidence in Germany. *International Journal of Health Geographics*, *19*(1).

Shakil, M. H., Munim, Z. H., Tasnia, M., & Sarowar, S. (2020). COVID-19 and the environment: A critical review and research agenda. *Science of the Total Environment*, *745*, 141022.

Tosepu, R., Gunawan, J., Effendy, D. S., Ahmad, L. O., Lestari, H., Bahar, H., & Asfian, P. (2020). Correlation between weather and COVID-19 pandemic in Jakarta, Indonesia. *Science of the Total Environment*, *725*, 138436.

Yatim, A. N., Latif, M. T., Sofwan, N. M., Ahamad, F., Khan, M. F., Mahiyuddin, W. R., & Sahani, M. (2021). The association between temperature and cause-specific mortality in the Klang Valley, Malaysia. *Environmental Science and Pollution Research*, *28*(42), 60209-60220.