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A Study on the Association Between Climate and Corona Virus Outspread in South Indian States

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Abstract: In this study, we objectively focus on the relationship between the number of coronavirus (COVID-19) cases and key climate variables. We found that the risk of COVID-19 was approximately doubled during warm summer months when the aerosol molecules are likely stimulated by temperature and rainfall. Given that India is currently emerging as the new epicenter for the third and fourth outbreaks of COVID-19, we selected four key hotspot states-Maharashtra, Andhra Pradesh, Kerala, and Tamil Nadu - to closely look into the impact of climate variables on the spread of COVID-19 infected cases during 2020 and 2021. We found that COVID-19 is most active in temperature between 27°C and 32°C, while it is active in monthly average rainfall between 250 mm and 350 mm. This study further confirms that, although temperature and rainfall are not the initial triggers of COVID-19, both variables seem to play significant roles in spreading COVID-19 in India, especially during the summer season of 2020 and 2021, when the Indian summer monsoon was stronger in these four states.

Keywords: Pandemic; COVID-19; Temperature; Rainfall; India.

Introduction

During the last two millennia, the world dealt with six pandemics: Bubonic plague (1346-1353), Cholera (1817), the Spanish flu (1918-1919), Severe Acute Respiratory Syndrome (SARS) (2002-2004), the Middle East Respiratory Syndrome (MERS) (2012-2016) and COVID-19 (2019-2022) (Snider, 2002). Among these pandemics, Spanish flu, SARS, and MERS are transmitted through the air, and therefore, are called air-borne diseases. COVID-19 is an infectious sickness due to a newly observed coronavirus that also falls in the same category. In December 2019, an unexpected outbreak of pneumonia occurred in the city of Wuhan, China and the outbreak has been traced to a novel strain of coronavirus on 31st December 2019. COVID-19 transmission has spread from China to almost all countries in the world (Goyal et al., 2020). Figure 1 schematically represents the simple way of COVID-19 transmission. Although the initial origin of COVID-19 is still a topic of uncertainty/debate (Koffman et al., 2020; Mulder et al., 2021), similar viral outbreaks in the recent past have a climate-driven spread, especially within the country (Sasikumar et al., 2020). Climate is a long-term (e.g., seasonal) weather pattern, and it may trigger the spread of the virus mainly during the peak monsoon season. Increased temperature and precipitation are predicted to have the greatest impact on the transmission of human infectious diseases like Influenza, Anthrax, and vibriosis in the Arctic (Waits

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et al., 2018). Neverthless, the relationship between the number of coronavirus cases and monthly average temperature and rainfall in India, one of the monsoon-driven economies in the world, is less understood.

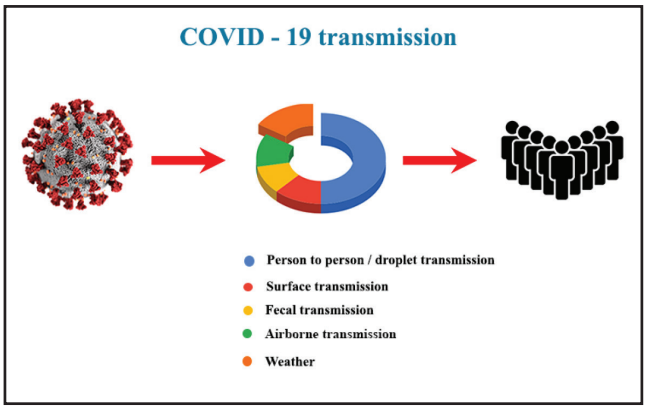

Figure 1: A coloured diagram showing a simple way of COVID-19 transmission in India.

India tends to be a favourable country for the COVID-19 outbreak during the first wave, which started in March 2020. Likewise, the second wave of COVID-19 started in April 2021, and within the same month, the number of COVID-19 cases increased dramatically. The first Covid case was observed in Kerala, a state located along the Southwest coast of India within the summer monsoon limit, after which COVID-19 spread to approximately 24,12,000 humans, resulting in around 3,08,883 deaths. On 9 September 2021, there had been at least 4,186,657 deaths, and more than 195,911,151 COVID-19 confirmed cases in overall India (World Health Organization 2020a; 2020b). The general public in India are advised to follow some protocols such as MSD (wearing **M**asks, **S**anitizing hand and keeping social **D**istance of up to one meter). The Government of India imposed a lockdown for a few months and launched its vaccine drive simultaneously on 16th January 2021, mostly relying on the COVISHIELD vaccine. These steps suggest that non-weather factors have a greater role in the spread of COVID-19 during the second wave from March to June 2021 (Pudjiastuti et al., 2020), though the role of climate and weather factors on the spread of COVID-19 was unknown. Hence, a relevant question about the spread of COVID-19 is that whether climatic or demographic traits permit a more significant expansion of the virus or not (Bukhari and Jameel, 2020; Sajadi et al., 2020).

In this study, we investigate the effect of climate variables such as monthly average temperature and rainfall, and their relationships with the number of COVID-19 cases. Climate change expands the geographical distribution of several vector-borne human infectious diseases and therefore shows some positive linearity between them (Goyal et al., 2020). The risk of coronavirus transmission is in general multiplied during warm summer climates, as the boom and development of aerosols and precipitation are significantly influenced by temperature and rainfall (Yang et al., 2020). Thus, one would expect a link between climate variables and the number of COVID-19 cases in India. In addition, there is also a possibility that the virus spread during the next waves may also show seasonality, which may increase the number of COVID-19 cases in India and other low-latitude countries.

Methods

This study focussed on the relationship between the number of COVID-19 cases and two climate variables. For this purpose, data on the number of COVID-19 cases, and meteorological parameters such as monthly average temperature and rainfall were collected for the year 2020 and 2021.

Data Collection

Several websites primarily maintained by governmental or non-governmental organisations provide the updated record of COVID-19 cases in India. The number of daily confirmed cases was collected from the Ministry of Health and Family Welfare (MoHFW) (https://mohfw.gov.in), India Meteorological Department (IMD) (https://mausam.imd.gov.in) and World Health Organization (WHO) (https://www.who.int). The temperature data were collected from accuweather.com, and rainfall data were collected from the CHRS data portal (https://chrsdata.eng.uci.edu/) and the later data was cross checked with the IMD data.

Data Handling

Two years (2020-2021) of temperature and rainfall data were collected from IMD and Covid-19 case data were collected from state government official websites. Hence, the statistical data on the coronavirus in India have been collected and classified in each province from 15 February 2020 to 30 August 2021 to illustrate the relationship between the number of COVID-19 cases and climate variables, especially temperature and rainfall. Therefore, the data were interpreted using the Spearman's linear correlation method among variables.

Monsoon Direction

The summer (southwest) monsoon is the most important weather phenomenon of the Indian climate. The COVID-19 cases have increased during warm summer monsoon months in 2020 and 2021. As the weather in India is largely governed by the Southwest monsoon, this study discusses the relationship between the Southwest monsoon and the number of COVID-19 cases in 2020 and 2021. The southwest monsoon begins in the Arabian Sea (Figure 2) and progresses along the coastal area of Kerala, Karnataka and Maharashtra. In this study, we observed increasing Covid-19 cases in four hotspot states during the monsoon periods. Figure 2 shows the monsoon winds through the states having a high amount of Covid confirmed cases.

Results

Coronavirus vs Temperature

In this study, we statistically evaluate the impact of temperature on the spread of COVID-19 in four west and south Indian states-Maharashtra, Kerala, Tamil Nadu, and Andhra Pradesh (Figure 3) - during the COVID-19 first and second waves. A total of 40 million people were affected by the two waves of COVID-19. Figure 4 shows the onset data of the first wave and the highest number of COVID-19 cases (8,000 to 12,000) was observed in all four hotspot states when the temperature was between 25°C and 35°C except Maharashtra wherein the confirmed Covid cases ranged from 10,000 to 22,000 when the observed temperature varied between 25°C and 32°C. During the second wave, the highest Covid cases (10,000 to 40,000) with a peak were observed when the temperature was high, i.e., 25°C to 38°C. Except in Maharashtra where the confirmed Covid cases are between 20,000 and 60,000 when the temperature ranged from 25°C to 40°C. The minimum and maximum temperatures during the first wave are 26°C and 35°C, respectively. Likewise, the minimum and maximum temperatures during the second wave were 25°C and 38°C, respectively.

We observed positive regional differences in climate variables. The hotspot states showed to have the highest number of Covid confirmed cases (65,000 cases) during April and after a small decline in the number of cases, it again increased in the month of May (Figure 4).

Relationship Between Temperature and COVID-19 Cases

Temperature linearly correlated with the confirmed cases of COVID-19. Within the study period, the monthly average temperature ranges between 25°C and 36°C.The observed monthly minimum, maximum, and average temperature for the entire country during the first wave from March 2020 to August 2021 is 25°C, 42°C, and 31°C (Figure 5).

The regression analysis reveals that there are some interactions between average temperature and the number of COVID-19 cases. Hence, we found positive relationship between temperature and higher Covid

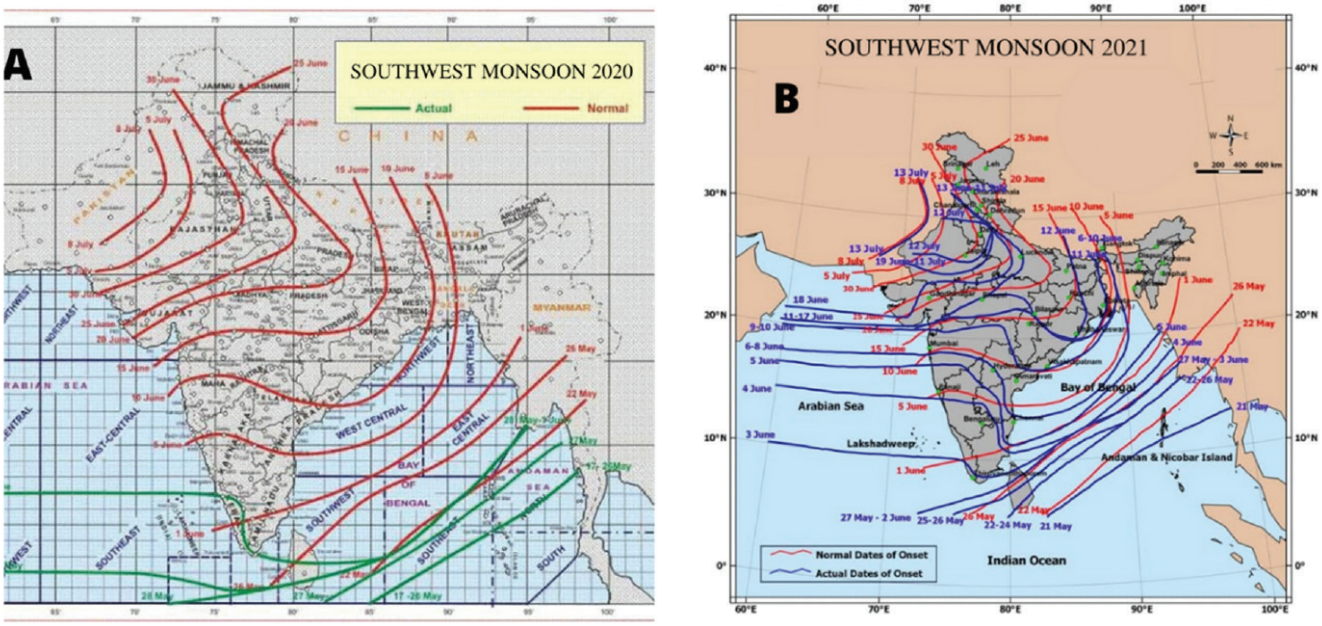

Figure 2: Onset data and advance of southwest or summer monsoon in India during (a) 2020 and (b) 2021.

cases (Figure 6). The R^2 of temperature in higher value $R^2 = 0.41$; $P = 0.2790$ and the lower value $R^2 = 0.35$; $P = 0.232$. The result of initial linear regression for higher case studies shows high accuracy. A strong correlation was also more common at a temperature between 28°C and 32°C. Our analysis showed that temperatures had a linear relationship with the number of confirmed Covid cases, indicating a significant role in temperature spreading COVID-19 during the summer season of 2020 and 2021.

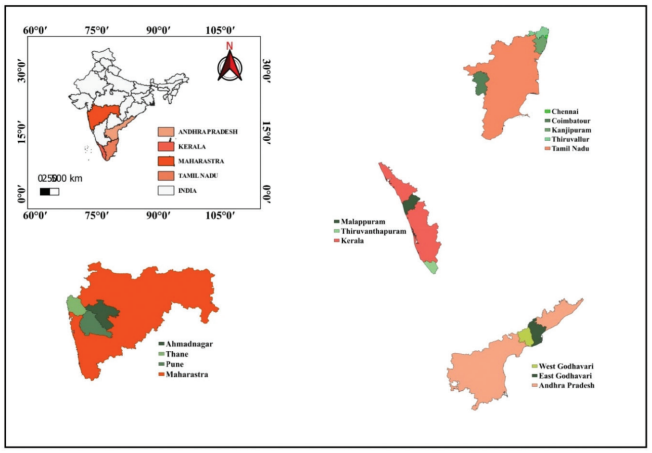

Figure 3: States hard hit by COVID-19 in India during 2020 and 2021.

Relationship Between Rainfall and COVID-19 Cases

Using the Spearman model, an attempt has been made to understand the relationship between the number of COVID-19 cases and rainfall. There is a poor relationship between overall Covid cases in India and monthly average rainfall (i.e., $R^2 = 0.22$). However, when we separated minimum and maximum rainfall data, the correlation between them improved with an R^2 value of 0.94, suggesting a positive linear relationship between the rainfall and the number of COVID-19 cases (Figure 7). Therefore, the relationship between rainfall and Covid case shows a higher value of $R^2 = 0.94$; P

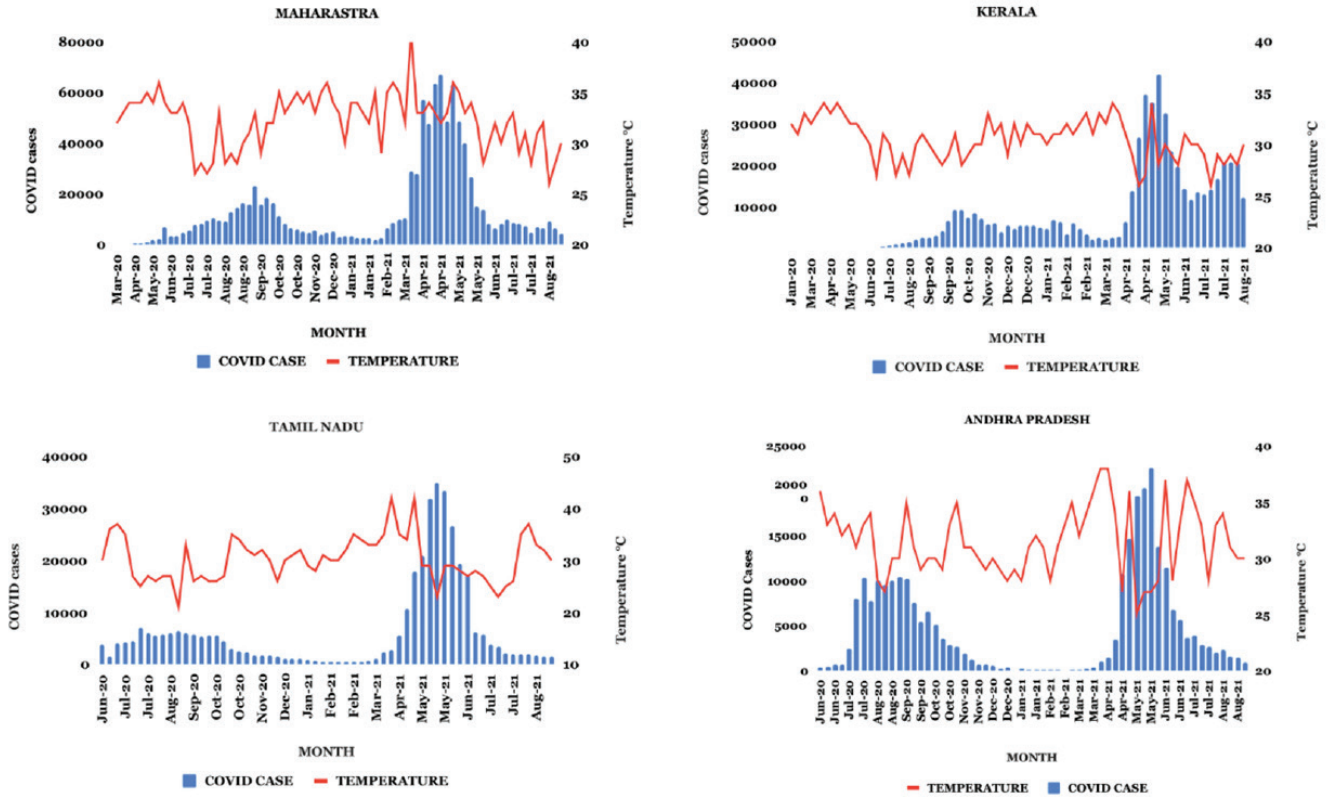

Figure 4: Relationship between the number of COVID-19 cases and temperature variables in four different states of India. Red lines in all plots represent temperature and blue bars indicate the number of COVID-19 cases. The daily temperature and COVID-19 cases were averaged into a ten-day interval to reduce the number of spikes. Note that COVID-19 cases in all states increased during the peak summer monsoon season (May-August) when temperature shows a large drop.

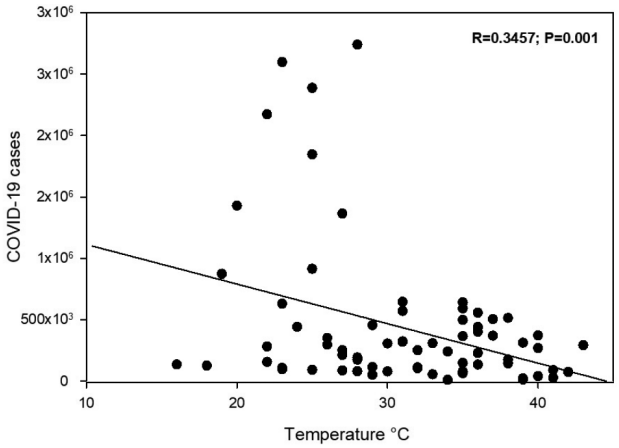

Figure 5: The relationship of the number of COVID-19 cases against temperature observed for entire India.

= 0.0168 when the rainfall was extremely high, while the relationship weakens when the rainfall reduces and the number covid case are low. Such strong linearity (0.94) between that rainfall rather than temperature may increase the infection during the monsoon season both in 2020 and 2021. Furthermore, our findings suggest that climate variables on a seasonal scale seem to have a reasonable contribution to explaining the behaviour of COVID-19 in the Indian subcontinent.

Discussion

The effect of climate variables/meteorological parameters on humans that have an inherent influence

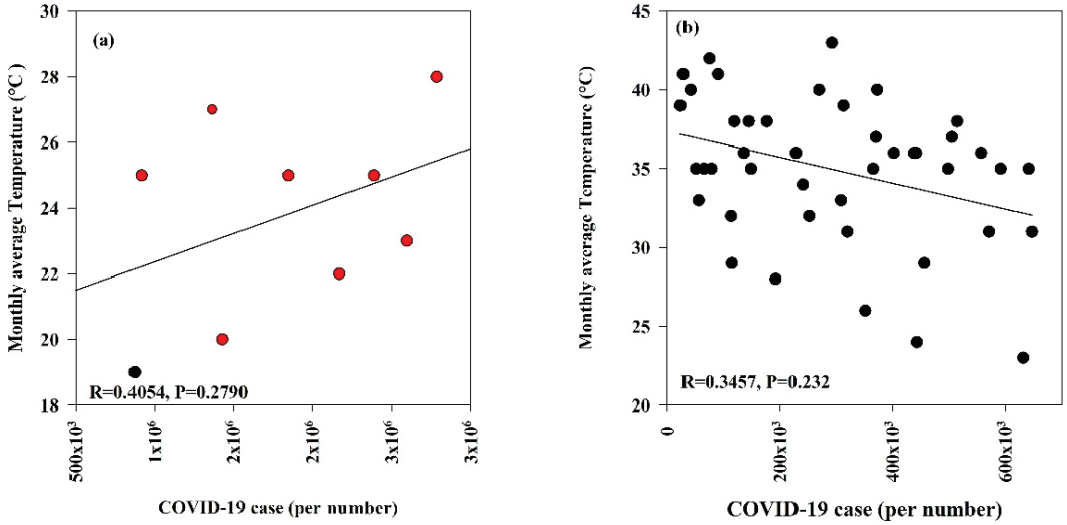

Figure 6: Relationship between monthly average temperature and the number of COVID-19 cases in India during 2020 and 2021. Black dots represent the data of 2020 and red dots indicate the data for 2021.

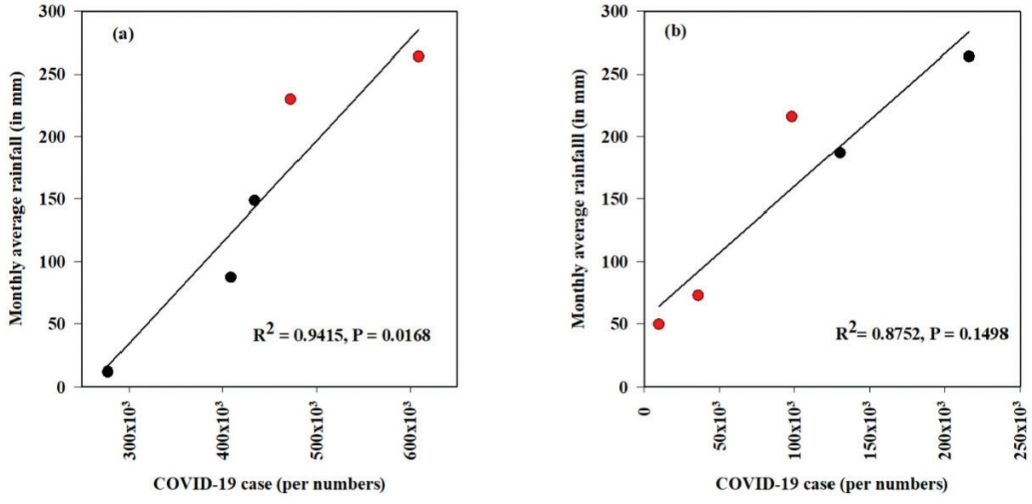

Figure 7: Relationship between monthly average rainfall and the number of COVID-19 cases in India during 2020 and 2021. Black circles represent the data for 2020 and red circles indicate the data for 2021.

on the environment is well known. For example, the Spanish flu outbreak spread quickly throughout the world in 1918, and climate change is thought to have had a crucial influence on its transmission (Towers et al., 2013). Similar to the previous pandemics, the link between the spread of coronavirus and the climate variables seems to be inevitable. The similarity of the study discussed in previous research is correlated with the study of Towers et al. (2013) who investigated the relationship of past decade's epidemics (such as Spanish flu) to climate change.

Previous studies in our study area have found that relative humidity and pressure have a relatively strong effect on active COVID-19 cases in Mumbai mega city (Kumar & Kumar, 2020). In addition, Wu et al. (2020) found that relative humidity was negatively correlated with daily new COVID-19 cases in Mumbai. However, due to the short-term dynamics of the pandemic, global temperature signals are expected to be lower (Amnuaylojaroen and Parasin, 2021).

Prata et al. (2020) identified a negative correlation between temperature and the number of Covid cases in Brazil. Likewise in India when the temperature reached a limit of 40°C, the number of Covid cases also increased. The positive correlations between temperature, rainfall, and the number of confirmed COVID-19 cases concluded the fact that both temperature and rainfall strongly influenced the spread of the coronavirus, at least during the peak monsoon season in 2020 and 2021. The strong correlation between these parameters indicated that climate (especially temperature) change was responsible on the virus spread in India. Sasikumar et al. (2020) found that COVID-19 cases were clustered in the temperature range between 27°C and 32°C. The combined effect of temperature and humidity spectrum is highly significant for predicting the number of COVID-19 cases that may occur in the forthcoming waves. Gupta et al. (2020) have thoroughly investigated the intricate non-linearity in the relationship between COVID-19 infections and geographical distribution.

Previous studies observed that temperature was favourable for the spread of coronavirus (Ozkan et al., 2021; Prata et al., 2020; Wang et al., 2020; Zhu et al., 2020; Núñez-Delgado et al., 2020) but our data shows that the amount of rainfall is more influential than temperature to trigger the spread of coronavirus. Smith et al. (2021) stated that the environment including population density and daily weather may have a role in the spread of COVID-19. However, COVID-19 transmission rates may vary seasonally and geographically, and these effects can be minimised through public health initiatives.

By exploring the relationship between annual average temperatures and confirmed cases of COVID-19, new studies concluded that the Indian tropical weather and monsoon season contribute to the transmission of Coronaviruses (Vikas, 2020; Prata et al., 2020). Thus, a timely intimation and preparedness of health workers, disaster management departments, and officials of South Asian countries was necessary while planning mitigation actions against COVID-19 spread during the summer monsoon season (May 2022).

Conclusions

Climate variables are not initial triggers of coronavirus outbreak, our data indicated a strong association between the number of COVID-19 cases, temperature and rainfall. Nevertheless, the relationship between the number of COVID-19 cases and temperature is not significantly stronger compared to rainfall, but when the temperature increases the number of cases is also seen to be drastically increased, especially in all four hotspot states in India during the summer monsoon. This study will be able to help the Government and other NGOs to overcome the fourth COVID-19 transmission and also may be useful to avoid the mortality rate. We suggest that the remaining population should be fully vaccinated before the onset of next summer monsoon to avoid mortality owing to the fourth wave of transmission. Although preliminary analysis suggested that the positive correlation between rainfall and the number of cases implies that the fourth COVID-19 wave will likely occur after the intial spell of the Indian summer monsoon.

Conflict of Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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