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Drought characterization in Ahmar dryland area of Morocco

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Abstract— The agriculture in dryland areas is inherently sensitive to climate conditions, and is among the most vulnerable sectors to the risks and impacts of global climate change. The objective of this study is to characterize drought periods and severity, rainfall patterns and the evolution of length of growth period in the arid dryland Ahmar area plain of Morocco. The climate data covers the last forty-three years period (1975-2017). The National Department of Meteorology (DMN) for Echemmaia climatic station provided them. Results of this study show a significant decline of the annual rainfall from 252.9 mm/year to 184.4 mm/year during the last 43 years. The Standardized Precipitation Index indicate that dry years are prevailing during the las 20 years with 80% of the years are either normal to moderately dry years or dry years (20%). The aridity Martonne index demonstrate a clear shift of climate from arid to hyper-arid in the study area. The length of growth period decreased from 125 days to only 95 days. The year 1996 is the break point for all these calculated indices. In conclusion, the rainfall pattern in the dryland area of Ahmar plain of Morocco is decreasing and becoming scares and erratic affecting therefore crop production and stability.

Index Terms— Climate change, Drought, Ahmar plain, Dryland, arid areas, growth period, Standardized precipitation index, Aridity index.

1 Introduction

According to GIEC (2007), climate change will lead to the displacement of climate zones and the changing rainfall patterns in all the countries located in the South Mediterranean region. Several studies indicate a possible amplification of precipitation extremes associated with a decrease of total precipitation in many countries within this region (Gao *et al.*, 2006; Giorgi and Lionello, 2008). Also, associated with rainfall decrease, an increase of seasonal temperatures is taking place in recent decades causing therefore droughts to become more frequent and severe (Stour and Agoumi, 2009; Xin *et al.*, 2006; Zou *et al.*, 2005; Steinberger and Gazit-Yaari, 1996; Steinberger, 1999). Agricultural productivity and sustainability are negatively impacted in the semi-arid and arid areas, particularly for small farms because of rainfall scarcity and temperature increase. Another challenge facing farmers in these areas is the reduction of growth period length that affects negatively the current cropping systems (Alahiane *et al.*, 2018; Jlibene and Balaghi, 2009; Benaouda *et al.*, 2008).

Most studies on climate characterization that were conducted in Morocco covered semi-arid areas receiving more than 300 mm/year, whereas arid areas with less rainfall and more vulnerable small holding-farmers remain uncovered. The objective of this work is to characterize climate trends in the aridland of Ahmar (Safi province, Morocco) known for its barley-sheep integrated farming systems.

2 Materials and Methods

2.1 Study area

The area covered by this study is located at the western central Morocco (Latitude 32.0833333, Longitude -8.6166667) (Fig.1). The climate of this area is Mediterranean with hot and dry summers, and cool rainy winters with an average rainfall of 180 mm. Farming systems in Ahmar arid plain are based on barley cropping systems heavily integrated with sheep production system.

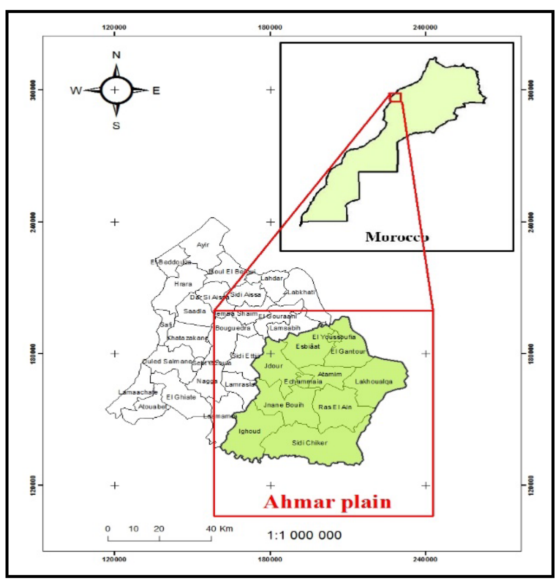

Fig.1. Localization of the arid Ahmar area (Safi province) western central of Morocco.

The climatic data (daily rainfall and temperatures) used in this study were provided by the National Department of Meteorology (DMN) and it covers 43 years period (1975-2017) for Echemmaia climatic station. The analyzed variables generated from this database are:

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- Annual rainfall evolution
- Aridity Martonne Index (I)
- Standardized Precipitation Index (SPI)
- Length of growth period (LGP)

2.2 Rainfall trend

The rainfall data was organized, processed and analyzed by using the no-parametric 'Pettit Method', 'Bayesian Method' of Lee and Heghinian, and the segmentation of Hubert (Lubès *et al.*, 1994). We used the statistical software: Khronostat (1998) developed by the Institute of Research for Development (Lubes-Niel *et al.*, 1998), to analyze the time series and to characterize the evolution, ruptures and the extreme rainfall events marked the study area during the period.

2.3 Standardized Precipitation Index (SPI)

Standardized Precipitation Index (Mckee *et al.*, 1993) serves as a tool for defining and monitoring drought events. It determines the rarity of drought at a given time-scale. Its computation involves fitting a gamma probability density function to a given frequency distribution of precipitation totals for a climatic station. The mathematical formula of SPI is:

$$SPI = (P_i - P_m) / \sigma$$

With:

Pi: Precipitation of the year i

Pm: Mean precipitation

σ: Standard deviation

The interpretation of SPI values is as follows:

- **SPI > 2.0:** Extremely wet
- **1.5 < SPI < 1.99:** Wet
- **1.0 < SPI < 1.49:** Moderately wet
- **-0.99 < SPI < 0.99:** Normal
- **-1.0 < SPI < -1.49:** Moderately dry
- **-1.5 < SPI < -1.99:** Dry
- **SPI < -2.0:** Extremely dry

2.4 Aridity Martonne Index (I)

The annual aridity index is used to define the type of climate of a given area based on the data of rainfall and thermal. This index established by De Martonne, (1923) is calculated by the following equation:

$$I = P / (T+10)$$

With:

P: The annual total precipitation (mm)

T: The annual average temperature (°C)

The interpretation of I values is as follows:

- **If I < 10,** the climate is arid
- **If 10 < I <20,** the climate is semi-arid
- **If 20 < I < 50,** the climate is cold, temperate or tropical
- **If I > 50,** the climate is equatorial or mountainous

Similarly, to the rainfall pattern, here also we used the no-parametric 'Pettit method', 'Bayesian Method' of Lee and Heghinian, and the segmentation of Hubert (Lubès *et al.*, 1994).

2.5 Length of growth period

The length of growth period is defined as the period of the year during which the average temperatures is above the optimum temperatures for plants growth (average temperature > 5°C) and during which precipitation exceed one half of the potential evapotranspiration. This method developed by the FAO in 1978 to determine the positioning of the crops in the agricultural season for given farming area, is widely used to analyze the fitting of cropping systems.

3 Results and Discussions

3.1 Rainfall evolution

The interannual rainfall evolution in the Ahmar area during the period from 1975 to 2017 shows a significant reduction by 26.9% of the quantities received annually (Fig. 2). Two distinct periods were observed, the first one from 1975 to 1996 with an average of 252.9 mm/year and the second period from 1997 to 2017 with an average of 184.4 mm/year. The annual reduction of rainfall during the last 43 years is about 2.7 mm/year with a break point in the year 1996. Similar results were reported in the dryland area of Abda north region of Safi province with an interannual decrease estimated about 28.3 % (3.2 mm/year) for the same period from 1975 to 2017 (Alahiane *et al.*, 2018). Sebbar *et al.*, (2012) also reported that the central region of Morocco has known a remarkable decrease of the total amount received during the period from 1935 to 2009.

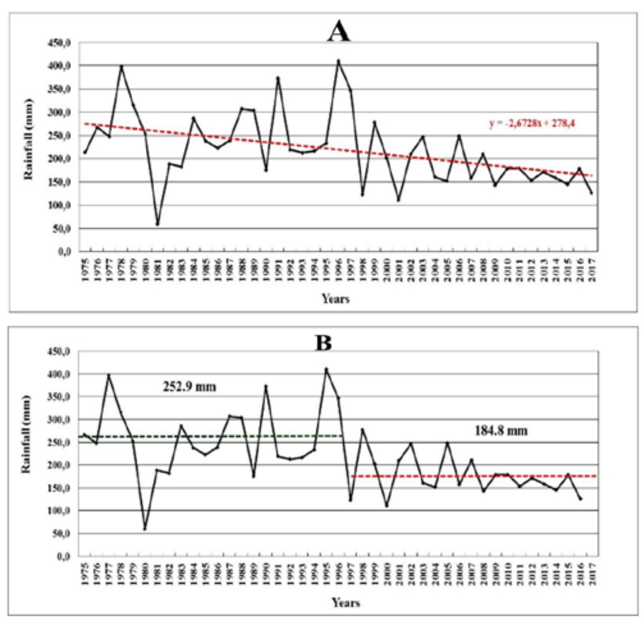

Fig. 1. The annual rainfall trend in Ahmar dryland area during the last 43 years (A) and the two distinct periods (1975-1996 and 1997-2017) with a rainfall break point in the year 1996 (B).

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3.2 Standardized Precipitation Index (SPI)

The standardized precipitation index values calculated for the same period show two distinct periods (Fig. 3). The first one, from 1975 to 1996 which is characterized by 26% wet years, 68% normal years and only 6% dry years. However, during the second period from 1997 to 2017, no wet years were observed and that all the years were either normal to moderately dry years (80%) or dry years (20%). These results show that the rainfall is becoming more erratic with a tendency toward more severe droughts that leads to crop failure and loss. The same results were reported by Alahiane *et al.,* 2018 in the semi-arid area of Abda plain of Morocco with a tendency of droughts period with about 71% the years were normal and that 29% were moderately or severe dry years but no wet years during the last two decades. Another study conducted by Daki *et al.,* (2016) shows a remarkable drought intensity and frequencies in the Safi region during the period from 1997 to 2001.

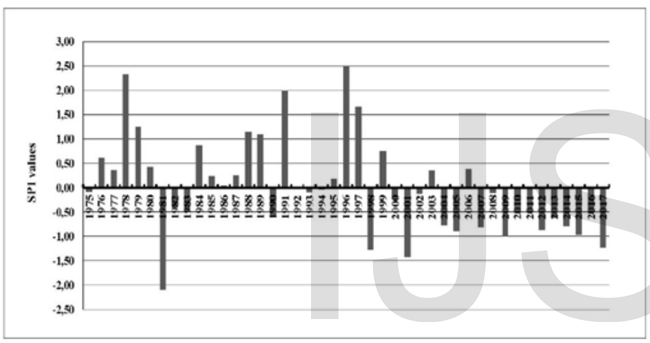

Fig. 2. The standardized precipitation index values variation during the period 1975 to 2017 in the Ahmar area (Safi province, Morocco).

3.3 Aridity Martonne Index (I)

The aridity Martonne index evolution from 1975 to 2017, calculated annually, shows a significant decrease during the last two decades (Fig. 4). Indeed, two distinct averages are observed for the two previous periods, the first one with an average of 9.28 for 1975-1996 period and a second one with an average of 6.20 for 1997 to 2017 period. The decline of this index show a clear displacement of Ahmar climate from moderately arid to an arid climate. This trend toward more aridity was reported by Driouech, (2010) and Sebbar *et al.,* (2012) and demonstrated that aridity is moving northward in Morocco during the last 30 years. Similar results were reported by Alahiane *et al.,* (2018) in the Northern part of Safi province, which is more favorable with semi-arid climate that is shifting toward the arid climate.

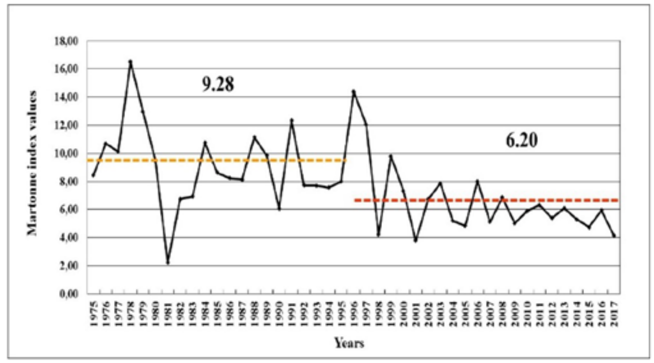

Fig. 3. The aridity Martonne index evolution in the Ahmar area between two distinct periods 1975 to 1996 (yellow) and 1997-2017 (red).

3.4 Length of growth period

The evolution of the length of growth period (LGP) in Ahmar area shows a significant decline during the period from 1975 to 2017 (Fig. 5). The average LGP which was 125 days during the period from 1975-1996 was reduced to 95 days during the 1997-2017 period. These results confirm those reported by Alahiane *et al.,* (2018), that show a clear decrease during the two last 20 years in the semi-arid with a decline from 192 days during the period 1975-1996 to only 138 days during the past 20 years. Benaouda *et al.,* (2008) confirmed similar results in the mountain region of Azilal which shows a clear decrease of the LGP from 178 during the period from 1953 to 1977 to only 103 days during the period from 1978 to 2002.

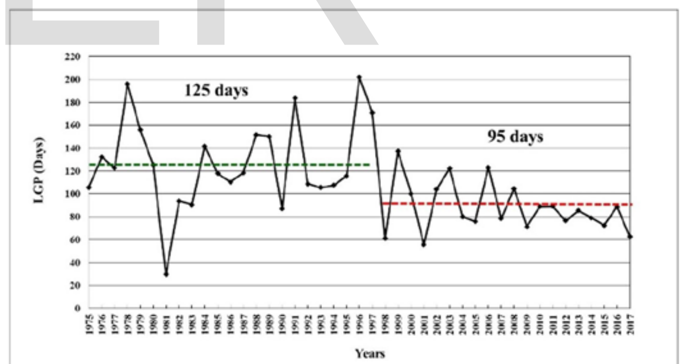

Fig. 5. The evolution of the length of growth period in the Ahmar area during the two distinct periods 1975-1996 (Green) and 1997-2017 (Red).

This change of LGP affects negatively the farm activities and the farming practices in Ahmar plain. This will influence species and varieties choices, soil tillage, crop rotation, fertilizer management weed and pest management, etc.… All of these changes force farmers to find a range of technological options to adapt in this situation of climate changing (El Mzouri *et al.,* 2010).

According to Lamb and Peppler, (1987), Moroccan precipitation is largely confined to the Northern Hemisphere winter semester and is at a minimum (often zero) during July-September. Results Relates Moroccan November-April precipitation aforementioned winter NOA index for 1933-1983. Three Moroccan precipitation indices are used. One is a 12 station national index whose values are the "annual" averages of the normalized precipitation departures for those stations; the second is a counterpart index for the four southernmost coastal station. It is clear from that Moroccan winter-semester precipitation in inversely related to the concurrent state of the NAO. High Moroccan precipitation tends to coincide with large negative values of the NAO index where the latter result from anomalously low subtropical (Azores) and anomalously high subpolar (Icelandic) North Atlantic surface pressures. This situation corresponds to the NAO extreme "Greenland-above" case defined earlier, one that is also characterized by relatively weak westerly flow across the North Atlantic. Low Moroccan precipitation tends to accompany a large-scale North Atlantic atmospheric circulation pattern that is the opposite in all respects to the one just described.

Another study conducted by Nicholson, (1997) and Ward *et al.*, (1999) show that the El Niño Southern Oscillation (ENSO) phenomena carries a certain influence on the Moroccan precipitation. The warm phase (positive) of the ENSO phenomena would lead to a reduction of spring precipitation.

4 Conclusion

The drought characterization in the arid dryland area of Ahmar shows a contentious and clear decline of the annual rainfall. The average of standardized precipitation indices calculated from 1975 to 2017 shows a significant increase of drought periods with high frequency of severe droughts. Also, the aridity Martonne index show a clear shift of the climate of Ahmar from arid to hyper-arid during the last two decades. The length of growth period was reduced from 125 days during the period 1975-1996 to only 95 days during the period 1997-2017.

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