Analysis of Rainfall Seasonality Index in Iraq

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Abstract

The Rainfall Seasonality Index(RSI) is used to study the spatial and temporal change in rainfall behavior in that contribute in improvement of water and management plans of water resources systems and agriculture in a certain region especially during dry seasons. Rainfall date is obtained for twenty-eight weather stations in Iraq to find the seasonality index for each station. To give a clear conception of rainfall regime, the study area is divided to three zone according to amount rainfall. The results described the rainfall regime and showed that RSI of study area is noticed at ranges (0.60-0.79), (0.80-0.99), (1.0-1.99) and (1.20<). The range (1.0-1.99) is most frequent in southern and middle regions whereas the range (0.80-0.99) is most frequent in northern zone. The results shows that RSI has significant variation form zone to other and obviously fluctuations from year to year through the study period.

Key words: Seasonality, Rainfall, Climate, Iraq.

تحليل مؤشر الامطار الموسمية في العراق

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الخلاصة

يستخدم مؤشر الموسمية لدراسة التغير الزماني والمكاني في سلوك الامطار والتي تساهم في تحسين خطط ادارة المياه بالنسبة للانظمة الزراعية ومصادر المياه خلال فترات الجفاف لمنطقة معينة . استخدمت بيانات الامطار لـ 28 محطة انوائية في العراق لايجاد مؤشر الموسمية لكل محطة . قسمت منطقة الدراسة الى ثلاث مناطق وفقا لكميات الامطار الساقطة لفهم

سلوك الامطار بشكل واضح. النتائج وضحت سلوك الامطار خلال فترة الدراسة لمنطقة الدراسة حيث ان قيم مؤشر الموسمية وقعت ضمن المديات (0.60-0.79)، (0.80-0.99)، (1.0-1.99) و (<1.20) كذلك وضحت بأن المدى (1.0-1.99) هو الاكثر تكرارا في المنطقة الجنوبية والوسطى في حين ان المدى (0.80-0.99) هو الاكثر تكرارا بالنسبة للمنطقة الشمالية. ان النتائج بينت بان قيم مؤشر الموسمية متباينة ومتذبذبة بشكل واضح من سنة لاخرى خلال فترة الدراسة.

الكلمات المفتاحية: الموسمية، الأمطار، المناخ، العراق.

Introduction

Rainfall is an important climatic variable that is effected by both droughts and floods. To understand the characteristics of temporal and spatial of rainfall, many researchers interest about planning of water resources and management, hydrological modeling, flood frequency analysis, flood hazard mapping, agricultural planning, climate change impacts, water resource assessments, and other environmental assessments. In addition, many studies deal with Rainfall seasonal index that helps researchers to describe the features of distribution precipitation and estimation of future. Although, Ramage (1971) [1], Jackson (1977) [2] and Nieuwolt (1977) [3] characterize seasonality of rainfall in qualitative terms, the estimation by Walsh and Lawler 1981[4] of Seasonality Rainfall Index is a basic of most studies. Rainfall seasonality is a complicated notion which integrates a numeral of independent components (Walsh & Lawler 1981) [4]. Seasonality estimates the seasonal variances of rainfall amounts, and not wetness or dryness in an absolute sense Livada and Asimakopoulos [5]. The aims of seasonality index are description characterize the distribution of precipitation of selected year or period and classification of climate of an area. (M.K.Patil)[6]. The changing in the seasonal rainfall has greatly effect on runoff, evapotranspiration and infiltration ,although, the changing in annual total rainfall could be absence which effects on responsibility of ecosystem, stream discharge and flood forecasting [7,8,9,10,11,12,] [Epstein et al., 2002; Groisman et al., 2001; Rosenberg et al., 2003; Small et al., 2006; Xiao and Moody, 2004]. Livada and Asimakopoulos determine the correlation of the average individual seasonality index with the seasonality Index initially, examined the time series trend of the seasonality index and they found there is no significant change in rainfall seasonality occurred [5]. P. Guhathakurta and Elizabeth S., studied a long rainfall data series (1901–2006) of districts of Maharashtra to get the spatial pattern and

variability by analyzing mean rainfall and coefficient of variability that performed by monthly and seasonal scales. Then identified the long term changes of the seasonality index by the trend analysis of scarcity in Maharashtra [13]. G. Sumner et al., 2001 used monthly precipitation values for 410 sites for 1964–1993 and calculated the seasonality index of Rainfall in eastern and southern coastal Spain and compared between southern and eastern areas [14]. Sharma, A. and Bose, M. Evaluated seasonal factors and predict the amount of quarterly rainfall in Kolkata based on the past dataset using Regression Model and uses the estimated values with the actual observations to make comparison [15].

In this paper we attempt to give description about dominant behavior precipitation by seasonality index and divided the study area to three zone according to amount rainfall to give understandable conception of rainfall regime then compare among them to select which range of *RSI* is more frequency which give understandable description of rainfall distribution.

Data and methodology

2.1 Data Acquisition

Historical records of monthly rainfall data for the time period 1980-2010 were acquired from the Iraqi meteorological origination and seismology (IMOS). The long-term data collected for 28 weather stations at different region of the country. The missing data was obtained and the average of the monthly rainfall of studied stations are calculated. Figure 1 shows geographical location of stations and table 1 gives the description of the stations.

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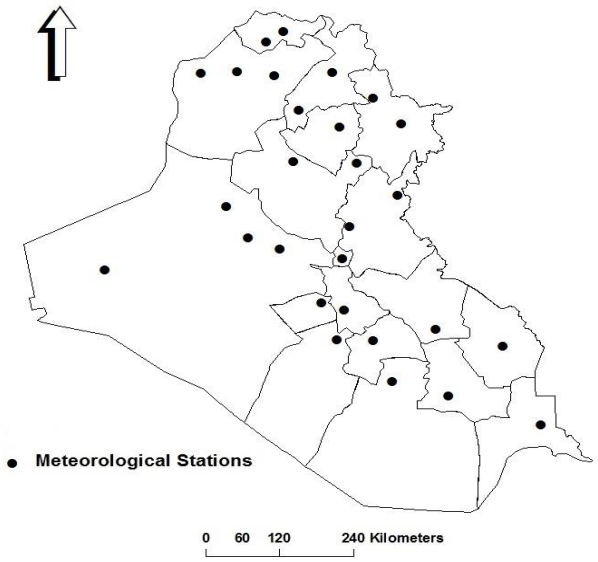

Figure1: Map of Meteorological stations of area study

Table 1: Iraqi meteorological stations

NO.	Stations	Longitude	Latitude	Elevation (Meter)
1	Emadiyah	43.30	37.05	1236
2	salahaddin	44.20	36.38	1075
3	Sulaymaniyah	45.45	35.53	843
4	Sinjar	41.83	36.32	583
5	Duhook	43.00	36.87	554
6	Teleafer	42.48	36.37	373
7	Kirkuk	44.35	35.47	331
8	Dukan	44.95	35.95	276
9	Mosul	43.15	36.31	223
10	Rutba	40.28	33.03	222
11	Tuz	44.65	34.88	220
12	Khanqin	45.38	34.35	202
13	Biji	43.53	34.9	116
14	Hadithah	42.35	34.13	108
15	Heet	42.75	33.63	58
16	Najaf	44.32	31.95	53
17	Ramadi	43.32	33.45	48
18	Khahlis	44.53	33.83	44
19	Baghdad	44.40	33.3	32
20	Kerbela	44.05	32.57	29
21	Hella	44.45	32.45	27

22	Makhmoor	43.60	35.75	22
23	Diwaniya	44.95	31.95	20
24	Hai	46.03	32.13	17
25	Samawa	45.27	31.27	11
26	Amara	47.17	31.83	9
27	Nasiriya	46.23	31.02	5
28	Basrah	47.78	30.52	2

According to the precipitation of meteorological stations of Iraq, the area study can be divided into three major zones : Northern zone includes (Dukan , Duhook , Emadiyah , Khanqin , Kirkuk , Makhmoor , Mosul , Salahaddin , Sinjar, Sulaymaniyah , Teleafer and Tuz). Middle zone includes (Amara, Baghdad, Basra, Biji, Hadithah, Hai, Heet, Khalis and Ramadi). Southern zone includes (Diwaniya, Hella, Kerbela, Najaf, Nasiriya, Rutba and Samawa). [16]

2.2 Climate of Study Area

The climate of Iraq is generally as continental and subtropical semi-arid type whereas the mountainous regions that are north-eastern and north are classified a Mediterranean climate. The occurrences of rainfall are in the winter from October to May. The mean annual is estimated at 216 mm, but in the northeast, the ranges of rainfall graded from 1200 mm to less than 100 mm which covers 60 % of south of Iraq. The winter season is cool and sometimes very cold with daily temperature approximates to 16 °C and falls down to 2 °C which happens at night and sometimes the frost occurs . However, the summer season is dry and hot (sometimes extremely hot), with over 43 °C of a shade temperature in July and August, yet reaches to 26 °C at night. The agro-ecological zones are four parts of climate of Iraq that is divided into [17]: Arid and semi-arid that cover the northern zone stations with a Mediterranean climate. The annual winter rainfall is over 400 mm and a growing season of about nine months also have mild/warm summer prevail. Wheat, barley, rice and chickpea are major crops in this zone. In addition, the productions of other field crops are smaller quantities. Steppes zone, in winter, the annual rainfall in range 200–400 mm with cold weather whereas, summer season is extremely hot. This zone is located between Desert and Mediterranean zones which has areas that produce feed barley and wheat. Desert zone has extreme temperatures in summer season and the rainfall in winter season at 200 mm and less annually. The location of this zone in middle of Iraq which expands from Baghdad's north to Saudi Arabian and Jordanian's borders. The irrigated area

extends between the Tigris and Euphrates rivers and from the Baghdad's north to Basra in south. The salinity and poor drainage seriously effect on this zone however the rice and sunflower are produced at most in this area.

2.3 Calculate Rainfall Seasonality Index RSI :

The definition of Seasonality index depend on the monthly distribution of rainfall that classify the behavior of rainfall. Therefore, (RSI) could be computed by monthly and annual mean rainfall [4]:

$$\overline{RSI} = \frac{1}{\bar{P}} \sum_{n=1}^{12} \left| p_n - \frac{\bar{P}}{12} \right| \dots\dots 1$$

Where p_n is the rainfall of n month and $\bar{P}$ is the annual average of rainfall. Theoretically, if the months of year have equal amount rainfall or the rainfall occurs in one month, the Seasonality index has variance from zero to 1.83. Table 2 explain the different classification of SI and rainfall behavior [18]. In spite of the usage of monthly distribution of rainfall during year, the Seasonality index explains the seasonal behavior when the value of it is more than 0.6.

Table 2: Classification of Seasonality Index.

RSI	Rainfall Behavior
< 0.19	Rainfall spread throughout the year
0.20-0.39	Rainfall spread throughout the year, but with a definite wetter season
0.40-0.59	Rather seasonal with a short drier season
0.60-0.79	Seasonal
0.80-0.99	Markedly seasonal with a long dry season
1.00-1.19	Most rainfall in less than 3 months
> 1.20	Extreme seasonality, with almost all rainfall in 1–2 months

Results and Analyses

The change of Rainfall Seasonality Index depend on the variation of amount Rainfall therefore the fluctuations are clear in figures. Figure 2 shows the Rainfall Seasonality Index at the stations in the northern zone of the country. Emadiah and Duhook stations were at same time of maximum and minimum values that were noticed at 1995 and 1984 respectively.

However, the maximum *RSI* of Emadiah was discriminated in range (1.20<) whereas, *RSI* of Duhook changed its behavior from range (0.80-0.99) to range (1.0-1.19) of end study period due to decrease amount of Rainfall. In similarity, the maximum and minimum *RSI* of Dukan and Kirkuk satiations were at 1989 and 1993 respectively. Surprisingly, *RSI* of Dukan steadied in range (0.80-0.99) at last decade of study period, while, *RSI* values of Kirkuk were unsteadied in middle decade of study period. Also, at 1989, the maximum *RSI* of Salahaddin and Makhmoor were noticed, however, the minimum *RSI* of Salaahddin was recorded at 1994 and of Makhmoor at 1993 and 2010. In Salaahddin, *RSI* distinguished that was stable within ranges (0.80-0.99 and 1.0-1.19) in 1995-2010. Conversely, *RSI* of Makhmoor was fluctuated and various. Moreover, the Seasonality Index has maximum values of Khanqin, Sinjar and Mosul at 1998, 1980 and 1988 which took place in range (1.20<) and minimum at 2009, 1982 and 1996 respectively that were recognized in range (0.60-0.79). Although, the *RSI* of Teleafer and Tuz stations was minimum value at 2010, maximum *RSI* was deferent between them where it could be apparent that the maximum value of Teleafer station happened at 1989 and 1995 whereas the maximum values of Tus station happened at 1998 and 1999. The fluctuation of *RSI* was very clear in Teleafer station than Tuz. For illustration, at the last decade, the *RSI* values were noticed in two range in Teleafer station however it was stable at same time in Tuz station. Figure 3 shows the Seasonality Index at the stations in the middle zone of the country. It can be seen that the *RSI* oscillated from year to year. The minimum values *RSI* of Baghdad, Basra, Baji, Heet, Khalis, and Ramadi were noticed at 1982 in range (0.80-0.99), exceptionally, Heet an Ramadi were occurred in range (0.60-0.79), whereas, the maximum values *RSI* of Baghdad, Heet and Ramadi were noticed at 1999 in range (1.20<), also, in the same range, the maximum *RSI* of Basra was showed at 1998 and at 1989 the peek *RSI* of Khalis and Baji were noticed. In addition, the maximum and minimum value of *RSI* of Amara station were recorded at 2001, 1990, Hai station at 1990, 1984 and Hadithah at 1995, 2006 respectively. *RSI* of Amara slightly increases at end study period that is conversed to starting study period, whereas in Bagdad it is much fluctuated and various also in Basra it is regular in 1987-1997 and jumped at 1998 than fluctuated in end of study period. Baji's *RSI* slightly increased at starting period to reach the peak, than dropped at 1993 and again increased at middle and end of study period.

Heet, Ramadi and Hadithah have same behavior of *RSI* which increased at starting period then dropped at 1982 (exception Hadithah which has minimum *RSI* at 2006) then obviously increased and jumped at 1999 and gradually decreased in end of study period likewise *RSI* of Khalis which slightly decreased as well as it was steady at 1985-1995.

RSI of Hai is the most stable than others, it could be clear the *RSI* stays steady in starting period then reached to peak at 1990 and again returned to take same range before its jumping at 1998 then dropped to steady at end study period.

Figure 4 shows the Rainfall Seasonality Index at the stations in the southern zone of the country. Diwaniya and Samawa have maximum *RSI* at1990 in range (1.20<) and minimum at 2006 in range (0.80-0.99) and at 2009 in (0.60-0.79). The maximum *RSI* of Hella, Najaf and Nasiriyah took place at 2003, 1999 and 1997 in range (1.20<).

In contrast, the minimum *RSI* of Hella and Najaf are noticed at 1985, 2010 in range (0.60-0.79) and of Nasiriyah at 2003 in (0.80-0.99). Minimum values of *RSI* of Kerbela and Rutba were at 1982 in range (0.60-0.79) and (0.80-0.99).

Also, the maximum values occurred in deferent years that were 1993 and 1991in range (1.20<). The *RSI* trend of these stations discriminates that is fluctuated and unstable throughout study period. The trend of *RSI* in Najaf station decreased at last study period convers of starting period likewise Samawa station which has dramatically dropping *RSI* at end period. Whereas, in spite of fluctuations between *RSI*'s ranges, the trend increased gradually in Kerbela and Rutba at middle study period but at end period the trend decreased. In similarity, Nasiriyah and Hella also slightly increased then at end period drops to change *RSI* behavior.

The *RSI* of Diwaniya decreased at starting of period and increased gradually to jump at peak point which occurred at 1990 then steady at middle of period with some fluctuations.

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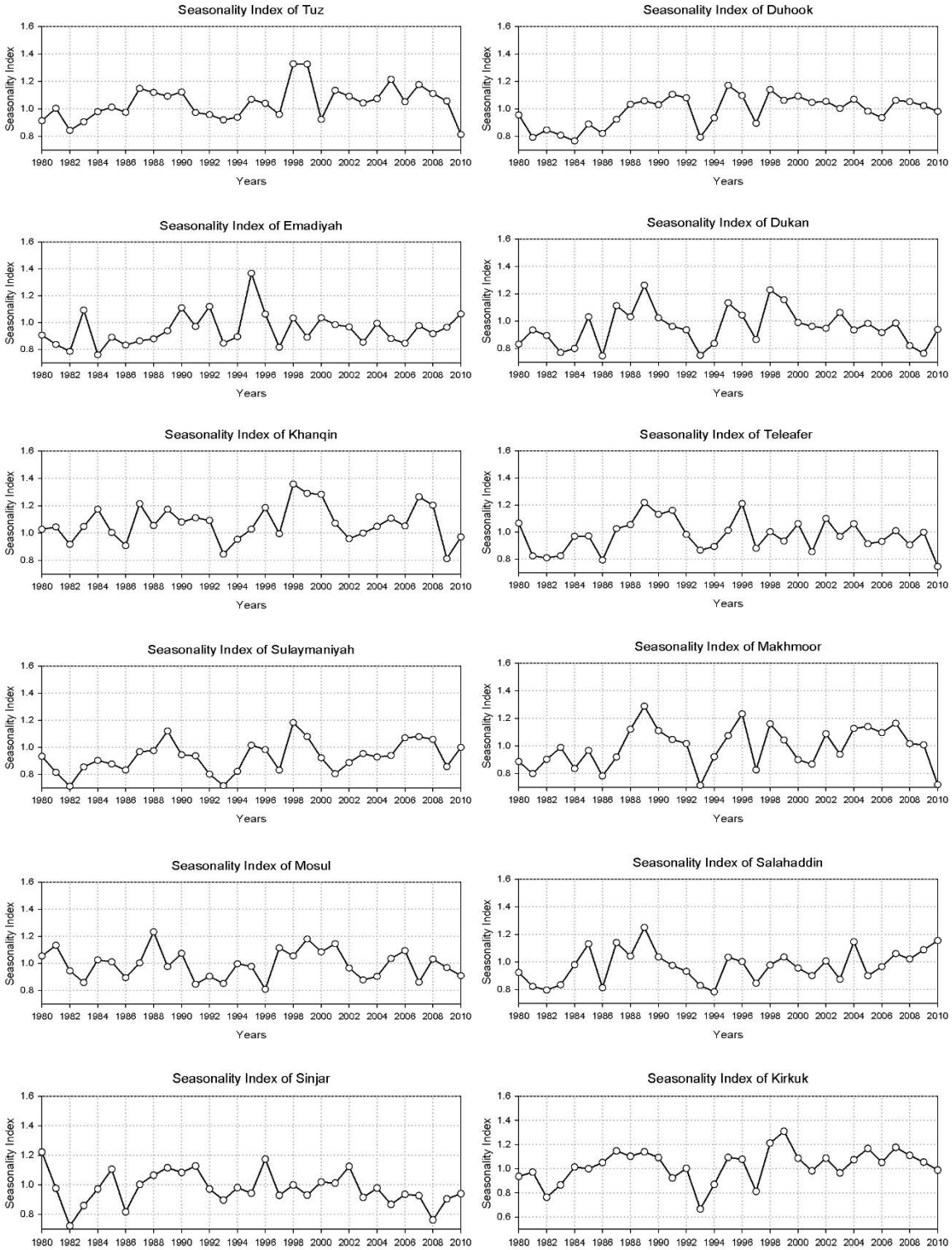

Figure 2: explain the seasonality index of Northern zone of 1980-2010 period

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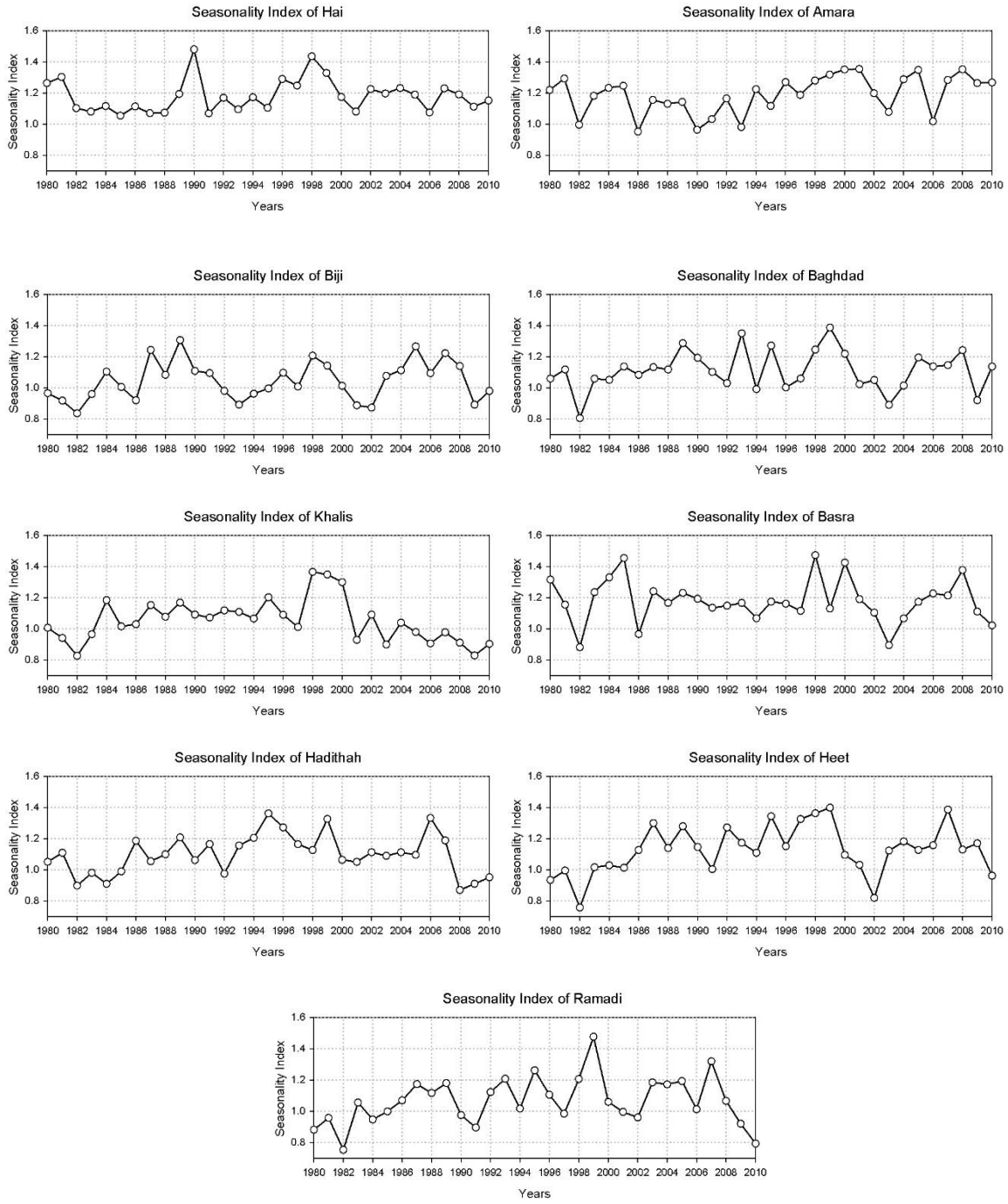

Figure 3: explain the seasonality index of Middle zone of 1980-2010 period.

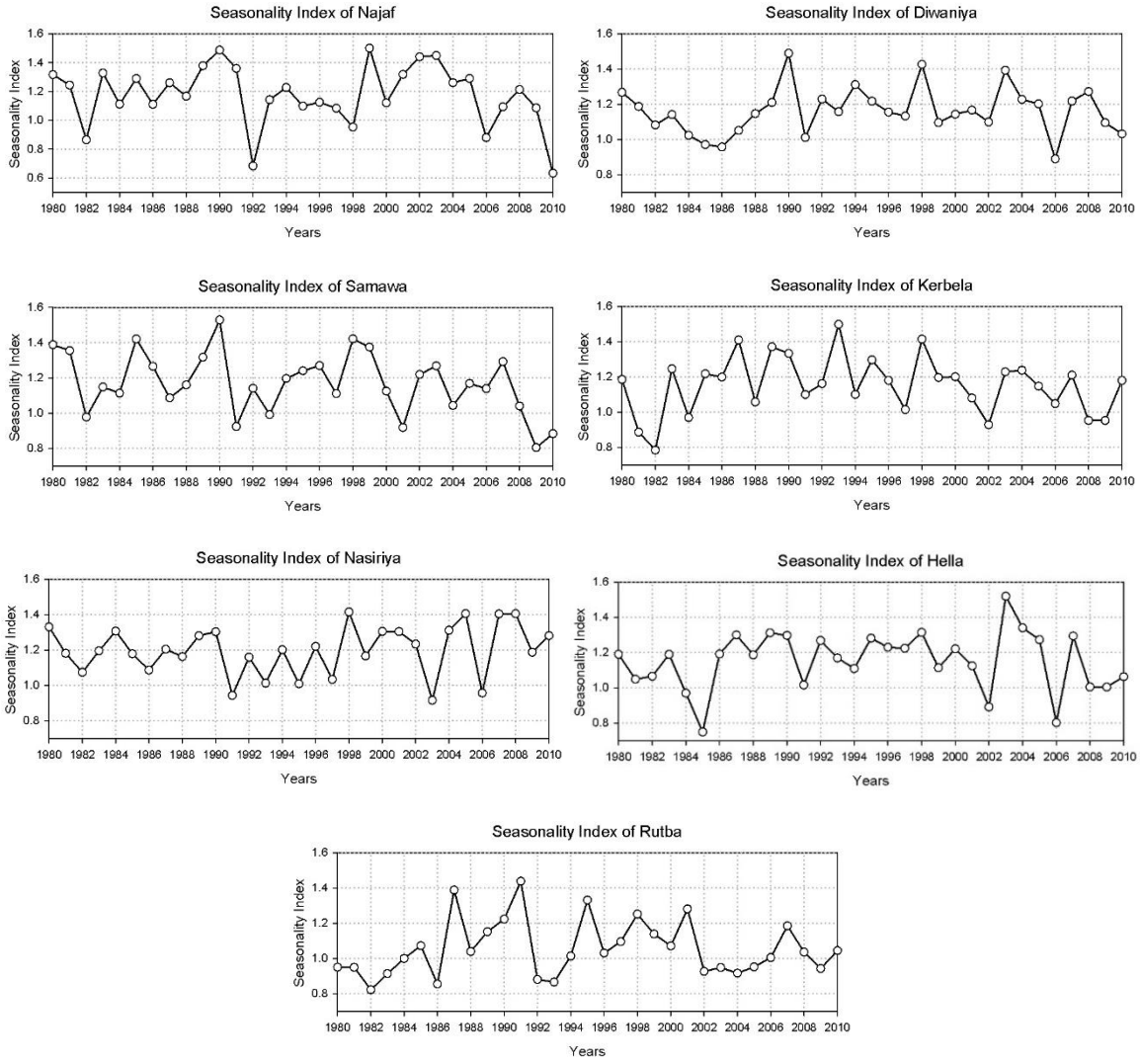

Figure 4: explain the seasonality index of Southern zone of 1980-2010 period.

On the other hand, the frequency of *RSI* to classifications of *RSI* were showed in figure 5 where these are important to give information about permanent behavior of rainfall in these area. Obviously, the range (0.80-0.99) of *RSI* which means markedly seasonal with a long dry season is more frequent than other range in Northern zone, whereas the range (1.0-1.19) which means most rainfall in less than 3 months is prevailing range in Middle and southern zone, however, the range (1.20<) is markedly frequent in southern zone. It was found that the Rainfall Seasonality Index of Iraq takes values among four ranges which are (0.60-079), (0.80-0.99),

(1.0-1.99) and (1.20<) and the range (1.0-1.99) is more frequency from others for all study area but in northern zone the range (0.80-0.99) is highest one.

That's means, the rainfall of Iraq is extreme seasonality and fluctuated, thus, the dominant behavior of rainfall refers to most of rainfall of Iraq falls in three months with a long dry season.

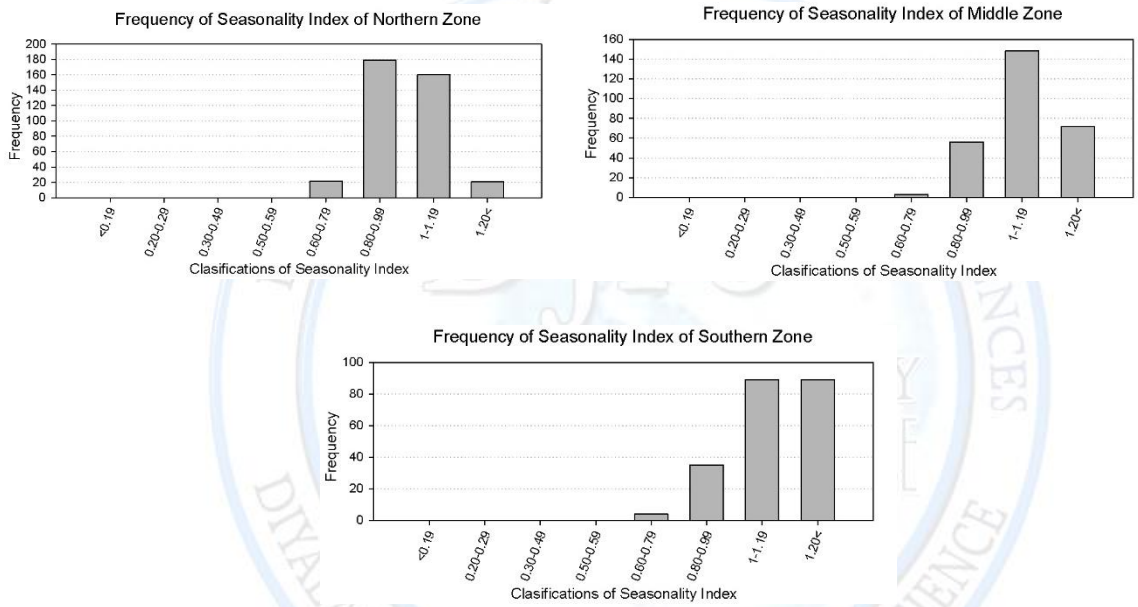

Figure 5: explain the frequency of Seasonality Index.

Conclusions

The results shows that the Rainfall seasonality index (*RSI*) of the study area was notable variation and obviously fluctuations from year to year through the study period. The results show that, in the Northern zone, Duhook and Khanqin stations have never recorded the range (0.6-0.79) of *RSI*, also, Mosul and Tuz stations have never recorded the range (1.20<) of *RSI*. On the other hand, in the Middle zone, Only Ramadi and Heet stations have *RSI* values in range (0.6-0.79). It could be interested that Hai Station are unique where *RSI* has not values in range

(0.8-0.99) as well as (0.6-0.79) and it has distinction from other stations that its *RSI* values are more regular and harmonic. In the Southern zone, Kerbela and Najaf Station are exception from all Southern zone stations which are studied where they have *RSI* value in range (0.6-0.79) therefore we can say that the precipitation in southern zone consternates in 2-3 months only and the weather have along dry seasons.

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