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Research Article

Geospatial infrastructure solutions for local government sectors: geo-enabling infectious disease monitoring system in state health departments

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Abstract
Nowadays, airborne disease is one of the most killer diseases, in particular among a high urban population and uncontrolled movement activities of low socio-economic communities. Most local health departments in poor developing countries have difficulty in fully applying geospatial technology for local agencies due to high-cost and technical skills. This study demonstrates the ways to develop a low-cost and minimal-skill disease system for the local health government sector using the ArcGIS solution platform in Selangor, Malaysia. Features and functions of ArcGIS such as ArcGIS Pro, ArcGIS Online and Web Apps were explored for the disease mapping, data analysis and system development. By focusing on tuberculosis (TB) cases as examples, the result showed that a TB monitoring system was developed by fulfilling the user requirements. The system displays the database and mapping of the cases and spatially analyses the cases. A geospatial solution platform, mainly ArcGIS could assist the local organisations in managing the disease datasets in a systematic way.

Keywords
IS, Geospatial, ArcGIS solution, Disease system, Spatial health, Local and state governments.

1.Introduction
Tuberculosis (TB) disease is one of the most common diseases among Selangor citizens, Malaysia, due to the high population density, particularly in urban areas and low socioeconomic strata. TB's death rate was nine times higher in Selangor last year, according to the statistics from the Selangor Health Department [1]. There were 3423 cases of TB recorded in 2012 and 5,071 cases of new TB cases recorded in Selangor in 2018; Sabah 5,008; Sarawak, 3,122; Johor, 2,150; and Kuala Lumpur / Putrajaya, 2,017. Out of 5,071 patients in the state, 367 died from the disease last year [1]. TB often appears in informal sources, such as the news media, before disease outbreaks become well known. There are a number of software’s that can integrate and elaborate TB disease data accurately, and one of these software’s is ArcGIS. The map visually organises news reports to show the global status of human and wildlife disease.

Geospatial technologies such as geographical information systems (GIS) are commonly used to chart, analyse, and interpret data related to a specific geographical location and disease distribution [2–6]. Besides basic mapping, a GIS has several powerful features, which include graphical analysis based on spatial position. GIS consists of computerised information systems that allow accessible spatial data to be collected, gathered, processed, manipulated, examined, interpreted, demonstrated, documented, and published. It is a powerful tool for global sources to retrieve, interrogate, transform, and view spatial data. GIS can serve as a decision support system that requires incorporating all the georeferenced data into an environment where problems are resolved.

Geo-enabled health information system (HIS) is a geoinformation system that makes full use of geospatial data and technology in the health field. Geo-enabled HIS involves a clear vision of the strategy and plan as a governance framework, technological resources, data requirements, standards and protocols, and master lists is placed in a GIS

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toolset to ensure the proper use of geospatial data and technologies. Geo-enabled HIS benefits the health sector by using GIS as a common and impartial integration and analytical tool that goes beyond thematic mapping, fostering data continuity across sources, eliminating duplication of effort, and thus cost-effective data management. The system also allows several public health problems to be approached simultaneously from a more comprehensive viewpoint and the use of maps for planning and decision-making [7].

There is great need for health administrators, professionals and study to be trained and get user support in geospatial technology, data and epidemiological methods in order to use the GIS properly and effectively [8, 9]. The use of GIS in public health still remains primarily in the hands of technical specialists who themselves have no knowledge of public health matters, thus there is a need to empower health administrators by providing GIS platforms that are simpler to operate. Though simplified systems can be made to work on computers that are available to public health workers, these systems require the highly-skilled people. Therefore, Esri ArcGIS products are designed to deliver location intelligence and meet digital transformation needs for organizations of all sizes. ArcGIS is a geographical information system for working with maps and geographic information. The interactive spatial analysis tool enabling the concerned departments to improve the performance of the health sector and to perform re-districting, re-locating health jurisdictions for effective utilization of health infrastructure.

Integrating data from multiple sources and formats is also part of Esri Geospatial Cloud, ArcGIS Online, and Web Apps to allow people, locations, and data to be connected using interactive maps [10]. This study aims to create a disease monitoring system at a minimal cost and easy way that help the government agencies and the public stay abreast of ongoing developments. An evaluation is then carried out to study ArcGIS software capabilities such as ArcGIS Pro, ArcGIS Online, and Web Apps to process the data and the map. The examination of TB disease hotspot in the Selangor with this particular ArcGIS tool is conducted properly using the ArcGIS platform. Several local studies have shown that geo-enabled health information system (HIS) could be adapted in TB epidemiology elements through people, time, and place [11–13, 14, 8, 9]. In particular, this study consists of two main objectives; i) to explore the capabilities of ArcGIS products (ArcGIS Pro, ArcGIS Online and Web Apps) for the local health application and ii) to create an airborne disease information system in the study area using ArcGIS products.

2.Literature review

Geospatial technology capabilities for local and state applications have been empirically conducted in the developed countries [15, 16]. For example, a Geo-HIS is an information system that fully benefits from the power of geography and geospatial technologies. Effective management and use of geospatial technologies support efforts to achieve universal health coverage (UHC). They also encourage the exchange and use of information by interoperability systems, particularly in countries with weak registration systems. The technology helps to analyse trends in health data by taking into account changes in geography over time [17].

An Australian expert [15] demonstrated how tools and processes in geospatial technology are applied to produce a smart infrastructure dashboard in Australia towards supporting the local governance of infrastructure services. In the local context, the Malaysia Geospatial Data Infrastructure (MyGDI) instituted national initiatives to promote geospatial information sharing infrastructure, raise awareness of the availability of geographic technology, and positively contribute to geographic technology among participating parties. The importance of spatial data infrastructure (SDI) as a framework has been addressed by [18] for geographic information, standards, policies, resources, geographic information system, technical infrastructure, metadata, and legal procedures for both the distribution of geospatial activities and resources.

A common SDI of Malaysian disease framework has been introduced by [4, 19, 20, 8]. They utilized a geospatial tuberculosis information system (GeoTBiS) as a geospatial decision support system to improve the existing system functions and a range of suggestions for practical use in Selangor. There is an urgent need for health administrators, professionals, and study to be trained and to obtain user support in GIS technology, data, and epidemiological methods to use the GIS properly and effectively [21]. As a part of Esri, ArcGIS Pro supports data visualisation, advanced analysis, and authoritative data maintenance in both 2D and 3D. There are several application areas in public health management where GIS as a spatial decision support system (SDSS) can be applied [22]. ArcGIS Pro is closely linked to the ArcGIS platform supporting data sharing across ArcGIS Online through Web GIS.

Esri ArcGIS products made to deliver location intelligence and address the digitalisation needs of large organizations. ArcGIS is the most versatile and expandable geographic information system for interacting with maps and geographic information. It can examine the mapping populations at risk and the stratifying risk factor, analysing the distribution, preparation and allocation of intervention. The products are also beneficial for monitoring diseases and measures over time as dot maps to display health incidents, choropleth maps, and diagram maps to portray quantifiable information on the map. For example, the ArcGIS Solutions Deployment Tool is an ArcGIS Pro Add-in in 2020 consents users to browse a catalogue and deploy them to an ArcGIS Online organization. During deployment the tool will create the items, groups, feature layers, maps, and applications that make up the ArcGIS Solution. When deployed, the solution can be customized to suit the unique needs of your company by changing the items generated during deployment.

Geospatial technologies as innovative approaches could help them manage the risk-decision making of extreme events or smart organizations by integrating with social network analysis [23], big data and prescriptive analytics [24, 25], IoT-cloud enabled SDI architecture [26] and open-source GIS [27]. The technologies will help geospatial community and SDI developers in various perspectives, including data sharing and management, interoperability, security and reliability, fault tolerance, mass market solution, upfront cost and global collaboration [26].

3.Methods

Figure 1 shows the flow chart of this study's methodology, which includes several guidelines and stages for analysing and mapping the result. Every stage needs are executed accurately, as the data gathered will affect the result obtained during data processing. Thus, accurate and precise data are necessary to minimise the error for generating a good result. The stages consist of project planning, data collection, data processing, data analysis and result, mapping of TB, analysing the spatial pattern of TB, and evaluating the functional capabilities of ArcGIS Pro, ArcGIS Online, and Web Apps tools for the map, analysis, and system design.

Preliminary study	- identify the study area - identify disease cases and user requirement
Data collection	- tuberculosis cases for the Ministry of Health - questionnaire
Data processing	-using Esri platforms
Data analysis **Data display**	- map and analysis - system testing whether it can perform successfully, fail or moderate and can be improved

Figure 1 Flowchart of the general methodology

3.1Study area

The study area that has been chosen for this study is the State of Selangor, Malaysia. The hardware that has been used in this study is Acer Aspire E15 (E5-575G-52AA) personal computer., while Esri product which is ArcGIS Pro Web Apps/, ArcGIS Online (AGOL) used to perform GIS applications. It is located in the heart of Peninsular Malaysia on the west coast and surrounds the Federal Territories of Kuala Lumpur and Putrajaya. The state also borders Perak to the north, Pahang to the east, Negeri Sembilan to the south, and Melaka's Straits to the west. Selangor is generally a sloping area. It is located between the Titiwangsa Range and the Straits of Melaka. The state of Selangor is divided into 9 districts, namely Gombak, Hulu Langat, Hulu Selangor, Klang, Kuala Langat, Petaling, Kuala Selangor, Sabak Bernam, and Sepang. The total area of the Selangor state is 8,104 km². The state capital of Selangor is Shah Alam, and its royal capital is Klang.

3.2Preliminary study and data collection

In project planning, the process of selecting the study area was taken firstly by selecting Selangor. Furthermore, the secondary data of the TB disease data used in this study were obtained from the State Health Department, Ministry of Health Malaysia. The Selangor state boundary was sourced from a digitising base map using ArcGIS software. Thus, to get the data for user requirements, a questionnaire created using Google form was then structured and distributed to the respondents. The questionnaire is divided into three (3) parts consisting of 11 questions. The questions include demographic information such as gender, working sector either in government or the private sector etc. The questions also included a section on understanding the health workers in Selangor's knowledge of geospatial application, such as respondents' skill and knowledge about GIS. The questionnaire also covered data protection, the information system used, geographical details in disease, and the last part is opinions on the information about the proposed system.

3.3 Data processing

The data and the boundary used in the study were processed by using three different ArcGIS product which is ArcGIS Pro, ArcGIS Online and Web Apps. Data processing and preparation were performed to change and take into account the current information to organize the data, making it simpler and easier to perform information analysis. Besides, the data processing carried out in flow charts was organized in the earlier stage of the project or studies to avoid redundant or unnecessary data. The first stage of the data processing in this study is the geocoding process to insert and find TB patients' coordinates by utilizing the addresses given. The processing was conducted by applying the Esri product such as ArcGIS Pro. This stage involved using the tools that are provided by the Esri platforms.

3.4Data display and system development

The data processed in 3 different ArcGIS platforms were produced in map form, in which the layout may be different based on the platform, and the web application was displayed on the map. The authors developed the desired web application or system following the user's requirement as conducted in the previous preliminary study at this stage. The requirement demanded from the target user is understandable and further identified to be converted into design documentation. From the documentation constructed based on basic needs, the authors were able to design a homepage representing an earlier perspective of the system to be applied in the development phase. This process is made using ArcGIS Pro, ArcGIS Online, and Web App Builder license registered under GeoUiTM.

Web App Builder used to develop a web mapping application for monitoring TB disease cases can be linked to ArcGIS Pro and ArcGIS Online. As a developer, user could get ArcGIS Pro, ArcGIS Online and Web AppBuilder license registered under GeoUiTM Portal and managed to get the software needed such as ArcGIS Pro equipped with license and ArcGIS Online and Web AppBuilder version easily.

4.Results and discussion

This section discusses the results and analyses of the datasets after data processing. ArcGIS Pro, Web App Builder for ArcGIS Online was used to create the application to achieve the desired output. The results and analyses are based on the primary objectives of this study, which include:

• To explore the capabilities of ArcGIS Pro, ArcGIS Online, and Web Apps for disease mapping and analysis in Selangor.

• To create a TB disease information system in Selangor using the ArcGIS platform to map and analyses the TB disease in Selangor.

4.1Exploring potential capabilities of ArcGIS products for the local disease applications

In general, ArcGIS Solutions for local government includes a series of targeted maps and applications designed to help local governments leverage their geographic information and the ArcGIS Platform to improve government activities and services delivered to the general public [28]. In the context of health applications, ArcGIS Online is a cloud-based mapping tool for organizations that can be used anywhere on a smartphone, web browser, or desktop application. Organizations can sign up and use this secure platform to manage, build, store, and access hosted resources, maps, and applications. For example, it can be used to access a collection of maps and applications used to communicate the severity of the opioid epidemic, promote treatment alternatives, and understand response activities' effectiveness [29].

ArcGIS Pro is an effective public health tool. The GIS programme allows the user to map the data. It also has powerful tools to evaluate the data by looking at spatial distribution and spatial relations [30]. Environmental health practitioners, epidemiologists, environmental health professionals, and almost every other public health field use maps to consider health determinants' spatial distribution. Mapping social and economic trends, location of hazardous materials handlers, and vulnerable communities help deter and mediate incidents that may affect public health. Most of the dashboards out there use ESRI technology to develop own social and economic trend maps.

ArcGIS Online is a powerful web stack that generates maps and draws dashboards quickly. The Johns Hopkins blog, like the WHO, uses ArcGIS Online. Over 250 sites in the U.S. alone use ArcGIS Online to map COVID-19 related data, as shown in *Figure 2*. This research shows the capabilities of the ArcGIS framework for health studies. Spatial distribution of TB was studied to view and analysis the high-risk area of TB in Selangor (*Figure 3*). By using this software source, such as ArcGIS Pro, ArcGIS Online, and Web App Builder, the distribution pattern is also analysed based on the pattern of TB cases.

There were 3423 cases reported in 2012 in the state of Selangor. Based on the map data, Selangor is divided into 9 divisions: Petaling, Kuala Langat, Gombak, Klang, Hulu Langat, Kuala Selangor, and Hulu Selangor, Sepang, and Sabak Bernam. From this map, it shows that Petaling recorded a high-risk area with 1163 TB Cases, followed by Hulu Langat and Gombak with 844 cases and 507 cases respectively. The lowest risk area is in Hulu Selangor, followed by Sabak Bernam and Sepang, with 84, 62, and 47 cases each. From the distribution of TB cases, the number of cases is divided based on the following category, as shown in *Table 1*.

Figure 2 COVID-19 map-based data dashboards using the Esri ArcGIS platform of IGIS

Table 1 Data of tuberculosis in Selangor 2012

No.	Division	Population	Area (KM²)	Number of cases (Person)
1.	**Petaling**	1,812,633	484.32	1163
2.	**Hulu Langat**	1,156,585	829.44	844
3.	**Gombak**	682,226	650.08	507
4.	**Klang**	861,189	626.78	492
5.	**Kuala Langat**	224,648	858	117
6.	**Kuala Selangor**	209,590	1,194.52	107
7.	**Hulu Selangor**	198,132	1,740.46	84
8.	**Sabak Bernam**	105,777	997.1	62
9.	**Sepang**	211,361	599.66	47
	Total	**5,462,141**	**7,980.36**	**3423**

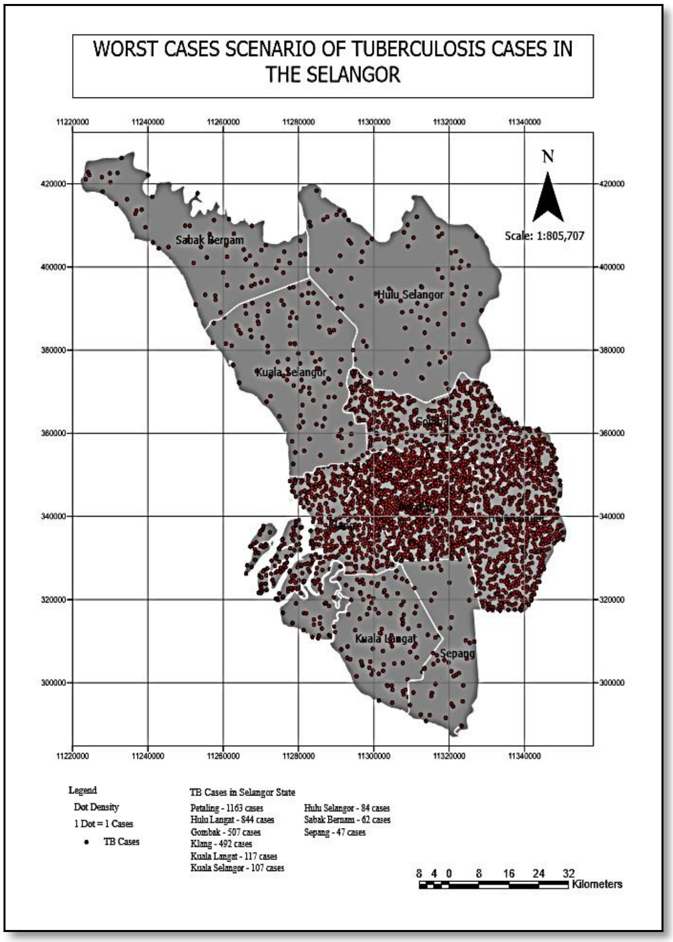

Figure 3 Dot density map of TB in Selangor using ArcGIS Pro

4.1.1Disease risk map by ArcGIS pro

ArcGIS Pro produces maps such as dot density map, heat map and choropleth map for the disease distribution. These maps are common maps that are used in the disease cases to describe the level of risk for each state or country as illustrated in *Figure 4* and *Figure 5*. This analysis has shown that Geo-enabled health information system (HIS) could be adapted in TB epidemiology elements through people, time, and place [11–13, 14, 8, 9].

4.1.2Disease risk map by ArcGIS online

A heat map utilises data analysis software that uses colour the way a bar graph uses high and low as a data visualisation tool. If the user wants to know which areas get the most attention, a heat map shows a visual way to assimilate and make decisions. The heat map displayed in *Figure 6* shows that the high area that gets the most concentration is in the middle of Selangor, which is the district of Petaling, and lower concentration is Sepang. This pattern analysis has demonstrated that ArcGIS platform has a basic GIS operation by using certain analysis, such as aggregated analysis, density analysis, and hotspot analysis. The products are beneficial for monitoring diseases and measures over time as dot maps to display health incidents, choropleth maps, and diagram maps to portray quantifiable information on the map.

The use of aggregated analysis: By using a layer of point features and a layer of area features, this tool determines which points fall within each area and calculates the statistics of all the points within each area, as shown in *Figure 7*. For example:

- Provide the point locations of TB cases and count the number of TB cases per county or other administrative district.
- Find the highest and lowest revenues for franchise locations by state.

The use of density analysis: Density analysis takes known quantities of some phenomena and spreads these quantities across the map. The users can use this tool to design the disease map, as illustrated in *Figure 8*, which shows the concentrations of lightning strikes or tornadoes, access to health care facilities, and population densities.

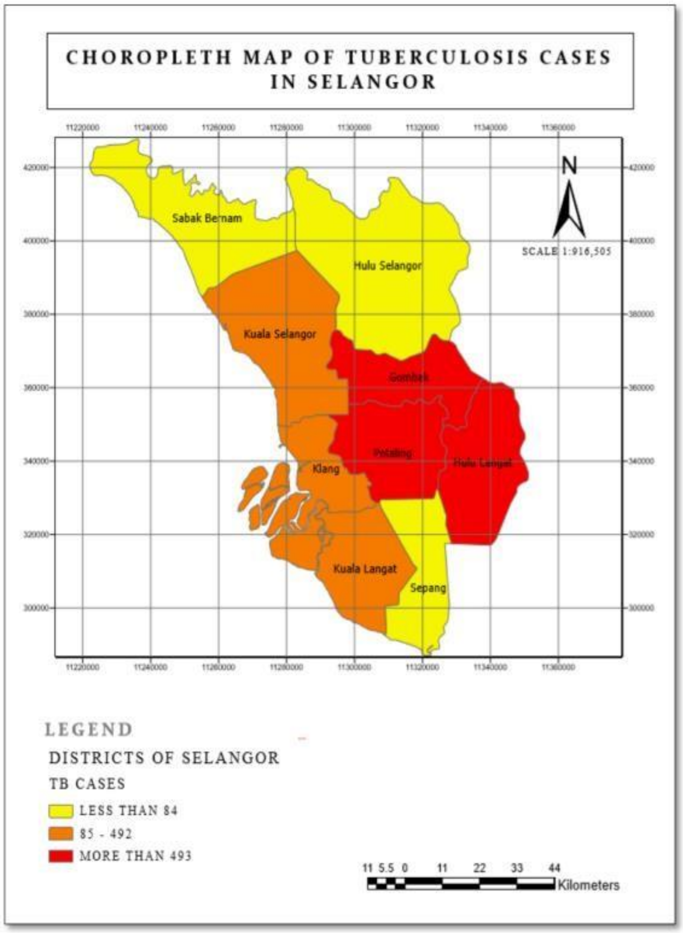

Figure 4 Choropleth map of tuberculosis cases

The use of hotspot analysis: This tool creates a map showing any statistically significant spatial clustering present in the data. This tool is also used to uncover unexpected hot spots (red) and cold spots (blue) of high and low TB cases. Disease Risk Map is also produced by Web App Builder, as shown in *Figure 9*.

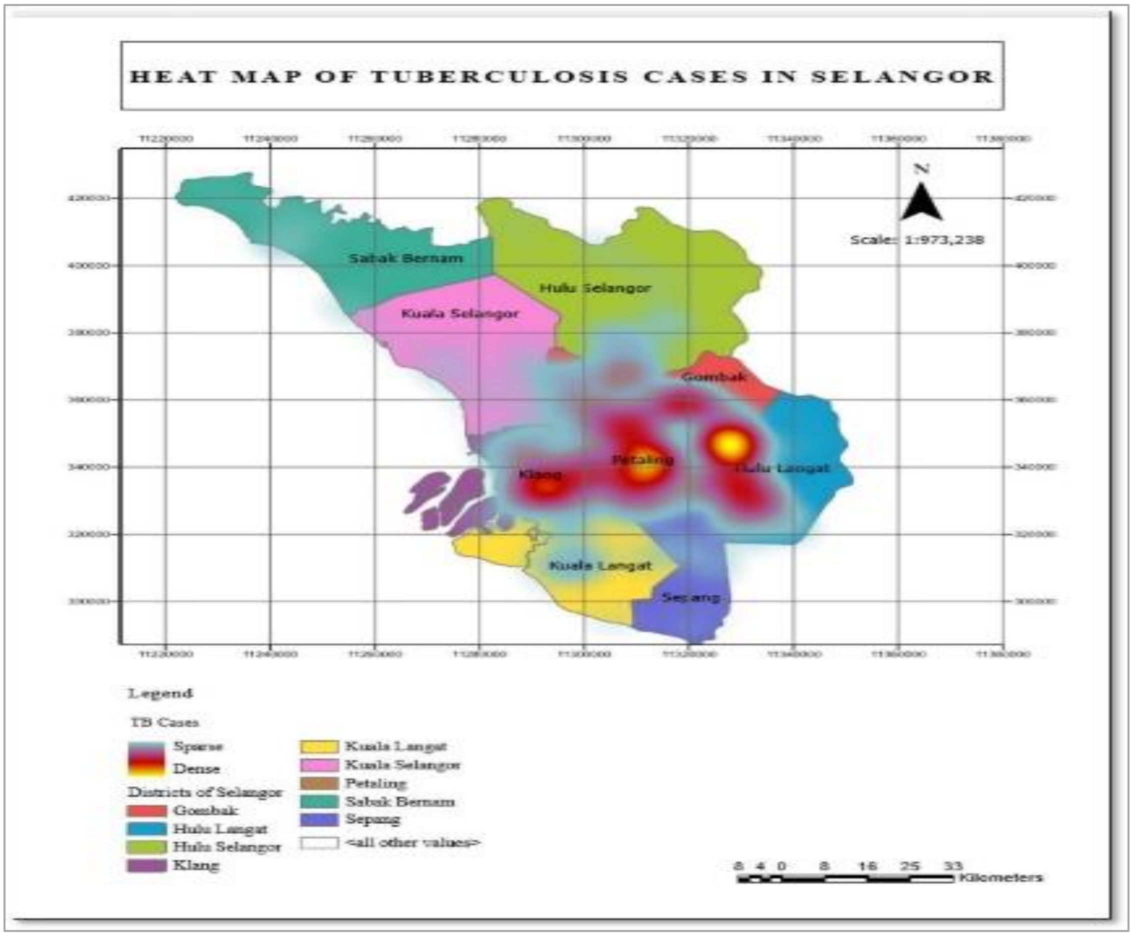

Figure 5 Heat map of tuberculosis cases

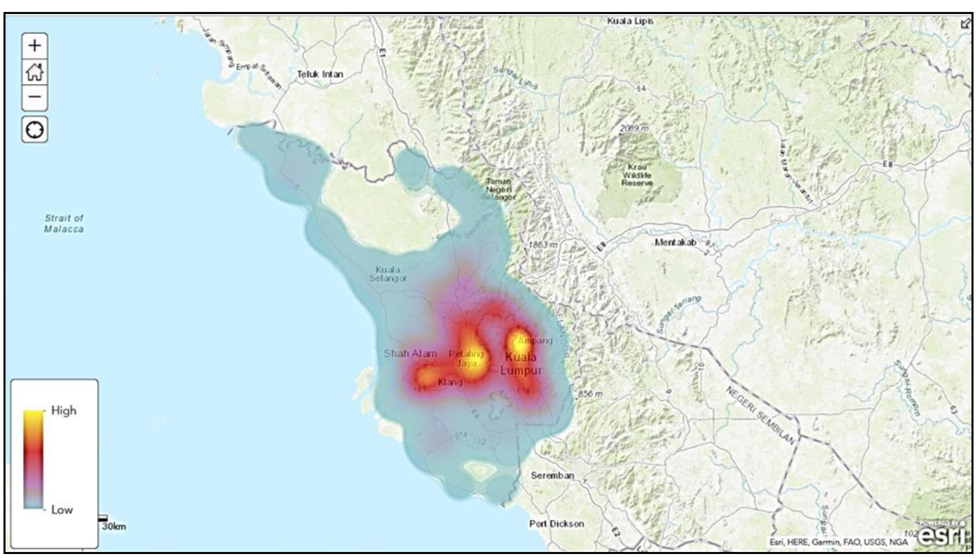

Figure 6 Heat map analysis of TB heat map analysis using monitoring's Web map application

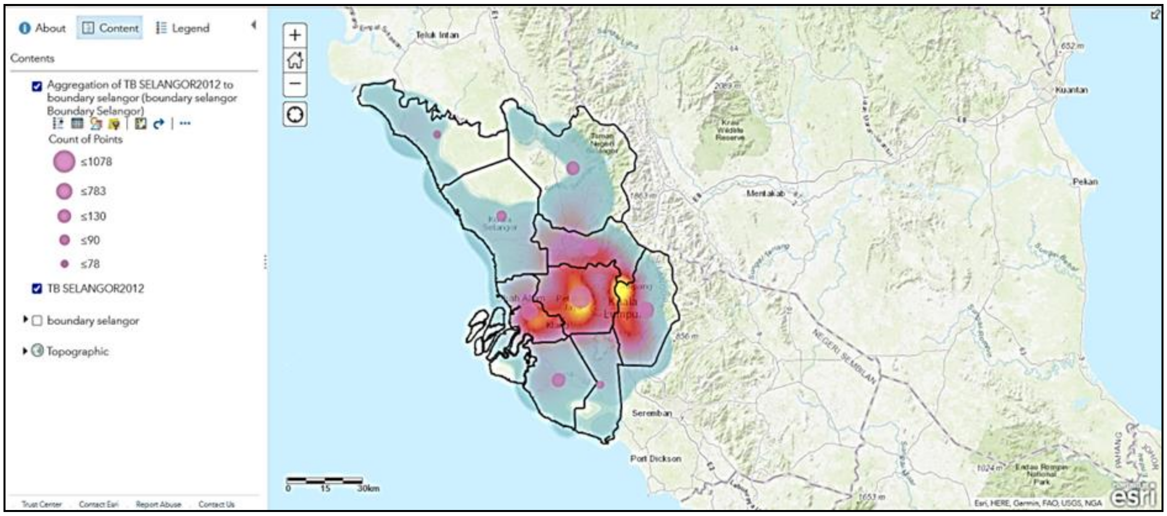

Figure 7 Aggregated analysis of TB pattern of using the web map application

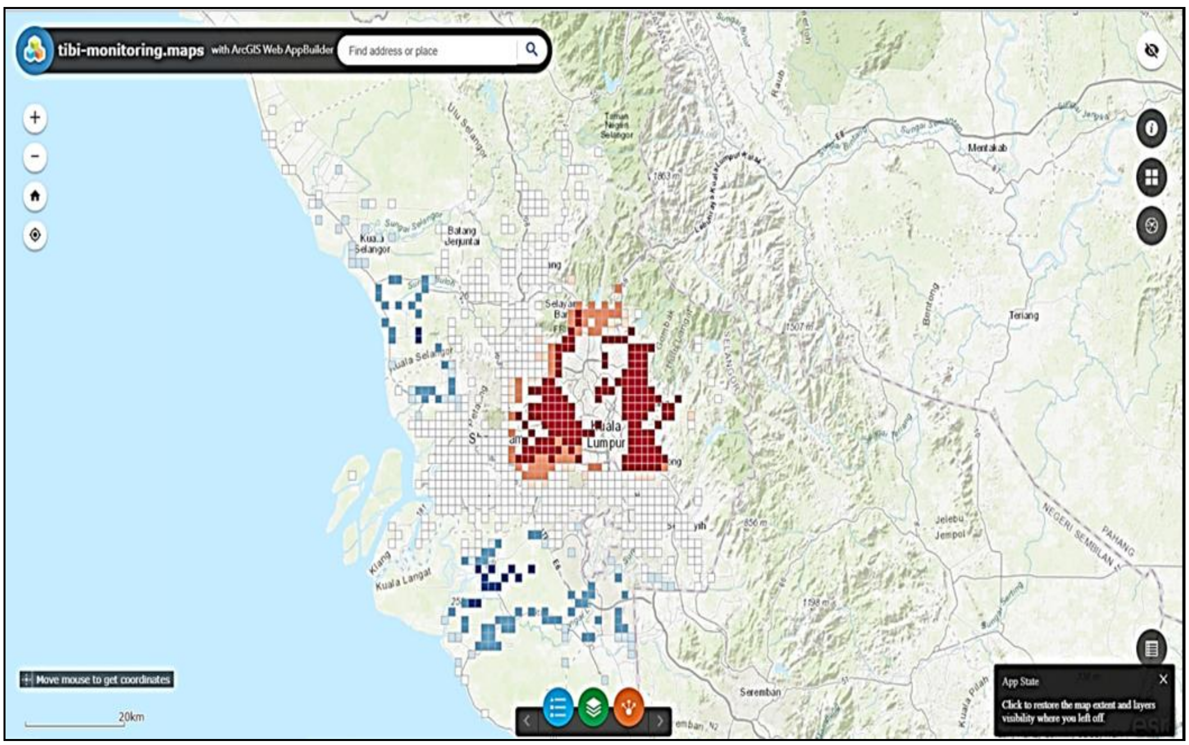

Figure 8 Density analysis of TB pattern using the Web map application

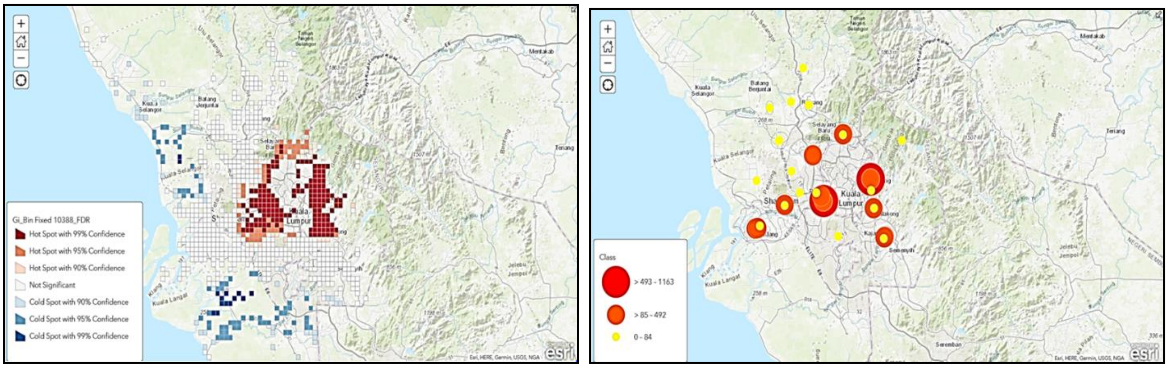

Figure 9 Hotspot analysis of TB cases using the web map application

4.2 Local user perception of a proposed Geo-disease information system

A preliminary study was conducted to observe the user requirements for a web map application for the disease monitoring of TB cases in Selangor. Questionnaires were randomly distributed and received 50 respondents of various ages, races, and occupations. Based on *Figure 10*, 61% of the respondents were female, mostly using the system monitoring for the disease. Moreover, it also shows that 74% of the respondent are mostly between 18 and 24 years old.

According to *Figure 11*, in answering whether the existing disease system is convenient and easy to use, 50% answered 'maybe' and 32% responded 'yes'. This is probably due to the fact that the respondents may not be familiar with the application of the current disease monitoring system. Next, in response to the previous system's performance, 45% responded 'medium', 48% responded 'satisfied' or "very satisfied" and 7% for "unsatisfied" response (*Figure 12*). The survey is also made to know whether those respondents are demanding a specialized Web App as if it is designed for those to monitor the TB cases in the Selangor communities. Based on the survey, about 80% of the respondents agreed for the proposed Web Apps development.

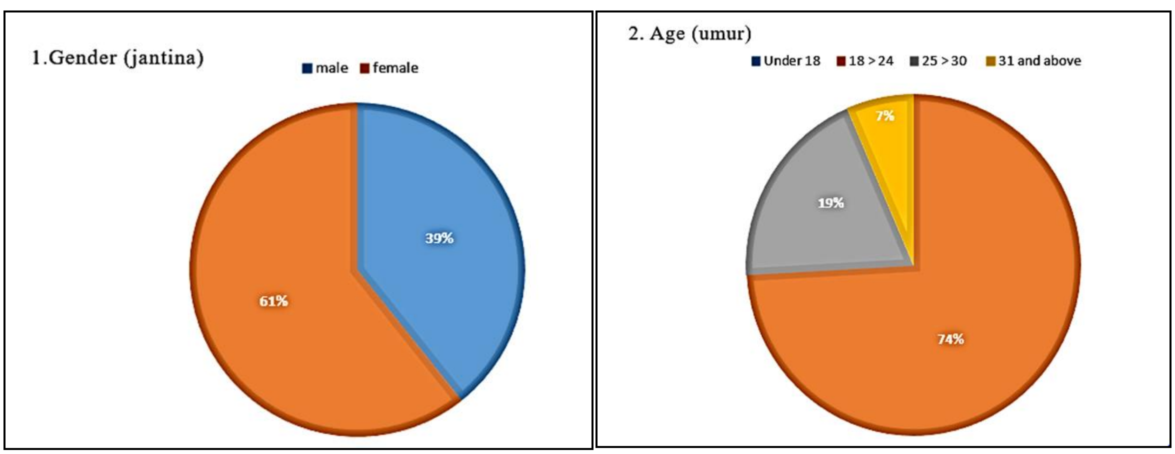

Figure 10 Respondents' demographic information in the user requirement questionnaire

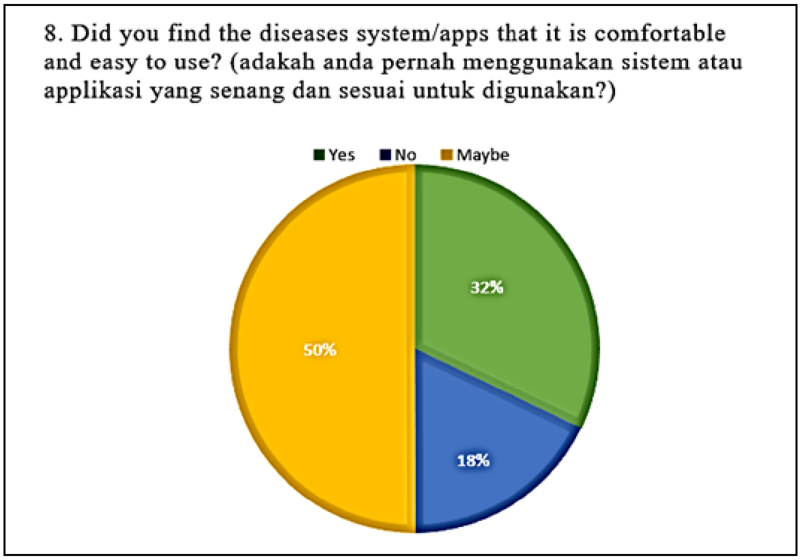

Figure 11 Respondent's response to any system or application that is Convenient and easy to use

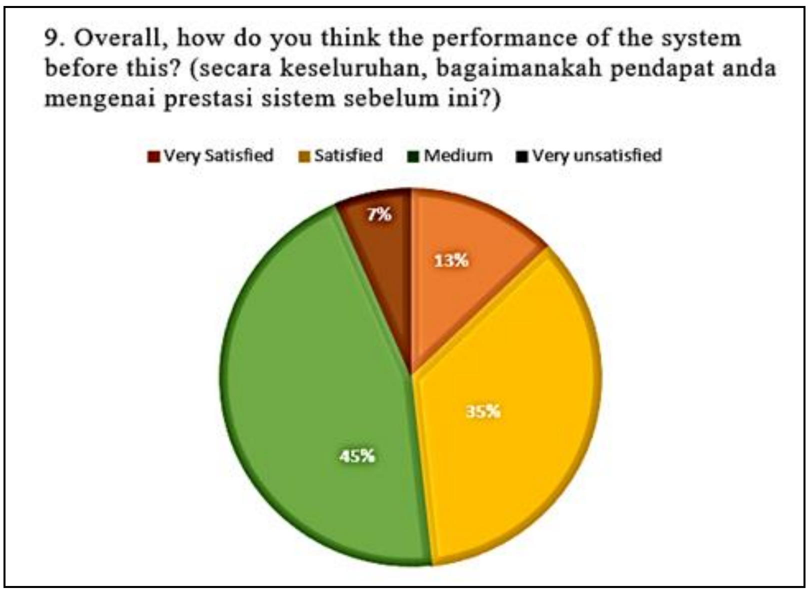

Figure 12 Respondents' opinions on the previous system's performance

4.3 Design and development of the local Geo-disease information system

This section demonstrates disease monitoring functions for TB by pages in the Web Map application. It also intends to list every function available on each page of the Web Map application that can be used to assist the disease cases. The development of the system was created by Web App Builder for monitoring TB Cases in Selangor. It shows that TB cases, monitoring can be viewed and analysed successfully. Several testing procedures on this web map application have also been carried out as developers want it to run smoothly. All the features available on the TB cases, monitoring system is explained in one page, displaying a base map from world topographic and widgets (*Figure 13*). This system offers important functions such as Added Map, Added Data Widget, Information Button, Added Data Widget for TB cases monitoring information.

First page of the proposed TB Cases Monitoring system displaying a base map from world topographic and widgets. On the right top of the home page, three widget buttons are available for user to getting information about the TB disease and cases (first, "i"), base map gallery (middle button) and analysis of the pattern TB cases that are used (lower button). On the left top of the home page, four widget buttons are available for users to zoom in (first button), zoom out (second button), default extend (third button), and my location (last button). At the bottom, top of the home page, three widget buttons are available for user to getting information about the legend pattern TB disease cases (left button), layer list for the TB cases (middle button) and share link of TB disease cases to others (right button). The last button at the lower left bottom is attribute table. Attribute table will display the data of TB disease cases in the each of the districts of Selangor state.

This proposed system provides health information for local organisations and public purpose, especially for identifying hotspot areas of the disease. This minimal cost system will also help the health department create a disease surveillance system to monitor current diseases [11–13]. The geospatial technology is innovative approaches because it could help the local agencies manage the risk-decision making of extreme events or smart organizations through SDI of Malaysian disease framework that has been introduced by [4, 19, 20]. For example, [20, 8] utilized a Geospatial Tuberculosis Information System (GeoTBiS) as a geospatial decision support system to improve the existing system functions and a range of suggestions for practical use in Selangor. There is an urgent need for health administrators, professionals, and study to be trained and to obtain user support in GIS technology, data, and epidemiological methods to use the GIS properly and effectively [21]. Furthermore, public awareness can be improved, and the health department can also systematically scrutinise the disease using the ArcGIS product such as ArcGIS Predictive Analysis Tools and other advanced analytics tools.

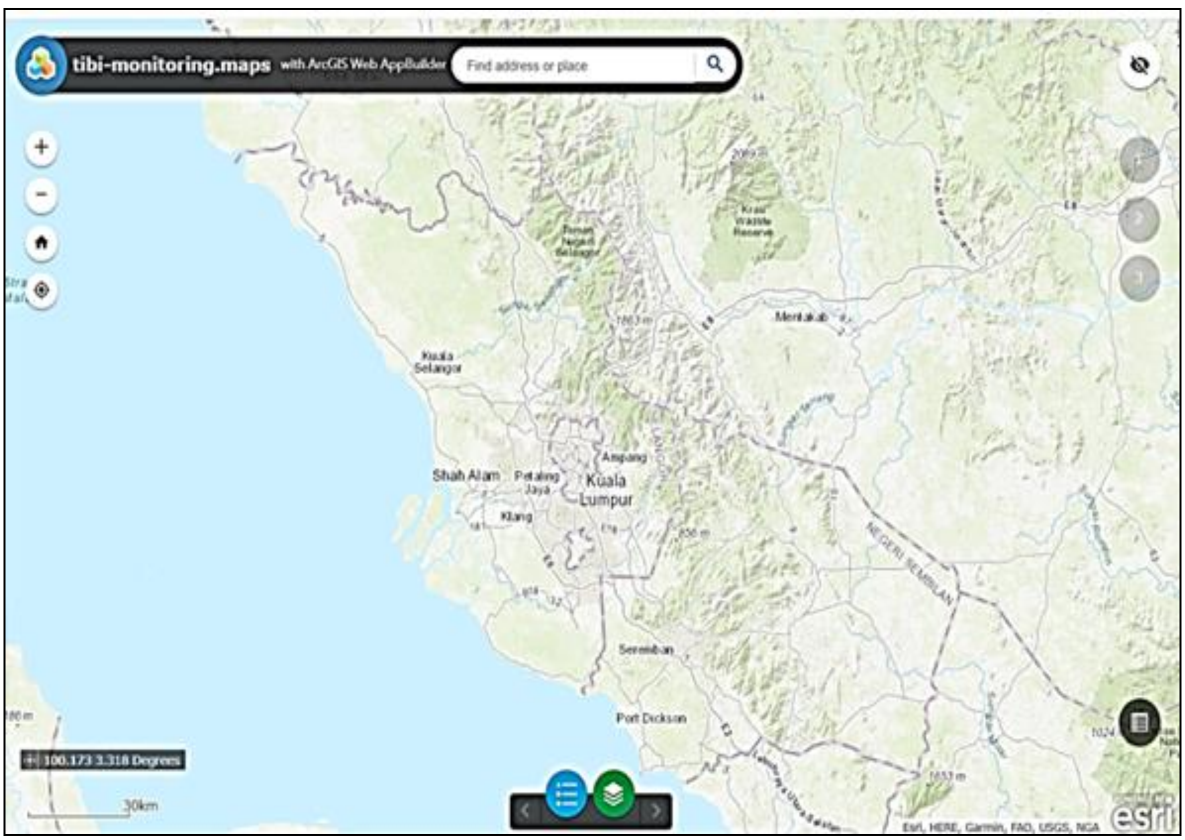

Figure 13 Home page design of TB cases monitoring theme

4.4Testing the performance of local Geo-disease information system

This section covers testing of the system's performance developed by Web AppsBuilder for ArcGIS, offering the user among the respondents to monitor the disease of TB cases in Selangor. There is a link to this system -https://arcg.is/TauHj0 (*Figure 14*). The development of TB Cases Monitoring System uses only one host feature layer that is uploaded on AGOL. As a result, the TB cases, the monitoring system will display TB cases on its base map. The home page of the application is named as TB monitoring maps. It has three main buttons, i.e. layer list, legend, and share. The user could click on the layer list to show the pattern of TB outbreaks in Selangor district areas. There are four patterns of the disease outbreak cases, including aggregated analysis, hotspot analysis, and density analysis. Since this proposed system is still in a prototype level, several recommendations have been made for a practical application. Firstly, more spatial analysis and system modules can be developed in the system such as social network analysis [23], big data and prescriptive analytics [24, 25], IoT-cloud enabled SDI architecture [26] and open source GIS [27] for significant predictive disease modelling, and lastly including the latest datasets and sharing limited information for the public health awareness.

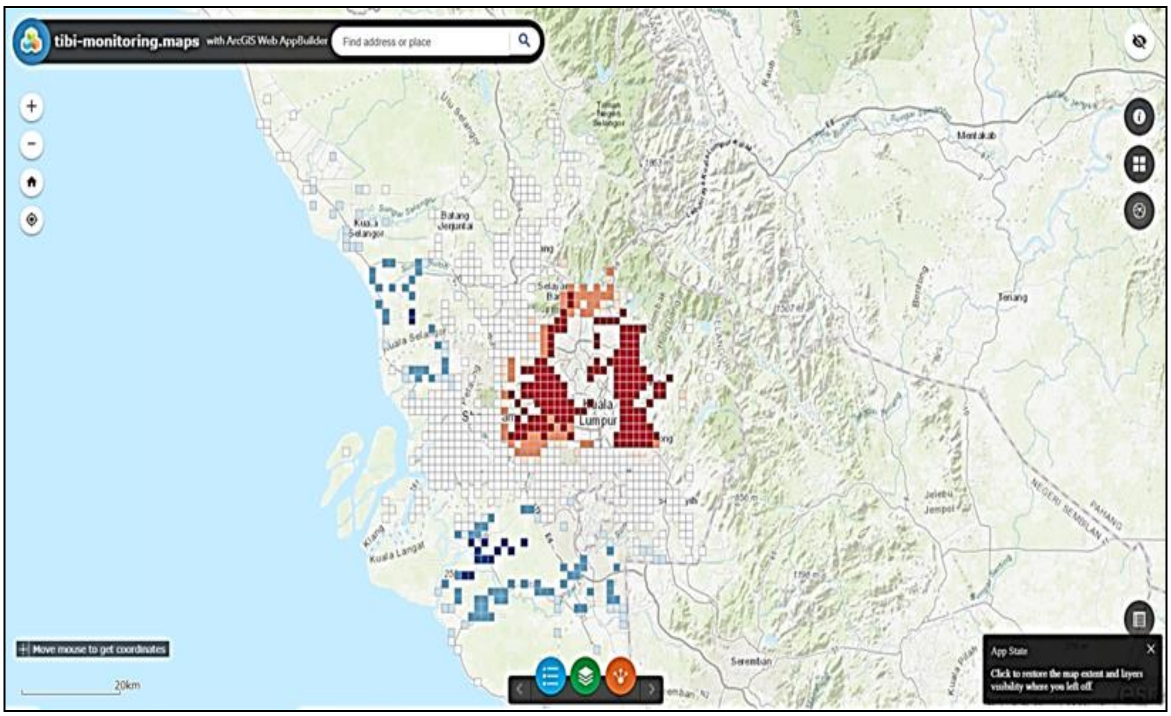

Figure 14 Main page of TB cases monitoring’s Web map application

5.Conclusion and future work

This study has demonstrated the features and functions of GIS and Web Apps software of Esri products in spatial health and disease application of TB in Selangor. Various techniques and tools have been explored to analyse and map the pattern of TB cases. Three main processes have been conducted in this study, including user requirement, spatial mapping and analysis, and system development. The dot map analysis using ArcGIS Pro shows that the Petaling district has the highest concentration of TB cases because it has a small area size but high incidence of tuberculosis. The TB monitoring case system is also successfully developed in this study with minimal cost and less-technical demand using ArcGIS Pro and ArcGIS Online. This monitoring system plays its role in observing and displaying the local scenario of the disease outbreaks. The system can assist the local health sectors in preventing TB disease cases from spreading further. This geo-enabling infectious disease monitoring platform has also demonstrated the capabilities of the GIS technology for the future public and local health governments applications in analysing the potential high-risk areas and conducting intervention programmes on the sites.

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Conflicts of interest

The authors have no conflicts of interest to declare.

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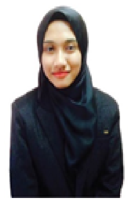

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