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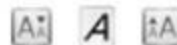
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**[Sains Malaysiana] Editor Decision**

6 messages

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**Prof. Dr. Rusli Daik** <rusli.daik@ukm.edu.my>  
To: R Azizah <azizah@fkm.unair.ac.id>

Mon, Nov 30, 2020 at 1:44 PM

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

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# EDITOR/AUTHOR CORRESPONDENCE

Section Editor  
2020-11-30 02:44 PM

Subject: [Sains Malaysiana] Editor Decision

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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

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

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

3  
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5 Budijanto<sup>2</sup>, Stefanny Surya Nagari<sup>1</sup>, Cendana Fitrihanjani<sup>1</sup>, Fairuz Haniyah Ramadhani<sup>1</sup>,  
6 Mohd. Talib Latif<sup>1,3</sup>

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13  
14 **Abstract**

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

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

31 **Keywords :** Climatic Conditions, COVID-19, Population Density

32

33

### Introduction

34 Starting at the end of 2019, a new respiratory disease, which was later named COVID-19,  
35 were found in Wuhan, China. This disease is caused by a novel coronavirus (SARS-CoV-2).  
36 The virus has spread throughout China within two months, which then develops into various  
37 countries. The World Health Organization (WHO) has declared the epidemic of public health  
38 emergencies since January 30th, 2020 (WHO, 2020a). This pandemic has caused panic  
39 around the World since the beginning of 2020. There were 177 countries with over  
40 43,000,000 confirmed cases and more than 1,000,000 deaths until October 27th, 2020 (WHO,  
41 2020b).

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

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

52 To date, the increase in daily COVID-19 cases in Indonesia is still an alarming number. Apart  
53 from manageable factors that can control the COVID-19 confirmed cases increase, there are  
54 some uncontrollable factors that we cannot handle, such as climate and population density  
55 and many other pre-existing conditions which increase the risk of death from COVID-19.

56 Scientists in the United States government estimate that COVID-19 could kill 10 out of 1000  
57 Americans. Crowd increases the potential for human contact and is a primary source of  
58 human-to-human **transmissions**. COVID-19 growth significantly in denser areas (Therese,  
59 2020). Another study on climate and COVID-19 in Brazil, with **an annual** average  
60 temperature, ranges from 16.8°C to 27.4°C, found a negative linear association between  
61 temperature and the number of COVID-19 cases. They also found that the increase of 1°C is  
62 associated with a decrease of -4.8951% ( $t = -2.29$ ,  $p = 0.0226$ ) in the cumulative daily  
63 number of confirmed cases of COVID-19 (Prata, 2020). Research on population density,  
64 wind speed and COVID 19 has also been conducted in Turkey by Coskun (2020). The results  
65 showed that population density and wind, accounting for 94% of the virus spread variance,  
66 had a significant impact on the spread of the virus or the number of cases. Coskun (2020)  
67 stated that the virus is spreading more in windy weather, indicating that the air threatens  
68 humans with wind speeds. A cluster and regression model was carried out on the group of  
69 cities with the highest COVID-19 cases, and the highest population density in Algeria shows  
70 a strong correlation between population density and the number of COVID-19 infections. The  
71 results showed that population density positively affected the spread of COVID-19 (Kadi,  
72 2020).

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

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

81

82

### **Materials and Methods**

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

#### **Figure 1**

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

97

98

### **Result and Discussion**

#### **COVID-19 Cluster Spreads in Indonesia**

99



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

### 103 **Table 1**

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

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

### 118 **Figure 2**

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

### 122 **Correlation Between Climatic Conditions (Temperature, Humidity, and Rainfall) and** 123 **COVID-19 In Indonesia**

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



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

129 **Table 2**

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

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

143 **Table 3**

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

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

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

168  
169

## 170 **Correlation Between Population Density (Population and Area of Province) And** 171 **COVID-19 In Indonesia**

### 172 *Population Density (Population and Area of Province) In Indonesia*

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

175 rates, while others found the opposite. According to research conducted in China, population  
176 density is not related to COVID-19 events. However, Sun et al. (2020) stated that territorial  
177 restriction is a useful measure in reducing the chance of infection in the community.  
178 Territorial restrictions, commonly referred to as regional quarantine, are traditional solutions  
179 used in antiquity to control the spread of infectious diseases (Wilder-Smith and Freedman,  
180 2020). This step is useful to limit communities' interaction within the region so that the virus  
181 does not increasingly spread mainly in densely populated areas.

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

#### 189 **Table 4**

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

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

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

202 **Figure 3**

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

212 **Table 5**

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

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

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

226 **Table 6**

227 Our study found that the six provinces with the highest COVID-19 cases were in Climatic  
228 conditions II (high mean air temperature with low rainfall and humidity) (Table.4). The  
229 findings are in stark contrast, as research analyzing the effects of climate and weather on  
230 COVID-19 cases found that countries with high mean air temperatures and low humidity  
231 have the effect of lowering the number of deaths caused by COVID-19. A study found that  
232 tropical regions with high mean temperature and high relative humidity, i.e., India, Pakistan,  
233 Saudi Arabia, Malaysia, Thailand, and Australia, have low death cases and high recovery  
234 rates (Pavani & Sunalini, 2020). Iqbal et al. (2020) also discovered that tropical regions, i.e.,  
235 Malaysia, Thailand, and Indonesia, are less affected by the coronavirus. However, Iqbal et al.  
236 (2020) study the regional climatic condition's effect by June 2020. Some researchers also  
237 conducted a study in the subtropical climate, i.e., China. They also found that higher average  
238 air temperatures will lower the risk of COVID-19 (Wang et al., 2020; Ma et al., 2020).  
239 However, Indonesia's high mean temperature did not follow the same conditions related to  
240 COVID-19 in other regions. Coronavirus will still last inside the human body and infect other  
241 humans during the incubation period. The more frequent human activities outside the house,  
242 the more the virus will likely spread and infect other humans.

243 Based on our results, the top 6 provinces with the highest COVID-19 cases are located in a  
244 fairly dense and dense region. As a high-density region, Jakarta is the region with the second-  
245 highest COVID-19 cases, while East Java is in the first position is a fairly dense region. The  
246 rest following a sequence order are West Java, Central Java, South Kalimantan, and South  
247 Sumatra. This region is fairly dense. Our result found a similar study conducted by Jawad  
248 (2020), which states that the results of an analysis conducted in countries vulnerable to  
249 COVID-19 spread show that population density affects the peak period of COVID-19 spread.

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

253

254

### **Conclusion**

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

270

271

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276 until this article was compiled.

277

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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:

- 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.
- 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.
- 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.
- 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°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<sup>2</sup>), while South Sumatra is a medium density province (92 people/km<sup>2</sup>). 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.

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

3  
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13  
14 **Abstract**



15 The first emergence of Corona Virus Disease 2019 (COVID-19) confirmed cases found in  
16 Wuhan, China, has become a global crisis. At least 177 countries have affected over  
17 43,000,000 confirmed cases of corona positive and more than one million deaths until  
18 October 27th, 2020. Recent research has analyzed any possible factors causing the COVID-  
19 19 spreads were climate factors and population density. Indonesia was a tropical region  
20 known as the high-populated country in the World, with a 52.9% area with a high mean air  
21 temperature and over 267.7 million population. Our study aims to analyze the correlation  
22 between climate, population density, and COVID-19 in Indonesia. We used the K-means  
23 cluster method and Fisher's exact test to determine climatic conditions, population density,  
24 and COVID-19 clusters and study the correlation. This research found that a correlation  
25 between climatic conditions (p: 0.034) and population density (p: 0,004) to COVID-19.



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

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

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33

### Introduction

34 Starting at the end of 2019, a new respiratory disease, which was later named COVID-19,  
35 were found in Wuhan, China. This disease is caused by a novel coronavirus (SARS-CoV-2).  
36 The virus has spread throughout China within two months, which then develops into various  
37 countries. The World Health Organization (WHO) has declared the epidemic of public health  
38 emergencies since January 30th, 2020 (WHO, 2020a). This pandemic has caused panic  
39 around the World since the beginning of 2020. There were 177 countries with over  
40 43,000,000 confirmed cases and more than 1,000,000 deaths until October 27th, 2020 (WHO,  
41 2020b).

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

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

52 To date, the increase in daily COVID-19 cases in Indonesia is still an alarming number. Apart  
53 from manageable factors that can control the COVID-19 confirmed cases increase, there are  
54 some uncontrollable factors that we cannot handle, such as climate and population density  
55 and many other pre-existing conditions which increase the risk of death from COVID-19.

56 Scientists in the United States government estimate that COVID-19 could kill 10 out of 1000  
57 Americans. Crowd increases the potential for human contact and is a primary source of  
58 human-to-human **transmission**. COVID-19 growth significantly in denser areas (Therese,  
59 2020). Another study on climate and COVID-19 in Brazil, with **annual** average temperature,  
60 ranges from 16.8°C to 27.4°C, found a negative linear association between temperature and  
61 the number of COVID-19 cases. They also found that the increase of 1°C is associated with a  
62 decrease of -4.8951% ( $t = -2.29$ ,  $p = 0.0226$ ) in the cumulative daily number of confirmed  
63 cases of COVID-19 (Prata, 2020). Research on population density, wind speed and COVID  
64 19 has also been conducted in Turkey by Coskun (2020). The results showed that population  
65 density and wind, accounting for 94% of the virus spread variance, had a significant impact  
66 on the spread of the virus or the number of cases. Coskun (2020) stated that the virus is  
67 spreading more in windy weather, indicating that the air threatens humans with wind speeds.

68 A cluster and regression model was carried out on the group of cities with the highest  
69 COVID-19 cases, and the highest population density in Algeria shows a strong correlation  
70 between population density and the number of COVID-19 infections. The results showed that  
71 population density positively affected the spread of COVID-19 (Kadi, 2020).

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

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

80

81

## **Materials and Methods**

82 This research was conducted in Indonesia using climatic conditions, population density, and  
83 COVID-19 data from secondary resources. Climatic conditions data are collected from  
84 Indonesia's Environmental Statistics 2019 report. Due to the limitation of data in Indonesia,  
85 we used the 2019 climate conditions in this study. Population density data is collected from  
86 the Indonesia Statistics 2020 report. COVID-19 data is collected from **COVID-19 Daily**  
87 **Media Report dated July 22, 2020, at 12.00 WIB, Indonesian Ministry of Health**. There were  
88 34 Province in Indonesia, which illustrated in figure 1 below.

### **Figure 1**

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

95

96

## **Result and Discussion**

### **COVID-19 Cluster Spreads in Indonesia**

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

101 **Table 1**

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

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

116 **Figure 2**

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

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

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

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

127 **Table 2**

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

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

141 **Table 3**

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

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

## 152 **Correlation Between Population Density (Population and Area of Province) And** 153 **COVID-19 In Indonesia**

### 154 *Population Density (Population and Area of Province) In Indonesia*

155 Various studies on population density correlation and COVID-19 spread are conducted in the  
156 world. Some studies found that population density correlates with COVID-19 distribution  
157 rates, while others found the opposite. According to research conducted in China, population  
158 density is not related to COVID-19 events. However, Sun et al. (2020) stated that territorial  
159 restriction is a useful measure in reducing the chance of infection in the community.  
160 Territorial restrictions, commonly referred to as regional quarantine, are traditional solutions  
161 used in antiquity to control the spread of infectious diseases (Wilder-Smith and Freedman,  
162 2020). This step is useful to limit communities' interaction within the region so that the virus  
163 does not increasingly spread mainly in densely populated areas.

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

## 171 **Table 4**

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

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

### 184 **Figure 3**

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

### 194 **Table 5**

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



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

### 205 **Six Provinces With The Highest COVID-19 Cases, Climate Conditions and Population** 206 **Density**

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

#### 208 **Table 6**

209 Our study found that the six provinces with the highest COVID-19 cases were in Climatic  
210 conditions II (high mean air temperature with low rainfall and humidity) (Table.4). The  
211 findings are in stark contrast, as research analyzing the effects of climate and weather on  
212 COVID-19 cases found that countries with high mean air temperatures and low humidity  
213 have the effect of lowering the number of deaths caused by COVID-19. A study found that  
214 tropical regions with high mean temperature and high relative humidity, i.e., India, Pakistan,  
215 Saudi Arabia, Malaysia, Thailand, and Australia, have low death cases and high recovery  
216 rates (Pavani & Sunalini, 2020). Iqbal et al. (2020) also discovered that tropical regions, i.e.,  
217 Malaysia, Thailand, and Indonesia, are less affected by the coronavirus. However, Iqbal et al.  
218 (2020) study the regional climatic condition's effect by June 2020. Some researchers also  
219 conducted a study in the subtropical climate, i.e., China. They also found that higher average  
220 air temperatures will lower the risk of COVID-19 (Wang et al., 2020; Ma et al., 2020).  
221 However, Indonesia's high mean temperature did not follow the same conditions related to

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

225 Based on our results, the top 6 provinces with the highest COVID-19 cases are located in a  
226 fairly dense and dense region. As a high-density region, Jakarta is the region with the second-  
227 highest COVID-19 cases, while East Java is in the first position is a fairly dense region. The  
228 rest following a sequence order are West Java, Central Java, South Kalimantan, and South  
229 Sumatra. This region is fairly dense. Our result found a similar study conducted by Jawad  
230 (2020), which states that the results of an analysis conducted in countries vulnerable to  
231 COVID-19 spread show that population density affects the peak period of COVID-19 spread.  
232 However, population density is not an essential factor in the spread of COVID-19 under strict  
233 lockdown policies. China's lockdown policy could effectively limit the speed at which  
234 COVID-19 spreads (Sun, 2020).

235

### 236 **Conclusion**

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

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

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