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Impact of vegetation cover on climate change in different regions of Iraq

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ABSTRACT

Vegetation determines the percentage of soil covered with green vegetation. Spatial and temporal changes of vegetation occur in the same year due to plant cycle, crop harvesting, animal grazing, and plant pruning. Vegetation areas can be divided into five main types: forest, grassland, tundra, desert, and ice cover. Climate, soil, the soil's water-holding capacity, and the slope or angle of the land determine the types of plants that will grow in a particular area. Relative humidity is the amount of moisture in the air at a given temperature compared to what the air can hold at that temperature. The air is not able to hold onto the water vapour, since it is moving so fast. To understand the expected changes in the climatic elements of the atmosphere and water, alterations in the behaviour of temperature, relative humidity, and vegetation cover were studied. Four stations were used over Iraq extending from north to south. The reason for choosing these stations is due to the difference in climatic changes and also, the geographical nature plays an important role in determining the difference of these variables from one region to another and other weather phenomena. We obtained average monthly and annual temperatures, dew point, and relative humidity during 1988-2018 for selected stations in Iraq from the European Centre for Medium-range Weather Forecast. Several results were reached, including that the highest value of vegetation cover for four selected stations during the study period recorded in Baghdad station was more than 0.9, and the lowest value observed in Basra station was less than 0.4. The highest relative humidity value was recorded in the Mosul Station where it covered 69% in the northern and central regions of the country specifically in the winter season, and 18% in the western regions of the Rutba Station in the spring and autumn, in addition, 13% in the southern regions in the summer as seen in the Basra Station .We note that the maximum temperatures were recorded in the summer in July and August due to evaporation in these areas as they are of a dry or semi-arid nature, reaching 55 ºC, while the lowest value in the Mosul station in December and January, since this area enjoys green plants and forests and precipitation. When using Spearman's test, it was found that the strength of the correlation is strong between relative humidity and vegetation cover and the relationship is positive between them. In contrast, the relationship between vegetation cover and temperature, the relationship is inverse and the strength of the correlation is weak to medium. Finally, it was found that the spring and autumn are characterized by dense vegetation cover, and this period is important for plant growth due to the availability of appropriate weather and environmental conditions.

Keywords: Vegetation cover, Relative humidity, Temperature, Climate change, Iraq.
Article type: Research Article.

INTRODUCTION

Temperature and relative humidity are important climatic variables in determining the nature of vegetation, as they are widely used in scientific research related to the environment and climate (Li *et al.* 2018). Vegetation cover is one of the important factors in ecology to know the relationship between vegetation cover and link it to different atmospheric variables such as temperature and humidity relativity (Liu *et al.* 2020). Many researchers presented various studies in which vegetative and desert areas were used to show the effect of temperatures on vegetation cover and the division of vegetation types based on the effect of cooling and heating by analysing these variables in different places of the study

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area (Jin *et al.* 2020). Other studies carried out by many scientists showed the use of several tests through which high temperatures can be reduced by increasing the number of green spaces in areas that lack plants to make urban areas cooler (Davtalab *et al.* 2020). Other researchers tested high temperatures and low relative humidity on plant leaves by performing a leaf water loss test by rising temperatures, which made evaporation and water loss of these plants very fast, affecting vegetation cover (Aparecido *et al.* 2020). Researchers have shown through several studies the extent of the difference in relative humidity compared to temperatures in areas with open spaces in urban areas by using several different places and seasons to show the spatial-temporal analysis on the scale of vegetation (Yang *et al.* 2020). They performed a sophisticated and in-depth scientific study on how to change the landscape of natural vegetation, which is linked to an increase in population numbers, as this leads to the erosion of agricultural spaces, which leads to an increase in surface temperatures and thus negatively affects the vegetation cover (Nimish *et al.* 2020). Several previous studies explored important factors that could affect the speed of germination through the use of several climatic variables, including temperature and relative humidity, and comparing their effectiveness at night and day, and this is what the scientist has done (Cox *et al.* 2020). To exhibit the extent effect of relative humidity on vegetation cover, several scientists used in a joint study a modern and advanced model to estimate the high temperatures that lead to evaporation in plant water which affects a change in the patterns and characteristics of vegetation, along with estimating the humidity in agricultural lands (Liu *et al.* 2020). To improve the green spaces in the long term, a model was used to predict changes in the weather and climate impact in the cultivated areas from the arid ones through scientific research (Berardi *et al.* 2020; Omidipour *et al.* 2021; Rostami *et al.* 2022). Li *et al.* (2020) presented completely different model from other researchers where he used over 100 cities to show the difference between urban and rural vegetation covers by studying the relationship between surface temperature and air temperature. They noticed that the correlation varies greatly according to climatic conditions. Other studies performed by many researchers show that temperature and relative humidity have a significant impact on human-environmental comfort through their impact on vegetation cover in building areas and green spaces in urban areas. So that, scientists considered them as important factors in establishing an integrated ecosystem in conjunction with climate regulation or minimization of the temperatures in these areas (Kuang 2020). The working paper reported by Fanourakis *et al.* (2020), showed the extent to which plant leaves are affected and the behaviour of subsidence when exposed to high humidity for long periods, as this contributes to the slow growth of these leaves and clogging of the stomata during the germination process, which explains the extent to which vegetation is affected by high relative humidity. Another study on more than 10 urban city centres found out comfort and freedom in the summer and how it relates to human comfort by comparing it with the global climate index. They indicated that the cooling process of these cities is closely related to vegetation cover (Lehnert *et al.* 2021). In another study, afforestation was suggested to enhance the range of vegetation cover through the selection of the summer and winter. When applying this study, it was found that all types of plants used in afforestation will reduce the temperatures and relative humidity from inside and outside the buildings in summer (Thomsitireland *et al.* 2020). The main objective of this study was to reach solutions and results to address the problem of warming and high relative humidity by strengthening the vegetation cover in the selected areas and achieving sustainable development through increasing afforestation and getting rid of human impacts on the environment.

MATERIALS AND METHODS Study site

The data was taken from the European Centre for Medium-range Weather Forecast (ECMWF 2020), which included total monthly mean relative humidity, temperatures, and vegetation cover. For thirty one consecutive years, it has been converted into annual and seasonal averages to show the extent of climatic changes from one region to another and according to the seasons of the year (Muter *et al.* 2020).

Data analysis

The data were taken from the European Centre in the form of an NC file and converted to an Excel file using MATLAB program, where the data is sorted for each area and converted from an unreadable file to a file that contains data easy to deal with. Then Sigma plot was used, which is a program that draws the charts required in this study according to the studied areas and to find the relationship between them (Al-Taai *et al.* 2020; Apfelbach *et al.* 2020). As for the geographical maps, seasonal data of temperature, relative humidity, and vegetation cover were taken for selected stations for spatial analysis. The Kriging method was used to configure fulfilment in ArcGIS version 10.4.1. The maps were drawn by converting the geographical coordinates of all sample locations into global Mercator Transverse Coordinates. However, the data was provided to display a connected surface as a visual display. Maps showed spatial interpolation **(**Vosshenrich *et al.* 2021).

Statistical analyses

Simple linear regression (SLR)

Several available statistical operations have been carried out, where the Sigma scheme program was used to calculate the slope value and the p-value by simple linear regression (SLR) method to predict the relationship between vegetation cover, relative humidity (RH) and temperature (T).

The equation below can be used to find out the simple linear regression value (Di *et al.* 2020; Padua 2020):

$$\bar{Y} = a + bx \qquad (\mathbf{1})$$

$$b = \frac{\sum_{i=1}^{n}(X_i - \bar{X}) - (Y_i - \bar{Y})}{\sum_{i=1}^{n}(X_i - \bar{X})^2}$$

where **b** is the slope and shows if the line is straight, and **a** is constant and shows the value of the section of the unit of the line, Eq. 1 (David 2000). The p-value is a statistical concept that is used to indicate the probabilistic value and the number that results is used in statistical evaluations in many arithmetic operations. This value is extracted by converting the existing data from an unreadable file to a file that is easy to use in the form of an Excel file after applying many operations. The software, and then the Sigma pilot program were used. The latter is a program that includes many charts and analyses many data, through which, it is possible to draw time series charts for each variable and find the relationship between each variable and vegetation coverage (VEG.COV) in addition to calculating the slope and linear regression value simply (Williams 1992; Mengistu 2021).

Pearson test

The Pearson correlation coefficient (r) is a matrix called the instantaneous correlation matrix. This test includes a series of scatter plots that draw the correlation between two or more variables individually or in the form of groups, which was reached by knowing the type of correlation if it was strong, weak, or medium. It includes two rows, the first row represents the first set of variables or the first column of data, while the second row includes the second set of variables. The third row of the matrix represents the third set of variables or the third data column. In the matrix, for example, the X-axis data for the graphs in the first row of the matrix is taken from the second column of the selected data, while the Y data is taken from the first column of the selected data. The X data of the graphs in the second row of the matrix is taken from the first column of the selected data, whereas the Y data is taken from the second column of the selected data. The data X of the graphs in the third row of the matrix is from the second column of the selected data, the data Y is from the third column of the tested data, etc. The number of graph rows in the matrix equals the number of columns of data being tested (Abbood *et al.* 2021; Al-Timimi *et al.* 2020). Usually, we use Pearson's correlation coefficient (r) to find out the strength of the correlation between two variables, if the top of the correlation t = 1, fully positive correlation, while if the value of the correlation = -1, this means that there is a completely negative correlation. (Nassif *et al.* 2021):

$$r = \frac{\sum_{i=1}^{n}(x_i - \bar{x})(y_i - \bar{y})}{\sqrt{\sum_{i=1}^{n}(x_i - \bar{x})^2}\sqrt{\sum_{i=1}^{n}(y_i - \bar{y})^2}}$$

RESULTS

Analyses of annual VEG.COV, RH (%) and T (ºC) in the selected stations over Iraq during 1988-2018

Fig. 1 illustrates the annual average of four selected stations. These stations were chosen to illustrate the climatic changes that differ from one region to another, as well as the geographical nature of each region. The largest value of vegetation cover was in Baghdad Station which amounted to more than 0.9, followed by Mosul Station (0.8), since these areas encompass a lot of agricultural lands, forests, rain, and little evaporation. The lowest value was recorded at the Basra Station (0.5). In the case of relative humidity, the largest value was in the Mosul Station (45%), where the relative humidity increases in these areas due to a large number of water bodies, so that they maintain temperatures, due to the closeness between night and day. The lowest value was found in Basra Station (33%), since this station is characterized by drought or semi-dry, which increases the evaporation processes and reduces the relative humidity due to the lack of vegetation cover. It was found that during 30 years, Basra Station reached a maximum temperature of 55 ºC due to the large discrepancy in temperatures between night and day. The reason for this discrepancy is the absence of vegetation and water cover in those deserts, in addition to the low relative humidity in the air. The temperature reached 20 ºC in the Rutba and Mosul stations.

Analysis of the monthly average of VEG.COV, RH (%) and T (ºC) in the selected stations over Iraq

Fig. 2 illustrates that the highest value of vegetation cover was in Mosul Station in March, April, and October with a value of 0.8, since this station has evergreen areas of grassland and agricultural land which affects the weather and climate, while the lowest was in the wet station during September and October. In the case of relative humidity, the highest value was found in Mosul Station, reaching 72% in December and January, while the lowest in June, July and August in Basra Station (13%.) Temperature plays an important role in climatic and environmental changes that affect human comfort through the apparent rise in some areas. The maximum temperature values were recorded in June, July, and August in Basra (50 °C) due to desertification and soil erosion. The increased evaporation led to a decline in the vegetation cover in this region. So that, the lowest value was observed in Baghdad and Mosul in December and January (35 °C).

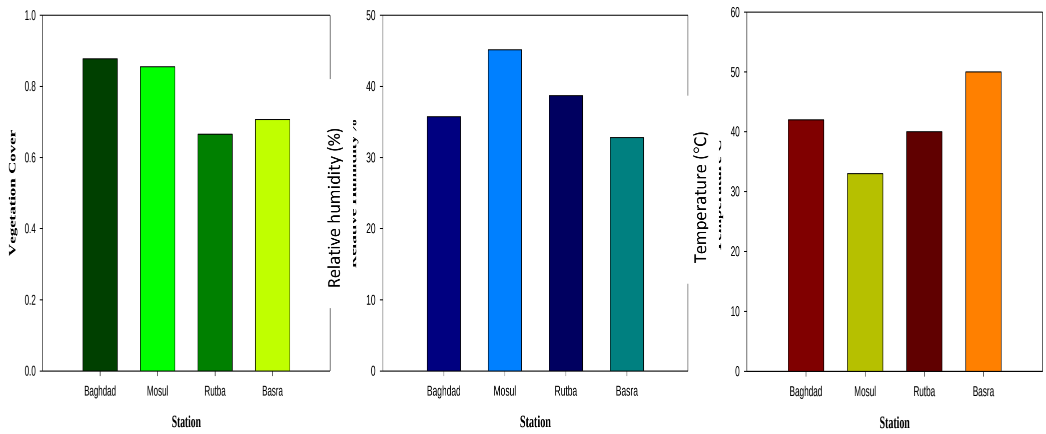

Fig. 1. Annual VEG.COV, RH (%) and T (ºC) in the selected stations over Iraq during 1988-2018.

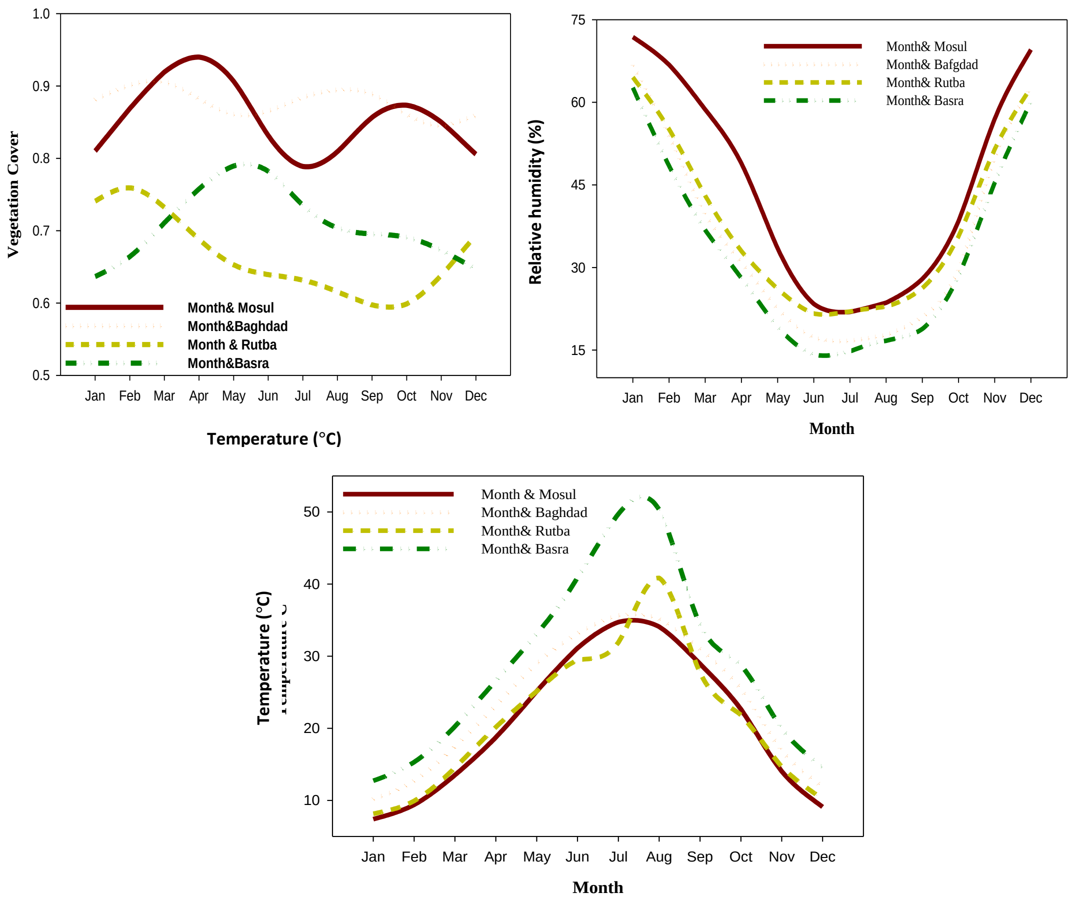

Fig. 2. Monthly mean of the vegetation cover, temperature, and relative humidity in the four stations over Iraq during 1988-2018.

Relationship analysis between vegetation cover and relative humidity in four selected stations in Iraq

Fig. 3 shows that the highest value of vegetation cover was in Mosul Station (0.9) in March and April due to rainfall and lack of solar radiation. In Baghdad City, the highest vegetation cover (0.9) was observed in April and September, while in Al-Rutba station (0.8), it was found in March. The lowest value was recorded in Basra Station (0.5) in July and August. In the case of relative humidity, the highest value was recorded in Mosul Station (covering 72%) which located in the northern regions of the study area. The lowest RH value was also recorded in the Basra Station (62%), exhibiting that the relationship between relative humidity and vegetation cover is positive.

Analysis of the monthly average of vegetation cover and temperature for four selected stations in Iraq

Fig. 4 shows that the maximum monthly average temperature in Basra Station was 50 ºC in June, July, and August and Al-Rutba Station was the second city in terms of temperature, rising to 40 ºC in August. The lowest temperature value during 31 years was found in Mosul Station (32 ºC). The noticeable temperature rise in Basra City exhibited a significant impact on the vegetation cover in the southern regions, where we note that the lowest value of the vegetation cover was 0.7, since Basra experiences a desert climate and is far from water bodies, which influences the regions climate. The desert is very cold in winter, and hot in summer. The highest value of vegetation cover was monitored at a monthly rate of 0.9 in Mosul Station, due to the large presence of water bodies that control high temperatures and humidity in summer. So, the climate in Mosul City is characterized by moderate temperatures in summer, while warm in winter, and finally it was concluded that the relationship between temperature and vegetation is an inverse relationship.

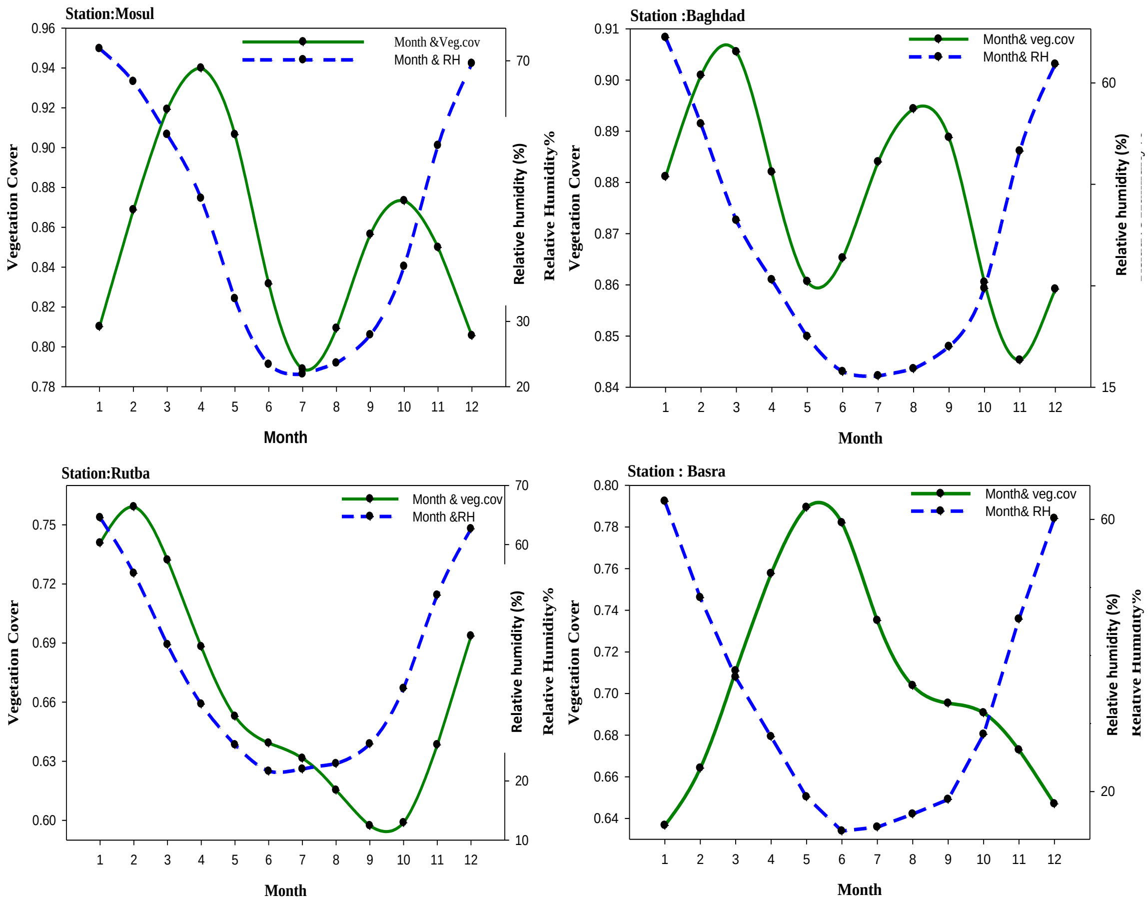

Fig. 3. Relationship between vegetation cover and relative humidity in the four selected stations.

Relationship between the monthly average of RH%, T, and VEG.COV over Iraq

In Figs. 5 and 6 using Pearson's test, it was found that the correlation coefficient between relative humidity and vegetation cover has a strong correlation in all study stations except for Baghdad City due to the erosion of agricultural areas and vegetation cover. As shown in Table 1, overpopulation and desertification led to the highest value of relation between vegetation cover and relative humidity (0.13) in Mosul Station, while the lowest in Baghdad Station. In the case of relationship between temperature and vegetation cover, the highest value was 0.9 in Basra Station, while the lowest in Baghdad (0.03). Consequently, it was found that the relationship between vegetation cover and relative humidity is positive, while is inverse between vegetation cover and temperature.

Spatial analysis

To perform spatial analysis, digital map layers including RH (%), T (ºC), and Vegetation cover were generated by GIS using Kriging's interpolation configuration method in ArcGIS version 10.4.1. The mapping procedure began by converting the geographic coordinates of all sample locations into the global transverse Mercator coordinates. The spatial interpolation maps of the above means in the study area are shown in Figs. 7-9 respectively.

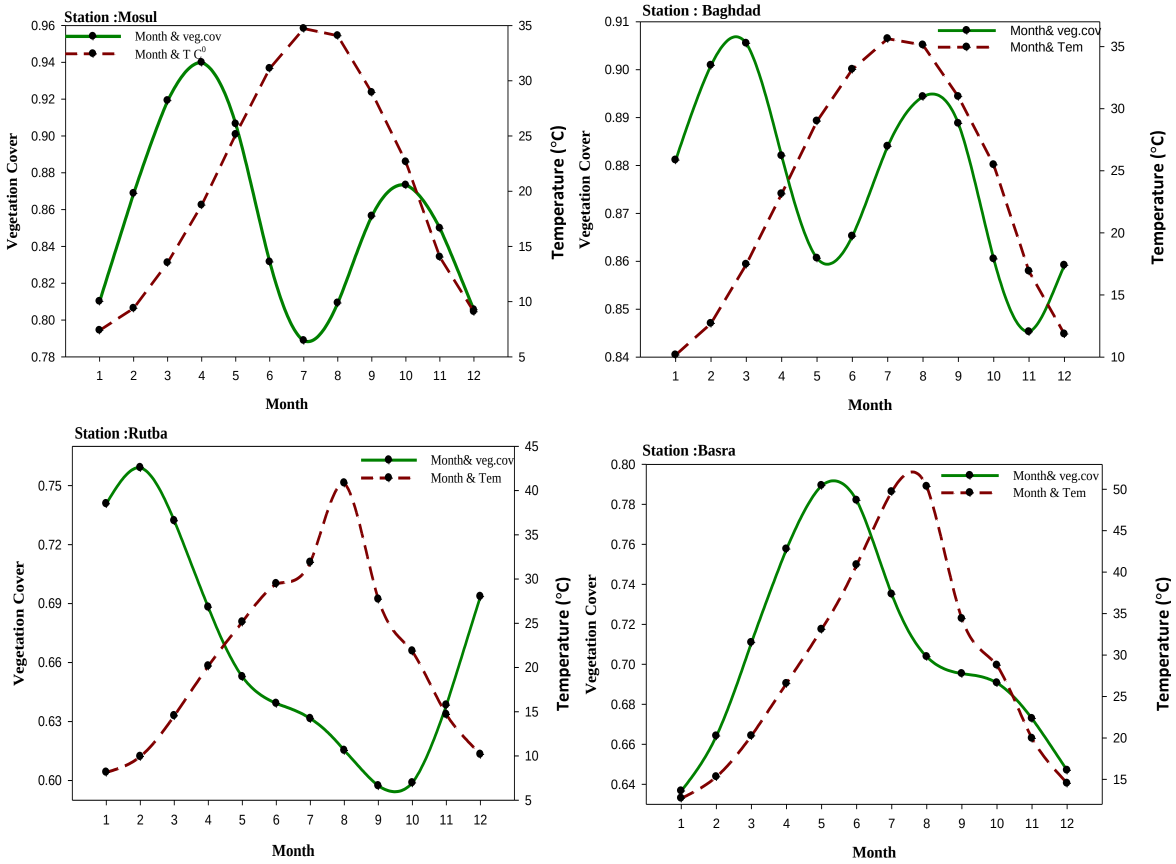

Fig. 4. Relationship between vegetation cover and temperature in the four selected stations.

Table 1. Pearson test for relative humidity, temperature, and vegetation cover for four selected stations in Iraq (Mosul, Baghdad, Rutba and Basra).

Stations	Relationship	**Pearson's test**		**(SLR)**	
		Correlation coefficient (r)	**Correlation degree**	**p-Value**	**Interpret the relationship**
Mosul	RH &VEG.COV	0.13	V. High positive	0.9	Non-Linear
	T & VEG.COV	0.2	Low positive	0.3	Linear
Baghdad	RH & VEG.COV	0.1	Low positive	0.6	Non Linear
	T & VEG.COV	0.03	Low positive	0.9	Non Linear
Rutba	RH & VEG.COV	0.7	V. High positive	0.05	Linear
	T & VEG.COV	0.8	V. High positive	0.001	Linear
Basrah	RH & VEG.COV	0.8	V. High positive	0.001	Linear
	T & VEG.COV	0.6	V. High positive	0.09	Linear

Fig. 7 illustrates spatial analysis of temperatures in the four seasons in Iraq. In summer, the highest value of temperature was 55 °C in the southern and central regions by 68% and the lowest value was 13 °C in the northern and western regions (32%). In winter, the highest temperature value was recorded in the southern regions by 45%, and the lowest in the northern and western regions by 16%. In spring and autumn, the highest value was in the southern and eastern regions (70%), while the lowest in the northern regions. Fig. 8 displays the spatial distribution of vegetation cover over Iraq. In winter, the highest value of vegetation cover was in the northern and central regions (71%), while the lowest in the southern and western regions (23%).

In the autumn and spring seasons, the largest percentage was in Mosul Station in the northern and central regions (33%), while the lowest in the western and southern regions (15%). Fig. 9 shows the spatial distribution of relative humidity in the four seasons over Iraq. In the spring, the highest value was concentrated in the northern regions (55%), while the lowest in the eastern regions (18%). In summer, the highest value of relative humidity was in the southern regions (41%), while the lowest in the northern and eastern regions (17.3%). In autumn, the value was highest in the southern regions (72%), whereas the lowest in the eastern (48%).

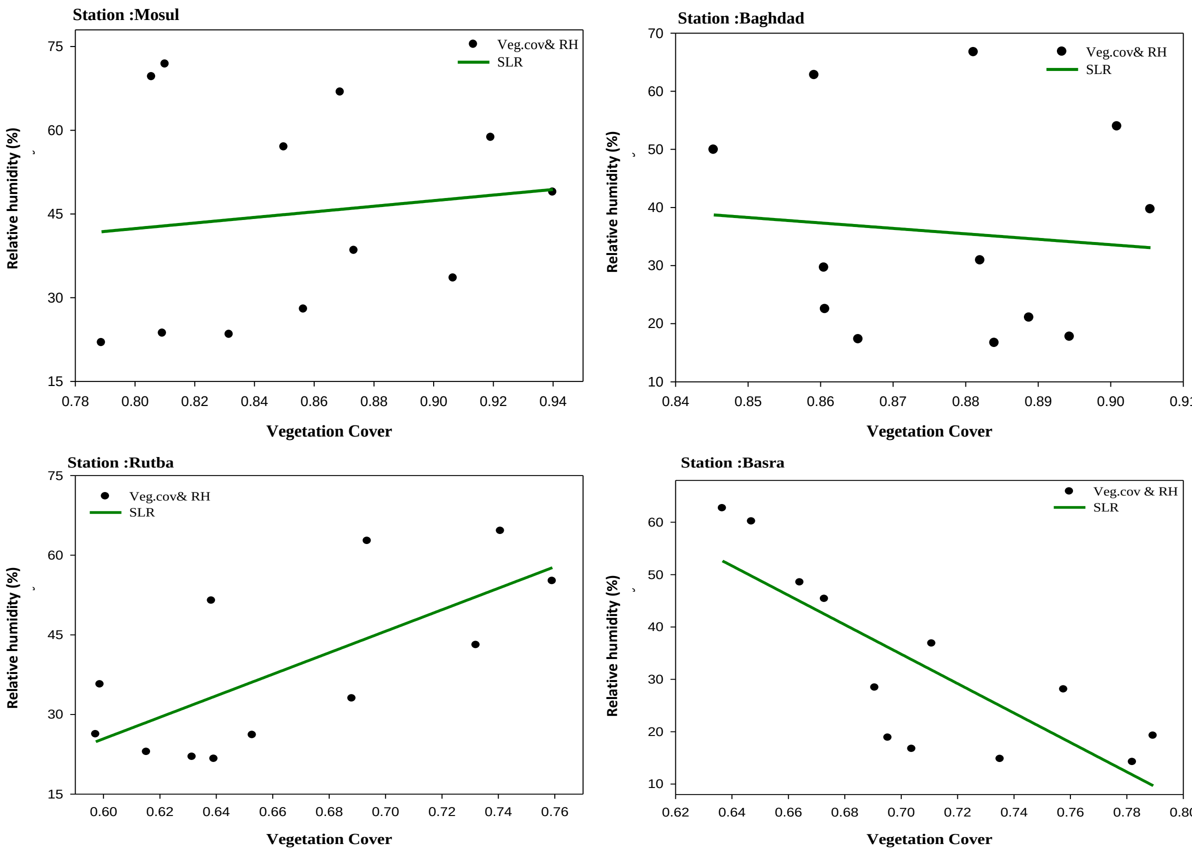

Fig. 5. Relationship between the monthly average between RH (%) and VEG.COV using the Pearson correlation coefficient.

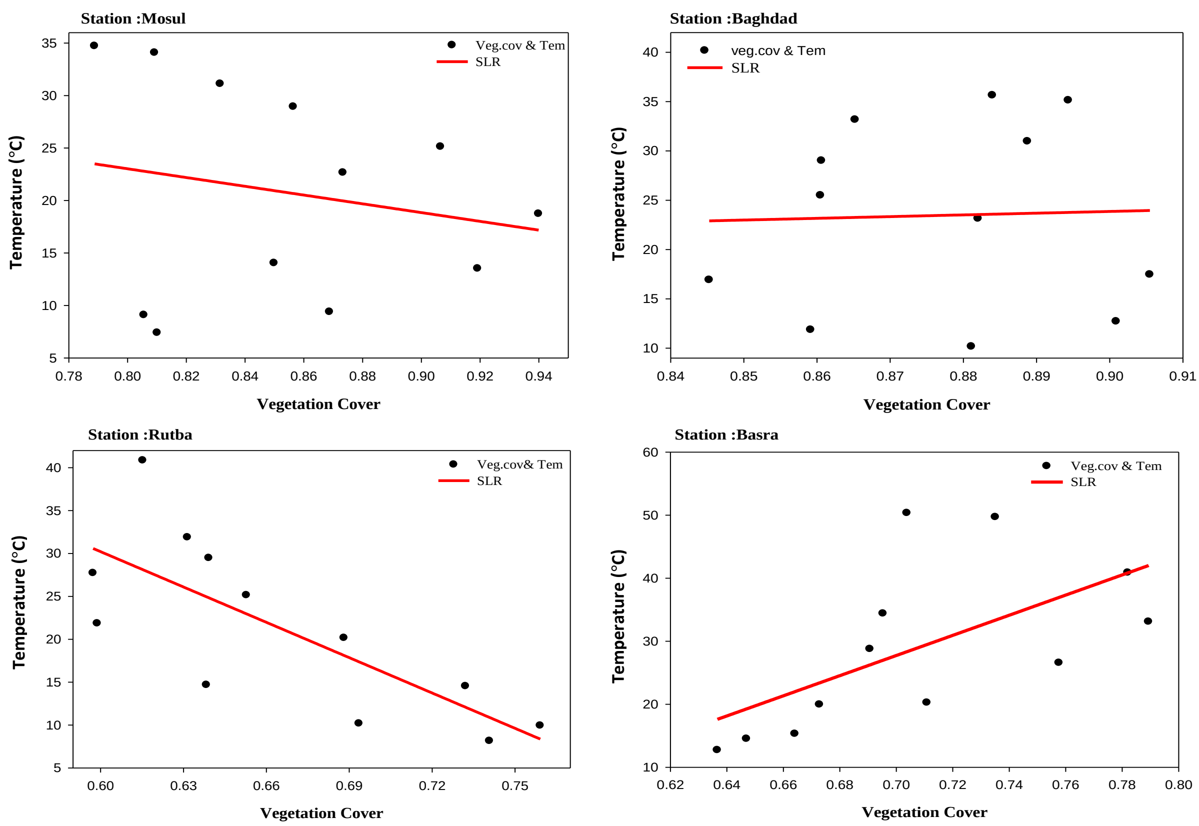

Fig. 6. Relationship between the monthly average between T (ºC) and VEG.COV using the Pearson correlation coefficient.

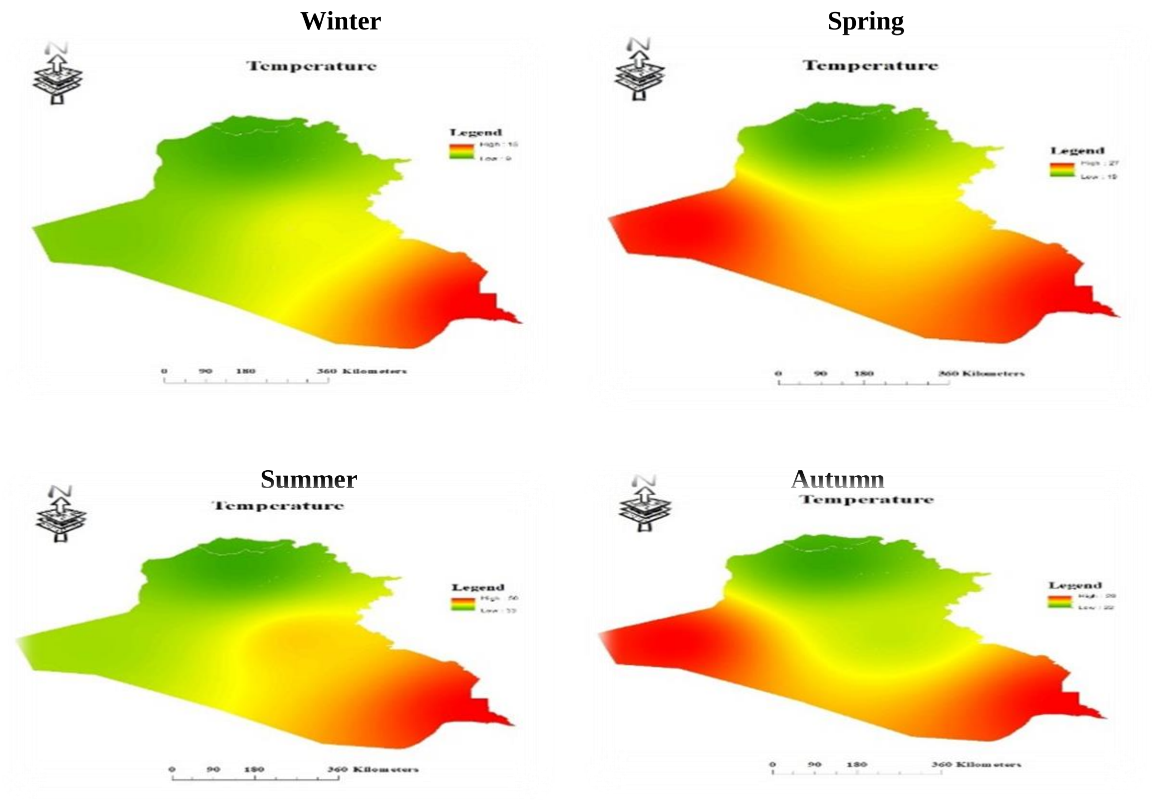

Fig. 7. Spatial seasonal analysis of the temperature in Iraq during 1988-2018.

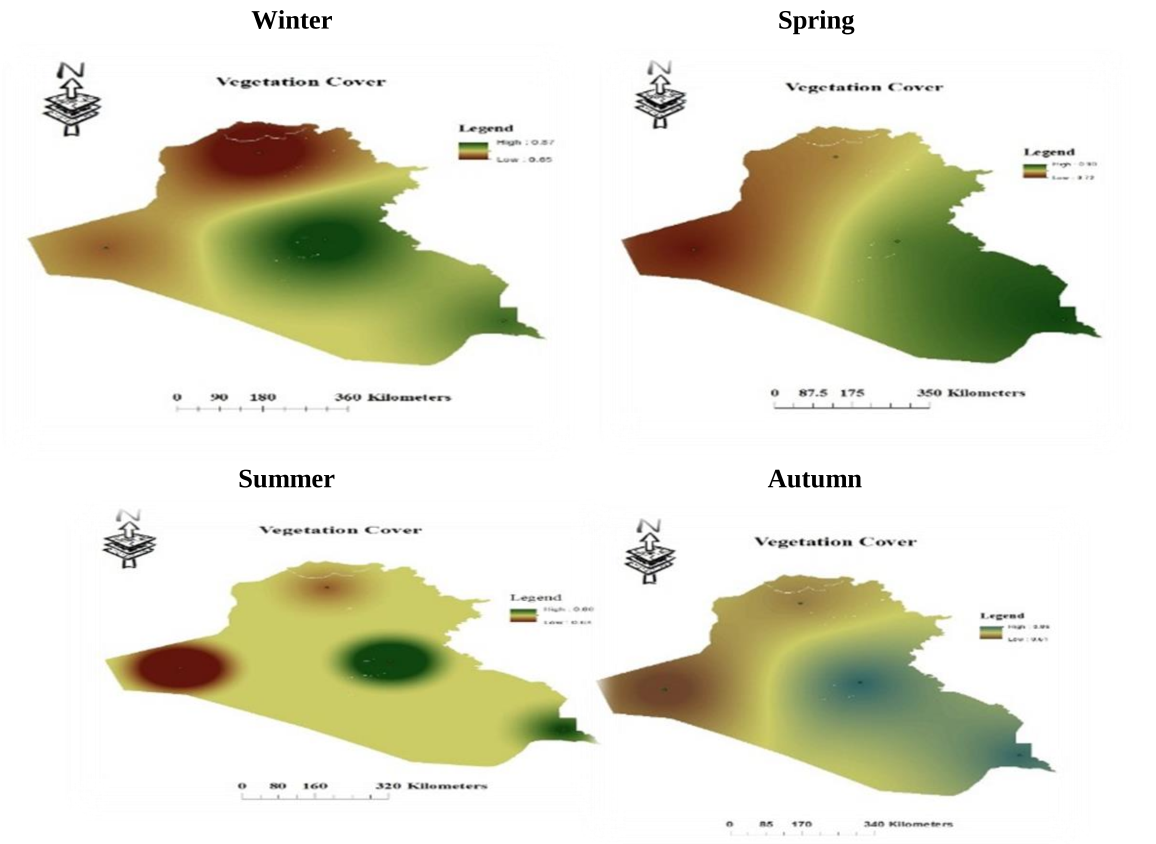

Fig. 8. Spatial seasonal analysis of vegetation cover in Iraq during 1988-2018.

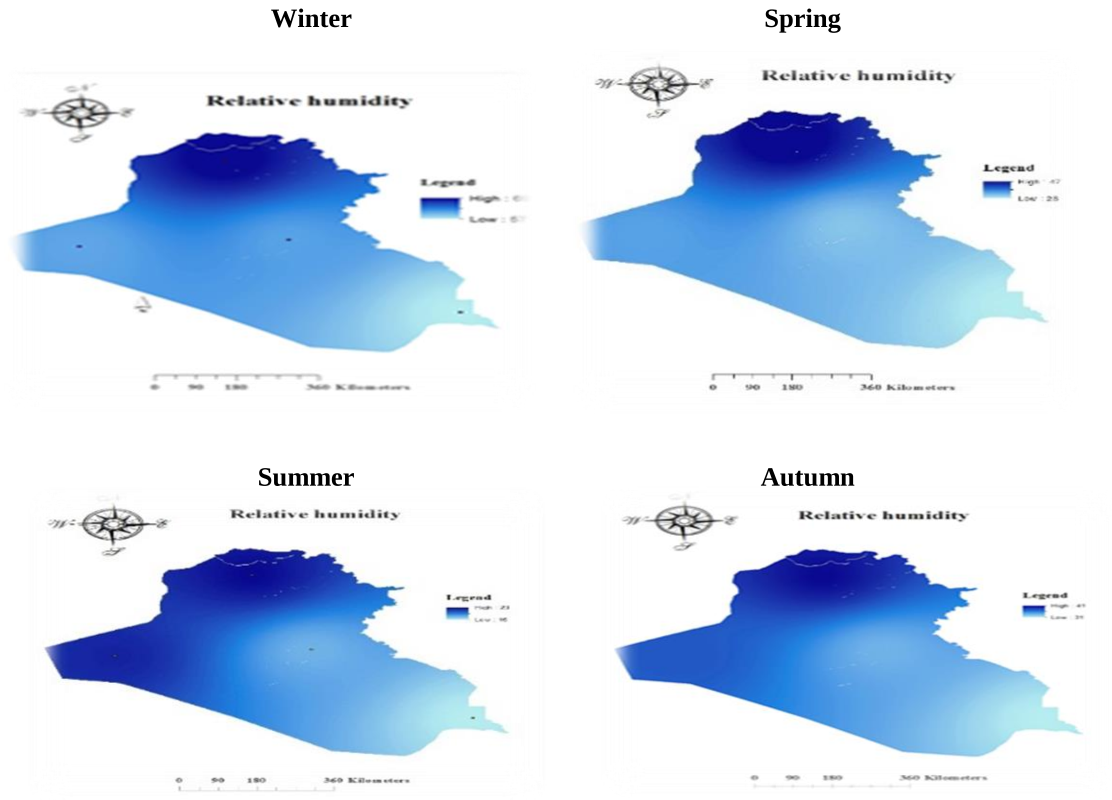

Fig. 9. Spatial seasonal analysis of relative humidity (%) in Iraq during 1988-2018.

DISCUSSION AND CONCLUSION

The highest monthly average of vegetation cover and relative humidity were in Mosul Station, while the lowest monthly average of temperatures was in Basra Station. The spatial analysis shows that the vegetation covers 72% in spring and autumn in all study stations. The inverse relationship was found between temperature and vegetation cover. The correlation strength was weak between temperature and vegetation, while was strong between vegetation and relative humidity. The relationship was positive between vegetation cover and relative humidity.

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