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SPATIOTEMPORAL ANALYSIS OF RELATIVE HUMIDITY USING GIS, IDW INTERPOLATION METHOD AND MANN-KENDAL TEST FOR KURDISTAN REGION OF IRAQ

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ABSTRACT

The spatial and temporal analysis of Relative humidity is very important for climatic variability. Seasonal and annual data for 8 meteorological stations in the Kurdistan region of Iraq (1992-2020) were analyzed to determine the significant trends and magnitude of RH using the Mann-Kendall test and Sens slope with the GIS interpolation method. The spatial analysis shows that the highest values were recorded at the Pirmam station with values of (71.40%) and (52.91%) in the winter season and annual data respectively, while the lowest value was recorded at Akre station of (19.21%) and (41.83%) in summer season and annual data respectively. According to the temporal variations of RH, the significant decreasing trends are found at Akre station at the different confidence levels with the lowest value of (-0.996%/yr) at the 95% confidence level during the winter season. However, in the Erbil, Chamchamal, and Sulaymaniyah stations, substantial positive increasing trends were identified, Chamchamal station has the highest value of (0.780 %/yr) at the 95% confidence level in the winter season. The annual RH trends indicated that Akre, Duhok, Erbil, Chamchamal, and Sulaymaniyah revealed significant increasing and decreasing trends at different confidence levels, Akre station has the maximum dropping trend with the value of (-0.858 %/yr), on the other hand, the maximum rising RH trends of (0.500%/yr) detected at Chamchamal station.

KEYWORDS: Trend, Relative humidity, GIS, Mann-Kendall, Kurdistan Region of Iraq.

I. INTRODUCTION

Climate change has become the most important environmental matter of concern in the last hundred years of the world because of its direct and indirect effects on human life. Global warming is caused by rising greenhouse gas levels in the atmosphere which has a large probability of affecting the hydrological cycle. Temperature is an important factor in identifying climatic change caused by industrialization and urbanization (Wahab 2015). According to the fourth assessment report of the Inter-Governmental Panel on Climate Change IPCC reports and climate scientists, the global average surface temperature has increased by around 0.72 °C between 1951 and 2012(IPCC 2013 According to the report, human activities that increase greenhouse gas emissions are responsible for to increase in average global surface temperature (Stocker et al. 2013).

The main key to understanding the dynamical and radiative aspects of climate change is changes in the atmosphere's humidity (Held IM& Soden 2000). Humidity is the quantity of water vapor in the air, it counts for just around 1/10,000th of the total quantity of water in the universal hydrological cycle. Nonetheless, the most significant factor affecting Earth's weather and climate is the water vapor in the atmosphere, because it has the same greenhouse gas role and the huge quantities of energy transferred when water transitions from gaseous (vapor) to liquid and solid phases. Earth's surface evaporation and plant transpiration are the two primary sources of water vapor in the tropospheric layer. Another source is sunlight-induced methane breakdown in the stratosphere layer (Abu-Taleb, Alawneh, and Smadi 2007). The quantity of atmospheric water vapor is a prospect to rise under conditions of greenhouse-gas-induced warming (Willett et al. 2007).

Some factors affect the temperature and absolute water vapor in the atmosphere, such as the increasing number of residents, human activities, transportation tools, electric generators, industry, factories, petroleum companies, etc, because they are increasing the number of atmospheric greenhouse gases. The number of residents of the Kurdistan region-Iraq has increased rapidly and heavily in recent years, resulting in a significant increase in greenhouse gas emissions, which contribute to global warming.

The relative humidity is defined as the proportion of the actual amount of water vapor pressure existent in the air to its saturation water vapor pressure at a given temperature and pressure. Hence, it can be expressed by the symbol (RH) (Callahan, Elansari, and Fenton 2019). It has a large influence on cloud formation, fog, and smog, as well as also has an impact on atmospheric vision (Ahrens 2000). Moreover, humidity is the most serious dangerous factor in the global because it influences changes in precipitation intensity and geographical distribution (Wentz et al. 2007). These changes have directly and indirectly dangerous impacts on human health patterns and psychology. The changes climate system has indirect impacts, such as heatwaves intensity stress-related mental health issues, reduced cold-related mortality, humanitarian and economic crises, and so on (Kim, Kabir, and Ara Jahan 2014). In addition, it affects environmental natural disasters such as earthquakes, volcanic eruptions, hurricanes, tsunamis, floods, droughts, etc(Morsy and El Afandi 2021). Atmospheric relative humidity depends on the absolute water vapor quantity and temperature. Relative and absolute humidity has the potential to be extremely useful tools in climate study (Abdulwahab 2015).

The study and analysis of long-time period trends in hydro-climatic variables and the evaluation of their statistical importance are basic tools in global climate change discovery (Huth and Pokorná 2004). Global climate change and its impacts had been widely researched around the world in the recent past. Studies had been published throughout the world, including in Iraq, to discover changes in the relative humidity trends, (Van Wijngaarden and Vincent 2004) Evaluated Canada's relative humidity trends from 1953-to 2003 and discovered the relative humidity has significantly reduced across the country. (Abu-Taleb, Alawneh, and Smadi 2007) discovered increasing trends of relative humidity at various stations in Jordan using statistical analysis and this upward trend is statistically significant in the summer and fall seasons. (Talaee, Sabziparvar, and Tabari 2012) Analyzed an increase in relative humidity and dew point temperature in northern and southern Iran's coastal regions by (1.03 and 0.28% /decade,0.29 and 0.15°C /decade) respectively over the period 1966-2005. (Frimpong, Oosthuizen, and Van Etten E 2014) concluded that the trends of relative humidity are decreased seasonally and annually in Binduri and Garu, while manga showed an upward trend throw the period 1961 and 2012. (You et al. 2015) discovered that the yearly relative humidity had dropped by nearly 23% over the last decade in the Tibetan Plateau's east and center for the period 1961–2013. (Nourani, Danandeh Mehr, and Azad 2018) statistically examined a drop in precipitation and relative humidity trends, as well as a rise in temperature at the Urmia Lake basin during the period 1971–2013. (Eymen and Köylü 2019) concluded that the relative humidity increased in the spring, summer, and fall seasons around the Yamula Dam in Turkey. (Denson, Wasko, and Peel 2021) showed that Australia's average relative humidity had decreased by about -1% / decade throughout all of Australia during the period 1955–2020, (Abdulwahab 2015) concluded that in most regions of Iraq spatially in northern parts the monthly and annual trends in relative humidity have been noticeably declining during the period 1951-2010. (Muter et al. 2020) used geographic information system (GIS) to analyze the seasonal and annual relative humidity in Iraq for the (1980-2017) period, he found a decreasing trend in relative humidity in the north, west, and east regions of the study area.

The main goal of this study was to use a geographic information system (GIS) interpolation method, the Mann-Kendall statistical test, and Sen's slope estimator techniques to analyze the spatial and temporal trends of seasonal and annual mean relative humidity of 8 stations in the Kurdistan Region -Iraq depending on the data of meteorological stations.

II. STUDY AREA AND DATA

The study area is focused on the Iraqi Kurdistan region. It is situated in the north part of Iraq, the geographical coordinates of the Kurdistan region are approximately between longitudes (43° and 46°

) East and latitudes (35°N and 37°) North in the Northern Hemisphere. It shares boundaries with Turkey in the (northern), Iran(eastern), Syria (western), and other the governorates of Iraq (southern) as shown in figure (1).

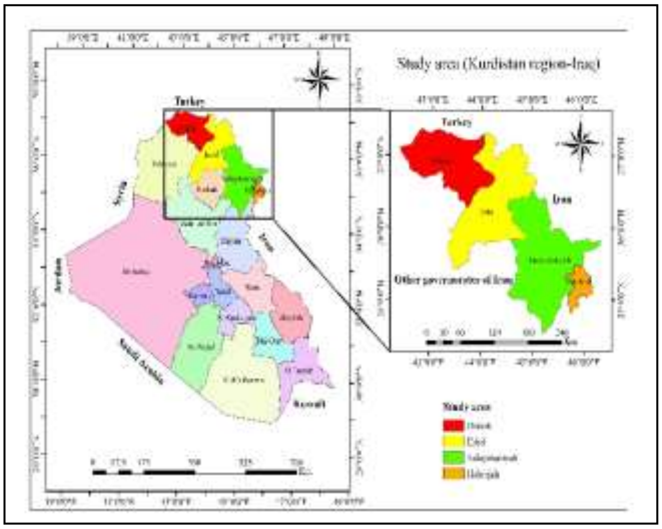


Fig. 1. Study area (Kurdistan Region of Iraq).

Generally, Iraq has extensive mountainous regions covering the north and north-eastern parts of the country, while the plain region goes from the center to the southern area, with the desert covering the western area, as well as the two largest rivers Tigris and Euphrates pass through Iraq, they are travel from the northwest to the southeast of Iraq (Al-Khalidi et al. 2020). The most influential water bodies in Iraq are the Mediterranean Sea and the Arabian Gulf because these water bodies have an obvious and strong influence on Iraq's climate and thermal characteristics, and they are observed by location (Al-Timimi and Al-Khudhairy 2018). The study area has a continental climate, which is hot and dry in summer, while it is cold and rainy in winter, and the spring and autumn are short transitional seasons (MUSTAFA 2018). For the current study, the monthly and annual mean relative humidity data of the eight selected stations have been obtained from the Erbil General Directorate of Meteorology and Seismology (EGDMS). Fluctuations in monthly and annual mean relative humidity were analyzed using the GIS method, non-parametric Mann-Kendall statistical test, and Sen's slope estimator technique. The consequences of the Digital Elevation Mapping (DEM) confirmed that the Kurdistan region-Iraq has a variety of natural elevations. Because Kurdistan-Iraq was surrounded by the biggest and highest mountains along its borders, the study's highest regions are found around the Turkey and Iran borders. On the other hand, the lowest regions are observed in the western part of it. The geographic coordinates in the Iraq Kurdistan region are demonstrated in Figure (2) and Table (I).

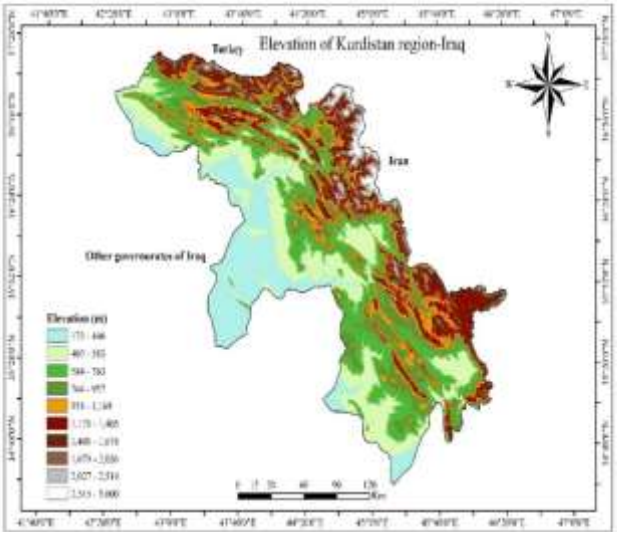


Fig. 2. Digital elevation map (Dem) of the Kurdistan region of Iraq.

TABLE I. Geographical coordinates of Iraq Kurdistan region stations in the present study

Weather station	Longitude (Degree)	Latitude (Degree)	Elevation (m)
Akre	43°52'	36°44'	636
Amedi	43°29'	37°05'	1195
Duhok	42°59'	36°55'	569
Zakho	42°40'	37°09'	433.8
Erbil	43°59'	36°11'	470
Pirmam	44°11'	36°23'	1088
Chamchamal	44°49'	35°31'	710
Sulaymaniyah	45°26'	35°33'	884.8

III. MATERIAL AND METHODOLOGY

The non-parametric Mann-Kendall statistical test is the most extensively utilized technique in climate time series analysis, including relative humidity, temperature, precipitation, evaporation, wind speed, wind direction, sunshine, etc(Adeeb and Al-Timimi 2020; Djaman et al. 2020). The Mann–Kendall trend test and Sen's slope estimator were used to analyze the seasonal and annual relative humidity data in the current study. The study of relative humidity trends in the study area was carried out in two steps; The first step was to use the Mann-Kendall non-parametric test on both seasonal and annual relative humidity data series to evaluate whether there was a rising, declining, or non-existent trend (Maurice G Kendall 1938; Mann 1945; M G Kendall 1975). The magnitude of the trend was assessed in the second step using Sen's slope estimator (Sen 1968). MAKE SENSE uses both the so-called S statistics and the normal approximation Z statistics to calculate this statistical test. When the number of observation years is smaller than 9, the test statistic S is applied and greater than this value, giving us the empty cell, but the test statistic Z is applied for ten or more years, which less than 10 years display an empty cell (Gilbert 1987). It can give us an important indicator of whether or not the time series has a trend. The MK test requires an assumption of normalcy, but it only indicates the direction of significant trends, not their magnitude. The Mann-Kendall trend test has different levels of significance: 0.001, 0.01, 0.05, and 0.1, from a high level of statistical significance to a level of insignificance. They mean 99.9%, 99%, 95%, and 90% confidence levels (Salmi et al. 2002). The spatial and temporal variations in relative humidity were analyzed using Excel programs. The MAKESENS template was applied to analyze trends using the MK test. The variations in mean relative humidity, Z, and Q values in the Iraqi Kurdistan region were interpolated spatially and temporally using the IDW and unique values of symbology techniques in GIS, which are two well-known methods inside ArcGis or ArcMap.

Over the last few years, GIS software has been widely used in a variety of fields, including scientific studies, climatology and meteorology, and assessment of the environment (Yavuz and Erdoğan 2012). The component's enhancements to GIS functions also are beneficial to software developers to meet the requirements of visualization and analysis of spatial and temporal data in meteorology. It would be beneficial for software and application developers to have a programming library that included both GIS and meteorological data analysis functions (Muter et al. 2020). According to several researchers, interpolation methods have been employed to evaluate the magnitude of variations in spatial and temporal meteorological parameters in different regions of the world, in relative humidity (Muter et al. 2020), minimum temperature (Al-Timimi and Al-Khudhairy 2017), Precipitation (Nabi, and Wu 2021; Buba, Kura, and Dakagan 2017; Gajbhiye et al. 2016; Hussain, Yavuz and Erdoğan 2012), wind speed (Adeeb and Al-Timimi 2020).

Mann originally proposed the Mann–Kendall test (Mann 1945), and Kendall later developed it(M G Kendall 1975). For determining time series direction, Mann-Kendall has been suggested by the World Meteorological Organization (Mitchell et al. 1966). These techniques have several important benefits that make them useful for meteorological data series analysis. Extreme values are permitted since the data does not have to be consistent with a specific distribution in the nonparametric methods. This technique is extremely important since it allows for missing data. It is more resistant to outliers and can deal with missing values (Wilcox 1998). It allows the integration of trace data instead of numeric values because it has the smallest measured value. In time series analysis, it is not required to identify whether the trend is linear or not. If the number of data points is fewer than nine, the MK trend test of a series RH1, RH2,... RHn is computed as follows:

$$\mathrm{S} = \sum_{\mathrm{a}=1}^{\mathrm{n}-1} \sum_{\mathrm{b}=\mathrm{a}+1}^{\mathrm{n}} \mathrm{sgn}\,(\mathrm{RH_b} - \mathrm{RH_a}) \qquad (1)$$

In the relationship mentioned above, n is the number of observation years, then, (RH_b and RH_a) are the consecutive seasonal and annual values in the years (a and b) when a > b. A symbol (sgn) is used to represent a sign function and can be computed in the following way (Nair and Mirajkar 2021):

$$\mathrm{sng}(\mathrm{RH_a} - \mathrm{RH_b}) = \begin{cases} +1 & \text{if } (\mathrm{RH_a} - \mathrm{RH_b}) > 0 \\ 0 & \text{if } (\mathrm{RH_a} - \mathrm{RH_b}) = 0 \\ -1 & \text{if } (\mathrm{RH_a} - \mathrm{RH_b}) < 0 \end{cases} \qquad (2)$$

Inside the study area, all meteorological stations have over 10 years of observation, and the variance is calculated using the following formula:

$$\mathrm{Var}\ (\mathrm{S}) = \frac{1}{18}\left[n\,(n-1)(2n+5) - \sum_{c=1}^{d} t_c(t_c-1)(2t_c+5)\right] \qquad (3)$$

In the preceding relationship, the number of sequences is denoted by d, while the repetition of data having equal values is shown by t_c. The Z-test statistic is calculated using VAR(S) as described in the following (Mohsin and Lone 2021):

$$\mathrm{Z} = \begin{cases} \frac{s-1}{\sqrt{Var(S)}} & if\ s > 0 \\ 0 & if\ s = 0 \\ \frac{s+1}{\sqrt{Var(S)}} & if\ s < 0 \end{cases} \qquad (4)$$

To determine the trend of a data series, If $|Z| > |Z_{1-\propto/2}|$, the no-trend null hypothesis is rejected, and the null hypothesis is the one that is accepted if $Z \leq Z_{\propto/2}$, where Z is the trend's significance measure and $\propto$ is the level of significance. The positive and negative Z-test statistics results show an upward and downward trend in the data series, respectively.

Sen's slope method was used to evaluate the size of the trend in the seasonal and annual relative humidity data. All data pairs' slope ($\mathrm{RH_i}$) is calculated by the following formula:

$$\mathrm{RH_i} = \frac{\mathrm{RH_a} - \mathrm{RH_b}}{\mathrm{a} - \mathrm{b}} \qquad (5)$$

In the previous formula, observed relative humidity data are expressed sequentially in $\mathrm{RH_a}$ and $\mathrm{RH_b}$ at times (a and b). The positive Q_i the result indicates an upward trend in the time series, whereas the negative Q_i the result indicates a downward trend.

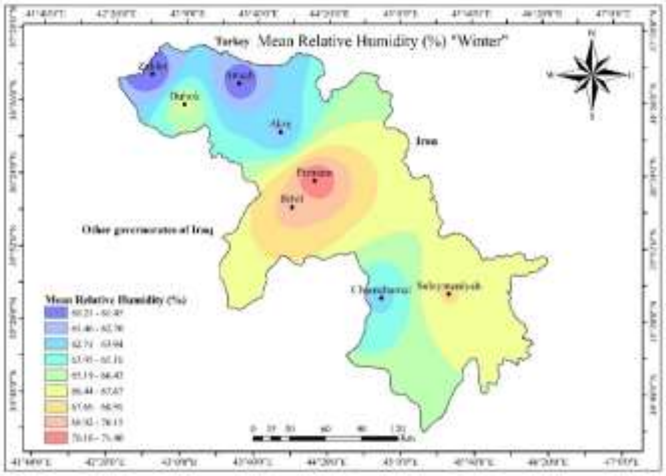
$$Q_i = \begin{cases} RH_{\frac{(N+1)}{2}} & \text{if N is odd} \\ \frac{1}{2}\left(RH_{\frac{N}{2}} + RH_{\frac{N+2}{2}}\right) & \text{if N is even} \end{cases} \qquad (6)$$

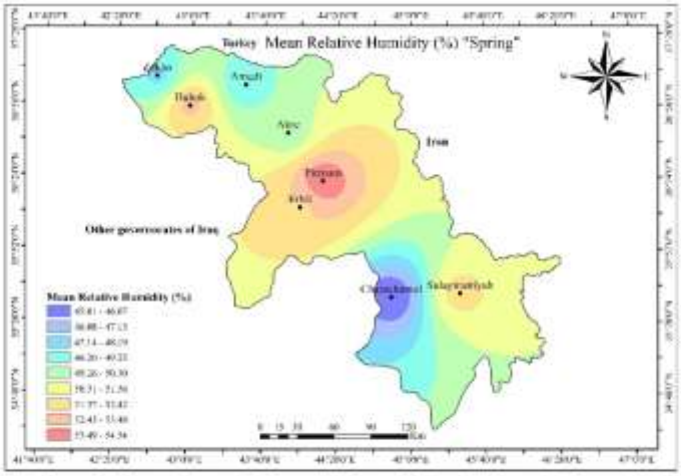
IV. RESULTS AND DISCUSSION

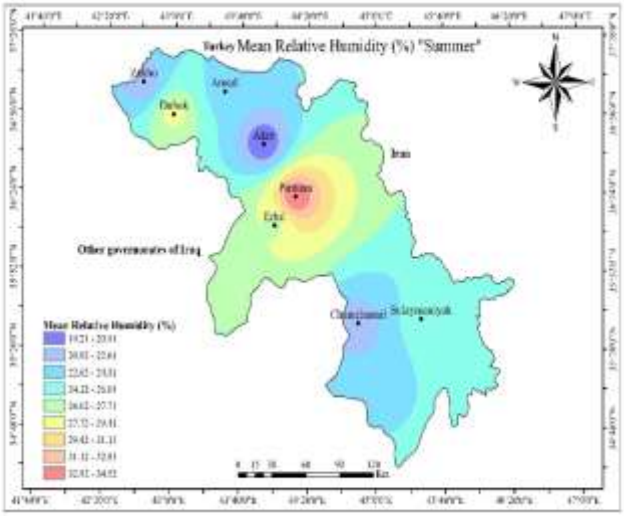
A. Spatial Analysis

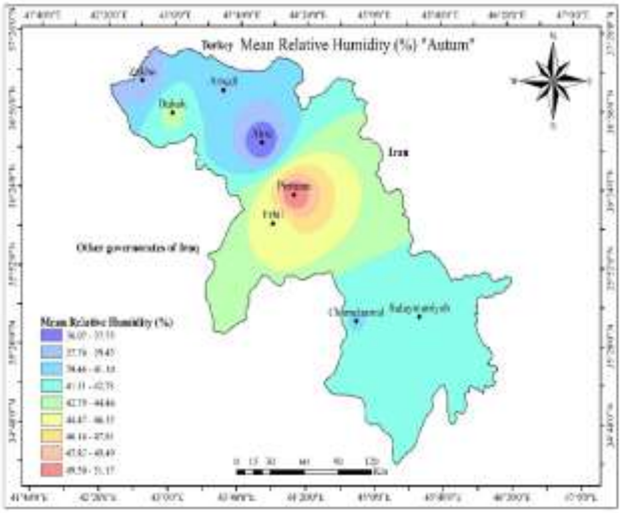
Seasonal and annual relative humidity (RH) averaged over the Kurdistan region of Iraq during the period (1992-2020) is shown in figure (3). The Geographical Information System (GIS) was used to map the spatial distribution of annual and seasonal relative humidity for the study area, these maps were analyzed by the inverse distance weight (IDW) interpolation method.

The minimum and maximum mean values of relative humidity that have been recorded at Zakho and Pirmam stations are (60.21% and 71.4%) in winter, respectively. While relative humidity levels declined across the study area during the spring season, the least humidity level was 45.01 % at Chamchamal station, but inside other stations, the greatest level of relative humidity appeared at Pirmam station at 54.54%. In the summer season, the values of relative humidity were extremely diminished at all weather stations, Akre and Pirmam stations successive had the lowest and highest relative humidity values (19.21% and 34.52%). At all stations, the amount of relative humidity rose dramatically throughout the autumn season, with the least and greatest relative humidity values being observed at Akre and Pirmam, consecutively (36.07% and 51.17%). According to meteorological data, the smallest and biggest annual mean relative humidity values at Akre and Pirmam stations were reported in order (41.83% and 52.91%). Overall, it can be noted that the lowest relative humidity is observed in the years at Akre, Zakho, and Chamchamal stations. Nevertheless, during the past years, the highest relative humidity values have been recorded at Pirmam station. The results of the study concluded that the Iraqi Kurdistan region had the highest relative humidity in the winter months in all the parts because it is a cold and rainy area. On the other hand, the lowest relative humidity is noted during the summer months due to the dry and hot climate of this region.


Turkey
Mean Relative Humidity (%) "Winter"
Zakho
Amadi
Duhok
Akre
Iran
Pirmam
Erbil
Other governorates of Iraq
Chamchamal
Sulaymaniyah
Mean Relative Humidity (%)
Km


Turkey
Mean Relative Humidity (%) "Spring"
Zakho
Amadi
Duhok
Akre
Iran
Pirmam
Erbil
Other governorates of Iraq
Chamchamal
Sulaymaniyah
Mean Relative Humidity (%)
Km


Turkey
Mean Relative Humidity (%) "Summer"
Zakho
Duhok
Amedi
Akre
Iran
Pirmam
Erbil
Other governorates of Iraq
Chamchamal
Sulaymaniyah
Mean Relative Humidity (%)
19.21 - 20.81
20.82 - 22.61
22.62 - 24.21
24.22 - 26.01
26.02 - 27.71
27.72 - 29.41
29.42 - 31.11
31.12 - 32.81
32.82 - 34.52
0 15 30 60 90 120 Km


Turkey
Mean Relative Humidity (%) "Autum"
Zakho
Duhok
Amedi
Akre
Iran
Pirmam
Erbil
Other governorates of Iraq
Chamchamal
Sulaymaniyah
Mean Relative Humidity (%)
36.07 - 37.78
37.79 - 39.45
39.46 - 41.10
41.11 - 42.78
42.79 - 44.46
44.47 - 46.15
46.16 - 47.81
47.82 - 49.49
49.50 - 51.17
0 15 30 60 90 120 Km

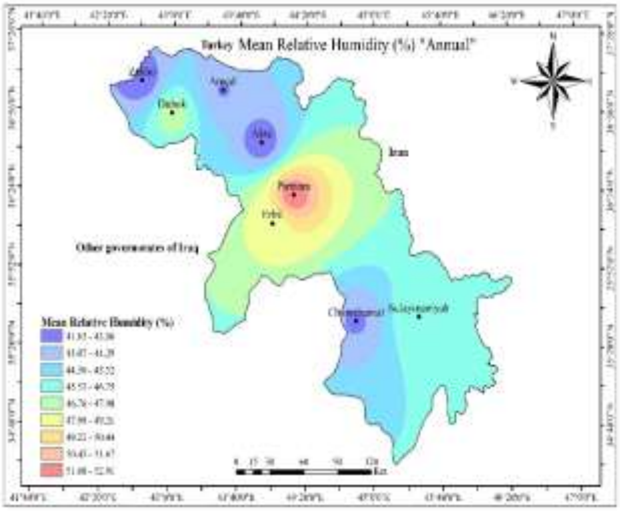


Fig. 3. Shows the spatiotemporal variability of annual and seasonal relative humidity in Kurdistan, Iraq (%).

B. Temporal Analysis

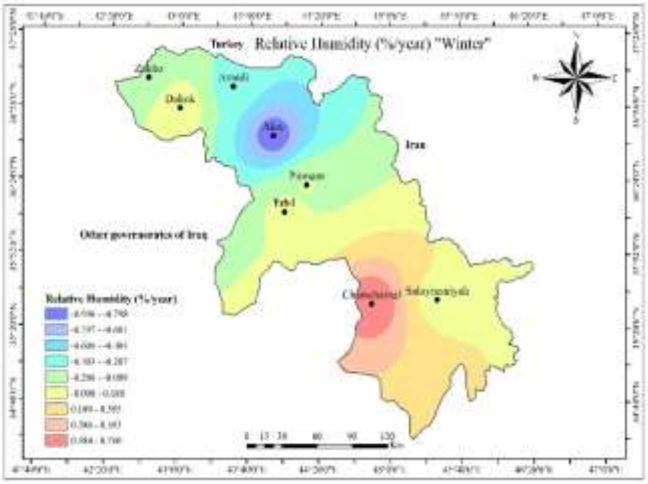
In the second part, the findings of the correlation coefficient (Z) and Sen's slope (Q) for the time series of seasonal and annual relative humidity values for all stations have been explained, as shown in figs. (4). On a seasonal and annual basis, positive and negative values of both Z and Q statistics show an increasing /decreasing trend in relative humidity. The values of Z and Q have risen in five and reduced in three stations, with the lowest value at Akre (Q=-0.996%/year) and the highest at Chamchamal (Q=0.780%/year) in the winter months. Significant down and up trends at 95% confidence levels were found in RH of Akre and Chamchamal only, whereas trends were positive and negative in the other stations, they were statistically insignificant.

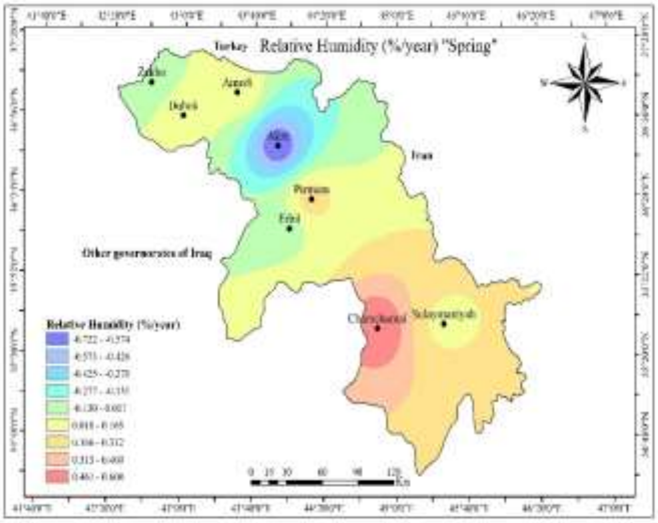
Different values of Z and Q throughout the spring showed different directions of increase and decrease, and the smallest value of Q has been found at Akre station (Q = -0.722%), but at Chamchamal station the biggest value of Q was noticed (Q = 0.608%), at 99 % confidence level. At other stations, a downward and upward trend in relative humidity can be observed, while it is not statistically significant.

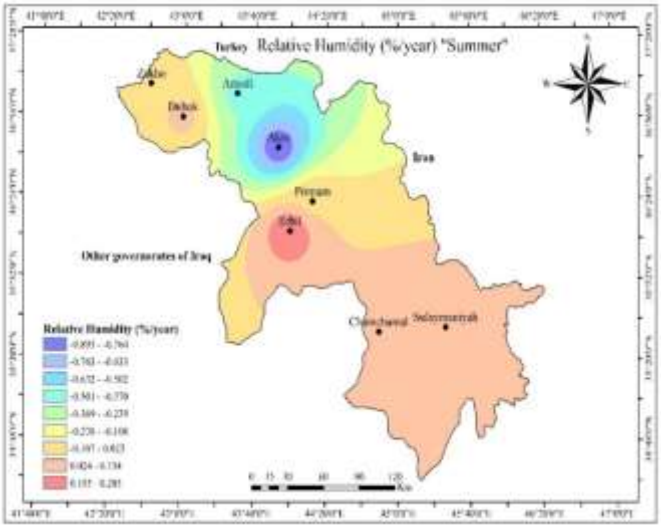
During the summer season, distinct values of Z and Q were confirmed to have varied directions of rising and fall, with the least value of Q discovered also at Akre station (Q = -0.895%/year) and the largest value of Q found at Erbil station (Q = 0.285%/year). The tendency for the relative humidity to drop consecutively for Akre and Amedi is significant at the 99.9% and 99% confidence levels. On the other hand, the Erbil station shows a significant uptrend only at the 99.9% confidence level. Except at the above stations, rising and lowering insignificant relative humidity trends were noticed at the remaining stations. According to the Autumn season, estimated values of both Z and Q statistics indicated various rising and diminishing directions have been found, where the minimal and maximal values of Q were detected successively at Akre and Sulaymaniyah stations (Q = -0.957%/year and Q = 0.349%/year). At the 90%/year confidence level, the tendency for the relative humidity to decrease in Akre was significant. In contrast, the Erbil and Sulaymaniyah stations showed a significant upward trend at the 95% confidence level.

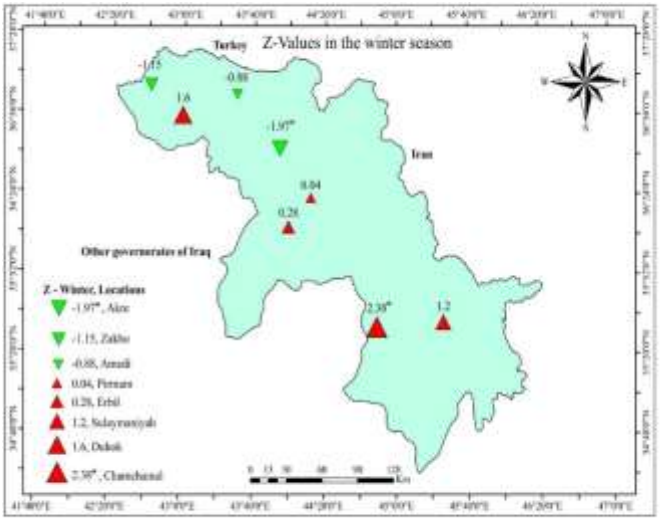
Annually, both Z and Q parameters have changed across all regions. However, the smallest and largest values of Q were sequentially displayed at the Akre (Q = -0.858%/year) and Chamchamal (Q = 0.500%/year) stations. The negative trend in relative humidity for Akre was significant at the 99%/year confidence level. However, the stations of Duhok, Chamchamal, Sulaymaniyah, and Erbil exhibited a significant positive trend at 90%/year and 95%/year confidence levels. At the remaining stations, insignificant trends upwards and downwards in relative humidity have been reported.

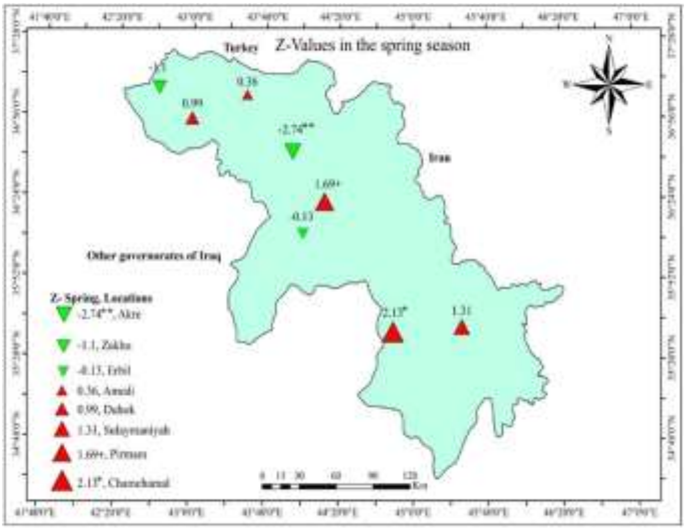
Generally, the results disclosed that relative humidity has decreased in Akre station over seasons and years at the different confidence levels. In contrast, the relative humidity quantity grew at the Erbil station during the summer months. It has risen at the Chamchamal station throughout the winter, spring, and annually. In addition, at the Sulaymaniyah station, the rate of relative humidity showed an increment within the autumn months. Moreover, the lowest and highest rates of relative humidity were recorded at the Akre (Q= -0.996 %/year) and Chamchamal (Q= 0.780 %/year) stations in the winter season respectively, with a confidence level of 95%.

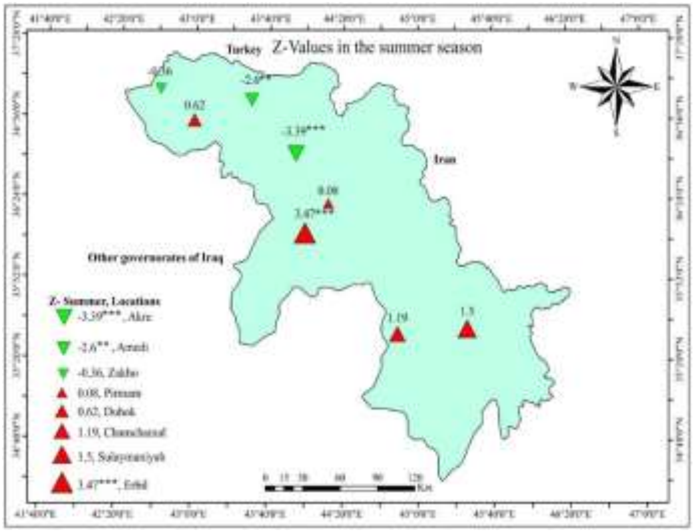


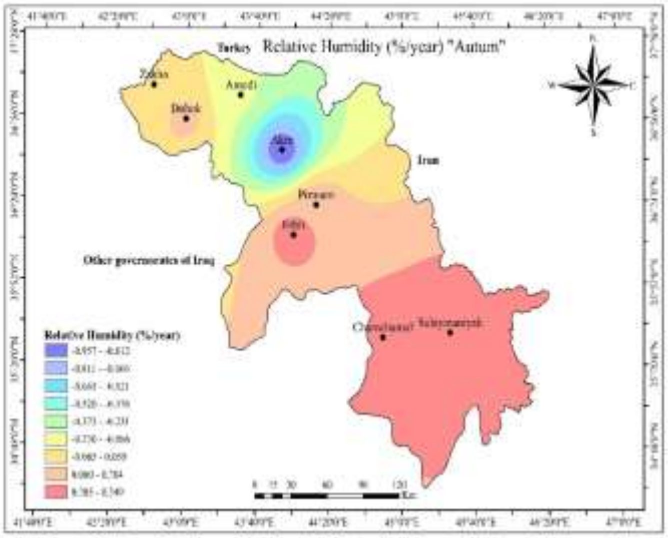

Relative Humidity (%/year) "Spring"
Turkey
Iran
Other governorates of Iraq
Zakho
Amedi
Duhok
Akre
Pirmam
Erbil
Chamchamal
Sulaymaniyah
Relative Humidity (%/year)
0
15
30
60
90
120
Km
N
W
E
S

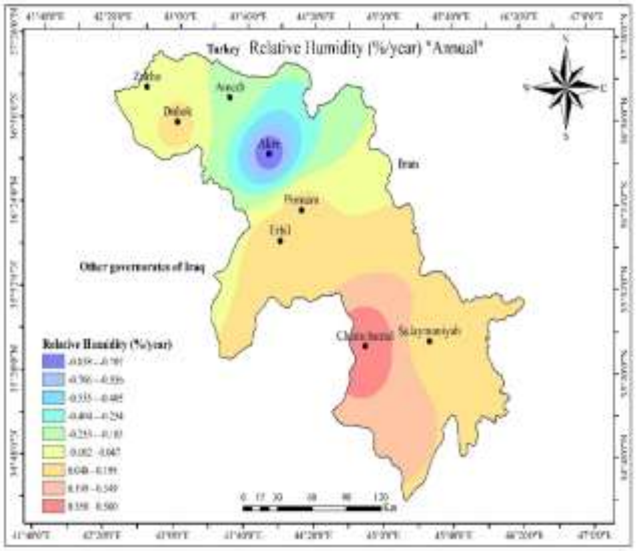

Relative Humidity (%/year) "Summer"
Turkey
Iran
Other governorates of Iraq
Zakho
Amedi
Duhok
Akre
Pirmam
Erbil
Chamchamal
Sulaymaniyah
Relative Humidity (%/year)
0
15
30
60
90
120
Km
N
W
E
S


Z-Values in the winter season
Turkey
Iran
Other governorates of Iraq
-1.15
1.6
-0.88
-1.97*
0.04
0.28
2.38*
1.2
Z - Winter, Locations
-1.97*, Akre
-1.15, Zakho
-0.88, Amadi
0.04, Pirmam
0.28, Erbil
1.2, Sulaymaniyah
1.6, Duhok
2.38*, Chamchamal
0 15 30 60 90 120 Km
N
S
W
E


Z-Values in the spring season
Turkey
Iran
Other governorates of Iraq
-1.1
0.36
0.99
-2.74**
1.69+
-0.13
2.13*
1.31
Z- Spring, Locations
-2.74**, Akre
-1.1, Zakho
-0.13, Erbil
0.36, Amadi
0.99, Duhok
1.31, Sulaymaniyah
1.69+, Pirmam
2.13*, Chamchamal
0 15 30 60 90 120 Km
N
S
W
E


Z-Values in the summer season
Turkey
Iran
Other governorates of Iraq
-0.36
-2.6**
0.62
-3.39***
0.08
3.47***
1.19
1.5
Z- Summer, Locations
-3.39***, Akre
-2.6**, Amadi
-0.36, Zakho
0.08, Pirmam
0.62, Duhok
1.19, Chamchamal
1.5, Sulaymaniyah
3.47***, Erbil
0 15 30 60 90 120 Km
N
S
W
E





V. CONCLUSION

The present research focuses on seasonal and annual variations of relative humidity at eight stations in the Kurdistan region of Iraq. The average RH of seasonal and annual trends was analyzed using the MAKESENS template, Mann–Kendall test, and Sen's slope estimator. On the other hand, the inverse distance weighting (IDW) interpolation method of (ArcGIS) (version 10.4.1) was used to show RH maps of the study area. The spatial results of mean seasonal RH showed that the greatest value is recorded in the winter season with a value of (71.40%) at Pirmam station, while the smallest value was recorded in the summer season at (19.21%) at Akre station. According to the annual analysis, the highest RH value was 52.91% at Pirmam station and the lowest was 41.83% at Ake station. The results of the temporal analysis showed that the seasonal RH trends have significant negative declining trends at Akre station at the different confidence levels, with the lowest trend detected at Akre station during the winter season.

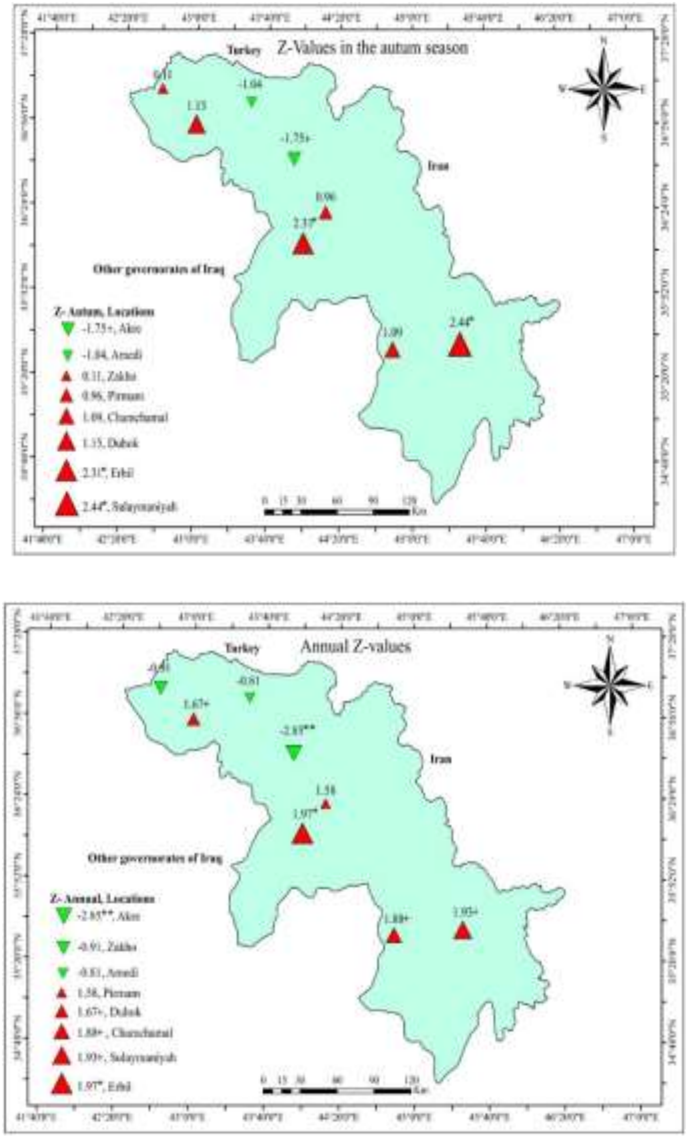


Fig. 4. Seasonal and annual Z with Q values of the study area.

of (-0.996%/year) at 95% confidence level. However, significant positive increasing trends were observed at the Erbil, Chamchamal, and Sulaymaniyah stations, with the highest increase trend in Chamchamal station during the winter season of (0.780%year) at 95% confidence level. The annual analysis of the RH time series revealed that the Akre station has a maximum dropping trend value of (-0.858%/year) at the 99% confidence level. On the other hand, it has a maximal increasing trend in Chamchamal station by (0.500%/year) at 90% confidence level.

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