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Communicating the High Susceptible Zone of COVID-19 and its Exposure to Population Number through a Web-GIS Dashboard for Indonesia Cases

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Abstract. The Medical Geographic Information System (Medical GIS) application during the COVID-19 pandemic crisis has become influential in communicating disease surveillance for health practitioners and society. The Johns Hopkins University has extensively used a well-known Web-GIS dashboard to track the COVID-19 cases since January 22 and illustrates the location and number of confirmed COVID-19 cases. Unfortunately, the dashboard particularly for Indonesian cases is only represented by one point (dot map) placed on the centroid of the Indonesian archipelago. Further research can fill the gap in downscaling the geographical location data of COVID-19 cases to the cities or even the village level in Indonesia and communicating the susceptible zoning to society. We uplift the point COVID-19 cases data to susceptible zoning gathered from official COVID-19 government websites, process it using Geographic Information System analysis, and communicate it to society through a Web-GIS dashboard. Five datasets, i.e., population data, administrative boundary, Landsat 8 OLI satellite imagery, COVID-19 cases geographic location, transportation infrastructure, and crowded places location, are used to analyze the susceptible area. Due to different standard data sources from each province in Indonesia, we only present provinces in Java Island with complete COVID-19 cases data on villages-scale. The technical challenges and future improvement in developing the national dashboard of Web-GIS-based susceptibility dashboard are also discussed. The dashboard information would further add some essential information for society to explore their zone status in adapting to the "New Normal" using the SICOVID-19 dashboard from their computers or gadgets during the pandemic crisis.

Keywords: COVID-19; Population exposure; Susceptible area; Web-GIS dashboard

1. Introduction

World Health Organization (WHO) officially announced Severe Acute Respiratory Syndrome Corona Virus-2 (SARS-CoV-2) or COVID-19 as a pandemic on March 11, 2020. In response to this pandemic event, the health authority and many world health researchers made several web-based dashboards to monitor the spreading of COVID-19 in near-real-time (Dong et al., 2020; Morettini et al., 2020; Zhou et al., 2020; Wissel et al., 2020; Bernasconi & Grandi, 2021). Location-based data of confirmed cases, deaths, and recovered patients are urgently needed to accurately measure the extent and severity of COVID-19 and assess the response's effectiveness (Franch-Pardo et al., 2020; Rosenkrantz et al.,

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During a pandemic event, the open geo-location COVID-19 database supplies information about the addition of new cases, the rate of death, and the recovery rate that understand the pandemic dynamics. It also provides reliable spatial information support for decision-making, measures formulation, and effectiveness assessment of COVID-19 prevention and control (Zhao et al., 2020; Bogoch et al., 2020). Some research also shows that geographical location data of pandemic cases can play a role in communicating the risk of transmission and even in evaluating the policy to deal with the outbreak, especially when the data is in near-real-time (Fang et al., 2008; Tatem et al., 2012; Kraemer et al., 2020; Kamel-Boulos & Geraghty, 2020). A device tracking and managing the spread of COVID-19 also needs innovation and contribution from the engineering perspective (Berawi et al., 2020). Moreover, the combination of geographical information big data with other relevant data sets, such as transportation hubs and the area where people gather, will provide additional insight into the potential local transmission region (Zhou et al., 2020; Costa et al., 2020).

A web-based map dashboard of world COVID-19 that was launched on January 22 by the Center for Systems Science and Engineering (CSSE) at The Johns Hopkins University illustrates rapid visualization of the confirmed case location of pandemic information (Dong et al., 2020). Unfortunately, it only shows Indonesian cases on the country centroid which is unavailing information for Indonesian. In early March, the Indonesia Institute of Science survey revealed that more than 60% of the respondent needed at least sub-district level infected case information, and 97% agreed that the government should expose 14 days of history mobilization of infected patients (Cahyadi, 2020). Considering patients' privacy while revealing the spatial data can be manageable by aggregating it and anonymizing it in the right way to protect privacy would take some burden off.

On the national level, the Indonesian government, through its National COVID-19 Task Force, develops a web-based COVID-19 dashboard with data visualization on the provincial level. While several local governments have been visualizing different administration boundary levels and formats, some local governments share detailed data and deliver interactive web mapping. However, some local governments also visualize the data on a static map. It is unfavorable information for a population that lives and travels inter-administrative boundaries. They must visit multiple websites to be well informed about their neighbourhood's susceptibility. One compact open web-based map dashboard that compiles the COVID-19 case on the village level is needed to supply the information. To address this issue, we develop a Web-GIS dashboard that integrates all of the COVID-19 case data from various provincial governments. To fill the gap of this issue, we develop a dashboard with sensitive zone information to inform the user directly from their smartphone using the geo-location application.

2. Material & Methods

Since the first case was reported by the President of the Republic of Indonesia, COVID-19 infected cases across Indonesia were continuously reported from various local government websites. COVID-19 infected cases data compilation comes from different provincial government websites through web scrapping (Diouf et al., 2019; Singrodia et al., 2019) that uses multiple programming languages, i.e., HTML, Python, R, and JavaScript, depending on the website (figure 2). All web scrapping was conducted every two days based on using copyright data consideration. Due to different standard data accuracy from each local government website, we only present provinces with complete data on villages scale. COVID-19 case data is aggregated according to village boundaries and displayed in the form of village centroids. Centroid data of every village with a confirmed COVID-19 case is analyzed using a kernel density (equation 1) to describe the COVID-19 hotspots (Ruckthongsook,, et al., 2018).

$$Kernel\ Density = \frac{1}{(Radius)^2} \sum_{i=1}^{n} \left[\frac{3}{\pi} \cdot Pop_i \left(1 - \left(\frac{Dist_i}{radius} \right)^2 \right)^2 \right] \quad (1)$$

Where: i = 1 to n are the input COVID-19 case points, Popi is the population field value of point i, disti is the distance between point i and the (x,y) location (Ruckthongsook,, et al., 2018). Previous spatial epidemiology studies used this analysis to map the spatial concentrations and clusters of disease outbreaks, and it was successful and accurate. (Cai et al., 2012; Atkinson & Utwin, 2012). As well as in determining the hotspots of potential crowd locations that potentially boost disease local transmission, transportation hubs point and economic activity center location are also analyzed using kernel density analysis (Chen et al., 2020; Yang et al., 2020; Kraemer et al., 2020; Shim et al., 2020; Chong et al., 2020; Sohrabi et al., 2020). The overlay between COVID-19 hotspots and potential crowd hotspots will produce a COVID-19 susceptible area. To overlay all of those variables, the Geographic Information System is used since its capability to handle spatial datasets (Wibowo & Salleh, 2018).

Two kernel density analyses generate a susceptible zone with three classifications: the green color represents a low level of susceptibility zone, the yellow for the medium-level zone, and the red for the high-level zone (see figure 3a). The number and percentage of the affected village area are shown on the left-hand side next to the map. While on the right-hand side, the population exposure generated in pixels units represents the population affected in the highly susceptible area. The receptive zone and the population affected in the highly affected area dynamically change over time, based on the input data every two days.

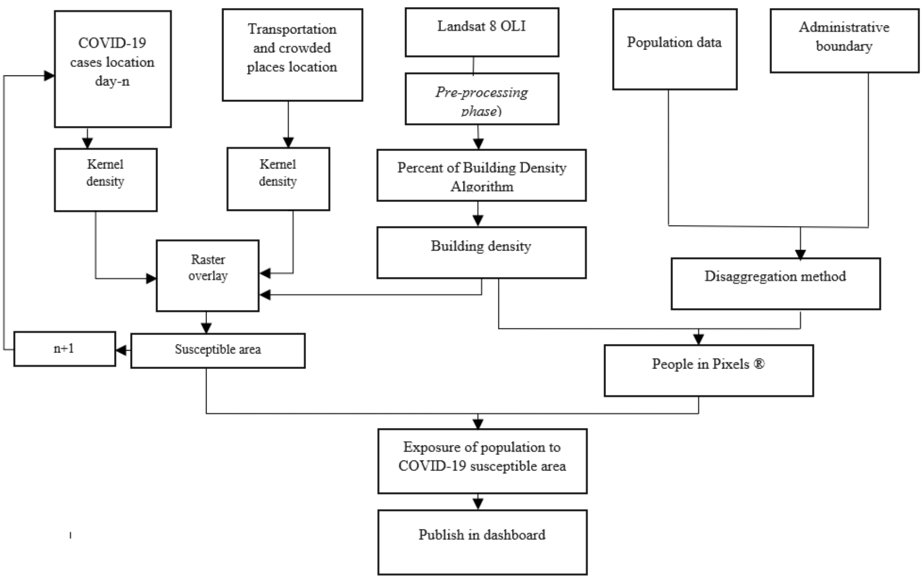


Figure 1 Methodology process

Outbreaks of infectious diseases will have a high level of exposure in urban areas with a high degree of density dwellers (Vlahov et al., 2007; Alirol et al., 2011; Jarquin C, et al., 2016). To investigate the exposure of COVID-19 susceptible areas, we build building density models (see equation 2) (Ardiansyah et al., 2018).

$$Building\ Density = -488.11 + 8.343\, x_1 + 2.221\, x_2 + 50.696\, x_3 + 52.090\, x_4 \quad (2)$$

Where: x_1, x_2, x_3, and x_4 are the composite values derived from the Landsat 8 OLI imagery. x_1 is the value of the Normalized Difference Built-up Index (NDBI), x_2 is the value of the Soil Adjusted Vegetation Index (SAVI), x_3 is the value of Normalized Difference Water Index (NDWI), and x_4 is the value of the Thermal Infrared Sensor (TIRS). This model produces a range of values between 0-100% of the dense dwellers' area (Ardiansyah et al., 2018).

The COVID-19 population exposure was created based on the population database from the Indonesia Statistics Agency (locally known as BPS) and the administrative boundary from Indonesia Geospatial Agency. The disaggregation method and Support Vector Machine algorithm, specifically the dasymetric method, was then used to deliver the population data in pixel units. (Zulkarnain et al., 2019). See more details of this preliminary study's methodology process and data sources in Figure 1 and Table 1.

In visualizing the COVID-19 case and its exposure, map data are displayed in the dashboard as a separate layer and symbolized differently. The COVID-19 case data was symbolized using points, while COVID-19 exposure was symbolized using the colored area. In addition to the map on the Web-GIS dashboard, we add widgets to display attributes in the tabular, graph, and chart forms. We use ArcGIS Dashboard as the platform because it has the advantages of pre-develop widgets and elements that are ready to use. Even a non-programmer user can develop a sophisticated customized dashboard quickly (Bhatia et al., 2019).

Table 1 Data collection

No	Data	Type	Source
1.	Population data	Secondary data	The Indonesia Statistics Agency
2.	Administrative boundary	Secondary data	Badan Informasi Geospasial
3.	Landsat 8 OLI imageries	Secondary data	United States Geological Survey dan The National Aeronautics and Space Administration, USA
4.	The geographic location of COVID-19 cases	Secondary data	Provincial government
5.	Transportation and crowded places location	Secondary data	OpenStreetMap
6	People in Pixels ®	Secondary data	PT. Infimap Geospasial Sistem

3. Results and Discussion

The Geographic Information system (GIS) operational dashboard is a web-based application used to analyze and visualize events and performance indicators in the form of maps, graphs, and tables in one view (Luan & Law, 2014; Agrawal & Gupta, 2017). The published dashboard, namely SICOVID-19, stands for "Sistem Informasi COVID-19 Indonesia" or translated as "Indonesia COVID-19 Information System" with URL address https://sicovid19-geography-ui.hub.arcgis.com/. SICOVID-19 is available in two formats, a web interface and a mobile interface (see figure 2, figure 3a and 3b), as an option for users to choose access through their computers or gadgets. While the mobile interface connects to the user's global positioning system (GPS) in their devices and allows live user interaction, the desktop interface design demonstrates complex spatial analysis. To update the SICOVID-19 dashboard, the dataset of COVID-19 cases from the official provincial website, datasets from OpenStreetMap, and People in Pixels® data are collected using the data scraping technique every two days.

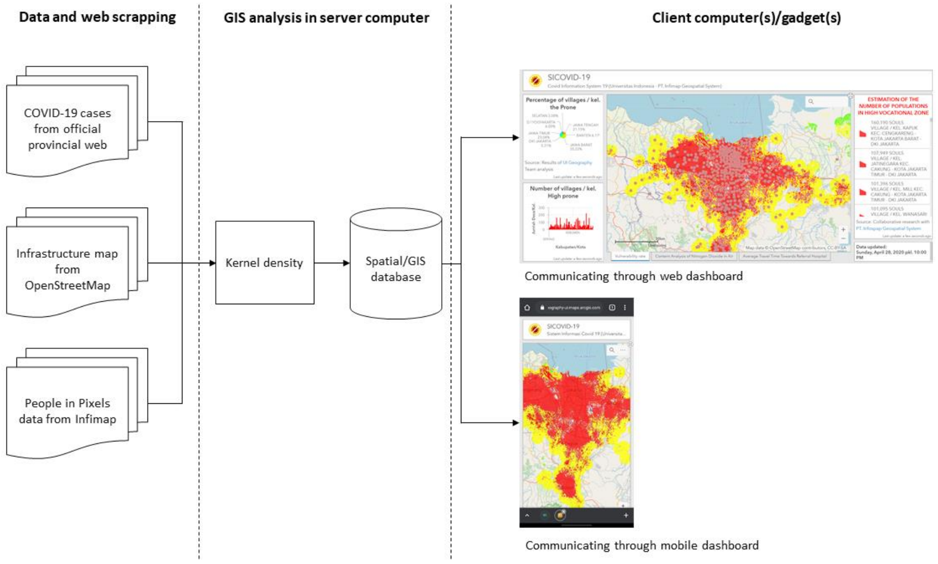


Figure 2 Web-GIS schematics

As one of the early COVID-19 dashboards in Indonesia, ESRI inc recognizes SICOVID-19 as one of the referred COVID-19 dashboards for the Indonesia region, alongside the National COVID-19 Task Force dashboard developed by the Central Government of Indonesia (ESRI Indonesia, 2020). Indonesian Medical Association also recognizes our dashboard as one tool to communicate the most affected region in Indonesia (Indonesian Medical Association, 2020). SICOVID-19 dashboard displays near-real-time official information cases of COVID-19 that visualise the number of confirmed cases as the centroid the village level. This website provides a piece of immense information due to the bureaucratic data challenge in Indonesia. The dashboard can visualize the map, tables, and graphs, both of which are presented side by side and are connected (see figure 3a).

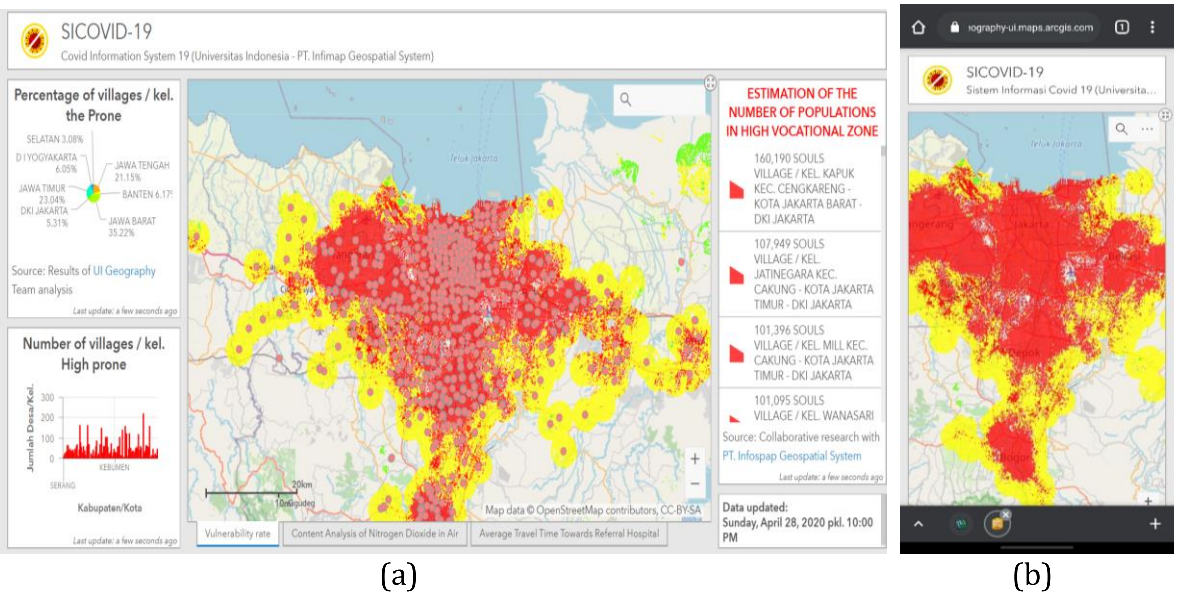


Figure 3 (a) Web interface of the dashboard and (b) Mobile interface of the dashboard (In Indonesian). The red dot is the location of the COVID-19 case. The red area, yellow area, and green area refer to high, medium, and low susceptible areas, respectively

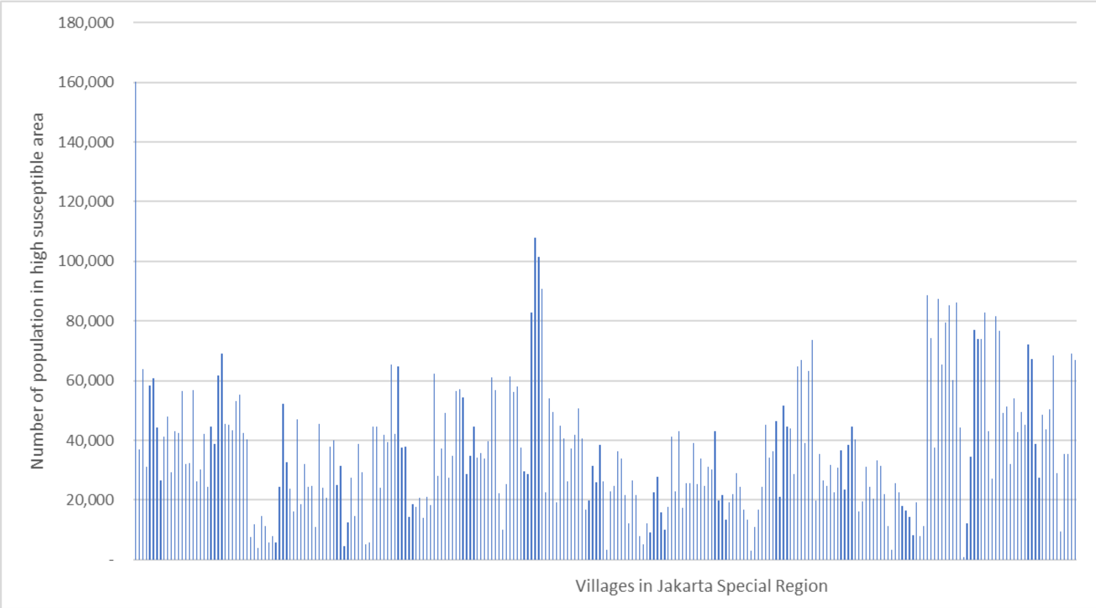
Until May 2021, we collected our website's analytics data using Google Analytics, which can describe the users' usability around a year since its first launch in June 2020. Most of the users are exploring the website using the search box tool to find their location. The average time of users exploring the website is around 3 minutes (Figure 4).

Figure 4 Average time of users

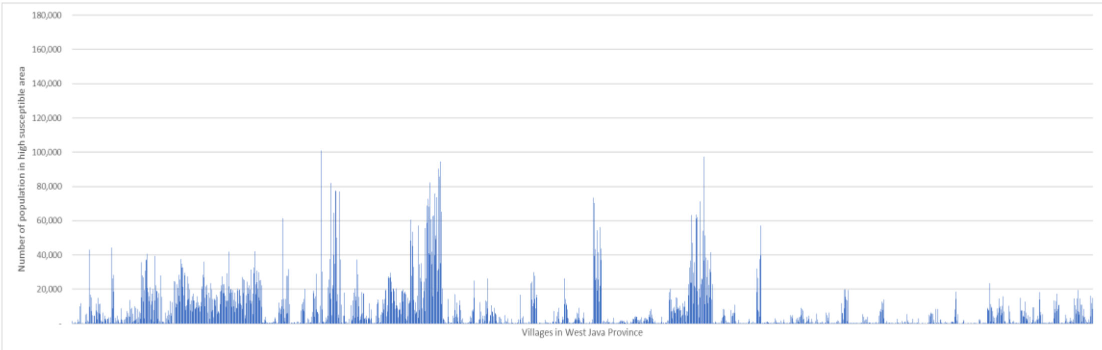
As the most populous island in Indonesia, so does the case and its availability of updated data, we chose Java Island as the study case in our dashboard. We extract an example dataset of the population exposure database from two main epicenters of COVID-19 in Indonesia, i.e., Jakarta Capital Region (Aldila et al., 2020) and West Java Province (Manessa et al., 2020), from the dashboard using figure 1 methodology process (see figure 5a and 5b). The x-axis shows the total affected villages, and the y-axis shows the exposure of the population to COVID-19 in a highly susceptible area. It portrayed that about 2.069,22 km^2 (85 %) of the Jakarta Capital Region and 1.241,56 km^2 (54%) of the West Java Province population are located in the highly susceptible area, respectively. Meanwhile, the medium susceptible category, DKI Jakarta or West Java, has an area of 69.38 km^2 (2.68%) and 1,057 km^2 (46%), respectively. Based on spatial analysis, the closer to the city center with high road density, the higher the potential to be exposed to COVID-19and vice versa.

The need for detailed data related to the distribution of COVID-19 cases up to the village level is very urgent to be provided by local governments, both at the provincial and regency/city levels. Distribution of patients at the village level is needed to estimate susceptible zones and develop predictions of the people exposed by COVID-19 nationally. With the estimated number of people potentially exposed to COVID-19, the central government will make policies related to COVID-19 disease handling. The guidelines by the central government will adjust to the number of potentially exposed people and the characteristics of the people in the region.

In response to the COVID-19 pandemic, President of the Republic of Indonesia, Joko Widodo, issued Government Regulation no 21/2020 about Large-scale Social Restriction for Accelerating COVID-19 Eradication and, after that “New Normal” concept for keeping the economic growth during COVID-19 pandemic (Djalante et al., 2020; Gorbiano, 2020; Berawi, 2020; Ivanka, 2020). The lack of geographical location information on COVID-19 cases can be an obstacle for making the right decision related to the Large-scale Social Restrictions policy and “New Normal” terms. We argue that if the government, particularly the provincial government, considers the geographic information of COVID-19 cases, the decision to apply a Large-scale Social Restrictions policy in their region will be more on target. Society will also become a frontline agent to achieve the success or failure of “New Normal” terms. The information of geographic location information of COVID-19 cases in our dashboard hopefully will raise society's awareness of their neighborhood to respond to the “New Normal” terms based on reliable data. Lessons learned from the Jakarta Capital Region, and West Java Province can be a benchmark for other provincial governments to gather and manage the geographic information of COVID-19 cases.



(a)



(b)

Figure 5 number of populations in a highly susceptible area. (a) Jakarta Capital Region, with a total of 1752 villages. (b) West Java Province, with a total of 2016 villages. Data update: April 28, 2020

The technical and data challenges in developing the national dashboard of Web-GIS based susceptibility dashboard can be categorized in 3 types i.e.: dataset standard, dataset quality, and dataset accessibility (Luan & Law, 2014). As mentioned by Wissel et al., (2020) the procedures for reporting the COVID-19 cases need to be standardized in particular if the practice of aggregating and combining various government data is applied in national Web-GIS dashboard. In terms of dataset quality, some province has different standard spatial data for example: some areas use the regency/city gravity centers to plot the location of COVID-19 cases. However, another province has more detailed data location, plotting their COVID-19 patients in districts or villages. From the perspective dataset accessibility, all provinces in Java Island do not provide any Application Programming Interface (API), making it difficult to transfer from machine to machine. The alternative to collect the COVID-19 cases in each province is using web scrapping methods (Diouf et al., 2019; Singrodia et al., 2019) that use multiple programming languages, i.e., HTML, Python, R, and JavaScript, depending on the local website. We furtherly suggest some improvement for the provincial government to organize better geospatial pandemic data in the future (Table 2):

Table 2 Technical challenges and future improvement

Challenges	Future improvement
Dataset standard	Need to be standardized if the practice of aggregating and combining from various sources
Dataset quality	Each provincial government need to have COVID-19 cases data in geospatial data format (*shp, *json, *kml, etc) at least in a district scale
Dataset accessibility	Each provincial government need to develop COVID-19 cases data Application Programming Interface (API)

The collection of COVID-19 data for various analysis will be made simpler for stakeholders and consumers by the availability of standards in data formats and data quality. The provision of national standards will also make the government able to decide the policies that must be taken in dealing with the COVID-19 pandemic quickly. The SICOVID-19 dashboard has been able to describe the condition of the latest COVID-19 cases at the regional level by combining COVID-19 statistical data with different formats and qualities from various provinces.

4. Conclusions and Closing Remarks

The development of a Web-GIS dashboard that can provide detailed information on COVID-19 case data is urgent because of the very dynamic nature of the disease every day. The dynamic nature of COVID-19 requires the government to be able to take policy quickly and strategically. This research is the first study on a COVID-19 information system application that integrates a COVID-19 dataset with different standards and formats into one complete data. The development of SICOVID-19 Dashboard is able to find use of the different formats of COVID-19 statistics and population estimation model to deliver new information which, is the prone area that is not available in other COVID-19 dashboards. The SICOVID-19 dashboard seeks to present the distribution of village-based cases and model the estimated number of people who have the potential to be exposed to COVID-19. The result for the spatial pattern of the susceptibility shows that high susceptibility to COVID-19 is higher closer to the city center with high road density and vice versa. The access option of the SICOVID-19 dashboard through the web interface and mobile interface makes it easier for the public to find information about their region’s vulnerability to COVID-19. It is hoped that the data presented in the SICOVID-19 dashboard could provide a more in-depth insight into the threat of COVID-19 in Indonesia and as a reference for society to adapting the “New Normal” way of life.

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