

Assessment of Drought Characteristics, and Its Impacts on Vegetation and Wheat Yield in Tunisia



Nada Ben Mhenni, Masato Shinoda, and Banzragch Nandintsetseg

Abstract Tunisia, located on the shores of the Mediterranean, is projected to experience most predominant droughts. However, detailed drought assessments at the regional scale of Tunisia are limited to date, with most studies only focusing on a specific region and/or making use of one drought index. This study identifies both vegetation and agricultural region-specific drought indices over the country. Tunisia was divided into three main vegetation zones: the northern forest, central steppe, and southern desert. Monthly meteorological (Standardized Precipitation Index (SPI) and Standardized Precipitation Evapotranspiration Index (SPEI)) and soil moisture (Palmer Drought Severity Index (PDSI) and soil moisture percentiles, W_p) drought indices were used to analyze drought characteristics using gridded-meteorological and ground-measured soil data, and compared with the weekly Normalized Difference Vegetation Index (NDVI) and the winter wheat yield data to assess vegetation and agriculture responses to drought, respectively. We found that short-term meteorological droughts were frequent, triggering soil moisture droughts that were more persistent and severe. The most important finding of this study was that SPI is the best indicator for assessing a drought impact on both vegetation and agriculture in the northern forest, while PDSI in the central steppe for vegetation and agriculture and in the southern desert for vegetation (no agricultural data on southern desert). The results of this study highlight the importance of region-specific drought indices which are most likely to provide a very useful measure for drought monitoring and mitigation in Tunisia.

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1 Introduction

Over the years, several studies affirmed that the Mediterranean Sea region is and will be more affected by climate change than most other regions of the world. In fact, droughts are one of the costliest natural hazards; their impacts are significant and widespread, affecting many sectors. In recent decades, Tunisia has faced frequent drought events, which have induced significant vulnerabilities in the region [1]. In particular, droughts represent a permanent risk for rain-fed agriculture in Tunisia.

2 Materials and Methods

This study explores drought characteristics, and its effect on vegetation in three vegetation zones of Tunisia (northern forest, central steppe, and southern desert; Fig. 1) during 1982–2011, analyzing various drought indices and identifying the

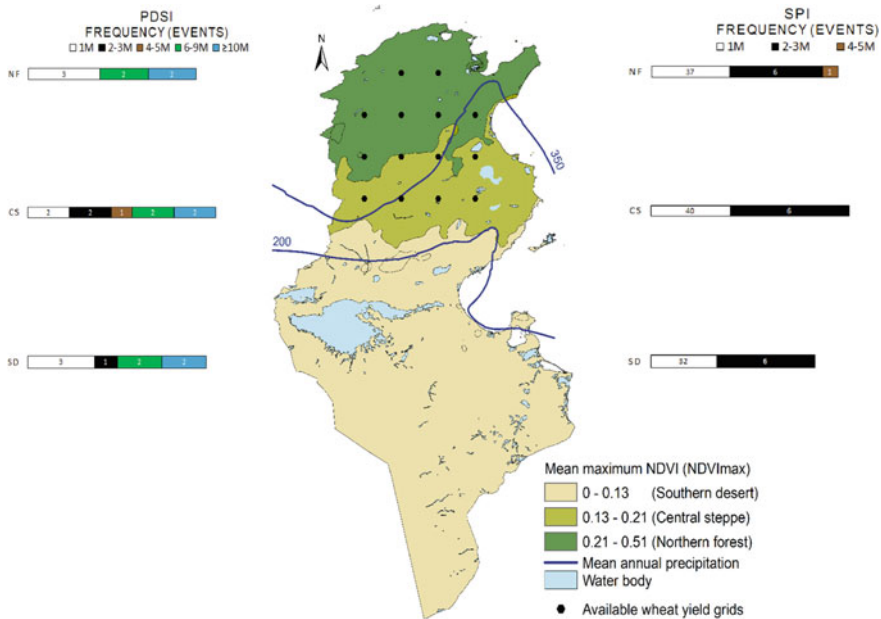


Fig. 1 Map of Tunisia with the three main vegetation zones: the main isohyets, the grids of wheat yield, and the frequencies of SPI and PDSI events

most appropriate one for each zone. It also assesses drought impacts on agriculture using winter wheat yield data, available for northern forest and central steppe.

Both monthly meteorological (Standardized Precipitation Index (SPI) and Standardized Precipitation Evapotranspiration Index (SPEI)) and soil moisture (Palmer Drought Severity Index (PDSI) and soil moisture percentiles, W_p) drought indices were used to analyze drought characteristics using gridded-meteorological (P and T from coordinated regional climate downscaling experiment for the Mediterranean area; Med-CORDEX) and ground-measured (Soil and Terrain Database (SOTER)) soil data, and compared with the weekly Normalized Difference Vegetation Index (NDVI from National Environmental Satellite, Data, and Information Service, NOAA-NESDIS) and winter wheat yield data (Data Integration and Analysis System (DIAS)) to assess vegetation and agriculture responses to drought, respectively.

3 Results

The climatological (1982–2011) seasonal changes in weekly NDVI and monthly precipitation averaged over the vegetation zones are shown in Fig. 2a. The vegetation growing season starts from September and ends with the greenness peak at the end of March; however, the winter wheat growing season starts after planting begins in December and ends with the beginning of the harvesting in June.

Correlation analysis revealed that the anomaly of yearly maximum NDVI was highly correlated with PDSI for the central steppe ($r = 0.83$, $p < 0.01$) and southern desert ($r = 0.63$, $p < 0.01$), while with SPI for the northern forest ($r = 0.63$, $p < 0.01$) (Fig. 2b). The yearly maximum NDVI showed trends in parallel with respective drought indices, having slight ($p < 0.05$) declining trends over the vegetation zones (except for the northern forest) with the most pronounced in the southern desert zone. In accordance with these results, the winter wheat yield data was highly correlated with PDSI for the central steppe ($r = 0.73$, $p < 0.01$), and with SPI for the northern forest ($r = 0.62$, $p < 0.01$).

4 Discussion

The short-term meteorological droughts (SPI and SPEI) were frequent, triggering mid-term (W_p) and long-term (PDSI) soil moisture droughts that were more persistent.

(PDSI) and severe (W_p) (Fig. 1). This could be explained in terms of soil moisture memory effect [3].

The drought indices show slight increasing trends in droughts ($p > 0.05$) with the longest period of consecutive drought years starting from 1999 until 2002. This long-lasting drought is considered to be the worst since the middle of the fifteenth century causing a significant reduction in agricultural production.

Out of the indices, PDSI was selected for assessing the impact of drought on both

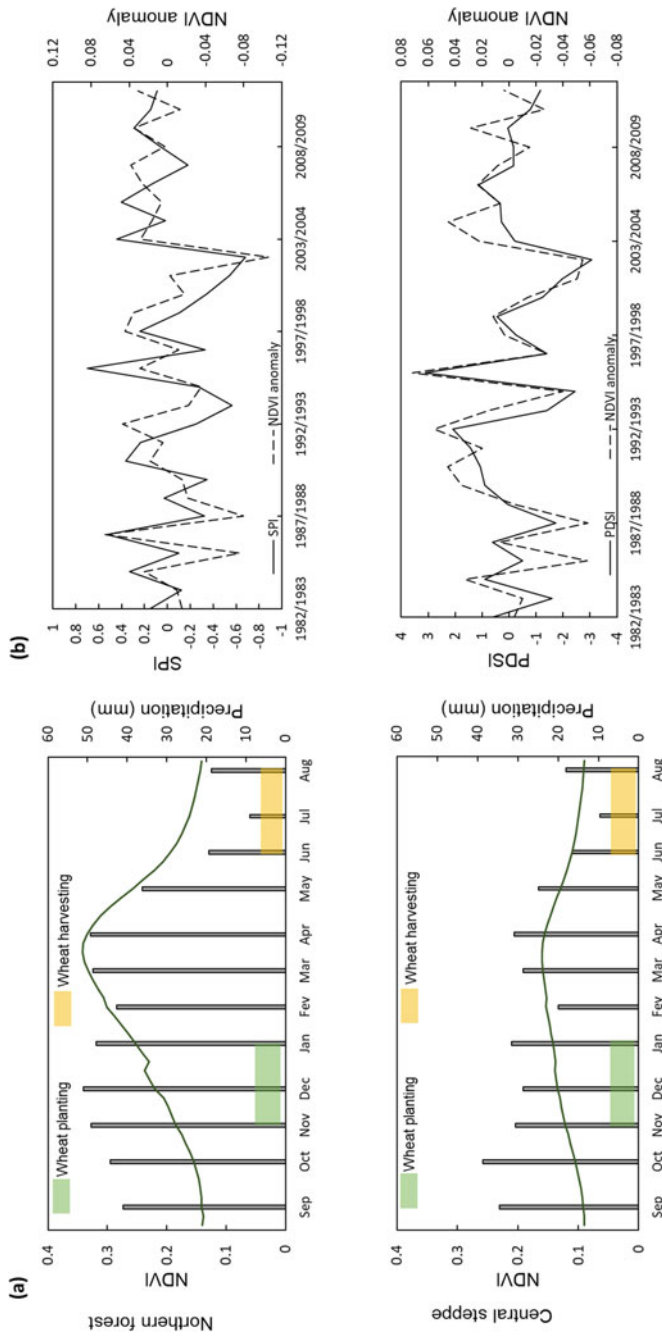


Fig. 2 a Mean monthly precipitation, and winter wheat planting and harvesting seasons for the northern forest and central steppe. b Yearly maximum NDVI anomaly and SPI (for northern forest), and PDSI (for central steppe), respectively, during the growing season of the period 1982–2011

vegetation and agriculture activities in the central steppe and southern desert (no data for wheat) zones, while SPI was selected for the northern forest. In fact, precipitation deficits have a significant impact on arable land vegetation (central steppe and southern desert in this case), while forests (northern forest) are less sensitive to soil moisture deficit at the start of the growing season, explaining the delay NDVI shows in response to moisture conditions with long-term scale in forests [4]. However, wheat shows a faster response to precipitation deficits on both zones pointing out the importance of the early growth stages [2]. The lag correlation analysis revealed that the response of vegetation and agriculture to droughts is more pronounced and has a longer significant lag in the central steppe.

5 Conclusions

Short-term meteorological droughts occurred more frequently than those of soil moisture droughts, whereas soil moisture droughts were more persistent (mid-term and long-term) than meteorological droughts in all the zones.

The study of vegetation and wheat responses to drought in Tunisia identified SPI as the best drought index for the northern forest, and PDSI for the central steppe and southern desert (no data for wheat). These results highlight the importance of region-specific drought indices which are most likely to provide a very useful measure for drought monitoring and mitigation in Tunisia.

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