ARIDITY INDEX BASED ON TEMPERATURE AND RAINFALL DATA FOR KURDISTAN REGION-IRAQ

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1. ABSTRACT

Aridity index is a numerical indicator of the degree of dryness of the climate at a given location. Time series of annual precipitation, minimum and maximum temperature records for 22 meteorological stations in Kurdistan region-Iraq were collected from different agencies. In Kurdistan region-Iraq neither aridity index non it's trend have been studied, therefore the purpose of this paper is to document the range of an aridity index, called De Martonne's aridity index (I_{DM}) and to find the trend of aridity index using Mann-Kendal nonparametric test.

Spatial zoning of the region was done using inverse distance weight (IDW) interpolation method by ArcGIS software. Results showed that different types of climate in the region were appeared however most of the study area falls in the range of semi-arid zone. Seasonal aridity showed that Kurdistan region-Iraq has extremely humid climate in winter and arid climate in summer. The De Martonne aridity index, average precipitation and average temperature were drawn for 10, 20 and 30 years according to availability of the data. Aridity index for 30 years from De Martonne were compared with two other indices and the results were very close. Trend analyses were performed for precipitation, temperature, and aridity index for the average data of 10, 20, and 30 years. Results revealed that for 10 year duration Dukan temperature has significant increasing trend at the 95% confidence level. It can be concluded that the last decade (2006-2015) undergo insignificant increasing in precipitation and temperature. For 20 year duration Dukan and Hawler temperature showed significant increasing trend at the 95% confidence level. For 30 year duration all stations temperature increased, Dukan precipitation showed decreasing trend while Dukan aridity index showed increasing trend significantly at the 95% confidence level. Increased significant trends at the 95% confidence level for temperature appears at both short and long durations (10, 20 and 30 years) while precipitation and aridity index trends appear only in long duration (30 years).

KEY WORDS: Aridity Index, Kurdistan, Spatial distribution. Temporal trend, Climate Change, GIS.

2. INTRODUCTION

Aridity is a known term that most people understand, and it evokes images of dry, desert lands with sparse natural surface-water bodies and precipitation (Maliva, Robert, Missimer, & Thomas, 2012). Arid and semiarid regions of the world are highly sensitive to human-induced climate and/or land transformation (Evans & Geerken, 2004). Estimation of aridity pattern has a major effect on global climate change. The arid and semiarid regions comprise almost 40% of the world's land surfaces. These sites, which are currently at the limit with respect to available water resources, are likely to be most sensitive to climate change (Vicente-Serrano, Cuadrat-Prats, & Romo, 2006), (Arora, Sairam, & Srivastava, 2002), and (Some'e, Ezani, & Tabari, 2013) .Water is going to be the major limiting factor for the healthy functioning of ecosystems, especially agriculture production worldwide (Lobell, Schlenker, & Costa-Roberts, 2011).The long-term average of the aridity computed on a yearly basis quantifies the degree of climatic dryness of a region.

Aridity, as defined by the shortage of moisture, is essentially a climatic phenomenon that is based on average climatic conditions over a region (Agnew & Anderson, 1992). Many numerical have been proposed to quantify the degree of dryness of a climate at a given location, and thus define climatic zones. De Martonne aridity index (1926) is an aridity-humidity index that uses precipitation and temperature as inputs and can be applied locally. . Emberger (1930) devised an index to categorize aridity which includes the mean annual range of temperature and shows a direct relation to evaporation (Quan, Han,

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Utescher, Zhang, & Liu, 2013).Thornthwaite classification (1948) is another major index and it is calculated using water deficiency and water need as inputs. Additionally, the Pinna Combinative Index (IP) which also uses precipitation and air temperature as inputs constitutes an index mainly applied in areas where irrigation is necessary since it takes into account the precipitation and air temperature of the driest month (Zampakas J., 1992). Finally, the United Nations Environment Program aridity index (Arnold, 1992), constitutes a numerical indicator of the degree of dryness of the climate at a given location and uses precipitation and potential evapotranspiration data. The chosen proxy (e.g. precipitation, evapotranspiration, and soil moisture or stream flow) and time scale can strongly affect the ranking of aridity classification over a certain area (Sheffield J., Andreadis, Wood, & Lettenmaier, 2009).

Several attempts have been made over the past decade to analyze the rainfall in the region, Rasheed (2010) analyzed rainfall records for nine metrological stations in the north of Iraq using standard precipitation index (SPI) and concluded that 56% of the study period were drought years (Rasheed, 2010). Al-Faraj et al (2015) explored drought and analyzed indicated climate change-induced alterations in transboundary Diyala watershed presenting a generic technical template to support decision-makers for management in transboundary watersheds (Al-Faraj, Scholz, Tigkas, & Boni, 2015). Şarlak and Mahmood Agha (2017) showed that arid and semi-arid regions cover about 97% of the country areas (Iraq) and it was observed that the aridity index tend to decrease for all stations used in the study. (Şarlak & Mahmood Agha, 2017).

In general, aridity severity trends have not been fully investigated in Kurdistan region-Iraq yet. This paper develops to spatial mapping the precipitation, temperature, and aridity index based on temporal variation of meteorological parameters such as temperature, precipitations and, these parameters being analyzed as De Martonne aridity index. In addition trend analysis of precipitation, temperature, and aridity index were performed which will be of interest to future water resources management and to find the potential influence of climate change on natural and environmental resources of the region.

3. STUDY AREA AND DATA USED
3.1 Study Area

The study area in this research is located at the, Kurdistan region-Iraq, between 42.33 and 46.58 E longitudes and 34.5 and 37.37 N latitudes. The region shares its borders with Syria in the west, Turkey in the north and Iran in the east. The elevation of the region changes from 3601m above mean sea level at the north east and to 134 m above mean sea level at the south west, with an approximate area of $45km^2$ as shown in Fig.1. The climate of Kurdistan region-Iraq is hot and dry in summer and cold and wet in winter, with short spring and autumn seasons compared to summer and winter (Rasheed, 2010).

3.2 Data Used

The climatological data used in the analysis concern monthly values of precipitation, maximum, minimum, and mean air temperature collected from 22 meteorological stations (General Authority of weather and seismic monitoring in Baghdad, General Directorate of meteorological and seismology of Erbil, Directorate of meteorological and seismology of Sulaimani, Department of meteorological and agriculture in Bakrajo) as shown in Table 1 and Fig. 2. Missing data were estimated by the average value of the other years observed at the same station (Huang, et al., 2015).

Table(1):-Meteorological stations and their characteristics.

| No.	Stations	Latitude N	Longitude E	Elevation in (m) above mean sea level	Years	Average Precipitation mm	Average Temperature C°
1	Sulaimani	35. 559	45. 4298	884. 8	1941-2015	715	19
2	Musl	36. 3649	43. 1639	223	1975-2015	352	20
3	Kirkuk	35. 4685	44. 3889	350	1975-2015	336	23
4	Hawler	36. 1966	44. 0000	470	1982-2015	406	22
5	Dukan	35. 9702	44. 9629	690	1984-2015	672	20
6	Duhok	36. 8686	42. 9538	569	1992-2015	562	20
7	Permam	36. 3881	44. 2076	1088	1992-2015	583	18
8	Darbandikhan	35. 1111	45. 6976	485	1996-2015	561	22
9	Zakho	37. 1459	42. 6736	440	1998-2015	544	21
10	Semeel	36. 868	42. 8453	416	1997-2015	428	20
11	Chamchamal	35. 53	44. 8200	710	2000-2015	430	20
12	Amedy	37. 0955	43. 5004	1200	2001-2015	832	15
13	Hallabja	35. 166	45. 9943	621	2002-2015	682	21
14	Zawita	36. 9052	43. 1361	848	2002-2015	805	16
15	Penjwen	35. 6327	45. 9531	1309	2004-2015	1032	14
16	Chwarta	35. 7175	45. 5672	1128	2004-2015	693	17
17	Bazian	35. 5981	45. 1400	829	2004-2015	582	18
18	Akre	36. 7444	43. 8835	636	2005-2015	620	20
19	Makhmur	35. 7811	43. 5773	254	2007-2015	195	23
20	Shamamk	36. 5082	43. 8396	338	2007-2015	290	21
21	Kanimasi	37. 2279	43. 4104	1250	2002-2015	960	14
22	Kalar	34. 63	45. 3272	200	2009-2015	254	36
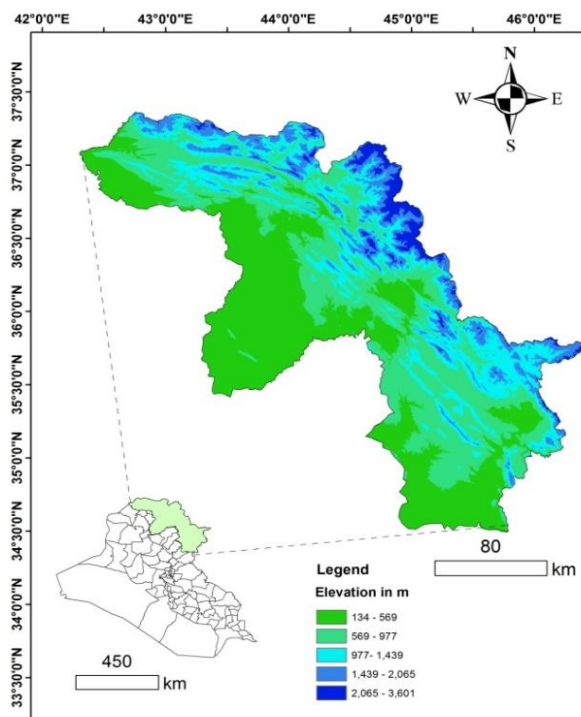
Fig.(1):- Study area (Kurdistan Region-Iraq).
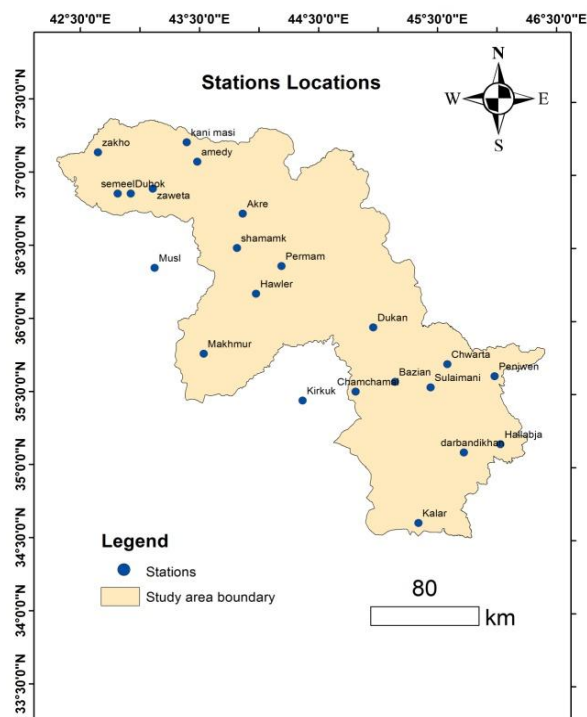

Fig.(2):- Locations of meteorological stations

4. METHODOLOGY

A variety of aridity indices have been formulated and none of them is appropriate for all uses. The data availability also limited the

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application of all aridity indices. The following are some of the indices used in the study which depends on precipitation and temperature only.

4.1 De Martonne Aridity Index

In the current study, De Martonne aridity Index (I_{DM}) was selected in order to estimate the aridity conditions. This index is the appropriate one for characterizing and projecting future aridity conditions. It has been proven to be very useful for planning and managing agricultural production (Ramachandran,, Praveen, Jaganathan, & Palanivelu, 2015). It was also found that the (I_{DM}) led to a more precise definition climate due to its more climate categories (Tabari, Talaee, Nadoushani, Willems, & Marchetto, 2014). A measure of aridity of a region, proposed by De Martonne (1926), is given by Eq. 1, (Baltas, 2007):

$$Aridity\ Index\ (I_{DM}) = \frac{P}{(T + 10)} \ \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots \ (1)$$

In which P is the annual mean precipitation (mm) and T is the annual mean air temperature (C^o). For seasonal aridity, the index was calculated as in Eq.2 (Croitoru, Piticar, Imbroane, & Burada, 2013)

$$Aridity\ Index\ (I_{DM\ Seasonal}) = \frac{4(P_s)}{(T_{as} + 10)} \ \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots \ (2)$$

In which P_s is the seasonal amount of precipitation (mm) and T_{as} is the mean seasonal air temperature (C^o) for the analyzed season. Seasonal aridity index was also calculated using De Martonne aridity index based on the average seasonal precipitation and temperature. The boundaries that define various degrees of aridity are involved as shown in Table 2, (Croitoru, Piticar, Imbroane, & Burada, 2013).

Geographical Information Systems (GIS) used for the spatial modeling of precipitation, temperature, and aridity index at various time scales using inverse distance weight (IDW) interpolation method. The interpolation methods are grouped into two main types: deterministic methods and geostatistical methods. The deterministic methods, such IDW and spline, are based on specified mathematical formulas, while the geostatistical ones, such as kriging, are based on statistical models that use autocorrelation in order to explain territorial variation (Apaydin, Sonmez, & Yildirim, 2004).In the current study the inverse distance weighted methodology was applied which uses information concerning the spatial structure of the data by giving relatively large weights to data close to the interpolation point, while those far away exert little influence (Chen & Liu, 2012).

Table(2):- De Martonne's aridity index classification. *(Baltas, 2007)*

I_{DM}	Climate Classification
I_{DM} <10	Arid
10≤ I_{DM} <20	Semi-arid
20≤ I_{DM} <24	Mediterranean
24≤ I_{DM} <28	Semi- humid
28≤ I_{DM} <35	Humid
35≤ I_{DM} ≤55	Very -humid
I_{DM} >55	Extremely -humid

4.2 Emberger Aridity Index

Emberger index is based on the mean annual precipitation and mean temperature of both the coldest and hottest months and is determined using the formula (Oliver, 2005)：

$$IE = \frac{100 * P}{M^2 - m^2} \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots. (3)$$

Where,

P = Annual average rainfall (mm)

M = Average temperature of the hottest month (° C)

m = Average temperature of the coldest month (° C)

The boundaries that define various degrees of aridity are involved as shown in Table 3

Table(3):- Climate types of Emberger *(Oliver, 2005)*

Aridity index *IE*	Climate type

>90	Humid
50-90	Sub-humid
30-50	Semiarid
<30	Arid

4.3 Thornthwaite Aridity Index

Thornthwaite precipitation effectiveness index PE is based on temperature and precipitation, defined by the formula (Mendez, 2006):

$$PE = \sum_{1}^{n=12} 115 * \left(\frac{P}{T-10}\right)^{10/9} \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots (4)$$

Where,

P = Monthly precipitation (inches)

T = Temperature (°F), n = months = 12

The boundaries that define various degrees of aridity are involved as shown in Table 4.

Table (4):- Thornthwaite climate classification *(Mendez, 2006)*

PE Index	Climate Type
<16	Arid
16-31	Semi-arid
32-63	Sub-humid
64-127	Humid
>127	Wet

4.4 Trend Analysis

Annual aridity indices were used to generate the trend lines of the aridity index versus time. The detection of trends in precipitation, temperature and aridity time series was performed using the nonparametric Mann–Kendall (M-K) test at 5% significance level and the software XLSTAT. The M–K test is superior in detecting both linear and nonlinear trends (Hisdal, Stahl, Tallaksena, & Demuth, 2001). Moreover Theil-Sen line is used to estimate the slope of the trend. According to this test, the null hypothesis (H_0) equals the non-existence of trend (in the time series), whereas the alternative hypothesis (H_1) equals the existence of trend (Şarlak & Mahmood Agha, 2017).

If a linear trend is present in a time series, then the true slope (change per unit time) can be estimated by using a simple nonparametric procedure developed by Sen (1968).The slope of the Theil-Sen line will be significantly different from zero when Kendall's tau is significantly different from zero and vice versa (Drápela & Drápelová, 2011).

5. RESULTS AND DISCUSSION

5.1 Spatial zoning of Annual Aridity Index, Precipitation, and Temperature

The De Martonne aridity index, average annual precipitation and average annual temperature were drawn for 10 (2006-2015), 20 (1996-2015), and 30(1986-2015) years as shown in (Figure 3, Figure 4, and Figure 5), (Figure 6, Figure 7, and Figure 8) and (Figure 9, Figure 10, and Figure 11) respectively. Depending on the available data only five stations have 30 years available data, eight stations have 20 years available data, and 19 stations have 10 years available data.

Regarding aridity index for 10 years duration there are different types of climate in the region however most of the study area falls in the range of semi-arid zone and the aridity index rang was from 6 to 42 for Makhmur and Penjwen stations respectively. In addition, for 20, and 30 years there are only two types of climate appears and most of the study areas falls in the range of semi-arid and Mediterranean zone. In terms of maximum aridity conditions, the study reveals that the most critical (maximum) aridity index values were reported in 2006, 2013, and 2015, while the minimum aridity index values were reported in 2008, 2009, and 2010.
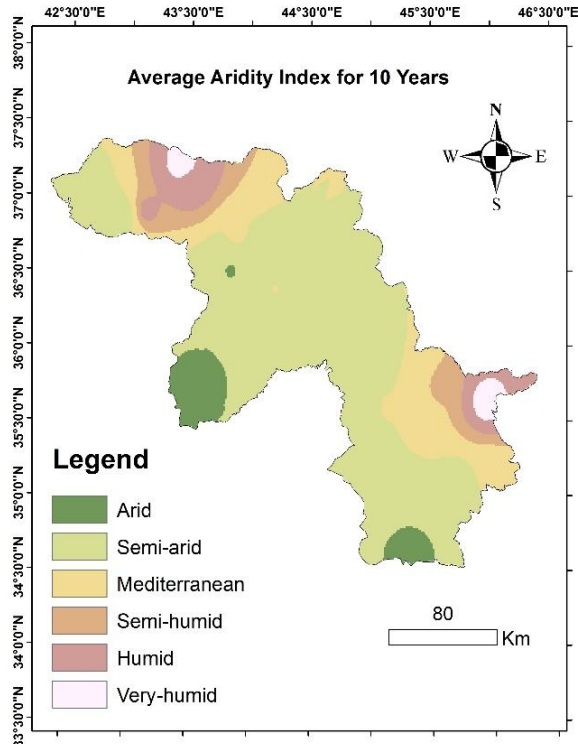
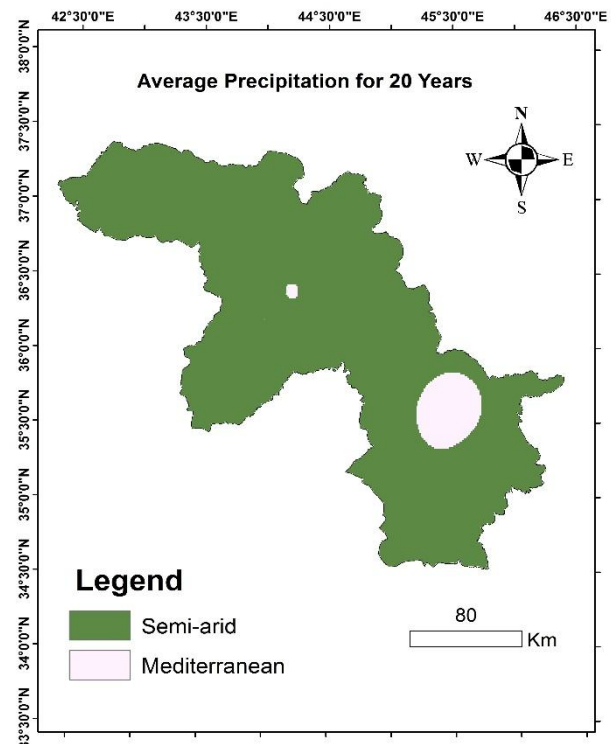**Fig. (3):-** Spatial zoning for aridity index for 10 years.

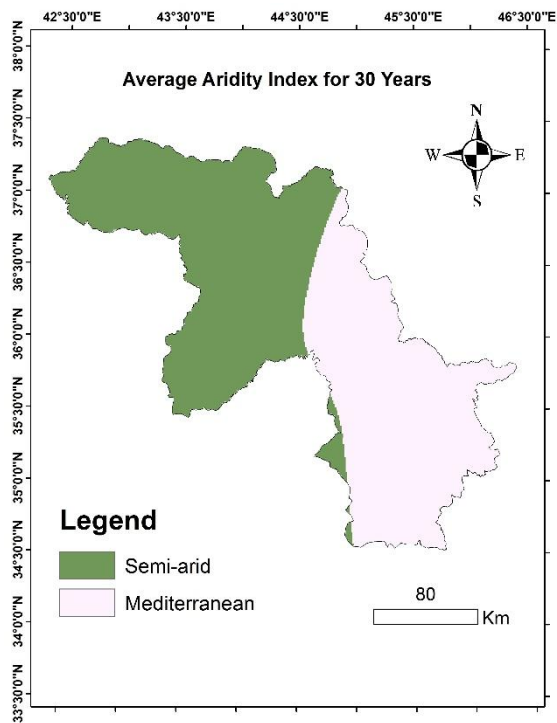**Fig.(4):-** Spatial zoning for aridity index for 20 years.

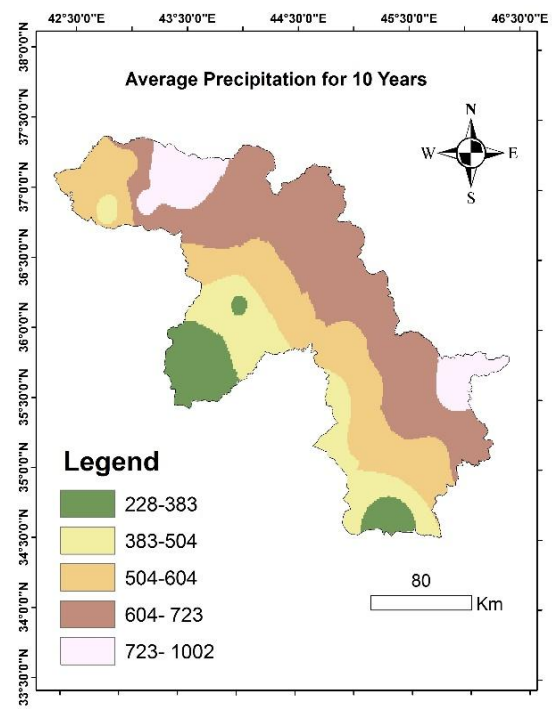**Fig.(5): -**Spatial zoning for aridity index for 30 years.

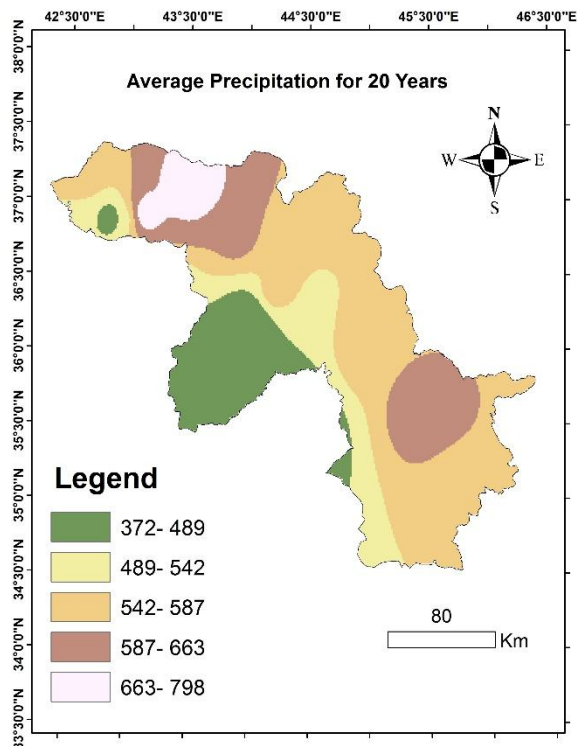**Fig. (6) :-**Spatial zoning for Precipitation for 10 years.

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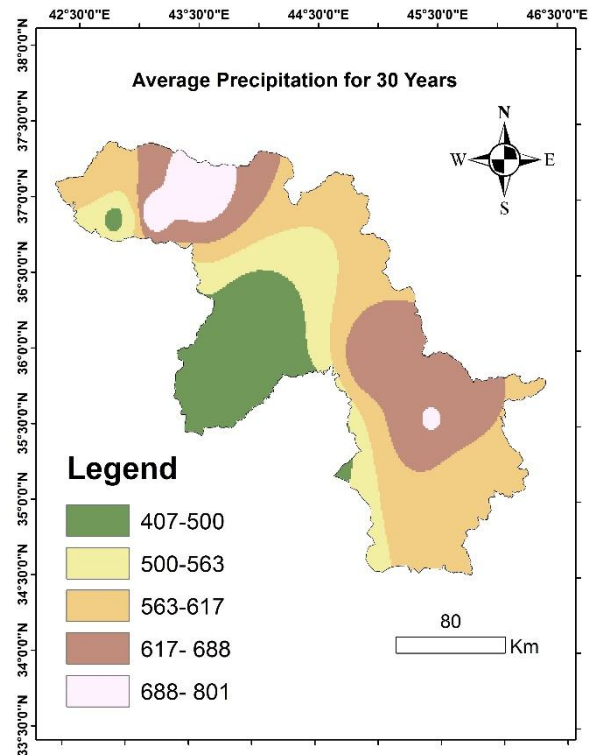**Fig.(7):-**Spatial zoning for Precipitation for 20 years.

Fig.(8):- Spatial zoning for Precipitation for 30 years**.**
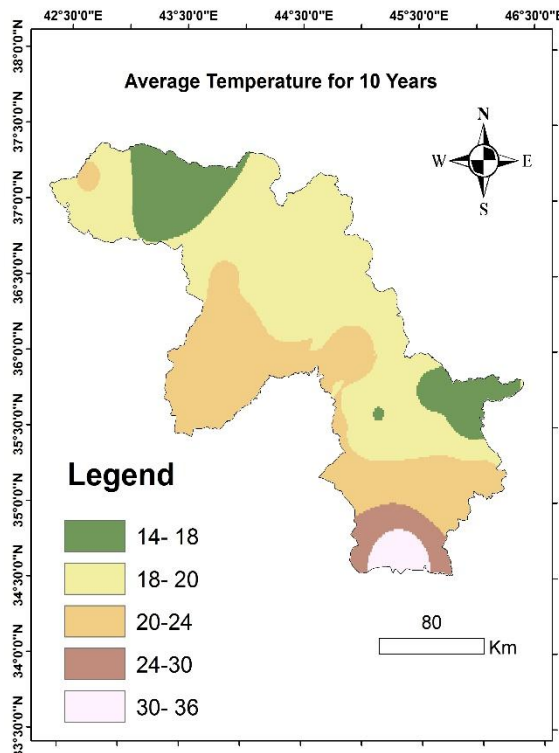

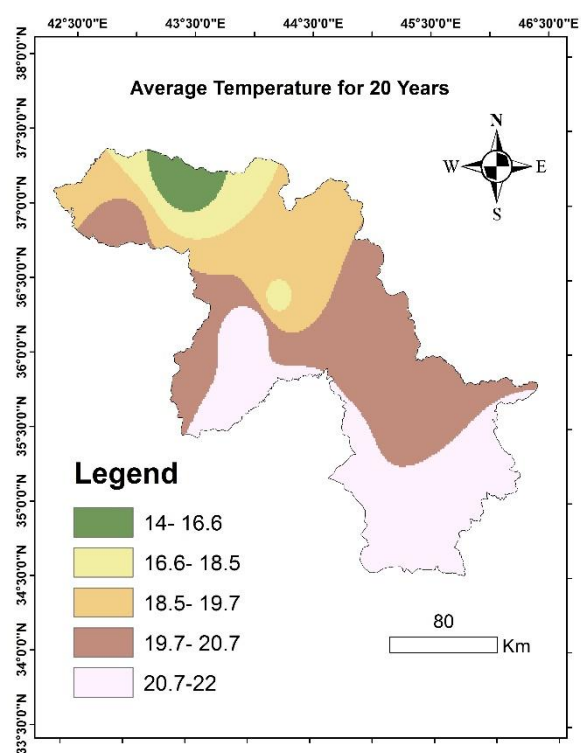**Fig.(9):-** Spatial zoning for Temperature for 10 years.

Fig.(10):- Spatial zoning for Temperature for 20 years.
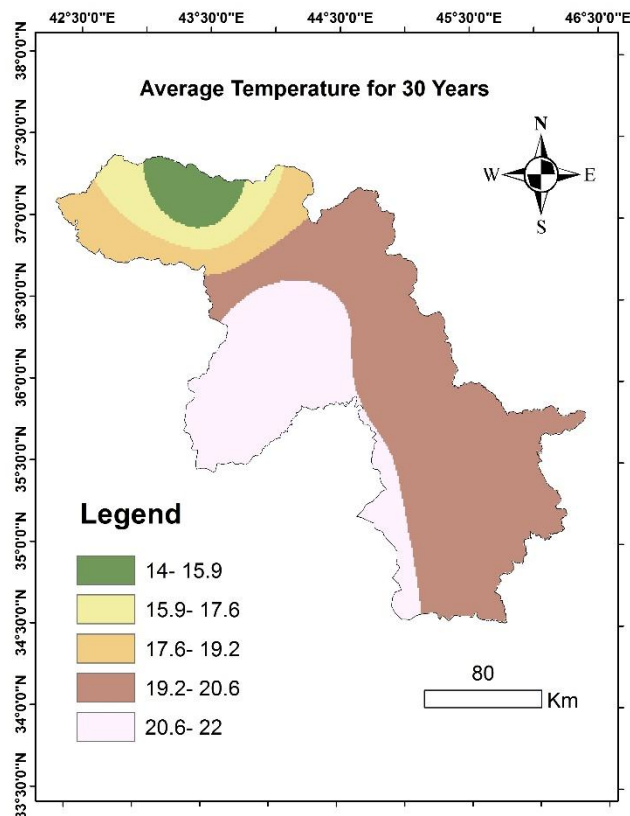
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Fig.(11):- Spatial zoning for Temperature for 30 years

Emberger index and Thornthwaite classification also calculated for the five stations with 30 year duration. The results in compare to De Martonne index are summarized in Table 5. Results of the three types of indices are approximately similar and the cause of difference can be related to the difference in climate category by each type. Moreover it cannot be expected that various aridity index results give same climate type. (Şarlak & Mahmood Agha, 2017)

Table (5):- Comparison between the methods used for aridity index

Index type	Sulaimani station	Dukan station	Hawler station	Musl station	Kirkuk station
De Martonne	Mediterranean	Mediterranean	Semi-arid	Semi-arid	Semi-arid
Thornthwaite	Sub-humid	Sub-humid	Semi-arid	Semi-arid	Semi-arid
Emberger	Sub-humid	Sub-humid	Semi-arid	Semi-arid	Arid

5.2 Seasonal Aridity Index

The spatial distribution of aridity index of 10 years duration (2006-2015) for spring, autumn, and winter were drawn as shown in Figure 12, Figure 13 and Figure 14 respectively. For spring there are six ranges of aridity index are appears in the study area. For winter and for most of the study area the aridity index ranged between 55-158 (extremely humid). For autumn aridity index ranged between 10-20 (semi-arid). It can be concluded that Kurdistan region-Iraq has extremely humid climate in winter and arid climate in summer due to which there are no precipitation in summer as a result all aridity are zero in summer.
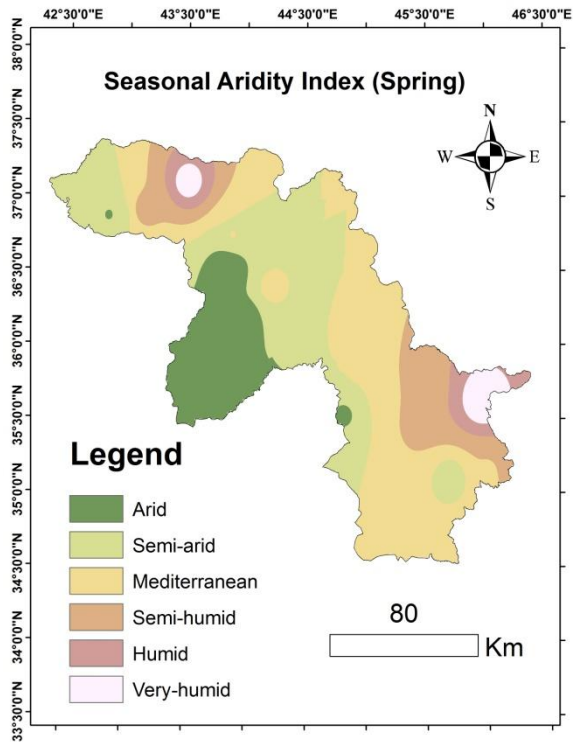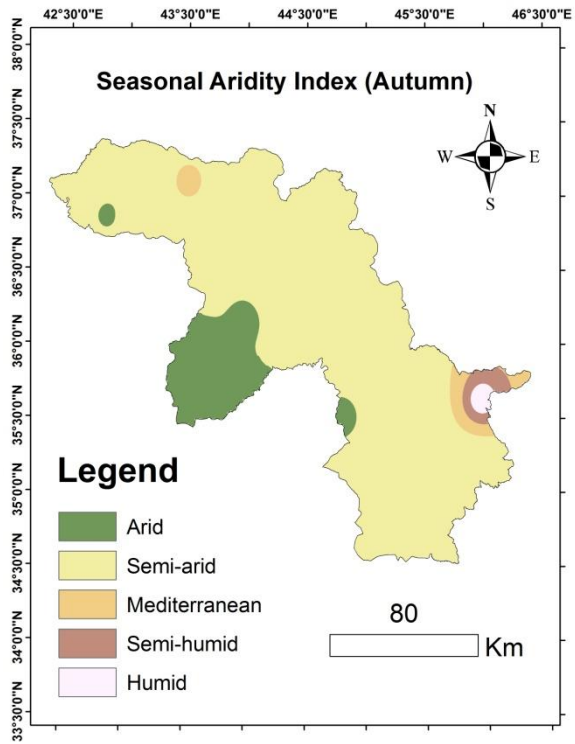
Fig.(12):- Spatial zoning for spring season.

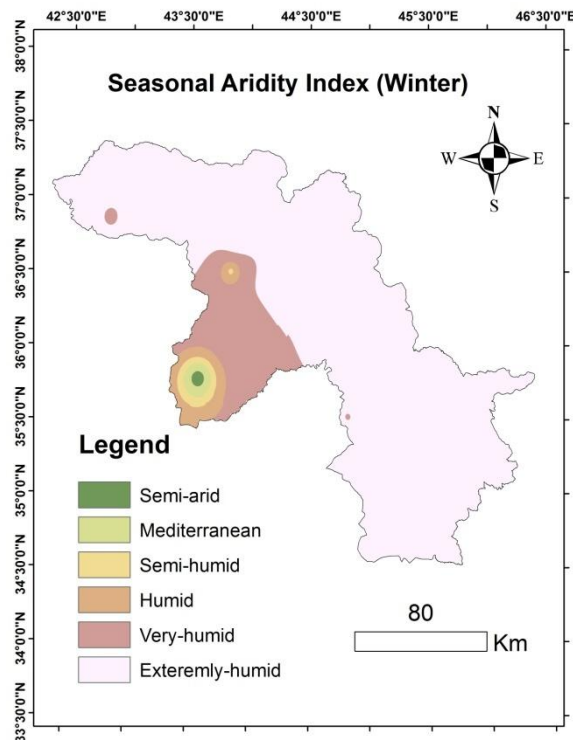**Fig.(13):-** Spatial zoning for autumn season.

Fig.(14):- Spatial zoning for winter season.

5.3 Trend Analysis Results
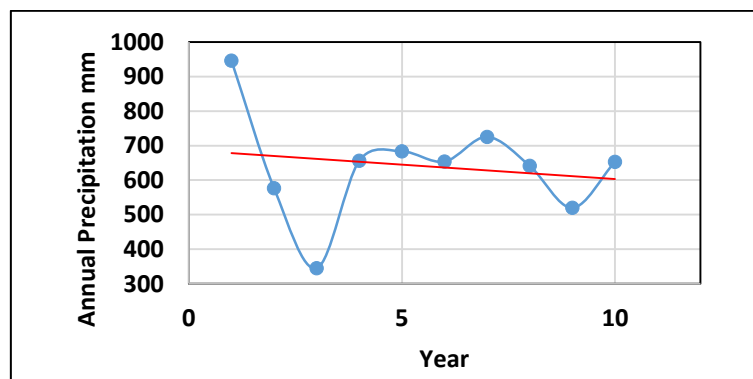**5.3.1 Trend Analysis of 10-Years Duration (2006-2015)**

The analyses were done for precipitation, temperature, and De Martonne aridity index I_{DM} for the average data of 10 years as shown in Table 6. Increasing insignificant trends at the 95% confidence levels in annual precipitation were observed in all stations except for Hallabja station where the annual precipitation decreased insignificantly (Figure 15). On the other hand only Kirkuk, Duhok and Permam stations showed decreasing trend in temperature while all other stations showed increasing trend in temperature. Similarly, all temperature trends were insignificant unless in Dukan station where

temperature increased at the 95% confidence level (Figure 16).

In terms of aridity index, this study reveals that for all the stations in the study area the aridity index showed insignificant trend at the 95% confidence level. The insignificant trends of all the stations where increased trend except in Hallabja and Chamchamal stations where the insignificant trends were in decreasing direction. Depending on the trend analysis results it can be concluded that the last decade (2006-2015) undergone insignificant increasing in precipitation and temperature, both were resulted in insignificant increasing in aridity indexes. The study area for the last decade demonstrated an increase trend toward wet climate.

Table (6):- Trend analysis results for precipitation, Temperature and De-Martone Aridity index(I_{DM}) -10-year duration**.**

No.	Station	Precipitation mm			Temperature ^{0}C			I_{DM}		
		Kendall's Tau	p-Value	Sen's Slope	Kendall's Tau	p-Value	Sen's Slope	Kendall's Tau	p-Value	Sen's Slope
1	Sulaimani	0.378	0.152	24.12	0.244	0.371	0.04	0.289	0.283	0.666
2	Musl	0.289	0.283	15.36	-0.045	0.928	0.00	0.333	0.210	0.390
3	Kirkuk	0.333	0.21	17.80	-0.067	0.858	-0.02	0.378	0.152	0.505
4	Darbandikhan	0.244	0.371	15.90	-0.022	1.000	0.00	0.200	0.474	0.323
5	Hawler	0.378	0.152	17.22	0.111	0.721	0.02	0.378	0.152	0.545
6	Dukan	0.422	0.107	31.70	0.556	0.032	0.11	0.422	0.107	0.913
7	Duhok	0.2	0.474	17.95	-0.333	0.210	-0.05	0.200	0.474	0.544
8	Zakho	0.333	0.21	29.93	0.378	0.152	0.10	0.289	0.283	0.886
9	Permam	0.449	0.088	27.11	-0.067	0.858	-0.02	0.289	0.283	0.891
10	Chamchamal	0.022	1	3.060	0.289	0.283	0.10	-0.022	1.000	-0.044
11	Hallabja	-0.156	0.592	-3.670	0.200	0.474	0.10	-0.156	0.592	-0.150
12	Amedy	0.2	0.474	24.15	0.449	0.088	0.21	0.156	0.592	0.935
13	Zawita	0.244	0.371	23.74	0.422	0.107	0.19	0.244	0.371	0.674
14	Penjwen	0.2	0.474	10.46	0.244	0.371	0.14	0.067	0.858	0.343
15	Chwarta	0.289	0.283	15.80	0.422	0.107	0.08	0.244	0.371	0.453
16	Bzian	0.378	0.152	21.47	0.244	0.371	0.08	0.333	0.210	0.907
17	Akre	0.23	0.414	17.14	0.386	0.149	0.17	0.200	0.474	0.698
18	Semeel	0.289	0.283	20.91	0.045	0.928	0.03	0.244	0.371	0.691

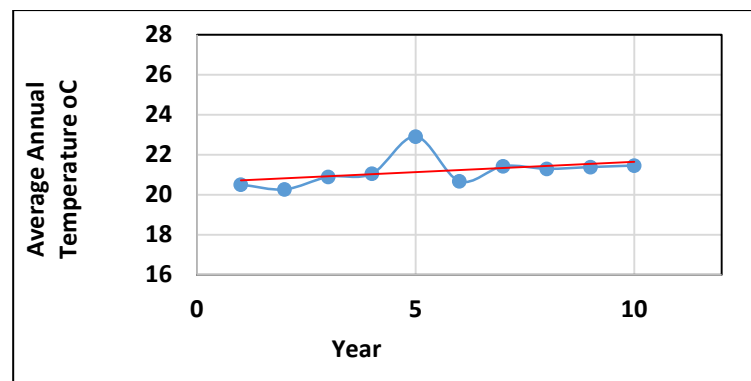**Fig(15):-** Trend of Hallabja precipitation 10-year duration

Fig.(16):- Trend of Dukan annual temperature 10-year duration**.**

5.3.2 Trend Analysis of 20-Years Duration (1996-2015)

The stations with 20 year available data were only 8 stations. The results of trend analysis of precipitation, temperature and aridity index 20-year time series varied between increase and decrease trends. All temperature trends were in increasing direction while precipitation and aridity index time series trends varied between increase and decrease trends with mostly increase in precipitation and aridity indexes. A significant increase trend at the 95% confidence level is noticed only in Dukan and Hawler temperature (Table 7 and Figure 17), all other trends were insignificant at the 95% confidence level.

Table(7):- Trend analysis results for precipitation, Temperature and De-Martone Aridity index(I_{DM}) -20-year duration.

| No.	Series\Test	Precipitation mm			Temperature °C			I_{DM}		
		Kendall's Tau	p-Value	Sen's Slope	Kendall's Tau	p-Value	Sen's Slope	Kendall's Tau	p-Value	Sen's Slope
1	Sulaimani	0.021	0.922	1.310	0.263	0.112	0.037	0.000	1.000	0.001
2	Musl	-0.032	0.871	-0.880	0.237	0.153	0.026	-0.032	0.871	-0.059
3	Kirkuk	-0.074	0.673	-1.513	0.063	0.721	0.013	-0.053	0.770	-0.040
4	Darbandikhan	0.168	0.315	6.493	0.185	0.270	0.021	0.126	0.456	0.220
5	Hawler	0.047	0.795	1.449	0.368	0.025	0.042	0.032	0.871	0.050
6	Dukan	-0.147	0.381	-4.749	0.684	< 0.0001	0.160	-0.179	0.284	-0.281
7	Duhok	0.032	0.871	1.642	-0.011	0.974	-0.001	0.021	0.922	0.064
8	Permam	0.111	0.516	3.642	0.016	0.948	0.003	0.063	0.721	0.108
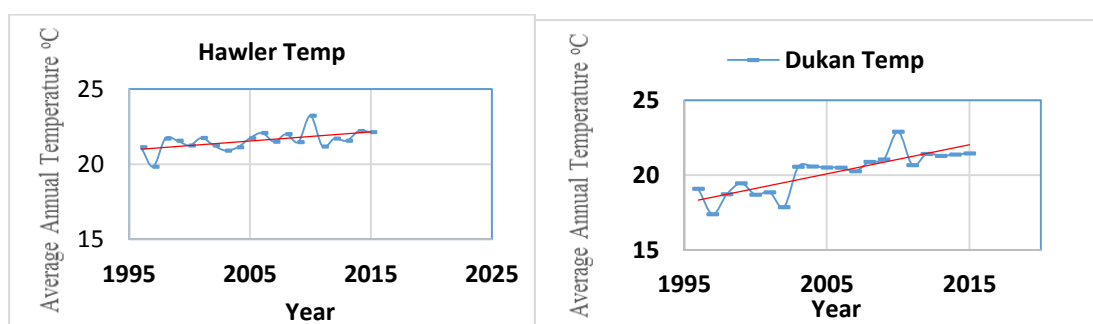
Fig.(17):- Trend of Hawler and Dukan annual temperature 20-year duration.

5.3.3 Trend Analysis of 30-Years Duration (1986-2015)

The station with 30-year available data were only 5 stations. For all stations a decrease trend in precipitation and aridity index and increase trend in temperature were found. However, for precipitation time series only Dukan station trend was significant at the 95% confidence level. Temperature increase trends for all stations were significant at the 95% confidence level except in Hawler station. In terms of aridity index only Dukan and Musl station showed significant decreasing trend at the 95% confidence level. The results are shown in Table8 and Figure 18.

Table(8): -Trend analysis results for precipitation, temperature and De Martonne aridity index, 30-year duration.

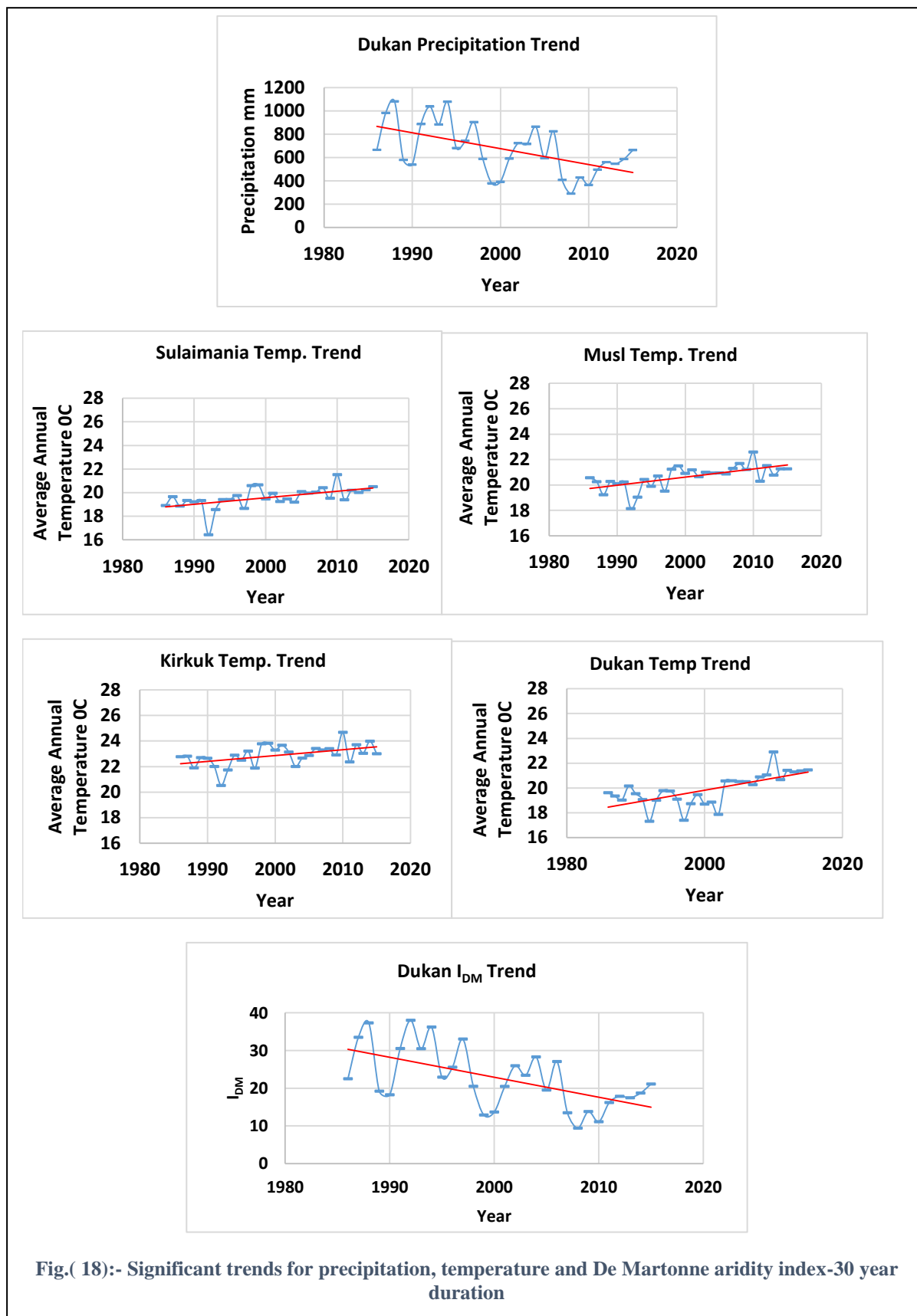| No.	Station	Precipitation			Temperature			I_{DM}		
		Kendall's Tau	p-Value	Sen's Slope	Kendall's Tau	p-Value	Sen's Slope	Kendall's Tau	p-Value	Sen's Slope
1	Sulaimani	-0.145	0.269	-6.128	0.462	0.000	0.046	-0.154	0.239	-0.236
2	Musl	-0.251	0.054	-4.940	0.493	0.000	0.051	-0.255	0.050	-0.183
3	Kirkuk	-0.228	0.080	-4.067	0.345	0.008	0.038	-0.246	0.059	-0.129
4	Hawler	-0.170	0.193	-3.530	0.030	0.830	0.011	-0.126	0.335	-0.073
5	Dukan	-0.343	0.008	-14.267	0.494	0.000	0.085	-0.370	0.004	-0.534

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Fig.(18):- Significant trends for precipitation, temperature and De Martonne aridity index-30 year duration

6. CONCLUSIONS

In the current study, De Martonne aridity Index (I_{DM}) was selected in order to estimate the aridity conditions which uses precipitation and air temperature as inputs. It has been proven to be very representative and for growing season period. The De Martonne aridity index, average precipitation and average temperature were drawn for 10, 20 and 30 years of available data. Spatial zoning of the region was done using inverse distance weight (IDW) interpolation method by ArcGIS software. Results of mapping showed that Kurdistan region-Iraq climate is mostly semi-arid. Different types of climate in the region were appeared however most of the study area falls in the range of semi-arid zone. Aridity index for 30 years from De Martonne's were compared with two other indices and the results were very close.

As per the 10 years duration and in terms of maximum aridity conditions (wet years), the study reveals that the most critical aridity index values of the stations were reported in 2006, 2013, and 2015, while the minimum aridity index values (dry years) were reported in 2008, 2009, and 2010. Seasonal aridity index analyzing showed that Kurdistan region-Iraq has extremely humid climate in winter and arid climate in summer. Results revealed that only Dukan temperature has significant increasing trend at the 95% confidence level for 10 years duration. It can be concluded that the last decade (2006-2015) undergone insignificant increasing in precipitation and temperature, both were resulted in insignificant increasing in aridity indexes.

For 20 years duration the results of trend analysis of precipitation, temperature and aridity index time series varied between increase and decrease trends. All temperature trends were in increasing direction while precipitation and aridity index time series trends varied between increase and decrease trends. A significant increase trend at the 95% confidence level was noticed only in Dukan and Hawler temperature.

For 30 years duration analyzing precipitation time series resulted in a significant decrease trend only for Dukan precipitation at the 95% confidence level. On the other hand, temperature increase trends for all stations were significant at the 95% confidence level except in Hawler station. In terms of aridity index only Dukan station showed significant decreasing trend at the 95% confidence level.

Increased significant trends at the 95% confidence level for temperature appears at both short and long durations (10, 20 and 30 years) while precipitation and aridity index trends appear only in long duration (30 years).

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