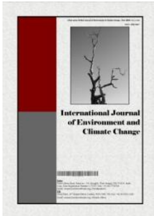

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Assessment of Drought Over Parambikulam Aliyar Basin of Tamil Nadu

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

Rainfall has a greater impact on agricultural, hydrological, economic, environmental and social systems. Inconsistencies in rainfall pattern could lead to extremities like drought and flood. Drought is a long period of unusually low rainfall that severely affects crop production and welfare of the people. Understanding the impacts of drought is crucial for planning, mitigation and responses. The Standardized precipitation index (SPI) method was employed for identifying drought occurrence in Parambikulam aliyar basin based on rainfall data of 37 years (1981–2017). SPI method indicated PAP basin had drought once in 4 years. In 19 per cent times, wet situation found to exist in PAP basin, five years exhibited moderately wet condition (1984, 1996, 2010, 2015 and 2017) and two years (1992 and 2005) fell under extremely wet event. Quantification on the drought events forms the scientific basis for decision makers to reduce the societal vulnerability to drought.

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Keywords: Drought; Standardized Precipitation Index (SPI); rainfall; Parambikulam Aliyar basin.

1. INTRODUCTION

Climate change and its impacts have long been forced into the reality of present century. According to the Special Report on Global Warming (SR15) by Intergovernmental Panel on Climate Change [1] the "global mean sea level is projected to is projected to rise from the 1986-2005 record of 0.26 m to about 0.77 m by 2100, for global warming temperature increase of 1.5 °C and about 0.1 m more for 2 °C. Many regions and seasons experience warmer temperature greater than the global annual average [2]. For instance the temperature rise is about two to three times higher in the Arctic. Warming is generally higher over land compared to the ocean and it correlates with temperature as well as precipitation extremes under heavy rain and drought situation [3]. The assessed levels of risk had generally increased compared to the previous IPCC report [1].

Drought is defined as an extended period of unusually dry weather that causes water shortages and damages to the crops [4, 5, 6]. Indian Irrigation Commission defines drought as a situation occurring with in any area where the yearly rainfall is less than 75 per cent of Long Period Average (LPA) [7]. Drought is broadly classified into three types as meteorological drought, hydrological drought, agricultural drought [8, 9]. Meteorological drought is the first to occur being defined as a condition, where the annual precipitation is less than long period average over a period of time [10, 11]. Hydrological drought is connected with the precipitation shortages on water reservoirs [12, 13] and agricultural drought follows with insufficient water for irrigation and agricultural requirements, mostly effecting the food production on a greater scale [14]. Agricultural drought and deficit precipitation will lead to soil water deficit conditions, making it vulnerable over agrarian country like India [15]. There are many drought indices such as percentage of normal precipitation, Standardised Precipitation Index (SPI), Palmer drought severity index (PDSI), Reconnaissance drought index (RDI), Moisture Availability Index (MAI), Moisture Adequacy Index, Aridity Index (Ia) and Normalized difference vegetative index (NDVI) etc being used for measuring and predicting the drought conditions [16, 17]. Among those, SPI is one among the widely used multi-scalar tool for drought predictions [18] which was developed by [19] and described in detail by [20]. The Index measures precipitation anomalies at a given location, based on a comparison of observed total precipitation amounts for an accumulation period of interest, with the long-term historic rainfall record for that period. Taking into the advantage and accuracy of SPI methodology, this research paper tends to use the SPI method for monitoring the drought over the Parambikulam Aliyar basin. Parambikulam aliyar basin (PAP) is considered to be an important basin in Tamil Nadu [21] favouring water for nine blocks in two districts.

2. MATERIALS AND METHODS

2.1 Study Area

Parambikulam-Aliyar basin is an inter-state water distribution project located in the south western part of the peninsular India collaborating between Kerala and Tamil Nadu states. This project diverts the water from the eight rivers. The PAP basin area lies in coordinates of 10° 10’ 00” N to 10°57’20” N latitude, 76°43’00” E to 77° 12’30” E longitudes and covering 2388.72 sq.km area (Fig. 1). Parambikulam Aliyar project diverts the water from the basins of three west flowing rivers originating from the western ghats along the Kerala-Tamil Nadu border, namely the Periyar, Chalakkudipuzha and Bharathapuzha. These rivers are mainly fed by the southwest monsoon and northeast monsoon rainfall. The water diverted to the east is mainly used for irrigation purpose.

2.2 Data

Rainfall data of ERA Interim at 0.125° ×0.125° resolution was used for the study period of 37 years (1981–2017). Verified and bias corrected data was used for SPI analysis. PAP has the distinct physiography covering plain area to hilly range. Total PAP basin as well as delineated PAP hilly areas, PAP plain areas were considered for analysis.

2.3 Standardized Precipitation Index (SPI)

SPI was calculated using the following formula and classification scheme (Table 1) as proposed by [19] and observed the spatio-temporal extent and intensity of drought events. This index is based on the cumulative probability of the considered precipitation as:

$$G(x) = \frac{1}{\beta_{pro}^{\alpha_{pro}} T(\alpha_{pro})} \int_0^x x^{\alpha_{pro}} - 1_{e^{-\frac{x}{\beta_{pro}}}} \, dx$$

Where

$$\alpha_{pro} = \frac{1}{4A} \left(1 + \sqrt{1 + \frac{4A}{3}} \right)$$

$$A = In(x_{sr}) - \frac{\sum_{i=1}^{n} In(x_i)}{n}$$

$$\beta_{pro} = \frac{x_{sr}}{\alpha_{pro}}$$

x_{sr} is the average value of the rainfall quantity, n is the rainfall data period and x_i is the quantity of rainfall in the sequence of data.

If x=0, then the cumulative probability turn out to be H(x)=q + (1−q)G(x); q is the probability of no rainfall event.

Table 1. Category of Standardized Precipitation Index (SPI) based on range values

SPI Range	Category
+ 2 to more	Extremely wet
1.5 to 1.99	Very wet
1.0 to 1.49	Moderately wet
-0.99 to 0.99	Near normal
-1.0 to -1.49	Moderately dry
-1.5 to -1.99	Severely dry
-2 to less	Extremely dry

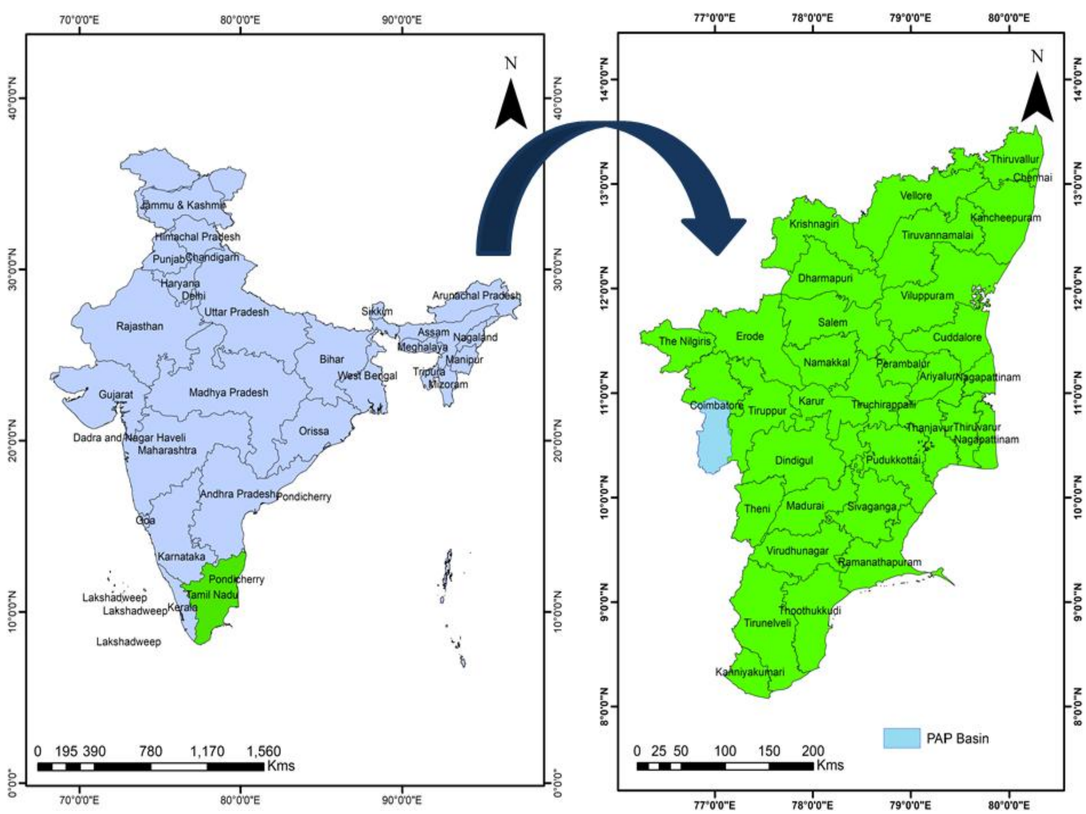

Fig. 1. Location of the study area

The normal standardized distribution with null mean and each data variance was then obtained from the transformation of the cumulative probability, and then SPI values were obtained from Equation (5) as below (see Edwards and McKee (1997) for further information):

$$SPI = \begin{cases} -\left(t - \frac{c_0 + c_1 t + c_2 t^2}{1 + d_1 t + d_2 t^2 + d_3 t^3}\right) & 0 < H(x) \leq 0.5 \\ +\left(t - \frac{c_0 + c_1 t + c_2 t^2}{1 + d_1 t + d_2 t^2 + d_3 t^3}\right) & 0.5 < H(x) \leq 1.0 \end{cases}$$

Where

$$t = \begin{cases} \sqrt{In \frac{1}{(H(x))^2}}, & 0 < H(x) \leq 0.5 \\ \sqrt{In \frac{1}{(1 - H(x))^2}}, & 0.5 < H(x) \leq 1 \end{cases}$$

H(x) is the cumulative probability of the observed rainfall. c0, c1, c2, d1, d2 and d3 are the constants values of 2.515517, 0.802853, 0.010328, 1.432788, 0.189269 and 0.001308, respectively. Classification of the SPI (McKee and others, 1993) is shown in the Table 1. The SPI values range from extreme wet to extreme drought.

3. RESULTS AND DISCUSSION

Variations and trend in the yearly rainfall for the span of 37 years from 1981 to 2017 in PAP hilly areas, PAP plain areas and total basin are represented in Figs. 2, 3 and 4 respectively. The average annual rainfall of PAP hilly area is 1478.7 mm followed by total PAP basin with rainfall of 942.4 mm. The PAP plain areas received the rainfall of 587.3 mm.

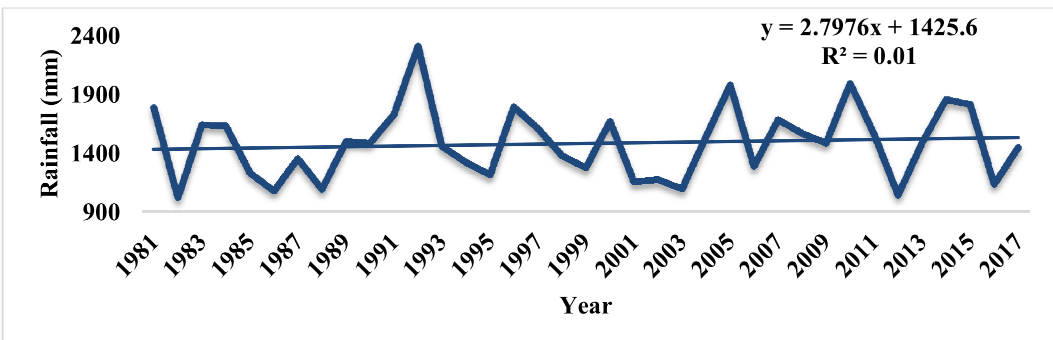

Fig. 2. Rainfall trend of Hilly areas in PAP basin from 1981 to 2017

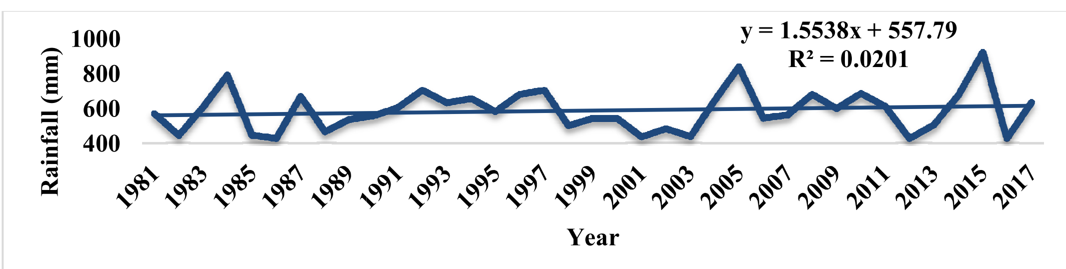

Fig. 3. Rainfall trend of Plain areas in PAP basin from 1981 to 2017

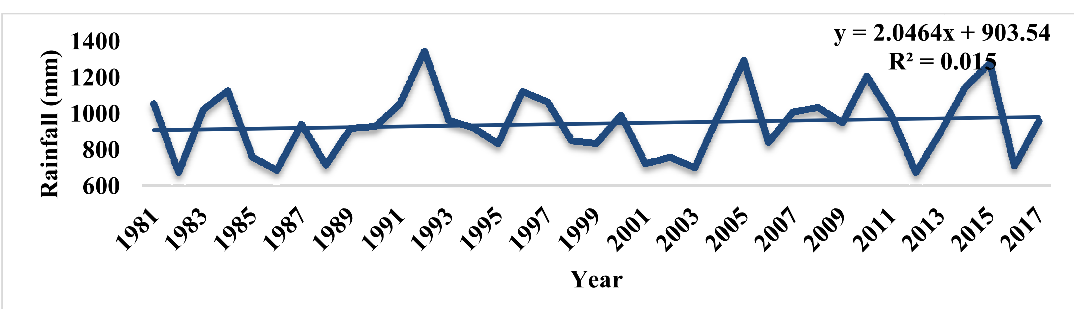

Fig. 4. Rainfall trend of Plain areas in Total PAP basin from 1981 to 2017

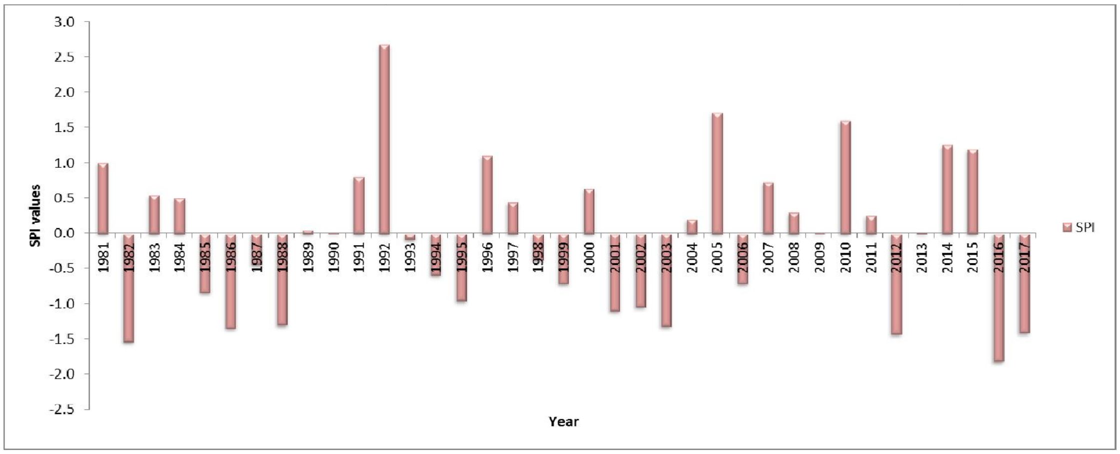

Fig. 5. 12-month time scale basis drought results using SPI method in PAP hilly areas

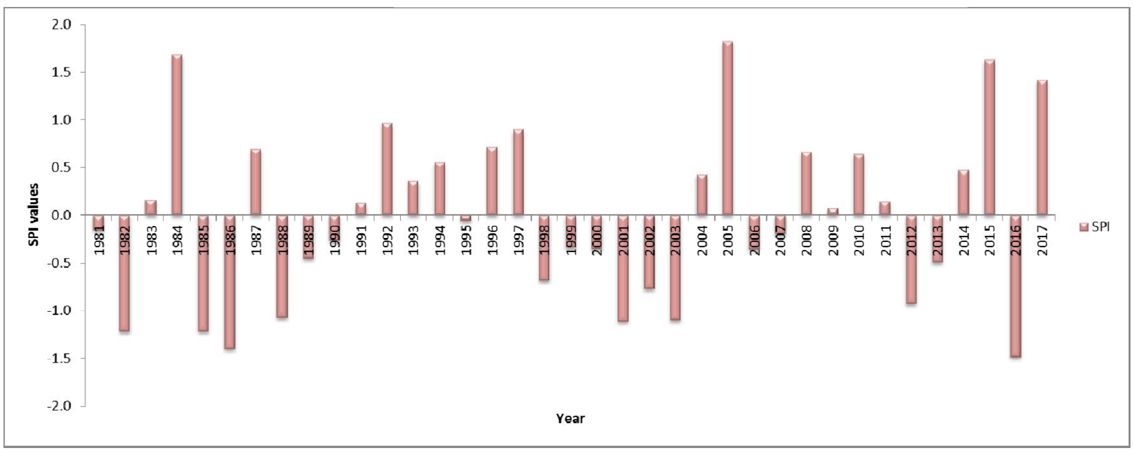

Fig. 6. 12-month time scale basis drought results using SPI method in PAP plain areas

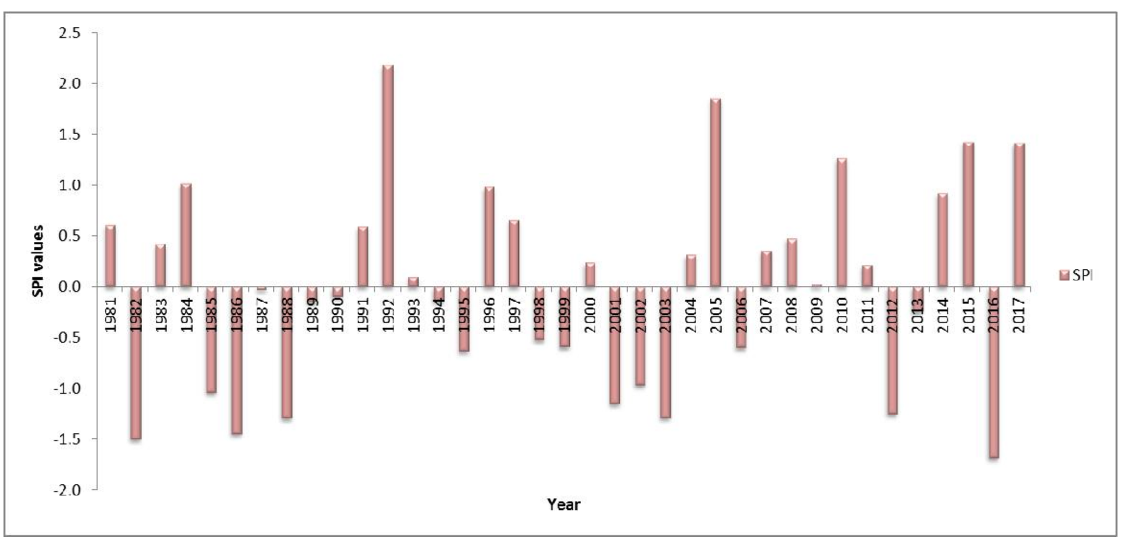

Fig. 7. 12-month time scale basis drought results using SPI method in Total PAP basin

The SPI values derived for plains, hills and total basin indicate that hilly areas of PAP basin experienced severe dry condition in three years (1982, 2016 and 2017) while seven years (1986, 1988, 1995, 2001, 2002, 2003 and 2012) showed moderately dry condition. In contrast, 1981 and 1996 had moderately wet condition, 1992 was extremely wet and 2005 and 2010 were very wet year. Overall, the hilly region had 10 drought years which indicate that the occurrence of drought once in four years. Conversely, the lesser number of years with wet condition (5 years) compared to drought years indicating the higher possibility for the occurrence of drought like situations (Fig. 5) over hilly region of PAP basin.

In case of plain area in PAP basin only one year (2016) was observed to be a severe drought while 6 years were moderately drought years (1982, 1985, 1986, 1988, 2001 and 2003). Moderately wet situation occurred in 1992 and very wet condition was witnessed in three years (1984, 2005 and 2015). Similar to the hilly area, drought years were more in plain area compared to wet years (Fig. 6). On an average more than 50 per cent of the years in hilly area experienced when compared with the wet years. Analysis indicated that drought event occurred once in 5 years over 37 years.

As far as entire basin is concerned 27 percent of the time exposed to drought with the severely dry condition in 2016 (1 year) and moderately dry situation during 1985, 1986, 1988, 2001, 2002, 2000 and 2012 (7 years). From the SPI analysis it could been the PAP basin had drought once in 4 years. In 19 per cent times, wet situation found to exist in PAP basin, five years exhibited moderately wet condition (1984, 1996, 2010, 2015 and 2017) and two years (1992 and 2005) fell under extremely wet event (Fig. 7). Find of the present study was in accordance with the results [22, 23] obtained in hilly and river basin.

4. CONCLUSION

The trend analysis of annual rainfall over the study area revealed that the entire PAP basin, hilly and plain areas have witnessed slight increase in rainfall. From drought analysis made using SPI method it is concluded that hilly areas of PAP basin witnessed three severe dry years, seven years of moderate dry, two years classified under each of moderately and very wet events and one year came under extremely wet situation. The plain area has faced one severe dry year, six moderate drought years, one moderately wet year and three very wet years. Basin as a whole, PAP basin risked with two severe dry years, eight moderately drought years, five moderately wet years, one extremely wet and very wet year The hilly region was exposed to the drought once in 4 years and drought occurred once in 5 years in plain. The basin as a single unit faced drought once in 4 years. SPI is the best index that requires only rainfall as an input parameter. As the SPI method describes the magnitude of drought it could be very well used by the policy makers to quantify the impact of drought on various sectors. SPI proves to be the best suited method for decision makes owing to its probabilistic nature provides it historical context. SPI can also be considered as an effective tool due to its representing capability of both wetter and drier conditions in the similar way.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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