DROUGHT CHARACTERISTICS OVER TWO LARGE BASINS IN MOROCCO (TENSIFT AND SEBOU)

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Abstract: Standardized precipitation index (SPI) is a key parameter for drought monitoring. Using SPI the present work provides a retrospective spatio-temporal analysis of the droughts occurring in Morocco over the last 39 years (1981-2020). The used data were driven from the satellite Climate Hazards Group InfraRed Precipitation with Station data (CHIRPS) products from which the drought index SPI was calculated. SPI allowed the characterization of drought over two large basins, namely Tensift and Sebou. The areas under drought conditions in both Tensift and Sebou basins were compared to derive regional differences at a time scale of 12 months. This analysis is vital for water resources management that is a challenging mission.

Keywords: Drought; SPI; CHIRPS; Morocco.

Introduction

Drought is one of the important recognized natural hazards that occur causing extended water scarcity. It can lead to a decrease in river flow regimes and groundwater reserves, with severe water shortages for drinking water and agriculture (Tramblay et al., 2020). The scientific community often classifies drought into three major types according to its nature : (1) Meteorological drought, which refers to a deficit in rainfall ; (2) Agricultural drought, which is defined as a deficit in soil moisture and (3) Hydrological drought, which affects water resources. Agricultural and hydrological droughts generally are subsequent to meteorological drought which makes the meteorological drought subject to several studies.

Many indices have been developed for drought assessment and monitoring. Precipitation is the primary variable often used in the calculation of indices, such as the Standardized Precipitation Index (SPI) (Mckee et al., 1993). SPI is widely used to monitor drought and manage climate-related risks. It is computed generally using long-term series of data, covering at least 30 years of rainfall data, with spatially well distributed gauges. The lack of sufficient measurement networks in most developing countries is one of the reasons for the existing uncertainties related to droughts analyses and prediction. Monitoring droughts through remote sensing data is particularly useful in this case, with a large amount of information on several hydrological variables. Indeed, for the regional assessment of drought using SPI, it is of particular interest to use satellite-based precipitation products. Multiple sensors provide information on rainfall such as Tropical Rainfall Measuring Mission (TRMM), Precipitation Estimation From Remotely Sensed Information Using Artificial Neural Networks (PERSIANN), and Climate Prediction Center morphing technique (CMORPH). Climate Hazards Group Infrared Precipitation with Stations (CHIRPS) is a gridded precipitation data showing a high concordance with ground measurements in Morocco (Bijaber et al., 2018). The product has also been evaluated in several parts of the world (Bai et al., 2018; Bouaziz et al., 2021; Neeti et al., 2021).

The study of aspects of drought in an African country like Morocco, where water resources are limited and where the agricultural sector contributes most to the economy, is necessary for scientific and resources management purposes. The present study aimed to analyze the temporal and spatial

patterns of drought over two major basins in Morocco, namely Tensift and Sebou, located in two different climatic conditions. Through the use of SPI calculated from long-term precipitation data from CHIRPS products, the drought resilience in the basins was analyzed and very dry and severe events were identified based on two drought severity thresholds.

1. Study area

The study was conducted in two large hydrological basins in Morocco. The Tensift basin is located in the center of Morocco with an area of 24 000 Km^2 (Figure 1). The region is known for its morphological diversity, hence a great spatial variability of precipitation. Rain and snowfall supply the semi-arid plain of Haouz and contribute to the recharging of groundwater (Bouimouass et al., 2020; Boukhari et al., 2015). The Sebou basin is one of the major basins in Northern Morocco covering nearly 40 000 km^2. From a hydrological perspective, the Sebou basin contributes to 30 % of the national potential of surface water resources and 20 % of groundwater resources (Chadli et al., 2016). The Köppen-Geiger climate classification map is used to identify the climatic zones of the study areas (Beck et al., 2018). The climatic context of the basins is different with a dominant semi-arid climate (BSk) for the Tensift basin and a Mediterranean climate (Csa) with oceanic influence for the Sebou basin.

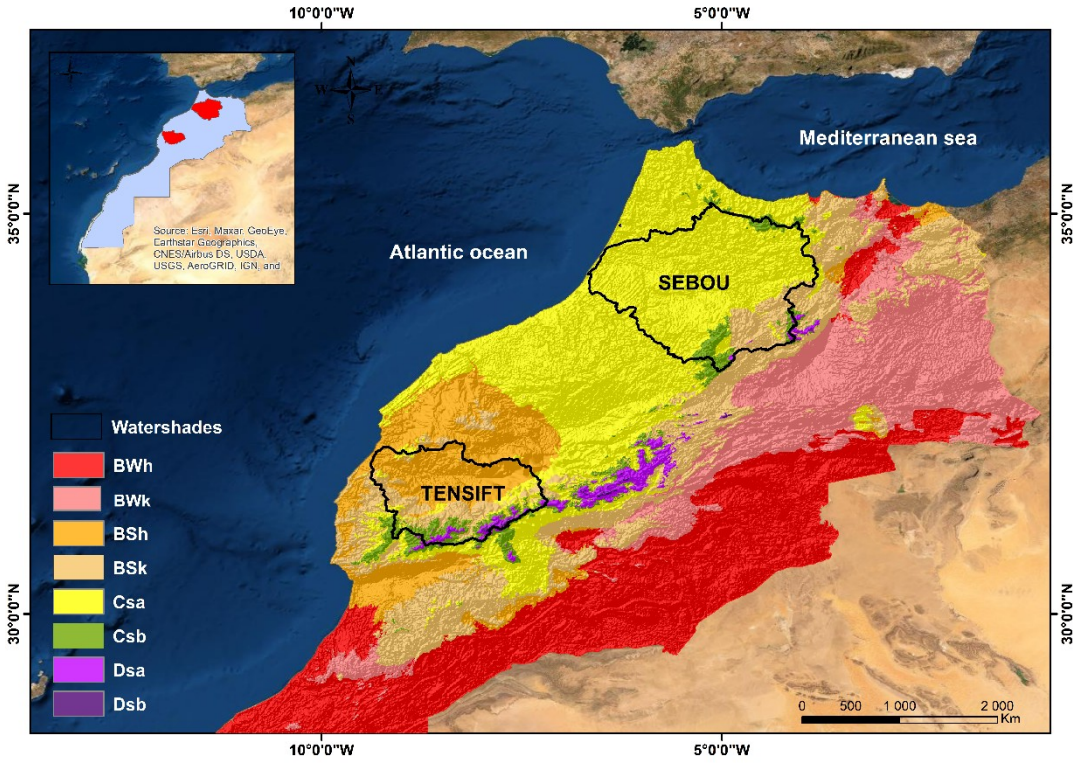

figure 1. The study area with the Köppen-Geiger climate classification map.

2. Methodology

2.1. Data

Monthly precipitation data from CHIRPS were used in this study. CHIRPS represents satellite estimates corrected by the integration of precipitation data from in situ weather stations. The open data set was provided by the Climate Hazards Center (CHC) Group at the University of Santa Barbara, California, in partnership with the U.S. Geological Survey Earth Resources Observation and Science

Center (https://www.chc.ucsb.edu/data/chirps). The used data are from 1981 to 2020, with a spatial resolution of 0.05° × 0.05°.

2.2. Method

Temporal and spatial analysis of drought was performed using the standardized precipitation index (SPI). The SPI is known as a key indicator of meteorological drought and has shown high performance compared to other drought monitoring indices (Sobral et al., 2019). The SPI is calculated over 1981-2020 to assess past drought events using CHIRPS precipitation data at 5 km resolution and at different time scales: 1, 3, 6, and 12 months. The use of multiple time scales allows verifying the impacts of drought on different water components. Indeed, meteorological and soil moisture conditions respond to precipitation anomalies on relatively short timescales, while streamflow, reservoirs, groundwater respond to precipitation anomalies on longer time scales (Livada & Assimakopoulos, 2007).

The SPI was defined by fitting a Gamma probability distribution function to the precipitation long-term dataset. According to Mckee et al., 1993, a drought event occurs when the SPI reaches a value of -1 or less and its severity is defined as the minimum value reached by the SPI. Mckee et al., 1993 also proposed a classification of drought intensity from which the most severe events, their frequency, and duration can be defined. The next step consisted in comparing drought events over the two hydrological basins. The most severe and dry events were identified using two thresholds corresponding to 20 % and 5 % respectively of the probability of occurrence of drought in the standard normal distribution. This method allows identifying two categories of drought severity according to Lloyd-Hughes & Saunders, 2002 classification (Table 1). The final part of the study was the temporal evolution of the areas under drought conditions. It was obtained by the SPI values below the thresholds explained above on a 12-months scale. The drought area was compared on the Sebou and Tensift basins.

Table 1. Drought classification based on the SPI index and corresponding event probability (Lloyd-Hughes & Saunders, 2002).

Index value	Drought categories	Probability (%)
2.00 or more	Extremely wet	2.3
1.99 to 1.5	Severely wet	4.4
1.49 to 1	Moderately wet	9.2
0.99 to 0	Mildly wet	34.1
0 to −0.99	Mild drought	34.1
−1 to −1.49	Moderate drought	9.2
−1.5 to −1.99	Severe drought	4.4
−2 or less	Extreme drought	2.3

3. Results

The results were obtained from calculating the SPI based on monthly CHIRPS rainfall data. SPI was computed over the two basins of Tensift and Sebou, over the period 1981-2020. Figure 2 shows the SPI time series at different time scales (1, 3, 6, and 12 months), where SPI values below 0 represent dry periods, and wet periods are represented by the positive SPI values. These fluctuations determine the drought parameters i.e. the duration, frequency, severity as well as the onset and cessation of each drought episode. The frequency and duration have a negative relationship with the time scale, consequently, the identification of drought periods is highly dependent on the time scale considered.

Both the basins have experienced several periods of drought. In the Tensift basin, the 6-month SPI (SPI6) and the 3-month SPI (SPI3) have reached values of -2.18 and -2.1 respectively in 2001, making this year the driest in terms of severity during the study period. For the Sebou basin in the north of Morocco, the SPI time series showed that 1995 was the driest year when SPI3 and SPI12 have reached an intensity of -2.19 and -2.12 respectively.

It should be noted that both basins have experienced wet periods. Thus, wetness episodes can be deducted from the SPI time series. The extremely wet year for the Tensift basin was 1996 with values of SPI12 greater than 2. On the other hand, the Sebou basin had reached a maximum of wetness in 2010.

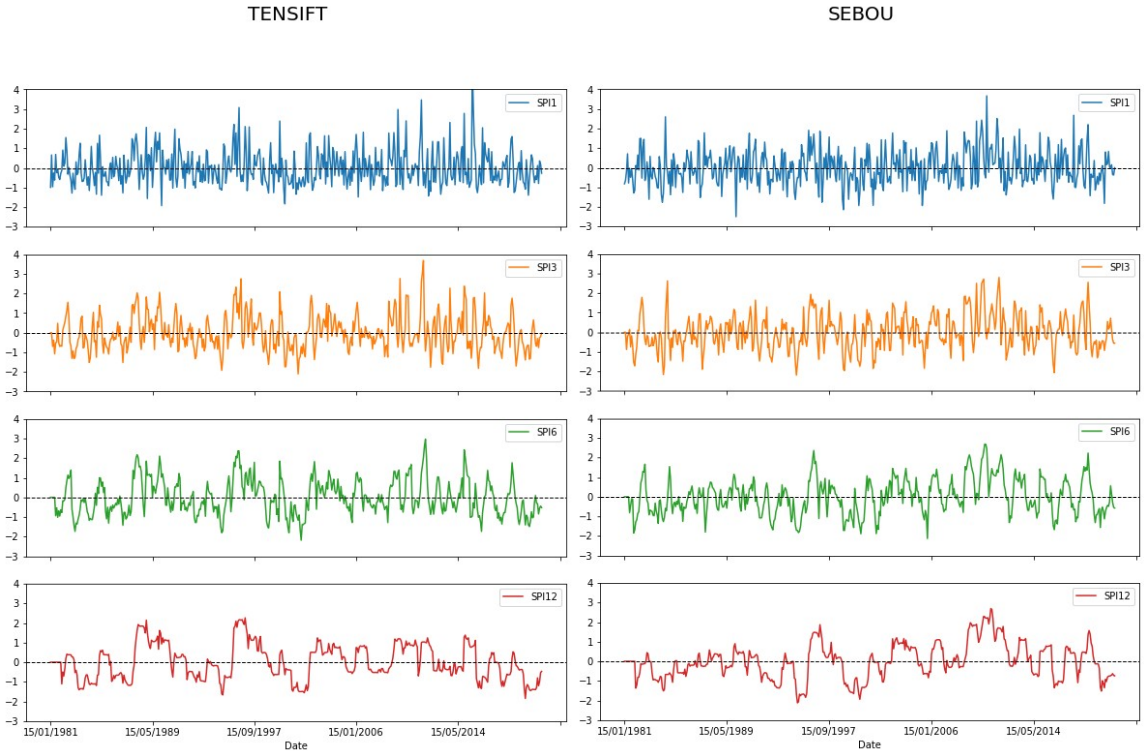

figure 2. Time series of SPI at different time scales during the 1981-2020 period for the Tensift and Sebou basins.

The spatial extent represents an essential parameter for the regional assessment of drought. The temporal evolution of the area affected by drought on the Tensift and Sebou basins is shown in Figure 3. Two thresholds of 20% and 5% were used respectively to synthesize the areas of moderate and severe droughts. In the Tensift basin, the drought of 2001 affected the whole basin for a threshold of 20 % and only 35 % of the basin at the 5 % threshold. In the Sebou basin, the drought of 1995 affected 98 % and 65 % using the 2 thresholds.

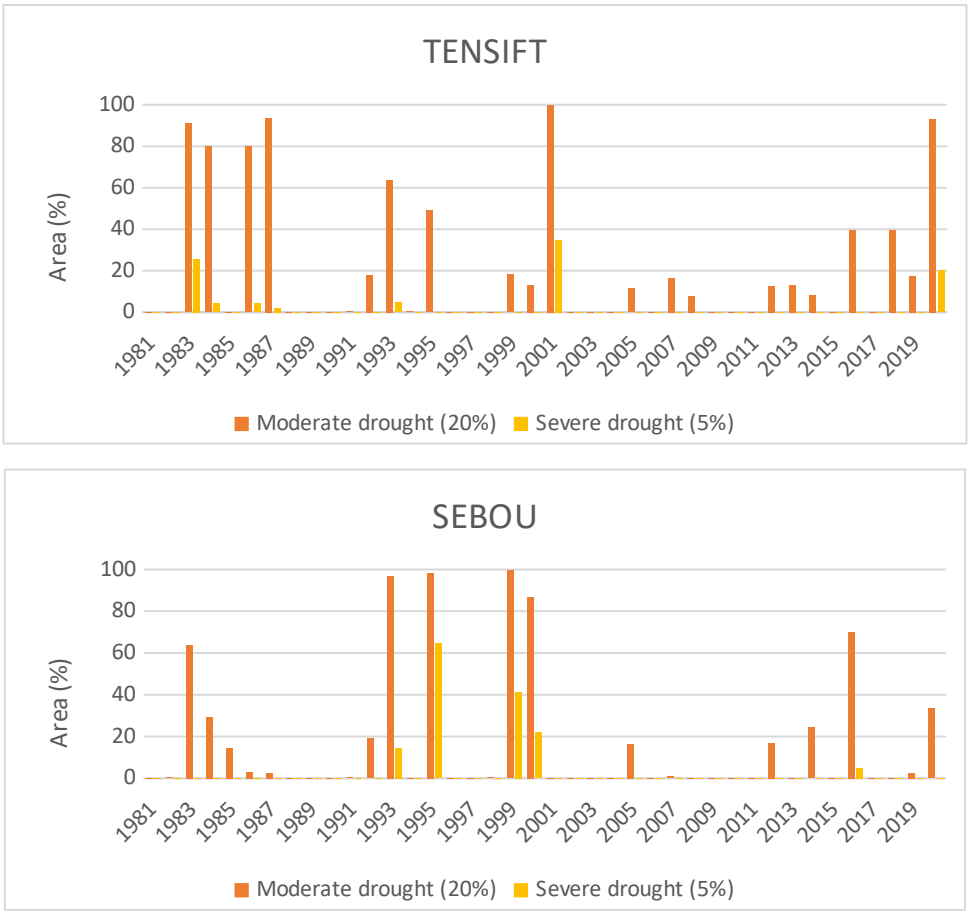

figure 3. Temporal evolution of the fraction of area under drought conditions during the study period from 1981 to 2020.

According to the summary results presented in Table 2, the Tensift basin has experienced multiple severe drought events, with seven drought periods: 1983, 1984, 1986, 1987, 1993, 2001, and 2020. However, the Sebou basin has recorded fewer severe drought events (1993-1999-2000-2016). One extreme drought was observed in the Sebou basin in 1995. Other drought episodes have been recorded in the basins but with less intensity. The Tensift basin had more episodes of drought than the Sebou basin. These differences can be explained by the difference in climate in the basins, and the spatial variability of rainfall in Morocco. In addition to the area covered by each basin and its morphological characteristics that can affect the spatial distribution of rainfall in the basin.

Table 2. Summary of dry years by category of drought.

Drought categories	**Basins**	
	Tensift	***Sebou***
Extreme		1995
Severe	1983-1984-1986-1987-1993-2001-2020	1993-1999-2000-2016
Moderate	1995-2000-2016-2018	1983-1984-1992-2019-2020
Mild	1992-1999-2005-2007-2008-2012-2013-2014	1985-1986-1987

Conclusion

In the present work, a long-term series (1981-2020) of CHIRPS satellite data was used to compute the standardized precipitation index (SPI) at different time scales, in Morocco. The SPI was an efficient tool for characterizing drought over two large basins, Tensift, and Sebou. The Tensift basin was the most affected by severe and moderate drought with long dry spells during the period 1981-2020. The most severe events were observed at different years over the basins which approve the different regional patterns of drought in two climate contexts. The Tensift basin is more vulnerable to drought, as it has experienced more drought events, in addition to the percentage of areas affected by drought was high compared to the Sebou basin. The results of this study open perspectives to assess drought occurrence over the whole country, and to adapt the existing water and agriculture strategies to the characteristics and drought vulnerability of each basin.

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