Environment and Ecology 39 (1) : 65—70, January—March 2021
ISSN 0970-0420

Analysis of Historical Drought Using Standardized Precipitation Index and Reconnaissance Drought Index (RDI) in Tharparkar, Sindh

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Received 26 September 2020, Accepted 27 November 2020, Published on 4 January 2021

ABSTRACT

Drought is recognized as disastrous hazard that can be take place in any terrain and can cause significant harming effects to environment of earth. Thus, the drought assessment is of crucial importance for planning mitigation and water resources management. In this study, historical drought was analyzed in the Tharparkar district of Sindh region of Pakistan. The two drought approaches namely: Standardized Precipitation Index and Reconnaissance Drought Index (RDI) were employed to assess the drought. The long term 35 years monthly precipitation (mm) and temperature (°C) data were used to calculate SPI and RDI. From the analysis, it was observed that extreme drought noticed by SPI and RDI in the years 1986-1987 and 1999-2000 with the values -2.48 and -4.63. However, both indicators perceived severe and moderate drought during 2001-2004. The strong correlation (r=0.158) comprehended by RDI. From the findings it is advised that to use RDI and SPI to monitor the drought in the region and for water resources and mitigation planning.

Keywords : Drought monitoring, Standardized Precipitation Index, Reconnaissance Drought Index (RDI).

INTRODUCTION

Drought is categorized as the dangerous meteorological threat of nature (Mishra and Singh 2010) . It is momentary situation which continues for months to years. Corresponding to Whilhit, drought can appear in any kind of environment and in any region in the world (Wilhite 2000). Now a day's major cause of drought in the world is climate variability and is also responsible for large economic losses over almost every region every year. Drought also could be defined as a continuous period of insufficient precipitation resulting in extreme damage to crops and loss of yield (Folger and Cody 2014). Generally, there are four types of drought, meteorological, agricultural, hydrological and socio-economical. Meteorological

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drought occurred from the deficiency of precipitation over regions with respect to their climatology. Agricultural drought assigns to a decline in soil moisture and crop water demand (Mishra and Singh 2010). Hydrological drought, due to the downturn in the flow of water in rivers, reservoirs, or canals (Dracup *et al.* 1980). Socio-economic drought appeared by the influence of already stated 3 types of drought conditions at the delivery and requirement of economic goods and offerings such as fish, food grain, forage and hydroelectric power (Marshall and Zhou 2004). Recently, a fifth class of drought has been notified as to the drought of groundwater (Mishra and Singh 2010).

Meteorological drought accumulates the agriculture drought as it materializes due to deficiency of rainfall and soil moisture throughout the growing season to sustenance vigorous growth of crop up to adulthood, causing crop stress and abating. It is considered when an area receives less than 75% seasonal rainfall of its normal lasting value (Indian Meteorological Department – IMD). Further, it is categorized as temperate and severe drought if the precipitation deficit is 26–50% and rainfall shortfall exceeds 50% of normal, respectively. A year is taken into account to be a dearth year for the country if the drought exaggerated region exceeds 20% of the entire area of the country (Karinki and Sahoo 2019). In recent years, floods and drought have befallen with better depth and harshness stages. Drought presently is accountable for increasing mortality rate and economic losses in the world. The drought has a vast effect on bad economics than on extra evolved ones. For example, in many nations of western Africa, 30% population is unprotected to drought each year the income of peoples robustly threatened (Rothman *et al.* 2009). In China and India, averagely 0.5 million people have affected annually through drought economically and environmentally. In 2011, 12 million people were affected in the entire east African region, and food crises occurred across Djibouti, Ethiopia, Kenya and Somalia. Europe is also distressed from 1998-2009 through a drought in the result of forest fires and heatwaves 80,000 peoples were stricken and overall losses € 4940 billion were estimated (Agency 2010). Australia has also experienced agricultural and industrial drought from 1995-2009 caused by a decline in reservoir precipitously; many cities, including Sydney, Melbourne and Perth, were affected. From 2001 to 2012, $ 4.5 billion provided by the federal government for relief to drought-pretentious agriculturalists and small businesses. According to National Disaster Management Authority (NDMA) report November 2018 titled "Report on prevailing drought-like situation in Sindh with Particular reference to district Tharparkar" it is reported that during last four years District Tharparkar received very nominal and inadequate rains during monsoon season. A detailed statement of rainfall since 2014. This has adversely affected Livestock and Agriculture in 167 Deaths which are the main sources of livelihood in Tharparkar. Lower incomes resulted in health and nutrition issues in most vulnerable groups like pregnant/lactating women and children particularly newly born (NDMA 2018). A recent study declares that more than 4500 drought events occurred during the period of 1951-2016 across the world, in which 52 events identified as mega drought events (Spinoni *et al*. 2019)

It is challenging to accurately ascertain the inception and end up of a drought event. Therefore, the appropriate knowledge about the commencement and dispersion of drought over a region is very effective for drought preparedness. However the assessment of drought is principal importance for the management of water resources and planning (Mishra and Singh 2010). This involves understanding historical drought in the area along their impact throughout their occurrence. Hence drought indices are key tool to gain useful information for drought monitoring in a region. Various drought indicators are being used around the world since climatic circumstances vary from terrain to terrain so just single drought index cannot deliver the comprehensive evidence about drought. Most common and broadly employed index is Standardized Precipitation Index (Spinoni *et al.* 2019), developed by (McKee *et al.* 1993) to examine and see drought situations as advised by (Adnan *et al.* 2018, Ahmad *et al.* 2016). Another index Reconnaissance Drought Index (RDI) is used by many European countries and is also recommended by (Adnan *et al.* 2018) to supervise drought significance in Pakistan. Thus, the keyaim of the study is to assess the historical drought event in Tharparkar, Pakistan. This would be beneficial for national meteorological services, mitigation planners and water resources management to cope up

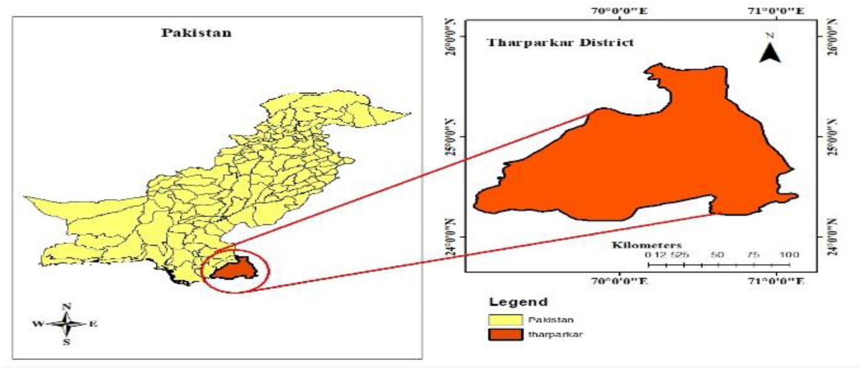

Fig. 1. Map of Pakistan showing Tharparkar district.

with future climatic change adaptation in Tharparkar.

MATERIALS AND METHODS

Study area

Tharparkar district lies in the domain of 24°10'N-25°45' N and 69° 04E-71°06E with an area of 19,638 km^2 as shown in Fig.1.

Administratively, Tharparkar district is divided into seven talukas Chachro, Dhali, Mithi, Diplo, Kaloi, Islamkot, and Nagarparkar. It is composed of virtually two thousand small villages. The population of Tharparkar district is 1,649,661 estimated by 2017 census as shown in Fig.2. Average population growth rate of district Tharparkar is 3.15 estimated from 1998-2017 census.

Data

The long term (1979-2013) daily climate data of two meteorological elements such as precipitation (mm) and temperature have been used in current study. For evaluating two indicators, 35 year's data were downloaded from Global Weather Data for SWAT.

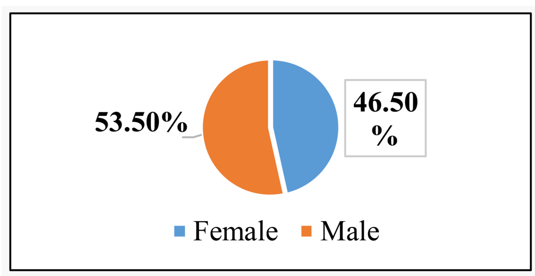

Fig. 2. Population figure of Tharparkar district Census 2017 (statistics).

Drought indices

Standardized Precipitation Index (Spinoni *et al.* 2019)

Due to single input variable the SPI index has more importance around the world for drought identification. SPI use precipitation values for exclusive month-to-month time scales (3, 6, 9, 12, 24, and 48 months) to capture the temporal performance of drought in the region. SPI required 20-30 years month-to-month records, 50-60 12 months (or extra) facts being most useful favored by (Guttman 1994). The gamma distribution is found to fit the climatological precipitation sequence. The gamma distribution is described with the assistance of its PDF, (probability density function).

$$g(\chi) = \frac{1}{\beta^a \Gamma(a)} \times {}^{a-1} e^{-1\chi/\beta} \text{ for } \chi > 0 \quad (1)$$

In which β and a are the scale and shape parameters respectively, Γ(χ) is the gamma function and, x is precipitation amount. Parameter β and a of the pdf are estimated for the different time scale. Where β and α estimation are given as:

$$\beta = \frac{\bar{\chi}}{\alpha}, \alpha = \frac{1}{4A}\left(1 + \sqrt{1 + \frac{4A}{3}}\right) \quad (2)$$

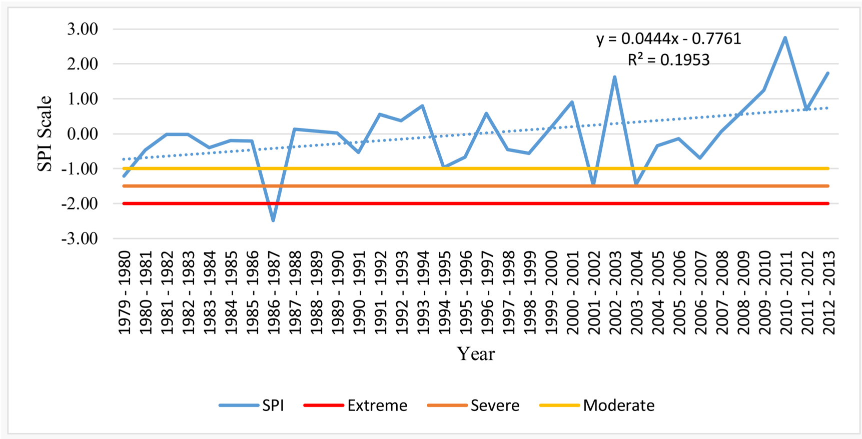

Figure 3. Annual time series analysis of SPI in Tharparkar.

Where $A = \ln(\bar{\chi}) - \frac{\Sigma \ln(\chi)}{n}$

n is the number of observations.

Reconnaissance Drought Index (RDI)

Reconnaissance Drought Index (RDI) is a meteorological index developed by (Tsakiris and Vangelis 2005). The RDI is based totally each on potential evapotranspiration (PET) and cumulative precipitation (P), that is one calculated (PET) determinant and one measured (P). The initial value (λk) is based on the proportion between potential evapotranspiration (PET) and precipitation. The PET calculation method does not affect the RDI results (Vangelis *et al*. 2013). So, RDI is calculated by applying the following equations

$$\lambda^{(i)}_{k} = \frac{\Sigma_{j-i}^{K}}{^{K}\Sigma_{j-i}\, PET}, \; i = 1\ N \text{ and } j = 1\ k \qquad (3)$$

Where PET_{ij} and P_{ij} are the potential evapotranspiration and precipitation of the j^{-th} month of the i^{-th} year and N is the total number of years of the available climate data. The standard RDI^{st} states that the λ_k takes the values of lognormal distribution given as :

$$RDI_{st}^{(i)} = \frac{y_k - \bar{y}_k}{\lambda_{yk}} \qquad (4)$$

y_k is the $\bar{y}_k$ the arithmetic mean and λ_{yk} is the standard deviation.

RESULTS AND DISCUSSION

The present study analysis the historical drought events for the period (1979-2013) in Tharparkar district (Table 1) . The annual time series is helpful to identify the drought event in the region. Therefore, the time series of SPI and RDI has been conducted for Tharparkar as shown in Figs 3 and 4 respectively.

According to the result obtained by SPI for Tharparkar, the extreme drought event occurred in

Table 1. Classification of drought based on SPI and RDI.

Drought class	SPI & RDI
Extreme wet	2.0+
Severe wet	1.50 to 1.99
Moderate wet	1.00 to 1.49
Near normal	-0.99 to 0.99
Moderate drought	-1.00 to -1.49
Severe drought	-1.50 to -1.99
Extreme drought	≤-2.00

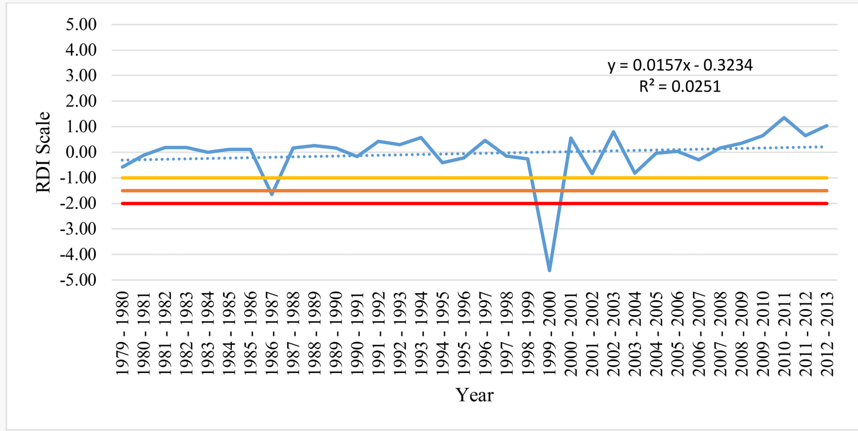

Figure 4. Annual time series analysis of RDI in Tharparkar.

1986-1987 where SPI value is -2.48. The severe drought captured by SPI is during the period 2001-2004 with -1.50 SPI value.

RDI figured out the extreme drought in the year 1999-2000, where RDI values reaches at -4.63. However the severe drought perceived in the year 1986-1987 with RDI value (-1.50). The moderate drought observed during the period 2001-2004 respectively. The main objective of the present study was to assess the historical drought by using the drought criterion SPI and RDI. Both the indices shows good competence to captured the drought in the selected region. The drought period 2001-2004 comprehend by both drought indices is also assessed by Malik *et al.* 2013. The correlation observed by SPI is (r=0.441), where the stronge correlation comprehend by RDI (r=0.158). The result obtained from the indicators pointed out that the indices SPI and RDI are better predictor to monitor the drought in the region. This study will be helpful to develop a mitigation plane and to tackle drought events and to build future scemarios of droght related desasters in the future.

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