# Association between Climate Parameters and COVID-19 Pandemic in Jordan

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**Research Article**

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# Abstract

This research aims to study the association between the daily confirmed COVID – 19 cases in the three major cities of Jordan; Amman, Zarqa, and Irbid and climate indicators to include the average daily temperature ($^0$C), wind speed (m/s), relative humidity (%), pressure (kPa), and the concertation of the four pollutants (CO, $NO_2$, $PM_{10}$ and $SO_2$). The data were obtained from both the World Air Quality Project website and the Jordanian Ministry of Environment. In this work, the multiple linear regression and feedforward artificial neural network were used for data analysis. It was concluded that the multiple linear regression and feedforward artificial neural network had the capability to forecast the COVID-19 confirmed cases in the case studies; Amman, Irbid and Zarqa. Finally, global sensitivity analysis using Sobol analysis indicated that pressure in Amman and Zarqa and the concentration of $NO_2$ in Irbid has a high rate of positive cases that supports the virus's spread.


# 1. Introduction

Since its detection in China in 2019, coronavirus, has been subjected to intense studies in many aspects to limit its transmission or suppressing it. Recently, research work was conducted to investigate the effect of metrological condition (the quality of air) and metrological data, (i.e. humidity, ambient temperature, solar radiation) on COVID-19 transmission around the world.

Huang et al. (2020) conducted a research work on the effect of ambient environment on the spread of SARS-CoV-2 and found that, the concentration increases with ambient environment. They suggested that this increase imply that the transmission of coronavirus may increase in large cities in mid-latitudes in Autumn season 2020.

Xie and Zhu (2020) used a generalized additive model to investigate how the active cases of COVID-19 is influenced by the mean ambient temperature in 122 cities in China, they concluded that COVID-19 active cases increase linearly with ambient temperature with a threshold of 3°C. They also concluded that there is no evidence supporting the fact that the positive cases will decline in warmer conditions.

Bashir et al. (2020) analyzed the relation of COVID-19 cases with metrological data in New York including average temperature, minimum temperature, maximum temperature, rainfall, average humidity, wind speed, and air quality. They concluded that, the minimum and maximum temperatures together with air quality are significantly related to the number of COVID-19 positive cases.

Méndez-Arriaga (2020) used Statistical analysis to investigate the association between the daily local COVID-19 positive cases and both climate characteristics and the regional meteorological data in 31 states and the capital city Mexico from February 29 to March 31, 2020. He concluded that there is no concrete association between temperature and positive cases, while precipitation is positively associated to positive cases.

Lian et al. (2020) conducted a study on the effect of lockdown caused by COVID-19 on air quality in Wuhan, china. They found that most common pollutants concentration were significantly reduced during the lockdown, with the average monthly air quality index was 59.7, which is 33.9% less than that before the lockdown.

Zambrano-Monserrate et al. (2020) Studied the effects of COVID-19 on the environment in China, USA, Italy, and Spain. They stated that contingency measures are related with clean environment including good air quality, noise reduction and clean beaches. However, they concluded that there is a reduction in recycling and increase in waste that leads to contamination of water and land.

Collivignarelli (2020) Studied the effect of the lockdown on air quality in Milan Metropolitan / Italy. He concluded that the lockdown caused a significant reduction of pollutants concentration ($PM_{10}$, $PM_{2.5}$, BC, benzene, CO, and $NO_x$) which is mainly due to the reduced vehicular traffic. While, O3 demonstrated a major increase, possibly, due to the minor NO concentration. Furthermore, He found that the lockdown led to a major drop in the concentration of SO2 in Milan city.

Pirouz et al, (2020) investigated the effect of climate on active cases of COVID-19 using (multivariate linear regression (MLR) in an attempt to propose a prediction model. They considered including the parameters of relative humidity, daily average temperature, and wind speed, with some urban parameters such as population density. Their analysis showed a positive effect of the proposed model on the confirmed cases and they concluded that Their findings may be applied by considering several variables that exhibit the exact delay to new confirmed cases of COVID-19.

Abdelhafez et al. (2021), performed a study to correlate the COVID-19 active cases with metrological components to include: relative humidity (%), the average daily temperature ($^0$C), maximum ambient temperature ($^0$C), pressure (kPa) wind speed (m/s), and average daily solar radiation ($W/m^2$). In their work, they used the Spearman correlation test for data analysis. They concluded that the most effective weather parameter on the active cases of COVID-19 is the average daily solar radiation in the initial wave transmission, while all other tests for other parameters failed. Furthermore, in the second wave transmission, the maximum temperature was found to be the most effective weather parameter. Finally, using a global sensitivity analysis using Sobol analysis it was found that the daily solar radiation has a high rate of active cases that support the virus's survival in both wave transmissions.

In this work, Artificial neural network (ANN) and multiple linear regression are used to predict COVID-19 active cases in the three cities in Jordan by using climate indicators as an input. Also, sensitivity analysis between variables (climate indicators) will be conducted using Sobol method.

# 2. Methods

## 2.1 Study Area

Jordan is located within latitudes 29°19’ N and 32°35’ N (southern region up to 31°12’ N, middle region up to 32°05’ N, and northern region up to 32°35’ N) (Batieha et al. 2011). According to the Jordanian department of statistics the area of Jordan is 89,342 $km^2$, and an estimated number of populations around eleven million.

To study the association between climate indicators and COVID-19 pandemic in Jordan, three cities were selected for the analysis based on the availability of data. The Jordanian Ministry of Environment has only 3 data stations, these stations are located in the three major cities of Jordan. Amman, the capital city, the administrative and the commercial center with an area of 1700 $km^2$ and a population of 4.5 million (Al-Khashman 2007). Irbid, the capital of the northern region of Jordan with an area of 410 $km^2$ and the second populated city with 2 million (Alomary 2013). Zarqa, the industrial city par excellence which houses more than 50% of Jordan industry, with an area of 60 $km^2$ and a population of 1.5 million (Abu-Dieyeh et al. 2010).

## 2.2 Data Collection

The daily data of confirmed COVID – 19 cases in Amman, Zarqa and Irbid in Jordan over the period from 2 March to 31 December, 2020, was obtained from the Jordanian Ministry of health, while the climate indicators including relative humidity (%), the average daily temperature ($^0$C), pressure (kPa), wind speed (m/s), and the concertation of the four pollutants (CO, $NO_2$, $PM_{10}$ and $SO_2$) in the three cities in Jordan was obtained from World Air Quality Project website (https://aqicn.org/) and the Jordanian Ministry of Environment.

## 3. Results And Discussion

Since the announcement made by WHO that COVID-19 is a pandemic, the number of active cases is continuously escalating worldwide (Cucinotta and Vanelli 2020). Officially, on March 2nd 2020, the first confirmed COVD-19 case was declared by the Jordanian Ministry of Health (Abdelhafez et al. 2021). The number of cases escalated to 294,494 on January 31st, 2021, though the number of recovered cases was 270,551, 20,109 cases were still under treatment. The total death numbers were 3834 cases. Figures (1), (2) and (3) show the number of confirmed COVID-19 cases over the period from 2nd March to 31st December 2020 in Amman, Irbid and Zarqa respectively.

## 3.1 Multiple Linear Regression

A multiple linear regression model has been implemented for predicting confirmed daily cases of the COVID-19 given climate indicators (average daily temperature, relative humidity, wind speed, pressure and the concertation of the four pollutants (CO, $NO_2$, $PM_{10}$ and $SO_2$)) in the study. This study uses the linear approach for modeling the relationship between a scalar dependent variable y and one or more independent variables or (explanatory variables) denoted X (Freedman 2009). In this study 305 samples were used to obtain the following Linear Equations:

$Y_1 = 6.816X_1 + 11.999X_2 - 30.618X_3 + 72.170X_4 - 0.318X_5 + 38.049X_6 + 40.228X_7 + 6.796X_8 - 74096.85$ **Equ. (1)**

$Y_2 = 0.086X_1 + 0.043X_2 - 0.142X_3 + 0.031X_4 - 0.443X_5 + 0.219X_6 - 0.290X_7 + 0.044X_8 - 24.582$ **Equ. (2)**

$Y_3 = 1.862X_1 + 3.327X_2 - 17.783X_3 + 16.533X_4 - 0.416X_5 - 5.327X_6 - 18.111X_7 + 2.968X_8 - 16874.087$ **Equ. (3)**

Where $Y_1$, $Y_2$, $Y_3$ are the number of COVID-19 confirmed cases in Amman, Irbid and Zarqa respectively. $X_1$ is average daily temperature, $X_2$ is relative humidity, $X_3$ is wind speed, $X_4$ is pressure, $X_5$ is the concentration of CO, $X_6$ is the concentration of $NO_2$, $X_7$ is the concentration of $SO_2$ and $X_8$ is the concentration of $PM_{10}$.

Table (1) shows the performance of the multiple linear regression, the mean absolute error (MAE) for Amman over the testing set is 0.327, which indicates that on average, the predicted values using multiple linear regression depart from the true value by 47.66% and the coefficient of correlation (R) for Amman is equal to 0.638.

The performance of the multiple linear regression, MAE for Irbid over the testing set is 0.246, which indicates that on average, the predicted values using multiple linear regression depart from the true value by 67.33% and R for Irbid is equal to 0.366.

The performance of the multiple linear regression, MAE for Zarqa over the testing set is 0.391, which indicates that on average, the predicted values using multiple linear regression depart from the true value by 57.63% and R for Zarqa is equal to 0.500.

**Table (1)**

Performance of multiple linear regression model

| | | |
|---|---|---|
| Amman | R | 0.638 |
| | Test Accuracy | 52.34% |
| | MAE | 0.327 |
| Irbid | R | 0.366 |
| | Test Accuracy | 32.67% |
| | MAE | 0.246 |
| Zarqa | R | 0.500 |
| | Test Accuracy | 42.37% |
| | MAE | 0.391 |

## 3.2 Feedforward Artificial Neural Network

Feedforward model was designed and tested using the MATLAB software. This model was used to correlate the climate indicators with the COVID-19 active cases in Amman, Irbid and Zarqa, of Jordan. More details and description about the proposed three models of ANN is found in (Al-Naami et al., 2014).

ANN network with neuron numbers (8, 20, 1) were designed and tested within the MATLAB. A total data consists of 305 model samples were attained from previously experimental data and is used as the input of ANN network. Furthermore, a total of 70% of this data is used for training, 15% is used for validation and 15% is used for testing. In the hidden layer, tangent sigmoid function is applied, and linear transfer function is used in the output layer. In this analysis and based on many trails and errors, 20 was selected as the number of the hidden layer. The proposed network was trained using Levenberg-Marquardt (trainlm) algorithm.

In Figures (4), (5) and (6), the scatter plots of training, testing, and validation are shown for Amman, Irbid and Zarqa.

Table (2) shows the performance of feedforward artificial neural network model, it is found that it has the value of R for Amman, Irbid and Zarqa; 0.96202, 0.93858 and 0.96305 respectively. also, it is found that the MAE for Amman, Irbid and Zarqa are 0.3467, 0.0835 and 0.4235 respectively.

**Table (2)**

Performance of Feedforward Artificial Neural Network.

| | | |
|---|---|---|
| Amman | R | 0.83527 |
| | Test Accuracy | 60.895% |
| | MAE | 0.3467 |
| Irbid | R | 0.32461 |
| | Test Accuracy | 16.45% |
| | MAE | 0.0835 |
| Zarqa | R | 0.63873 |
| | Test Accuracy | 50.34% |
| | MAE | 0.4235 |

## 3.3 Sobol Sensitivity Test

This test is based on the decomposition of model output variance into summands of variances of the input parameters in increasing dimensionality (Saltelli et al. 1999 and Sobol 2001). Furthermore, its analysis, which may be carried out via the global sensitivity analysis toolbox in MATLAB. is very useful in quantifying the interactions between parameters, and can be attained by computing the first-order, second-order, higher-order, and the overall sensitivity indices (Abdelhafez et al. 2021). In this work, Sobol sensitivity test was conducted to Investigate the potential of variables in the prediction of the climate indicators (the concertation of the four pollutants (CO, $NO_2$, $PM_{10}$ and $SO_2$), and average daily temperature, relative humidity, wind speed, and pressure),

Global sensitivity analysis toolbox in MATLAB is used to conduct the Sobol sensitivity analysis. Figures (7), (8) and (9) show the significance and sensitivity analysis of the Sobol method for climate indicators in Amman, Irbid and Zarqa. The results show that: Pressure is the most important variable in prediction of COVID-19 confirmed cases in Amman, the concentration of $NO_2$ is the most important variable in prediction of COVID-19 confirmed cases in Irbid, Pressure is the most important variable in prediction of COVID-19 confirmed cases in Zarqa.

# 4. Conclusion

In this study climate indicators variables including average daily temperature, relative humidity, wind speed, pressure and the concertation of the four pollutants (CO, $NO_2$, $PM_{10}$ and $SO_2$) were correlated with COVID-19 active cases in Amman, Irbid and Zarqa, of Jordan. This was achieved by using multiple linear regression and feedforward artificial neural network.

It was found that the multiple linear regression and feedforward artificial neural network had the capability to forecast the COVID-19 confirmed cases in Amman, Irbid and Zarqa, of Jordan

In the examination of the importance of variables of global sensitivity analysis by using Sobol analysis it was shown that the pressure plays an important role in the COVID-19 outbreak in Amman and Zarqa. While the concentration of $NO_2$ plays an important role in the COVID-19 outbreak in Irbid.

# 5. Declarations

### Ethical Approval

Not applicable

### Consent to Participate

Not applicable

### Consent to Publish

Not applicable

### Contributions

Conceptualization: [Eman Abdelhafez]; Methodology: [Eman Abdelhafez] Formal analysis and investigation: [Loai Dabbour]; Writing - original draft preparation: [Eman Abdelhafez, Loai Dabbour and Mohammad Hamdan]; Writing - review and editing: [Mohammad Hamdan] and [Loai Dabbour];


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### Competing Interests

The authors declared that they have no conflict of interests

### Availability of data and materials

The datasets used and/or analysed during the current study are available from the corresponding author on reasonable request.

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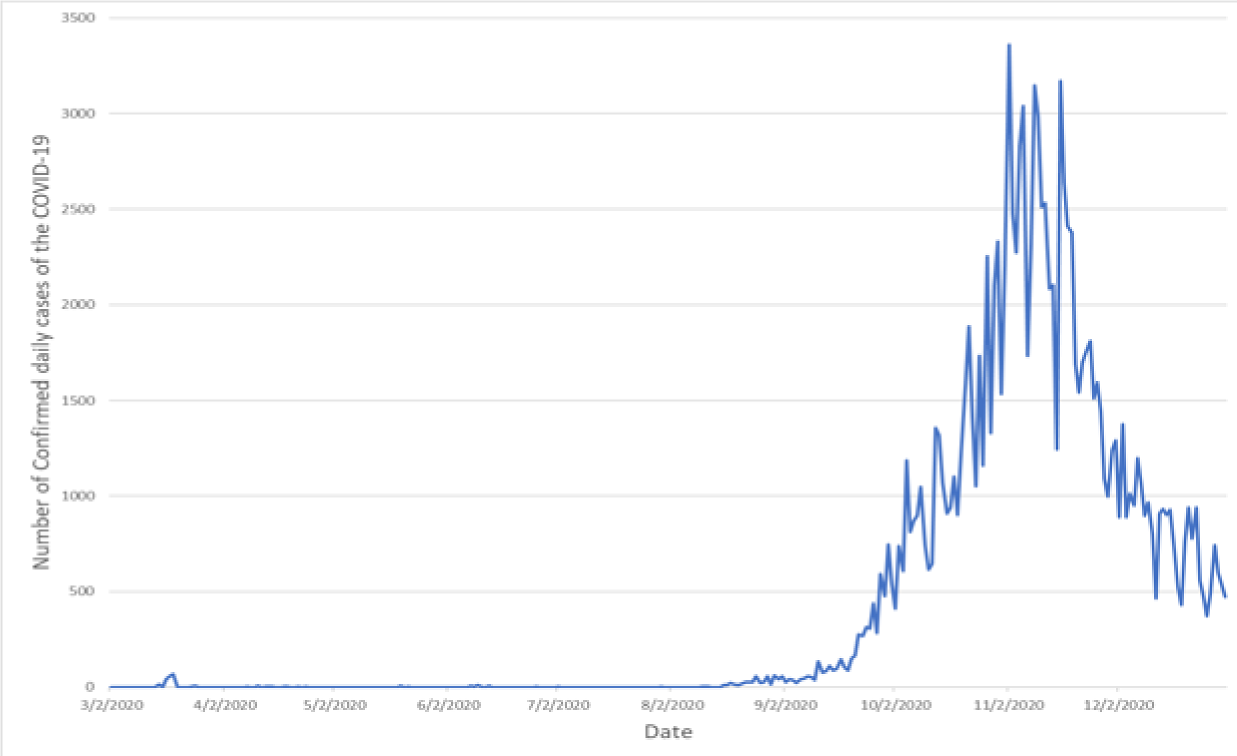
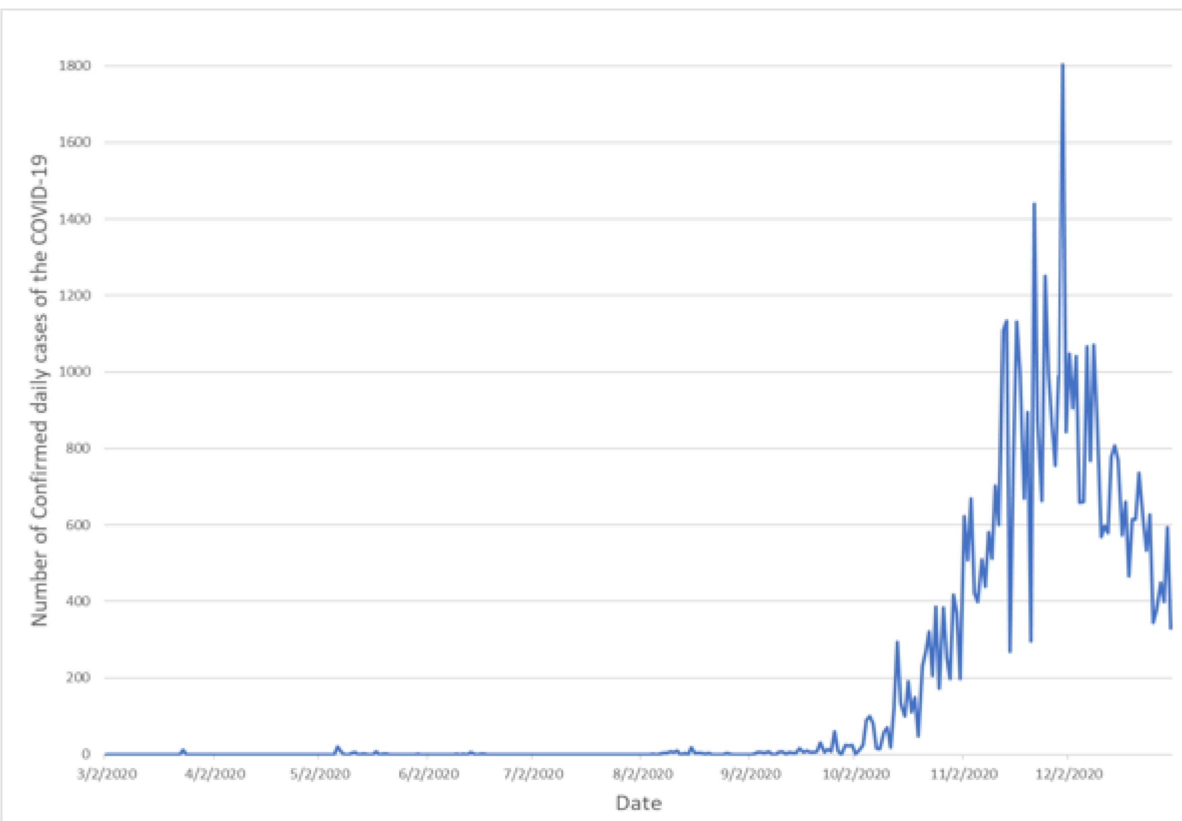
# Figures



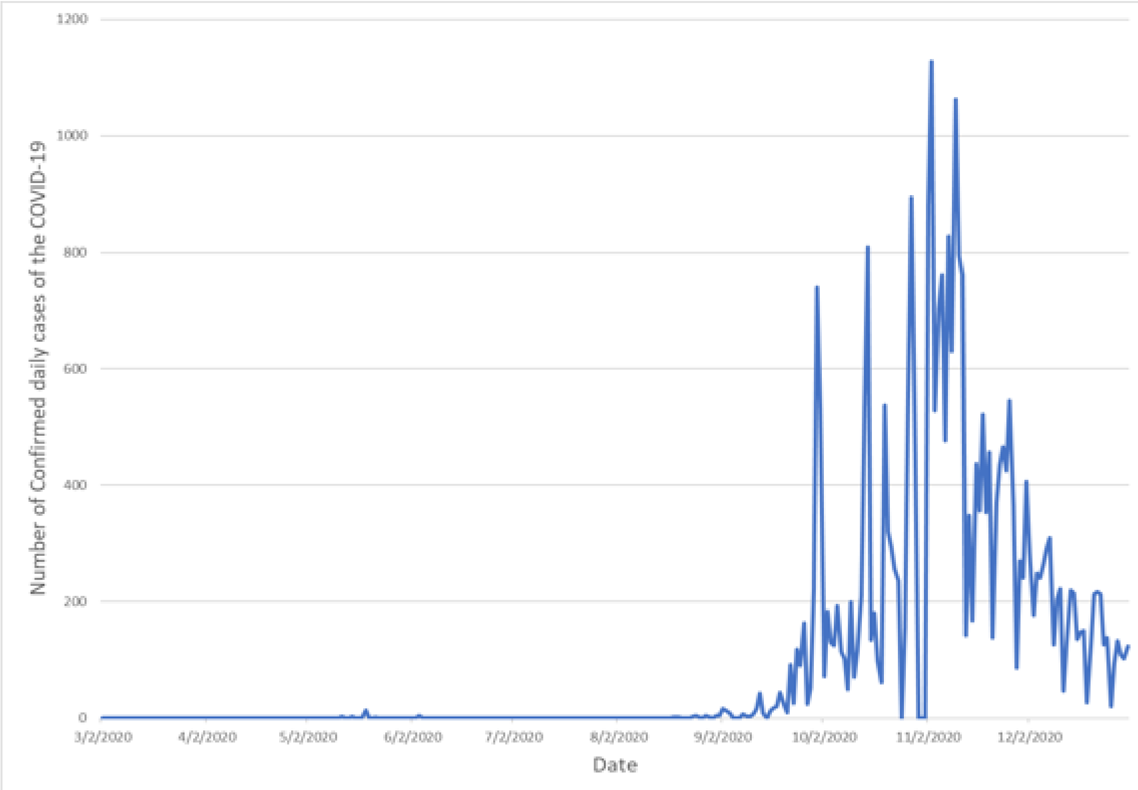

## Figure 1

Confirmed daily cases of the COVID-19 in Amman, Jordan



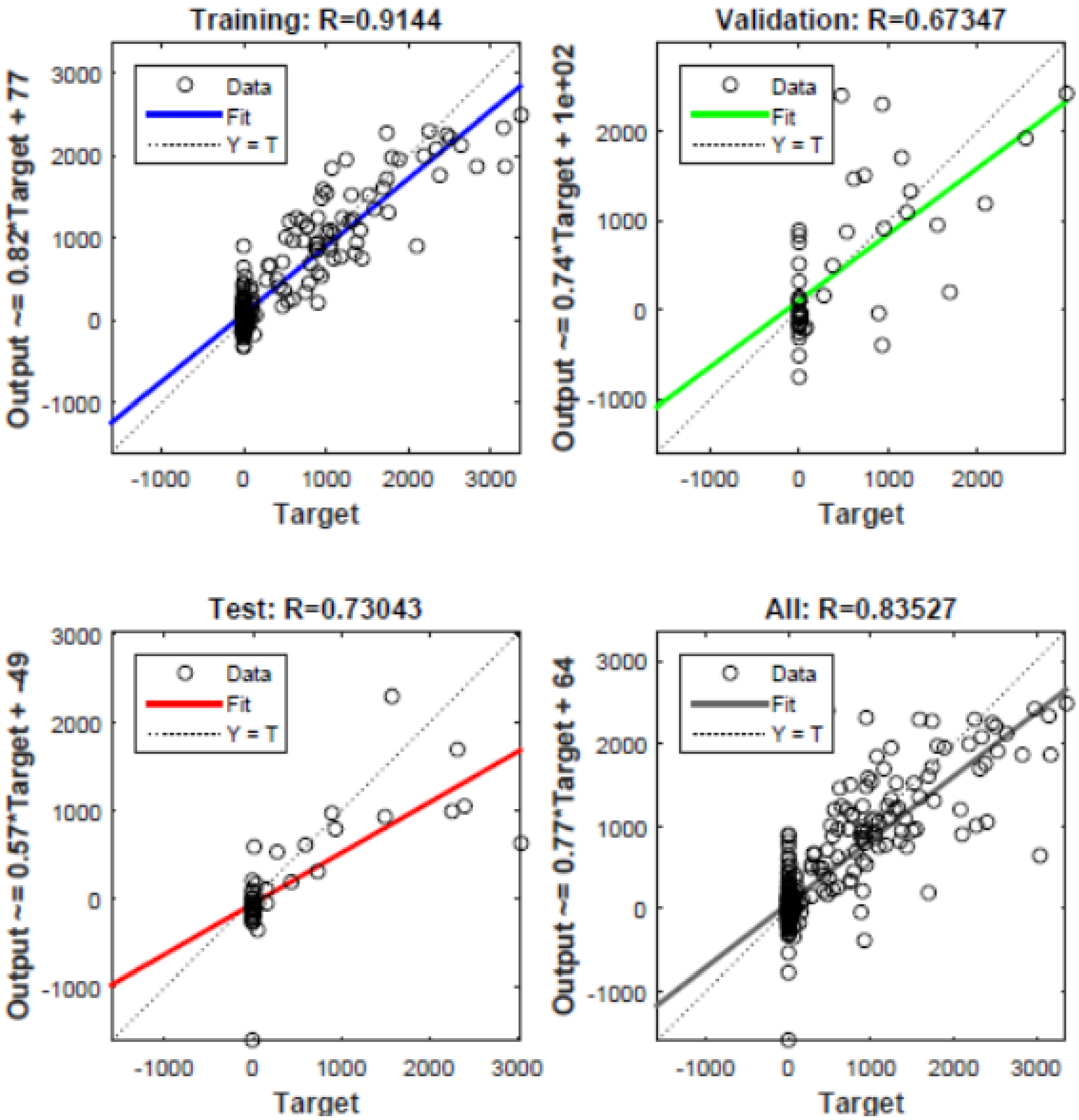

## Figure 2

Confirmed daily cases of the COVID-19 in Irbid, Jordan




## Figure 3

Confirmed daily cases of the COVID-19 in Zarqa, Jordan




## Figure 4

Scatter plot of the model for Amman.

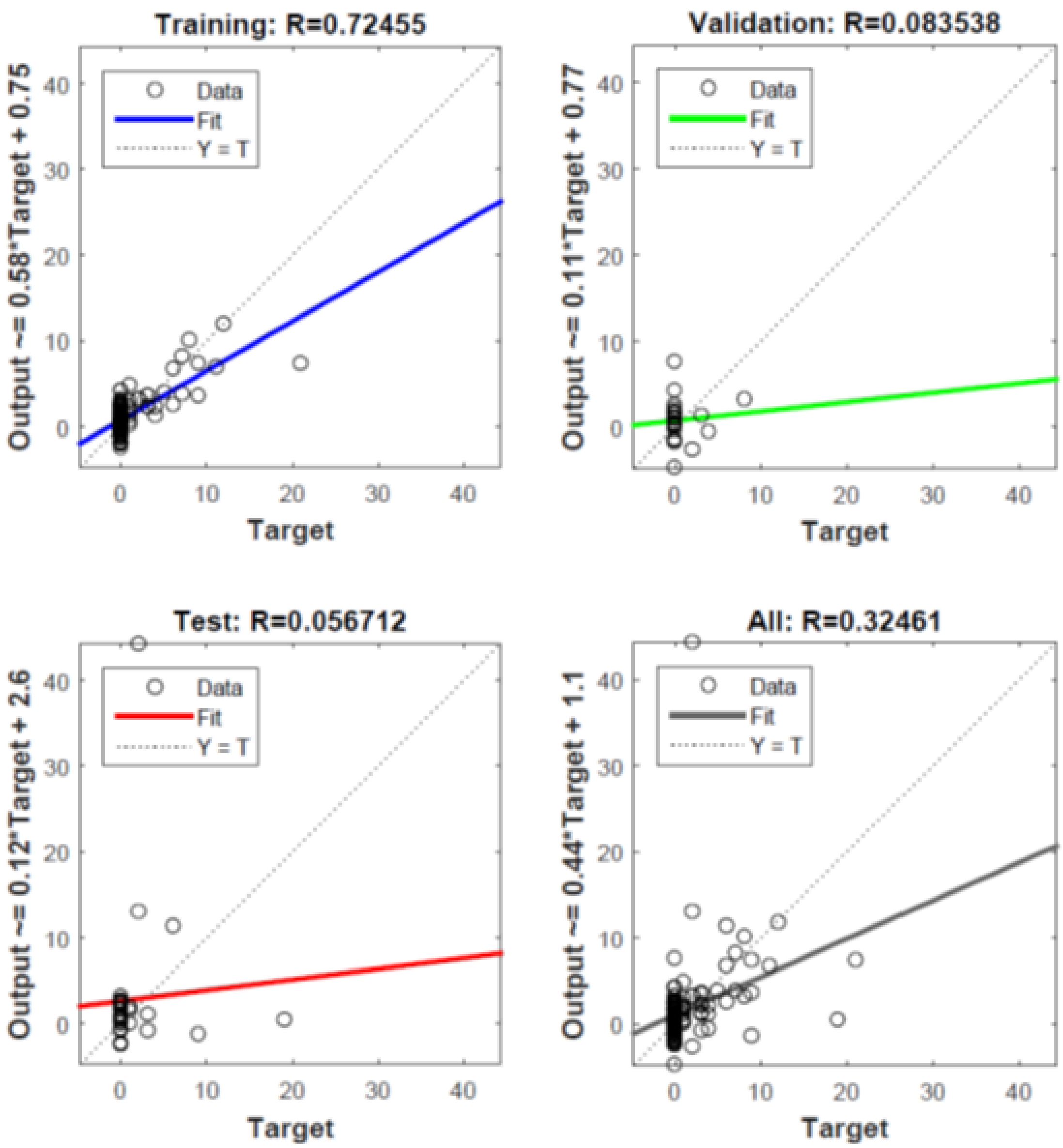
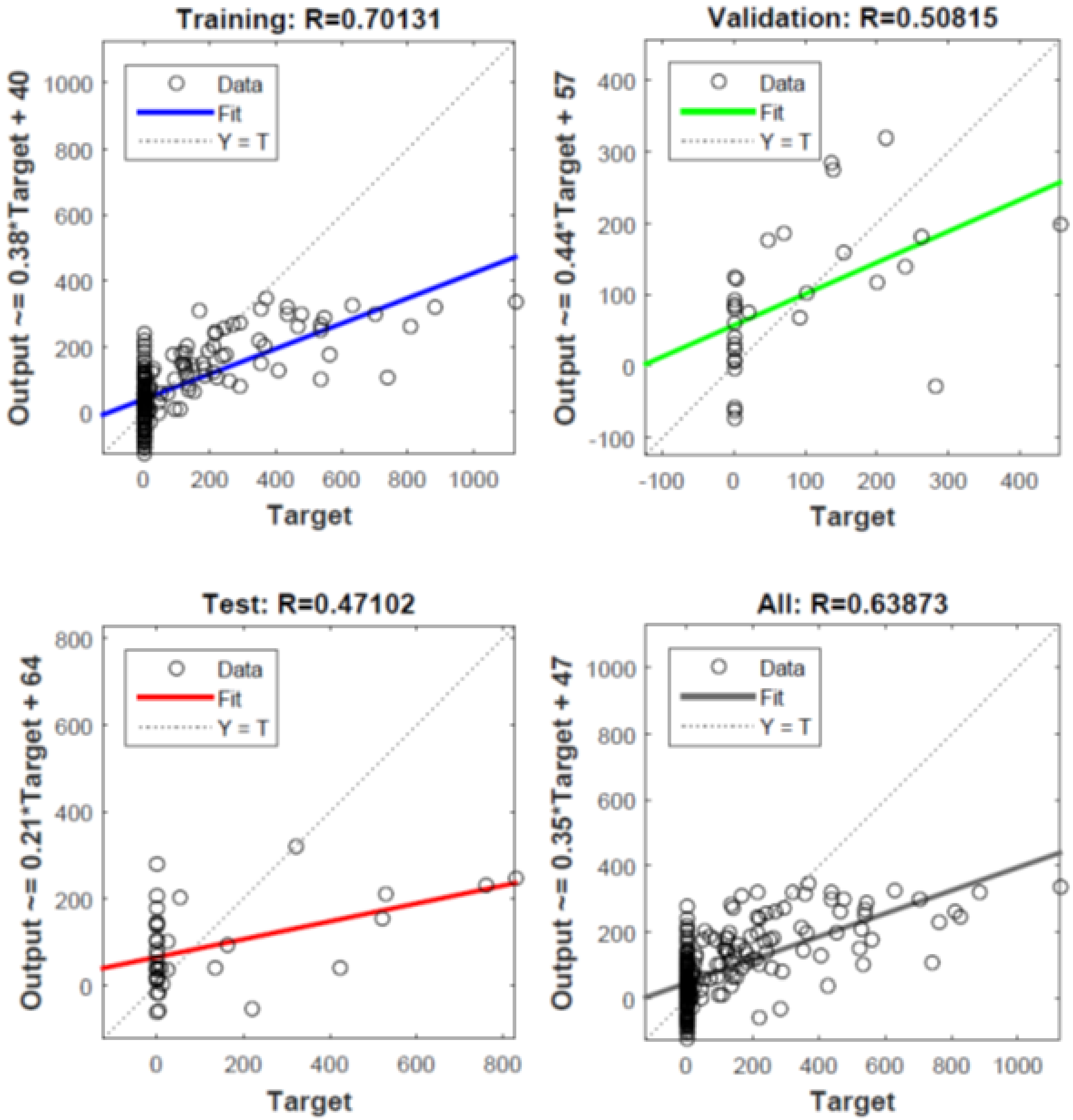



**Figure 5**

Scatter plot of the model for Irbid.




## Figure 6

Scatter plot of the model for Zarqa.

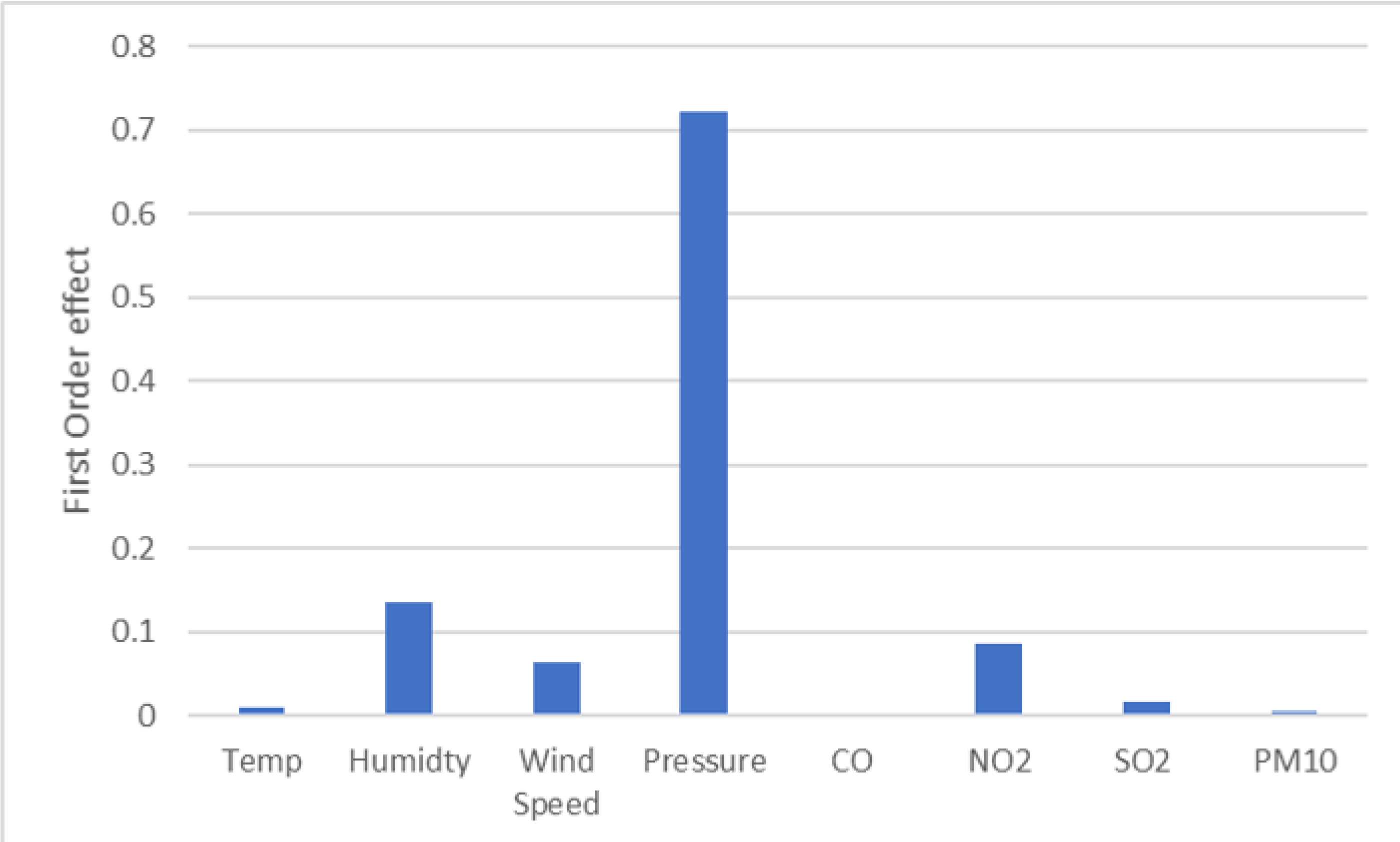



**Figure 7**

First order effect of Sobol sensitivity analysis for Amman

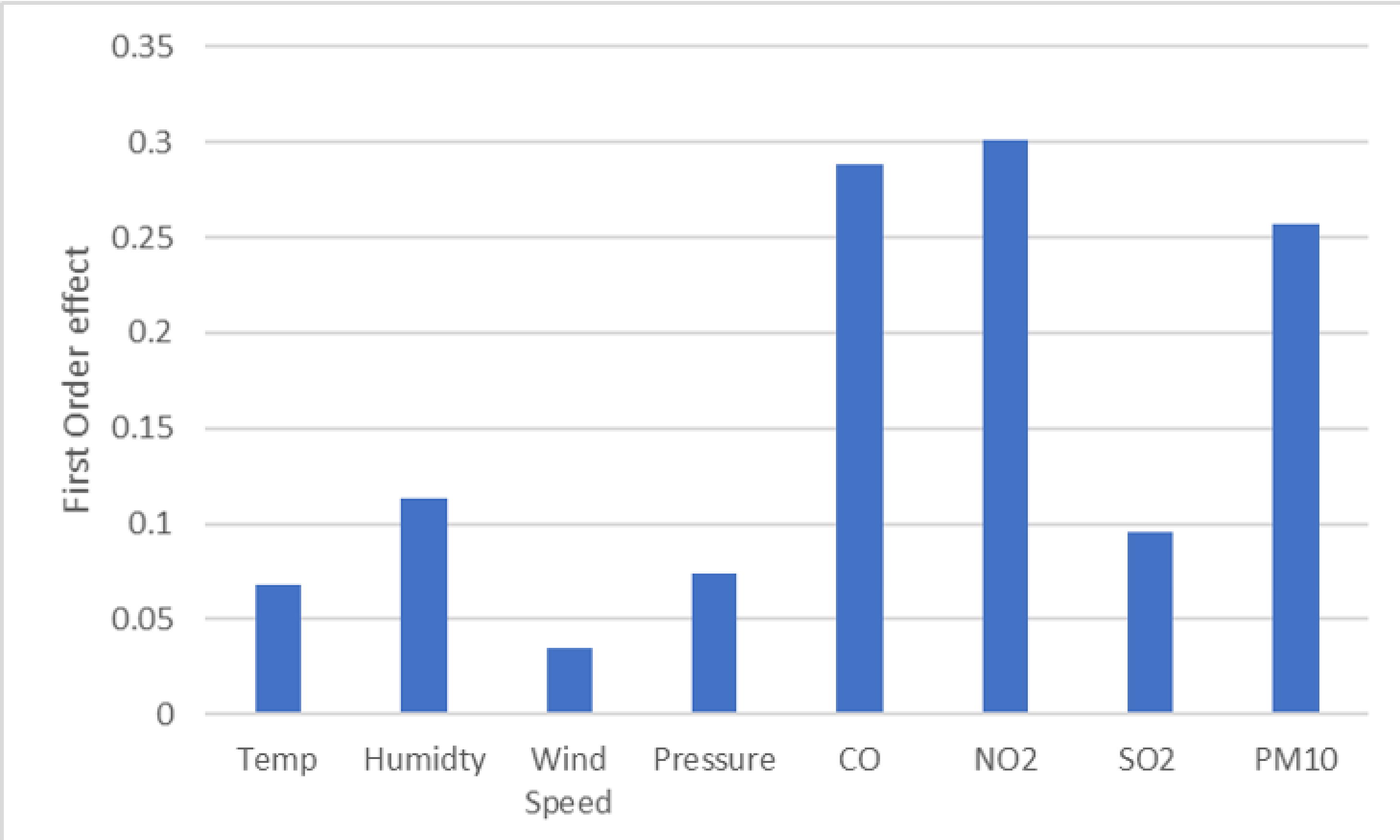



**Figure 8**

First order effect of Sobol sensitivity analysis for Irbid

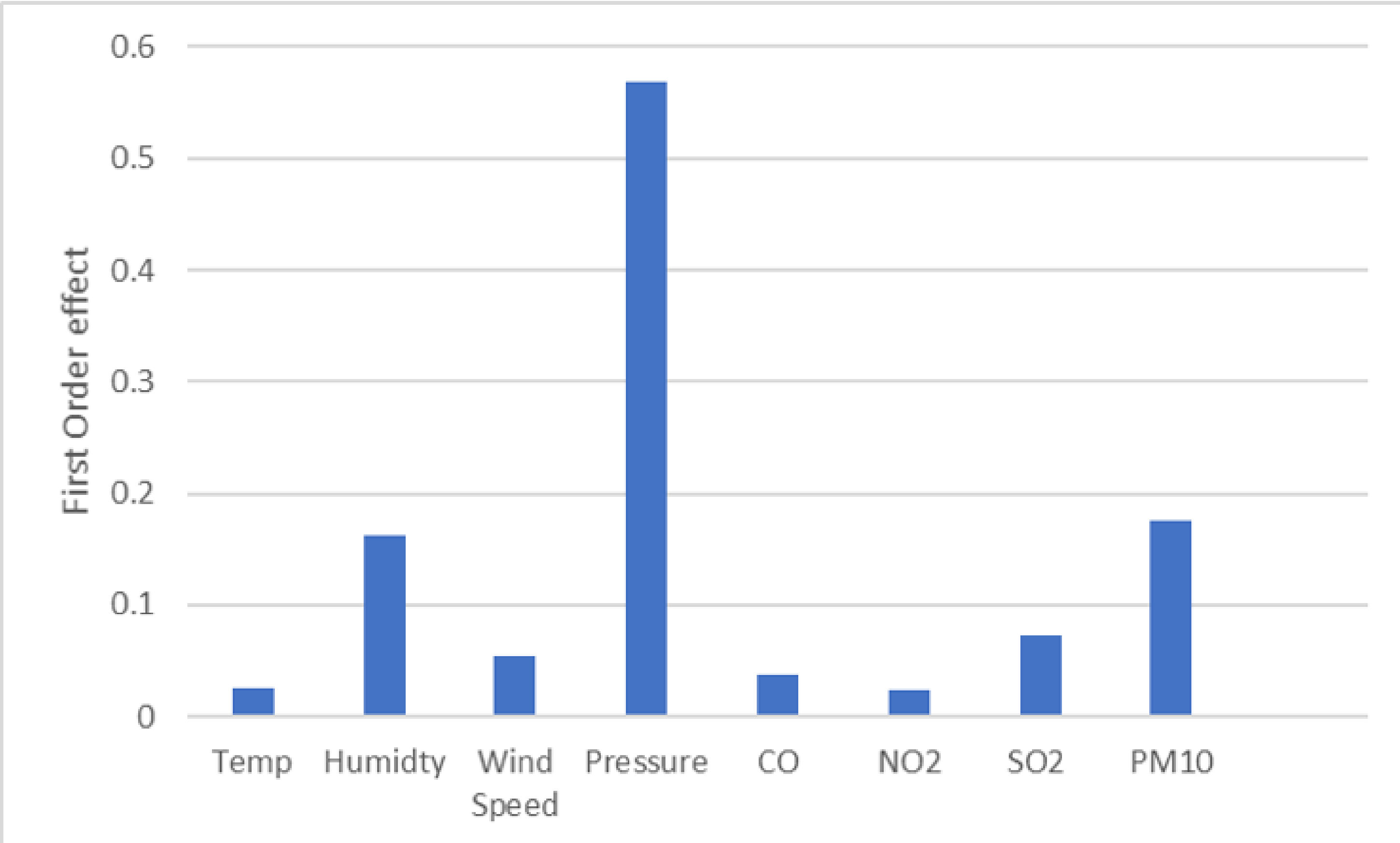



**Figure 9**

First order effect of Sobol sensitivity analysis for Zarqa