Journal of Scientific Research & Reports

26(10): 107-121, 2020; Article no.JSRR.64012
ISSN: 2320-0227

Effect of Climatic Factors on the Spread of COVID-19 Pandemic: Evidence from Tunisia

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Authors' contributions

This work was carried out in collaboration between both authors. Author FA conceptualized the study, performed the statistical analysis, wrote the methodology and wrote the first draft of the manuscript. Author MS supervised the study, validated the results, wrote and edited the final version of the manuscript. Both authors read and approved the final manuscript.

Article Information

DOI: 10.9734/JSRR/2020/v26i1030326
Editor(s):
(1) Dr. Surapong Pinitglang, University of the Thai Chamber of Commerce (UTCC), Thailand.
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(5) Muhammad Idris, Ayub Medical College, Pakistan.
Complete Peer review History: http://www.sdiarticle4.com/review-history/64012

Original Research Article

Received 06 December 2020
Accepted 30 December 2020
Published 31 December 2020

ABSTRACT

Since the end of December 2019, the COrona VIrus Disease (COVID-19) is sweeping the world and has caused huge damage to the health, economy, and social life of the communities. Meteorological variables are among the factors influencing the spread of contagious diseases. The aim of this study was to explore the correlation between climatic parameters and COVID-19 spread in Tunisia. To do this, we designed a daily dataset including the number of confirmed and deaths cases, minimum temperature (°C), maximum temperature (°C), mean temperature (°C), rainfall (mm), and wind speed (km/h) during the period of June 27 to October 22, 2020. To investigate the association between climatic variables and COVID-19, the Spearman correlation test was employed. The Mann-Kendall test has been also used to detect the direction of the COVID-19 trend. As many researchers have demonstrated that the incubation period of the ongoing pandemic

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varies from 1 to 14 days, the correlation of each parameter with COVID-19 was examined on the day of the confirmed cases and deaths, and before 7 and 14 days. The results showed that out of the five selected climatic variables, four variables were correlated with COVID-19 cases and deaths (statistically significant at a 99% confidence level). A positive correlation of the rainfall with COVID-19 confirmed cases and deaths was observed, the highest was 14 days ago. However, negative correlations were observed for minimum, maximum, and mean temperature, the highest was on the day of the incident. Besides, the Mann-Kendall test showed increasing trends for COVID-19 cases and deaths (statistically significant at a 99% confidence level). The results of this study might be useful to understand the role of climatic factors in the spread of COVID-19 and provide insights for healthcare policymakers to well manage this global pandemic.

Keywords: COVID-19; Tunisia; temperature; rainfall; wind speed; correlation.

1. INTRODUCTION

The novel Corona Virus Disease 19 (COVID-19) was first acknowledged in Wuhan city, China in late December 2019 [1,2]. COVID-19 has been acknowledged as a contagious disease that spreads rapidly around the globe [3]. Till December 5, 2020, the World Health Organization (WHO) has reported that globally the COVID-19 has affected 219 countries with a total of 66,501,425 confirmed cases and 1,529,154 deaths [4]. On January 30, 2020, the WHO has declared the disease as an international public health emergency, and later, on March 11, 2020, the WHO recognized COVID-19 as a global pandemic [5]. Countries around the world have taken several actions to reduce the spread of the virus, for instance, border closure, national lockdown, teleworking, school fermeture, social distancing, self-isolation, closing of restaurants and coffee shops, etc. Although these measures have helped to control the disease, it was coupled with negative socio-economic impacts, for example, an increase in public debt, a decline of investment, a high unemployment rate, and an increase in the poverty rate [6,7].

COVID-19 spreads among the population, mainly through close contact with an infected person. The transmission can particularly occur in indoor, crowded and insufficiently ventilated spaces where one or more infected people spend long periods with other people, such as restaurants, classrooms, and offices [4]. Clinical and laboratory investigations of COVID-19 have discovered respiratory droplets as the most frequent agent of contamination [8]. Therefore, infected people could leave infectious droplets when they sneeze, cough, or touch objects or surfaces, such as tables, doorknobs, and handrails. Healthy people might then become infected with the virus if they touch these contaminated surfaces and then touch their eyes, nose, or mouth before washing their hands [4].

In addition to person-to-person transmission, epidemiological researches have shown that meteorological parameters play an important role in the transmission of viruses [9,10]. Investigations on similar contagious diseases showed that seasonal variations may affect their incidence [11,12]. Infections with influenza virus, respiratory syncytial virus, human rhinovirus, and severe acute respiratory syndrome corona virus were directly related to ambient temperature and humidity [9]. It seems that earlier researches on previous infectious diseases have motivated further investigations on the new COVID-19. In fact, despite the novelty of COVID-19, there is a fast-growing body of literature that investigates its association with meteorological factors (Appendix 1).

Meteorological factors that have been explored in most researches include temperature, rainfall, wind speed, and humidity. For instance, recent researches in China, Japan, Singapore, Rio de Janeiro, and other countries have investigated the impact of temperature on the transmission of COVID-19 [10,13,14]. Besides, other studies based on samples from Indonesia, Canada, Norway have revealed that rainfall is another contributor to the spread of COVID-19 [15,16]. Wind also acts as a crucial factor in the transmission of the virus [17]. Appendix 1 provides results of investigations of such factors in many countries. Together, these studies indicate that the impact of meteorological factors on COVID-19 is controversial, ranging from positive, to negative, to insignificant (Appendix 1).

As climate factors vary throughout the world, the influence of climate parameters on the COVID-19 spread needs to be explored in each country. To the best of our knowledge, this is likely to be the first study that investigates the relationship between climate parameters and COVID-19 for the case of Tunisia.

The aim of this study is to investigate the correlation between meteorological variables and the COVID-19 daily cases and deaths in Tunisia. The fact that we have limited our investigations on meteorological variables only does not mean that they are considered as primary factors of the COVID-19 transmission. Probably, several determinants other than meteorological ones could influence the COVID-19 spread.

2. METHODOLOGY

2.1 Study Area and Data Collection

Tunisia is a country in North Africa at latitude 33 ° 58′48.00 ″ North and longitude 9 ° 32′24.00″ East. Its climate is Mediterranean, with mild and rainy winters and hot and sunny summers. In Tunisia, the spread of Covid-19 worries professionals in the health sector. The first announced COVID-19 case was on March 02, 2020. Until June 27 only 1191 cases had been identified. The number of cumulative cases (Fig. 1) and deaths (Fig. 2) detected from March 2 to October 22 was 48799 and 1039, respectively. In fact, from the beginning of the pandemic until June 27, the spread of the virus was slow because the State had taken strict measures to limit the spread. However, from June 27, the spread of the virus has accelerated. Thus the study period that we have considered in this paper is from June, 27 to October, 22 (118 days). The data of COVID-19 confirmed cases and deaths of Tunisia were collected from the official website of the Tunisian ministry of public health (https://covid-19.tn/fr/tableau-de-bord/) [18].

The daily meteorological data were collected from https://www.infoclimat.fr/ [19]. After an extensive literature review on the climatic parameters affecting the spread of COVID-19 (Appendix 1) and in accordance to data availability, we considered the following five variables: minimum temperature (°C), maximum temperature (°C), mean temperature (°C), rainfall (mm), and wind speed (km/h). The gathered data have been analyzed with EXCEL spreadsheets to present graphs.

2.2 Statistical Analysis

In this study, the statistical analysis has been performed using two tests. First, the Mann-Kendall test [20,21] has been employed to detect the trends of COVID-19 daily confirmed cases and deaths. Second, the Spearman correlation test was used to explore the correlation between the climatic parameters and the COVID-19 confirmed cases and deaths. The Spearman coefficient explores how properly the association between two variables can be specified. This test has been used in several previous studies to investigate the relationship between meteorological variables and COVID-19 [17,22, 25]. The values of the Spearman coefficient are ranked between 1 and -1 (a perfect positive and negative correlation, respectively) and is calculated using the following equation:

$$rs = 1 - 6 \times \left(\sum di^2 \ / \ n\,(n^2 - 1) \right) \qquad (1)$$

Where rs is the Spearman coefficient, di is the difference between the ranks of two parameters, and n represents the number of alternatives.

The statistical tests were employed using the statistical software XLSTAT.

3. RESULTS

3.1 Descriptive Analysis of COVID-19 and Meteorological Variables

As mentioned earlier, the count of COVID-19 confirmed cases (Fig. 1) and deaths (Fig. 2) has been small up to June 27, which corresponds to the date of border opening by the State. Nevertheless, from June 27, an obvious rise in the COVID-19 transmission has been revealed. Fig. 3 and Fig. 4 show the COVID-19 confirmed cases and deaths during the study period, from June 27 to October 22 (118 days). To present an exhaustive picture of COVID-19 rapid spread, the 118 days study period (from June 27 to October 22) has been divided in four periods. From June 27 to July 27, July 27 to August 27, August 27 to September 27, and September 27 to October 22, a total of 293, 1983, 14416, and 30916 COVID-19 confirmed cases have been registered, respectively. Besides, the count of cumulative deaths has been rising rapidly. These findings could be supported by the results of Mann-Kendall test that have shown a statistically significant increasing trends of COVID-19 confirmed cases and deaths.

Furthermore, Fig. 5, Fig. 6, and Fig. 7 shows the daily meteorological variables during 118 days study period from June 27 to October 22. During this period, the mean temperature was 27.19 °C (the lowest mean was 17.47°C and the highest mean was 33.08°C), the mean minimum temperature was 21.42°C (the lowest minimum was 11.59°C and the highest minimum was 26.56°C), the mean maximum temperature was 32.91°C (the lowest maximum was 21.59°C and the highest maximum was 40.29°C). The mean rainfall was 1.08 mm (the lowest mean was 0 mm and the highest mean was 16.98 mm). The mean wind speed was 32.58 km/h (the lowest mean was 17.89 km/h and the highest mean was 55.25 km/h).

3.2 Correlation between the Selected Metrological Parameters and COVID-19 Pandemic

The relationship between the five parameters and COVID-19 confirmed cases and deaths on the day is shown in Table 1 and Fig. 8. Among the selected parameters, the minimum temperature, maximum temperature, mean temperature, and rainfall were statistically significant at a 99% confidence level. However, the wind speed was not statistically significant.

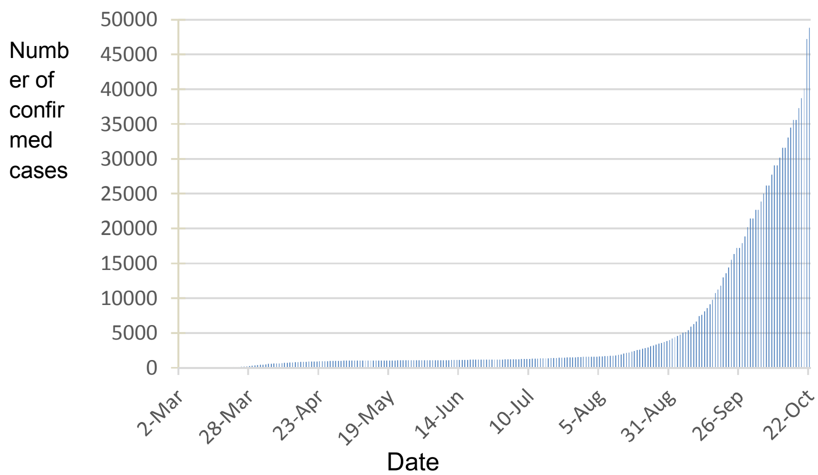

Fig. 1. Number of cumulative confirmed cases from March 2 to October 26, 2020, in Tunisia

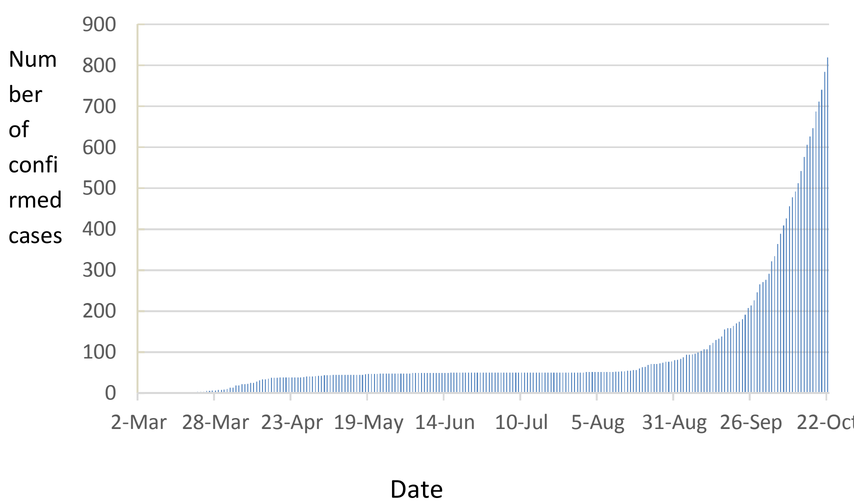

Fig. 2. Number of cumulative deaths because of COVID-19, from March 2 to October 26, 2020, in Tunisia

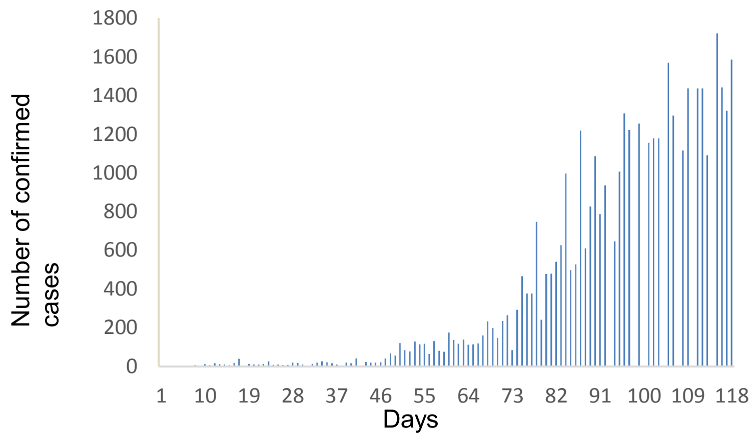

Fig. 3. Daily confirmed cases during 118 days period from June 27 to October 22, 2020, in Tunisia

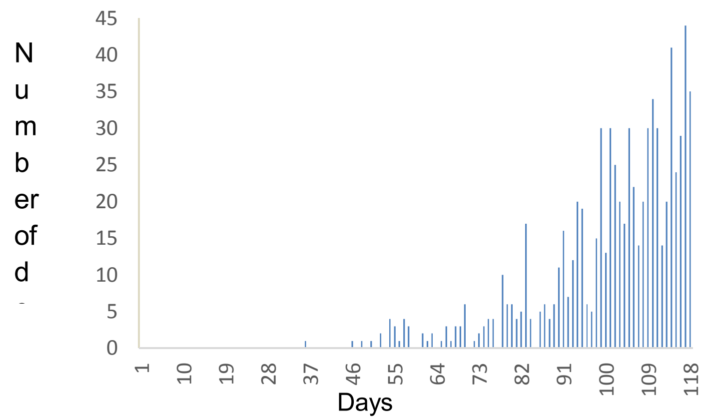

Fig. 4. Daily deaths due to COVID-19 during 118 days period from June 27 to October 22, 2020, in Tunisia

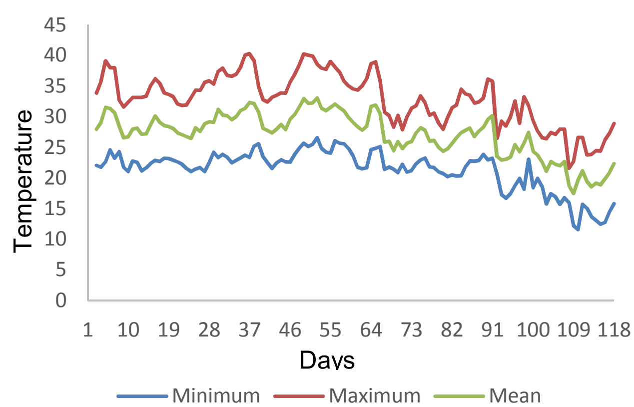

Fig. 5. Daily pattern of temperature during 118 days period from June 27 to October 22, 2020, in Tunisia

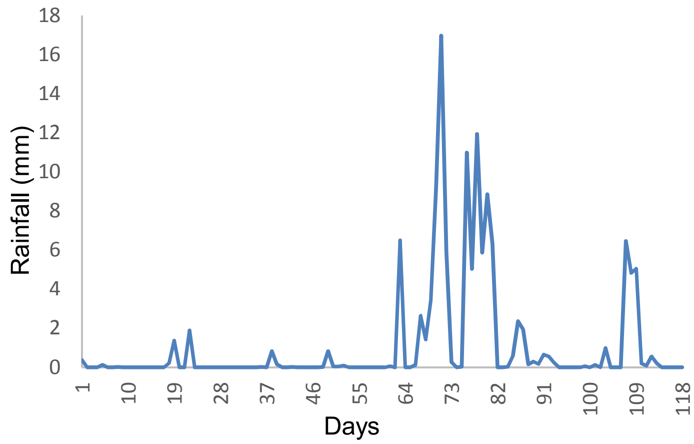

Fig. 6. Daily pattern of rainfall during 118 days period from June 27 to October 22, 2020, in Tunisia

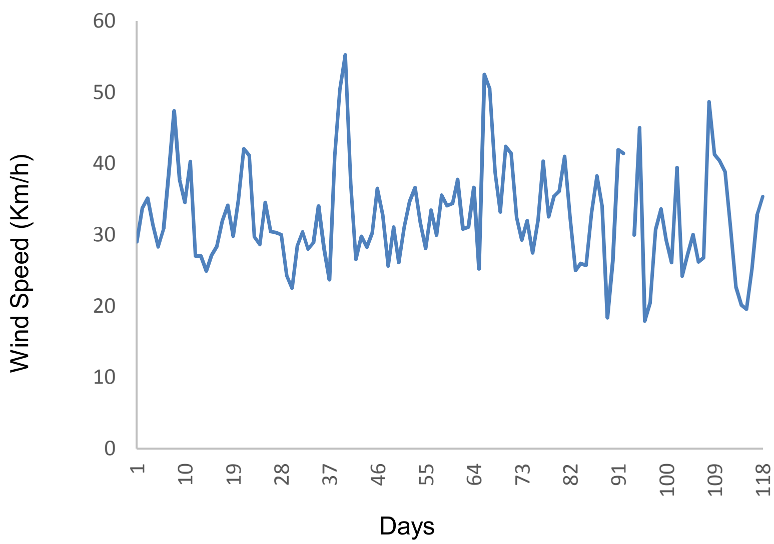

Fig. 7. Daily pattern of rainfall during 118 days period from June 27 to October 22, 2020, in Tunisia

Table 1. Spearman correlation coefficients of meteorological parameters with the COVID-19 transmission in Tunisia

Meteorological parameters	Confirmed cases	Deceased
Minimum temperature (°C)	-0,527*	-0,591*
Maximum temperature (°C)	-0,605*	-0,624*
Mean temperature (°C)	-0,609*	-0,641*
Rainfall (mm)	0,325*	0,273*
Wind Speed (Km/h)	-0,048	-0,054

** Statistically significant at 99% confidence level*

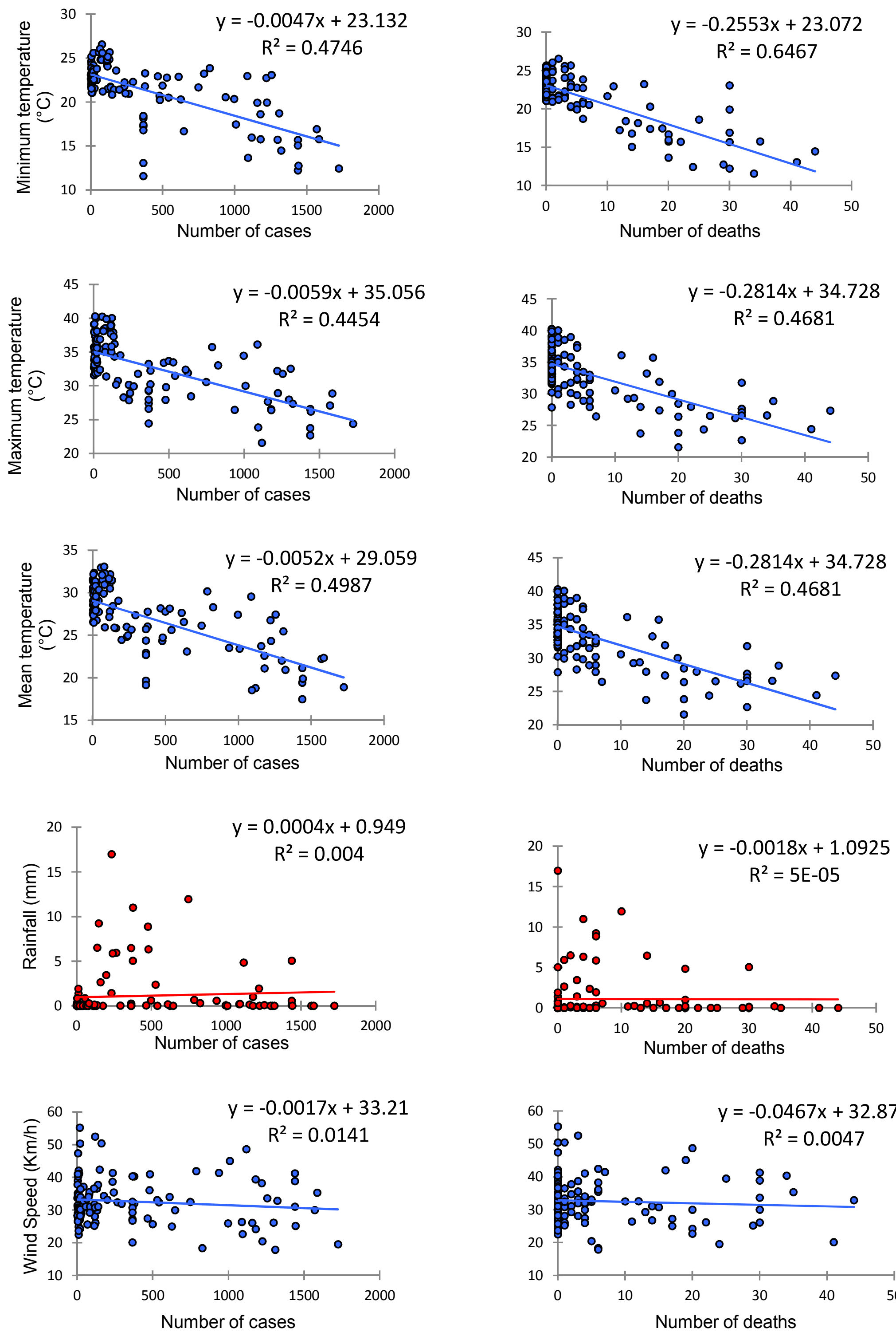

Fig. 8. Correlation tests of number of daily cases and deceased on the day with the meteorological parameters during 118 days period from June 27 to October 22, 2020, in Tunisia

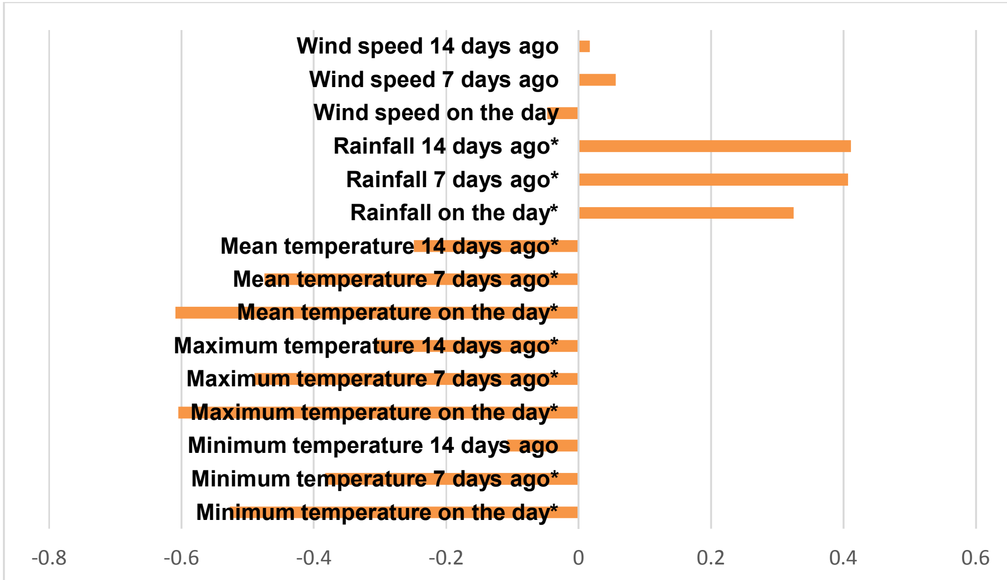

Fig. 9. Comparison of spearman correlation coefficients (Statistically significant at 99% confidence level)

4. DISCUSSION

A strong negative relationship of minimum temperature, maximum temperature, and mean temperature with the count of COVID-19 confirmed cases and deaths was noted (Fig. 8). It suggests that when the temperature decreases, the count of patients and deaths increases. Interestingly, this result is in agreement with several previous studies. For instance, Rosario et al. [26] have observed that the COVID-19 transmission is likely to increase with the decrease of temperature in the Rio de Janeiro State. Qi et al. [8] also examined the association of daily temperature with the daily COVID-19 confirmed cases in China and found a significant negative interaction between them. Besides, they demonstrated that for every 1°C increase in the average temperature, the daily confirmed cases decreased by 36%. In addition, Prata et al. [10] have also demonstrated a negative relationship between temperatures and daily cumulative confirmed cases of COVID-19 in Brazil. Further, they found that each 1 °C rise of temperature was associated with a −4.8 % in the number of daily cumulative confirmed cases of COVID-19. Similarly, in a worldwide study, from 166 countries, Wu et al. [27] have investigated the impact of climatic factors on the COVID-19 spread, they found that the temperature was negatively associated with daily confirmed cases and deaths. They noted that a 1 °C increase in temperature was associated with a 3.08% reduction in daily new cases and a 1.19% reduction in daily new deaths.

In addition to evidence from samples of different countries, our result is consistent with in vitro experimentations which suggests that warmer weather could decrease the spread of COVID-19. In fact, Chan et al. [9] have observed that coronavirus was stable for over five days on smooth surfaces when the temperature ranges between 22°C and 25°C. Keeping in touch with previous studies on other contagious diseases, Bi et al. [28] have reported a negative correlation between temperature and SARS spread in Beijing and Hong Kong in 2003. Nevertheless, other researchers came to the contrary conclusion. In fact several other studies have shown that the ambient temperature is positively associated with the spread of COVID-19. Among others, Pani et al. [23] have tested the correlation between COVID-19 and temperature in Singapore and found a significant positive association between them. Other investigations from samples in Turkey, Norway, and Indonesia revealed the same kind of correlation [15–17]. Apart from negative and positive correlations, other researchers, namely Ahmadi et al. [29] and Jamil et al. [30] have not found any association between temperature and COVID-19.

Further, our results revealed a positive association of rainfall with COVID-19 confirmed cases and deaths (Table 1). However, the Spearman coefficient for this correlation is weak (Fig. 9). Similarly, in a worldwide study, Sobral et al. [31] have witnessed that the count of COVID-19 confirmed cases and deaths is positively correlated with rainfall. Rosario et al. [26] have also revealed a positive correlation between COVID-19 transmission and rainfall in the Rio de Janeiro State. Besides, our result may be supported by Raina et al. [32] who have observed a higher count of COVID-19 patients and deaths in cold countries. Nonetheless, Ahmadi et al. [29] have registered an inverse correlation between COVID-19 incidences and rainfall. Moreover, studies based on samples from India, Indonesia have not shown an association between rainfall and COVID-19 transmission [16,33].

Finally, our study has not registered any association between wind speed and COVID-19 transmission (Table 1). This result is in agreement with Oliveiros et al. [34] who have not identified any association between COVID-19 and wind speed in China. Contrastingly, Rendana et al. [35] has observed that the COVID-19 incidences decrease with the rise of wind speed.

In view of all that has been mentioned so far, we can highlight that the results of previous studies have been controversial. Probably, this is due to weather specificities in each country. Therefore, authors need to be cautious when interpreting the findings given the possible influence of the statistical method on the results [36] .

In addition, we have analyzed the selected climatic parameters for three timeframes, notably, on the day of the incidence, 7 days ago, and 14 days ago (Fig. 9). In fact, previous studies have highlighted the importance of considering the incubation period in COVID-19 studies [37]. The results suggest that the maximum temperature, the minimum temperature, and the mean temperature on the day have the highest negative correlation with the count of COVID-19 confirmed cases. That is to say, the temperature on the day of the confirmed case is strongly related to the case. This result is consistent with Şahin [17] who came to the same conclusion. Besides, the rainfall of 14 days ago has the highest correlation with the count of new cases. This correlation decreases as the timeframe diminishes.

5. CONCLUSION

The results have revealed that the COVID-19 daily confirmed cases and deaths are negatively correlated with minimum temperature, maximum temperature, mean temperature. However, a negative correlation has been identified between the COVID-19 spread and rainfall. The study provided important insights that can help health authorities to strengthen the health system depending on temperature and rainfall variability.

ACKNOWLEDGEMENTS

The authors acknowledge the Laboratory of Economy and Rural Societies in the Arid Regions Institute of Medenine-Tunisia in which this study has been performed.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Huang C, Wang Y, Li X, Ren L, Zhao J, Hu Y et al. Clinical features of patients infected with 2019 novel coronavirus in Wuhan, China. The Lancet. 2020; 395(10223):497–506.
2. Zhu N, Zhang D, Wang W, Li X, Yang B, Song J et al. A novel coronavirus from patients with Pneumonia in China, 2019. N Engl J Med. 2020;382(8):727–33.
3. Anderson RM, Heesterbeek H, Klinkenberg D, Hollingsworth TD. How will country-based mitigation measures influence the course of the COVID-19 epidemic? The Lancet. 2020;395(10228): 931–4.
4. WHO. Coronavirus disease (COVID-19) – World Health Organization [Internet]; 2020. [cited 2020 Oct 30]. Available:https://www.who.int/emergencies/diseases/novel-coronavirus-2019
5. Gupta A, Pradhan B, Maulud KNA. Estimating the impact of daily weather on the temporal pattern of COVID-19 outbreak in India. Earth Systems and Environment. 2020;4(3):523–534.
6. Bar H. COVID-19 lockdown: Animal life, ecosystem and atmospheric environment. Environment, development and sustainability. 2020;1–18.
7. To T, Zhang K, Maguire B, Terebessy E, Fong I, Parikh S et al. Correlation of

ambient temperature and COVID-19 incidence in Canada. Science of The Total Environment. 2020;750:141484. Available:https://doi.org/10.1016/j.scitotenv.2020.141484
8. Qi H, Xiao S, Shi R, Ward MP, Chen Y, Tu W et al. COVID-19 transmission in Mainland China is associated with temperature and humidity: A time-series analysis. Science of The Total Environment. 2020;728:138778. availabl:http//doi.org/10.1016/j.scitotenv.2020.138778
9. Chan KH, Peiris JSM, Lam SY, Poon LLM, Yuen KY, Seto WH. The effects of temperature and relative humidity on the viability of the SARS coronavirus [Internet]. Advances in Virology. Hindawi. 2011;2011: e734690. [cited 2020 Oct 31]. Available:https://www.hindawi.com/journals/av/2011/734690/
10. Prata DN, Rodrigues W, Bermejo PH. Temperature significantly changes COVID-19 transmission in (sub) tropical cities of Brazil. Science of the Total Environment. 2020;138862.
11. Fisman DN. Seasonality of Infectious Diseases. Annu Rev Public Health. 2007;28(1):127–43.
12. Tan J. An initial investigation of the association between the SARS outbreak and weather: With the view of the environmental temperature and its variation. Journal of Epidemiology and Community Health. 2005;59(3):186–92.
13. Azuma K, Kagi N, Kim H, Hayashi M. Impact of climate and ambient air pollution on the epidemic growth during COVID-19 outbreak in Japan. Environmental research. 2020;190:110042. Available:https://doi.org/10.1016/j.envres.2020.110042
14. Ujiie M, Tsuzuki S, Ohmagari N. Effect of temperature on the infectivity of COVID-19. International Journal of Infectious Diseases. 2020;95:301–3. Available:https://doi.org/10.1016/j.ijid.2020.04.068
15. Menebo MM. Temperature and precipitation associate with Covid-19 new daily cases: A correlation study between weather and Covid-19 pandemic in Oslo, Norway. Science of The Total Environment. 2020;139659. Available:https://doi.org/10.1016/j.scitotenv.2020.139659
16. Tosepu R, Gunawan J, Effendy DS, Lestari H, Bahar H, Asfian P. Correlation between weather and Covid-19 pandemic in Jakarta, Indonesia. Science of The Total Environment. 2020;138436. Available:https://doi.org/10.1016/j.scitotenv.2020.138436.
17. Şahin M. Impact of weather on COVID-19 pandemic in Turkey. Sci Total Environ. 2020;728:138810. Available:https://doi.org/10.1016/j.scitotenv.2020.138810
18. Tableau de Bord - Covid-19.tn [Internet]. [cited 2020 Dec 31]. Available:https://covid-19.tn/fr/tableau-de-bord/
19. Association Infoclimat - la météo passionnément : [Internet]. [cited 2020 Sep 24]. Available:https://asso.infoclimat.fr/
20. Kendall MG. Rank correlation methods. London: Griffin; 1975.
21. Mann HB. Nonparametric tests against trend. Econometrica. 1945;13(3): 245–59.
22. Doğan B, Ben Jebli M, Shahzad K, Farooq TH, Shahzad U. Investigating the Effects of meteorological parameters on COVID-19: Case study of new jersey, United States. Environmental Research. 2020;191: 110148. Available:https://doi.org/10.1016/j.envres.2020.110148
23. Pani SK, Lin N-H, Ravindra Babu S. Association of COVID-19 pandemic with meteorological parameters over Singapore. Sci Total Environ. 2020;740:140112. Available:https://doi.org/10.1016/j.scitotenv.2020.140112
24. Shahzad K, Shahzad U, Iqbal N, Shahzad F, Fareed Z. Effects of climatological parameters on the outbreak spread of COVID-19 in highly affected regions of Spain. Environ Sci Pollut Res. 2020; 27(31):39657–66. Available:https://doi.org/10.1007/s11356-020-10551-3
25. Zhu L, Liu X, Huang H, Avellán-Llaguno RD, Lazo MML, Gaggero A et al. Meteorological impact on the COVID-19 pandemic: A study across eight severely affected regions in South America. Science of the Total Environment. 2020;744: 140881. Available:https://doi.org/10.1016/j.scitotenv.2020.140881

26. Rosario DK, Mutz YS, Bernardes PC, Conte-Junior CA. Relationship between COVID-19 and weather: Case study in a tropical country. International Journal of Hygiene and Environmental Health. 2020; 229:113587.
Available:https://doi.org/10.1016/j.ijheh.2020.113587
27. Wu Y, Jing W, Liu J, Ma Q, Yuan J, Wang Y et al. Effects of temperature and humidity on the daily new cases and new deaths of COVID-19 in 166 countries. Science of the Total Environment. 2020;139051.
Available:https://doi.org/10.1016/j.scitotenv.2020.139051
28. Bi P, Wang J, Hiller JE. Weather: Driving force behind the transmission of severe acute respiratory syndrome in China? Internal Medicine Journal. 2007;37(8):550–554.
Available:https://doi.org/10.1111/j.1445-5994.2007.01358.x.
29. Ahmadi M, Sharifi A, Dorosti S, Ghoushchi SJ, Ghanbari N. Investigation of effective climatology parameters on COVID-19 outbreak in Iran. Science of the Total Environment. 2020;138705.
Available:https://doi.org/10.1016/j.scitotenv.2020.138705
30. Jamil T, Alam I, Gojobori T, Duarte CM. No evidence for temperature-dependence of the COVID-19 epidemic. Front Public Health.
Available:https://doi.org/10.3389/fpubh.2020.00436
31. Sobral MFF, Duarte GB, da Penha Sobral AIG, Marinho MLM, de Souza Melo A. Association between climate variables and global transmission oF SARS-CoV-2. Science of The Total Environment. 2020;729:138997.
Available:https://doi.org/10.1016/j.scitotenv.2020.138997
32. Raina SK, Kumar R, Bhota S, Gupta G, Kumar D, Chauhan R et al. Does temperature and humidity influence the spread of COVID-19?: A preliminary report. Journal of Family Medicine and Primary Care. 2020;9(4):1811.
Available:https://doi.org/ 10.4103/jfmpc.jfmpc_494_20
33. Singh O, Bhardwaj P, Kumar D. Association between climatic variables and COVID-19 pandemic in National Capital Territory of Delhi, India. Environment, Development and Sustainability. 2020;1–15.
Available:https://doi.org/10.1007/s10668-020-01003-6
34. Oliveiros B, Caramelo L, Ferreira NC, Caramelo F. Role of temperature and humidity in the modulation of the doubling time of COVID-19 cases [Internet]. Public and Global Health; 2020.
[cited 2020 Nov 3].
Available:http://medrxiv.org/lookup/doi/10.1101/2020.03.05.20031872
35. Rendana M. Impact of the wind conditions on COVID-19 pandemic: A new insight for direction of the spread of the virus. Urban Climate. 2020;34:100680.
Available:https://doi.org/10.1016/j.uclim.2020.100680
36. Briz-Redón Á, Serrano-Aroca Á. The effect of climate on the spread of the COVID-19 pandemic: A review of findings, and statistical and modelling techniques. Progress in Physical Geography: Earth and Environment. 2020;44(5):591–604.
Available:https://doi.org/10.1177/0309133320946302
37. Abdollahi A, Rahbaralam M. Effect of Temperature on the Transmission of COVID-19: A Machine Learning Case Study in Spain [Internet]. Infectious Diseases (except HIV/AIDS).
Available:https://doi.org/10.1101/2020.05.01.20087759
38. Zhang Z, Xue T, Jin X. Effects of meteorological conditions and air pollution on COVID-19 transmission: evidence from 219 Chinese cities. Science of the Total Environment. 2020;741:140244.
Available:https://doi.org/10.1016/j.scitotenv.2020.140244
39. Passerini G, Mancinelli E, Morichetti M, Virgili S, Rizza U. A Preliminary Investigation on the Statistical Correlations between SARS-CoV-2 Spread and Local Meteorology. International Journal of Environmental Research and Public Health. 2020;17(11):4051.
Available:https://doi.org/10.3390/ijerph17114051
40. Sehra ST, Salciccioli JD, Wiebe DJ, Fundin S, Baker JF. Maximum Daily Temperature, Precipitation, Ultra-Violet Light and Rates of Transmission of SARS-Cov-2 in the United States. Clinical Infectious Diseases; 2020.

Available:https://doi.org/10.1093/cid/ciaa681
41. Islam ARMT, Hasanuzzaman M, Azad MAK, Salam R, Toshi FZ, Khan MSI et al. Effect of meteorological factors on COVID-19 cases in Bangladesh. Environment, Development and Sustainability. 2020;1-24.
Available:https://doi.org/10.1007/s10668-020-01016-1
42. Aslam B, Khalil U, Azam U, Maqsoom A. A correlation study between weather and atmosphere with COVID-19 pandemic in Islamabad, Pakistan. Spatial Information Research. 2020;1–9.
Available:https://doi.org/10.1007/s41324-020-00366-2
43. Abdul IW, Appiahene P, Kessie JA. Effects of weather and policy intervention on COVID-19 infection in Ghana. 2020;14.
44. Pan J, Yao Y, Liu Z, Meng X, Ji JS, Qiu Y et al. Warmer weather unlikely to reduce the COVID-19 transmission: An ecological study in 202 locations in 8 countries. Science of the Total Environment. 2020;753:142272.
Available:https://doi.org/10.1016/j.scitotenv.2020.142272

APPENDIX

A literature review of 21 published papers on the effect of climatic factors on the COVID-19 transmission

Title	Author	Country	Method	Main findings
Impact of meteorological factors on the COVID-19 transmission: A multicity study in China	[15]	China	Generalized linear models	COVID-19 transmission may be affected by meteorological factors, and a weather with low temperature, mild diurnal temperature range and low humidity likely favor its transmission.
Effects of meteorological conditions and air pollution on COVID-19 transmission: Evidence from 219 Chinese cities	[38]	China	Multivariate regression model	Daily maximum temperature,minimum temperature, and average temperature are negatively significantly correlated to the new cases. Air pollution indicators are all positively correlated to the new confirmed cases
COVID-19 transmission in Mainland China is associated with temperature and humidity: a time-series analysis	[8]	China	Generalized Additive Model	The average temperature and relative humidity showed significantly negative associations with COVID-19. Every 1°C increase in the average temperature led to a decrease in the daily confirmed cases by 36% to 57% when relative humidity was in the range from 67% to 85.5%.
Relationship between	[26]	Brazil	Shapiro	Solar radiation showed

Title	Author	Country	Method	Main findings
COVID-19 and weather: Case study in a tropical country			Wilk's test; Spearman rank correlation test	a strong negative correlation with the COVID-19. Temperature and wind speed showed negative correlation.
A Preliminary Investigation on the Statistical Correlations between SARS-CoV-2 Spread and Local Meteorology	[39]	Italy	Pearson correlation coefficient	Strong positive correlations were observed between new cases and temperatures. Strong negative correlations were observed between the moving means of new cases and relative humidity values.
Investigating the Effects of Meteorological Parameters on COVID-19: Case Study of New Jersey, United States	[22]	United States	Pearson correlation, Spearman correlation and Kendall's rank correlation.	Temperature (◦C) was found to have a negative correlation, while humidity and air quality highlighted a positive correlation with daily new cases of COVID-19.
Maximum Daily Temperature, Precipitation, Ultraviolet Light, and Rates of Transmission of Severe Acute Respiratory Syndrome Coronavirus 2 in the United States	[40]	United States	Binomial regression model	A maximum temperature above 52°F on a given day was associated with a lower rate of new cases at 5 days. Among observations with daily temperatures below 52°F, there was a significant inverse association between the maximum daily temperature and the rate of cases at 5 day. Precipitation was not associated with a greater rate of cases at 5 days
Association between climatic variables and COVID□19 pandemic in National Capital Territory of Delhi, India	[33]	India	Karl Pearson's correlation	Maximum temperature, minimum temperature, mean temperature, relative humidity, evaporation, and wind speed are positively associated with coronavirus disease cases. No association of coronavirus disease has been found with bright sunshine hours

Title	Author	Country	Method	Main findings
				and rainfall.
Effect of meteorological factors on COVID-19 cases in Bangladesh	[41]	India	Distributed lag nonlinear models, Pearson's correlation coefficient and wavelet transform coherence	Minimum and mean temperature, wind speed, relative humidity and absolute humidity had a significant positive correlation with the number of COVID-19 confirmed cases.
Correlation between weather and Covid-19 pandemic in Jakarta, Indonesia	[16]	Indonesia	Spearman rank correlation test	Temperature average (°C) was significantly correlated with covid-19 pandemic.
Impact of the wind conditions on COVID-19 pandemic: A new insight for direction of the spread of the virus	[35]	Indonesia	Spearman correlation test	A low wind speed is significantly correlated with a higher COVID-19 cases. Similarly, low temperatures and sunshine hours are correlated with a higher COVID-19 cases. There are not significant linear correlations between humidity and rainfall with COVID-19 cases.
Impact of climate and ambient air pollution on the epidemic growth during COVID-19 outbreak in Japan	[13]	Japan	Weighted random-effects regression analysis	Epidemic growth of COVID-19 was significantly associated with increase in daily temperature or sunshine hours.
Temperature and precipitation associate with Covid-19 new daily cases: A correlation study between weather and Covid-19 pandemic in Oslo, Norway	[15]	Norway	Spearman correlation coefficient	Maximum temperature, normal temperature, and precipitation level were significantly correlated with covid-19 pandemic.
A correlation study between weather and atmosphere with COVID-19 pandemic in Islamabad, Pakistan	[42]	Pakistan	Spearman cor-relation coefficient	Precipitation level, normal temperatureas well as the maximum temperature were very much associated with COVID-19 virus.
Effects of weather and policy intervention on COVID-19 infection in Ghana	[43]	Ghana	Generalized linear model	Significant effects of maximum temperature, relative humidity and precipitation in predicting new cases of the disease.
Effects of climatological parameters on the outbreak spread of COVID-19 in highly	[24]	Spain	Pearson correlation, Spearman correlation,	Temperature may not be a determinant to induce COVID-19 spread in Spain, while

Title	Author	Country	Method	Main findings
affected regions of Spain			and robust panel regressions	the rising temperature may reduce the virus transmission.
Effect of Temperature on the Transmission of COVID-19: A Machine Learning Case Study in Spain	[37]	Spain	A machine learning approach	Inverse correlation between temperature and the daily number of infections
Association of COVID-19 pandemic with meteorological parameters over Singapore	[23]	Singapore	Spearman and Kendall rank correlation	Temperature, dew point, relative humidity, absolute humidity, and water vapor showed positive significant correlation with COVID-19 pandemic.
Meteorological impact on the COVID-19 pandemic: A study across eight severely affected regions in South America	[25]	South America	Spearman's correlation coefficients	A highly significant correlation between daily incubative cases and absolute humidity.
Impact of weather on COVID-19 pandemic in Turkey	[17]	Turkey	Spearman's correlation test	The highest correlations were observed for population, wind speed 14 days ago, and temperature on the day, respectively.
Warmer weather unlikely to reduce the COVID-19 transmission: An ecological study in 202 locations in 8 countries	[44]	UK, US, Italy, Germany, Australia, Canada, China, Japan	Multiple linear regression models	Temperature did not exhibit significant association with COVID-19. Relative humidity, wind speed, and ultraviolet (UV) radiation were not significantly associated with COVID-19.

Peer-review history:
The peer review history for this paper can be accessed here:
http://www.sdiarticle4.com/review-history/64012