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Applications of Remote Sensing and GIS in Assessing Climate Change and Forecasting Air Quality in Iraq

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Abstract

The relationship between temperature and air quality (AQ) is complex and can vary depending on various factors, including the specific pollutants present in the air, the local climate, and the sources of pollution. However, some general patterns and interactions can be observed. Recently, there has been a significant change in climate and a rise in temperatures. This research aims to evaluate weather factors and the effect of high temperatures on air quality in Iraq. Remote sensing data were used in addition to historical air quality data from ground stations in July 2023. The study relied on the survey method and geographical distribution analysis from remotely sensed images and collected ground station data, in addition to statistical modeling. The study resulted in a large increase in surface air temperatures and a decrease in surface relative humidity. The effect of air quality due to the increase in temperatures has been concluded, as the main factor contributing to the formation of the obtained statistical model is temperature, followed by air pressure. The statistical model was derived using geographic information systems (GIS) with an accuracy of 85%, as the estimated values for air quality ranged between (41.3-308). It's important to note that while temperature is a significant factor, air quality is influenced by multiple factors such as pollutant emissions, wind patterns, humidity, topography, and local air circulation patterns. Therefore, understanding and managing air quality requires considering the interplay of these various factors.

Keywords: Air quality; Climate change; Meteorological factors; Regression; Remote sensing

1. Introduction

Air quality and climate factors are closely interconnected, as climate change can significantly impact air quality, and vice versa **[1-3].** Rising temperatures and increased frequency of heatwaves can lead to the formation of ground-level ozone, a harmful air pollutant **[4]**. Changes in precipitation patterns can affect the dispersion and transport of air pollutants, potentially leading to localized air quality issues **[5]**. Also, climate change can influence the frequency and intensity of wildfires, which release large amounts of smoke and particulate matter into the air, degrading air quality **[6]**. Furthermore, greenhouse gases contribute to global warming and climate change **[7-10]**. These gases are released by various human activities, including burning fossil fuels, industrial processes, and deforestation **[11]**.

Poor air quality, resulting from both human-made and natural sources, has detrimental effects on human health, causing respiratory and cardiovascular diseases, allergies, and premature death **[12-16]**. Climate change-related phenomena, such as extreme weather events and changes in infectious disease patterns, can also have indirect impacts on air quality and human health **[17-20]**.

Mitigation Strategies are used for decreasing the effects **[21-23]**. Addressing climate change by reducing emissions can have co-benefits for air quality by reducing pollution sources **[24,25]**. Transitioning to cleaner and renewable energy sources, improving energy efficiency, and promoting sustainable transportation can help mitigate both climate change and air pollution **[26]**. Implementing policies and regulations to reduce emissions from industrial activities, agriculture, and waste management can also improve air quality and contribute to climate change mitigation **[27].**

Extensive research and monitoring systems are primed to study air quality and weather factors, including measuring various air pollutants, meteorological parameters, and climate models **[12, 14, 16]**. In the case of analysing air quality concerning climate factors, you can perform a regression analysis to understand how climate factors influence air quality **[12, 14, 28-30]**. Regression analysis is a statistical method used to model the relationship between a dependent variable and one or more independent variables **[12, 14, 16, 29-30].**

Remote sensing technologies, satellite data **[14, 16]**, and ground-based monitoring stations play a crucial role in assessing air quality and climate trends on regional and global scales **[14, 16, 29-30]**.

This study evaluates climate variables and their effect on air quality based on remotely sensed data and GIS analysis. Besides, data from ground stations was collected from different sources. The study presents a linear statistical model for calculating air quality in the study area based on notable changed climate factors during July 2023.

It is worth noting that ongoing research and advancements in understanding the complex interactions between air quality and climate factors are continually evolving our understanding of these topics.

2. Study area

Iraq is a Middle Eastern country located in Western Asia. Iraq is a country with a diverse and historically significant study area. Geographically, Iraq is situated on coordinates 29°36′N to 33°24′N latitude and 38°47′E to 48°34′E longitude **[31]** (Figure 1).

Iraq's geography is characterized by varied lands that include deserts, fertile plains, and mountainous regions. In terms of weather, Iraq experiences a predominantly arid climate, with significant variations throughout the country. Summers in Iraq are generally hot and dry, particularly in the central and southern regions. Average temperatures during the summer months range from 40 °C to 48°C in these areas, with occasional heatwaves pushing the temperatures even higher. The northern regions, including the mountainous areas, have milder summers with temperatures averaging around 30°C. Winters in Iraq are relatively mild in the southern parts of the country, with temperatures ranging from 9°C to 21°C. However, in the northern regions, including the mountainous areas, temperatures can drop below freezing, and snowfall is not uncommon. Rainfall in Iraq varies significantly based on the region and the season. The northern parts of the country receive more precipitation, especially in the mountainous regions, while the central and southern areas are considerably drier. Most rainfall occurs during the winter months, with some sporadic showers in spring and autumn **[14]**.

Dust storms are a characteristic feature of the weather in Iraq, particularly during the summer months. These storms can significantly reduce visibility and have adverse effects on air quality. Sandstorms are more prevalent in the western and southern regions, where the desert lands dominate **[16].**

It's worth noting that climate change and regional environmental factors have had an impact on Iraq's weather patterns, including shifts in rainfall patterns and an upsurge in the occurrence and strength of droughts in certain regions, and currently in the entire Iraq which caused bad air quality.

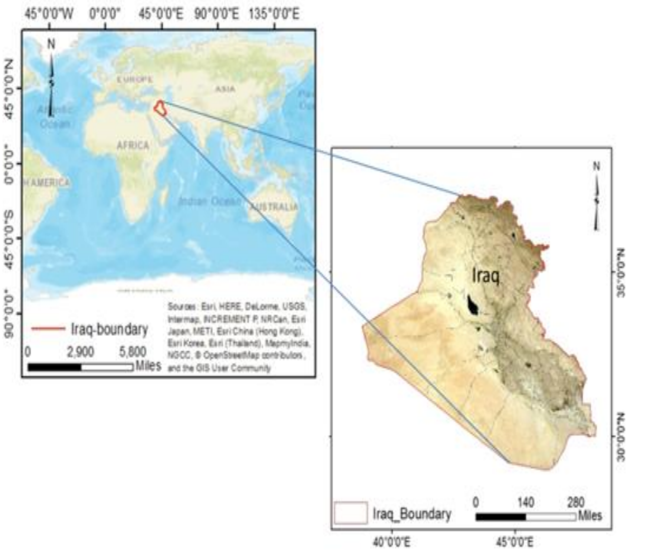


Figure 1: *Iraq map, the study area.*

3. Materials and Methods

Here's a general framework that was used in the study to perform a regression analysis for air quality and climate factors (Figure 2).

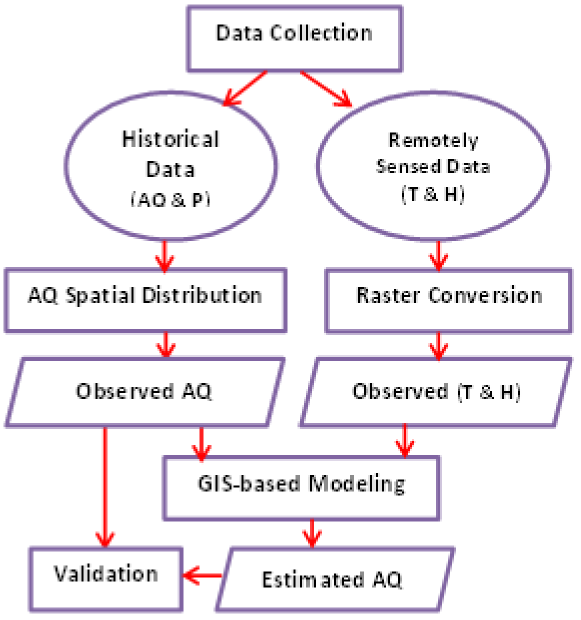


Figure 2: *Flowchart of general framework performed in the study.*

4. Data collection

Gather data on air quality and climate factors. Air quality data may include measurements of pollutants such as particulate matter (PM2.5, PM10), ozone (O3), nitrogen dioxide (NO2), etc. Climate factors can include temperature, humidity, wind speed, rainfall, etc. Must ensure that we have enough observations for accurate analysis. Here we relied on AQI as air quality data for investigation, surface air temperature, surface relative humidity, and air pressure as climate data for model inputs. The first factor of meteorology that was used is temperature. The remotely sensed temporal coverage is from 2002 to the present. The Surface Air Temperature (L3, Day, Daily) layer displays the temperature of the air in units of Kelvin (K) two meters above sea level. In mapping, we transferred to Celsius. Globally spatial coverage, and overpasses twice daily (day and night). The second factor used was surface relative humidity. The remotely sensed temporal coverage is from 2002 to the present. The surface relative humidity (L3, Day, Daily) layer displays humidity in percentage units, located at 2 meters above sea level. Globally spatial coverage, and overpasses twice daily (day and night). Other data like air pressure was collected via the RetScreen program. While AQ data from the link reported in Table 1 dataset characteristics.

Table 1: *Dataset characteristics.*

	Data		
Type	**Remotely Sensed**		**Historical**
Factor	T&H	P	AQ
Source	EOSDIS Worldview	RetScreen program	IQ Air
Link	https://worldview.earthdata.nasa.gov	RETScreen (canada.ca)	https://www.iqair.com/iraq

4.1. Data preprocessing

Spatial distributions were used for checking the missing values. Extracting point data by GIS-based analysis from remotely sensed data to put the data in a suitable format for regression analysis.

4.2.Modeling by variable selection

We determined climate factors as independent variables in the regression analysis while AQ was the dependent factor. We Considered factors that are likely to influence air quality. For example, temperature, humidity, and Pressure are commonly considered relevant climate factors.

Choosing an appropriate regression model based on the nature of the data and research question. Multiple linear regression is a common choice for analyzing the relationship between air quality and climate factors. Based on multiple linear regression **[12, 14, 29, 30]** we specified the following equation including the used variables.

$$AQ = I - a*T - b*P \quad (1)$$

where AQ is the estimated values, I am the intercept, a is the temperature coefficient, T is the surface air temperature, b is the air pressure coefficient, and P is the air pressure.

4.3. Validation of the regression model

In regression analysis fitting the regression model needs to assess the model's goodness of fit using statistical measures such as R-squared, adjusted R-squared, and p-values associated with the coefficients. These measures indicate how well the independent variables explain the variation in air quality.

Validation was applied using cross-validation. This step helps assess the model's predictive performance and generalizability. The coefficient value reflects the power of the correlation. Additionally, analyzing P-values is to determine the statistical significance of the relationships. Based on our analysis the model is based on surface air temperature and air pressure. The surface relative humidity was out of the regression model with a P value of 0.06.

5. Results and Discussions

5.1. Remote sensing data results

Figure 3 represents the outputs of remotely sensed data. Where Figure 3(a) is the raster conversion outputs of the surface air temperature satellite image, Figure 3(b) is the raster conversion outputs of the surface relative humidity satellite image, Figure 3(c) Estimated data of surface air temperature, surface relative humidity, and air pressure.

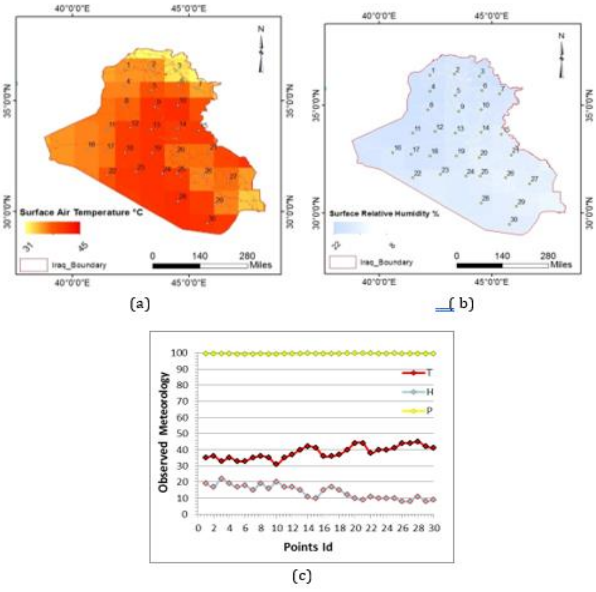


Figure 3: *Outputs of remotely sensed data of; (a) Surface air temperature satellite image, (b) Surface relative humidity satellite image, and (c) Estimated data of surface air temperature, surface relative humidity, and air pressure.*

5.2. AQ spatial distribution results

Based on several AQ stations in the study area we mapped the AQ distributions as shown in Figure 4. The distribution ranged between 62-472 which is described as moderate to unhealthy air (hazardous), based on standards listed in **[14, 16]**. The northern part of the country was within so bad air quality represented hazardous air type concentrated in two provinces (Kirkuk and Salahuddin) for this period. Southern parts were moderate AQ.

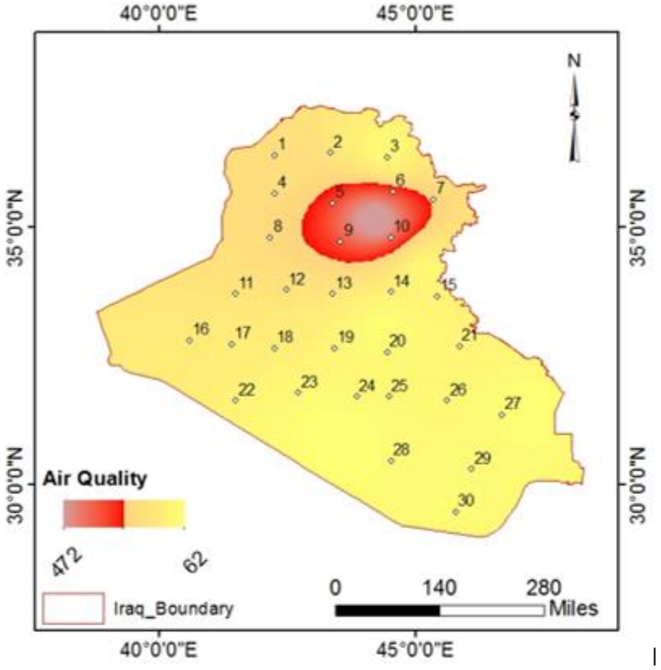


Figure 4: *AQ distribution map from ground stations.*

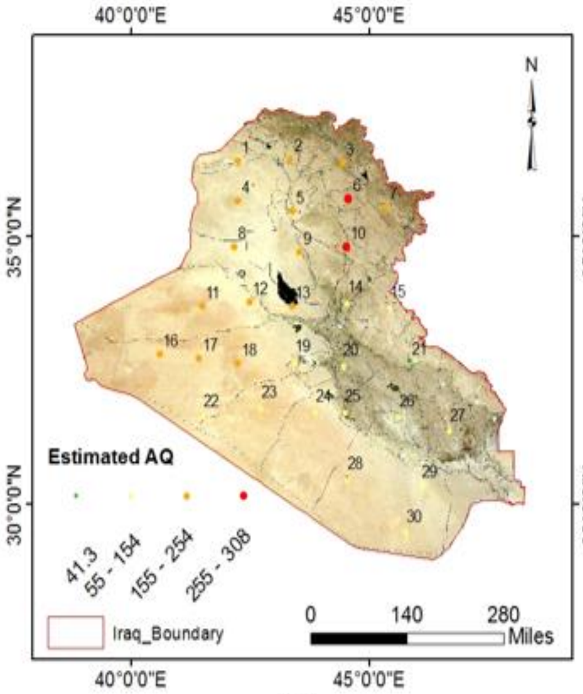
5.3.GIS-based modeling results

Table 2 represents the AQ estimation GIS-based modeling summary. While Figure 5 represents the estimated maps where Figure 5 (a) is the estimated AQ map at selected points, and Figure 5(b) is the estimated AQ distribution along Iraq. Moreover, the observed and estimated AQ at selected points were reported in Figure 6.

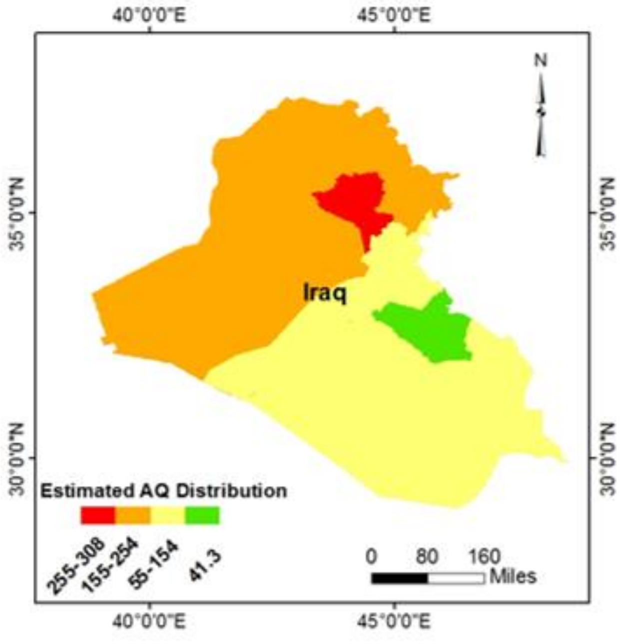
Table 2: *AQ estimation GIS-based modeling summary.*

Variables	Coef.	Std-Error	t-Stat	P-value	Std-Coef
Intercept	13694	4153.16	3.297157	0.002829*	0
Surface Air Temperature	-7.9939	3.81792	-2.09378	0.046177*	-0.3865
Surface Relative Humidity	6.2769	3.29246	1.906444	0.067701	0.32297
Air Pressure	-133.84	42.3262	-3.16205	0.003958*	-0.3153
Coefficient of Determination R^2	0.85				
Adjusted R^2	0.84				

Based on Table 2, the derived equation for estimating AQ was set as: AQ=13694 - 7.99T - 133.84P (2)
The coefficient of determination R2 was equal to 0.85 and the adjusted R2 was equal to 0.84.



(a)



(b)

Figure 5: *Estimated maps of; (a) AQ at selected points, and (b) AQ distribution along Iraq.*

Based on Figure 5, the estimated AQ was distributed between 41.3 and 308. Which is described as good for unhealthy air. Based on AQI breakpoints **[16]**, Kirkuk province and part of Salahuddin province were described as unhealthy. While good air was in Wasit province. South-east parts were moderate air. North-west parts were unhealthy for sensitive people. This description may differ from period to period based on pollutants' existence or meteorological effects.

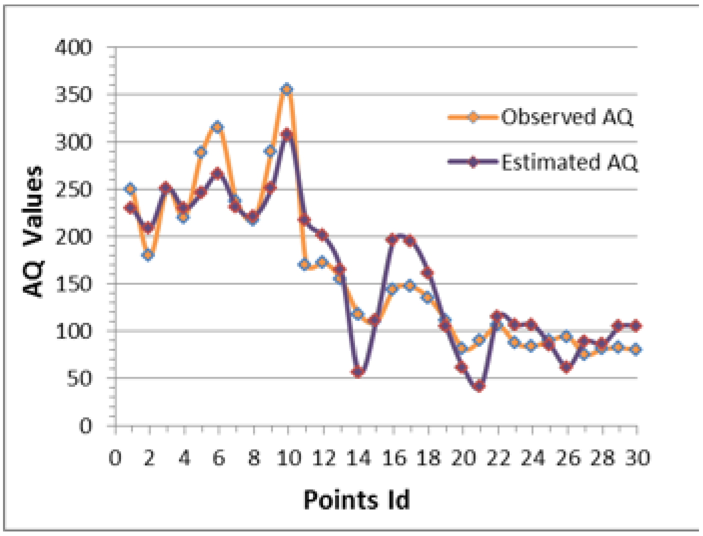


Figure 6: *Observed and Estimated AQ.*

In Figure 6 we can see the same trend of ups and downs in air quality in both observed and estimated AQ values.

5.4. Validation results

Validation was applied by the GIS modeling process to gain accurate estimations of AQ, Estimated AQ tested in corresponding to observed AQ. A positive trend was gained and accurate estimations with 85% accuracy.

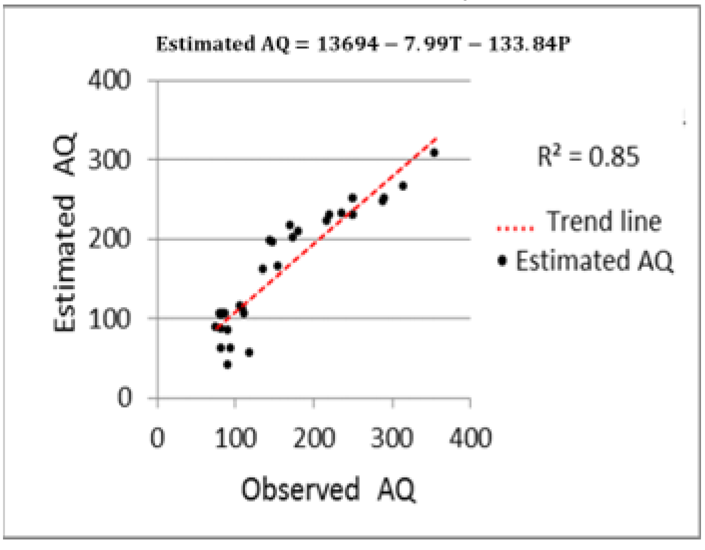


Figure 7: *Validation of Estimated AQ model.*

6. Conclusion

The study examined the relationship between temperature and air quality by generating a multiple regression model for calculating air quality. The study aimed to evaluate weather factors in Iraq during hot periods exactly in July 2023. Remote sensing historical data was used. The study concluded the high increase in surface air temperatures and a decrease in surface relative humidity. Significant impacts of temperatures on air quality have been concluded. The surface air temperature was the main factor that contributed to the obtained GIS-based statistical model, followed by air pressure. The statistical model R2 was about 0.85, and the estimated AQ values reached unhealthy air class in the northwest of the country.

The regression analysis provides statistical associations, but it does not establish causality. It's crucial to consider other factors and external influences that may affect air quality but were not included in the analysis.

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