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Geo-visualization of Sarawak COVID-19 Publicly Available Data Employing Open-source Geospatial Software

Piau Phang[1,*], Ming Yan Yap[1], Syerrina Zakaria[2], Jane Labadin[1]

[1]Faculty of Computer Science and Information Technology, Universiti Malaysia Sarawak, 94300 Kota Samarahan, Sarawak, Malaysia
[2]Faculty of Ocean Engineering Technology and Informatics, Universiti Malaysia Terengganu, 21030 Kuala Nerus, Terengganu, Malaysia

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Abstract The state government of Sarawak with the help of the Sarawak Disaster Management Committee (SDMC) has continuously made the updated information on the state COVID-19 situation and its ensuing control measures available to general public in the form of daily press statements. However, these statements are merely providing textual information on daily basis though the data are in fact rich in temporal and spatial properties. Since the onset of COVID-19 pandemic, spatiotemporal analysis becomes the key element to better understand the spread of COVID-19 in various spatial levels worldwide. Hence, there is an urgent need to convert this textual information into more valuable insights by applying geo-visualization techniques and geospatial statistics. The paper demonstrates the prospect of retrieving geospatial data from publicly available document to locate, map and analyze the spread of COVID-19 up to division level of Sarawak. Specifically, map visualization and geospatial statistical analysis are performed for the list of exposed locations, which are indeed locations visited by COVID-19 patients prior to being tested positive in Kuching division, using open-source geospatial software QGIS. It is found that these exposed locations concentrate on the build-up areas in the division and are in south-west to north-east direction of the center of Kuching in September and October 2021. Despite the number of exposed locations published is relatively small compared to the number of confirmed cases reported, both are nearly strongly correlated. The insights gained from such geospatial analysis may assist the local public health authorities to impose applicable disease control interventions at division level.

Keywords Geo-visualisation, Geospatial Analysis, QGIS, Publicly Available Data, COVID-19, Exposed Location, Sarawak, Malaysia

1. Introduction

Sarawak, the largest state in Malaysia by land area and separated from Peninsular Malaysia by South China Sea, was unavoidably affected by COVID-19 pandemic. Sarawak recorded its first COVID-19 confirmed case on 13 March 2020 and Malaysia first COVID-attributable death on 17 March 2020 [1]. Having said that, the pandemic could be considered well controlled throughout 2020 since the total number of confirmed cases in whole Sarawak was just 1117 with 19 fatalities [2]. However, the cumulative confirmed cases and fatalities reached 252 300 and 1 619 in the end of year 2021 [3], which provisionally ranked Sarawak the second highest for the cumulative COVID-19 confirmed cases among 13 states and 3 federal territories in

Malaysia.

The COVID-19 pandemic has dramatically changed our lives [4-5]. One of the most important properties of pandemics is their spatial spread which mainly depends on the disease transmission mechanism, human mobility and control strategy [6]. The study of spatial dependency of COVID-19 cases among neighboring regions with spatial statistics can be used to help mitigate the pandemics through acquiring scientific information on transmission dynamics [7]. Both spatial statistical tools and geographical information system (GIS) software were widely applied in revealing the evolution of COVID-19 pandemic at finer spatial and temporal scales [8]. Indeed, spatiotemporal (i.e. space-time) analysis becomes the key element to have better understanding on the spread of COVID-19 in various spatial levels (e.g. regional, national, international) worldwide, as highlighted in the recent reviews ([8-10] and the references therein). Overall, a substantial amount of literatures reviewed in [8-10] is devoted to map visualization of the geographical distribution of COVID-19 confirmed cases, hotspots and clustering analysis, modelling of the spatial transmission characteristics of the pandemic, as well as the exploration of the relationships among socio-economic, demographic, environmental and epidemiological-related variables with COVID-19 intensity using spatial regression, for various study areas. It is important to note that all these spatiotemporal studies were relied heavily on the availability of geographically detailed data.

However, collecting high-quality data at a fine spatial resolution is hard and encounters many barriers at the technological and privacy level [11]. Furthermore, lack of access to authentic spatial COVID-19 data at finer scales has prevented scientists from implementing spatial analytical techniques to gain insights into the spread of COVID-19 [12]. In Malaysia, COVID-19 epidemiological datasets were publicly available only as counts at state and/or district levels. Despite these data availability issues, it is possible for researchers to create dataset for COVID-19 using publicly available news articles (as demonstrated in work by Thakar [12]), press or media statements. These datasets could be used to perform spatial analysis to unfold events in space and time even up to city levels whereby mapping, tracing, modelling and forecasting a COVID-19 phenomenon could be conducted.

In the context of Sarawak, since the onset of pandemic in 2020, the state government of Sarawak with the help of Sarawak Disaster Management Committee (SDMC) has continuously made the updated information on the state COVID-19 situation and its ensuing control measures available to the general public in the form of daily press statements, disseminated via social media. This information includes not only the district-wise daily statistics on testing, person under investigation (PUI), confirmed cases, recovered and death, but also the details on COVID-19 infection clusters, several control measures such as standard operating procedures (SOPs), quarantines, the localities under Enhanced Movement Order Control (EMCO) and the exposed locations (which are actually the locations visited by COVID-19 patients prior to being tested positive).

Even so, the daily press statements are merely providing textual information on daily basis though the data are not only rich in temporal and spatial properties, but also have the potential to become geospatial data, including discrete point data. The ability to represent spatiotemporal data in different forms provides better understanding of the different phenomena involved, resulting in either better dissemination of the information or better decision-making [13]. Hence, there is an urgent need to convert this textual information into more valuable insights by applying geo-visualization techniques and geospatial statistical analysis. The geo-visualization (i.e. geographic visualization) is defined in [14] as the set of visualization tools that allow exploration of geolocated data in order to build knowledge without assumptions a priori. On the other hand, the geospatial statistics refer to the application of statistical concepts and methods to data that have a geographical component (e.g. spatial location) attached to them.

Even though there are numerous software tools for generating geographic visualization and performing spatial analysis, many are paid access and difficult interpretation for non-GIS professionals [15]. Hence, as a free alternative to more costly GIS platform [16], the Quantum GIS (QGIS) has gained its popularity upon its simplicity. It allows user to create, edit, visualize, analyze and publish geospatial information on various operating systems and mobile devices [17].

Hence, this paper focuses on the potential for retrieving geospatial point data at finer scales from publicly available information to locate, map and analyze the spread of COVID-19 in the capital of Sarawak, Kuching and its two rural districts, namely Bau and Lundu, within the same Kuching Division. Specifically, lack of access to authentic COVID-19 confirmed cases spatial data at finer scales prompts the use of list of exposed locations in Kuching Division published by SDMC as the geospatial datasets in investigating the space-time pattern of COVID-19 transmission in urban and rural districts in Sarawak.

Although several spatiotemporal modeling on district-wise aggregated COVID-19 data were carried out in Malaysia [18-20] and specifically for Sarawak [21], to our best knowledge, no such geo-visualization and geospatial analysis were performed for COVID-19 exposed location point data within a division in Sarawak. Motivated by several studies on examining the distribution of the contagion by COVID-19 in urban environments of a city in Spain [22] and China [23] using authentic but anonymized microdata of infected people, this paper illustrates the utility of QGIS on geospatial visualization and analysis for the communication of publicly available COVID-19 exposed location data in Kuching, Sarawak. The list of exposed locations published to general public is useful for notifying the public on the selected locations visited by an infectious person and can serve as a type of bulletin board contact tracing [24]. By using exposed locations data, but not microdata of infected people as in [22-23], whether the amount of exposed locations listed is sufficient to comprehend the disease intensity can be examined. Besides, this offers a significant case study on how and how much public communication needs spatial related data [25], as well as effective implementation of open-source geospatial software can impact decision-making at finer spatial levels.

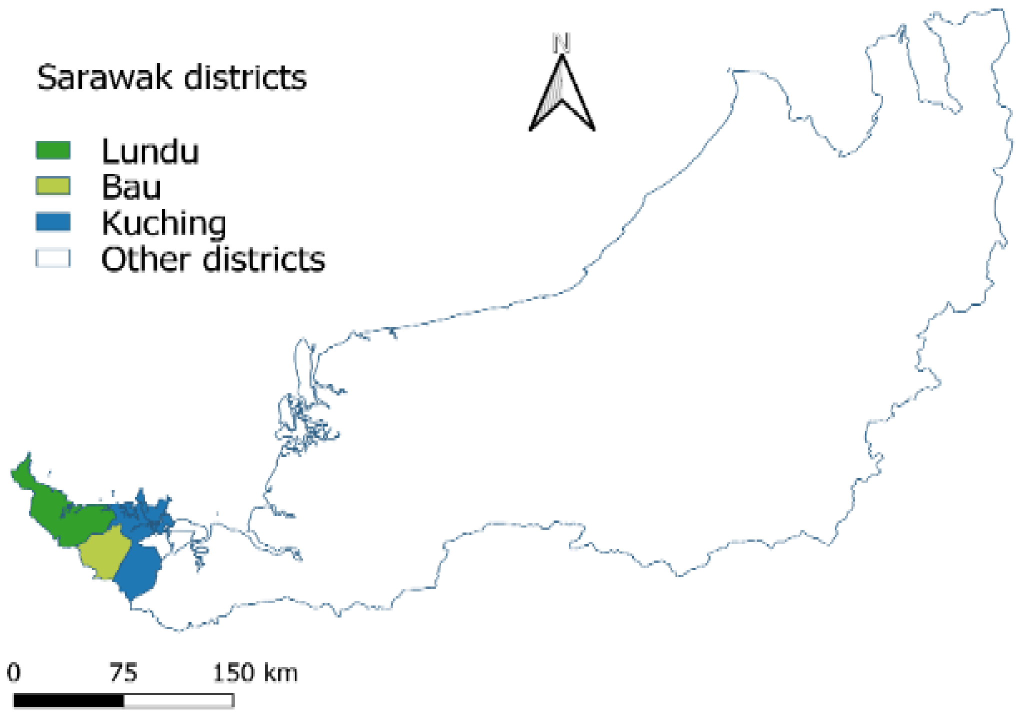
In the following, a brief introduction for the study area is given. The source of Sarawak COVID-19 public available information used for generating geospatial data in this paper is outlined. Map visualization and geospatial statistical analysis produced in open-source geospatial software QGIS are presented to highlight the necessity of transforming textual information into more valuable insights in combating COVID-19 in Sarawak.

2. Materials and Methods

Study Area, Data Collection and Preprocessing

This research uses Kuching Division as the study area for geo-visualization of Sarawak COVID-19 publicly available data employing open-source geospatial software. Sarawak is divided into 12 administrative divisions and further subdivided into 40 districts. The Kuching Division is located in the southwest of Sarawak and made up of three districts, namely Bau, Kuching and Lundu (see Figures 1(a) and 1(b)). The city of Kuching is the capital and most populous city in the state of Sarawak, whereby Bau and Lundu are rural districts with relatively low population density and establishments (see Table 1).

(a)



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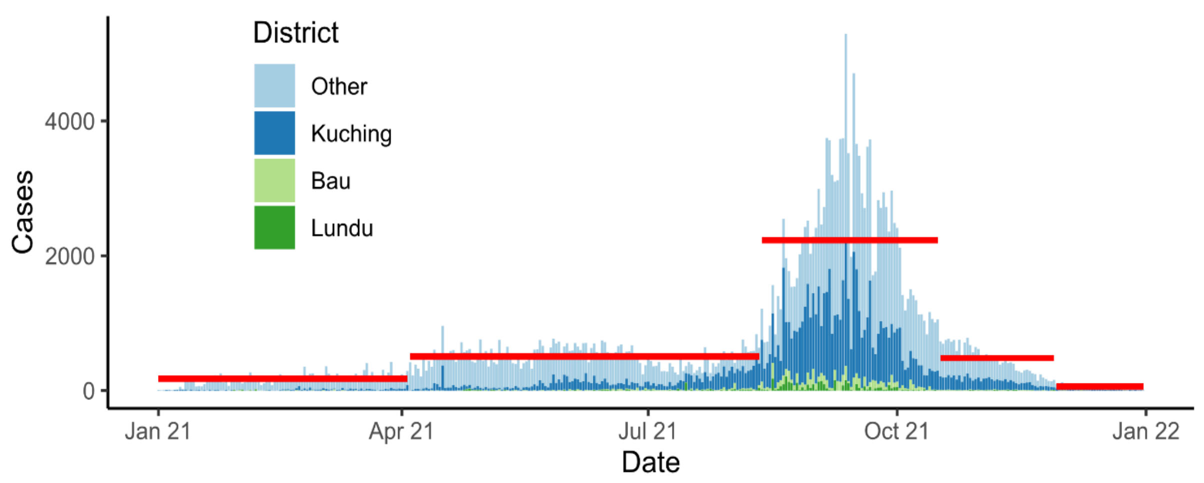


(c).

Figure 1. The three districts (i.e. Kuching, Bau and Lundu) of Kuching Division in (a) Malaysia and (b) Sarawak map. (c) The number of daily confirmed cases in three districts in Kuching Division, as compared to remaining 37 districts (represented by "Other") in Sarawak throughout 2021. The changes in mean value of the confirmed cases are presented by the red horizontal lines

Table 1. The population density of three districts in Kuching division

District	**Population** (people)	**Size of land area** (km^2)	**Population density** (per km^2)	**Establishments**
Bau	61 000	884	69	1 007
Kuching	691 300	1 498	461	24 443
Lundu	38 200	1 812	21	776

Note: Data are from https://dosm.gov.my

The population density is of year 2020 while the number of establishments is of year 2016

This COVID-19 geospatial dataset exploration relies mainly on publicly available information, namely the daily press statements published by Sarawak Disaster Management Committee (SDMC). As a series of COVID-19 waves occurred and the evolution of COVID-19 confirmed cases for Kuching Division is closely resemble the cases in the whole Sarawak for the year of 2021 (see Figure 1(c)), we focus on extracting the geospatial dataset from the list of locations visited by COVID-19 patients prior to being tested positive (see Figure 2(a)), in Kuching Division. This type of locations listed could be considered as one type of bulletin board contact tracing [24] focusing on notifying the public on the locations visited by an infectious person. Although publishing a full complete list of locations visited by all infectious person in the division on manual approach is infeasible, the daily selected exposed locations listed in SDMC are incredibly rich in both temporal and spatial properties. Therefore, it can be utilized to create geospatial dataset to comprehend the transmission dynamics in Kuching Division which comprises of urban and rural districts.

As the highest peak of COVID-19 confirmed cases in Sarawak occurred in the month of September for the year 2021 and its associated abrupt changes in mean found by using change-point analysis used in [26] are on 12 August, 17 October and 29 November, hence it may be sufficient to focus on the exposed locations listed in the SDMC daily press statements ranging from the month of August to November 2021. For creating the location geospatial dataset, the place name of each location visited is converted to latitude and longitude coordinates using Google Maps. This geocoding process for multiple locations can be conveniently carried out by installing a free Google Sheets add-on tool called "Geocoding by SmartMonkey" [27]. As for data validation, the latitude and longitude range check are performed by specifying a lower and upper boundary value to verify whether the geographic data input falls within a reasonable predefined range.

The related temporal information, the date(s) and/or time period of the location visited are important to unfold the space-time spread dynamics at division level. In constructing this location dataset, several assumptions are made. The locations are further subdivided into workplace, eatery (café, coffee shop, restaurant etc.), retail (supermarket, grocery, shopping mall etc.), and others (such as bank, worship places, vehicle service centers). As the time period affected for workplace is usually not recorded, its temporal duration is assumed to be 8 hours. Also, the specific time period affected for social activity (namely eatery, retail and others) is converted to hour so as to be used as a form of weightage in the analysis later. For the purposes of unfolding the space-time pattern of these exposed locations, if one particular exposed location is categorized as workplace, then it will typically contribute to several entries with different dates in our location visited dataset. An example of such entries is given in Figure 2(b) which indicates that the number of point locations in our geospatial dataset can be far greater than the number of exposed locations in SDMC press statements.

6. LOKASI DAN MASA KES POSITIF DILAPORKAN
(Data sehingga **02.08.2021 @ 3.00 Petang)**

Division/District : KUCHING

Name of Exposed Location	Category	Date of Exposure	Time Period Affected
Alu-Ken Powder Coating Sdn. Bhd	Workplace	20 - 23 & 28.07.2021	N/R
Cocoa Wonder, Vivacity	Workplace	20 - 23 & 26 - 28.07.2021	N/R
RHB Bank, Jalan Kulas	Workplace	20 - 23 & 26 - 28.07.2021	N/R
Bank Islam, Simpang Tiga	Workplace	26 - 30.07.2021	N/R
Everrise, Padungan	Social Activity - Customer	24.07.2021	7.15 pm - 7.35 pm
Borneo Supermarket Kuching	Social Activity - Customer	25.07.2021	10.00 am - 10.20 am
Choice Astana	Social Activity - Customer	25.07.2021	7.50 pm - 8.10 pm
H&L Xtra Petra Jaya	Social Activity - Customer	25.07.2021	6.50 pm - 7.20 pm
Chai Jee Kiong Trading, Petrajaya	Social Activity - Customer	26.07.2021	11.10 am - 11.30 am
Warung Bunga Serai	Eatery	29.07.2021	10.00 am - 10.20 am

(a)

A	B	C	D	E	F
Date	Location	Longitude	Latitude	Type	Hours
2021-07-20	RHB Bank, Jalan Kulas	110.334252	1.5544099	Workplace	8
2021-07-21	RHB Bank, Jalan Kulas	110.334252	1.5544099	Workplace	8
2021-07-22	RHB Bank, Jalan Kulas	110.334252	1.5544099	Workplace	8
2021-07-23	RHB Bank, Jalan Kulas	110.334252	1.5544099	Workplace	8
2021-07-26	RHB Bank, Jalan Kulas	110.334252	1.5544099	Workplace	8
2021-07-27	RHB Bank, Jalan Kulas	110.334252	1.5544099	Workplace	8
2021-07-28	RHB Bank, Jalan Kulas	110.334252	1.5544099	Workplace	8
2021-07-26	Bank Islam, Simpang Tiga	110.3560838	1.5370614	Workplace	8
2021-07-27	Bank Islam, Simpang Tiga	110.3560838	1.5370614	Workplace	8
2021-07-28	Bank Islam, Simpang Tiga	110.3560838	1.5370614	Workplace	8
2021-07-29	Bank Islam, Simpang Tiga	110.3560838	1.5370614	Workplace	8
2021-07-30	Bank Islam, Simpang Tiga	110.3560838	1.5370614	Workplace	8
2021-07-24	Everrise, Padungan	110.354736	1.556082	Retail	0.33
2021-07-25	Borneo Supermarket Kuching	110.3025283	1.5688199	Retail	0.33
2021-07-25	Choice Astana	110.3379058	1.5719571	Retail	0.33
2021-07-25	H&L Xtra Petra Jaya	110.3314361	1.5824842	Retail	0.5
2021-07-26	Chai Jee Kiong Trading, Petrajaya	110.3250339	1.5577679	Retail	0.33
2021-07-29	Warung Bunga Serai	110.3901752	1.5558991	Eatery	0.33

(b)

Figure 2. (a) A screenshot of the list of exposed locations in a daily press statement published by Sarawak Disaster Management Committee (SDMC). (b) A screenshot of part of the exposed location geospatial dataset created

QGIS and Its Plugins for Geo-visualization and Geospatial Analysis

QGIS (Quantum GIS) is a free and open-source geographic information system (GIS) created by the QGIS Development Team since 2002 that supports viewing, editing, analysis and publishing of geographical spatial data and cartography. QGIS version 3.24.3 together with several plugins for geo-visualization and geospatial statistical analysis used in this paper are briefly encapsulated in Table 2.

The location visited point data is first visualized through QGIS. In particular, the open-source base map, Open Street Map (OSM), is used as the study area map layer by zooming to Kuching Division. The static map of location point is created by adding its csv file as delimited text layer and defining its symbology. Then, the static map is transformed to incorporate temporal animation through its Temporal Controller. This is a feature available from QGIS version 3.14 onwards which supports temporal animations of spatial data. Also, the map visualization could be published and shared with others in the form of interactive web map created through its qgis2web plugins and QGIS cloud services.

Apart from this map visualization, we also make use of geo-statistic tools in QGIS to perform geospatial statistical analysis on the COVID-19 location point data extracted. This includes calculating the centrography-based descriptive statistics such as mean center and standard deviation ellipse (SDE) for point data in order to obtain the center and its directional trends of exposed location in different temporal duration, for instance on a bi-weekly basis. This allows us to identify the possible shift of spatial tendency for the exposed locations. The process of geo-visualization and geospatial analysis in this paper is summarized in Figure 3.

Table 2. The brief description on the plugins used for geo-visualization and geospatial analysis

Plugin	Extended features or functions used
QuickMapServices and QuickOSM	For adding base map Open Street Map (OSM) to QGIS project
qgis2web	For generating an interactive web map as Leaflet (or Open Layers) without requiring server-side software
Standard Deviational Ellipse	For producing the standard deviation ellipse as a polygon vector layer by using the default Yuill method with (or without) weighting

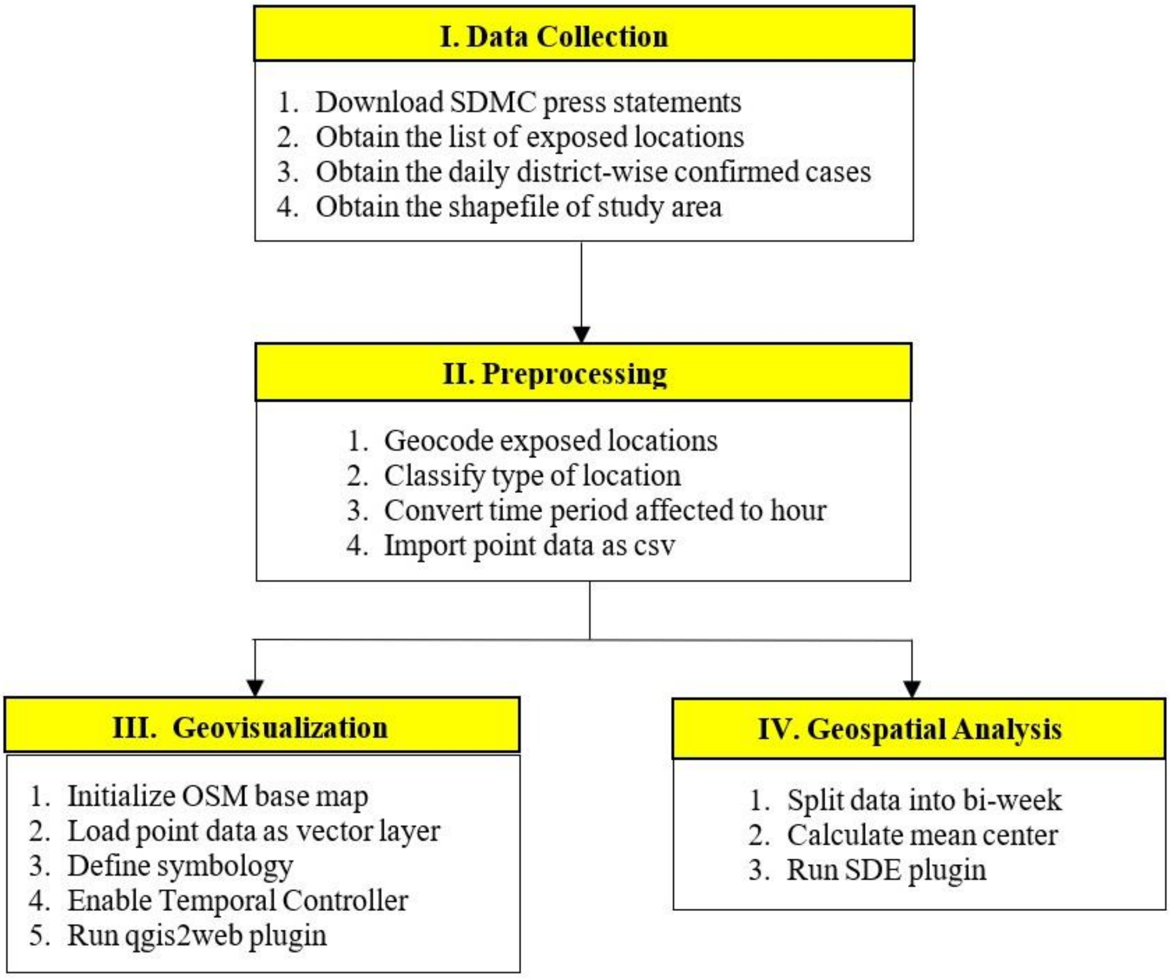


Figure 3. The process of geo-visualization and geospatial analysis with QGIS

3. Results and Discussion

Geo-visualization of Exposed Location Data

The dates for the time period affected of the exposed locations within Kuching Division appeared in daily press statements published by SDMC for the month of August to November 2021 span from 18 July to 25 November 2021, as shown in the animation range of Temporal Controller at the top of Figure 4. By setting the event duration to 1 day, the space-time pattern of exposed locations in division level can be viewed on daily basis, in which all locations visited by COVID-19 patients prior to being tested positive, for instance, on 10 September 2021 are given in Figure 4.

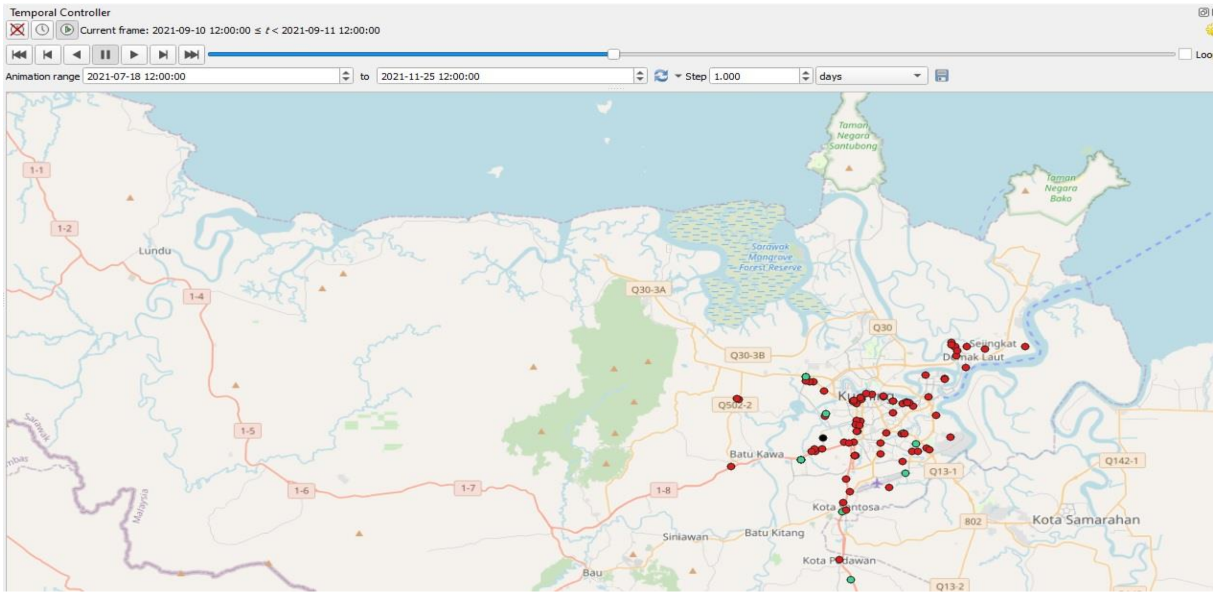


Figure 4. A screenshot for all locations visited by COVID-19 patients on 10 September 2021 prior to being tested positive. Red, green and black dots represent workplace, retail and eatery, respectively

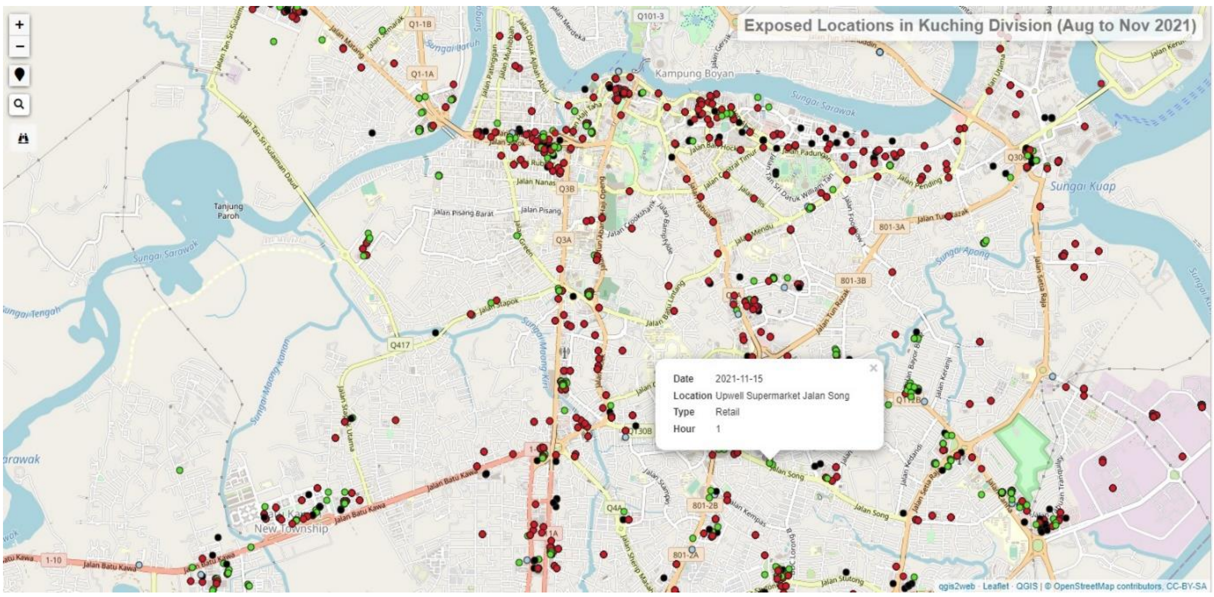
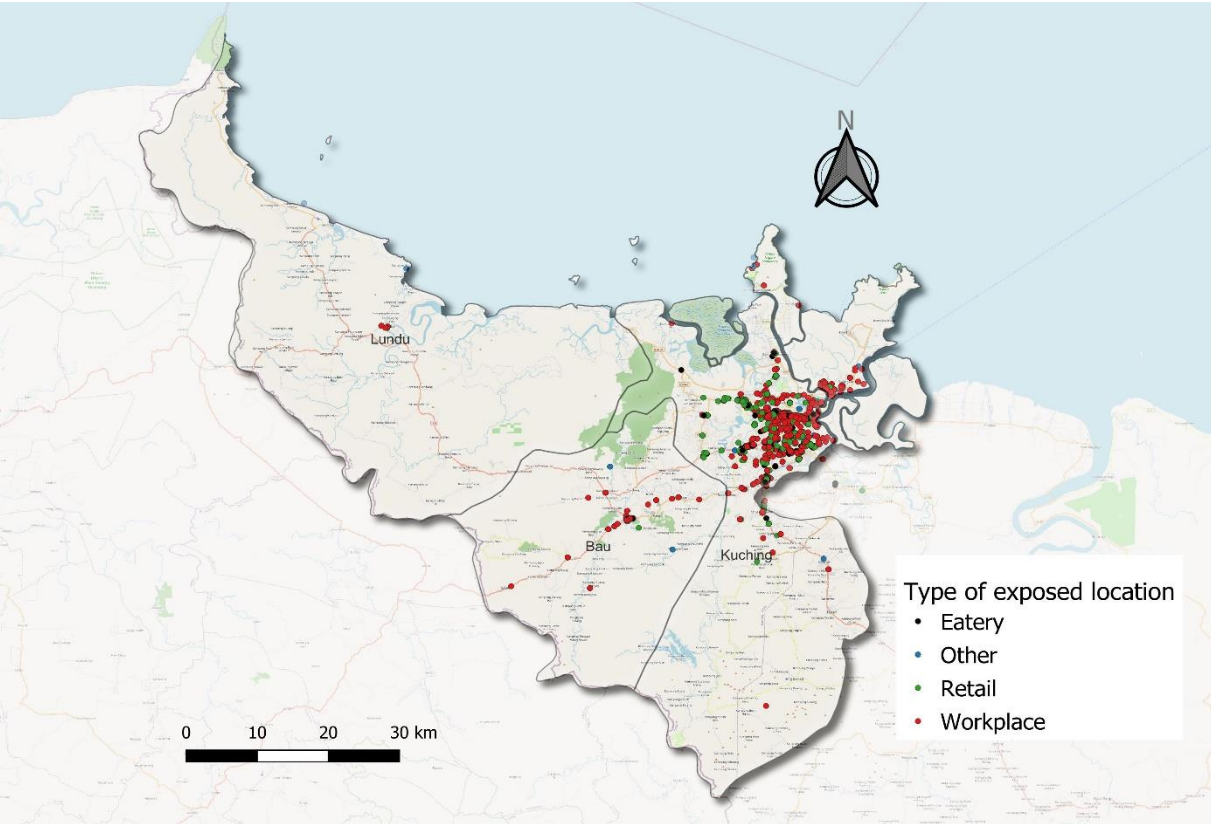


Figure 5. A screenshot of interactive web map for exposed locations in Kuching Division created using qgis2web plugin

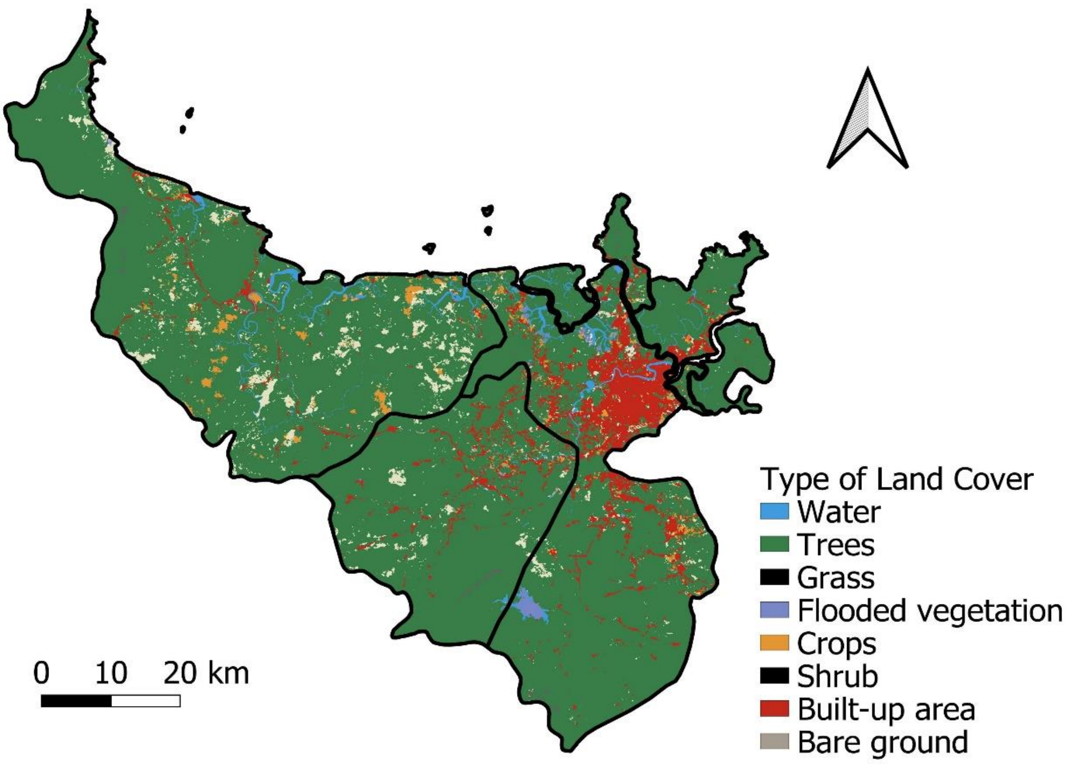
Without requiring server-side software, an interactive web map could be generated by using qgis2web plugin. By ticking the check boxes for "Add address search", "Geolocate user" and "Highlight on hover" in its Appearance dialog box, a map can be conveniently created on the fly and exported in a desired folder which contains all the required files (i.e. css, data, images, js, legend, markers, webfonts, index.html) for creating a web map. Figure 5 gives a screenshot of interactive web map for exposed locations in Kuching Division created using qgis2web plugin.

Results of Geospatial Statistical Analysis

We first give the overview on the spatial pattern of all the location point data (see Figure 6(a)) collected from the list of exposed location (i.e. the locations visited by COVID-19 patients prior to being tested positive) under Kuching Division published by SDMC from 1 August to 30 November 2021. Overall the distribution of the exposed locations does not spread homogeneously in the division. When comparing these location points to the land use map of Kuching Division (see Figure 6(b)) by bare eye inspection, it can be seen that a large majority of the location points may be associated to the built-up areas within Kuching Division. From the number of establishments in the respective district shown in Table 1, it may indicate that the exposed locations are more related to socioeconomic conditions in the three districts of the study area. Besides, 6175 out of 7328 (or 84%) locations visited by COVID-19 patients in our extracted dataset fall under category of workplace and this is clearly depicted in Figure 6(a). This agrees with the finding that the workplace clusters represent the highest percentage of all clusters in Malaysia [28] and disease prevention measures have to be targeted on high-risk areas such as the workplace. It is also worth mentioning that the exposed locations listed under a division might go beyond the administrative boundary of that division, as depicted by several points outside Kuching Division in Figure 6(a). This may suggest that the inter-division travel ban is challenging to impose due to the nature of road connectivity for Kuching Division and its nearby divisions.



(a)



(b)

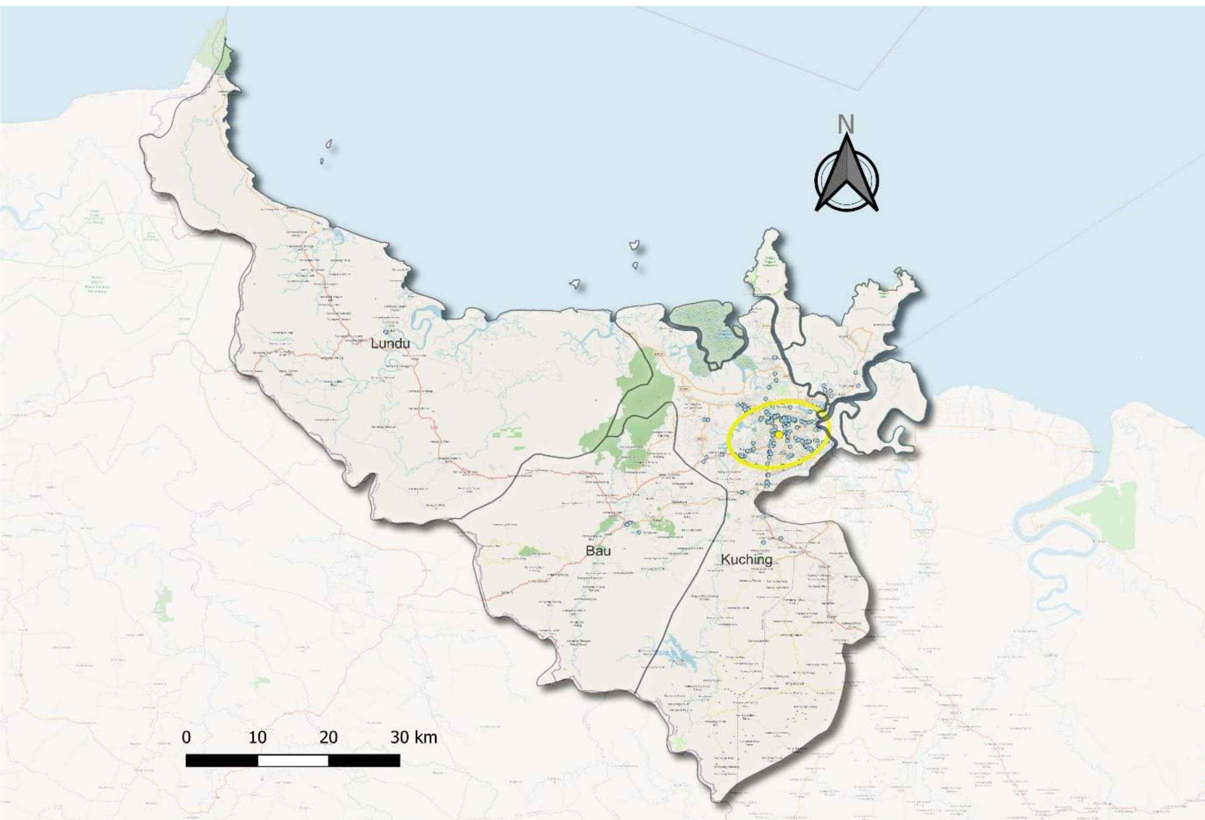
Figure 6. (a) The map shows all the location points collected from the list of exposed location under Kuching Division published by SDMC from 1 August to 30 November 2021. (b) The Sentinel-2 imagery of land use map for Kuching Division

Table 3. The average number of daily cases in Kuching Division and the number of point locations for 8 different selected bi-weekly periods

Period	Dates	Total number of cases	Average number of daily cases	Number of point locations	The coordinates of mean center (longitude, latitude)
1	2 – 15 Aug	5 372	383.7	740	(110.34683, 1.53366)
2	16 – 29 Aug	13 965	997.5	750	(110.31712, 1.52879)
3	30 Aug – 12 Sept	18 882	1 348.7	1 232	(110.34861, 1.53593)
4	13 – 26 Sept	15 413	1 100.9	1 048	(110.34504, 1.53025)
5	27 Sept – 10 Oct	8 823	630.2	819	(110.34831, 1.53570)
6	11 – 24 Oct	3 291	235.1	955	(110.34587, 1.53412)
7	25 Oct – 7 Nov	2 491	177.9	828	(110.34461, 1.54499)
8	8 – 21 Nov	1 715	122.5	578	(110.34524, 1.54168)

The daily exposed location data are then grouped into bi-week periods (see Table 3) by following the temporal scale chosen in [22], whereby 14 days represent the common official estimated range for incubation period used in COVID-19 pandemic. By all means, the aggregation of geospatial data into different temporal durations has significant effects on the pattern detected, which is part of the more theoretical framework of the Modifiable Temporal Unit Problem (MTUP) [29] and may require another study. Apart from that, in order to examine whether the amount of exposed locations listed by SDMC as a type of bulletin board contact tracing is sufficient or not to comprehend the disease intensity, the total number of COVID-19 confirmed cases recorded for all three districts (Bau, Kuching and Lundu) in Kuching Division in those bi-week periods is also presented in Table 3. Even though the list of exposed locations only covers a very small subset of daily activities of COVID-19 patients in Kuching Division prior to being tested positive, it is found that the correlation of the number of point locations in bi-week period and the average number of daily confirmed cases is 0.693, which demonstrates a moderate to nearly strong correlation between the two variables. This implies that the small number of exposed locations listed in SDMC daily press statements as a form of bulletin board contact tracing is surprisingly valuable and sufficient for showing a good representation on the space-time pattern of COVID-19 transmission dynamics at the division level to the general public. This may further support the claim in [25] that the evolution of the disease in time and space, which also includes the location visited by COVID-19 patients prior to being tested positive used in this study, ought to be paired with a need for awareness and of effective visualization of the dynamics of disease pattern.

We next carry out central spatial tendency analysis on the bi-weekly exposed point locations for the quantitative assessment of possible changes in locations or times. More concretely, we find the weighted mean center and standard deviation ellipse (SDE) of all the location coordinates for each of these bi-week periods (see the last column of Table 3). The SDE, also known as directional distribution, is used for summarizing the spatial characteristic of geographical features such as central tendency and dispersion, and also making a basic judgement on the directional trends [30] of the exposed locations. This SDE analysis mainly aims at characterizing the activity space of the COVID-19 patients prior to being tested positive. Figures 7(a) and 7(c) depict all the point locations together with their mean center and SDE for highlighting the spatiotemporal concentration of exposed locations in Kuching Division, in Period 1 and 5, respectively. Meanwhile, Figures 7(b) and 7(d) focus only on the mean center and SDE for the first four and last four periods, respectively. Except for Period 2 (denoted as red dot and ellipse, in east-west direction, in Figure 7(b)), the exposed locations appear densely throughout the eight periods, in time and converge on the center of build-up area in the city of Kuching, in space. This reflects that the exposed locations mostly distribute closely, with south-west to north-east direction in Period 3 to 6, switching gradually to south-east to north-west direction in Period 8. To some extent, the SDE is largest in Period 2. This suggests that COVID-19 patients might have a larger activity space in that period which is about two weeks prior to the epidemic peak. This finding on the spatial and temporal changes of exposed locations in urban space of Kuching could assist local public health officials in making decision for employing more effective control strategies to curb the disease spreading in the finer scale of division level.



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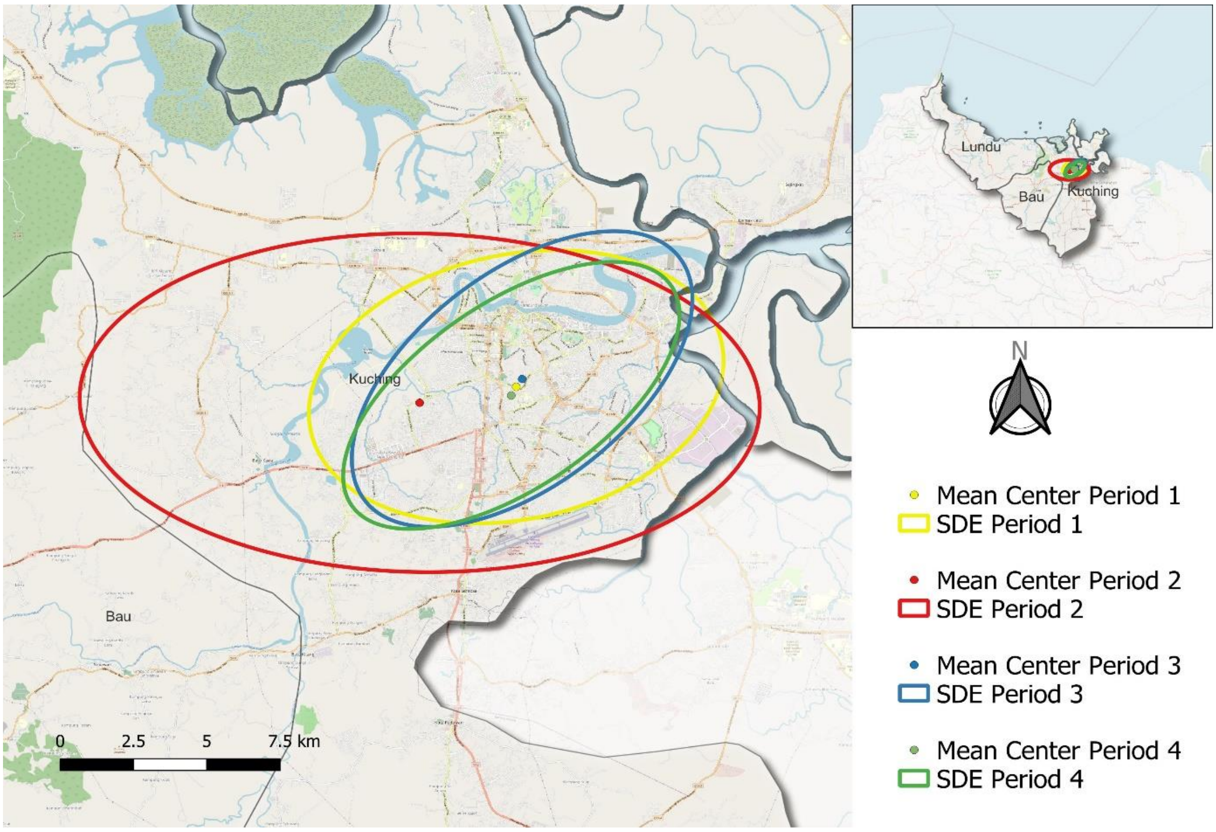
Kuching
Bau
0 2.5 5 7.5 km
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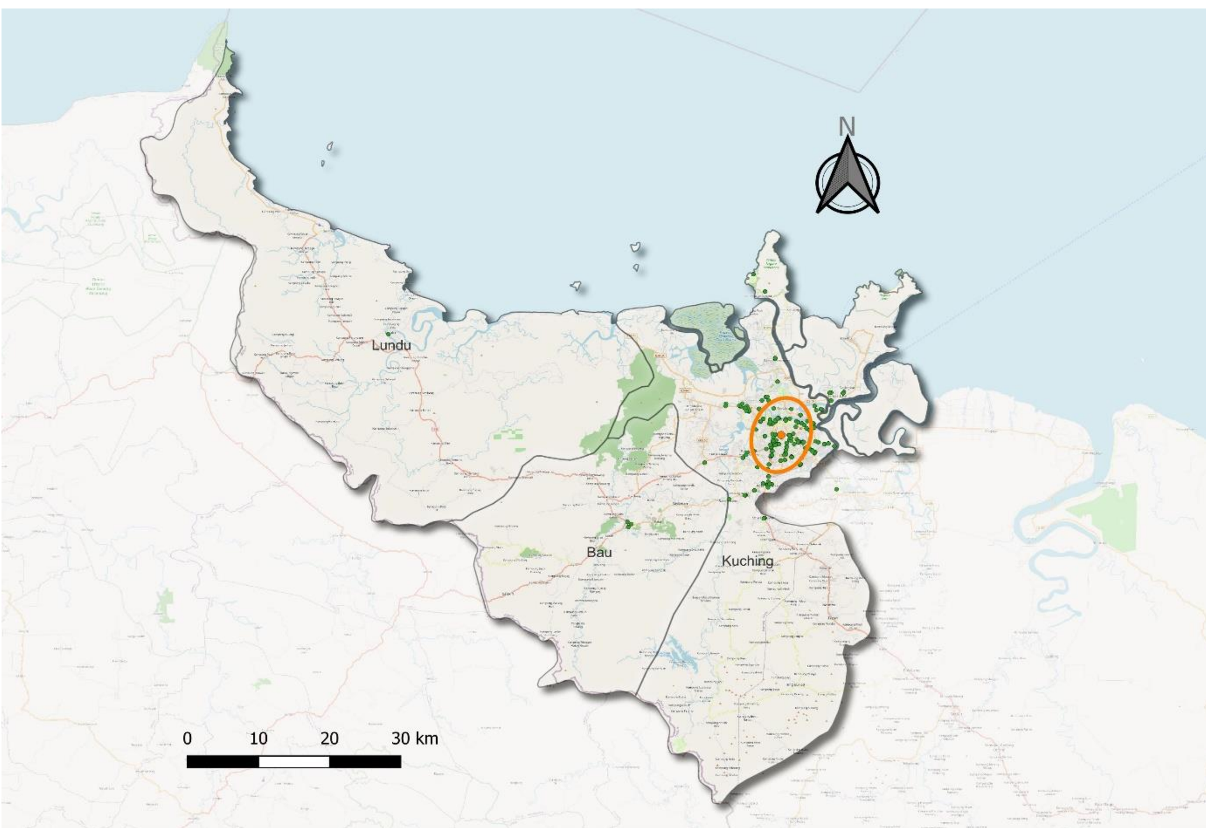
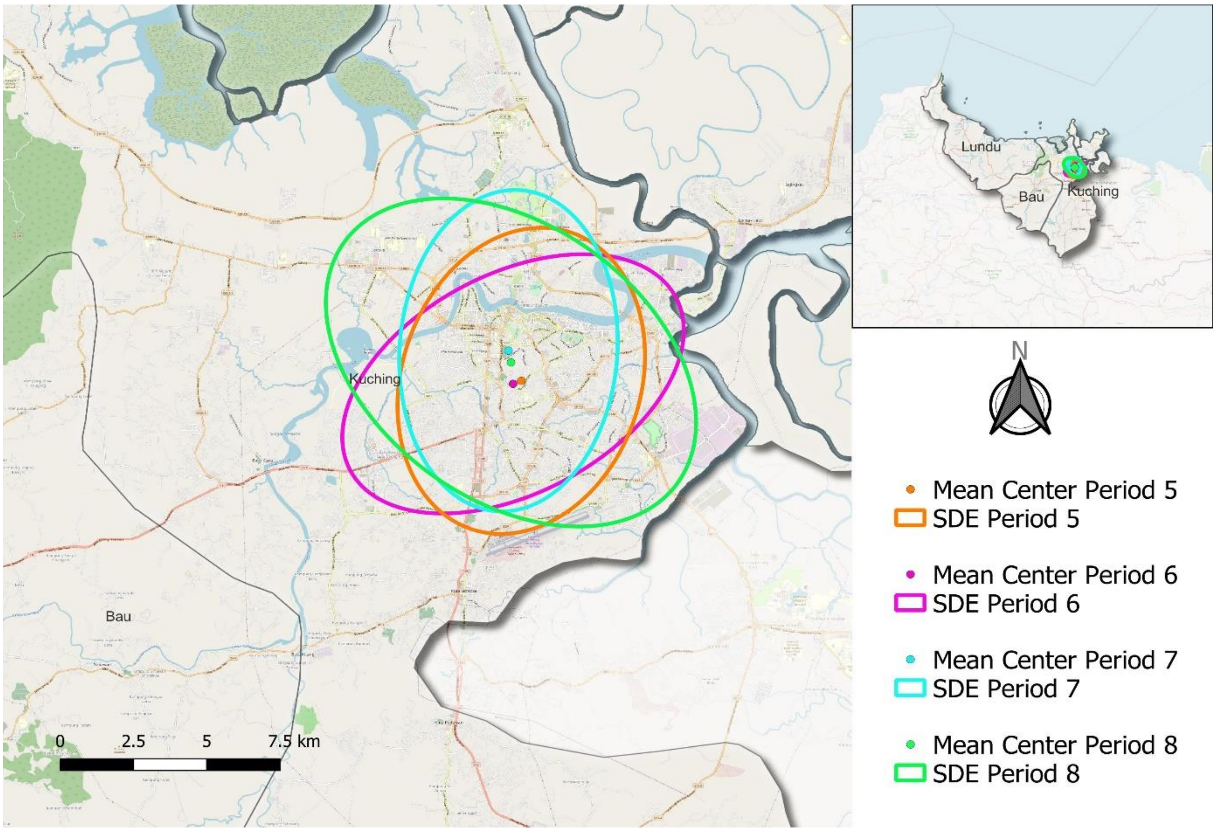
Mean Center Period 4
SDE Period 4

(b)


N
Lundu
Bau
Kuching
0 10 20 30 km

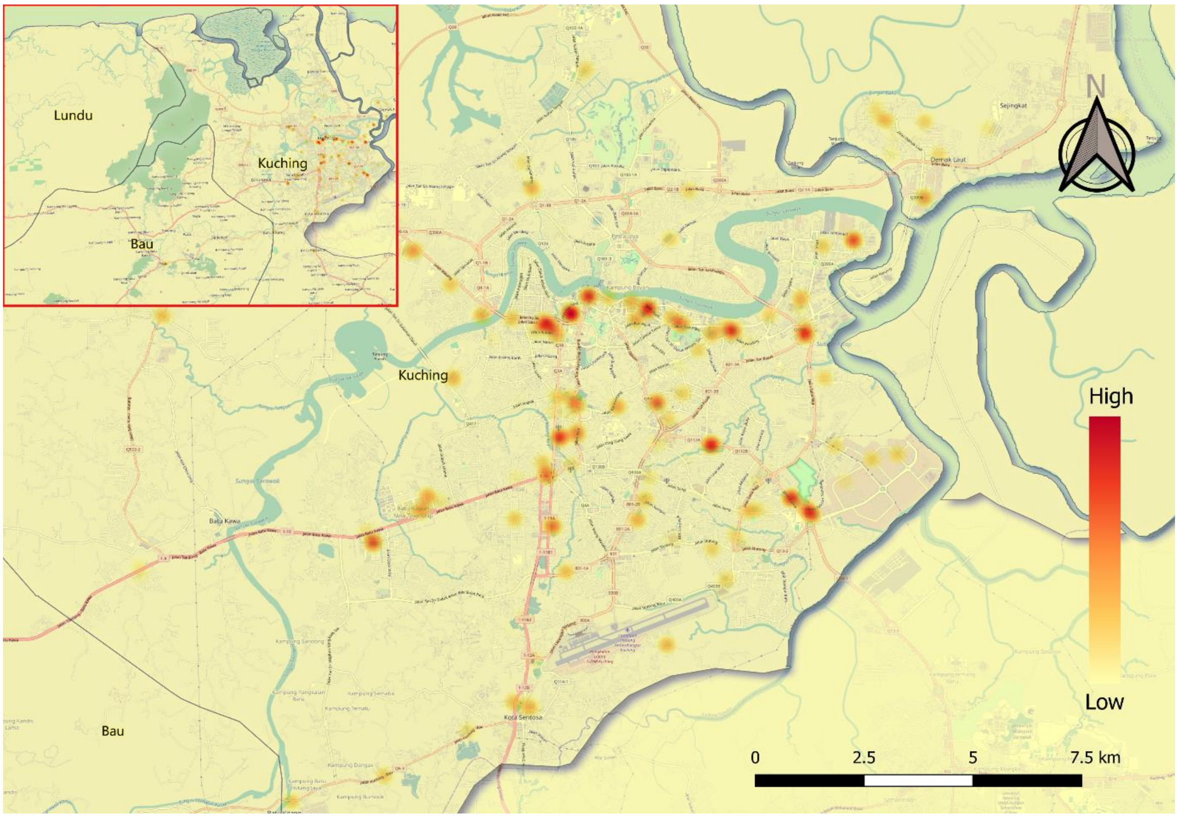
(c)



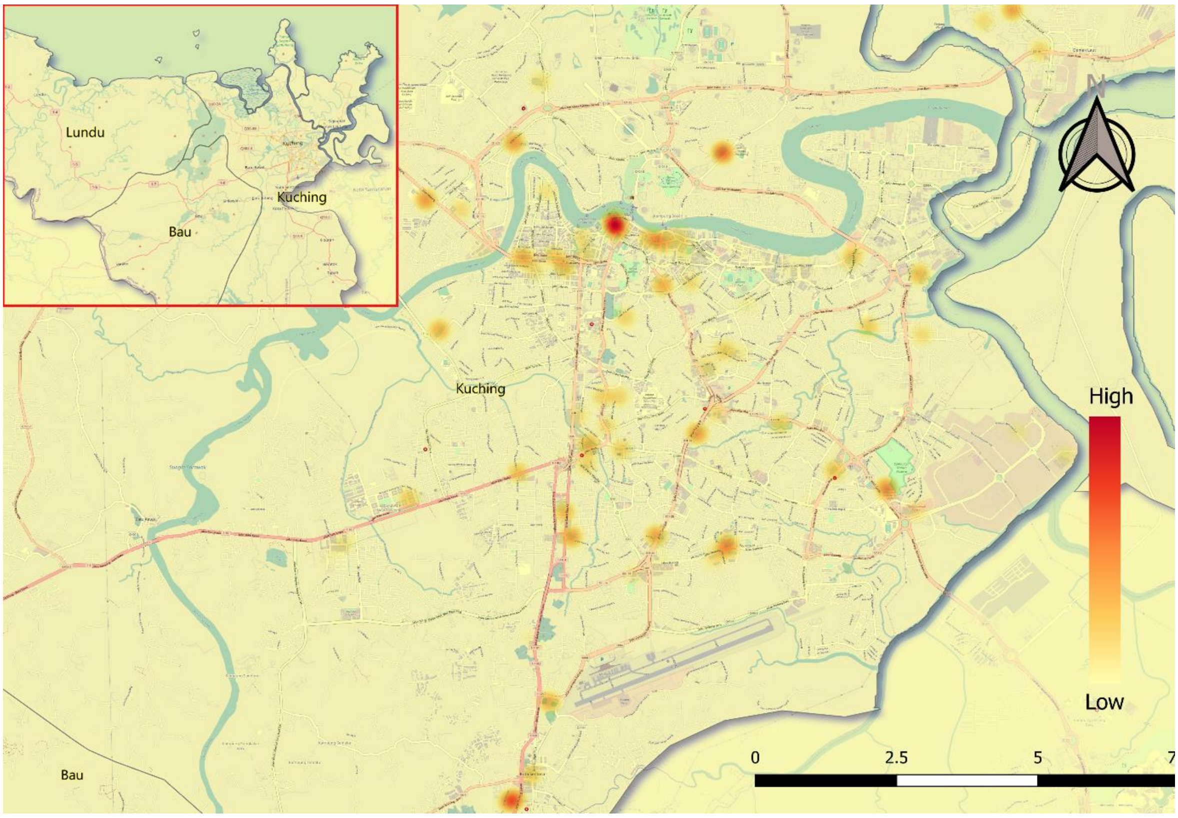
(d)

Figure 7. (a) The mean center and SDE, together with the exposed locations for Period 1. (b) The zoom-in view of the mean center and SDE for Period 1 to 4. (c) The mean center and SDE, together with the exposed locations for Period 5. (d) The zoom-in view of the mean center and SDE for Period 5 to 8

In addition to mean center and SDE, the relative density of the exposed locations in the Kuching division in selected periods is shown in the form of geographic heat maps in Figure 8. Through heat maps, the hotspots and clustering of points could easily be identified. Period 4 (see Figure 8(a)) gives more hotspots if compared to Period 8 (Figure 8(b)) partly because the total number of confirmed cases in Period 4 is much higher. The spatial distribution of hotspots detected in Period 8 agrees well with its corresponding SDE as given in Figure 7(d). Such detection of hotspots can be useful for local public health authorities to identify areas that may require more strict control measures to control the spread of COVID-19.



(a)



(b)

Figure 8. The geographic heat map of exposed location in Kuching division for (a) Period 4 and (b) Period 8

4. Conclusion

This research examines the potential of extracting geospatial data from publicly available information published by the Sarawak Disaster Management Committee (SDMC) on COVID-19 exposed locations in Kuching Division for the month of August to November 2021. The geospatial dataset created is then visualized and analyzed with the help of open-source geospatial software QGIS. This translates the daily textual information on COVID-19 exposed locations into geographical map for better spatial temporal visualization at finer scale within Kuching Division. The geospatial statistical analysis can also be performed for gaining more valuable insights into the central spatial tendency of the exposed locations in any selected temporal scale. Therefore, this study serves as a practical example on how such easy-to-use geospatial software can be of benefit to local public health authorities in better informing the general public on the possible locations with risk of infection characterized by the geo-visualization support, rather than static text information. Insight obtained from such geo-visualization and its subsequent geospatial analysis may also alleviate the sense of fear and uncertainty brought by epidemics to the general public as the daily information can be easily aggregated, summarized and visualized in suitable temporal scale.

In general, the exposed locations do not distribute evenly but concentrate on the build-up areas in Kuching Division where the socioeconomic activities take place. Although the list of exposed locations only captures a very small subset of workplaces and/or daily activities of all COVID-19 patients, its resulting number of point locations almost correlates strongly with the average number of daily confirmed cases and therefore serves as a good indicator in informing the general public on the intensity of disease transmission at division level. Through geospatial analysis on bi-weekly basis, the distribution of exposed locations is found to be in south-west to north-east direction of the center of Kuching City in September and October, switching gradually to south-east to north-west direction in November 2021. This spatial and temporal pattern analysis could assist local public health authorities in decision making and employing more effective control strategies to curb the disease spreading at division level.

However, the process of extracting the exposed locations for geocoding, geo-visualization and its ensuing geospatial analysis are still not implemented in a full automation way. Perhaps an integrated user interface of the existing applications could be developed to facilitate and speed up the output of its geo-visualization and analysis. By this means, the findings in this paper could be verified by extending the study area to other divisions in Sarawak. Also, other forms of information available in the SDMC press statements such as infection cluster and localities under Enhanced Movement Control Order (EMCO) could also be considered to probe into the infectious disease exposure and control strategy perspective.

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