

## Research Article

# Evaluation of the Effect of Environmental Parameters on the Spread of COVID-19: A Fuzzy Logic Approach

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In recent months, the world has experienced the outbreak and spread of a new infectious disease, COVID-19. The spread of this disease has been so severe, and even many developed countries have struggled to manage this situation. However, some countries, such as China and Australia, have shown success in taking effective steps towards tackling the crisis. So far, some preventive measures to contain the spread of infection have emerged. Numerous studies have been undertaken worldwide in parallel in order to develop strategies to contain the virus, as well as to determine climatic or atmospheric conditions favoring COVID-19 spread. In this research, an artificial intelligence (AI) system has been adopted to assess the effective role of various environmental conditions in the spread of COVID-19. Temperature, relative humidity (RH), and UV index (UVI) of some affected countries were considered as input parameters while the total number of infected people is taken as the output variable. After plotting all available data as linguistic variables, a relationship is established between temperature, RH, UVI, and the number of infected people. From the surface graph, it can be stated that in addition to UVI, temperature and RH have a significant impact on the number of affected people. The maximum and minimum temperatures as well as other parameters are considered on the basis of mean values.

## 1. Introduction

Coronavirus disease 2019 (COVID-19) is an infectious disease caused by the novel coronavirus SARS-CoV-2. Coronaviruses consist of spherical or pleomorphic enveloped particles containing single-stranded (positive-sense) RNA associated with a nucleoprotein within a capsid composed of matrix proteins, which is surrounded by an envelope that bears club-shaped glycoprotein projections. The virus is transmitted through respiratory droplets released when an infected individual coughs or sneezes. The most commonly recommended health and safety protocols to reduce the spread of infection include frequent hand washing, wearing face masks, avoiding touching one's face, and maintaining physical distance in public places (at least 1 meter or 3 feet).

COVID-19 has mainly respiratory symptoms, including cough, fever, and, in more serious cases, severe breathing difficulties. As of now, no specific vaccines or medications are available to treat or prevent the disease; however, numerous clinical trials of potential vaccines or medications are being reported by the WHO on an almost daily basis [1]. Figure 1 shows the distribution of COVID-19 cases worldwide [2]. Table 1 lists country-wide affected people [3] considered in this work.

In addition to continuous research on microbiology, virology, and biotechnology, artificial intelligence (AI) is being used in many biomedical applications. AI is a humanlike intelligence system that is trained from defined rules to predict any probable consequences from conditional outputs. Fuzzy logic is one kind of AI that has been used in many engineering and

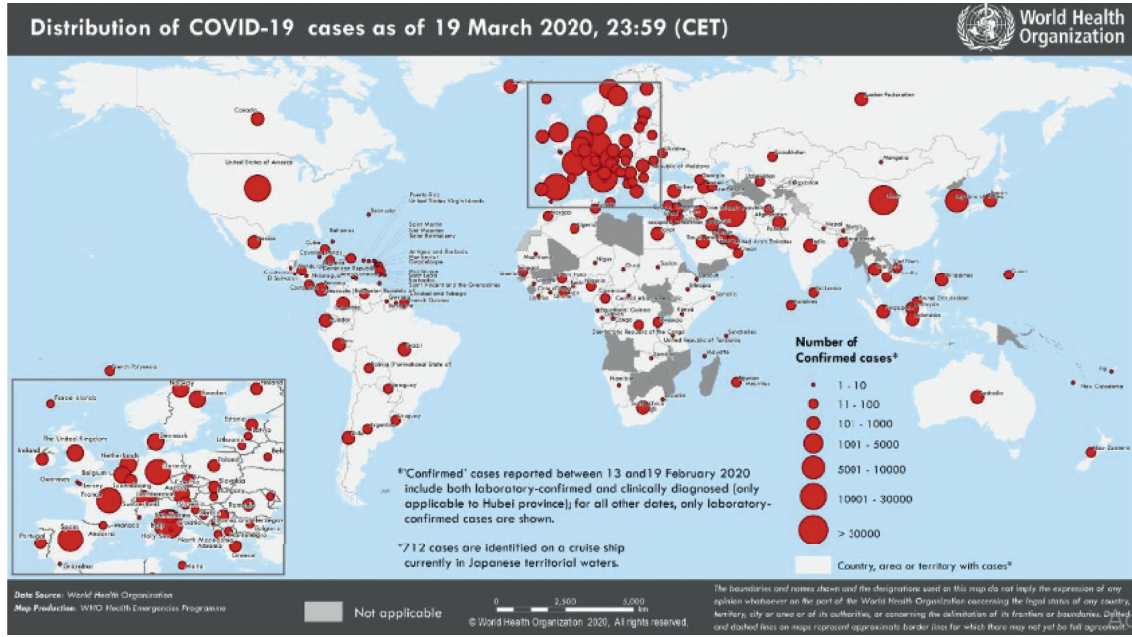


FIGURE 1: Distribution of COVID-19 cases as of 19 March 2020 [2].

TABLE 1: Number of infected people by country as of 19 March 2020 [3] considered in this work.

Country	Affected numbers
China	81174
Italy	35713
Spain	13716
Iran	17361
USA	7087
India	151
Saudi Arabia	238
Bangladesh	10
Somalia	1
Bolivia	12
UK	2630
South Korea	8413

biomedical applications [4, 5]. It is used for predicting and optimizing various dimensions of physical inputs as numerical factors to define the effect on the desired output. Fuzzy logic has found increasing applications within the biomedical field [6–9].

## 2. Fuzzy Logic Approach

Fuzzy logic is an AI system used for problem solving when the numerical solver is not enough for any accurate results, which has been pioneered by Zadeh et al. [10]. It utilizes a soft computing system dealing with extreme conditions. Fuzzy logic is a stepped illustrated calculation system based on “degree of truth,” an alternative to Boolean logic. It considers numbers between 0 and 1 as a partial truth that can calculate for both numeric and linguistic parameters. It improves known identity and converts into numeric and functional parameters in surface graphs [5, 11–15]. In this system, the relationship between input function (temperature, relative humidity [RH], and UV index [UVI]) and output function (number of infected people) constructs the

TABLE 2: Fuzzy linguistic variables and parameters.

Parameters	Linguistic variables	Range
Temperature	Low, medium, high	10–50
Relative humidity	Low, medium, high	20–80
UV index	Low, medium, high	1–12
Number of affected people	Low, medium, high	1–100000

rule to define the required expression. The fuzzy linguistic variables and parameters for this system are shown in Table 2.

In this system, Gaussian and triangular membership functions are used for input and output variables, respectively. The equations being used to calculate the output are given below:

$$\mu(x) = e^{-((x-m)^2/2a^2)},$$

$$\int (x; a, b, c) = \begin{cases} 0, & x \leq a, \\ \frac{x-a}{m-a}, & a \leq x \leq m, \\ \frac{b-x}{b-m}, & m \leq x \leq b, \\ 0, & c \leq x. \end{cases} \quad (1)$$

Figures 2 and 3 show the variables and output for this fuzzy logic system.

## 3. Results and Discussion

Figures 4–6 show the three-dimensional surface graphs that relate the inputs to the outputs. In Figure 4, it is shown that

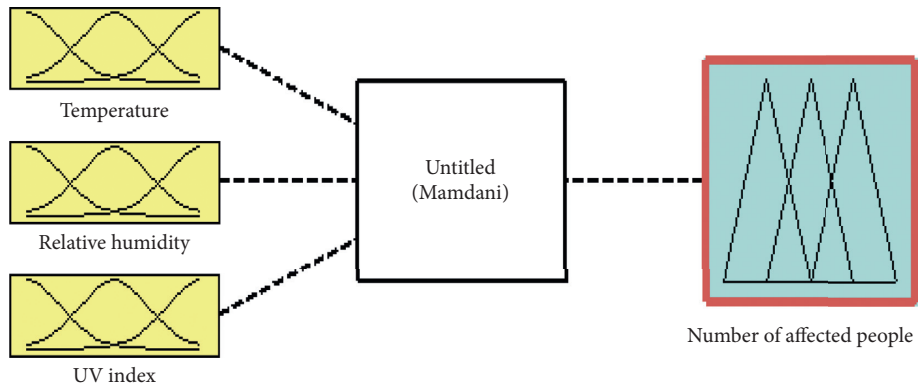


FIGURE 2: Variables in fuzzy logic.

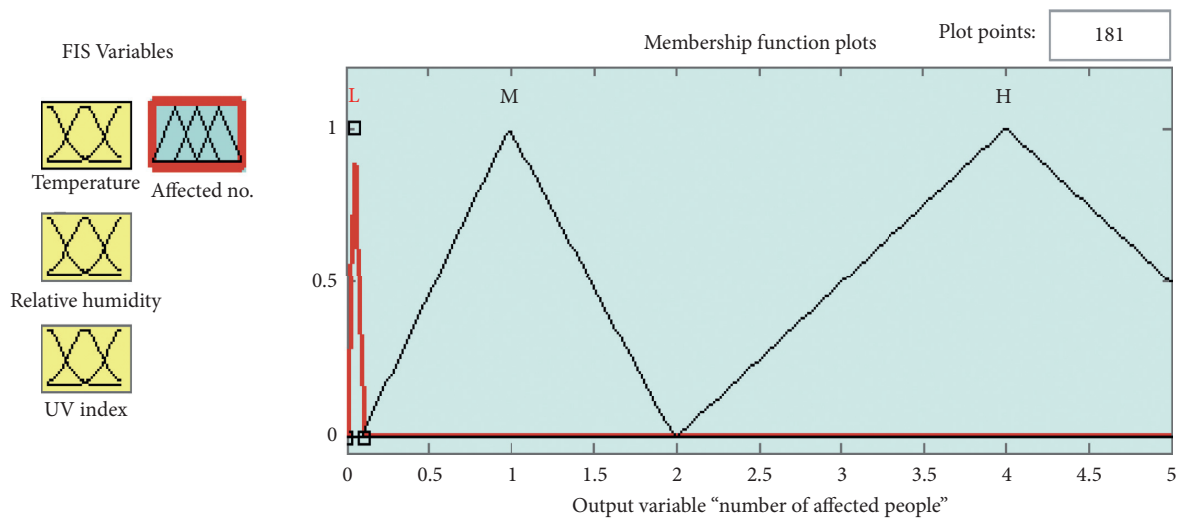


FIGURE 3: Number of affected people as the output variable.

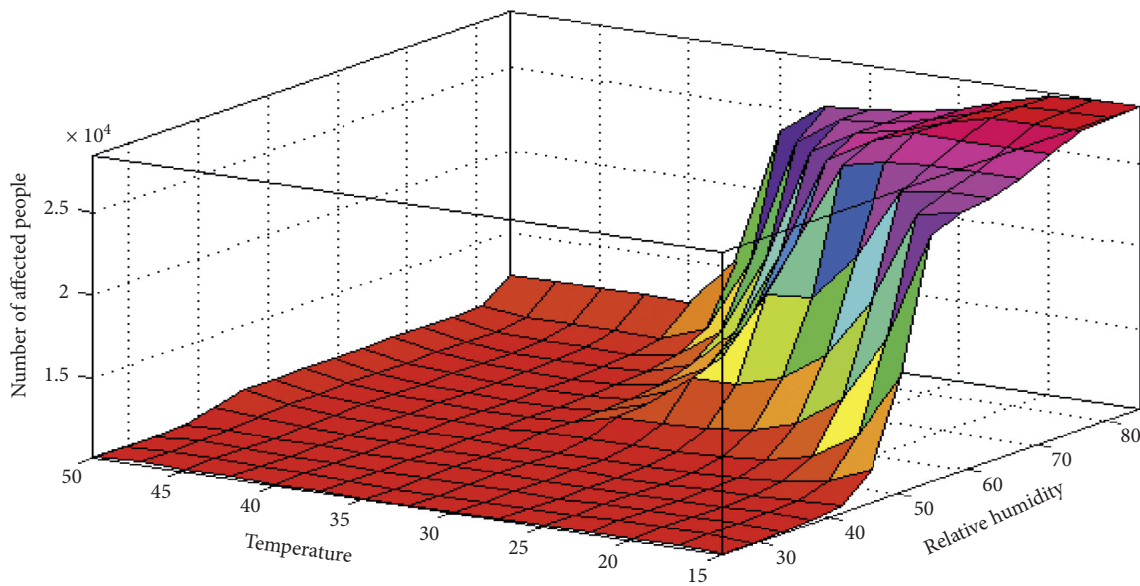


FIGURE 4: Relationship between temperature, RH, and the number of affected people.

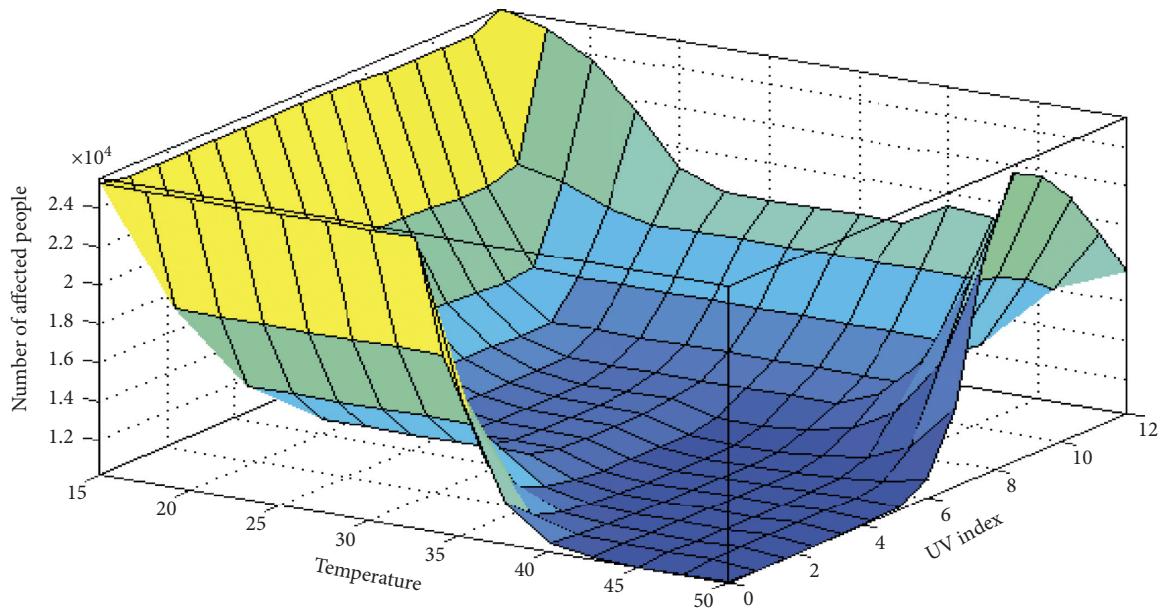


FIGURE 5: Relationship between temperature, UVI, and the number of affected people.

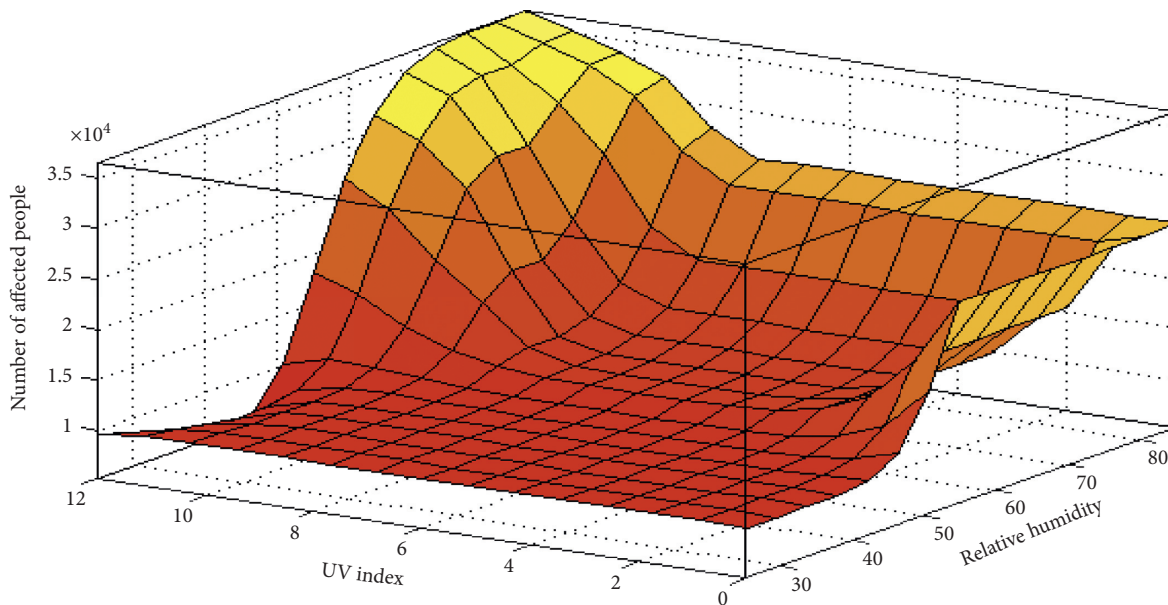


FIGURE 6: Relationship between UVI, RH, and the number of affected people.

as the temperature increases with a low RH, the number of affected people decreases inversely. In other words, when the RH goes down below 40%, at any temperature, the number of affected people is found to be considerably low. However, if the RH is high at a higher temperature, it also yields the same result. Therefore, it can be said that both RH and temperature have a significant impact on the spread of COVID-19.

Figure 5 shows that the temperature has a greater impact on the number of affected people than the UVI. As the temperature increases with a lower UVI, it decreases the number of affected people. Almost the same result is observed in comparison with the RH and UVI as illustrated in

Figure 6. As the RH decreases, the number of affected people decreases, which is independent of the UVI.

#### 4. Conclusions

In this research, comparison of three environmental parameters is made to assess the impact of these factors on the spread of COVID-19. A fuzzy logic model is designed and applied. It is found that both RH and temperature have a more significant impact on COVID-19 spread compared with UVI. A higher temperature with a low RH decreases the spread of COVID-19. On the other hand, a lower temperature with a high RH provides the desirable atmosphere for



COVID-19 spread. Hence, it can be concluded that dry weather along with a higher temperature, i.e., in hot regions, the spread of COVID-19 seems to be less aggressive than regions that experience a comparatively colder winter season with high moisture in the atmosphere.

### Data Availability

The WHO data used to support the findings of this study are included within the article.

### Conflicts of Interest

The authors declare that there are no conflicts of interest regarding the publication of this paper.

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