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Impact of weather conditions on incidence and mortality of COVID-19 pandemic in Africa

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Abstract. – OBJECTIVE: The weather-related conditions change the ecosystem and pose a threat to social, economic and environmental development. It creates unprecedented or unanticipated human health problems in various places or times of the year. Africa is the world's second largest and most populous continent and has relatively changeable weather conditions. The present study aims to investigate the impact of weather conditions, heat and humidity on the incidence and mortality of COVID-19 pandemic in various regions of Africa.

MATERIALS AND METHODS: In this study, 16 highly populated countries from North, South, East, West, and Central African regions were selected. The data on COVID-19 pandemic including daily new cases and new deaths were recorded from World Health Organization. The daily temperature and humidity figures were obtained from the weather web "Time and Date". The daily cases, deaths, temperature and humidity were recorded from the date of appearance of first case of "Severe Acute Respiratory Syndrome Coronavirus 2 (SARS-CoV-2)" in the African region, from Feb 14 to August 2, 2020.

RESULTS: In African countries, the daily basis mean temperature from Feb 14, 2020 to August 2, 2020 was 26.16±0.12°C, and humidity was 57.41±0.38%. The overall results revealed a significant inverse correlation between humidity and the number of cases (r= -0.192, $p<0.001$) and deaths (r= -0.213, $p<0.001$). Similarly, a significant inverse correlation was found between temperature and the number of cases (r= -0.25, $p<0.001$) and deaths (r=-0.18, $p<0.001$). Furthermore, the regression results showed that with 1% increase in humidity the number of cases and deaths was significantly reduced by 3.6% and 3.7% respectively. Congruently, with 1°C increase in temperature, the number of cases and deaths was also significantly reduced by 15.1% and 10.5%, respectively.

CONCLUSIONS: Increase in relative humidity and temperature was associated with a decrease in the number of daily cases and deaths due to COVID-19 pandemic in various African countries. The study findings on weather events and COVID-19 pandemic have an impact at African regional levels to project the incidence and mortality trends with regional weather events which will enhance public health readiness and assist in planning to fight against this pandemic.

Key Words:
COVID 19, Weather, Temperature, Humidity, Prevalence, Mortality, Africa.

Introduction

The "Severe Acute Respiratory Syndrome Coronavirus 2 (SARS-CoV-2) infection" has caused the COVID-19 pandemic, which has involved the entire world with many upsetting consequences on public health and economies[1]. In comparison to some similar pandemics which have occurred before, such as "Severe Acute Respiratory Syndrome Coronavirus (SARS-CoV-1), and Middle East Respiratory Syndrome Coronavirus (MERS-CoV)", this pandemic has been more widespread[2]. On August 22, 2020, it involved 216 countries, and has infected 22,812,491 people with a mortality rate of 7,95,132 (3.48%)[3].

The highly contagious nature of the disease and pandemic situation has first developed an extraordinary instable and threatened situation in the world. The transmission of this pandemic and its subsequent incidence and mortalities have continued worldwide. There is great debate on the weather conditions, impact of heat and humidity

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on the incidence and mortality due to COVID-19 pandemic[4]. More recently, a few published studies[4,5] demonstrated that warm weather and humidity may change the epidemiological trends of COVID-19 pandemic, which has already infected over 22 million people worldwide[3].

The SARS-CoV-2 infection can be transmitted through aerosols, large droplets, or direct contact with secretions or fomites, the effects of different environmental factors on the incidence of COVID-19 remain to be clarified. The climate conditions have an impact on air, water, soil, ecosystem, feelings behaviors[6], and pattern of health and disease[2]. The present study aimed to investigate the impact of weather conditions, heat and humidity on the daily basis incidence and mortality due to COVID-19 pandemic in 16 highly populated African countries, including "South Africa, Ghana, Nigeria, Egypt, Algeria, Morocco, Kenya, Congo, Côte d'Ivoire, Cameroon, Niger, Somalia, Tanzania, Zambia, Mozambique, Madagascar"[7].

Materials and Methods

Africa is the world's second most largest and most populous continent, surrounded by the Mediterranean sea to the north, the Isthmus of Suez and the Red sea to the northeast, the Indian ocean to the southeast and the Atlantic ocean to the west. It covers 6% of Earth's total surface area and 20% of its land area. There are 54 states in Africa, an approximate population of 1.3 billion people, 17 % of the total world population with median age is of 19.7 years[7,8].

In this study, from 54 African countries, we selected 16 countries including, South Africa, Ghana, Nigeria, Egypt, Algeria, Morocco, Kenya, Congo, Côte d'Ivoire, Cameroon, Niger, Somalia, Tanzania, Zambia, Mozambique, Madagascar" (Figure 1). These countries are highly populated in the region, have relatively changeable weather conditions, socioeconomic culture and health care problems. The data on COVID-19 pandemic, daily new cases and daily new deaths were collected from the World Health Organization[3]. The daily information on meteorological conditions, temperature and humidity was recorded from climate web "Time and Date"[9], and mean values were calculated. The daily new cases and new deaths due to COVID-19, daily information on meteorological conditions, temperature and humidity were recorded from the date of appearance of first case of SARS-COV-2 in the region, Feb 14, 2020 to August 2, 2020. The daily mean temperature during this period was 26.16±0.12°C, and humidity was 57.41±0.38%.

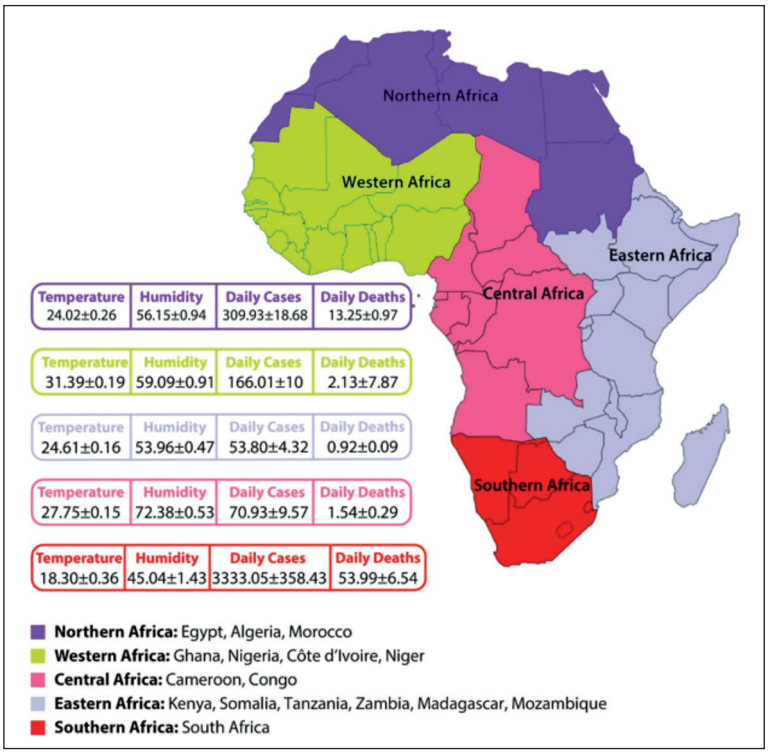

Figure 1. Mean temperature, humidity, daily cases and daily deaths in sixteen countries in various regions of Africa.

Statistical Analysis

The data were analyzed using R Core Team (2020). R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. URL http://www.R-project.org/. Mean ± SEM has been reported for quantitative meteorological factors. Normality of data for Normal and Poisson distributions was checked through one-sample Kolmogorov-Smirnov test. One Way ANOVA was applied to compared quantitative parameters with countries, post-hoc Tukey test was applied to observe which group mean differs. Pearson correlation was applied to assess the relationship between various meteorological factors at 1% level of significance, whereas, Poisson Regression Analysis was performed to predict the number of cases and deaths with humidity and temperature after fulfilling the assumptions. Goodness of Fit tests and Model tests for all regression analysis were significant. An α=0.05 was considered as statistically significant.

Results

The impact of heat and humidity on the daily new cases and deaths due to COVID-19 pandemic in 16 African countries was analyzed. The daily basis mean temperature and humidity were recorded from the date of appearance of first case of SARC-COV-2 in the African region, from Feb 14, 2020 to August 2, 2020 (Table I). The mean values of number of daily cases, daily deaths and cumulative cases due to SARS-COV-2 infection are presented in Table I.

The impact of temperature and humidity on the epidemiological trends on number of cases and deaths were presented and correlation coefficient values are given in Table II, and regression analysis results are presented in Table III. The mean temperature and humidity in South Africa 18.30±0.36, 45.04±1.43, Ghana 30.18±0.38, 69.44±0.80, Nigeria 30.31±0.36, 62.05±1.68, Egypt 27.20±0.48, 36.19±1.17, Algeria 21.97±0.40, 71.31±1.26, Morocco 22.62±0.31, 62.54±0.81, Kenya 21.98±0.18, 61.66±0.84, Congo 28.28±0.22, 69.27±0.62, Côte d'Ivoire 29.75±0.20, 70.75±0.75, Cameroon 27.24±0.20, 75.30±0.79, Niger 35.62±0.33, 32.71±1.68, Somalia 31.90±0.22, 47.60±0.99, Tanzania 24.55±0.15, 55.67±0.93, Zambia 21.76±0.38, 49.04±1.54, Mozambique 25.69±0.26, 52.45±1.20, Madagascar 21.72±0.28, 57.18±0.78. The overall mean temperature in all these 16 African countries was 26.16±0.12°C, and humidity was 57.41±0.38%. Number of cases and deaths in South Africa significantly varied with other African countries (p<0.001). The cumulative number of cases occurred in South Africa and Egypt significantly dif-

Table I. Mean temperature, humidity, number of daily cases, cumulative cases, daily deaths and cumulative deaths in 16 African countries

Countries	Temperature °C (mean ± SEM)	Humidity % (mean ± SEM)	Daily cases (mean ± SEM)	Cumulative cases (mean ± SEM)	Daily deaths (mean ± SEM)	Cumulative deaths (mean ± SEM)
South Africa	18.30 ± 0.36	45.04 ± 1.43	3333.05 ± 358.43	89924.65 ± 11252.49	53.99 ± 6.54	1461.59 ± 171.95
Ghana	30.18 ± 0.38	69.44 ± 0.80	250.01 ± 26.12	9993.73 ± 884.38	1.28 ± 0.21	54.59 ± 4.70
Nigeria	30.31 ± 0.36	62.05 ± 1.68	277.31 ± 20.37	11749.25 ± 1100.63	5.62 ± 0.51	278.31 ± 23.85
Egypt	27.20 ± 0.48	36.19 ± 1.17	551.55 ± 43.37	26995.38 ± 2515.93	28.26 ± 2.29	1233.85 ± 117.91
Algeria	21.97 ± 0.40	71.31 ± 1.26	193.44 ± 15.70	8298.36 ± 653.67	7.64 ± 0.50	524.44 ± 30.43
Morocco	22.62 ± 0.31	62.54 ± 0.81	162.66 ± 15.21	7299.15 ± 511.38	2.38 ± 0.24	162.22 ± 7.72
Kenya	21.98 ± 0.18	61.66 ± 0.84	150.44 ± 18.22	3966.50 ± 453.37	2.56 ± 0.30	85.23 ± 7.61
Congo	28.28 ± 0.22	69.27 ± 0.62	24.02 ± 4.19	860.83 ± 82.11	0.39 ± 0.09	21.40 ± 1.51
Côte d'Ivoire	29.75 ± 0.20	70.75 ± 0.75	111.86 ± 12.03	4764.79 ± 431.74	0.70 ± 0.09	36.04 ± 2.68
Cameroon	27.24 ± 0.20	75.30 ± 0.79	115.03 ± 17.41	6222.15 ± 497.85	2.60 ± 0.55	163.55 ± 11.64
Niger	35.62 ± 0.33	32.71 ± 1.68	8.29 ± 1.13	787.97 ± 30.59	0.50 ± 0.07	45.94 ± 2.17
Somalia	31.90 ± 0.22	47.60 ± 0.99	22.94 ± 2.20	1600.58 ± 104.83	0.66 ± 0.10	53.78 ± 3.18
Tanzania	24.55 ± 0.15	55.67 ± 0.93	3.66 ± 1.52	373.73 ± 17.41	0.15 ± 0.05	15.15 ± 0.72
Zambia	21.76 ± 0.38	49.04 ± 1.54	45.13 ± 8.87	1151.84 ± 115.21	1.19 ± 0.38	25.68 ± 3.67
Mozambique	25.69 ± 0.26	52.45 ± 1.20	14.33 ± 1.44	503.75 ± 48.46	0.09 ± 0.02	3.12 ± 0.34
Madagascar	21.72 ± 0.28	57.18 ± 0.78	83.50 ± 11.33	1929.58 ± 249.04	0.79 ± 0.14	16.36 ± 2.28
Mean ± SEM	26.16 ± 0.12	57.41 ± 0.38	349.20 ± 28.76	11604.49 ± 881.23	7.29 ± 0.54	228.34 ± 17.04
p-value	---	---	$p < 0.001$	$p < 0.001$	$p < 0.001$	$p < 0.001$

Data presented from the date of appearance of first case of SARS-COV-2 in the selected 16 African countries from Feb 14, 2020 to August 2, 2020. Values are presented in Mean and SEM. (Temperature °C: Humidity %).

Table II. Correlation coefficient between daily cases, cumulative cases, daily deaths and cumulative deaths due to COVID-19 pandemic in 16 African countries.

Comparable parameters	Correlation Coefficient	Significance Level
Temperature and daily cases	-0.250	$p < 0.001$
Temperature-cumulative cases	-0.196	$p < 0.001$
Temperature-daily deaths	-0.180	$p < 0.001$
Temperature-cumulative deaths	-0.103	$p < 0.001$
Humidity-daily cases	-0.192	$p < 0.001$
Humidity-cumulative cases	-0.163	$p < 0.001$
Humidity-daily deaths	-0.213	$p < 0.001$
Humidity-cumulative deaths	-0.190	$p < 0.001$

Temperature and humidity were recoded from the date of appearance of first case of SARS-COV-2 in the region, Feb 14, 2020 to August 2, 2020. Correlation coefficient based on daily cases and daily deaths recoded from Feb 14, 2020 to August 2, 2020.

fered with rest of the African countries ($p<0.001$), whereas the cumulative number of deaths occurred in Algeria, South Africa and Egypt significantly differed with rest of the African countries ($p<0.001$) (Table I).

The mean number of cases and deaths in South Africa were 3333.05±358.43, 53.99±6.54, Ghana 250.01±26.12, 1.28±0.21, Nigeria 277.31±31, 5.62±0.51, Egypt 551.55±43.37, 28.26±2.29, Algeria 193.44±15.70, 7.64±0.50, Morocco 162.66±15.21, 2.38±0.24, Kenya 150.44±18.22, 2.56±0.30, Congo 24.02±4.19, 0.39±0.09, Côte d'Ivoire 111.86±12.03, 0.70±0.09, Cameroon 115.03±17.41, 2.60±0.55, Niger 8.29±1.13, 0.50±0.07, Somalia 22.94±2.20, 0.66±0.10, Tanzania 3.66±1.52, 0.15±0.05, Zambia 45.13±8.87, 1.19±0.38, Mozambique 14.33±1.44, 0.09±0.02, Madagascar 83.50±11.33, 0.79±0.14 . The overall mean cases in all these 16 African countries was 349.20±28.76, and deaths was 7.29±0.54 (Table I).

Relationship Between Temperature and Humidity With Daily Cases and Daily Deaths

While analyzing the overall correlation coefficient the results showed that an increase in temperature was linked with decrease in the number of cases (r=-0.025, $p<0.001$) and deaths (r=-0.180, $p<0.001$). Moreover, the correlation coefficient between temperature and cumulative cases was (r=-0.196, $p<0.001$) and temperature and cumulative deaths (r=-0.103, $p<0.001$) (Table II). In addition, for humidity, the overall correlation coefficient results showed that an increase in humidity was associated with a decrease in the number of cases (r=-0.192, $p<0.001$) and deaths (r=-0.213, $p<0.001$). The results between humidity and cumulative cases was (r=-0.163, $p<0.001$) and humidity and cumulative deaths (r=-0.190, $p<0.001$) in the African countries (Table II, Figure 2).

Regression Analysis Between Temperature and Humidity With Number of Cases and Deaths

Poisson regression results showed that with 1% increase in humidity the number of cases (β = -0.037, S.E=0.0001, $p<0.001$) and deaths (β = -0.035, S.E=0.0004, $p<0.001$) significantly reduced by 3.6% and 3.7%, respectively. Similarly, with 1°C increase in temperature the number of cases (β = -0.163, S.E=0.0002, $p<0.001$) and

Table III. Poisson Regression – humidity and temperature predicting the overall number of cases and deaths.

Humidity	Intercept	β	S.E	Exp (ß)	*p*-value
Deaths	3.862	-0.035	0.0004	0.963	$p < 0.001$*
Cases	7.717	-0.037	0.0001	0.964	$p < 0.001$*
Temperature	**Intercept**	**β**	**S.E**	**Exp (β)**	***p*-value**
Deaths	4.668	-0.111	0.0013	0.895	$p < 0.001$*
Cases	9.661	-0.163	0.0002	0.849	$p < 0.001$*

**Statistically significant at 5% level of significance; S.E = Standard Error. β = Coefficient Estimates; Exp (β) = Exponentiated Values

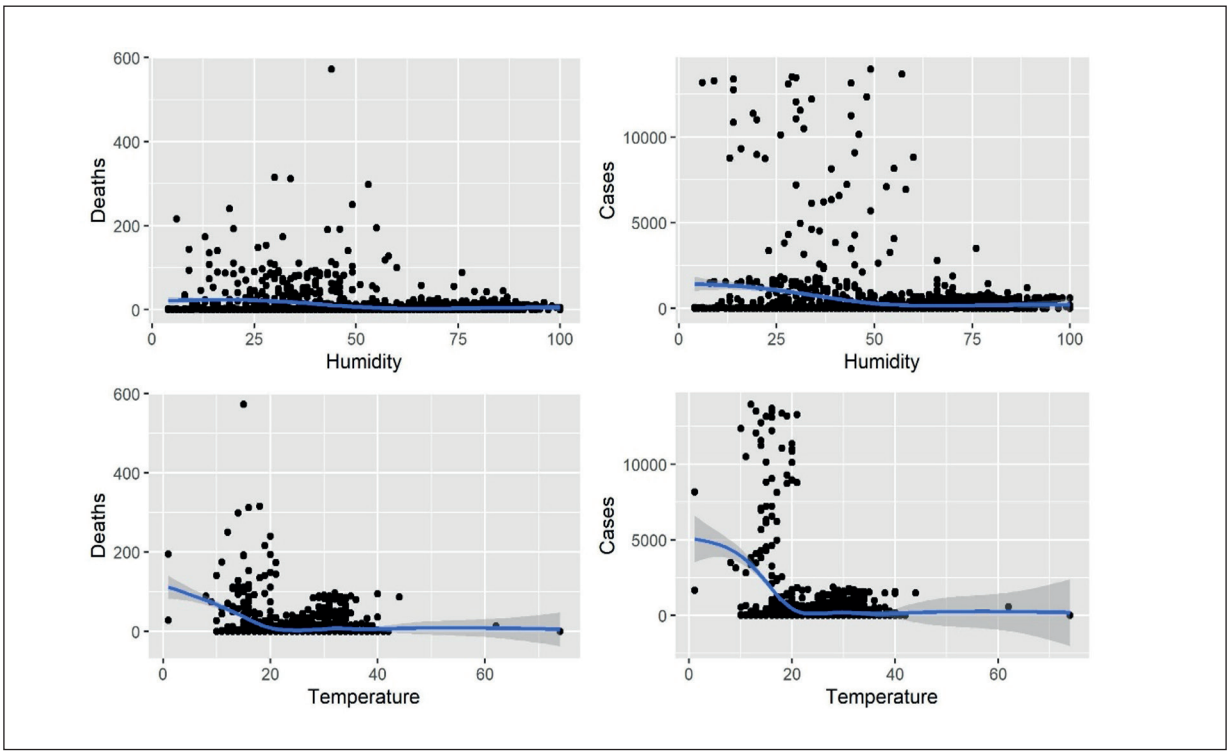

Figure 2. The relationship between humidity, temperature with number of cases and deaths.

deaths (β = -0.111, S.E=0.0013, p<0.001) also significantly reduced by 15.1% and 10.5% respectively (Table III).

Discussion

In African countries, the weather conditions pose a significant threat to economic, social and environmental development. The climate change is likely to reduce crop yields, increase water scarcity, aggravate biodiversity loss and contribute challenges on the entire continent. The African continent has an outbreak of viral infectious diseases in the past few years[10]. The epidemiologic and public health facts considering the periodic variation in weather conditions are essential factors in defining the seasonal behavior of some forms of diseases and health phenomena[11]. The environmental conditions required for the persistence and spread of SARS-COV-2 are discussed in the literature, but there is limited knowledge about the climate associated causes of SARS-COV-2 transmission from various regions[12,13]. However, few studies on SARS-CoV-2 have shown that humidity and temperature possibly affect the transmissibility of the SARS-COV-2.

Harmooshi et al[5] demonstrated that environmental conditions are essential for the survival and spread of SARS-COV-2 infection. The virus may survive for about 9 days at 25°C, and life span may reduce if temperature rises to 30°C. The SARS-COV-2 is also sensitive to humidity. The authors further reported that low temperature and unventilated environment may affect the constancy and spread of virus.

Sajadi et al[14] piloted a study on COVID-19 pandemic and climate conditions but they did not find a relationship between weather changes and spread of SARS-CoV-2. Correspondingly, Huang et al[15] finding proves an optimal climatic zone in which SARS-CoV-2 increases in ambient environment. Their findings demonstrate that COVID-19 pandemic may episodically appear, and outbreak may recur in metropolitan areas in autumn season. Wu et al[16] identified that both "temperature and relative humidity have negative association to daily new cases and deaths". Similarly, Qi et al[17] reported that temperature and humidity showed significant negative association with COVID-19. Their study findings suggest that daily temperature and relative humidity influenced the occurrence of COVID-19.

The present study results revealed that in 16 African countries, an increase in temperature and humidity was allied with a decrease in the number of daily cases and deaths due to COVID-19 pandemic. The results reflect that temperature and humidity play an important role in minimizing the daily incidence and mortality due to COVID-19 pandemic in the African countries.

Xie and Zhu[18] assess the correlation between COVID-19 and temperature in China, their results showed a positive linear association between the number of COVID-19 cases and the mean temperature. Ogaugwu et al[19] reported a weak negative relationship between temperature and the spread of SARS-COV-2 disease, as well as its related mortality. The authors also found that a high temperature may reduce the transmission of the disease. Similarly, Bannister-Tyrrell et al[20] demonstrated that an average temperature increase was negatively correlated with the number of cases. Shi et al[21] also observed that an incidence of COVID-19 decreases with an increase in temperature.

Meo et al[4] conducted a series of studies on the topic and investigated the impact of whether events, temperature and humidity on the daily basis new cases and new deaths due to COVID-19 pandemic in Gulf Cooperation Council (GCC) countries in the Middle East region. They identified an increase in relative humidity was associated with a decrease in the number of daily cases and deaths due to COVID-19 in GCC countries. Meo et al[22] reported a decrease trends in the incidence of daily cases and deaths in world's top ten warmest countries compared to world's top ten coldest countries. Meo et al[23] conducted a study in European countries and demonstrated that an increase in humidity was associated with a decrease in the number of daily cases and deaths, however, a rise in temperature was allied with an upsurge in the number of daily cases and daily deaths due to COVID-19 pandemic in European countries. In the present study, we identified that the increase in humidity and temperature decreases the number of daily cases and daily deaths due to COVID-19 in African countries. We believe that meteorological parameters are important elements influencing infectious diseases, including the SARS-COV-2 infection.

Study Strengths and Limitations

This is the first article added in literature that has investigated the impact of weather conditions on epidemiological trends of incidence and mortality of COVID-19 on African countries, with the findings being based on sixteen countries from the African region. Second strength is that the study period is long, starting from Feb 14 2020 till August 2, 2020, and the longer the study period, the more stable the findings. One limitation of our paper is that, we were unable to consider other climate factors, such as socio-economic conditions, population mobility, population immunity, and urbanization, which may affect the dynamics of the COVID-19 epidemic in African countries.

Conclusions

In African countries an increase in relative humidity and temperature was associated with a decrease in the number of daily cases and deaths due to COVID-19 pandemic. The findings have outcomes for policymakers and health officials about the impact of weather conditions on the epidemiological trends of daily new cases and deaths due to COVID-19 pandemic in the African region. Predicting the COVID-19 pandemic's regional epidemiological trends and weather events can enhance public awareness and readiness to take more appropriate measures and will assist in future planning to fight against such pandemic situations.

Conflict of Interest

The Authors declare that they have no conflict of interests.

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Ethical Statement

For this study the data on the daily new cases and deaths due to COVID-2019 pandemic and related information were obtained from the "World Health Organization, climate web Time and Date" from the publicly available data, hence ethical approval was not required.

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