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Evaluation of The Intra-Annual Variability of The Dynamics Of Precipitation in The Mediterranean Zone:

EXAMPLE OF THE TADLA-AZILAL BASIN (MOROCCO).

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ABSTRACT: This study focuses on intra-annual rainfall variability in the Tadla-Azilal basin, for which we use two approaches. The first method is purely statistical and seeks to describe the temporal behaviour of rainfall and identify possible trends. The second uses the standardised seasonal precipitation index (SPI) and the moving average method (9-year**)**.The aim is to look for possible internal trends and identify dry and wet periods. For seasonal cutting we applied the method of Gasparin (P<2T).
The results obtained show that the rains of this region are characterised by a great inter-annual and intra-annual variability. Most stations reported an upward trend in autumn rains, the winter and spring rains showed a statistically insignificant downward trend. These results are in perfect agreement with the SPI, which indicates that autumn and winter droughts are less frequent than spring droughts.
This pattern of relative variability is probably related to a shift from the rainy period to fall.

Keywords: Variability, precipitation, trends, seasonal, standardised precipitation index

I. INTRODUCTION

Climatic variability (especially rainfall) in Mediterranean areas and particularly in Morocco is no longer demonstrable. Various indices have been proposed by researchers to analyse the dry periods (Eljihad, 2004; Stour, 2009; Sebbar & *al*., 2011; Jouilil & *al*., 2013; Bitar & *al.*, 2013; 2013; Krimissa & *al*.., 2016). But very few of them are interested in intra-annual or seasonal variability and rainy periods often have an extremely uncertain beginning and end; they may also be subjected to more or less long phases of drought. These conditions have major consequences for establishments for long periods of the year due to a chronic water deficit resulting from the imbalance between two antagonistic physical processes of the climate (low rainfall and very high evaporation). The deficit established during the drought essentially affects the physiological processes of the plants and causes the degradation of the plant cover.

This study attempts to fill this gap, focusing on the analysis of intra-annual rainfall using a monthly or seasonal step.

II. PRESENTATION OF THE STUDY AREA

The Tadla-Azilal basin is located in the centre of Morocco, between 7 ° and 5 ° 30 'east longitude and 31 ° to 32 ° 5' north latitude. The study encompasses three topographically distinct areas: the plain; the piedmont and the mountain.

The mountain covers the southern Middle Atlas and the central High Atlas. The relief consists of heavy platforms delimited by sub-vertical cornices. The piedmont is a narrow strip of fertile land in a transitional position between the plain and the mountain. The plain, at altitudes between 400 and 700m, covers an area of 3500km^2 inclined from east to west drained by the Oued Oum Erbiaa.

The Tadla-Azilal is characterised by a strong spatial variability in precipitation with a climatic staging of the plain to the mountain, the climatic seasonality is marked with a rainy period from October to May and a dry period from June to September. Snow is a significant part of mountain precipitation in winter. This seasonality strongly influences the river regime.

III. DATA AND METHODS

The basic data consists of rainfall records from 9 meteorological stations (Table 1). The study variable is the monthly rain. The selected positions are subject to criteria of continuity, the duration of the information available and the quality of the data. The choice of stations was also made to allow the most homogeneous coverage of the study area. Rainfall data was provided by the Oum Rbiaa Watershed Agency.

Table 1: Identification of rainfall positions.

Stations	Lambert coordinates in grades		elevation	Periods
	X	Y	Z	
Beni Mellal	409165	193045	537	1983-2015
Tilouguite	422670	158500	1100	1974-2015
OuledGnaou	395860	192675	455	1963-2015
ZawyatAhnsal	43230	139600	1595	1983-2015
Tizi Nisli	464924	207560	1595	1975-2015
Admaghene	372900	125400	1125	1984-2015
Ait Segmine	361400	128000	1025	1971-2015
Ait Tamlilt	357600	93700	1860	1974-2015
Moulay Bouzkri	376993	208472	435	1983-2015

First, we will analyse the magnitude of the relative variability of the annual rainfall totals by mapping the coefficients of variation. Secondly, to refine the analysis we propose a detailed study of the seasonal variability. The tools we have chosen to achieve the objectives are:

THE COEFFICIENT OF VARIATION

The coefficient of variation (Cv) is the ratio of standard deviation to mean. The high values of the coefficient indicate that the dispersion around the mean is large. It is usually expressed as a percentage. It allows the comparison of distribution of values whose scales of measurements are not comparable.

MANN KENDALL'S TEST

The Mann-Kendall test is used to determine if an identifiable trend in a time series is significant or not in the statistical sense of the term.This nonparametric trend test is the result of an improvement of the test studied firstly by Mann in 1945, improved by Kendall in 1975 and finally optimised by Hirsch in 1982, 1984, 1985 and 1988 to consider a seasonal component.

The null hypothesis H0 of these tests; is that there is no trend. The three alternative hypotheses of negative (not null or positive) trend can be chosen to assess the statistical significance of the trends cited above. The Mann Kendall test was applied with a 95% confidence level (Sneyer, 1990). The parameters used for this test are: alternative hypothesis ≠ 0; satisfaction level of 5%; number of simulations: 10,000; maximum simulation time 180 (s). Its application was made by the software XL

STAT the results obtained are mentioned in Table 4.

ESTIMATOR OF SEN'S

The SEN'S J. S. Brauner method, 1997 is used to estimate the slope of a time series of regularly spaced data. It consists of calculating the slopes of all the data in the series. Then estimates the slope of Sen's by the median slope PM per the equation:

$$PM = \frac{1}{2}\left(P_{\frac{N}{2}} + P_{\frac{N+2}{2}}\right) if\ N\ is\ even$$
$$PM = P_{\frac{N+1}{2}} if\ N\ is\ odd$$

where N is the number of calculated slopes. A confidence interval of Lower Slope (Pinf) and Upper Slope (Psup) are calculated to define the real confidence interval for the median slope PM.

STANDARDISED PRECIPITATION INDEX SPI

The SPI Standardised Precipitation Index was developed by McKee & *al*. (1993) to quantify the precipitation deficit for multiple timescales, which reflects the impact of drought on the availability of different types of water resources for a given period.

It is expressed mathematically as follows:

$$\text{SPI} = \frac{Pi - Pm}{S}$$

Where Pi: is rain of the year i;

PM is the average rainfall of the series on the time scale considered;

S is standard deviation of the series on the time scale considered.

Studying this index also makes it possible to distinguish dry years from wet years or deficit years from surplus years. A drought occurs when the SPI is consecutively negative and its value reaches an intensity of -1 or less and ends when the SPI becomes positive. Dryness is classified according to SPI values (Table 2).

Table 2: Classification of drought sequences per SPI

Value of SPI	Sequence of drought
-0.99 à 0.99	Near normal
-1.00 à -1.49	Moderately dry
-1.50 à -1.99	Severely dry
-2 and less	Extremely dry

MOVING AVERAGE

The World Meteorological Organization has recommended in Technical Notice No. 79 the use of moving averages for the study of rainfall fluctuations. This statistical technique consists of calculating an arithmetic mean from a value (Xi) and the neighbouring values that surround it. Odd values are often used and for our case, we used the nine-year moving average. This choice is strongly related to the duration of the observations, which is sufficiently long. The 9-year moving average:

$$X = \frac{X_{i-4} + X_{i-3} + X_{i-2} + X_{i-1} + X_i + X_{i+1} + X_{i+2} + X_{i+3} + X_{i+4}}{9}$$

The use of moving averages makes it possible to better visualise the possible evolution between any two terminals. This method reduces the influence of accidental variations and eliminates the effect of fluctuations in very short periods. But it must be used with great caution when trying to specify a trend.

IV. RESULTS AND DISCUSSION

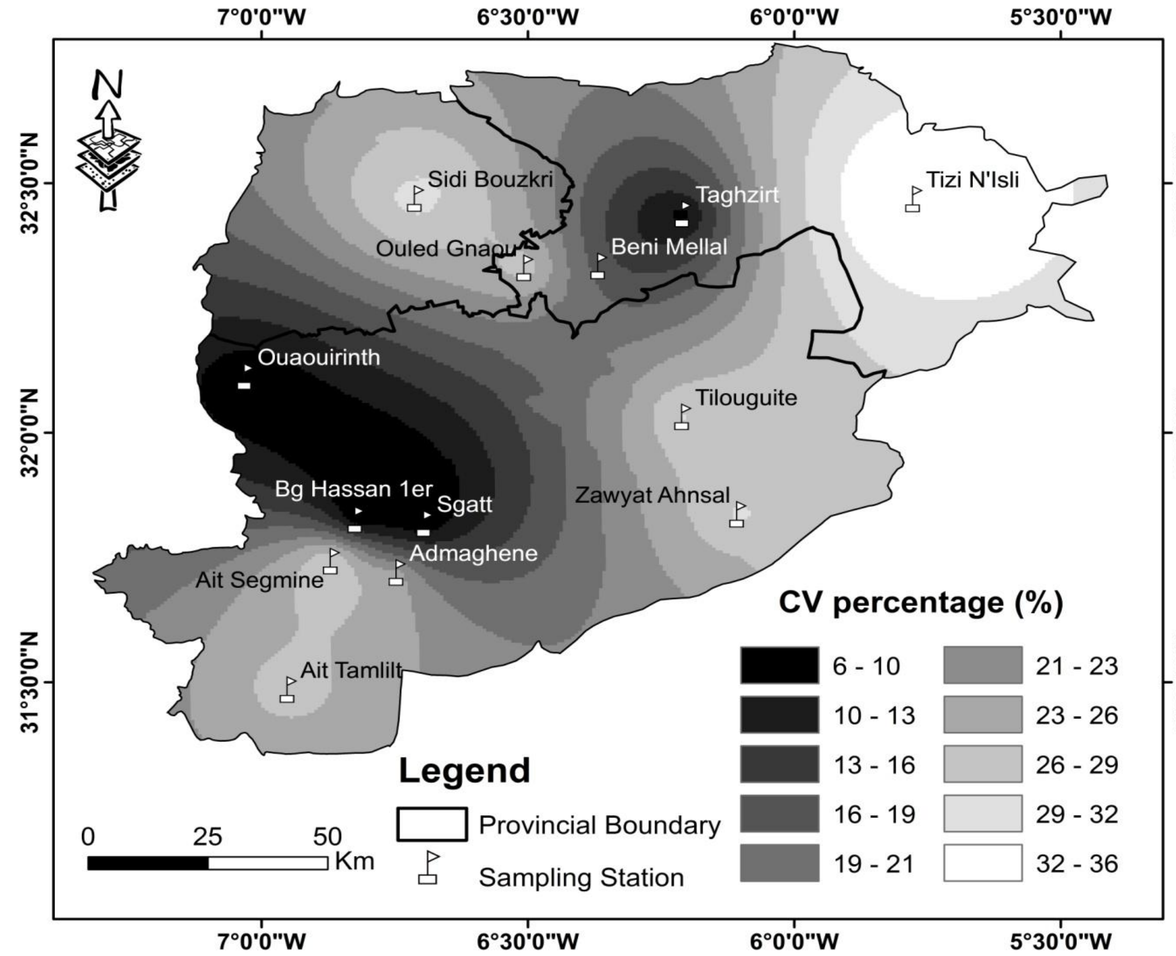
Before beginning the analysis of the seasonal variability of precipitation, an overview of the interannual variability is essential. Table 3 gives the indices of quantification of the annual variability of rainfall in all stations; the coefficient of variation of rainfall is around 30%.

Table 3: Statistical characteristics of the annual rainfall of the studied stations

Stations	First quartile	Minimum	Maximum	Median	Third quartile	Coefficient of variation
Beni Mellal	354.9	229.7	641	436.5	499	15%
Tilouguite	293.4	219	601.2	367.5	444.1	31%
OuledGnaou	245.2	158.4	533.3	304.1	365.4	30%
ZawyatAhnsal	294	195	625	304	446	31%
Tizi Nisli	313.4	218.7	7.3.6	430.3	547.3	40%
Admaghene	367.3	304.1	896	450	685.5	27%
Ait Segmine	416.1	269.1	727	460.3	548	32%
Ait Tamlilt	320.4	203.2	727	460.3	520	30%
Moulay Bouzkri	203	143	503	254.5	294	33%

To better visualise the regional extension of this climatic variability, we have combined cartographic representation with the statistical procedures deployed. The spatial interpolation performed on the coefficients of variation illustrates a well-contrasted spatial variability.
The values of the coefficients of variation of the interannual contributions for the period 1984 to 2015, common to all the stations treated (Figure 1), are relatively high, which indicates an irregular regime. This irregularity is increased in Tizi N'isli, Ait Tamlil and Zaouit Ahnsal characterised by high altitudes.

Figure 1: Coefficients of variation of interannual contributions for the period 1984 to 2015.



To find out if the rainfall variability highlighted previously is due to a given season we studied the intra-seasonal evolution. With regards to seasonal cutting, we applied the method of Gasparin, taken up by Gaussen (1954).This method is based on two criteria. Summer is made up of the three driest and consecutive months;

•One month (i) is dry if:P(i) < 2 T(i).

Where : P (i) is the mean rain of the month (i) in (mm);T (i) is the average temperature of the month (i) in (° c).To apply this approach, we chose the stations of Beni Mellal, and Ouled Gnaou. Both stations have temperature records covering a common 30-year period.

The results in Table 4 show that the driest consecutive months (summer season) correspond to June, July and August. Since the division is quarterly, the adopted seasons correspond to the following division: autumn (September, October, November), winter (December, January, February), spring (March, April, May) and summer (June, July, August).

We also find that all years have a dry month greater than or equal to 5 months, and that no month of the year escapes the drought. The summer season is the most distinguished dry season as the months of June, July, August, and September are constantly dry. The number of successive dry months reached up to 10 months in 2001.The winter season also experiences occasional periods of drought and is less durable than the summer season (rarely exceeding two months).

To better appreciate this temporal variability, we analysed the percentage distribution of precipitation per season for all the stations selected (Table 5).We notice that the winter rains have a large percentage compared to other seasons. This type of regime (HPAE) is characterised by a dry season in the summer, then a longer rainy season which persists during autumn, winter and spring. The dominance of this type of regime is mainly a result of the geographical situation of this zone, which extends to the piedmont of the Middle Atlas.

Table 4: Monthly index of drought P<2T in Beni Mellal (B) and Ouled Gnaow (O) from 1986 to 2015.

	J	F	M	A	M	J	J	O	S	O	N	D	B	O
1986					O-B	O-B	O-B	O-B	O-B			O-B	6	6
1987			O-B	O	O-B	O-B	O-B	O-B	O-B	O-B			7	8
1988				O-B	O-B	O-B	O-B	O-B	O-B	B		O-B	8	7
1989				B	O-B	O-B	O-B	O-B	O-B				6	5
1990		O-B	O		B	O-B	O-B	O-B	O-B	O-B	O-B		8	8
1991	O				O-B	O-B	O-B	O-B	O-B	O	O	B	6	8
1992	O-B			O	O-B	O	O-B	O-B	O-B	O-B	O	O	6	10
1993		B		O-B	O-B	O-B	O-B	O-B	O-B	O-B			8	7
1994			O	O-B	O-B	O-B	O-B	O-B	O-B	O-B	O-B	O-B	9	10
1995	O-B		O-B		O-B	O-B	O-B	O-B	O-B	O-B			8	8
1996				B		O-B	O-B	O-B	O-B	O-B	O-B		7	6
1997		O	O		O-B	O-B	O-B	O-B	O	B	O		5	8
1998	B		O-B	O-B	O-B	O-B	O-B	O-B	O-B	O-B	O-B		10	10
1999			B	B	O-B	O-B	O-B	O-B	O-B	O-B			8	6
2000	O-B		O-B	O	O	O-B	O-B	O-B	O-B		O		6	9
2001		O-B	O-B	O-B	O-B	O-B	O-B	O-B	O-B	O-B	O-B		10	10
2002	B	O-B			O-B	O-B	O-B	O-B	O-B	O-B		O	8	7
2003			O	O	O-B	O-B	O-B	O-B	O-B	O-B			6	8
2004	O-B					O-B	O-B	O-B	O-B	O-B	O		6	7
2005	O-B		O	O-B	O-B	O-B	O-B	O-B	O-B	O			7	9
2006	O		O	O-B	O	O-B	O-B	O-B	O-B	O-B	O	O	11	6
2007	O-B		O-B	O	O-B	O-B	O-B	O-B	O-B	O-B			8	9
2008		O-B	O-B	O-B	O-B	O-B	O-B	O-B	B				8	7
2009				B	O-B	O-B	O-B	O-B	O-B	O-B	O-B		8	7
2010				B	O-B	O-B	O-B	O-B	O-B	B			7	5

2011	O	O				O-B	O-B	O-B	O-B			O-B	4	7
2012		O-B	O-B	O	O-B	O-B	O-B	O-B	O-B			O-B	8	9
2013		O-B			O-B	O-B	O-B	O-B	O-B	O-B	O	O	7	9
2014					O-B	O-B	O-B	O-B	O-B	O-B			6	6
2015		O			O-B	O-B	O-B	O-B	O-B	O-B	O	O	6	9

The variability of seasonal precipitation was also evaluated by the coefficient of variation Cv (Table 6). The extent of this irregularity differs temporally and spatially. During the summer, the intensity of the relative variability becomes strong. Cv values reach excessively high values. They are well above the 100% threshold because summer rains are extremely random. Autumn and spring are of the same degree of rainfall variability, they correspond respectively to the beginning and the end of the rainy season. Such variability reflects the instability of the rainy season, sometimes early and sometimes late. Winter is the core of the rainy season characterised by a relatively low variability compared to other seasons. Rainfall accidents are less redoubtable during this season (Sebbar & *al*., 2011).

Table 5: Rainfall Distribution by Season in%

Stations	**Autumn in %**	**Winter in %**	**Spring in %**	**Summer in %**
Beni Mellal	28%	38%	32%	2%
Tilouguite	27%	38%	33%	2%
OuledGnaou	27%	37%	34%	2%
ZawyatAhnsal	29%	28%	27%	16%
Tizi Nisli	26%	38%	33%	3%
Admaghene	27%	37%	33%	3%
Ait Segmine	26%	38%	33%	3%
Ait Tamlilt	27%	36%	34%	3%
Moulay Bouzkri	27%	41%	31%	1%

Table 6: Relative Variation of Seasonal Precipitation (Cv)

Stations	**Cv (Autumn)**	**Cv (Winter)**	**Cv (Spring)**	**Cv (Summer)**
Beni Mellal	61%	45%	54%	152%
Tilouguite	65%	54%	67%	90%
OuledGnaou	52%	42%	48%	119%
ZawyatAhnsal	50%	46%	65%	78%
Tizi Nisli	60%	45%	70%	90%
Admaghene	56%	52%	58%	90%
Ait Segmine	62%	50%	63%	92%
Ait Tamlilt	60%	52%	50%	80%
Moulay Bouzkri	47%	50%	60%	140%

To better understand the chronological evolution of seasonal precipitation and to refine the analysis, we propose the study of the fluctuations of rainfall by the analysis of the tendencies only for Autumn, winter and spring. Summer trends are difficult to determine because of the poor total summer rainfall. To do this, we used the nonparametric Mann Kendall test with a 95% confidence level (Sneyer, 1990).
From the results reported in Table 7, we note that almost all fall rainfall series show an increasing trend in magnitude as a function of altitude. Winter and spring rains do not show any trend. To complete the analysis and more precisely assess the statistical significance of these trends, we used Sen's statistical test. This method consists of determining the value and the orientation of the slope (PM) of the adjustment line of the rain variable as a function of time.Its application gave the results mentioned in Table 8.It appears that almost all stations have negative values for winter and spring rains, which means that the rainfall trend is characterised by a gradual

decrease, on the other hand, autumn rains indicate an upward trend.This is probably a shift from the rainy period to autumn.These results are in perfect concordance with those of Nouaceur & *al*.(2012) and Sebbar (2013).

Table 7: Application of the Man Kendall test for seasonal rainfall at the 95% threshold (α = 0.05)

Station	P value		Trend
Beni Mellal	Autumn	28%	Not significant
	Winter	86%	Absent
	Spring	95%	Absent
Tilouguite	Autumn	0.03%	Significant to increase
	Winter	80%	Absent
	Spring	90%	Absent
OuledGnaou	Autumn	30%	Not significant
	Winter	77%	Not significant
	Spring	24%	Not significant
ZawyatAhnsal	Autumn	14%	Not significant
	Winter	72%	Absent
	Spring	95%	Absent
Tizi Nisli	Autumn	0.02%	Significant to increase
	Winter	34%	Not significant
	Spring	70%	Absent
Admaghene	Autumn	0.04%	Significant to increase
	Winter	58%	Absent
	Spring	26%	Not significant
Ait Segmine	Autumn	0.08%	Significant to increase
	Winter	25%	Not significant
	Spring	25 %	Not significant
Ait Tamlilt	Autumn	14%	Not significant
	Winter	51%	Absent
	Spring	33%	Not significant
Moulay Bouzkri	Autumn	10%	Significant upward
	Winter	77%	Absent
	Spring	24%	Not significant

Table 8: Sen's test application

Stations		Pinf	PM	P sup
Beni Mellal	Autumn	-34.24	2.04	43.3
	Winter	-51.9	-0.53	48.1
	Spring	-46.45	0.13	51.77
Tilouguite	Autumn	-22.15	3.5	32.57
	Winter	-53.5	-0.4	46.91
	Spring	-49.06	-0.42	36.25
OuledGnaou	Autumn	-4.44	0.14	5.29
	Winter	-5.34	-0.02	5.53
	Spring	-5.81	-0.15	5.64
ZawyatAhnsal	Autumn	-33	1.25	5.64
	Winter	-35.33	-0.5	35.5
	Spring	-38.41	0	35.92
Tizi Nisli	Autumn	-21.9	1.6	27.9
	Winter	-57.93	-1.46	48.59
	Spring	-40.26	-0.69	36.76

Admaghene	Autumn	-27.8	4.35	41
	Winter	-62.32	-0.83	53.97
	Spring	-57.69	1.98	68.24
Ait Segmine	Autumn	-24.66	1.64	27.07
	Winter	-43.4	-1.42	40.2
	Spring	-47.46	-1.55	41.75
Ait Tamlilt	Autumn	-31.39	1.6	35.89
	Winter	-40.08	-0.61	39.53
	Spring	-32.7	-0.91	28.27
Moulay Bouzkri	Autumn	-19.95	1.8	30.53
	Winter	-24.35	0	27.3
	Spring	-27.42	0.73	27.2

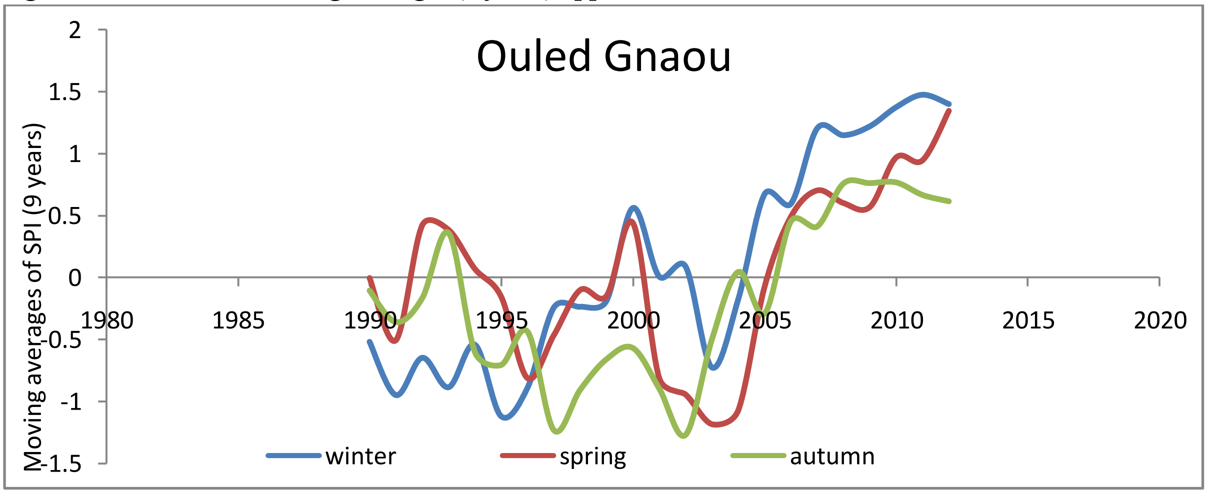
Although the identification of trends in a rainfall series is important, the identification of dry years and their intensities is much more important because the succession of dry years can lead to extreme situations.

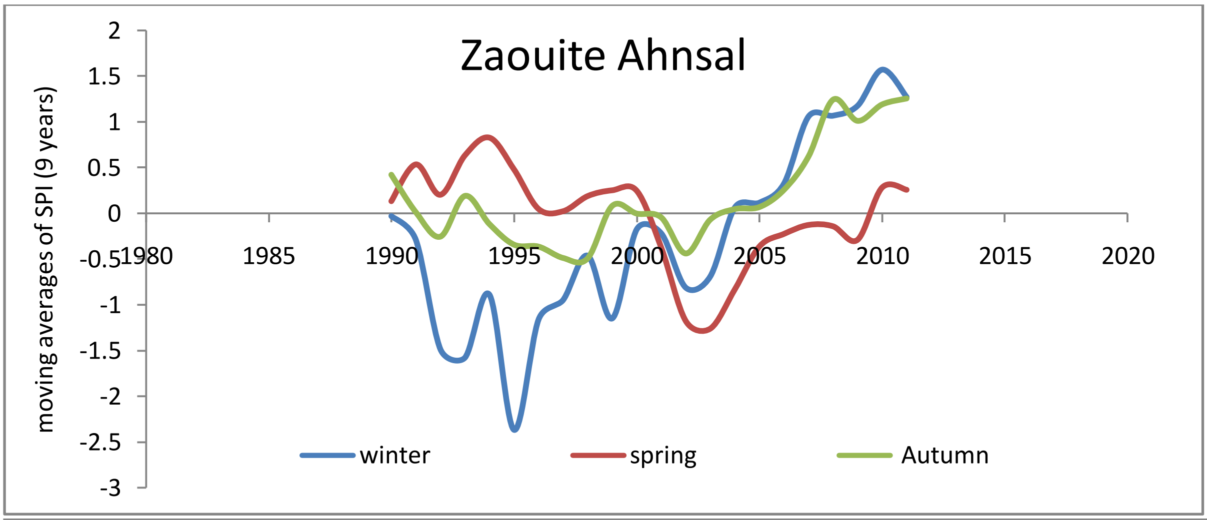
In order to characterise the drought and its dynamics at the seasonal scale, an evaluation of the standardised index of precipitation has been made at this scale.To reduce errors in measurement data, we needed to clearly distinguish interannual fluctuations in precipitation and identify periods of rainfall deficit and excess more clearly. We therefore applied the moving averages on the 9-year overlapping slices to the calculated seasonal SPIs. The results obtained are shown in Figure 2.

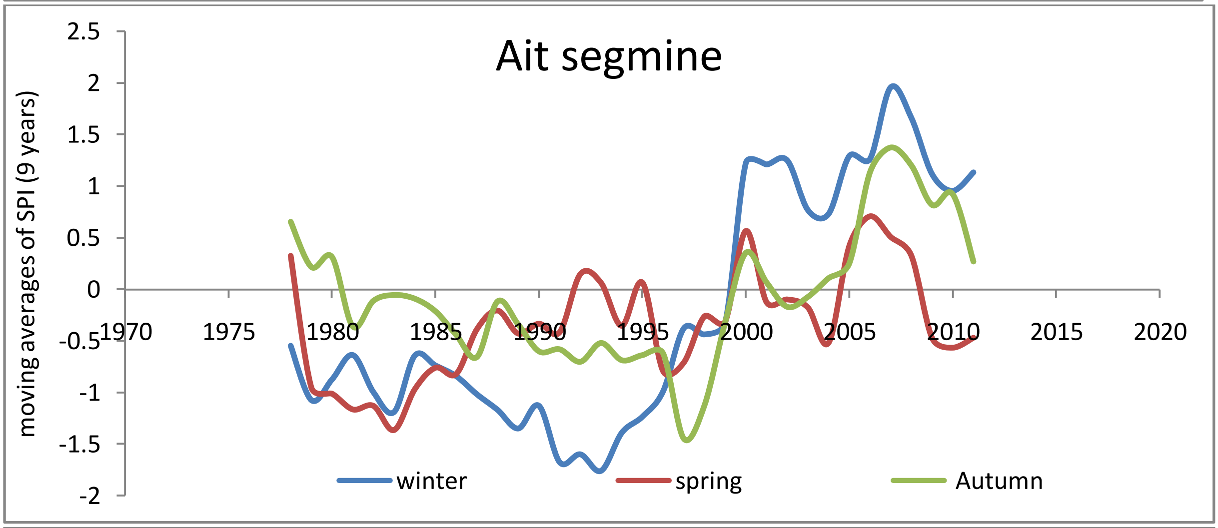
During the autumn, the evolution of the moving average applied to seasonal SPI between 1985-2005 shows two dry phases.The first centred on the year 1997 (severely dry year characterised by a winter and spring drought and mentioned among the exceptionally dry years in Morocco), and the second on 2003 (the other values oscillate around the normal). Beyond that date, a general wet phase took hold and continued until the end of the study period. For other seasons and in most resorts, we can notice a phase opposition between the winter and spring rains.Indeed, for each dry winter season the spring rains reward this rain reduction and vice versa.

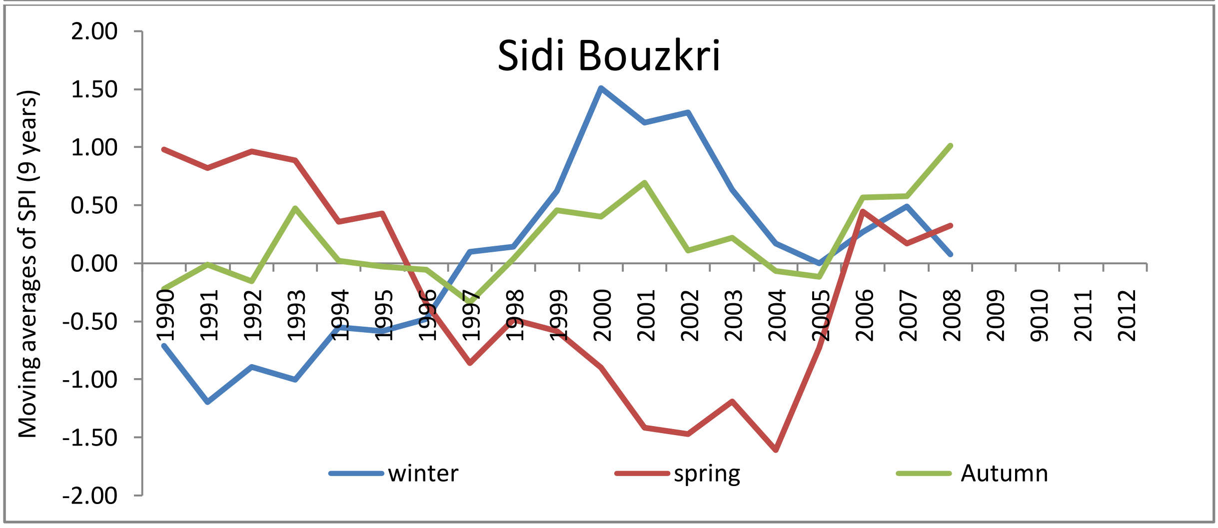
On the other hand, between 1984-2015, spring droughts were more frequent with an average frequency of 38%, followed by winter droughts with an average of 32%, and autumn not exceeding 27%.

Figure 2: Evolution of moving averages (9 years) applied to seasonal SPI.




Zaouite Ahnsal
moving averages of SPI (9 years)
2
1.5
1
0.5
0
-0.5
-1
-1.5
-2
-2.5
-3
1980
1985
1990
1995
2000
2005
2010
2015
2020
winter
spring
Autumn


Ait segmine
moving averages of SPI (9 years)
2.5
2
1.5
1
0.5
0
-0.5
-1
-1.5
-2
1970
1975
1980
1985
1990
1995
2000
2005
2010
2015
2020
winter
spring
Autumn


Sidi Bouzkri
Moving averages of SPI (9 years)
2.00
1.50
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0.50
0.00
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-2.00
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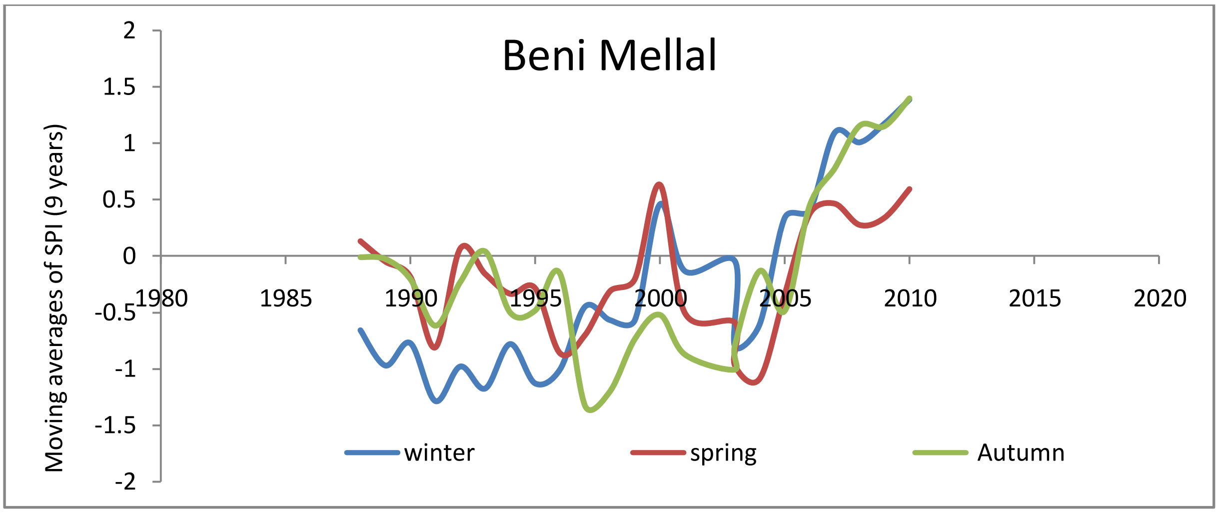
Autumn


Beni Mellal
Moving averages of SPI (9 years)
2
1.5
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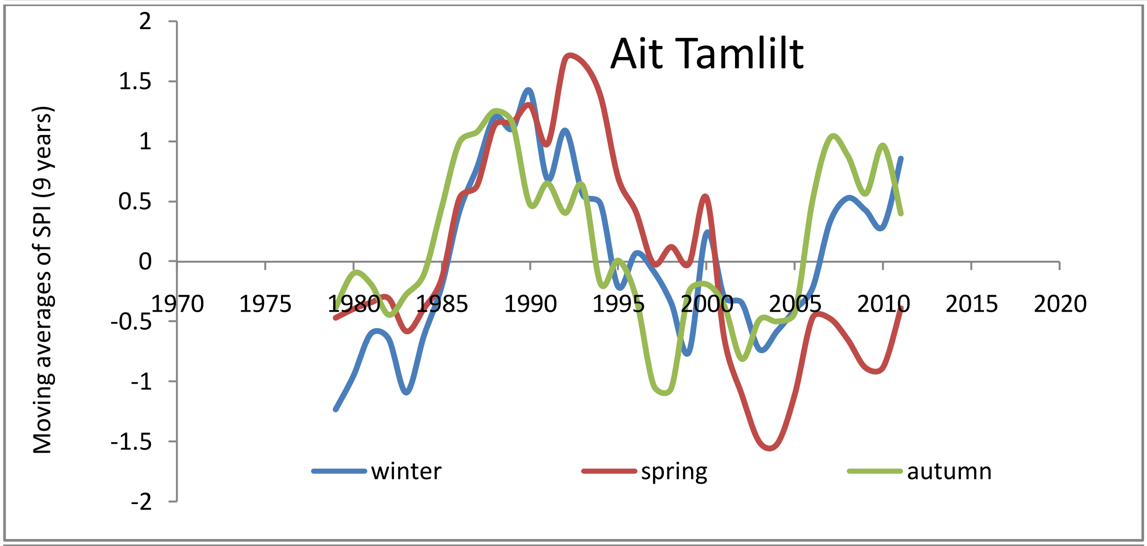
Autumn


Ait Tamlilt
Moving averages of SPI (9 years)
2
1.5
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0.5
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-0.5
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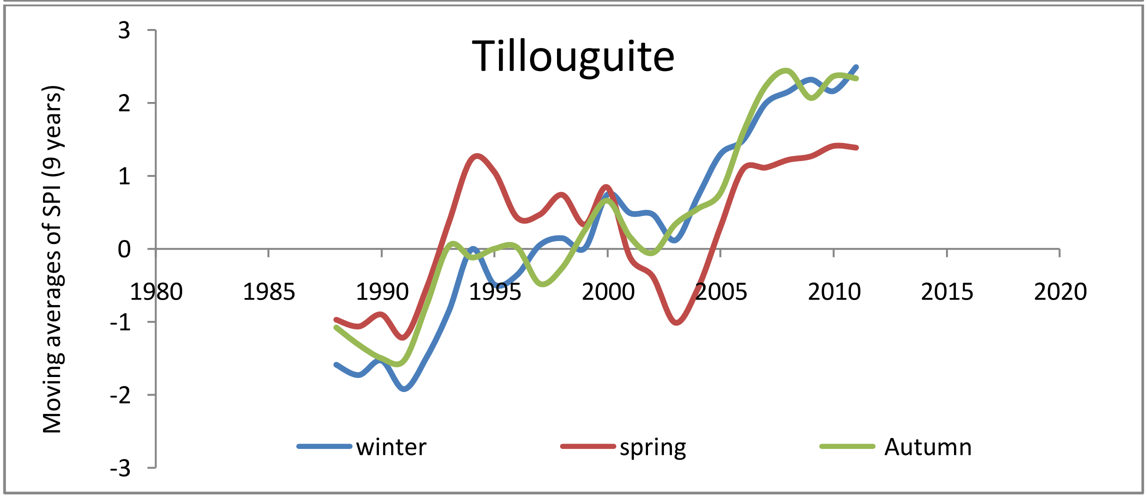
Tillouguite
Moving averages of SPI (9 years)
3
2
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-3
1980
1985
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1995
2000
2005
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2015
2020
winter
spring
Autumn

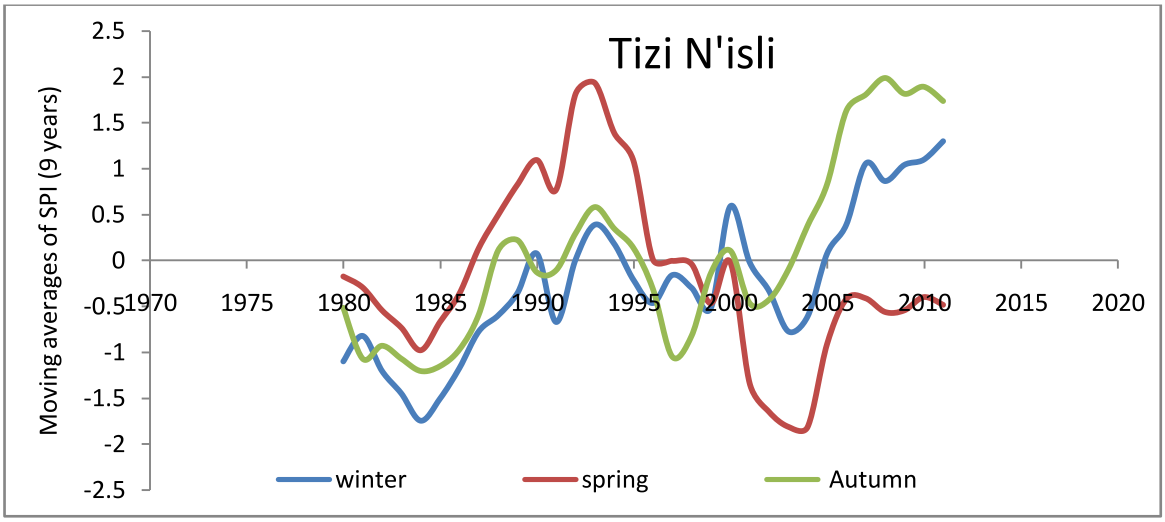
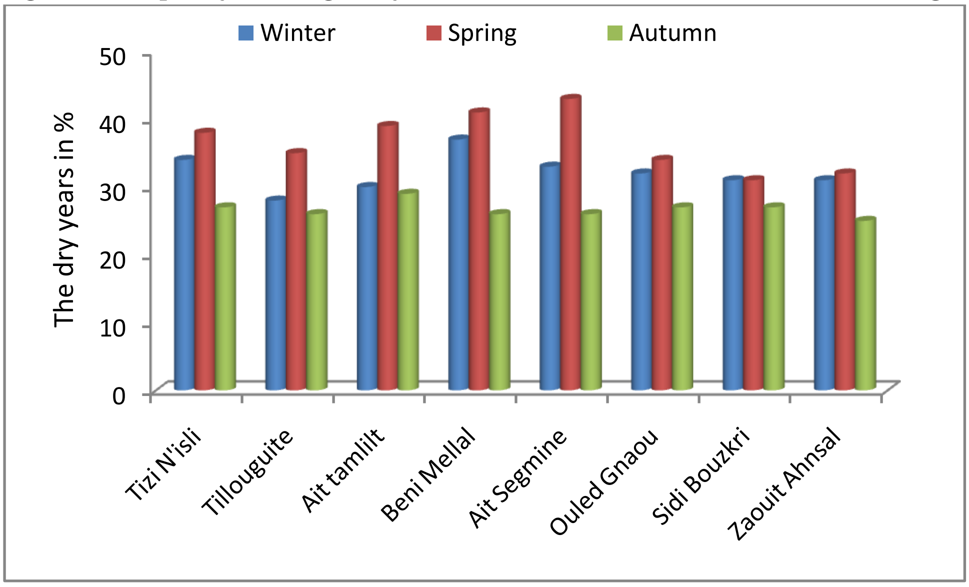


Figure 3: Frequency of droughts by season for the different stations studied during the period 1984/2015.



V. CONCLUSION

It appears through this study that seasonal rainfall in Tadla-Azilal is characterised by a high degree of irregularity that varies from one season to another and from one station to another. This irregularity is more increased in high areas. From a trend point of view, we have observed an upward trend of autumn rains, while winter and spring rains have reported no significant downward trend. To identify the dry seasons and their intensities, an analysis of standardised precipitation indices has been made at this scale and it emerges that for most stations, autumn and winter droughts are less common than spring droughts. The overall results agree on the occurrence of strong seasonal variability of precipitation, dragging the rainy season to winter.

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