Review Paper:

Impact of Climate on Diffusion of COVID-19

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Abstract

Present study attempts to examine the impact of temperature and precipitation on spread of COVID-19, the disease caused by a zoonotic coronavirus- SARS CoV-2. Originated from the Wuhan city of China in December, 2019, this disease very rapidly gripped the world with cries. The crisis is still on and national economies are crumbling amid lockdown. As SARS CoV-2 belongs to human-coronavirus family, it is hypothesized here that like other members of this family, this virus should also follow similar seasonality behaviour viz. most active during winters and dormant during summers.

To examine this presumption, the study uses monthly temperature and precipitation values of December, January, February, March and April months of the COVID-19 affected countries and the cases and fatalities registered by them due to this disease. Through mapping the month-wise spread of the disease it was observed that countries having coastal climate or, countries situated in between 30° to 60° north latitudes were severely affected by this highly contagious disease. Regression analysis reveals that temperature is someway linked with this disease, however no significant connection was found between precipitation and spread of the disease. It was also observed that this virus is showing a notable deviation from the seasonality behaviour of other human-coronaviruses. However, as the challenge is alive and even griming, these conclusions are still inconclusive.

Keywords: Zoonotic, coronavirus, respiratory disease, pandemic, diffusion, ANOVA.

Introduction

Coronavirus Disease 2019 (COVID-19) is an infectious, zoonotic disease caused by Severe Acute Respiratory Syndrome Coronavirus-2 (SARS-CoV-2), previously known as 2019 novel coronavirus. These viruses belong to Orthocoronavirinae subfamily of the family Coronaviridae. They consist of 4 genera in which Alpha-coronavirus (α-CoV) and Beta-coronavirus (β-CoV) infect mammals, where members of the Gamma-coronavirus (γ-CoV) and Delta-coronavirus (δ-CoV) infect avian species.

From their discovery in mid-1960s till date, as many as 7 human coronaviruses (HCoV) have been discovered. Four of them (HCoV-229E, NL63, OC43 andHKU1) mainly cause mild respiratory diseases, while the other three (2 severe acute respiratory syndrome coronaviruses- SARS-CoV andSARS-CoV-2 and1 Middle East respiratory syndrome coronavirus- MERS-CoV) cause severe respiratory diseases.

The two human coronaviruses- 229E and NL63 belong to alpha coronavirus, while the rest five- SARS-CoV-2, SARS, MERS, OC43, HKU1 are from Betacoronavirus genera. Both Alphacoronavirus and Betacoronavirus descend from the bat gene pool. Human coronaviruses generally transmit through airborne droplets to the nasal mucosa and replicate in ciliated epithelium cells causing cell destruction and inflammation.

Coronavirus infection normally peaks in winter months and gradually declines with rise in temperature.[9] Considering this view, present paper examines the impact of temperature and precipitation conditions on the effectiveness of SARS CoV-2 and on diffusion of COVID-19.

This novel coronavirus disease (COVID-19) originated in Wuhan city of China and spread to every corner of the world in just few months. While in December this disease was confined to China only, it reached to 20 countries in January. By February, 2020 this virus had swallowed nearly 3,000 lives and had affected more than 80,000 people. This tally increased to 750,890 confirmed cases and 36,405 deaths by 31 March, 2020 and to 31 million confirmed cases and 217,769 deaths by 30 April, 2020 (WHO, COVID-19 Situation Reports – 11; 40; 51; 71; 101). Fig. 1 shows the global growth trend of the disease. From this figure it is evident that out of total numbers till date, nearly 80 percent deaths and cases were reported during April month only. This reflects how fast the disease is spreading.

This deadly pandemic has gripped the world in lockdown and has crushed national economies. While its challenge is still growing, even more rapidly, this situation shows the need to understand the behaviour of this virus in different climatic conditions for better treatment and management of COVID-19.

Literature suggest that activeness of coronaviruses and the climate conditions especially temperature, are linked together[9]. While most of the coronavirus infections get reported during winter months, the virus remains almost dormant during spring, summer and fall seasons (Fig. 2).

As SARS CoV-2 belongs to the coronavirus family, it is anticipated here that like other members of the family, this virus may also follow the same seasonality behaviour.

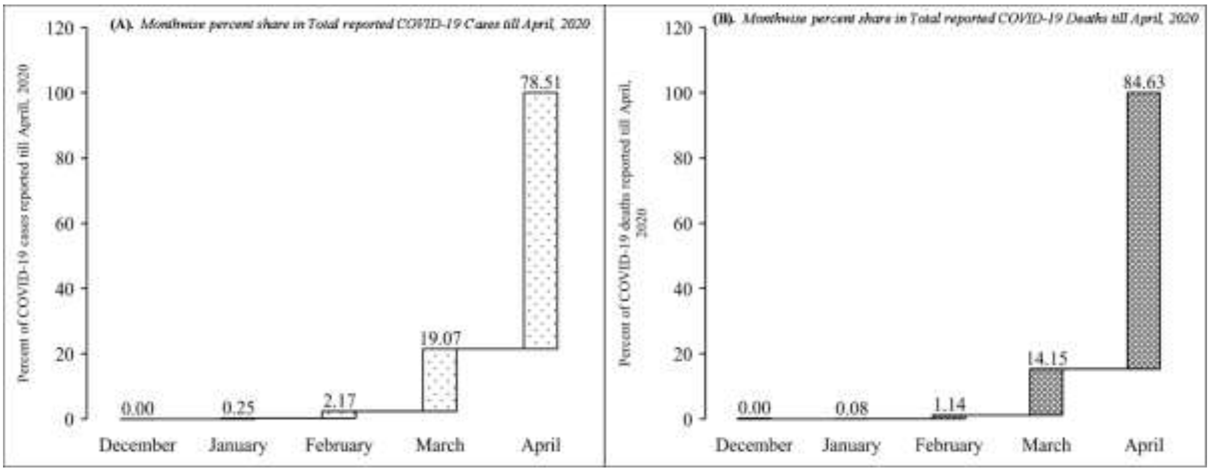

Fig. 1: Percent share in globally (A) total reported COVID-19 cases and (B) Deaths till 30 April, 2020

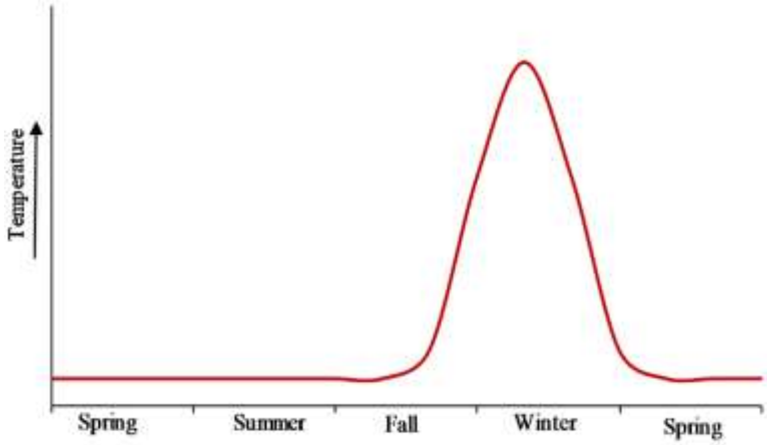

Fig. 2: Seasonality of coronavirus infections[9]

Chin et al[3] find that this virus is sensitive to heat stress and while it remains stable at low temperatures, it loses its activeness as temperature goes up. Ma et al[7] noted that the virulence of SARS CoV-2 declines with increasing humidity. They also observe that with rise in temperature, the COVID-19 linked deaths declined significantly at 95% CI.

Studies observe a comparatively better defense response offered by respiratory system against foreign element at higher temperature while it gets compromised in cold climate. D'Amato et al[5] observed that when cold air passes through the respiratory track, it produces a cooling and drying effect. This cold air decreases the rate of mucus secretion but increases its viscosity.[1]

Further, its drying effect slows down mucociliary function in the respiratory track and thus, impairs the ability of respiratory system to effectively clear out the invading foreign pathogens through mucosa.[4] Reduction in nasal epithelium temperature due to inhalation of cold air inhibits the phagocytic activity of leukocytes also.[6] Naturally a compromised respiratory defense system elevates the risk against infections.[2] Thus, immune response of human body remains compromised at lower temperature. And while available studies suggest that the virulence of SARS CoV-2 is reportedly higher in cold climate, managing this virus becomes a two-way challenge. However, drawing a clear conclusion about behavioral seasonality of the virus is yet early as there is dearth of enough literature on this issue and the studies published till date have failed to proven this point with a robust statistical significance. Present study is an attempt in this direction to carry this question further.

Data Source and Methodology

Present study uses mean monthly temperature and precipitation values of December, January, February, March and April months of the COVID-19 affected countries to examine the effect of temperature and precipitation on the SARS CoV-2 behaviour. This climate data was accessed from the Climate Change Knowledge Portal of the World Bank. The data related to COVID-19 cases and deaths was accessed from the web-portal of the European Centre for Disease Prevention and Control and from the official website of World Health Organisation.

To understand the gradual spread of the disease, month-wise total reported cases and fatalities were mapped. To see the relationship between COVID-9 incidences with temperature and precipitation conditions, simple scatter diagrams were plotted by using all five months data of affected countries. Further, a simple regression analysis was exercised to examine the direction and level of association between climate and effectiveness of SARS CoV-2.

Diffusion pattern of COVID-19

The coronavirus-19 originated in China during December, 2019 and gradually spread over almost the entire world within a few months. Fig.3 displays the extent of COVID-19 outbreak during December, 2019. Evidently, till this time this disease was confined to China only where 27 cases were reported without any fatality.

In January the SARS CoV-2 virus spread to 20 countries leaving nearly 10,000 people sick (Fig. 4). During this period COVID cases around the world increased by more than 360 folds. However, at this stage too China was the epicenter of the disease and 99 percent reported cases (9687) and 100 percent deaths (213) linked to COVID-19, were from this country alone (Fig. 5).

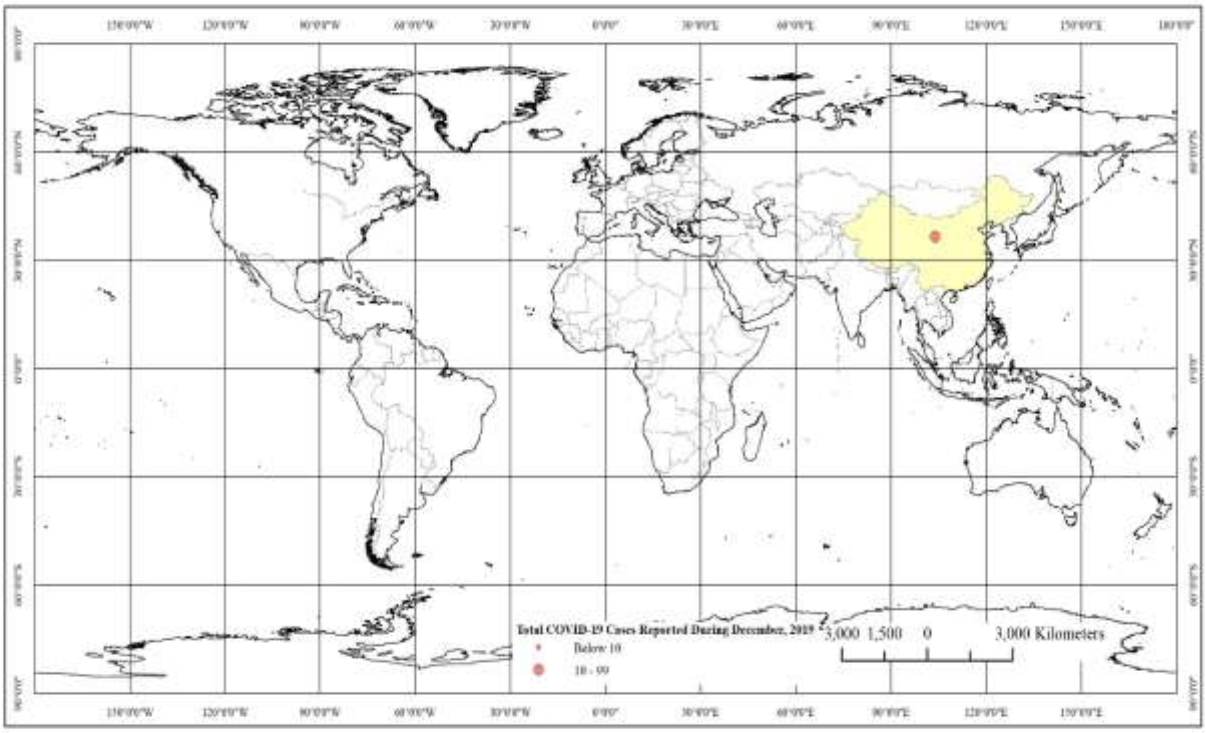

Fig. 3: Total COVID-19 cases reported during December, 2019

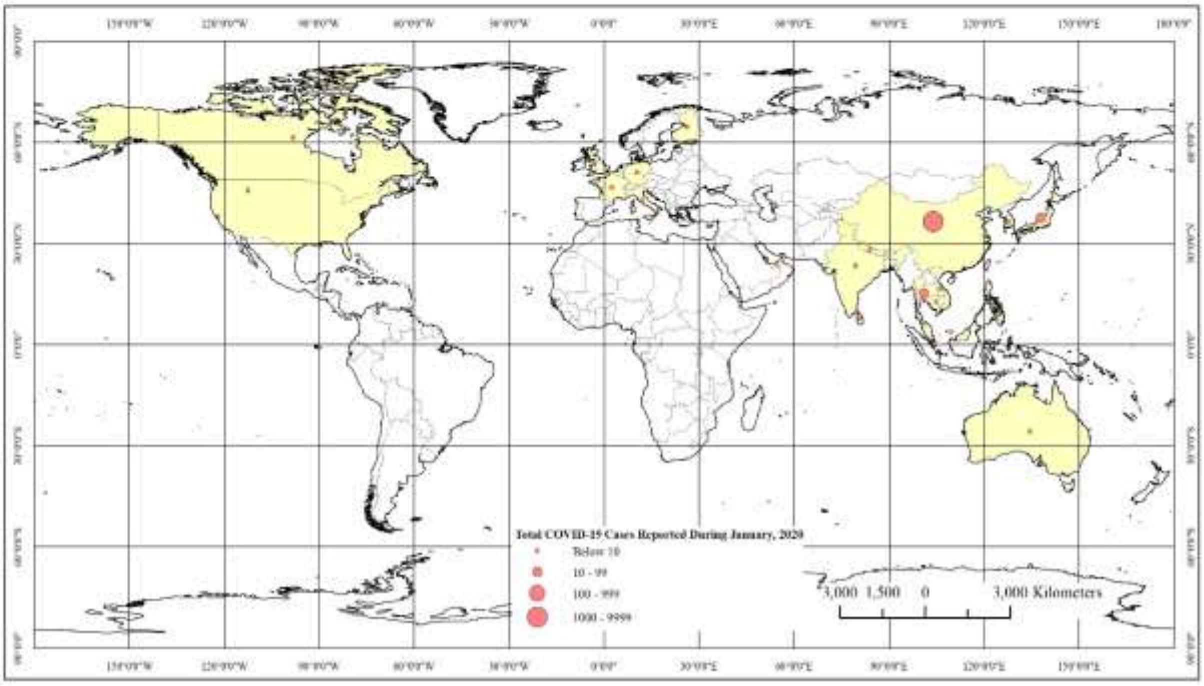

Fig. 4: Total COVID-19 cases reported during January, 2020

The virus reached to more than 50 countries in February by expanding its diffusion to six continents. Countries like China (69641), South Korea (2924), Italy (885), Iran (388), Japan (216), United States (60), Germany (52) and France (51) remained most affected during this month (Fig. 6).

Fig. 7 displays the fatalities linked to SARS CoV-2 recorded by various countries in February. During this period the world witnessed more than 2,700 deaths due to this virus. Affected Eurasian countries were- China (2624), Iran (34), Italy (21), South Korea (16), Japan (3), France (2) and Philippines (1).

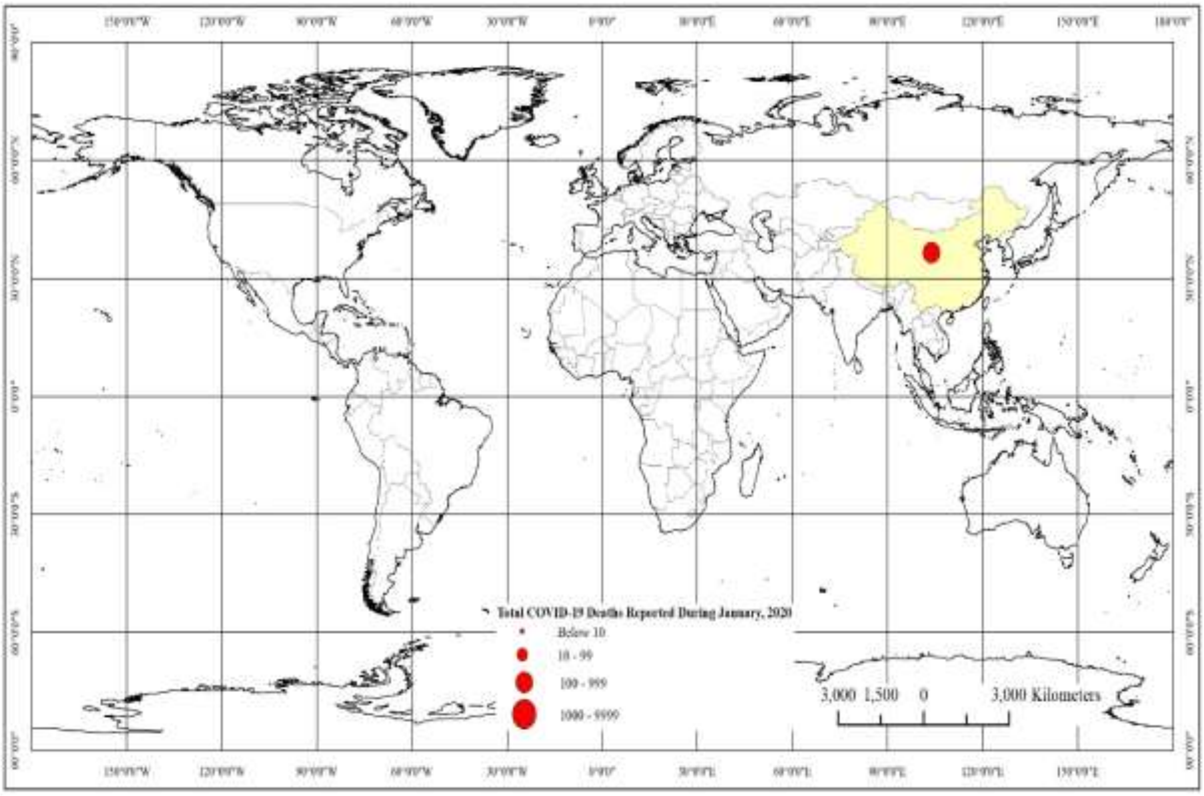

Fig. 5: Total COVID-19 deaths reported during January, 2020

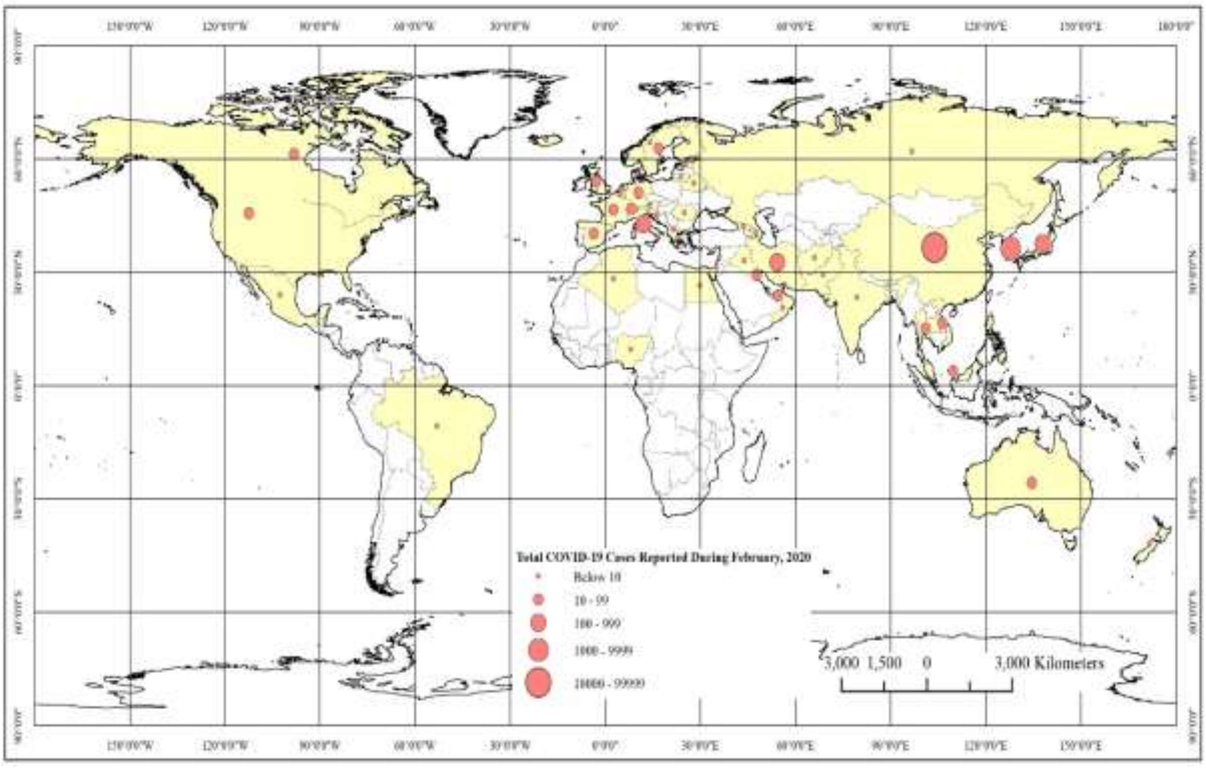

Fig. 6: Total COVID-19 cases reported during February, 2020

In month of march the world witnessed a big jump in COVID-19 cases when more than 160 countries around the world reported presence of SARS CoV-2 in their land. During this month the virus infected more than 700,000 people and consumed more than 35,000 lives around the globe. Fig. 8 portrays the pattern of worldwide dispersion of COVID-19 in March, 2020.

By this time the Europe and United States of America (USA) emerged as two epicenters of the disease while China from where the disease originated, recorded a significant decline- from more than 70,000 in February to below 3000 COVID-19 cases in March.

On the other hand, USA recorded the highest surge where it increased from only 60 cases in February to about 170,000 in March. Italy recorded second highest growth in cases where it increased from 885 in February to 100,851 in March. Spain, Germany, France, Iran and United Kingdom were the other countries most severely affected by the SARS CoV-2 in March, 2020. It is evident from the fig. 8 that during this month almost the entire populated world was under threat of COVID-19.

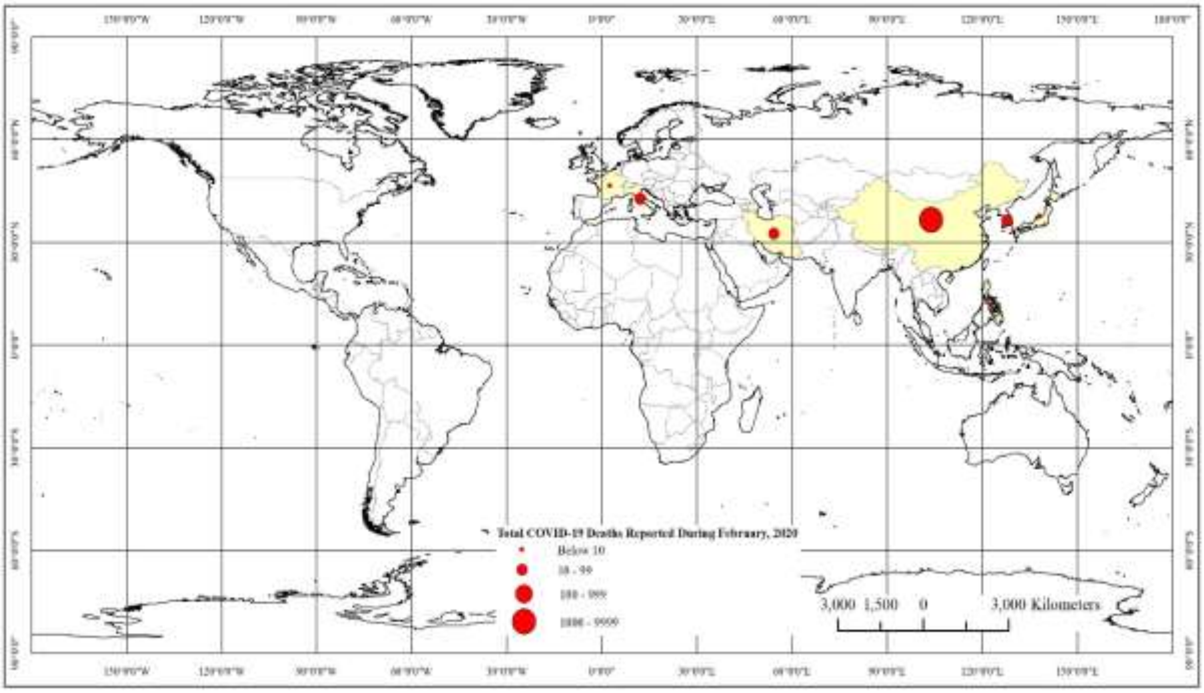

Fig. 7: Total COVID-19 deaths reported during February, 2020

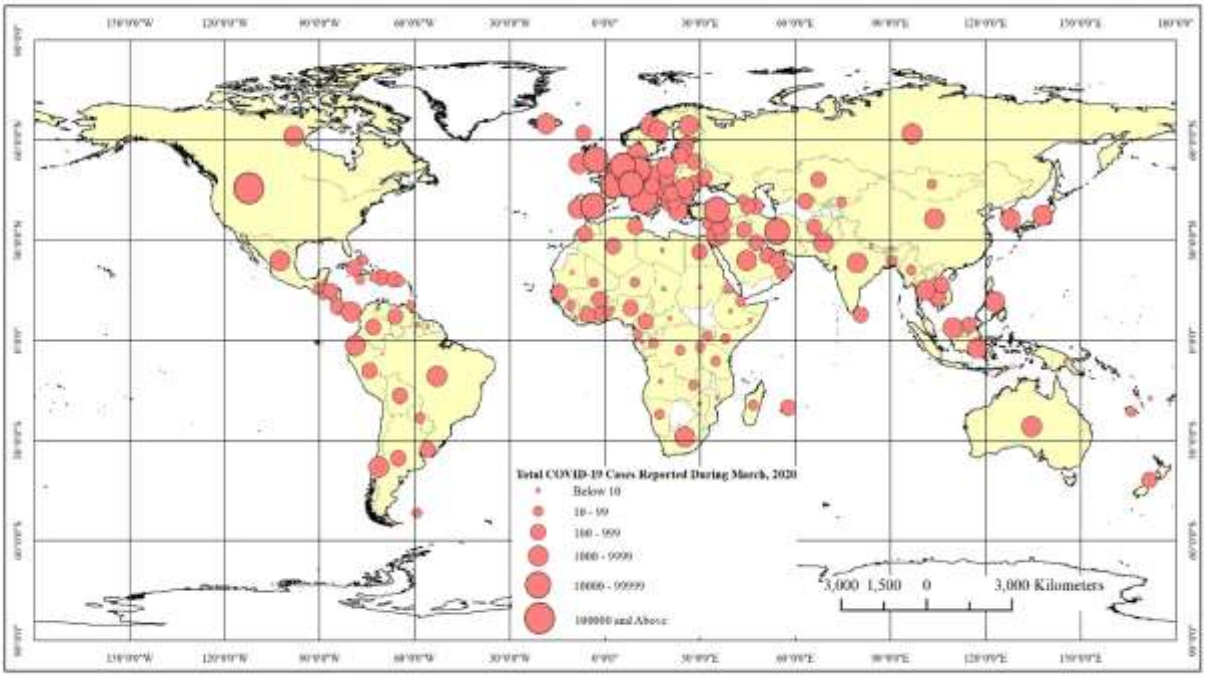

Fig. 8: Total COVID-19 cases reported during March, 2020

While in February, more than 90 percent SARS CoV-2 related deaths around the world were reported from China alone, but the country successfully managed to reduce this count during March. On the other hand, the countries like Italy (11,570), Spain (7,340), United States (3,170), France (3,022), Iran (2,723) and United Kingdom (1,408) remained the most affected in terms of COVID-19 fatalities during this period. Fig. 9 displays that almost the entire Europe and the United States of America witnessed a colossal damage to their lives due to this viral attack during March, 2020.

In April month, the United States of America (875,289) remained worst affected by the coronavirus and the country alone recorded more than 37 percent of the total reported COVID-19 cases around the world. United Kingdom (143,080), Spain (128,240), Turkey (106,762), Italy (101,852), Russia (97,563), Germany (97,206), France (83,892), Brazil (73,583) and Iran (52,162) were also among the countries badly affected by this disease during this period. These countries along-with USA recorded more than 75 percent cases of the globe during April month.

Fig. 10 shows the concentration of coronavirus cases in April. During this period too, the countries situated between 30° to 60° north latitudes remained severely affected. Perusal of fig. 10 also indicates that costal countries were worst hit by this virus.

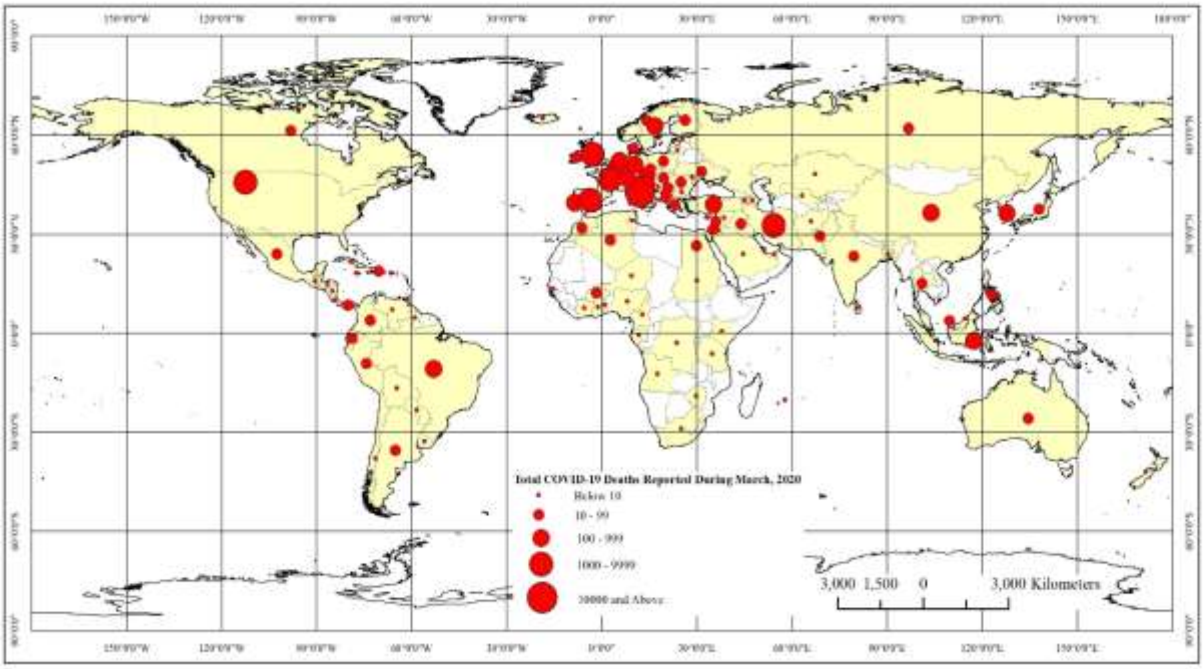

Fig. 9: Total COVID-19 deaths reported during March, 2020

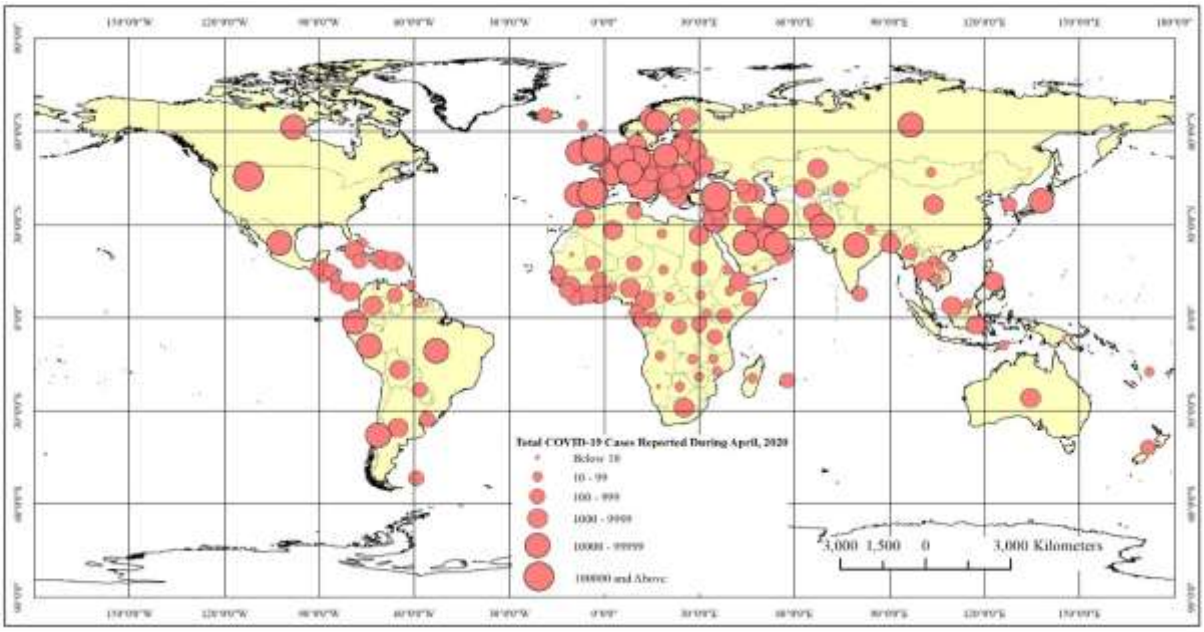

Fig. 10: Total COVID-19 cases reported during April, 2020

Fig. 11 displays the worldwide deaths reported due to coronavirus during April. As is evident, the United States of America (57,796), United Kingdom (21,065), France (21,063), Spain (17,203) and Italy (16,091) were most affected countries. USA alone witnessed more than 30 percent of total fatalities reported in April month due to coronavirus while combining with UK, France, Spain and Italy, more than 70 percent of the total COVID-19 linked deaths were reported in these countries only.

By examining figs. 3-11, it can be deduced that coastal countries and the countries lying in between 30° to 60° north latitudes are most affected by this lethal virus. This indicates that there may be some causal relationship between climate and SARS CoV-2 effectiveness. Although, it is also a fact that this zone is densely populated and economically most active. Heavy migration rate in between these countries makes them more susceptible to such contagious diseases. Although this may have helped virus to reach these countries easily, but if like other human-coronaviruses SARS CoV-2 also follows a seasonality pattern, then it may be more virulent and lethal in cold climate than in tropical or warm regions.

Climate and COVID-19

Fig. 12 displays relationship between temperature and COVID-19 cases reported by countries during five months i.e. from December, 2019 to April, 2020.

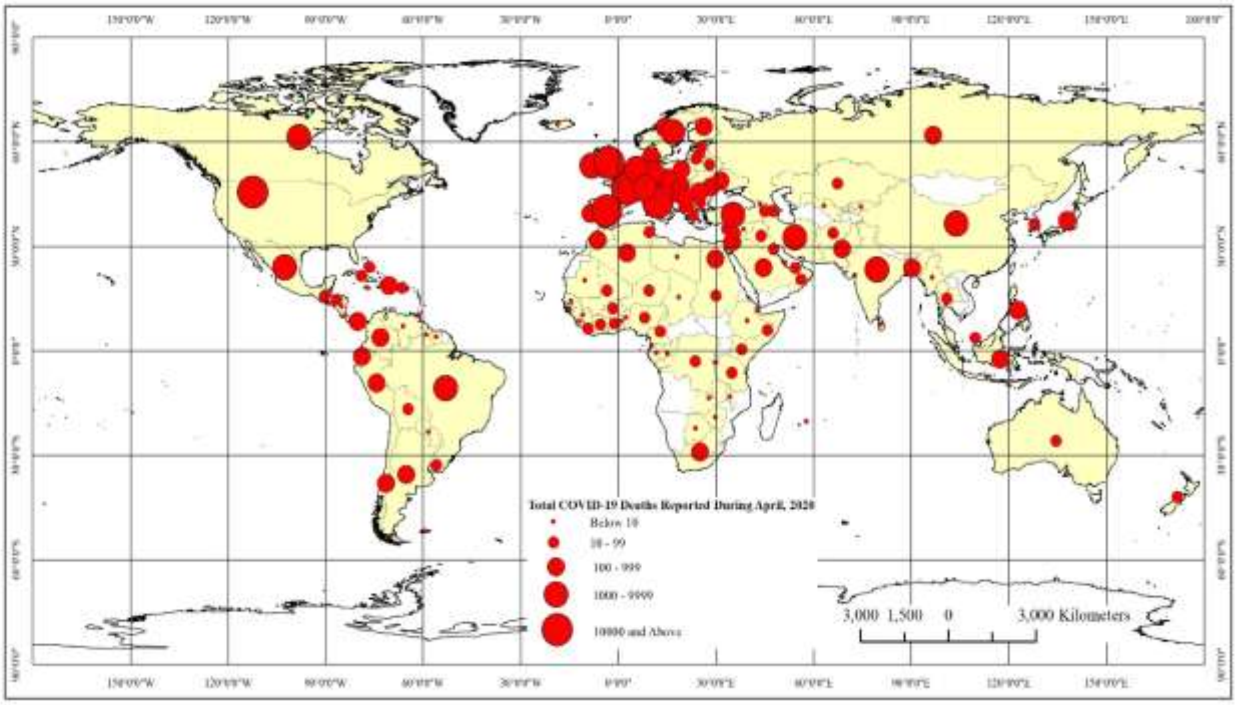

Fig. 11: Total COVID-19 deaths reported during April, 2020

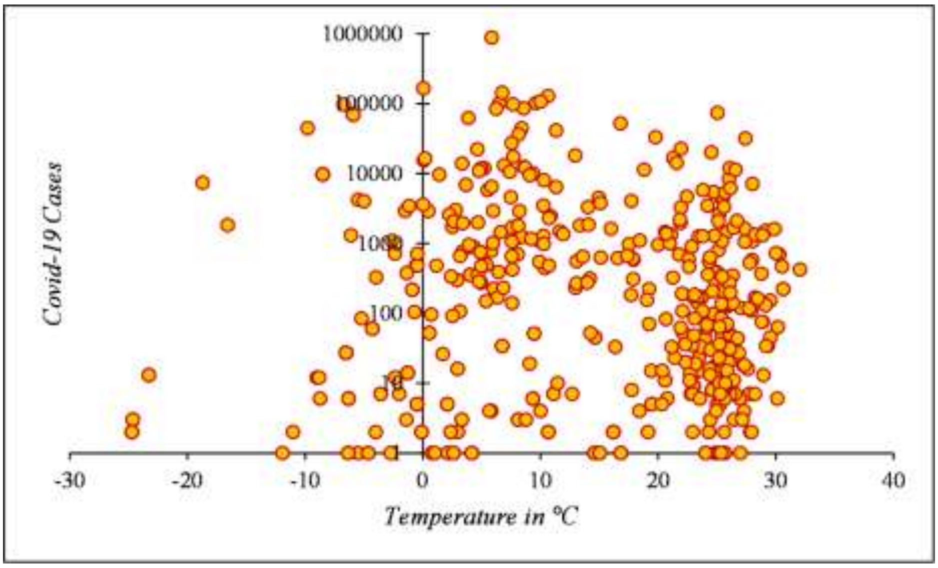

Fig. 12: Temperature Versus COVID-19 Cases (December, 2019 – April, 2020)

This scatter diagram (Fig. 12) shows that infection rate is higher below 20°C and comparatively low above it. However, there is too much data noise. In case of reported deaths, it is high in low temperature and gradually declines as temperature goes up (Fig. 13). Fig. 14 displays the relationship between precipitation and COVID-19 incidences. As is evident, no definite trend was observed in this case.

Similar results were obtained in case of precipitation versus death. The graph (Fig. 15) shows that precipitation has not any determining impact on the behavior of SARS CoV-2 and on the spread of the disease.

The results of regression analysis for cumulative series of COVID-19 cases and linked deaths with temperature and precipitation as a predictor have been shown in table 1. From the perusal of the ANOVA results, it is clear that temperature has a significant impact on occurrence of COVID-19 infection incidences and, thus, null hypothesis is rejected here {$F (1, 822) = 3.96$, $p = 0.047$}.

However, in case of death, null hypothesis could not be rejected due to low significance {$F (1, 822) = 3.45$, $p = 0.06$}. The analysis also reveals that precipitation is not linked with COVID-19 cases or deaths as the level of significance is very weak.

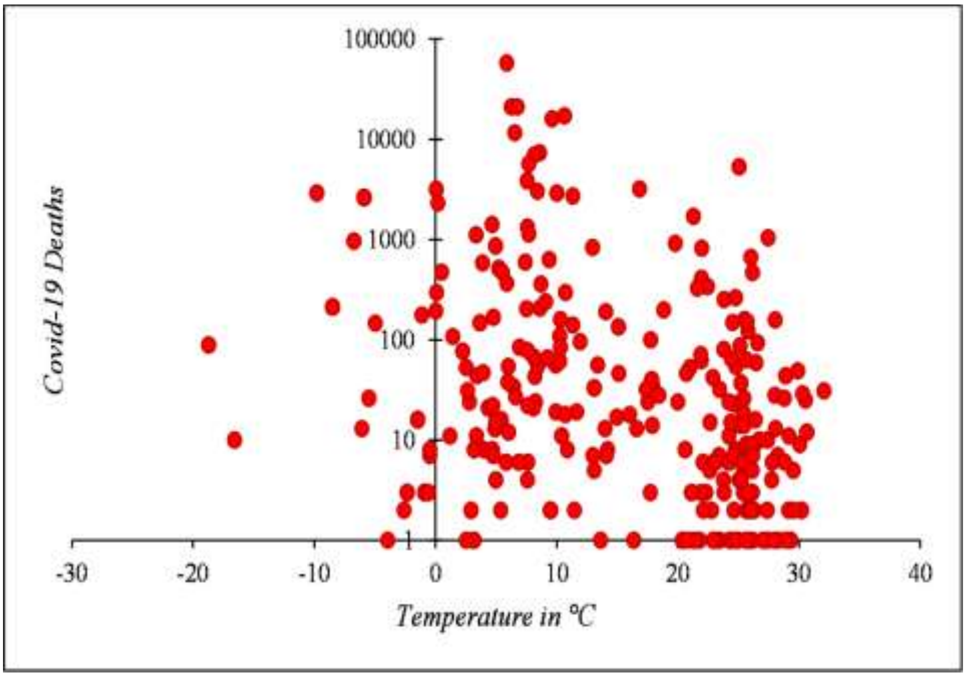

Fig. 13: Temperature Versus COVID-19 Death (December, 2019 – April, 2020)

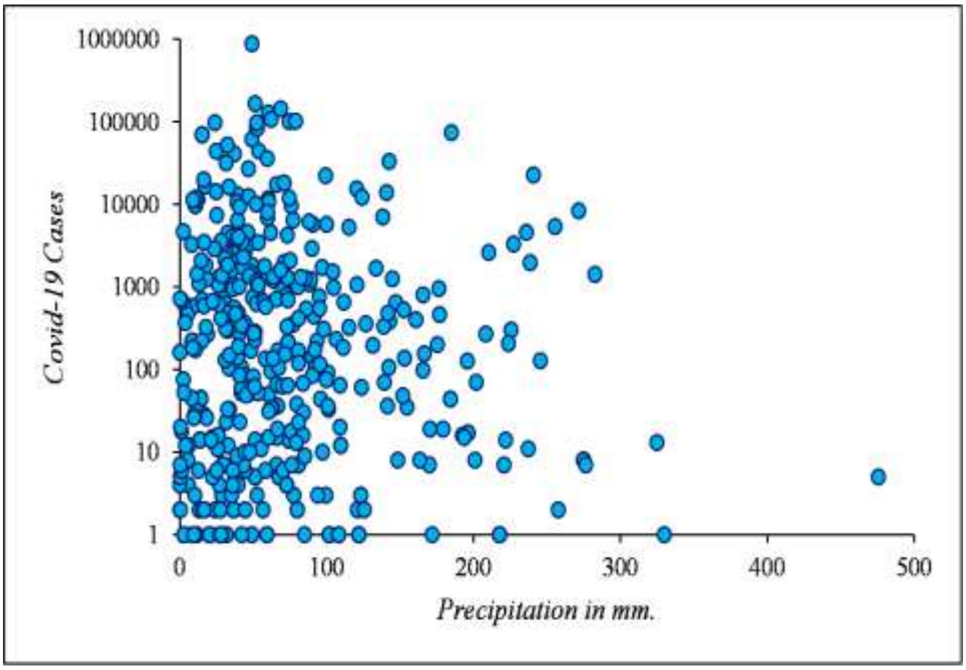

Fig. 14: Precipitation Versus COVID-19 Cases (December, 2019 – March, 2020)

To examine this link further, similar exercise was again performed for each of the months separately. The results of the analyses are presented in table 2 and table 3. It is evident that with increasing spread of the disease, level of confidence about impact of temperature on it has increased too as the null hypothesis was rejected significantly for the month of March {F (1, 163) = 8.73, p = 0.004} and April {F (1, 163) = 7.27, p = 0.008}. Similar result was obtained while evaluating the impact of temperature on COVID-19 linked deaths {F (1, 163) = 9.20, p = 0.003} for the month of April.

Month-wise regression analysis regarding role of precipitation on spread of this disease shows that no reportable association exist between precipitation and the effectiveness of the novel coronavirus (Table 3).

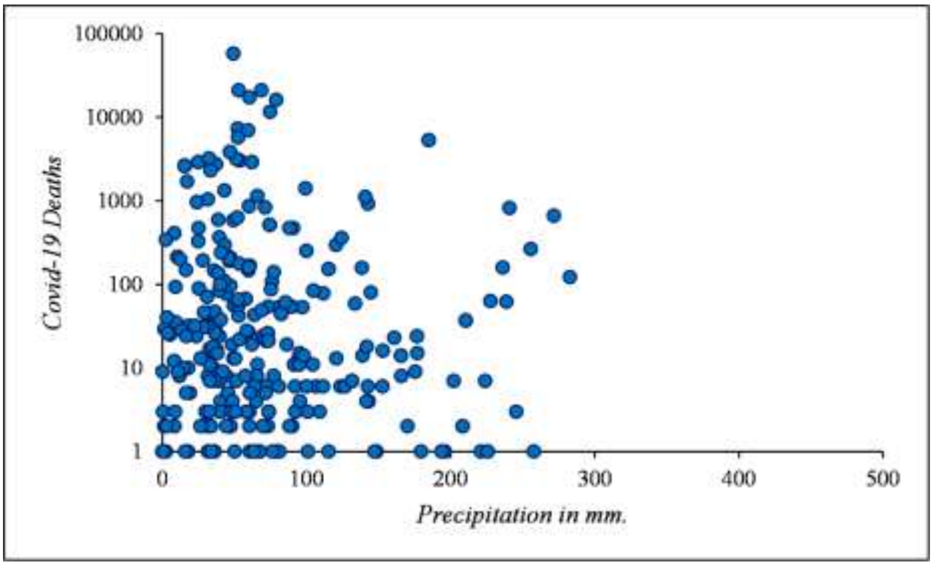

Fig. 15: Precipitation Versus COVID-19 Deaths (December, 2019 – March, 2020)

Table 1
ANOVA results for COVID-19 cases and deaths (December, 2019- April, 2020)

Predictor	COVID-19 Cases			COVID-19 Deaths		
	F	p	r	F	p	r
Temperature	**3.96**	**0.047**	**-0.07**	3.45	0.06	-0.07
Precipitation	0.47	0.495	-0.02	0.32	0.57	-0.02

Table 2
Month-wise ANOVA results for COVID-19 cases and deaths where predictor is temperature

Month	COVID-19 cases			COVID-19 deaths		
	F	p	r	F	p	r
December	2.86	0.09	-0.13	--	--	--
January	2.74	0.10	-0.13	2.73	0.10	-0.13
February	2.66	0.11	-0.13	2.53	0.11	-0.12
March	**8.73**	**0.004**	**-0.23**	3.76	0.054	-0.15
April	**7.27**	**0.008**	**-0.21**	**9.20**	**0.003**	**-0.23**

Table 3
Month wise ANOVA results for COVID-19 cases and deaths where predictor is precipitation

Month	COVID-19 cases			COVID-19 deaths		
	F	p	r	F	p	r
December	0.88	0.35	-0.07	N/A	N/A	N/A
January	0.71	0.40	-0.07	0.71	0.40	-0.07
February	0.64	0.43	-0.06	0.63	0.43	-0.06
March	0.30	0.59	-0.04	0.11	0.74	-0.03
April	0.56	0.45	-0.06	0.55	0.46	-0.06

From the analysis it can be said that with increasing spread and infection rate of the disease, the confidence in considering temperature as a predictor of COVID-19 has enhanced. However, role of precipitation in spread of the disease could not be established. Further, it is notable that correlation between COVID-19 cases and deaths with temperature as well as with precipitation is negative always.

Conclusion

The analysis reveals that coastal countries and the countries lying in between 30° to 60° north latitudes were most affected by this disease. While examining the impact of temperature and precipitation on diffusion of COVID-19, it was observed that temperature is playing some decisive role in determining the spread and severity of the disease, however role of precipitation is still uncertain. This points out that SARS CoV-2 virus is although showing some association with temperature, however, it is not following the same seasonality pattern shown by other members of human-coronavirus family (Fig. 2). This deviation of SARS CoV-2 from normal seasonality behaviour is really alarming. However, as the challenge is alive and even becoming serious every-day, these conclusions are still inconclusive.

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