



## Research article

## Spatio-temporal analysis of meteorological factors in abating the spread of COVID-19 in Africa

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## ARTICLE INFO

## Keywords:

Climatology  
Environmental analysis  
Environmental economics  
Environmental health  
Environmental impact assessment  
Mean temperature  
Average wind speed  
Relative humidity  
COVID-19  
Climatic conditions  
Africa

## ABSTRACT

In Asia, Europe and South America, the role of atmospheric condition in aiding or abating the growth curve of COVID-19 has been analysed. However, no study to date has examined such climatic extensions for the growth or otherwise of the novel coronavirus in Africa. Africa, with a mostly relatively warmer temperature differs from other regions of the world and in addition, has recorded far fewer cases compared to Asian, Europeans and the Americans (North and South). It then becomes imperative to examine the influence of meteorological indices in the growth or otherwise of coronavirus diseases in Africa to establish whether findings on the climatic conditions-COVID-19 growth are regionally specific. In this study, we examined the influence of meteorological factors for aiding or abating the spread of the aerosolised pathogen of COVID-19 in Africa. We rely on the generalised additive model (GAM) and found wind speed to positively relate to COVID-19 growth while mean temperature and relative humidity to inversely relates to COVID-19 growth curve in Africa. We accounted for potential cofounders in the core GAM model and discuss policy implications.

## 1. Introduction

While the search for the cure of the novel coronavirus disease (COVID-19) agonisingly continues, social distancing (Wee et al., 2020; Yezli and Khan, 2020; Vos, 2020; WHO, 2020a, 2020b) and practice of good hygiene (Ali and Alharbi, 2020; WHO, 2020a, 2020b) has been advised by researchers, epidemiologist and clinical scientists as physical preventive measures to abate human-to-human transmission of the disease. In other related findings, scientists (Coccia, 2020a, 2020b; Pyankov et al., 2018; Woon-Fong Leung and Sun, 2020) suggested that the pathogens from the virus can survive in the air for up to three (3) hours, for twenty-four (24) hours on paper facades, up to four (4) hours on copper materials and about three (3) to four (4) days on metals, stainless steel and COVID-19 survives for very different time periods on latex and plastics. What is not clear is the meteorological conditions that precede these findings. In the risk analysis, containment, features and structures of COVID-19 growth in Africa, unobserved factors such as meteorological indices are essential in establishing a clear line of thought on credible solution framework in the fight against spread and associated fatalities caused by COVID-19. Therefore, modelling cases and deaths and any

possible links to meteorological conditions might aid the estimation of the true incidence of Covid-19 in Africa. Ample findings from different geographic areas have lent credence to an inverse relationship between humidity and survival of aerosolised coronavirus using their regional data (see Iqbal et al., 2020; Wu et al., 2020; Prata et al., 2020 citing some examples). In other climes, Ma et al. (2020); Qi et al. (2020); Shi et al. (2020); Xie & Zhu (2020) found that epidemic intensity of COVID-19 reduces with higher temperature.

Apart from the fact that most of these studies have been done using Chinese meteorological indices, Africa remains the warmest region on earth with 60% of its entire land surface consisting of drylands and deserts (Africa: Environmental Atlas, 2008). The climatic conditions are tropical and subarctic on its peak conditions. The northern part of Africa is mostly desert or arid. The central and southern Africa contains dense rainforest (jungles) with broad savanna plains. In between the north, central and southern Africa, there lies a convergence hosting vegetations (Sahel and Steppe). The regional meteorological conditions in Africa needs to be considered in the debate of meteorological factors and COVID-19 structures, features, risk factors and containment. Apart from some North Africa countries (Algeria, Morocco, Egypt etc.), and South

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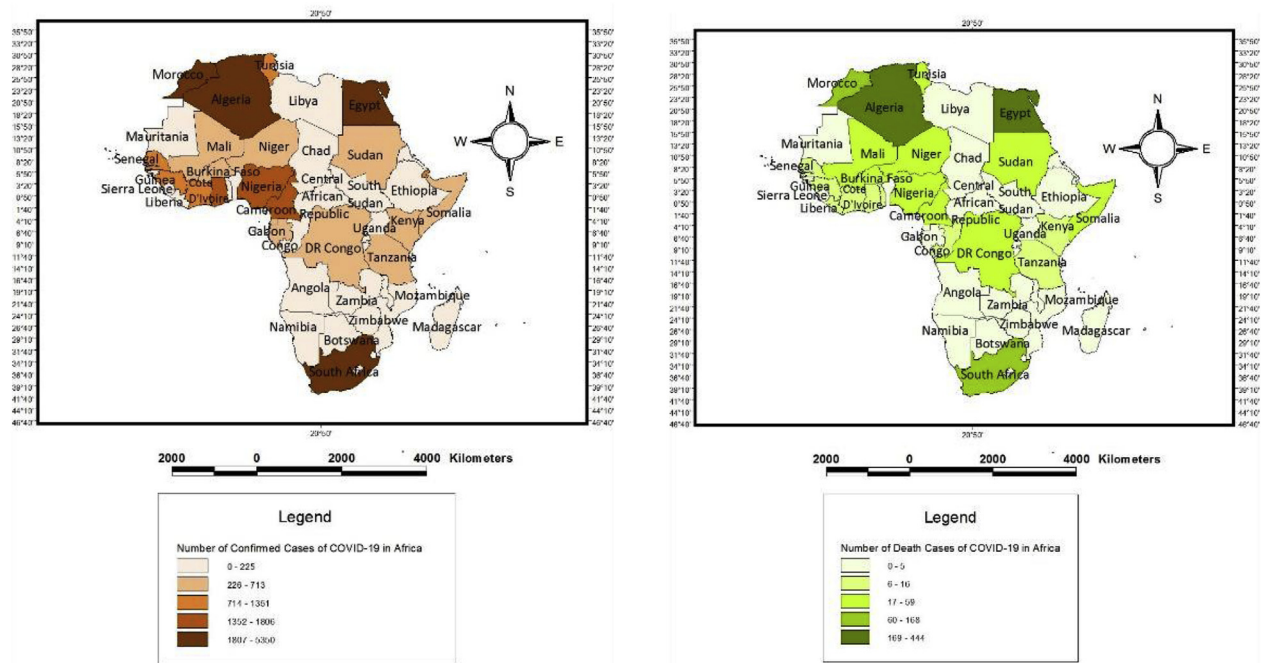


Figure 1. Panel A: Mapping Africa COVID-19 Fatalities, Panel B: Mapping Africa COVID-19 exposure.

Table 1. Description of variables.

Abbreviation	Description	Source
$Confmrd\ Cases_{i,t}$	Total Number of Confirmed Cases across country $i$	World Health Organisation (2020a, b)
$Temp_{i,t}$	Mean Daily Temperature	National Oceanic and Atmospheric Administration Center, 2020
$Wind_{i,t}$	Average Wind Speed	National Oceanic and Atmospheric Administration Center, 2020
$HUM_{i,t}$	Relative Humidity	National Oceanic and Atmospheric Administration Center, 2020

Africa, a significant part of Africa has recorded far lesser confirmed cases and attributable deaths of COVID-19 compared to other regions of the world.

In this study, we examine the relationship among mean temperature, wind speed, relative humidity and confirmed cases of COVID-19 and attributable deaths vis-à-vis the geographical divide and based on average weather and atmospheric conditions in African cities. We seek to unravel the dynamic relationship between regional meteorological conditions and its plausibility in abating the spread of coronavirus and linked fatalities in Africa. In the North African region, that is closer to Europe and has an average temperature of around 13 °C, the number of confirmed cases has ascended, and death figures appalling. In other African regions with the average temperature well above 20 °C, the number of confirmed cases and attributable deaths are minimal compared to what is observable elsewhere (Adekunle et al., 2020). The overarching aim of this study then becomes how relevant are temperature and other meteorological indices in abating COVID-19 spread and fatalities in Africa. The intricacies of these unobserved meteorological factors in the regional weather conditions in Africa humid and non-humid environments for the survival of pathogens from the virus underpin this study. We rely on a generalised additive model (GAM) estimation procedure to estimate the daily meteorological factors in Africa and its associative consequence for confirmed cases of coronavirus. It is plausible to employ GAM to obtain asymptotically consistent estimates that could inform containment and risk analysis approach (Duan et al., 2019).

## 2. Materials and methods

### 2.1. Study area

We analysed the mean temperature and the associative consequences for the survival and spread characterising COVID-19 across 52 Africa states. In Figure 1, we described the pretentious African states, their total number of confirmed cases and fatalities (as at the time of writing-29<sup>th</sup> April 2020). Our choice of these countries was informed by the desire to limit attention to Africa and by the availability of aggregate meteorological and health indices.

### 2.2. Data

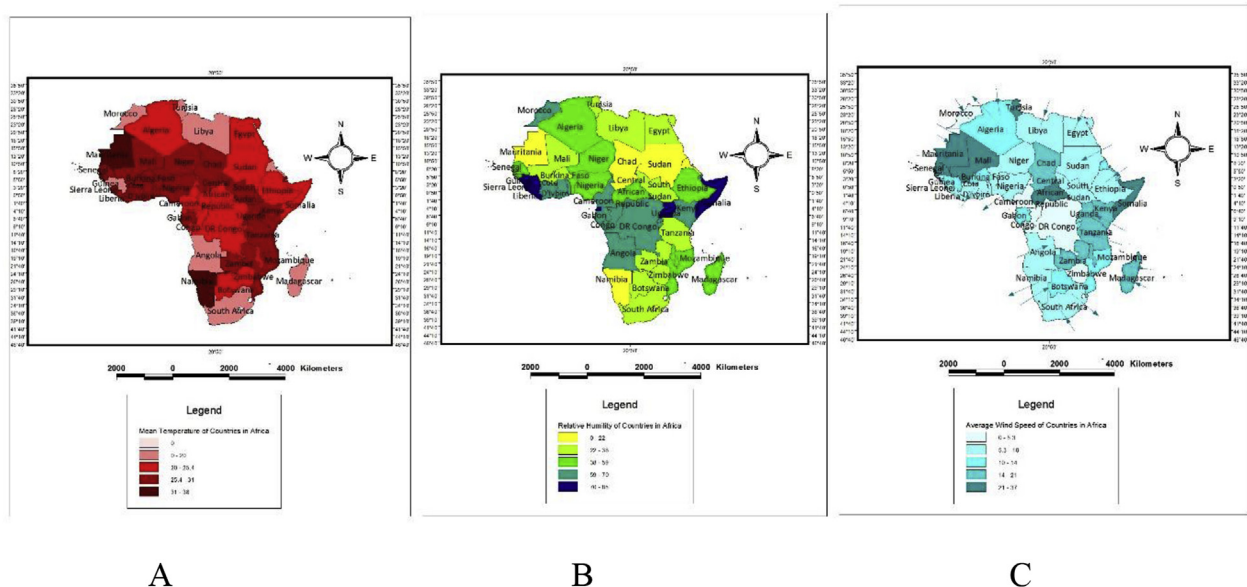
In gauging the transmission and attributable deaths of coronavirus disease (COVID-19) as induced by meteorological factors, we rely on the daily temperature (mean), average wind speed and relative humidity as well as the number of confirmed cases from COVID-19 in Africa. Both the observed meteorological factors and health indices have daily frequencies and as such inferences drawn along such path can be used to guide the containment, risk analysis, features and structures of the spread of COVID-19. The meteorological indices data were obtained from the National Oceanic and Atmospheric Administration Center<sup>1</sup>, confirmed cases and fatalities in fifty-two (52) African states were obtained from the

<sup>1</sup> <https://www.ncei.noaa.gov/access/search/data-search/global-summary-o-f-the-day>.

**Table 2.** Descriptive analysis.

	Mean	St. Dev.	Min.	Max.
Confirmed Cases	447.19	32.76	0	532.19
Mean Temperature (°C)	21.32	6.12	-2.42	33.37
Wind Speed (m/s)	3.21	1.19	0	7.89
Relative Humidity (%)	23.21	15.28	14	41.03

Source: Authors Computation, 2020



**Figure 2.** Mapping Africa Climatic exposures A) Average Temperature (Mean) in (°C), B) Average Wind Speed in (m/s) and C) Relative Humidity (%).

World Health Organisation various daily situation reports {Situation report 70<sup>2</sup> (March 30<sup>th</sup>, 2020) through Situation report 100<sup>3</sup> (April 29<sup>th</sup>, 2020)} (an invariant time plot of 31 observations). Data were transformed to fit a dynamic panel model procedure as in Sarkodie and Owusu (2020); Adekunle et al. (2020). The pressure of the actual water vapour relative to the pressure of the saturation water vapour at the predominant temperature characterised the relative humidity (Wu et al., 2020). Other meteorological factors such as average wind speed are crucial in the movement of the aerosolised pathogens of COVID-19, and this aid or abate transmission depending on the prevailing climatic conditions of the observed region (Ellwanger and Chies, 2018). The variables of the study and their respective descriptions and sources are contained in Table 1.

**2.3. Model**

We estimated the generalised additive model (GAM) to gauge the linear relationship between meteorological factors and survival of COVID-19 in Africa. We estimated the GAM model for some reasons. In parametric and non-parametric regression as well as exponential smoothing, the generalised additive model (GAM) produce consistent estimates (Liu et al., 2020). It produces a consistent result in the linear and non-linear estimation of weather conditions and health outcomes (Xie and Zhu, 2020). The GAM is a moving average estimation procedure that is capable of accommodating the cumulative lag effect of climatic conditions (Zhu et al., 2020). In our analysis, we observe that climatic

conditions could be extended over a prolonged period with incubation of COVID-19 estimated to be around two (2) to 14 (fourteen) days. Our core GAM-COVID-19 attributable confirmed cases model as induced by weather conditions is expressed as:

$$\ln \text{Confrmd Cases}_{i,t} = \delta + \ln \text{Confrmd Cases}_{i,t-1} + \varnothing \text{Temp}_{i,t} + \pi \text{Wind}_{i,t} + \omega \text{HUM}_{i,t} + \text{WDY}_t + \text{Country}_i + s(t, df) + \mu_{it} \tag{1}$$

Where  $\varnothing$ ,  $\pi$  and  $\omega$  are the COVID-19 attributable spread elasticities coefficients;  $\delta$  is the drift intercept parameter,  $\mu_{it}$  is the idiosyncratic error component;  $\text{Confrmd Cases}_{i,t}$  is the total number of confirmed cases across country  $i$  defined over  $t$ ;  $\text{Temp}_{i,t}$  gives mean daily temperature,  $\text{Wind}_{i,t}$  is the average wind speed and  $\text{HUM}_{i,t}$  gives the relative humidity;  $\ln$  is the logarithm transformation of the response variable;  $\ln \text{Confrmd Cases}_{i,t-1}$  is the logarithm transformation of the one-period lag value of the response variable accommodating strict orthogonal variance is the core GAM model;  $\text{WDY}_t$  is the categorical variable representing fixed effects of days observed;  $\text{Country}_i$  is the categorical variable denoting country fixed effect;  $s(\cdot)$  gives the smother predicted upon the penalised smoothing spline with not more than two (2) degree of freedom to avoid overfitting;  $t$  is the daily time counts,  $df$  is the degree of freedom, and  $i$  defines the cross-sectional dimensions.

We controlled for regional variations in the model (unobserved heterogeneity). We accounted for time trend and cycle by introducing the penalised smoothing spline function with the accustomed days of the week in our estimated model. We found a basis for lagged weather conditions and cumulative consequences of overstretched exposure to account for variances in measurement and misalignment in daily

<sup>2</sup> [https://www.who.int/docs/default-source/coronaviruse/situation-reports/20200330-sitrep-70-covid-19.pdf?sfvrsn=7e0fe3f8\\_4](https://www.who.int/docs/default-source/coronaviruse/situation-reports/20200330-sitrep-70-covid-19.pdf?sfvrsn=7e0fe3f8_4).

<sup>3</sup> [https://www.who.int/docs/default-source/coronaviruse/situation-reports/20200429-sitrep-100-covid-19.pdf?sfvrsn=bbfb3d1\\_2](https://www.who.int/docs/default-source/coronaviruse/situation-reports/20200429-sitrep-100-covid-19.pdf?sfvrsn=bbfb3d1_2).

**Table 3.** Collinearity statistics.

Meteorological Indices	Coefficients
Mean Temperature (°C)	-0.624 {0.041}
Wind Speed (m/s)	0.212 {0.003}
Relative Humidity (%)	-0.551 {0.001}

**Source:** Authors Computation, 2020

**Note:** Spearman's Rank Correlation coefficients are reported in the text box while the Prob, values are in the parentheses. The dependent variable is the total number of Confirmed Cases. Decision rule: Reject Null when Prob. Value is <0.05.

exposures. We employed the R statistical package (4.0.0)<sup>4</sup> to obtain percentage changes in confirmed cases attributable to a unit increase in meteorological indices at 95 confidence interval. We also adjusted for time variations and heterogenous epidemic outbreaks in various African countries in our sensitivity analysis to establish the stability of the model. We estimated an unbalanced panel model (predicted on non-occurrence of cases in some situation reports in some African countries at alternate days of data collection).

### 3. Results

There were 3,018,681 confirmed cases around the world with 207,973 death cases (WHO, 2020b) as at 29<sup>th</sup> April 2020. Africa has recorded a cumulative total of 23254 confirmed cases with 903 deaths. In Europe, there exist 1406899 confirmed cases with 129,311 deaths. Elsewhere in South East Asia, there are 51,351 confirmed cases and 2001 deaths. In the Western Pacific region, there exist 146,499 confirmed cases and 6,037 deaths. Across America (North and South), 1,213,088 with 62,404 deaths. We report in Table 2 our summary, using the descriptive statistics of the exposure-response cases of meteorological factors associated with COVID-19 in Africa. We took about 1,612 observation (some reported no matching scores predicted upon no occurrence of confirmed cases or deaths of COVID-19 in some African states as the time of writing) from March 30, 2020, through April 29, 2020, across Africa. We recorded an average daily count of confirmed cases of 447 with a mean relative temperature of around 21.32 °C in Africa. The mean value of the wind speed was 3.21 m/s and relative humidity at 23.21%. In Figure 2, we mapped the density of mean temperature, average wind speed and relative humidity (as at the time of writing) across Africa states.

#### 3.1. Collinearity statistics

##### 3.1.1. Spearman ranks correlation

In our preliminary correlation analysis in Table 3, we found mean temperature (°C) ( $r = 0.624$ ,  $p < 0.01$ ), average wind speed (m/s) ( $r = 0.212$ ,  $p < 0.01$ ) and relative humidity (%) ( $r = 0.551$ ,  $p < 0.01$ ) to be significantly negatively, positively and negatively respectively correlated with COVID-19 growth in Africa. This may be due to hot climatic conditions in Africa and the African culture of staying under the sun for a predominantly large part of their daily activities which is mostly informal and agricultural. The structure of services obtainable in most African states is informal mainly compared to a developed nation where employment conditions come mostly under a well organised and conducive atmosphere. Similar findings to those established in our correlation analysis can be found in cross border outcomes of Tosepu et al. (2020) whose study found a positive association between mean temperature and growth curve of COVID-19 in their study of meteorological factors in Jakarta, Indonesia. However, Briz-Redón and Serrano-Aroca (2020) found no association between COVID-19 cases and temperature in Spain. In other climes, Ma et al. (2020); Qi et al. (2020); Shi et al.

(2020); Xie and Zhu (2020) found the exposure-growth association (meteorological factors considered in this study) to have inverse relations in China. Far in South America, Brazil Prata et al. (2020) found confirmatory outcomes for growth in the number of confirmed cases of COVID-19 to be associated with lower mean temperature, lesser humidity. In the Middle East, Iran, Jahangiri et al. (2020) corroborate our result just like those observed in Prata et al. (2020) for Brazil.

To estimate the exact structural influence of climatic conditions for the spread of COVID-19 in Africa, we proceed to estimate the magnitude of the linear influence of these meteorological indices on the growth curve of COVID-19 in Africa using our core generalised additive model (GAM) (see Table 4).

We accounted for potential confounders. Mean temperature was negatively related to confirmed cases of COVID-19 in Africa at a 0.05 level of significance, while average wind speed was positively related to COVID-19 growth in Africa. A 1 °C increase in mean temperature was associated with 13.53% (95CI: 1.53–4.63) decrease in confirmed cases of COVID-19 in Africa. Similarly, a 1% increase in average wind speed (m/s) is associated with 11.21% (95CI: 0.51–1.19) increase in confirmed cases of COVID-19 in Africa. The observed results could be as a result of the median temperature across African cities, which are usually hot. These climatic conditions halt the humidification capacity of the African continent not only for diseases emanating from viruses of these types but also other outbreaks like flu, cold and bronchitis related ailment. The level of dehydration across African states are usually high such that its resident consumes more liquid and these pushes further down the particles inherent in the pathways. We are not overruling the superiority of clinical procedure to provide more robust clarification on the subject matter. In other climes, relative humidity is not statistically significant at any level of significance and by implication does not predict variations in COVID-19 growth equation in Africa. The Spearman's rank correlation results also corroborated the negative association between mean temperature, but a positive relationship with average wind speed and confirmed cases of COVID-19 in Africa.

#### 3.2. Sensitivity analysis

We retained robust estimates even after the exclusion of Egypt, South Africa, Morocco, and Algeria because of their higher number of cases relative to other African nations. Our piecewise linear estimates in the sensitivity model demonstrated greater stability. Heterogenous influences of the climatic conditions on the events of exposure and record of index cases as well exponential rise in the number of confirmed cases observable in some Africa countries led us to exclude Egypt, South Africa, Morocco, and Algeria to fit our core GAM model to determine the relative stability of our empirical outcomes.

The mean temperature was negatively and statistically associated with the exposure-growth nexus of confirmed cases of COVID-19 in Africa at a 0.05 level of significance while average wind speed was positively related to the growth of COVID-19 in Africa. A 1 °C increase in mean temperature was associated with 25.44% (95CI: 1.12–3.65) decrease in growth of COVID-19 in Africa. Similarly, a 1% increase in average wind speed is associated with 22.13% (95CI: 0.22–1.43) increase in confirmed cases of COVID-19 in Africa (Table 5).

**Table 4.** GAM %Δ in exposure-growth curve in Africa.

Meteorological Factors	Coefficients ( $\varnothing$ , $\pi$ , $\omega$ )	tStat	Prob.
Mean Temperature (°C)	-0.1353	-1.6519	0.0014*
Wind Speed (m/s)	0.1121	0.3538	0.0021*
Relative Humidity (%)	-0.5181	-0.5302	0.4231

**Source:** Authors Computation, 2020

**Note:** \*  $P < 0.01$ .

<sup>4</sup> <https://cran.r-project.org/bin/windows/base/R-4.0.0-win.exe>.



**Table 5.** GAM % $\Delta$  in exposure-growth curve in Africa (Egypt, South Africa, Morocco and Algeria excluded).

Meteorological Factors	Coefficients ( $\phi, \pi, \omega$ )	tStat	Prob.
Mean Temperature ( $^{\circ}$ C)	-0.2544	-1.4553	0.0043*
Wind Speed (m/s)	0.2213	0.5522	0.0001*
Relative Humidity (%)	-0.4211	-0.9813	0.1712

Source: Authors Computation, 2020

Note: \*  $P < 0.01$ .

#### 4. Conclusion

In this study, we lent spatio-temporal credence to the exposure-response curve of meteorological factors and COVID-19 growth in Africa using the generalised additive model (GAM). We relied on the daily count of the number of confirmed cases from WHO situation reports (70 through 100) and the meteorological factors from the National Oceanic and Atmospheric Administration Center to estimate a linear relationship. Proper caution must be observed in the interpretations of our phenomenological model as it differs from clinical research that relies on point estimates of 1% chance error (CI: 99%). We establish the robustness of our GAM model by conducting the sensitivity test using a balanced sample for accounting for the probable influence of outliers in the COVID-19 under detection rates across African countries on our identification strategy. Findings of this study are limited to meteorological indices in abating or aiding the growth of COVID-19 in Africa. Our findings suggested that the mean temperature and average wind speed are inversely related to the growth curve of COVID-19 in Africa. We found relative humidity to have no statistically significant association with the exposure-response curve of COVID-19 in Africa. Our findings align with findings of Ma et al. (2020); Qi et al. (2020); Shi et al. (2020); Xie and Zhu (2020) who find similar outcomes using Chinese meteorological data. The result of this study is different from those of Huynh (2020), who examined the socio-economic and media attention for the risk perception of COVID-19 in Vietnam. Nonetheless, continuous measures to search for an effective vaccine, strict adherence to social distancing and preventive measures must be sustained even in the uttermost assurances that temperature and wind speed abate and contribute to COVID-19 growth in Africa respectively. The findings of this study explain the critical roles of wind speed and mean temperature in aiding and abating COVID-19 growth in Africa, respectively. Nonetheless, it is essential to keep to social distancing and safe, hygienic procedure in navigating socio-economic interactions amid global search for vaccination and cure. The study is limited to the obtained findings permitted by the GAM model. Other pervasive limitation of this study could be traced to regional differences in testing rates, political interests to withhold information on Covid-19 cases and deaths, unavailability of data on non-meteorological covariates, limited health system services and different travel patterns and contact rates with people from other continents. Social distancing and handwashing may be difficult in poor African countries with limited access to clean water sources, but meteorological conditions reducing survival of Sars-Cov-2 may offset these disadvantages. Indirect deaths from Covid-19 have to be considered when deciding on preventative measures like lockdowns and curfews. Policy decisions by African governments should take this into account, but more research is needed for clarity on the containment and risk analysis of COVID-19.

#### Declarations

##### Author contribution statement

Ibrahim A Adekunle: Conceived and designed the experiments; Wrote the paper.

Sheriffdeen A Tella: Performed the experiments.

Kayode O Oyesiku: Analyzed and interpreted the data.

Isiaq O Oseni: Contributed reagents, materials, analysis tools or data.

##### Funding statement

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

##### Competing interest statement

The authors declare no conflict of interest.

##### Additional information

Data associated with this study is available in the World Health Organisation Situation reports of various issues (70 through 100) ([https://www.who.int/docs/default-source/coronaviruse/situation-reports/20200330-sitrep-70-covid-19.pdf?sfvrsn=7e0fe3f8\\_4](https://www.who.int/docs/default-source/coronaviruse/situation-reports/20200330-sitrep-70-covid-19.pdf?sfvrsn=7e0fe3f8_4); [https://www.who.int/docs/default-source/coronaviruse/situation-reports/20200429-sitrep-100-covid-19.pdf?sfvrsn=bbfb3d1\\_2](https://www.who.int/docs/default-source/coronaviruse/situation-reports/20200429-sitrep-100-covid-19.pdf?sfvrsn=bbfb3d1_2)) and National Oceanic and Atmospheric Administration Center (<https://www.ncei.noaa.gov/access/search/data-search/global-summary-of-the-day>).

##### Acknowledgements

First and foremost, we give thanks to almighty Allah for the grace of living at this unprecedented time of the global pandemic. Our thoughts are with those who have contracted the virus and those who lost their lives in the process. We thank the frontline health workers making enormous sacrifices for the sake of humanity. We are most grateful to the anonymous reviewers and the handling editor for their constructive criticism and suggestions. We extend thanks to Mr O.W. Ogunbanjo, Mr O.H. Adebayo and Dr A.T. Onanuga for quality feedback on the manuscript.

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