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R. Azizah <azizah@fkm.unair.ac.id>

[Sains Malaysiana] Editor Decision

6 messages

Prof. Dr. Rusli Daik <rusli.daik@ukm.edu.my> Mon, Nov 30, 2020 at 1:44 PM
To: R Azizah <azizah@fkm.unair.ac.id>

Dear R Azizah:

The referee has commented on your paper titled: "ASSOCIATION BETWEEN CLIMATIC CONDITIONS , POPULATION DENSITY AND COVID-19 IN INDONESIA".

We would be glad to reconsider the paper if you are willing to amend the paper according to the recommendations by the referee.

Please find the comments with this email (located towards the end of this email, or as an email attachment, or both).

Please provide a List of Responses by answering / responding to every comments / suggestions when resubmitting the revised paper in a separate file.

Re-submission should be made online within 4 weeks.

Thank you.

Sincerely,

Prof. Dr. Rusli Daik
rusli.daik@ukm.edu.my

EDITOR/AUTHOR CORRESPONDENCE

Section Editor
2020-11-30 02:44 PM

Subject: [Sains Malaysiana] Editor Decision DELETE

Dear R Azizah:

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Re-submission should be made online within 4 weeks.

Thank you.

Sincerely,

Prof. Dr. Rusli Daik
rusli.daik@ukm.edu.my

Comments on the manuscript for authors:
this manuscript is acceptable but needed some revisions. The revisions have been written in the comments

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ASSOCIATION BETWEEN CLIMATIC CONDITIONS , POPULATION DENSITY AND COVID-19 IN INDONESIA

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Abstract

The first emergence of Corona Virus Disease 2019 (COVID-19) confirmed cases found in Wuhan, China, has become a global crisis. At least 177 countries have affected over 43,000,000 confirmed cases of corona positive and more than one million deaths until October 27th, 2020. Recent research has analyzed any possible factors causing the COVID-19 spreads were climate factors and population density. Indonesia was a tropical region known as the high-populated country in the World, with a 52.9% area with a high mean air temperature and over 267.7 million population. Our study aims to analyze the correlation between climate, population density, and COVID-19 in Indonesia. We used the K-means cluster method and Fisher's exact test to determine climatic conditions, population density, and COVID-19 clusters and study the correlation. Our research found that there is a correlation between climatic

conditions and population density with COVID-19 (p: 0,034; p:0,004). Warmer climate conditions and densely populated regions contributed to the risen COVID-19 transmission in Indonesia. These are highlighted by the evidence of the top six provinces with highest COVID-19 cases are province classified in warmer climatic conditions (high air temperature, low rainfall, and humidity) and a fairly-dense to densely populated region.

Keywords : Climatic Conditions, COVID-19, Population Density

Introduction

Starting at the end of 2019, a new respiratory disease, which was later named COVID-19, were found in Wuhan, China. This disease is caused by a novel coronavirus (SARS-CoV-2). The virus has spread throughout China within two months, which then develops into various countries. The World Health Organization (WHO) has declared the epidemic of public health emergencies since January 30th, 2020 (WHO, 2020a). This pandemic has caused panic around the World since the beginning of 2020. There were 177 countries with over 43,000,000 confirmed cases and more than 1,000,000 deaths until October 27th, 2020 (WHO, 2020b).

Elderly and people with congenital diseases are considered to be a high-risk group for COVID-19. The disease is spread through direct and indirect contact (Dangi, 2020). Through direct contacts, droplets can spread up to 1-2 m from the contact source. Many studies predict that the virus can spread through the air (Wang and Du, 2020), looking at the rapid spread of COVID-19. Some research was done to prove the spread of the SARS-CoV-2 virus in addition to through droplets. In October, The Center for Disease Control and Prevention (CDC) announced that the virus could spread through the air (CDC, 2020). The CDC's statement further confirmed that the spread of the virus is very frightening because the

potential spread of the virus is more comfortable and faster when it is through the air. The theory states that crowds can be the most vulnerable source for COVID-19 spread.

To date, the increase in daily COVID-19 cases in Indonesia is still an alarming number. Apart from manageable factors that can control the COVID-19 confirmed cases increase, there are some uncontrollable factors that we cannot handle, such as climate and population density and many other pre-existing conditions which increase the risk of death from COVID-19. Scientists in the United States government estimate that COVID-19 could kill 10 out of 1000 Americans. Crowd increases the potential for human contact and is a primary source of human-to-human transmissions. COVID-19 growth significantly in denser areas (Therese, 2020). Another study on climate and COVID-19 in Brazil, with an annual average temperature, ranges from 16.8°C to 27.4°C, found a negative linear association between temperature and the number of COVID-19 cases. They also found that the increase of 1°C is associated with a decrease of −4.8951% ($t = -2.29$, $p = 0.0226$) in the cumulative daily number of confirmed cases of COVID-19 (Prata, 2020). Research on population density, wind speed and COVID 19 has also been conducted in Turkey by Coskun (2020). The results showed that population density and wind, accounting for 94% of the virus spread variance, had a significant impact on the spread of the virus or the number of cases. Coskun (2020) stated that the virus is spreading more in windy weather, indicating that the air threatens humans with wind speeds. A cluster and regression model was carried out on the group of cities with the highest COVID-19 cases, and the highest population density in Algeria shows a strong correlation between population density and the number of COVID-19 infections. The results showed that population density positively affected the spread of COVID-19 (Kadi, 2020).

Indonesia is a highly-populated country; Indonesia's population deploys across 34 provinces, so does the climatic conditions. Although it is a tropical area, climatic conditions in various

provinces in Indonesia are diverse. Some regions may have a lower air temperature than others. Given these diverse conditions in Indonesia, it is necessary to study the climate conditions and population density to see whether these two factors are related to the enormous COVID-19 event in Indonesia. This study analyzes the correlation between climatic conditions (temperature, rainfall, and humidity), population density, and COVID-19 in 34 provinces in Indonesia.

Materials and Methods

This research was conducted in Indonesia using climatic conditions, population density, and COVID-19 data from secondary resources. Climatic conditions data are collected from Indonesia's Environmental Statistics 2019 report. Due to the limitation of data in Indonesia, we used the 2019 climate conditions in this study. Population density data is collected from the Indonesia Statistics 2020 report. COVID-19 data used in this study is a cumulative data of total, recovered, and death cases from early March until July 22, 2020. The data collected from COVID-19 Daily Media Report, Indonesian Health Ministry. There were 34 Province in Indonesia, which illustrated in figure 1 below.

Figure 1

This study used computer-based data processing with a statistical approach. There were two analyses conducted in this study: K-means cluster and Fisher's exact test. K-means cluster was used to determine the clusters of climatic conditions, population density, and COVID-19. Fisher's exact test is used to determine the correlation between the climatic condition and COVID-19 and the correlation between population density and COVID-19.

Result and Discussion

COVID-19 Cluster Spreads in Indonesia

K-means cluster is used to determine the COVID-19 clusters. There are three indicators used to determine the COVID-19 clusters; total, recovered, and death cases. Table 1 below shows three COVID-19 clusters; low, medium, and high.

Table 1

From table 1, low clusters are cluster with lower total COVID-19 cases than the medium and high cluster. The recovery rate means recovered cases per mean total cases in each cluster in the low cluster are 56.9%. It is higher than the medium cluster with a 44.73% recovery rate and lower than the high cluster is 58.83%. The case fatality rate means death cases per mean total cases in each cluster; in the low cluster, they are lower with a 3.49% than the medium cluster 4.82% and high cluster 6.12%.

From the cluster analysis, 28 provinces classified in low clusters are Aceh; Bali; Banten; Bangka Belitung; Bengkulu; DI Yogyakarta; Jambi; West Kalimantan; East Kalimantan; Central Kalimantan; North Kalimantan; Riau Islands; West Nusa Tenggara; South Sumatra; West Sumatra; North Sulawesi; North Sumatra; Southeast Sulawesi; Central Sulawesi; Lampung; Riau; North Maluku; Maluku; West Papua; Papua; West Sulawesi; East Nusa Tenggara; Gorontalo; then four provinces classified in medium clusters West Java Province; Central Java; Kalimantan Selatan; South Sumatra; and two clusters are classified in high clusters East Java and Jakarta.

Figure 2

Figure 2 shows the six provinces in Indonesia with the highest number of total cases: East Java 19,093; Jakarta 17,621; South Sulawesi 8,407; Central Java 7,726; West Java 5,741; and South Kalimantan 5,216.

Correlation Between Climatic Conditions (Temperature, Humidity, and Rainfall) and COVID-19 In Indonesia

Climatic Conditions (Temperature, Humidity, and Rainfall) In Indonesia

There are three climate indicators used to determine the Climatic Conditions cluster; air temperature, rainfall, and humidity. The three indicators used different units, so a value standardization is performed. There are two Climatic Conditions clusters; Climatic Conditions I and Climatic Conditions II.

Table 2

The mean air temperature in Climatic Conditions I is lower than Climatic Conditions II, while the mean rainfall and humidity in Climatic Conditions I are higher than the Climatic Conditions II. These show that Climatic Conditions I is a colder area than Climatic Conditions II.

From the cluster analysis, 16 provinces within Climatic conditions I are Aceh; West Sumatra; Riau; Jambi; Bangka Belitung; Riau Islands; West Kalimantan; Central Kalimantan; North Kalimantan; North Sulawesi; South Sulawesi; Southeast Sulawesi; Maluku; North Maluku; West Papua; Papua; and 18 provinces within Climatic conditions II are North Sumatra; South Sumatra; Bengkulu; Lampung; Jakarta; West Java; Central Java; Yogyakarta; East Java; Banten; Bali; West Nusa Tenggara; east Nusa Tenggara; South Kalimantan; East Kalimantan; Central Sulawesi; Gorontalo; West Sulawesi. This finding shows that 52.9% of Indonesia's area indicates having a high mean air temperature, low rainfall and humidity, included in Climatic conditions II.

Table 3

Our study found a correlation between Climatic conditions and COVID-19 clusters p=0.034 with a positive correlation coefficient of 40%, indicates a strong correlation between climatic conditions and COVID-19. It shows a linear correlation, that higher climate conditions led to higher COVID-19 cases. In all provinces in Climatic Conditions I, have low COVID-19 cases. We predict that the coronavirus can live under high temperatures. Indonesia's mean air temperature ranges from 26.7°C – 29.5°C and COVID-19 spread in Indonesia is also high.

The condition is not according to the previous studies state that coronavirus can survive with lower air temperatures 5°C – 11°C (Sajadi et al., 2020). However, Indonesia's humidity level is relatively high, ranging from 67% - 87% to the range of humidity, which is considered following the coronavirus environment (44% - 88%) (Sajadi et al., 2020). The humidity level in Indonesia is suitable for the survival of the coronavirus. We predict humidity is an essential climate factor in the survival of the coronavirus.

A study conducted in Brazil revealed that warm temperature (above 25^{o}C) were not associated with the declined of the COVID-19 cases (Prata et al, 2020). Pan et al (2020) suggest that warmer weather unlikely to reduce the COVID-19 transmissions. Although a surge in COVID-19 cases in the hot and humid region is not as rapid as in the cold and dry region, COVID-19 cases in the hot and humid region keep increase constantly. Warm weather alone may not be able to stop the COVID-19 transmissions and several other factors other than meteorological factors should take into account (Bukhari et al, 2020). The spread of COVID-19 appears to be lower in warm and wet climates, but the certainty of the resulting evidence is rated low. Temperature and humidity alone do not explain most of the variability of the COVID-19 outbreak. The spread of COVID-19 may be influenced by others factors such as public isolation policy, herd immunity, migration patterns, population density, and cultural aspects (Macenas et al, 2020).

Correlation Between Population Density (Population and Area of Province) And COVID-19 In Indonesia

Population Density (Population and Area of Province) In Indonesia

Various studies on population density correlation and COVID-19 spread are conducted in the world. Some studies found that population density correlates with COVID-19 distribution

rates, while others found the opposite. According to research conducted in China, population density is not related to COVID-19 events. However, Sun et al. (2020) stated that territorial restriction is a useful measure in reducing the chance of infection in the community. Territorial restrictions, commonly referred to as regional quarantine, are traditional solutions used in antiquity to control the spread of infectious diseases (Wilder-Smith and Freedman, 2020). This step is useful to limit communities' interaction within the region so that the virus does not increasingly spread mainly in densely populated areas.

High-density regions can cause the spread of the SARS-Cov-2 virus faster than lower density regions, based on research conducted in Japan (Sajadi et al., 2020). High-density levels increase the likelihood of physical contact with others due to increasingly limited wiggle room (Ramadhani, 2020). Besides, people in densely populated areas will have less chance of treating properly if the health service in the region is inadequate inpatient surges. Population density is related to the number of COVID-19 cases, the case fatality rate from COVID-19, and the willingness of health services in the region (Amoo et al., 2020).

Table 4

We divided population density into three categories; low, medium, and high. Population density is the amount that represents how dense the population in one particular area. Population density is calculated by dividing the population by the area. There is a large discrepancy in high population density compared to the low and medium population.

There 27 low density provinces are Aceh; North Sumatra; West Sumatra; Riau; Jambi; South Sumatra; Bengkulu; Lampung; Bangka Belitung; Riau Islands; West Nusa Tenggara; East Nusa Tenggara; West Kalimantan; Central Kalimantan; South Kalimantan; East Kalimantan; North Kalimantan; North Sulawesi; Central Sulawesi; South Sulawesi; North Sulawesi; Gorontalo; West Sulawesi; Maluku; North Maluku; West Papua; Papua. The six medium density provinces are West Java; Central Java; Yogyakarta; East Java; Banten; Bali. The

high-density province is Jakarta. The province in Java Island has a medium to high population density.

Figure 3

Jakarta province has a high population of 15,900 people/km^2 with population is 10,557,800 and 664.01 km^2. Jakarta is one of the metropolitan areas with a dense population. In addition to having a dense population, Jakarta is one of the areas with a high positive case. Most metropolitan areas in different countries have dense populations. New York is one of the states of the United States with high population density and positive cases. In research conducted in the United States, New York accounted for 37% of positive cases in the United States. In addition to New York, other metropolitan areas such as Chicago, Washington and Los Angles are also among the top ten densely populated metropolitan areas contributing to positive cases in the United States (Zhang and Schwartz, 2020).

Table 5

Our study found a correlation between population density and COVID-19 with p=0.004 and a positive correlation coefficient of 63.3%. Based on cross-tabulation results, 92.6% of low-density provinces have low COVID-19 cases. As well as 100% high-density have high COVID-19. This research is in line with research (Sarmadi et al., 2020) that population density in the United States affects deaths from COVID-19 in the United States. The greater the population density, the greater the mortality rate in the United States. Similar research was conducted in India, which ranks in the top ten of the world's top population as Indonesia. The research shows an association between population density and COVID-19 spread (Bhadra, Mukherjee and Sarkar, 2020). This result is similar to this study and the United States study, which shows that population density has a role in the spread of COVID-19.

Six Provinces With The Highest COVID-19 Cases, Climate Conditions and Population Density

The Top Six Provinces with the Highest Cases, Climatic Conditions and Population Density

Table 6

Our study found that the six provinces with the highest COVID-19 cases were in Climatic conditions II (high mean air temperature with low rainfall and humidity) (Table.4). The findings are in stark contrast, as research analyzing the effects of climate and weather on COVID-19 cases found that countries with high mean air temperatures and low humidity have the effect of lowering the number of deaths caused by COVID-19. A study found that tropical regions with high mean temperature and high relative humidity, i.e., India, Pakistan, Saudi Arabia, Malaysia, Thailand, and Australia, have low death cases and high recovery rates (Pavani & Sunalini, 2020). Iqbal et al. (2020) also discovered that tropical regions, i.e., Malaysia, Thailand, and Indonesia, are less affected by the coronavirus. However, Iqbal et al. (2020) study the regional climatic condition's effect by June 2020. Some researchers also conducted a study in the subtropical climate, i.e., China. They also found that higher average air temperatures will lower the risk of COVID-19 (Wang et al., 2020; Ma et al., 2020). However, Indonesia's high mean temperature did not follow the same conditions related to COVID-19 in other regions. Coronavirus will still last inside the human body and infect other humans during the incubation period. The more frequent human activities outside the house, the more the virus will likely spread and infect other humans.

Based on our results, the top 6 provinces with the highest COVID-19 cases are located in a fairly dense and dense region. As a high-density region, Jakarta is the region with the second-highest COVID-19 cases, while East Java is in the first position is a fairly dense region. The rest following a sequence order are West Java, Central Java, South Kalimantan, and South Sumatra. This region is fairly dense. Our result found a similar study conducted by Jawad (2020), which states that the results of an analysis conducted in countries vulnerable to COVID-19 spread show that population density affects the peak period of COVID-19 spread.

However, population density is not an essential factor in the spread of COVID-19 under strict lockdown policies. China's lockdown policy could effectively limit the speed at which COVID-19 spreads (Sun, 2020).

Conclusion

Indonesia region is identified in high air temperature with 26.7°C – 29.5°C and high humidity 67 - 87%, due to its tropical climate. However, the majority of the province in Indonesia are classified in Climatic Conditions II in 52,9%. Climatic conditions II is a Climatic condition with higher mean air temperatures, lower rainfall and humidity than the rest. Indonesia is also known as a highly-dense country. Jakarta is the most populated region in Indonesia (population density: 15,900). Our results found a correlation between the climatic conditions and the COVID-19 cluster (p:0,034), and there is a correlation between population density and COVID-19 clusters (p:0,004). Population density is more related to the high number of COVID-19 cases in Indonesia, which has a positive correlation of 63.3%. The top six provinces that have the highest COVID-19 cases in Indonesia are classified in Climatic Conditions II and a fairly-dense to densely populated region. There need to be adaptation and mitigation measures in COVID-19 control related to climate conditions in Climatic conditions II and high population density so that policies in their respective provinces in crowd control, social distancing, and efforts to reduce COVID-19 cases through increased community-based awareness.

Acknowledgments

Thanks to Department of Environmental Health and Environmental Health Master Program, Faculty of Public Health, Universitas Airlangga which has facilitated the activities of writing scientific articles in the framework of international journal publication. We also thank Prof.

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Dear chief editor and reviewers,

We would like to thank for giving us the opportunity to submit a revised draft of our manuscript entitled "Association between Climatic Conditions, Population Density and COVID-19 in Indonesia" to the Sains Malaysiana Journal. We very much appreciate the editors' insightful and thoughtful review, comments and constructive suggestions. The comments helped clarify and improve our paper. We have revised our paper accordingly. The revised text according to the reviewers' comments and suggestion is highlighted in yellow. We reply to the reviewers' comments point by point as the following lists.

Response to Editors:

1. Comment: There is no conclusion from this article
   Response: We thank the editors for the thorough review. We have added conclusion in our abstract. Our research found that there is a correlation between climatic conditions and population density with COVID-19 (p: 0,034; p:0,004). Warmer climate conditions and densely populated regions contributed to the risen COVID-19 transmission in Indonesia. These are highlighted by the evidence of the top six provinces with highest COVID-19 cases are province classified in warmer climatic conditions (high air temperature, low rainfall, and humidity) and a fairly-dense to densely populated region.

2. Comment: Whether this data can be validated, why not use the cumulative mean data. What about other secondary data ?
   Response: We thank the editors for the thorough review. We missed to mention in the materials and methods section that the data used in this study is a cumulative COVID-19 data from early March to 22 July, 2020. We have change the text accordingly.
   COVID-19 data used in this study is a cumulative data of total, recovered, and death cases from early March until July 22, 2020.

3. Comment: Positive correlation coefficient 40%. How to explain this statement ?
   Response: We thank the editors for the valuable comments. A positive correlation coefficient of 40% shows that there is a strong correlation between climatic conditions and COVID-19. It shows a linear correlation which stated that higher climate conditions led to higher COVID-19 cases. We have added these explanations to explain the positive correlation coefficient of 40% terms.

4. Comment: Based on all the results of these studies, what do you think about the nature and characteristics of the COVID-19 virus which has an RNA base (almost never wrong in the replication process, is very easy to mutate, and is very easy to adapt to extreme conditions so that its spread is very fast. Many early studies stated hot climatic conditions can inhibit the spread of COVID-19, and not proven.
   Response: We thank the editors for the valuable comment. We agreed with reviewers comment which stated that COVID-19 virus is very easy to mutate and is very easy to adapt to extreme conditions. Recent research has also stated that hot climatic conditions may not be related to the spread of COVID-19. Hereby, in the text we have added some additional reference which can support this statement.

A study conducted in Brazil revealed that warm temperature (above 25^{o}C) were not associated with the declined of the COVID-19 cases (Prata et al, 2020). Pan et al (2020) suggest that warmer weather unlikely to reduce the COVID-19 transmissions. Although a surge in COVID-19 cases in the hot and humid region is not as rapid as in the cold and dry region, COVID-19 cases in the hot and humid region keep increase constantly. Warm weather alone may not be able to stop the COVID-19 transmissions and several other factors other than meteorological factors should take into account (Bukhari et al, 2020). The spread of COVID-19 appears to be lower in warm and wet climates, but the certainty of the resulting evidence is rated low. Temperature and humidity alone do not explain most of the variability of the COVID-19 outbreak. The spread of COVID-19 may be influenced by others factors such as public isolation policy, herd immunity, migration patterns, population density, and cultural aspects (Macenas et al, 2020).

5. Comment: North Sumatra and South Sumatra some time ago occupied the top ranking positions, in a study revealed that these two provinces were categorized as low density. How is your research related ?

   Response: We thank the editors for the valuable comment. Using the k-means cluster analysis, our study classified North Sumatra is a low-density province (200 people/km^2), while South Sumatra is a medium density province (92 people/km^2). North Sumatra with low density, evidence with lower COVID-19 cases. South Sumatra with medium density, also evidence with medium COVID-19 cases.

6. Comment: Grammatical errors
   a. fair densely : fairly dense
   b. direct contact : direct contacts
   c. state : states
   d. transmission : transmissions
   e. annual : an annual

   Response: We have reviewed our paper and revised them accordingly.

ASSOCIATION BETWEEN CLIMATIC CONDITIONS , POPULATION DENSITY AND COVID-19 IN INDONESIA

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Abstract

The first emergence of Corona Virus Disease 2019 (COVID-19) confirmed cases found in Wuhan, China, has become a global crisis. At least 177 countries have affected over 43,000,000 confirmed cases of corona positive and more than one million deaths until October 27th, 2020. Recent research has analyzed any possible factors causing the COVID-19 spreads were climate factors and population density. Indonesia was a tropical region known as the high-populated country in the World, with a 52.9% area with a high mean air temperature and over 267.7 million population. Our study aims to analyze the correlation between climate, population density, and COVID-19 in Indonesia. We used the K-means cluster method and Fisher's exact test to determine climatic conditions, population density, and COVID-19 clusters and study the correlation. This research found that a correlation between climatic conditions (p: 0.034) and population density (p: 0,004) to COVID-19.

However, population density is more related to the high number of COVID-19 cases in Indonesia, which has a positive correlation of 63.3%. The top six provinces in Indonesia with the highest COVID-19 cases are the region with high mean air temperature, low rainfall and humidity, and a fair densely populated area.

Keywords : ~~Climate, COVID-19, Population Density~~

Introduction

Starting at the end of 2019, a new respiratory disease, which was later named COVID-19, were found in Wuhan, China. This disease is caused by a novel coronavirus (SARS-CoV-2). The virus has spread throughout China within two months, which then develops into various countries. The World Health Organization (WHO) has declared the epidemic of public health emergencies since January 30th, 2020 (WHO, 2020a). This pandemic has caused panic around the World since the beginning of 2020. There were 177 countries with over 43,000,000 confirmed cases and more than 1,000,000 deaths until October 27th, 2020 (WHO, 2020b).

Elderly and people with congenital diseases are considered to be a high-risk group for COVID-19. The disease is spread through direct and indirect contact (Dangi, 2020). Through direct contact, droplets can spread up to 1-2 m from the contact source. Many studies predict that the virus can spread through the air (Wang and Du, 2020), looking at the rapid spread of COVID-19. Some research was done to prove the spread of the SARS-CoV-2 virus in addition to through droplets. In October, The Center for Disease Control and Prevention (CDC) announced that the virus could spread through the air (CDC, 2020). The CDC's statement further confirmed that the spread of the virus is very frightening because the

potential spread of the virus is more comfortable and faster when it is through the air. The theory state that crowds can be the most vulnerable source for COVID-19 spread.

To date, the increase in daily COVID-19 cases in Indonesia is still an alarming number. Apart from manageable factors that can control the COVID-19 confirmed cases increase, there are some uncontrollable factors that we cannot handle, such as climate and population density and many other pre-existing conditions which increase the risk of death from COVID-19. Scientists in the United States government estimate that COVID-19 could kill 10 out of 1000 Americans. Crowd increases the potential for human contact and is a primary source of human-to-human transmission. COVID-19 growth significantly in denser areas (Therese, 2020). Another study on climate and COVID-19 in Brazil, with annual average temperature, ranges from 16.8°C to 27.4°C, found a negative linear association between temperature and the number of COVID-19 cases. They also found that the increase of 1°C is associated with a decrease of −4.8951% ($t = -2.29$, $p = 0.0226$) in the cumulative daily number of confirmed cases of COVID-19 (Prata, 2020). Research on population density, wind speed and COVID 19 has also been conducted in Turkey by Coskun (2020). The results showed that population density and wind, accounting for 94% of the virus spread variance, had a significant impact on the spread of the virus or the number of cases. Coskun (2020) stated that the virus is spreading more in windy weather, indicating that the air threatens humans with wind speeds. A cluster and regression model was carried out on the group of cities with the highest COVID-19 cases, and the highest population density in Algeria shows a strong correlation between population density and the number of COVID-19 infections. The results showed that population density positively affected the spread of COVID-19 (Kadi, 2020).

Indonesia is a highly-populated country; Indonesia's population deploys across 34 provinces, so does the climatic conditions. Although it is a tropical area, climatic conditions in various provinces in Indonesia are diverse. Some regions may have a lower air temperature than

others. Given these diverse conditions in Indonesia, it is necessary to study the climate conditions and population density to see whether these two factors are related to the enormous COVID-19 event in Indonesia. This study analyzes the correlation between climatic conditions (temperature, rainfall, and humidity), population density, and COVID-19 in 34 provinces in Indonesia.

Materials and Methods

This research was conducted in Indonesia using climatic conditions, population density, and COVID-19 data from secondary resources. Climatic conditions data are collected from Indonesia's Environmental Statistics 2019 report. Due to the limitation of data in Indonesia, we used the 2019 climate conditions in this study. Population density data is collected from the Indonesia Statistics 2020 report. COVID-19 data is collected from COVID-19 Daily Media Report dated July 22, 2020, at 12.00 WIB, Indonesian Ministry of Health. There were 34 Province in Indonesia, which illustrated in figure 1 below.

Figure 1

This study used computer-based data processing with a statistical approach. There were two analyses conducted in this study: K-means cluster and Fisher's exact test. K-means cluster was used to determine the clusters of climatic conditions, population density, and COVID-19. Fisher's exact test is used to determine the correlation between the climatic condition and COVID-19 and the correlation between population density and COVID-19.

Result and Discussion

COVID-19 Cluster Spreads in Indonesia

K-means cluster is used to determine the COVID-19 clusters. There are three indicators used to determine the COVID-19 clusters; total, recovered, and death cases. Table 1 below shows three COVID-19 clusters; low, medium, and high.

Table 1

From table 1, low clusters are cluster with lower total COVID-19 cases than the medium and high cluster. The recovery rate means recovered cases per mean total cases in each cluster in the low cluster are 56.9%. It is higher than the medium cluster with a 44.73% recovery rate and lower than the high cluster is 58.83%. The case fatality rate means death cases per mean total cases in each cluster; in the low cluster, they are lower with a 3.49% than the medium cluster 4.82% and high cluster 6.12%.

From the cluster analysis, 28 provinces classified in low clusters are Aceh; Bali; Banten; Bangka Belitung; Bengkulu; DI Yogyakarta; Jambi; West Kalimantan; East Kalimantan; Central Kalimantan; North Kalimantan; Riau Islands; West Nusa Tenggara; South Sumatra; West Sumatra; North Sulawesi; North Sumatra; Southeast Sulawesi; Central Sulawesi; Lampung; Riau; North Maluku; Maluku; West Papua; Papua; West Sulawesi; East Nusa Tenggara; Gorontalo; then four provinces classified in medium clusters West Java Province; Central Java; Kalimantan Selatan; South Sumatra; and two clusters are classified in high clusters East Java and Jakarta.

Figure 2

Figure 2 shows the six provinces in Indonesia with the highest number of total cases: East Java 19,093; Jakarta 17,621; South Sulawesi 8,407; Central Java 7,726; West Java 5,741; and South Kalimantan 5,216.

Correlation Between Climatic Conditions (Temperature, Humidity, and Rainfall) and COVID-19 In Indonesia

Climatic Conditions (Temperature, Humidity, and Rainfall) In Indonesia

There are three climate indicators used to determine the Climatic Conditions cluster; air temperature, rainfall, and humidity. The three indicators used different units, so a value standardization is performed. There are two Climatic Conditions clusters; Climatic Conditions I and Climatic Conditions II.

Table 2

The mean air temperature in Climatic Conditions I is lower than Climatic Conditions II, while the mean rainfall and humidity in Climatic Conditions I are higher than the Climatic Conditions II. These show that Climatic Conditions I is a colder area than Climatic Conditions II.

From the cluster analysis, 16 provinces within Climatic conditions I are Aceh; West Sumatra; Riau; Jambi; Bangka Belitung; Riau Islands; West Kalimantan; Central Kalimantan; North Kalimantan; North Sulawesi; South Sulawesi; Southeast Sulawesi; Maluku; North Maluku; West Papua; Papua; and 18 provinces within Climatic conditions II are North Sumatra; South Sumatra; Bengkulu; Lampung; Jakarta; West Java; Central Java; Yogyakarta; East Java; Banten; Bali; West Nusa Tenggara; east Nusa Tenggara; South Kalimantan; East Kalimantan; Central Sulawesi; Gorontalo; West Sulawesi. This finding shows that 52.9% of Indonesia's area indicates having a high mean air temperature, low rainfall and humidity, included in Climatic conditions II.

Table 3

Our study found a correlation between Climatic conditions and COVID-19 clusters p=0.034 with a positive correlation coefficient of 40%. In all provinces in Climatic Conditions I, have low COVID-19 cases. We predict that the coronavirus can live under high temperatures. Indonesia's mean air temperature ranges from 26.7°C – 29.5°C and COVID-19 spread in Indonesia is also high. The condition is not according to the previous studies state that coronavirus can survive with lower air temperatures 5°C – 11°C (Sajadi et al., 2020).

However, Indonesia's humidity level is relatively high, ranging from 67% - 87% to the range of humidity, which is considered following the coronavirus environment (44% - 88%) (Sajadi et al., 2020). The humidity level in Indonesia is suitable for the survival of the coronavirus. We predict humidity is an essential climate factor in the survival of the coronavirus.

Correlation Between Population Density (Population and Area of Province) And COVID-19 In Indonesia

Population Density (Population and Area of Province) In Indonesia

Various studies on population density correlation and COVID-19 spread are conducted in the world. Some studies found that population density correlates with COVID-19 distribution rates, while others found the opposite. According to research conducted in China, population density is not related to COVID-19 events. However, Sun et al. (2020) stated that territorial restriction is a useful measure in reducing the chance of infection in the community. Territorial restrictions, commonly referred to as regional quarantine, are traditional solutions used in antiquity to control the spread of infectious diseases (Wilder-Smith and Freedman, 2020). This step is useful to limit communities' interaction within the region so that the virus does not increasingly spread mainly in densely populated areas.

High-density regions can cause the spread of the SARS-Cov-2 virus faster than lower density regions, based on research conducted in Japan (Sajadi et al., 2020). High-density levels increase the likelihood of physical contact with others due to increasingly limited wiggle room (Ramadhani, 2020). Besides, people in densely populated areas will have less chance of treating properly if the health service in the region is inadequate inpatient surges. Population density is related to the number of COVID-19 cases, the case fatality rate from COVID-19, and the willingness of health services in the region (Amoo et al., 2020).

Table 4

We divided population density into three categories; low, medium, and high. Population density is the amount that represents how dense the population in one particular area. Population density is calculated by dividing the population by the area. There is a large discrepancy in high population density compared to the low and medium population.

There 27 low density provinces are Aceh; North Sumatra; West Sumatra; Riau; Jambi; South Sumatra; Bengkulu; Lampung; Bangka Belitung; Riau Islands; West Nusa Tenggara; East Nusa Tenggara; West Kalimantan; Central Kalimantan; South Kalimantan; East Kalimantan; North Kalimantan; North Sulawesi; Central Sulawesi; South Sulawesi; North Sulawesi; Gorontalo; West Sulawesi; Maluku; North Maluku; West Papua; Papua. The six medium density provinces are West Java; Central Java; Yogyakarta; East Java; Banten; Bali. The high-density province is Jakarta. The province in Java Island has a medium to high population density.

Figure 3

Jakarta province has a high population of 15,900 people/km^2 with population is 10,557,800 and 664.01 km^2. Jakarta is one of the metropolitan areas with a dense population. In addition to having a dense population, Jakarta is one of the areas with a high positive case. Most metropolitan areas in different countries have dense populations. New York is one of the states of the United States with high population density and positive cases. In research conducted in the United States, New York accounted for 37% of positive cases in the United States. In addition to New York, other metropolitan areas such as Chicago, Washington and Los Angles are also among the top ten densely populated metropolitan areas contributing to positive cases in the United States (Zhang and Schwartz, 2020).

Table 5

Our study found a correlation between population density and COVID-19 with p=0.004 and a positive correlation coefficient of 63.3%. Based on cross-tabulation results, 92.6% of low-

density provinces have low COVID-19 cases. As well as 100% high-density have high COVID-19. This research is in line with research (Sarmadi et al., 2020) that population density in the United States affects deaths from COVID-19 in the United States. The greater the population density, the greater the mortality rate in the United States. Similar research was conducted in India, which ranks in the top ten of the world's top population as Indonesia. The research shows an association between population density and COVID-19 spread (Bhadra, Mukherjee and Sarkar, 2020). This result is similar to this study and the United States study, which shows that population density has a role in the spread of COVID-19.

Six Provinces With The Highest COVID-19 Cases, Climate Conditions and Population Density

The Top Six Provinces with the Highest Cases, Climatic Conditions and Population Density

Table 6

Our study found that the six provinces with the highest COVID-19 cases were in Climatic conditions II (high mean air temperature with low rainfall and humidity) (Table.4). The findings are in stark contrast, as research analyzing the effects of climate and weather on COVID-19 cases found that countries with high mean air temperatures and low humidity have the effect of lowering the number of deaths caused by COVID-19. A study found that tropical regions with high mean temperature and high relative humidity, i.e., India, Pakistan, Saudi Arabia, Malaysia, Thailand, and Australia, have low death cases and high recovery rates (Pavani & Sunalini, 2020). Iqbal et al. (2020) also discovered that tropical regions, i.e., Malaysia, Thailand, and Indonesia, are less affected by the coronavirus. However, Iqbal et al. (2020) study the regional climatic condition's effect by June 2020. Some researchers also conducted a study in the subtropical climate, i.e., China. They also found that higher average air temperatures will lower the risk of COVID-19 (Wang et al., 2020; Ma et al., 2020). However, Indonesia's high mean temperature did not follow the same conditions related to

COVID-19 in other regions. Coronavirus will still last inside the human body and infect other humans during the incubation period. The more frequent human activities outside the house, the more the virus will likely spread and infect other humans.

Based on our results, the top 6 provinces with the highest COVID-19 cases are located in a fairly dense and dense region. As a high-density region, Jakarta is the region with the second-highest COVID-19 cases, while East Java is in the first position is a fairly dense region. The rest following a sequence order are West Java, Central Java, South Kalimantan, and South Sumatra. This region is fairly dense. Our result found a similar study conducted by Jawad (2020), which states that the results of an analysis conducted in countries vulnerable to COVID-19 spread show that population density affects the peak period of COVID-19 spread. However, population density is not an essential factor in the spread of COVID-19 under strict lockdown policies. China's lockdown policy could effectively limit the speed at which COVID-19 spreads (Sun, 2020).

Conclusion

Indonesia region is identified in high air temperature with 26.7°C – 29.5°C and high humidity 67 - 87%, due to its tropical climate. However, the majority of the province in Indonesia are classified in Climatic Conditions II in 52,9%. Climatic conditions II is a Climatic condition with higher mean air temperatures, lower rainfall and humidity than the rest. Indonesia is also known as a highly-dense country. Jakarta is the most populated region in Indonesia (population density: 15,900). Our results found a correlation between the climatic conditions and the COVID-19 cluster (p:0,034), and there is a correlation between population density and COVID-19 clusters (p:0,004). Population density is more related to the high number of COVID-19 cases in Indonesia, which has a positive correlation of 63.3%. The top six provinces that have the highest COVID-19 cases in Indonesia are classified in

Climatic Conditions II and a fairly-dense to densely populated region. There need to be adaptation and mitigation measures in COVID-19 control related to climate conditions in Climatic conditions II and high population density so that policies in their respective provinces in crowd control, social distancing, and efforts to reduce COVID-19 cases through increased community-based awareness.

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Dear author,

Manuscript: for SAINS MALAYSIANA

I am pleased to inform you that your paper entitled '**Association between Climatic Conditions, Population Density and COVID-19 in Indonesia**' by R. AZIZAH, SANTI MARTINI, LILIS SULISTYORINI, MAHMUDAH, ADITYA SUKMA PAWITRA, DIDIK BUDIJANTO, STEFANNY SURYA NAGARI, CENDANA FITRAHANJANI, FAIRUZ HANIYAH RAMADHANI & MOHD. TALIB LATIF has been accepted for publication in Sains Malaysiana.

Thank you for submitting your work to the journal.

Your sincerely,

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