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GEOGRAPHICAL INFORMATION SYSTEM BASED COVID-19 VULNERABILITY MAPPING IN PONTIANAK REGENCY WEST KALIMANTAN

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ABSTRACT

2020 was the start of the toughest year for the world community in general, especially Indonesia in the health sector. The outbreak of the Covid-19 case in various regions requires clear and accurate information in efforts to deal with this pandemic. This study aims to spatially map the vulnerability of COVID-19 based on Geographic Information Systems (GIS). The method d used is a weighted overlay. The data used are population (P), population density (PD), elderly (EP), school students (SS), and hospital beds (HB). The analysis s used is a spatial analysis using ArcGIS 10.8. The results of the study show that North Pontianak District has a very high vulnerability to COVID-19. West Pontianak District and Pontianak City have high vulnerability. South and East Pontianak sub-districts have moderate vulnerability. For Pontianak Tenggara District, the level of vulnerability to COVID-19 is very low. The vulnerability to COVID is very low in Southeast Pontianak District because it has the smallest population, low density, few elderly people, few school-age children, and lots of hospital beds. An information system is an effective tool in conveying information on the spatial distribution of the level of vulnerability of Covid-19 in an area, so that steps and handling policies can be taken according to existing priorities.

Keywords: *Covid-19 Vulnerability; Geographical Information System; Mapping*

INTRODUCTION

Beginning in 2020, various countries worldwide are very vulnerable to the turmoil of the Coronavirus or what is often referred to as SARS-CoV-2 (COVID-19) (Organization, 2020; Shadeed & Alawna, 2021). The spread of this virus was so massive that it was finally designated as a pandemic which until now has not been able to be controlled (Shadeed & Alawna, 2021; WHO, 2020). The global pandemic that emerged from SARS-COV-2 (COVID-19) continues to pose health and socio-economic challenges worldwide (Kraemer et al., 2020; Phiri et al., 2021) and various aspects of people's lives around the world (Gralinski &

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Menachery, 2020; Shadeed & Alawna, 2021).

Cause Coronavirus (COVID-19), caused by severe acute respiratory syndrome coronavirus 2 (SARS-COV-2) (Kontis et al., 2020; Kraemer et al., 2020; Wu et al., 2021). This virus was first confirmed in Wuhan, China, in late December 2019 (Kontis et al., 2020; Mollalo et al., 2020; Phiri et al., 2021; Wu et al., 2021). At the end of January, on January 30, 2020, WHO declared that COVID-19 was a public health emergency (Mollalo et al., 2020; WHO, 2021).

In Indonesia, the initial response to this pandemic was slow, and there was even a hint of trust from the government regarding this outbreak. However, as time goes on, the number of COVID-19 victims increases. The government was finally confused in responding to the increasing number of victims. Therefore, the government takes steps that are considered effective in preventing and inhibiting the transmission of COVID-19. Schools, universities, and most business activities were closed, and the government asked the public to stay at home for 14 days. Wearing a mask and using a steriliser every 15-20 minutes is very important to reduce the COVID-19 outbreak (Shadeed & Alawna, 2021). In addition, social distancing and avoiding crowded places are essential to reduce the population's COVID-19 vulnerability.

Vulnerability is when exposure to a particular hazard from a specific community may increase (2,13). In the event of a disaster, generally, the community will face many risks, in this case, the COVID-19 outbreak. Local communities are potentially very vulnerable to these risks (Palaiologou et al., 2019; Rufat et al., 2015). Understanding of the term vulnerability also needs to be socialised to the community. It is intended that the public be more aware of the dire possibilities against (Holand et al., 2011; Shadeed & Alawna, 2021).

Vulnerability to the risk of the COVID-19 disaster needs to be treated immediately. Dynamic vulnerability, or what is often referred to as social vulnerability, is a dynamic process whose resolution is highly dependent on the actions and mitigation plans of the government (Lancet, 2020). Social vulnerability to the effects of any disaster is usually spatially distributed (Palaiologou et al., 2019; Rufat et al., 2015; Shadeed & Alawna, 2021). Social vulnerability is difficult to quantify

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because it involves factors of a person's life, livelihood, property, and other assets in nature or society (Blaikie et al., 1994; Holand et al., 2011). Factors that influence social vulnerability include age, race, health, income, place of residence, occupation, population growth, urbanisation, and economy (Blaikie et al., 1994).

A study is needed that discusses mapping related to epidemics with several analytical criteria (Chretien et al., 2014). For mapping, the COVID-19 vulnerability, some of the criteria considered are applying the analytical approach. This decision approach usually uses a multi-criteria decision (Multi-Criteria Decision Analysis) (Sangiorgio & Parisi, 2020; Shadeed & Alawna, 2021).

Demographic factors (population), epidemiology (chronic disease), and ecology (temperature) are the driving factors for mapping COVID-19 (Acharya & Porwal, 2020; Meraj et al., 2021; Sangiorgio & Parisi, 2020); in other words, this mapping usually uses the Analytic Hierarchy Process (AHP). The Analytic Hierarchy Process (AHP) is a well-structured approach to assigning weights to various influential criteria. Geographic information system (GIS) based on Multi-Criteria Decision Analysis (MCDA) is a precise or professional way to map epidemic susceptibility and risk assessment, such as for COVID-19 vulnerability) (Cox et al., 2013; Kanga et al., 2021). This study used GIS-based MCDA to develop a COVID-19 Vulnerability Index (CVI).

The maps developed have high value for guiding decision-makers in predicting potential COVID-19 outbreaks and thereby developing appropriate mitigation measures to protect public health, especially in highly vulnerable provinces. The use of the Geographic Information System for mapping the vulnerability of Covid-19 is something new in Pontianak City because no one has done this research yet, so this is a novelty especially in West Kalimantan Province. This study aims to map the level of vulnerability of COVID-19 in the Pontianak City area and its spatial distribution.

MATERIALS AND METHODS

Study Area

This research was conducted in the city of Pontianak, West Kalimantan Province, which has an area of 107.82 km^2. Astronomically, Pontianak City is located between 0° 02' 24" North

Latitude and 0° 05' 37" South Latitude and between 109° 16' 25" East Longitude to 109° 23' 01" East Longitude (**see figure 1**). Based on the geographical location of Pontianak City is right traversed by the equator; therefore, Pontianak City is a tropical area with high air temperature and high humidity. Pontianak city consists of 6 sub-districts, namely West Pontianak, Kota Pontianak, South Pontianak, Southeast Pontianak, East Pontianak, and North Pontianak.

Geographically, the location of the city of Pontianak is in the west bounded by Sungai Kakap sub-district, Kuburaya Regency, in the eastern part by Sungai Raya Sub-district and Ambawang Sub-district, Kuburaya Regency, in the north by Siantan District, Mempawah Regency, and in the south by Sungai Raya District and Sungai Kakap District, Kuburaya Regency.

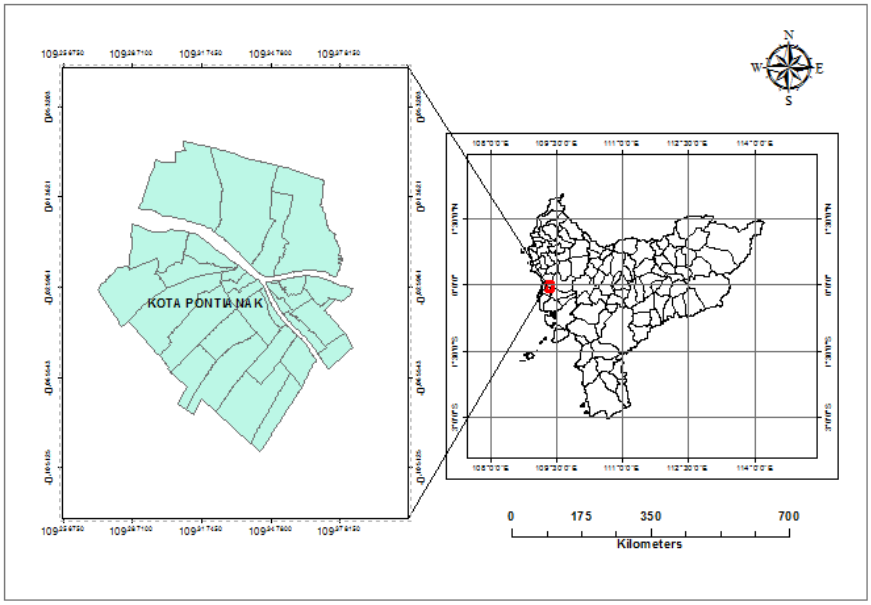

Figure 1. Study Area

Method

This study obtained the COVID-19 vulnerability map based on the COVID-19 Vulnerability Index (CVI) map development. This development is influenced by these criteria driven by population data, health services, and epidemiology. These criteria include population number (F), population density (PD), elderly (EP) (Awad & Abu Harb, 2020), school students (SS), hospital beds (HB) (Shadeed & Alawna, 2021).

The role of this parameter in the CVI formulation is as a factor that influences the

size of the covid susceptibility index in a region. High numbers and density as well as high elderly will increase CVI and vice versa. Many school-age children also have a tendency to increase CVI because the frequency of interactions at school is also high. The opposite role is for hospital beds where, a hospital that has a bed capacity for more Covid-19 patients will reduce CVI. The overall methodological approach for developing the COVID-19 vulnerability map was presented in **Figure 2**.

The AHP pairwise comparison matrix approach was introduced by (Saaty, 1980) to assign weights to different CVI criteria. Furthermore, the weight set is teste for consistency by calculating the consistency index and consistency ratio with the formula:

Indexes of consistency (consistency index) by using the formula:

CI = (λ max - n)/n - 1

CR = CI/IR

Where :

CR	=	Consistency Ratio
CI	=	consistency Index
IR	=	Random Index
λ max	=	Eigen maximum
n	=	number of criteria

- If CI = 0, then the hierarchy is consistent
- If CR < 0,1, then the hierarchy is quite consistent
- If CR > 0,1, then the hierarchy is very inconsistent

So actually the relationship between CVI and Ci and CR in the formula above is to test the consistency of weighting in calculating CVI, you have to calculate the consistency index and consistency ratio with the formula above. In order for the consistency of the AHP method users to be maintained so that the resulting solution is optimal.

The selected criteria were rasterised and reclassified using different GIS tools (ArcMap 10.8). GIS was used to estimate CVI using a weighted overlay summation process (Malczewski, 1999) for other selected criteria by combining the weighted cell values. Each measure is multiplied by the assigned weight, and the result is summed as:

$$CVI = \sum_{i=1}^{n} Wi \times Sij)$$

Where CVI is the final cell index, Wi is the normalised weight (Wi = 1), Sij is the i-cell score for the to-j layer, and n is the number of cells in each to-j layer. Finally, the total CVI with GIS analysis can be developed into a COVID-19 vulnerability map. The entire methodology in this study can be seen in **Figure 2**.

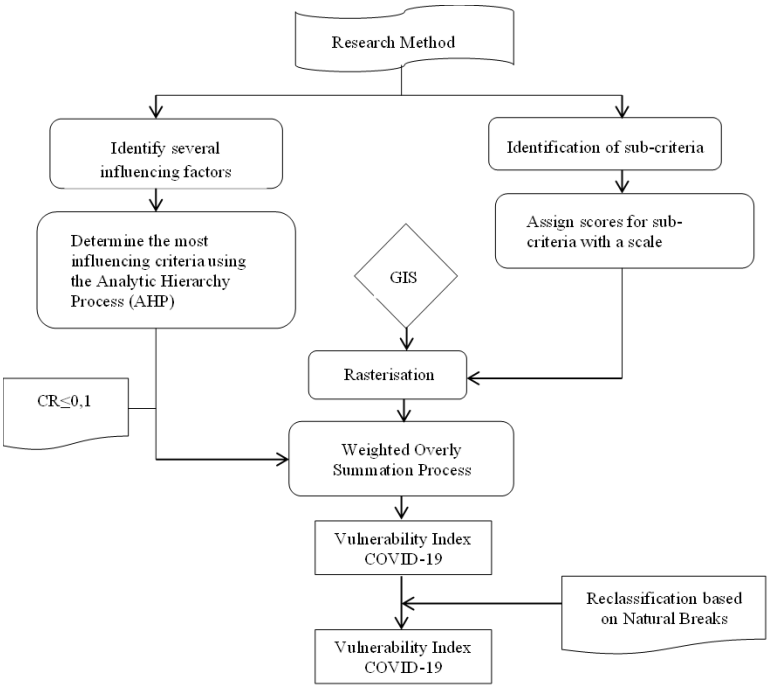

Figure 2. Overall Research Method

The Analytical Hierarchy Process (AHP) method of determining COVID-19 susceptibility criteria and pairwise comparison matrices can be seen in **Table 1**.

Table 1. Pairwise Comparison Matrix

Criteria	HB	SS	EP	PD	P	Weight
HB	1	0.33	0.3	0.14	0.11	0.04
SS	3	1	0.6	0.42	0.33	0.12
EP	5	1.66	1	0.71	0.55	0.2
PD	7	2.33	1.4	1	0.77	0.28
P	9	3	1.8	1.28	1	0.36
Total	25	8.32	5	3.55	2.76	1

Source: Result Analysis

Based on the pairwise comparison matrix calculation, the normalisation criteria and the weight of the requirements, and the consistency test, the consistency ratio is obtained with a CR value of ≤0.1.

RESULTS AND DISCUSSION

in this study, five variables determine the vulnerability of Covid-19, including population, population density, elderly population, school-age children, and the availability of beds to accommodate COVID patients. The results of the analysis of secondary data in 2020 are as follows:

Total population

The total population in each sub-district in Pontianak Regency can be seen in **Table 2**. The population data above is presented in graphical form as shown in the **Figure 3.**

Table 2. Total Population of Pontianak Regency in 2021

No	District	Number
1	South Pontianak	93.302
2	East Pontianak	106.033
3	West Pontianak	150.639
4	North Pontianak	145.639
5	Pontianak City	126.431
6	Southeast Pontianak	49.055

Source: Secondary Data

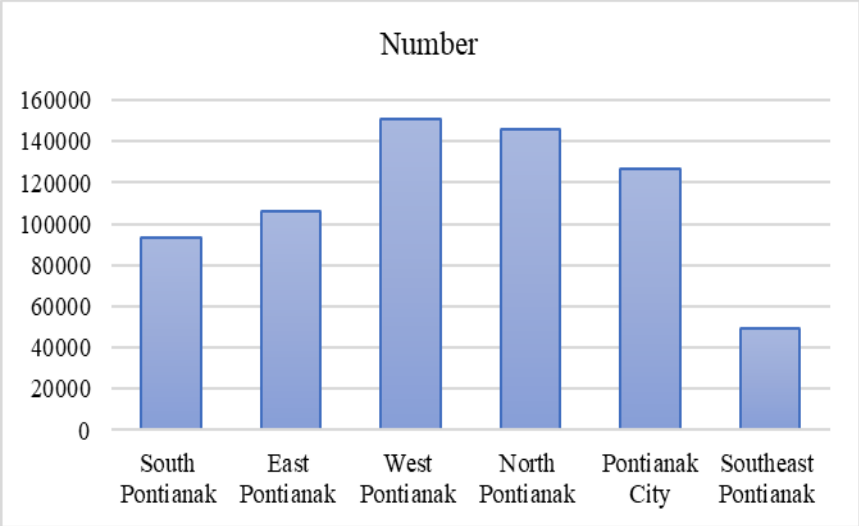

Figure 3. Total Population Graphical of Pontianak Regency

Based on the data in Table 2, it is known that the largest population is in West Pontianak District and the least is South Pontianak. When viewed from the population, the potential for the outbreak of Covid-19 in the West Pontianak District is greater than that of other sub-districts. The high number of Covid-19 cases is influenced by a high population size (Martins-Filho, 2021; Shadeed & Alawna,

2021) . This is due to the possibility of more significant interaction between communities compared to other sub-districts. The impact of population size on new infectious diseases has rarely been studied. Exploratory analysis of the relationship between population demographics and estimates of COVID-19 is important for policy planning and medical resources (Kodera et al., 2020).

Population Density

The distribution of population density in each sub-district of the city of Pontianak can be seen in **Table 3** and **Figure 4**.

Table 3. Population Density of Pontianak Regency in 2021

No	District	Density (Km^2)
1	South Pontianak	15,14
2	East Pontianak	8,98
3	West Pontianak	16,47
4	North Pontianak	37,22
5	Pontianak City	14,82
6	Southeast Pontianak	14,22

Source: Secondary Data

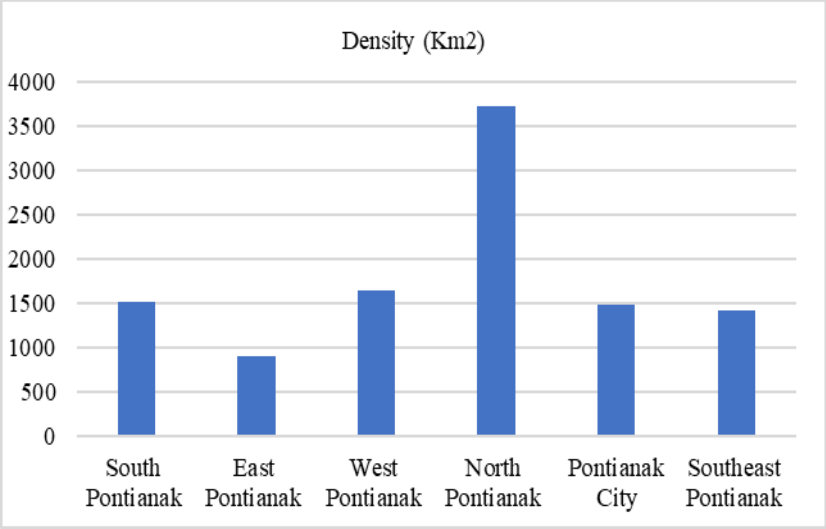

Figure 4. Population Density Graphical of Pontianak Regency

Density in North Pontianak is highest when compared to other sub-districts. This condition causes North Pontianak to have the highest potential to contract COVID-19. This is due to the high density automatically population mobility, and the level of population interaction will also be higher (Shadeed & Alawna, 2021). Population density has been used as a surrogate measure of social distancing capacity and studies (D. Chen et al., 2020; K. Chen & Li, 2020; Ilardi et al., 2020; Kodera et al., 2020; Martins-Filho, 2021; Suppawittaya et al., 2020; Wong & Li, 2020). Under normal conditions, there are no preventive efforts to prevent the transmission of COVID-19 by wearing masks, maintaining distance, and

maintaining personal hygiene, which will potentially lead to the transmission of this VOVID-19 disease.

Elderly Age

The number of older people in Pontianak Regency from each sub-district can be seen in **Table 4** and **Figure 5**.

Table 4. Number of Elderly Populations in Pontianak Regency in 2021

No	District	Number
1	South Pontianak	4.867
2	East Pontianak	4.842
3	West Pontianak	7.278
4	North Pontianak	6.717
5	Pontianak City	6.568
6	Southeast Pontianak	2.608

Source: Secondary Data

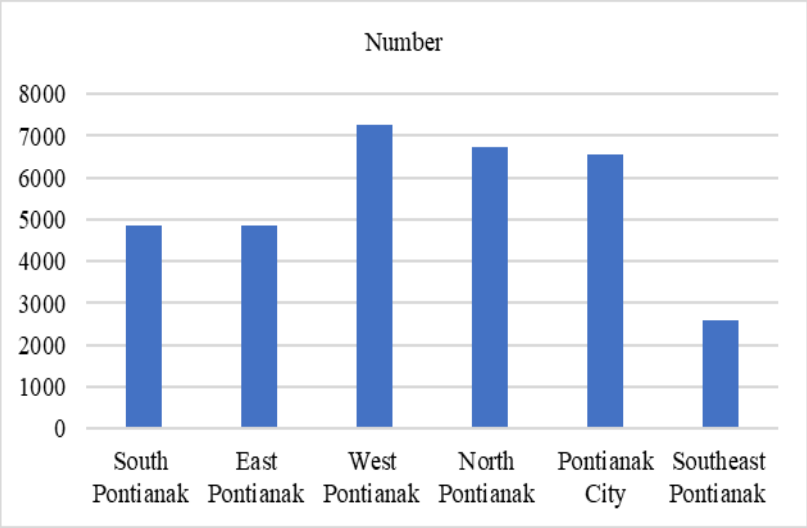

Figure 5. Elderly Age Graphical of Pontianak Regency

While there will not be a group of the population untouched by this crisis, the elderly population is likely to face the worst effects. Initial reports have shown that ~80% of the deaths due to COVID-19 occur in those over the age of 65 (CDC, 2020a). Since the virus has largely affected the elderly, lockdown measures for older individuals have been stricter, and may need to be extended in some countries (CDC, 2020b; Roberts, 2020). This means that the elderly will be most impacted by the side effects that follow in the coming months (Armitage & Nellums, 2020).

The elderly population is a population above 65 years. The elderly population is used as a variable because the elderly population is very vulnerable to COVID-

19. The immunity of the elderly, which on average has begun to decline, is the main factor in being easily infected by the virus. Pontianak has the most elderly population compared to other sub-districts. This causes North Pontianak to have a more significant potential for its people to be infected with the COVID-19 virus.

School Age

The number of school-age children in Pontianak Regency from each sub-district can be seen in **Table 5** and **Figure 6**.

Table 5. Number of School-Age Population in Pontianak Regency in 2021

No	District	Number
1	South Pontianak	19.550
2	East Pontianak	19.233
3	West Pontianak	22.991
4	North Pontianak	25.944
5	Pontianak City	26.050
6	Southeast Pontianak	10.723

Source: Secondary Data

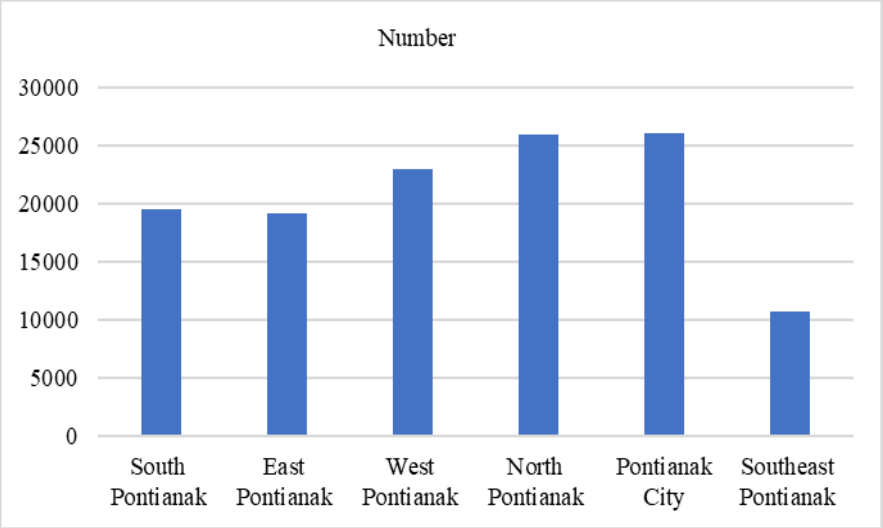

Figure 6. School Age Graphical of Pontianak Regency

The age of school children is used as a variable because they are considered potentially vulnerable to COVID-19 infection. The highest number of school-age children is in the Pontianak City sub-district. The number of school-age children who are deemed energetic to socialise amid society sometimes heed the rules of health protocols and are lulled because they understand that their age is the age of the new strong immunity. This condition is also considered a trigger for the transmission of COVID-19.

COVID has affected the physical and mental health of many students, distance learning led to dropping grades and many failures. COVID has also caused me to gain weight and be less active. Mental health affects the way you feel, act and behave, which can result in an inability to express feelings and lead to depression. Many students feel depressed because of COVID (Cruz, 2021).

Hospital Bed Availability

The number of available hospital beds for COVID-19 patients published by the COVID-19 task force, which researchers summarised from various hospital areas in Pontianak district, can be seen in **Table 6** and **Figure 7**.

Table 6. Number of Pontianak Hospital Beds in 2021

No	District	Number
1	South Pontianak	21
2	East Pontianak	9
3	West Pontianak	137
4	North Pontianak	194
5	Pontianak City	49
6	Southeast Pontianak	210

Source: Secondary Data

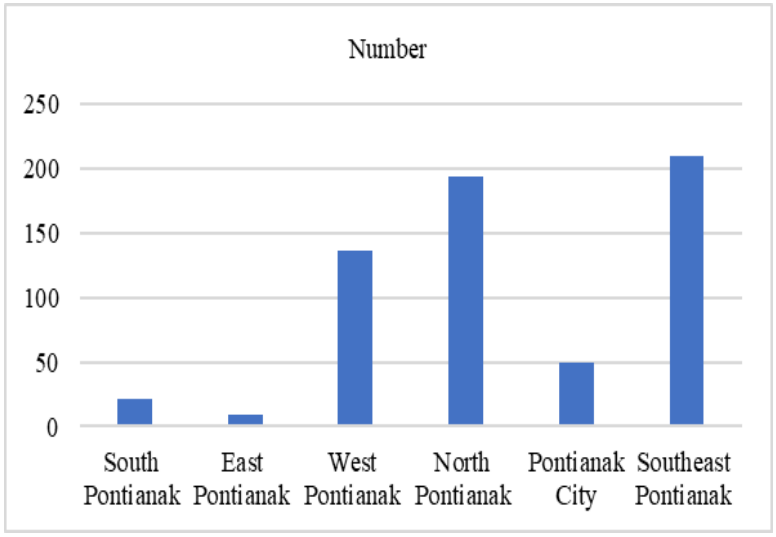

Figure 7. Hospital Bed Availability Graphical of Pontianak Regency

The availability of beds for people with COVID1- is a factor that also affects the vulnerability to the spread of COVID-19. Hospitals with good beds will accommodate more COVID-19 patients and are expected to be a factor for faster patient recovery. A smaller number of beds with a drastic reduction in all procedures and activities in an emergency condition need attention. The limited availability of

beds in a pandemic situation is quite counterintuitive, deaths started to decline after beds and resources were allocated specifically for COVID-19 patients (Castagna et al., 2022; Zhuang et al., 2021). Patients can be treated intensively under the supervision of the medical team, so they recover faster than those who are self-isolating at home.

Based on the above variables and data, the Pontianak district's COVID-19 vulnerability with the help of the Geographical Information System can be mapped. With the weighting method, the COVID-19 vulnerability index in Pontianak Regency can be made based on the COVID-19 Vulnerability Index (CVI) map development. The Pontianak Regency COVID-19 vulnerability map can be seen in **Figure 8**.

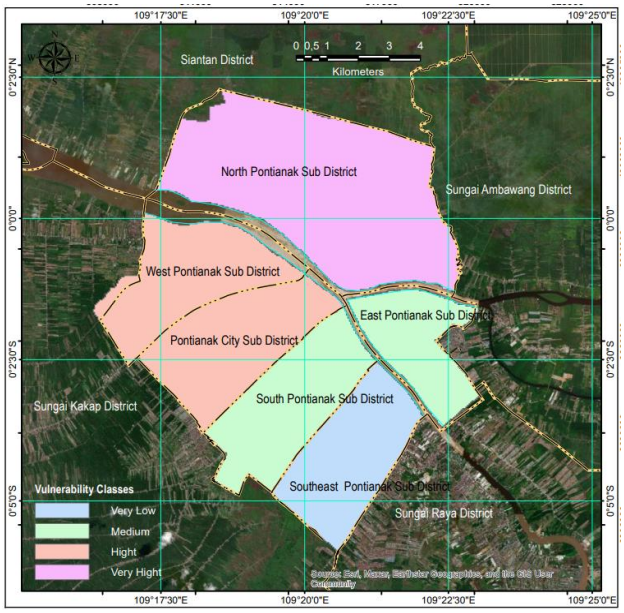

Figure 8. Spatial Map of COVID-19 Vulnerability in Pontianak Regency

Based on the map above, it was known that the sub-district that has a very high COVID-19 vulnerability is the North Pontianak sub-district. The main factor that causes it to have a very high vulnerability is a large population and very high density. The sub-districts with high vulnerability are the sub-districts of West Pontianak and Pontianak City. The sub-districts of South and East Pontianak have medium susceptibility. For the Southeast Pontianak sub-district, the level of vulnerability to COVID-19 is very low. The low vulnerability of COVID in the Southeast Pontianak District has the least number of educators and a density level included in the low category. The number of elderly is small, the number of school-age children is the least, and it has the most

number of hospital beds for Covid sufferers compared to other sub-districts. This condition causes Southeast Pontianak to have a very low susceptibility to COVID-19 transmission in the Pontianak district.

Based on the data available in each sub-district and data from the COVID-19 Task Force in early September 2021, information on the vulnerability of COVID-19 in the Pontianak district can be mapped. The goal is for the public to get complete information on the potential risks of COVID-19 in each sub-district so that vigilance increases.

The main factor that causes it to have a very high vulnerability is a large population and very high density. The number and high population density automatically cause a high level of interaction between communities. If people do not heed health protocols, the potential for COVID-19 transmission will be more significant. The number of older people in the North Pontianak sub-district is also high. The high number of older people causes many people to be vulnerable. Older people generally have low immunity to disease when compared to young people. The number of school-age children in the North Pontianak sub-district is high. A large number of school-age residents causes a high level of interaction between children in the school environment. The risk of school-age children contracting COVID-19 is very high. Children who like to play often forget the health protocols.

The sub-district of southeast Pontianak has the lowest level of vulnerability compared to other sub-districts. The contributing factor is that the Southeast Pontianak sub-district has the least population, the least number of older people, the least number of school-age children but has the most hospital beds for COVID-19 sufferers. The low population, the number of older people, the number of school-age children cause intense interaction between communities. The availability of beds for people with COVID1-19 is a factor that also affects the vulnerability to the spread of COVID-19. Hospitals with good beds will accommodate more COVID-19 patients and are expected to be a factor for faster patient recovery. Patients can be treated intensively under the supervision of the medical team, so they recover faster than those who are self-isolating at home.

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CONCLUSIONS

Human populations have been threatened due to the ongoing COVID-19 pandemic in early 2019 to 2020, predominantly those with low immunity with high intensity of interaction without strict health protocols that make them more prone to higher risk levels. To address this, one of them is presented with information a COVID-19 vulnerability map with the aim that the public gets more precise information related to the transmission of COVID-19 in their respective areas.

The researcher used vulnerability parameters linked with the COVID-19 contagion to identify the areas under different risk levels. COVID-19 vulnerability indicators that have been set are population number (F), population density (PD), elderly (EP) (Awad & Abu Harb, 2020), school students (SS), hospital beds (HB).

The results showed that the North Pontianak sub-district had a very high COVID-19 vulnerability. Districts of West Pontianak and Pontianak City have vulnerabilities. The sub-districts of South and East Pontianak have medium susceptibility. For the Southeast Pontianak sub-district, the level of vulnerability to COVID-19 is very low. The low vulnerability of COVID in the Southeast Pontianak District has the least number population, has a density level that is included in the low category. The number of elderly is small, the number of school-age children is the least, and it has the most number of hospital beds for Covid sufferers compared to other sub-districts.

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