Hydrological Analysis of Rainfall Data for Drought Investigation in Albaha City

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Abstract

Rainfall is a prime input for various engineering design such as hydraulic structures, bridges and culverts, canals, storm water sewer and road drainage system. The detailed analysis of each region is essential to estimate the relevant input value for design and analysis of engineering structures and for crop planning. A rainfall data record from Ministry of Water collected for Al-Baha city for hydrological analysis where agriculture is the prime occupation. The daily rainfall data for a period of 42 years had used to understand normal rainfall, deficit rainfall, excess rainfall and seasonal rainfall of the Al-Baha city. From the daily records, annual, monthly, and seasonal rainfall were calculated. Extensive hydrological analysis had done comprising the maximum values of rainfall with the mean value of rainfall using trend line method. For more accuracy, Index of Wetness (I.W.) and Rain Deficiency (R.D.) had calculated to check the rainfall variability. The analysis leads to results that the amount of rainfall is decreasing below the average value and the number of drought years increasing (more than 65% of records are drought years). The hydrological parameters (I.W. & R.D.) for annual, monthly and seasonally confirmed the results that obtained by trend line method that the rainfall in Al-Baha city is decreasing and the climate is changing to be drought (arid).

Keywords: Drought, season, Rainfall, Al-Baha, Index o Wetness, Rainfall deficiency

1. Introduction

Rainfall is the most important natural hydrologic event and is a unique phenomenon varying in both space and time, the rainfall distribution is very uneven and it not only varied considerably from place to place but also fluctuates from year to year. The rainfall is one of the most important and governing factor in the planning and

operation strategies of any agricultural programme for any given area. As such, proper and specific information about the rainfall distribution pattern over a period for a particular place is quintessential for proper and optimal planning of requisite irrigation system and cropping pattern.

A comprehensive knowledge of the trend and persistence in rainfall of the area is of great importance because of economic implications of the rain sensitive operations and since it plays vital role of any agricultural and nonagricultural programme. If proper and comprehensive study of various rainfall data had analyzed, the severity and reoccurrence of drought can be known beforehand thus various measures can be taken to cope up with the problems and drought. KSA gets around 75% of the annual rainfall during monsoon period, which lasts from June to September i.e. four months.

2. Study Area

Al-Baha City (BC) lies in the south-west of the kingdom of Saudi Arabia, between Mecca and Asser. It is the smallest of the kingdom's provinces (11,000 square kilometers (1,100,000 ha)). It is surrounded by a number of cities, including Taif on the north, Beesha on the east, Abha on the south and the Red Sea coast city of Al Qunfuda on the west. This tourist city is situated in an area characterized by natural tree cover and agricultural plateaus. It consists of six towns, the most important of which are Beljarshy, Almandaq, and Almekhwah, in addition to the Baha city in the center of the province. The province comprises 31 administrative centers and has a population of 533,001.

The climate in Al Baha is greatly affected by its varying geographic features. Generally, the climate in Al-Baha is mild with temperatures ranging between 12 to 23 °C (53.6 to 73.4 °F). Due to its location at 2,500 metres (8,200 ft) above sea level, Al Baha's climate is moderate in summer and cold in winter. The area attracts visitors looking for a moderate climate and pristine, scenic views.

In the Tehama area of the province, which is down on the coast, the climate is hot in the summer and warm in the winter. Humidity ranges from 52%–67%. While in the mountainous region, which is known as As-Sarah, the weather is cooler in summer and winter. Rainfall in the mountainous region lies in the range of 229 to 581 millimetres (9 to 23 in). The average throughout the whole region is 100 to 250 millimetres (3.9 to 9.8 in) annually.

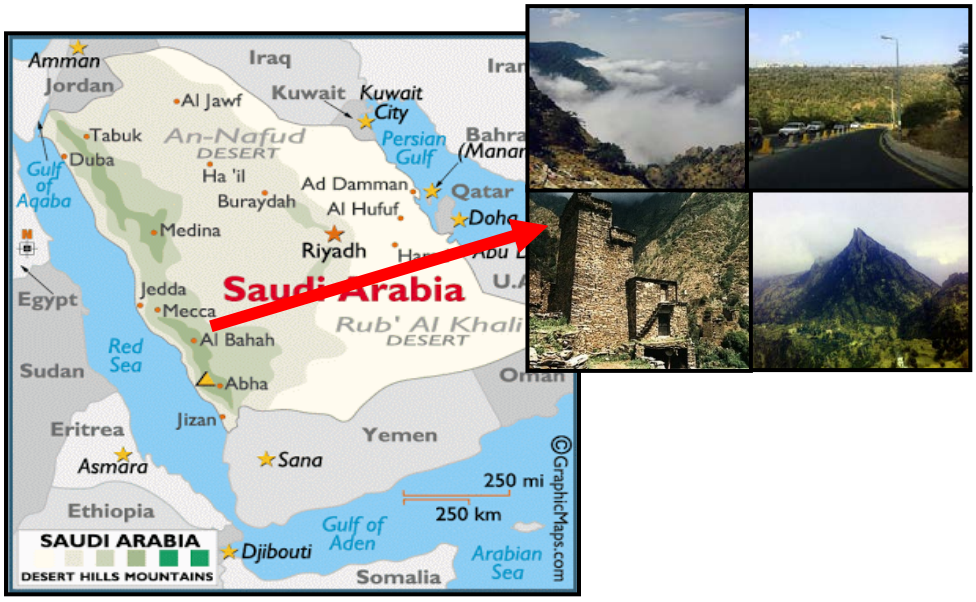


Fig.1 Location of Study Area

3. Materials and Methodology

Because of the variety of needs of water, it is not practicable to define a drought specifically. A period of only few weeks without precipitation may be a serious matter for agricultural operations particularly if the weather is hot and the humidity is low such as what prevails in our country. On the other hand, an irrigation project with adequate storage may operate several months without rain. Because of our inability to define a drought in terms, which are generally applicable to all problems, there exists no general consensus for the quantitative definition of droughts under varying field conditions. However, in general drought implies of a deficiency of precipitation of sufficient magnitude over a significantly prolonged duration. Drought as such, is a “non-event” as opposed to a distinct event such as flood. Drought requires an extended period of time to develop. Extreme rainfalls or floods can occur several times in one year, whereas two or three years of subnormal runoff may be required to develop a serious drought problem for basins having large volumes of storage. The information on drought is a viable tool for multi objective water resources planning problems and is implicitly of great value for the incumbent planners for designing of storage capacity reservoirs to store the water for contemporaneous irrigation requirement during such drought periods. The main cause of drought of drought experienced in all places is the insufficient non-linear rainfall. Although precipitation

for a few years may be abnormal, there is usually a tendency to return to the mean pattern. Hence, a period of abnormally heavy precipitation is sooner or later balanced by a dry period so that the mean over a long interval does not change appreciably. Such variations in precipitation are of rather irregular occurrence. The interactive factors such as duration, aerial extent, intensity and probability of occurrence are also involved unto a certain extent. While it is feasible to estimate the maximum possible storm which can occur in a given basin on the basis of meteorological theory, it is not possible to estimate the worst possible drought condition which might develop in a given area because to the long period involved in droughts and the great number of weather sequences which might lead to protracted dry periods. The only alternative, then, is to deal with the most severe dry period of record.

Keeping the above points in view, the rainfall data records from Ministry of Water collected for Al-Baha city for hydrological analysis. The daily rainfall data for a period of 42 years were used. From the daily record, annual, monthly, and seasonal rainfall were calculated.

Extensive hydrological analysis had done comprising the maximum values of rainfall with the average one. Index of Wetness (I.W.) and Rain Deficiency (R.D.) were calculated to check the rainfall variability.

The rainy data for a period of 42 years collected had analyzed in the presented paper to study the magnitude and drought frequency in terms of rainy deficiency for Al-Baha city. The rainy data for period of 42 years of Al-Baha were collected from Ministry of Water. The mean value of rainfall monthly, annually and seasonally were consummately analyzed in this paper. The analyzed data were compared with mean monthly, mean seasonal and mean annually rainy. On the basis of above comparison, and In order to increase verification, Index of Wetness (I.W.) and Rain Deficiency (R.D.) were calculated.

$$Index\ of\ Wetness\ (I.W.) = \frac{P_i}{P_{av}} \ldots\ldots\ldots (1)$$

Where:

P_i: Rainfall in given time at given place

P_{av} : Average rainfall at that place

If $I.W. < 1$ that mean year is drought , and $I.W. > 1$ that mean year is rainy

$$\%Rain\ Deficiency = \%\ Index\ of\ Wetness - 100 \quad \text{(2)}$$

If % Rain Deficiency negative value that mean it is drought year and rainy year if rain deficiency positive value.

3.1 Annual Rainfall Analysis

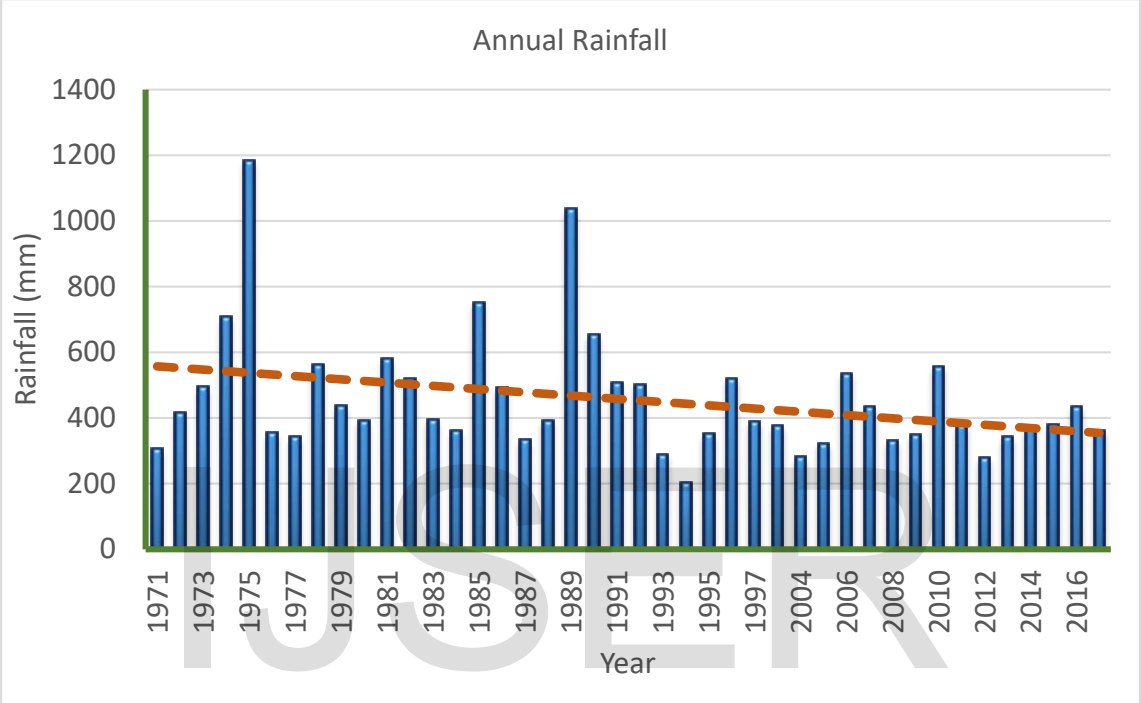


Fig.2 Annual Rainfall with trend line

In Fig.2, the trend line shows that the rainfall amount is decreasing that result encouraged to calculate the mean value of rainfall to find the years below the average value as shown in Fig.3.

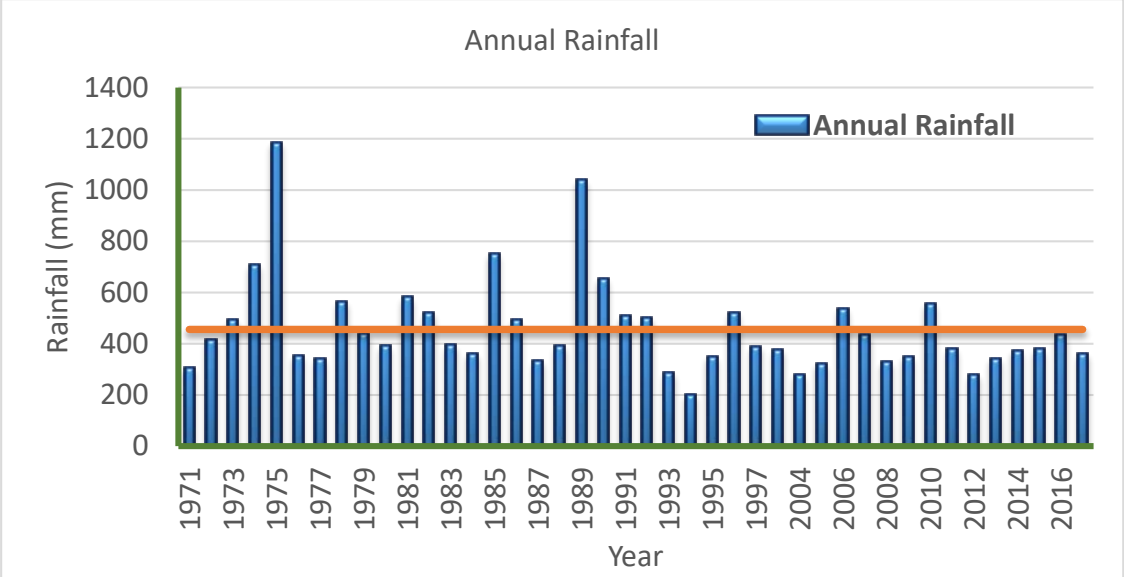


Fig.3 Annual Rainfall with mean rainfall line

In the Fig.3, 27 years of rainfall records is below mean value that mean 65% of the records less than the mean.

It is noticeable that, from year 1971 the rainfall sequence changing is 2 years of rainfall less than the mean, and 2 years of rainfall more than the mean, this pattern continue until year 1993. Then the sequence is changed to be 3 years of rainfall less than the mean, and 1 year of rainfall more than the mean, this pattern continue till year 2010, and then the pattern changed again to be worse (7 years less than the mean).

For further confirmation Index of Wetness (I.W.) and Rain Deficiency were calculate for annual rainfall as illustrated in Fig.4.and Fig.5. rom Fig.4 and Fig.5, it is clear that that index of wetness for 65% of records less than one and about 27 years located in part of rain deficiency.

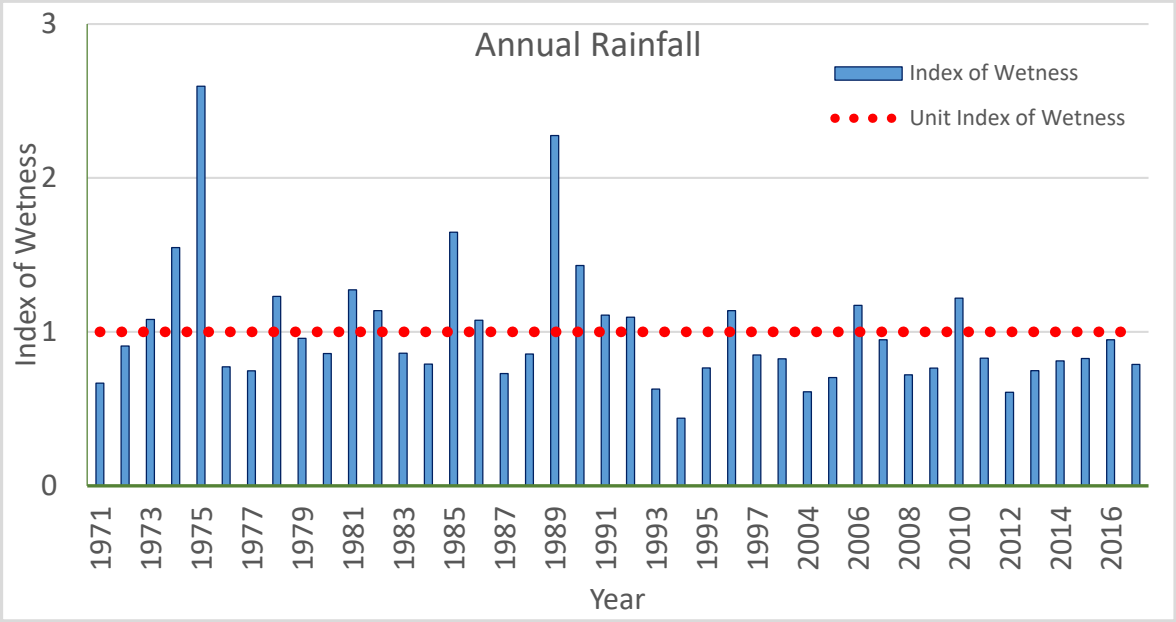


Fig.4 Index of Wetness for annual rainfall

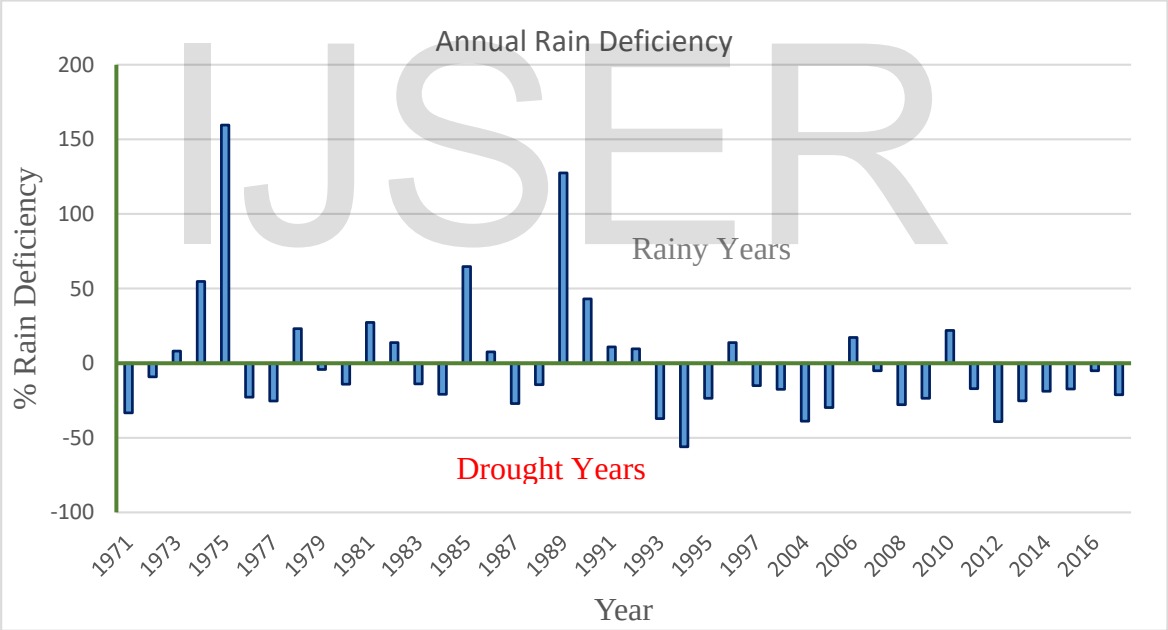


Fig.5 Annual Rain Deficiency

3.2 Monthly Rainfall Analysis

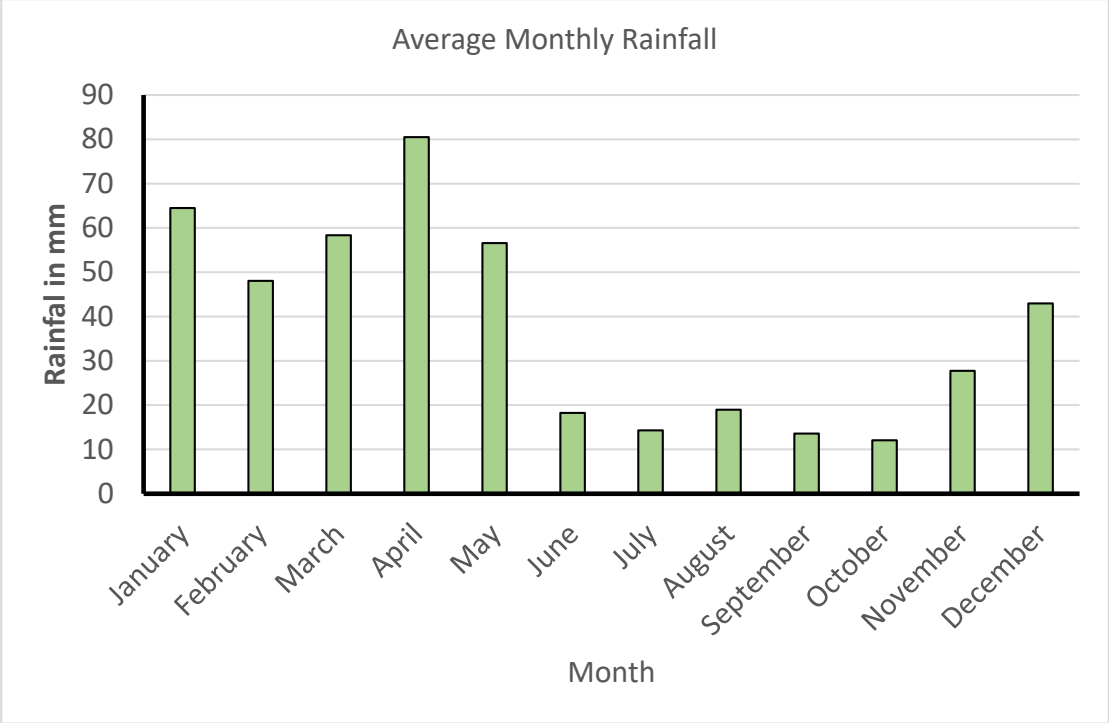


Fig.6 Average Monthly Rainfall

In the Fig.6 it is clear that the season of rain in Al-Baha city starts in winter in November with average amount of rain equal to average value 27 mm and the amount of rain increasing to reach the maximum value in Spring (April) with average value 80mm. The minimum amount of rain occur in summer in the last month of the season (October) with average value 12 mm.

According to the information presented in Fig.5, our analysis will concentrate in the rainy months to detect the change in their pattern. In the Fig.7 rainfall records for all months constructed in charts with trend line showing the direction of the changing.

The months that have downwards trend are January, February, March, April, May, August, November and December.

It is noticeable that April, which is classified, as maximum rainy month its trend decreasing, with 9 years have amount of rainfall less than 100 mm, also in February, it is clear that from year 1995 to 2016the amount of rainfall less than 100mm.

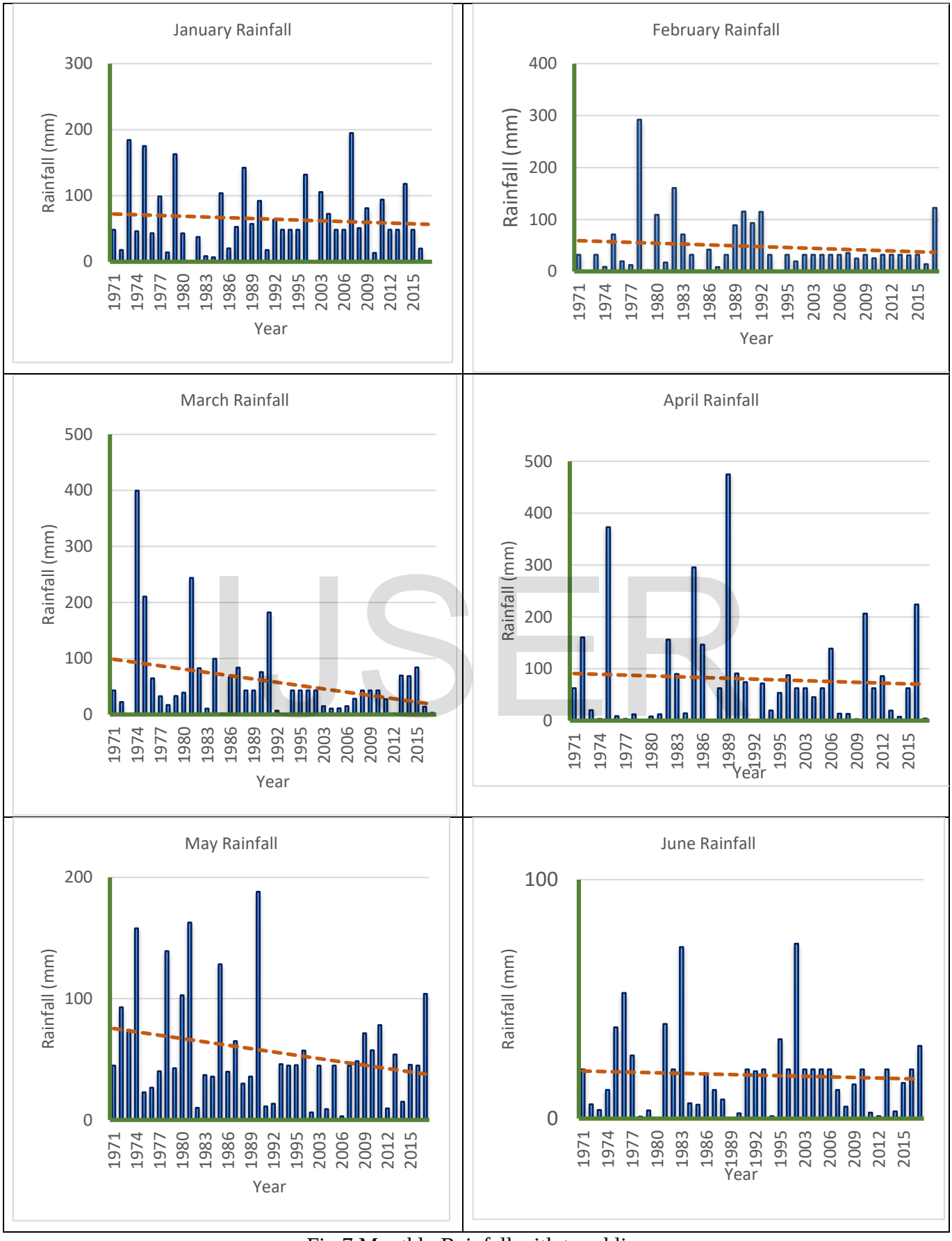
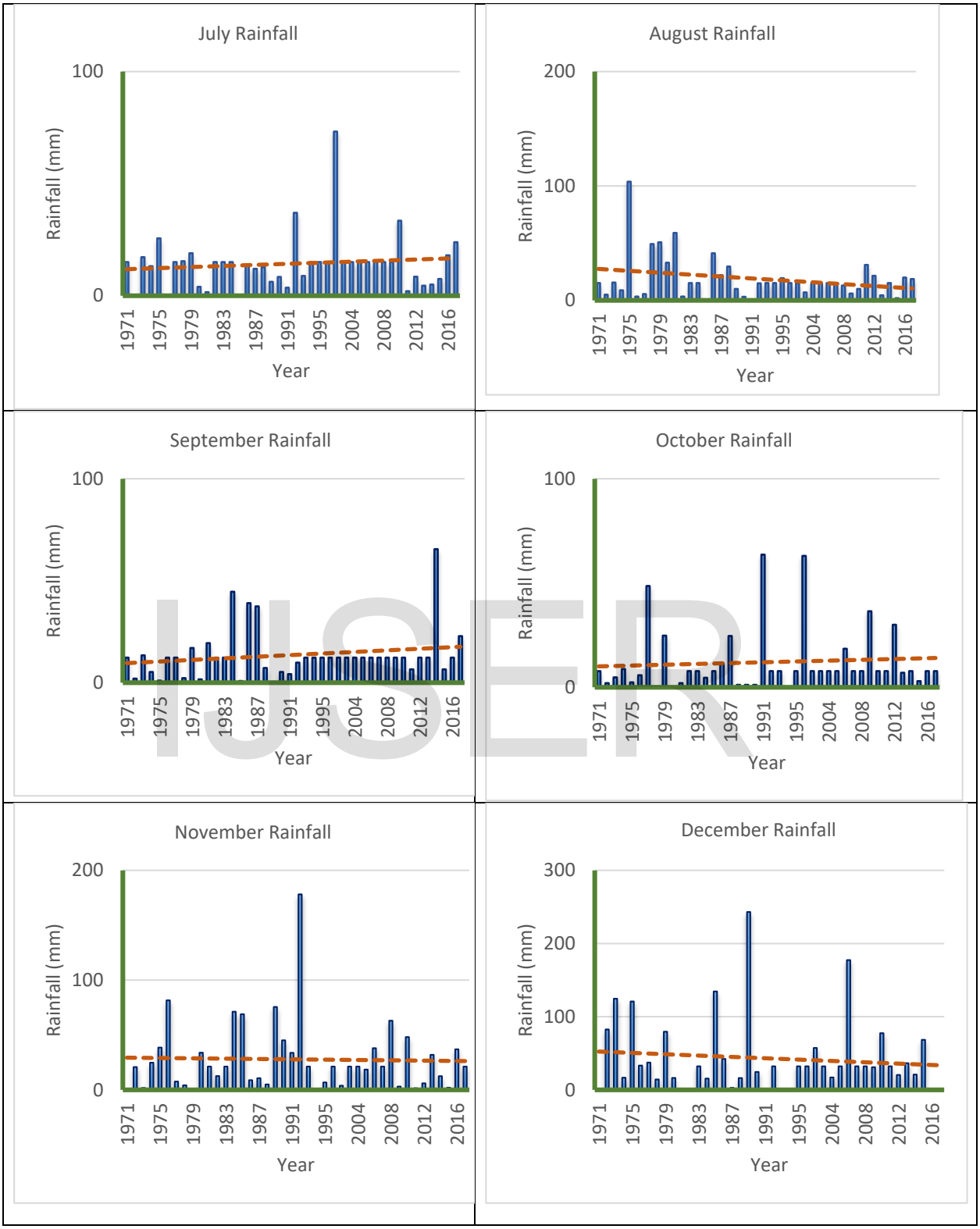


Fig.7 Monthly Rainfall with trend line



Cont.Fig.7 Monthly Rainfall with trend line

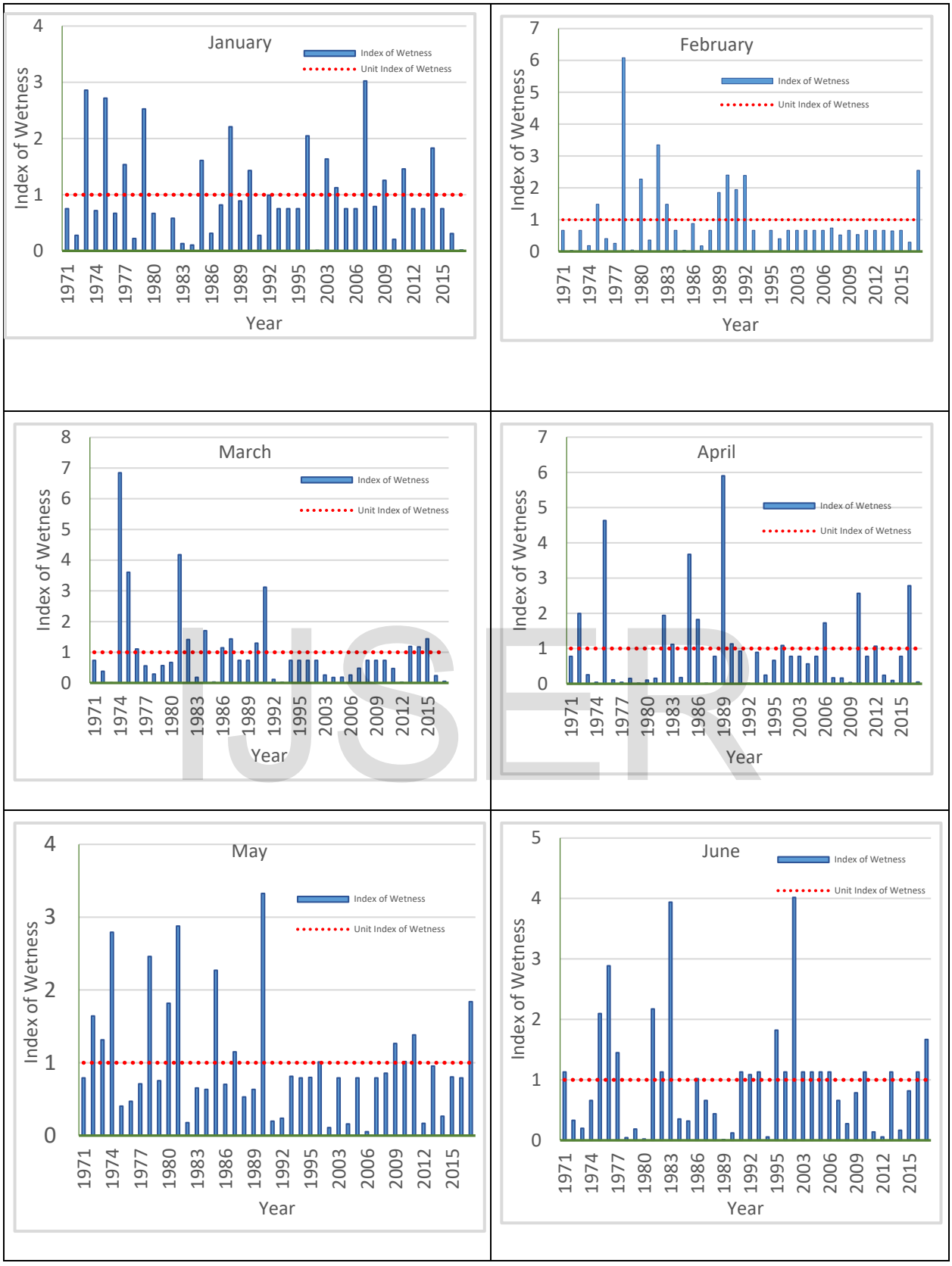
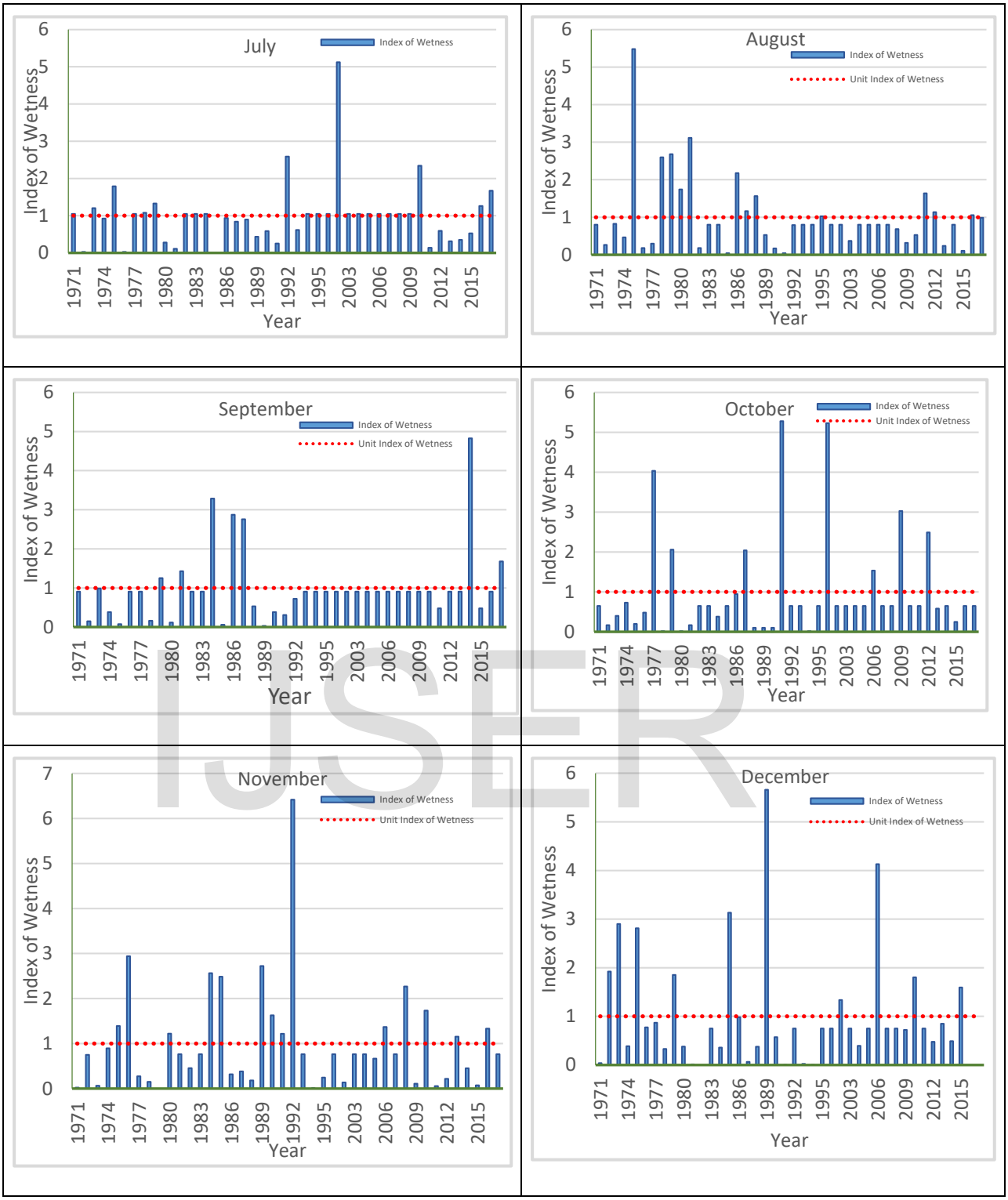


Fig.8 Index of wetness of all months



Cont. Fig.8 Index of wetness of all months

The percent of rain deficiency for every month had calculated and the result listed in table (1) and illustrated in Fig.9

Table1. Classification of months due to rainfall amount (Rain Deficiency)

Month	Number of Rainy Years	% of Rainy years	Classification	Number of Drought Years	% of Drought years	Classification
January	15	36	Rainy Years	27	64	Drought Years
February	10	23		32	76	
March	13	30		29	69	
April	12	29		30	71	
May	14	33		28	67	
June	22	52		20	48	
July	25	60		17	40	
August	13	31		29	69	
September	8	19		34	81	
October	9	21		33	79	
November	14	33		28	67	
December	11	26		31	74	

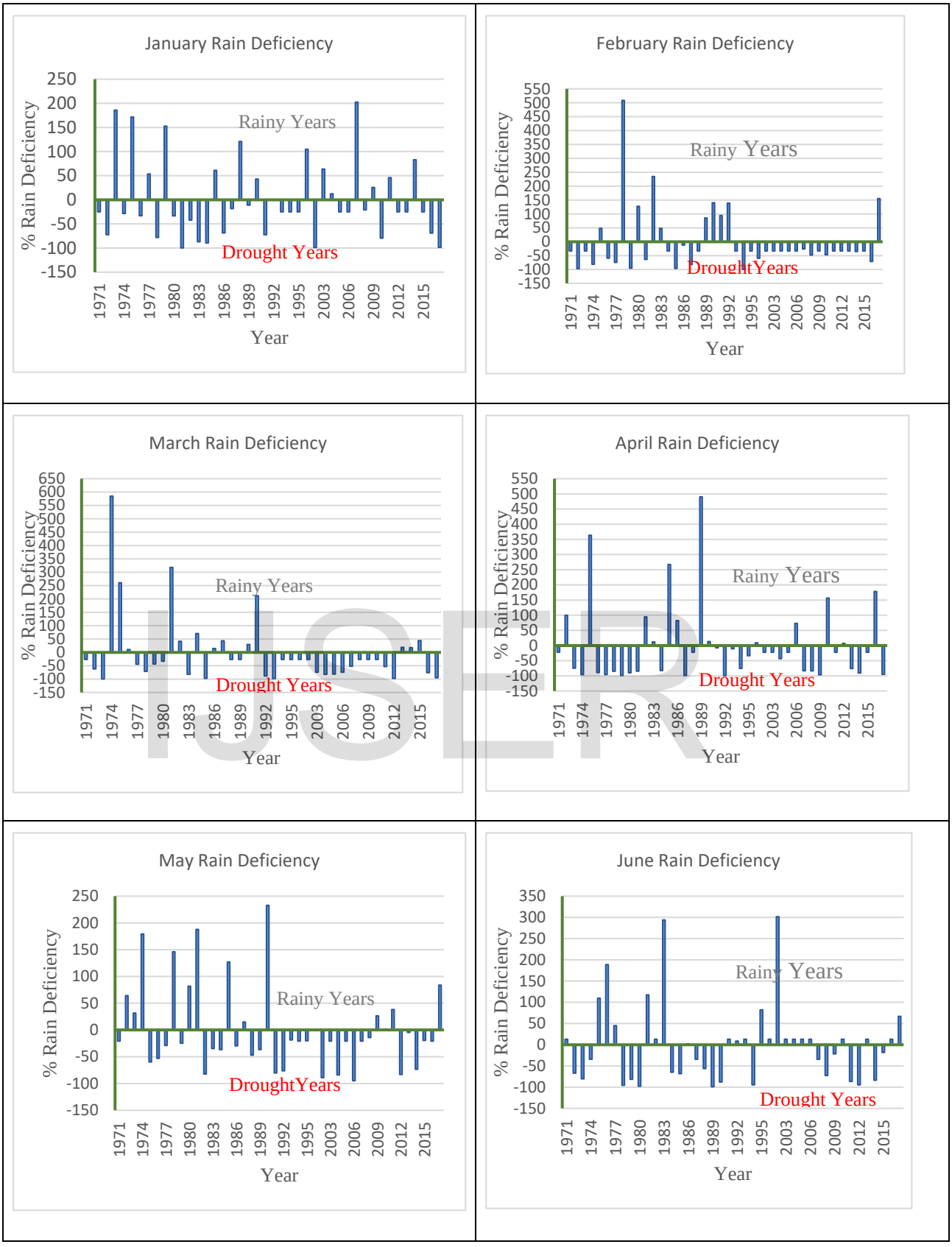
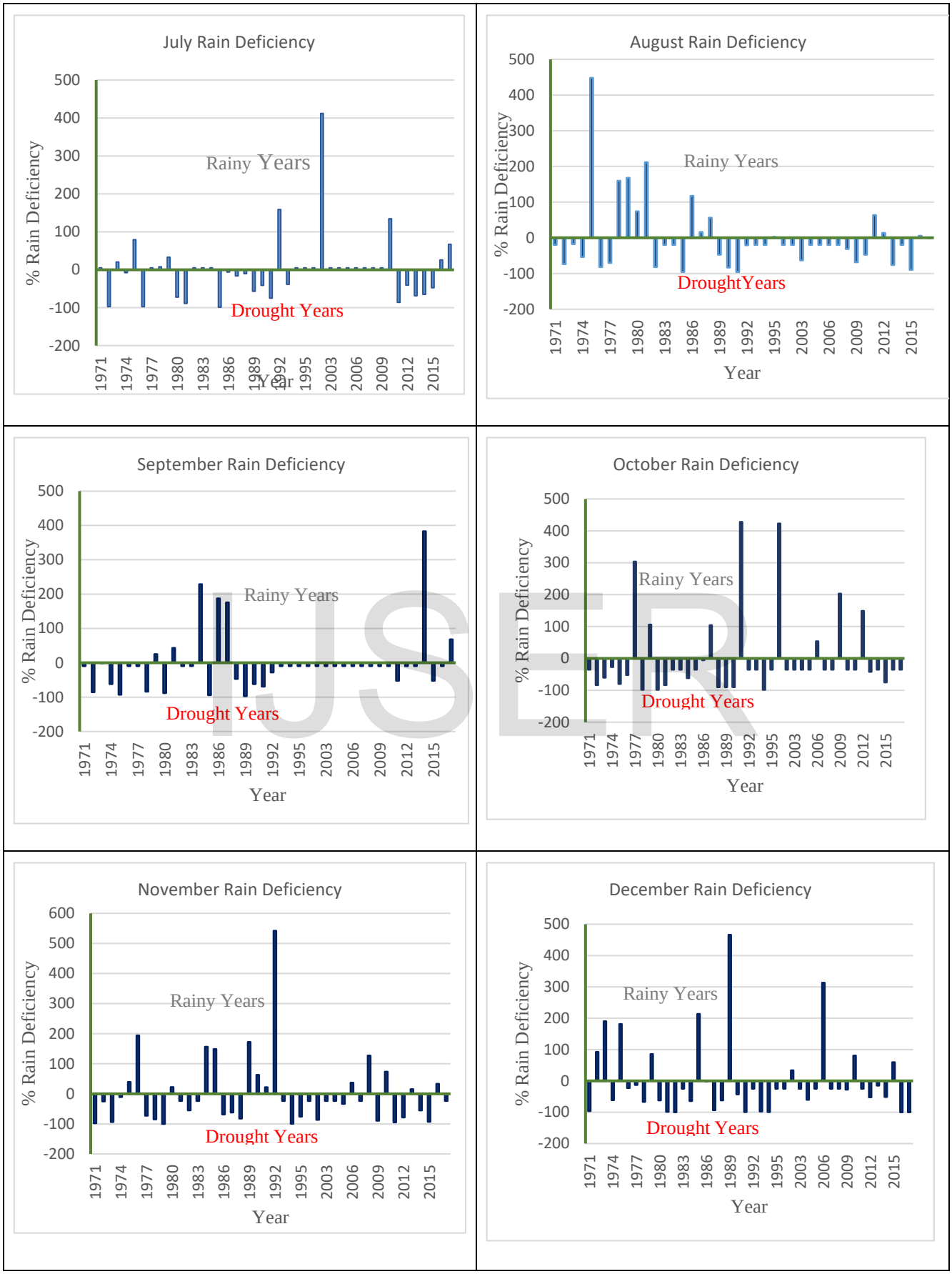


Fig.9 Rain Deficiency all months



Cont. Fig.9 Rain Deficiency all months

From table 1 and Fig.9 it is clear that the percent of drought years (Rain Deficiency) is high in comparison with the rainy years its range between 40% to 81% and this percent for April about 71%.

3.3 Seasonal Rainfall Analysis

To check the results of monthly results, analysis for seasonal rainfall took place. The year was divided in to 4 seasons, Winter (November, December and January), Spring (February, March and April), Summer (May, June and July) and Autumn (August, September and October). The amount of rainfall and the mean of rain was calculated for each season and the results illustrated in Fig.9. Table 2 formulated from Fig.9.

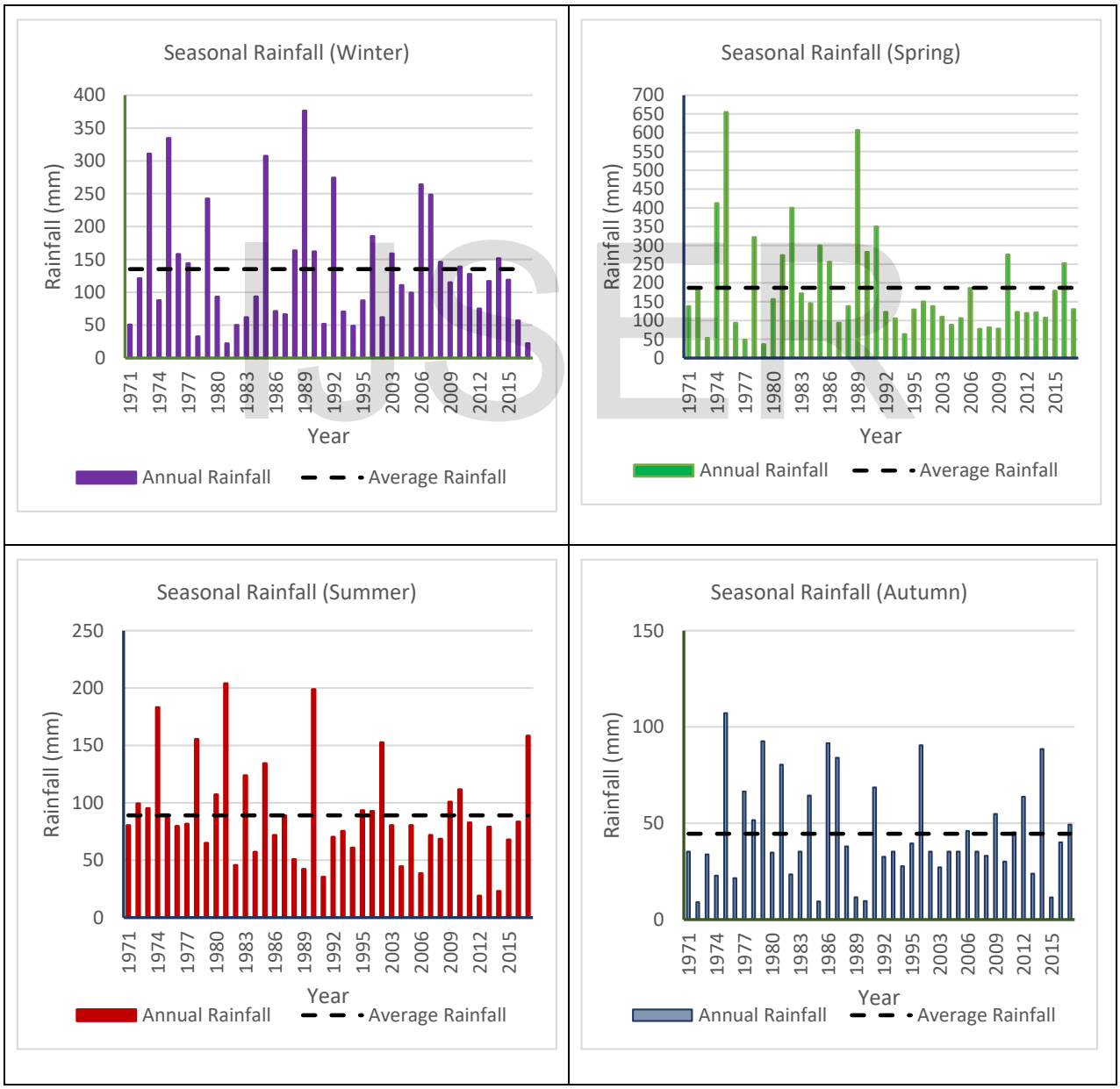
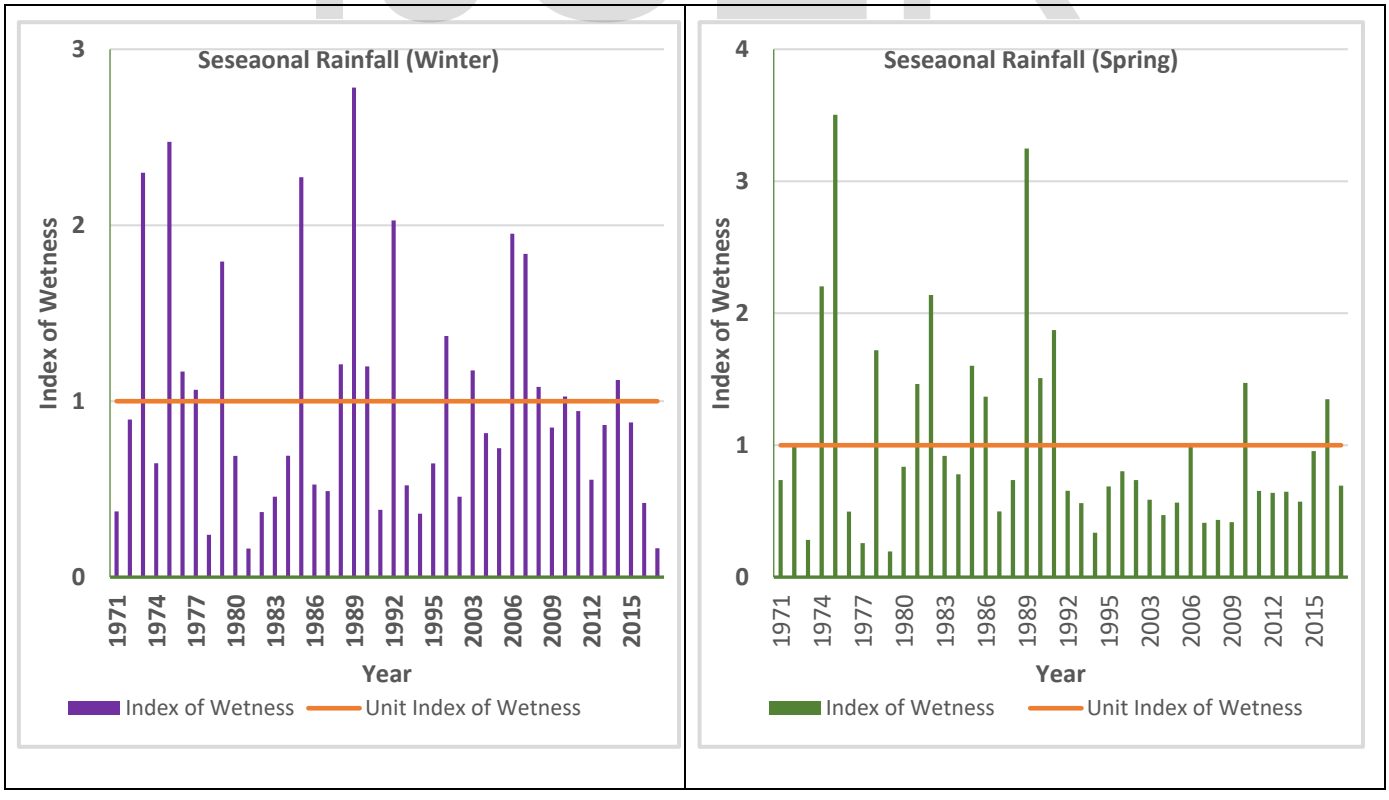


Fig.9 seasonal rainfall with average rainfall value

Table 2 Classification of seasons due to rainfall amount (Rain Deficiency)

Season	Average Rainfall in (mm)	Number of Years more than Average	% of Years more than Average	Classification	Number of Years less than Average	% of Years less than Average	Classification
Winter	135.22	17	40	Rainy Years	25	60	Drought Years
Spring	186.85	15	36		27	64	
Summer	89	17	40		25	60	
Autumn	44.6	16	38		26	62	

From Fig.9 and Table 2, more than 60% of years in each season are drought. The same result founded by calculating index of wetness and rain deficiency for the seasonal rainfall records as shown in Fig.10 and Fig.11.



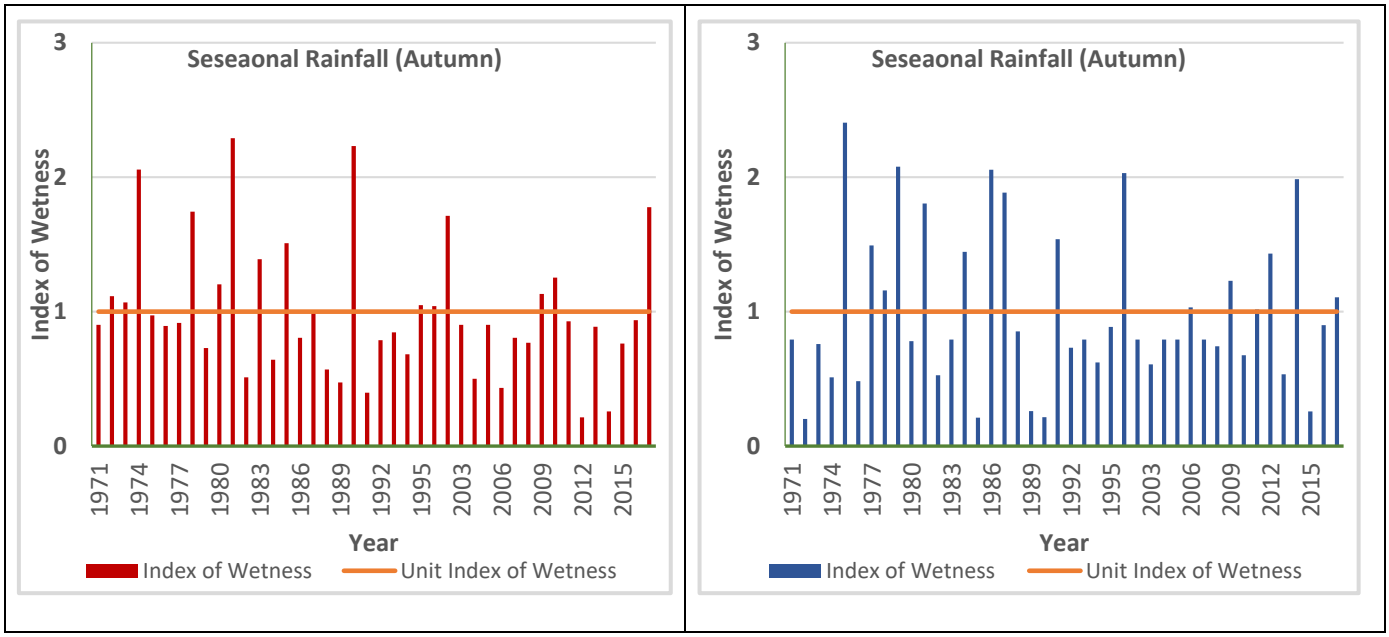
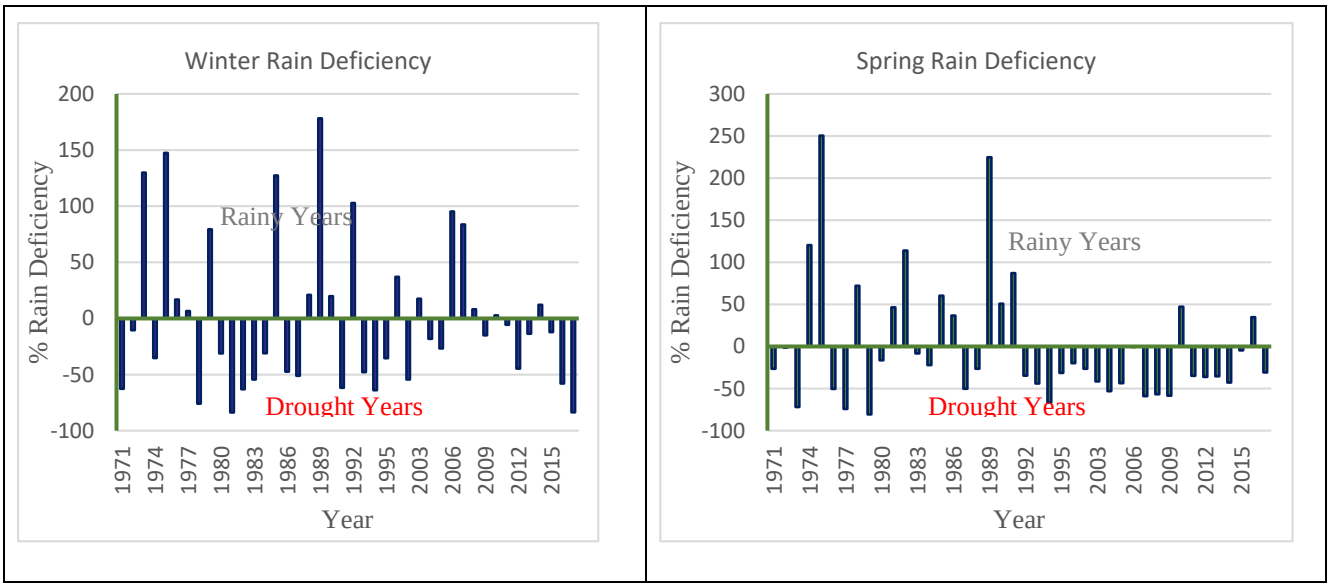


Fig.10 Index of Wetness for seasonal rainfall



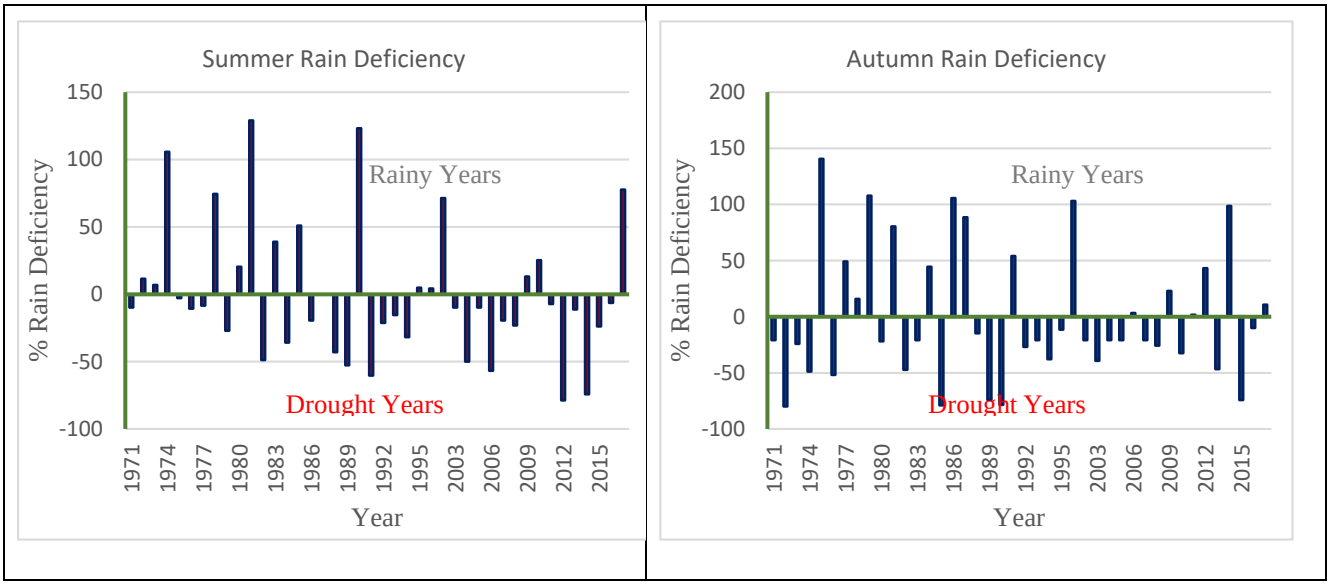


Fig.11 Rain Deficiency for seasonal rainfall

4. Results and Discussions

The concept of this paper based on hydrological analysis of the daily rainfall records for Al-Baha city.

Monthly records, annual records and seasonal records of rainfall were formulated from the maximum daily rainfall records.

Analysis started first with annual records for drought investigation by calculating mean , index of wetness and rain deficiency, the results of this analysis gives 65% of rainfall records are classified as drought and the sequence of drought getting worse (7 drought years continuously).

Secondly the analysis takes the monthly rainfall records, the results gives 40% as percent of drought for July and the maximum percent with 81% for September, but the serious percent is the percent of April because its higher rainy month (71%) . The percent of drought is range between 40% and 81% and this is high values (it means that drought took place).

Finally, the seasonal rainfall records analyzed and the percent for each season greater than 60% especially in the rainy seasons (Winter & Spring)

5. Conclusions

It can be conclude that the rainfall mode in Al-Baha city is going in drought direction. For this the decision maker in field of water resources can take the results of this

paper in consideration in planning for each water project in this city, also it's a call for the scientists to study the reasons of the climate change in Albaha city.

6. Acknowledgment

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