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Examining drought behaviour using departure index and rainfall anomaly index in Nambiyar river basin, Tamil nadu

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Abstract

Drought is one of the complex natural phenomena. In extreme cases, drought causes great damage to the economy and human life. Drought is caused by a lack of long-term rainfall. The humans as well as the environment are greatly affected due to drought. It is not related to particular climate regions but it causes a similar effect in all climatic regions of the world. There are several drought-prone areas in India so the Government of India has developed a Drought Affected Area Plan which is being implemented in drought-prone areas. An attempt has been made in this paper studying two drought indices such as Departure Index (DI) and Rainfall Anomaly Index (RAI) in the Nambiyar River Basin of Tamil Nadu to assess the drought condition. Only 3 classifications (moderate, mild, and no droughts) are observed in the Departure Index. Mild drought years are highly found in the Nambiyar River basin followed by moderate and no droughts. Chidambarapuram, Nainaputhoor station had a maximum drought of 24 years and 6 years of moderate drought is observed in Vallioor station. The frequency of drought years for RAI index are repeatedly noted high during the year 2003, 2016, and Keeriparai station had the highest negative anomaly value of -10.67 in the year 2017.

Keywords: Rainfall; RAI; DI; drought; Nambiyar river basin

Introduction

Drought is one of the complex natural phenomena. In extreme cases, drought causes great damage to the economy and human life. The economic loss caused by drought is high compared to all other weather disasters. (Wilhite, 2000). Globally, drought causes an economic loss at an average of 6 to 8 billion USD (Yagci *et al.,* 2013). Drought is one of the least mention natural calamities (Kao and Govindaraju, 2010). Droughts can be classified as agricultural, hydrological, meteorological, and socio-economic droughts (Shiau *et al.,* 2012). The climatic parameters such as rainfall and temperature play a crucial role in defining drought. Among the climatic parameters, rainfall is an important factor and is a readily available weather measurement. Using rainfall data from thirty or more years is better for effective growth planning than using short-term ones (Dennett et al., 1985). It also affects agriculture, drainage, human settlements, and politically and its impact varies from place to place. The main factor leading to the impact of drought

depends on the size, frequency, duration of the drought, and extent. (Degefu and Bewket, 2015; Zargar*et al.,* 2011; Surendran*et al.,* 2017).Many drought indices have been developed for drought forecastingsuch asPalmer Drought Severity Index, Rainfall Anomaly Index, Departure Index, Drought area Index, Drought Severity Index, Gumbel Recurrence Interval, and Standardized Precipitation Index,etc. There are drought indices that use rainfall alone to define drought. Consecutively,some indices combine other parameters such as potential evapotranspiration (PET), temperature,and soil moisture along with rainfall to understand drought. Here, an attempt has been made in this study considering rainfall as a prime factor to understand the drought characteristics of the study area using the Rainfall anomaly index (RAI) and departure index.

Study area

The Nambiyar basin covers a part of the Tirunelveli, Thoothukudi, and Kanyakumari districts of Tamil Nadu. Geographically, the basin extends between 08° 08'00"N to 08° 33' 00" N latitude and 77° 28'00" E to 78° 15' 00" E longitude. The basin is surrounded by the Tamiraparani basin and Kodaiyar basin on the north and south side respectively. The Eastern part of the basin is covered by the Gulf of Mannar and the western part is by Kerala state. The total area of the basin is 2018.4 sq.km. Karamaniyar river on the northern side, Hanumanadhi river in the southern part, and the Nambiyar river lie in between these two rivers are the major rivers draining this basin. The maximum and minimum temperature of the basin is 33°C and 28°C respectively. The Nambiyar river originates in the eastern slopes of Western Ghats exactly over Nalikkal Mottai located 9.6 km west of Thirukkarangudi village. Millets, pulses, oilseeds, coconut, and the fewer area is under paddy cultivation are some of the major crops of the basin (Figure 1).

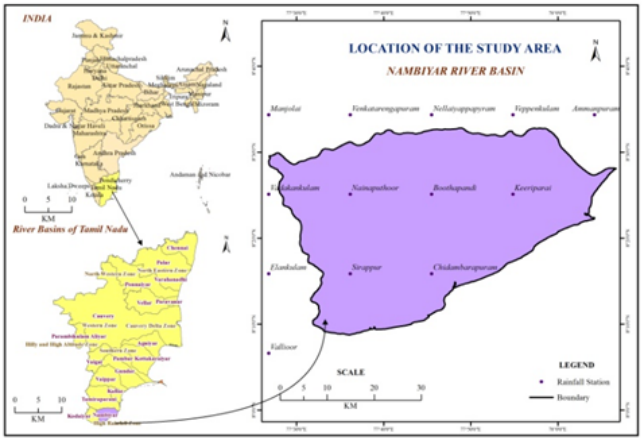

Fig. 1. Location of the study area

Data and Methodology

The base map of the Nambiyar river basin was digitized from the river basin map of Tamil Nadu. The in and around rainfall data for the Nambiyar basin from the year 1981 to 2017 were used in this study to understand the drought. The basin covers 13 gridded points collected from the ECMWF reanalysis Interim (ERA-1) data set having a horizontal resolution of 0.75^0. This gridded data was downscaled to 17X17 km resolutions using the WRF re-initialization method were adopted. The gridded points are considered as rainfall locations such as Valliure, Elankulam, Sirappur, Chidambarapuram, Vadakankulam, Nainaputhoor, Boothapandi, Keeriparai, Manjolai, Venkatarngapuram, Nellaiyappapuram, Veppenkulam, and Ammanpuram. The graphs were prepared using Excel software and spatial maps were prepared using the Arc GIS platform.

Departure Index

Based on the annual precipitation deficiency the droughts are classified by the Nation Commission on Agriculture and Indian Meteorological Department (IMD and National Commission on Agriculture). Departure Index is based on long-term averages of precipitation value.

DI = Percentage of departure from long term average precipitation

RF= the annual precipitation particular year

M_{RF}= the long-term average of annual precipitation

$$DI = \left(\frac{RF - M_{RF}}{M_{RF}}\right) \times 100$$

Rainfall Anomaly Index

Rainfall Anomaly Index assesses the frequency and intensity of the dry and rainy years. RAI had two anomalies; there is a positive and negative anomaly. The rainfall data were arranged in descending and ascending order based on rainfall intensity. The mean values of maximum 10 values (M_{H10}) and minimum 10 values (M_{L10}) were considered for calculations. Based on the average ten rainfall values stand for positive and negative anomalies respectively. The following equations were used to calculate RAI for the annual.

$$RAI = +3\left(\frac{RF - M_{RF}}{M_{H10} - M_{RF}}\right)$$

$$RAI = -3\left(\frac{RF - M_{RF}}{M_{L10} - M_{RF}}\right)$$

RF= Sum of annual rainfall receiving particular year

MRF= the average rainfall receiving over the study period

M_{H10} and M_{L10} = theaverage value of 10 highest and 10 least values respectively.

Result and discussion

The Meteorological Department of India and the National Agriculture Authority provide the percentage of normal rainfall and associated weather drought intensity rainfall departures (Table 1). During this study period, the study area comes under two categories such as moderate and mild drought. Most of the location in this study area is under mild drought. The stations which have a maximum number of years fall under moderate drought is Vallioor, followed by the stations are Veppankulam, Elankulam, Sirappur, Vadakkankulam, Venkatarengapuram, Nellaiyappapuram, Manjolai and Ammanpuram. Minimum drought years are noted in Chidambarapuram, Nainaputhoor and Boothapandi stations during the study period (Figure 2). Chidambarapuram and Nainaputhoor are the location have high number of years with mild droughts and minimum year are found in Elankulam station followed by Boothapandi, Keeriparai, Manjolai, Venkatarengapuram and Nellaiyappapuram station (Table 2).

Table 1. Departure index

Departure Index	Intensity of Meteorological drought
0.00 <	No Drought
00.0 to -25.00	Mild Drought
-25.00 to -50.00	Moderate Drought

Table 2. Station wise departure index in Nambiyar river basin

Sl. No	Station	No drought	Mild drought	Moderate drought
1	Vallioor	15	16	6
2	Elankulam	19	15	3
3	Sirappur	15	18	3
4	Chidambarapuram	12	24	1
5	Vadakkankulam	17	17	3
6	Nainaputhoor	12	24	1
7	Boothapandi	14	22	1
8	Keeriparai	15	22	0
9	Manjolai	13	21	3
10	Venkatarengapuram	15	20	2
11	Nellaiyappapuram	14	21	2
12	Veppenkulam	17	16	4
13	Ammanpuram	16	19	2

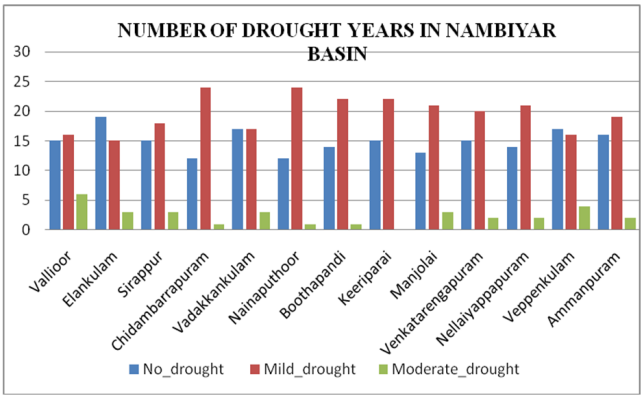

Fig. 2. Number of drought years

Spatially, the moderate drought years found above three years are noted in the western part, the northeastern part of the study area, and below 3 drought years found in the central and southeastern part of the basin. The northern, central, and southeastern parts of the study area have a maximum number of mild drought category i.e., above 20 years and below 20 years were found in the western and northeastern parts. The years which have greater than 15 years of no droughts were observed in the western and eastern part of the study area. Below 15 drought years found in the central part of the study period (Figure 3).

Rainfall anomaly index

Rainfall Anomaly Index is mainly used for maximum and minimum rainfall which is compared to the long-term mean of a particular study period. Rainfall Anomaly Index value differs from station to station, it shows how many years comes under the positive anomaly as well as a negative anomaly. If the values of RAI are generally less than minus three it is associated with drought (Tilahun, K. 2006).

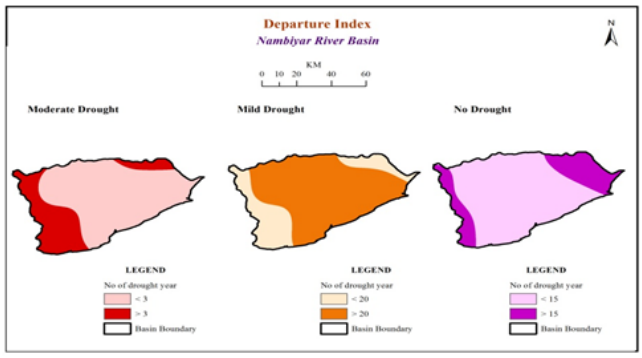

Fig. 3. Departure index

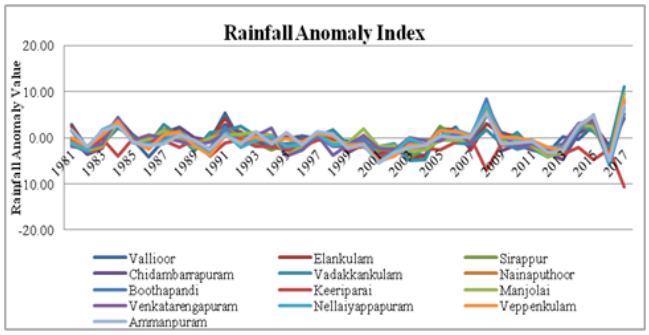

Fig. 4. Rainfall anomaly index

During this study period RAI value less than minus 3 are noted in Vallioor during the years 1986, 2001, 2002, 2003, 2004, 2012, in Elankulam location during 2001, 2003,2004 and 2012, Sirappur (1982, 1990, 2003 and 2013) Chidambara-puram (1982, 1999, 2003, 2012 and 2013) Vadakkankulam (2003, 2004, 2012. 2012, 2013 and 2016) Nainaputhoor and Boothapandi (2001, 2002, 2013 and 2016) Keeriparai (1984, 1990, 2002, 2008, 2012, 2013, 2015 and 2017) Manjolai (1995, 2012, 2013, 2016)Venkatarengapuram (1995, 1998 and 2016) Nellaiyappapuram and Veppenkulam (1990, 2001, 2002 and 2016) Ammanpuram (2001, 2002, 2012 and 2016) (Figure 4).

Table 3. Mean values of RAI and DI

Sl.No	Year	RAI	DI
1	1981	0.03	3.22
2	1982	-2.65	-17.62
3	1983	-0.38	-1.46
4	1984	2.76	29.55
5	1985	-0.35	-1.69
6	1986	-1.42	-9.91
7	1987	0.63	6.69
8	1988	0.66	9.03
9	1989	-1.42	-9.86
10	1990	-1.31	-7.75
11	1991	1.79	18.56
12	1992	-0.22	0.04
13	1993	-0.28	0.14
14	1994	-0.72	-4.35
15	1995	-1.55	-7.54
16	1996	-1.42	-8.90
17	1997	0.45	4.57
18	1998	-0.50	-2.21
19	1999	-1.91	-12.56
20	2000	-0.72	-4.18
21	2001	-3.46	-22.66
22	2002	-2.65	-17.33
23	2003	-2.45	-17.06
24	2004	-2.29	-15.79
25	2005	0.52	8.34
26	2006	0.50	5.38
27	2007	-0.81	-5.76
28	2008	4.80	51.21
29	2009	-0.60	-2.90
30	2010	-0.59	-2.75
31	2011	-1.66	-11.14
32	2012	-3.08	-20.51
33	2013	-2.62	-16.67
34	2014	1.65	16.91
35	2015	2.79	30.20
36	2016	-3.83	-24.86
37	2017	5.98	64.89

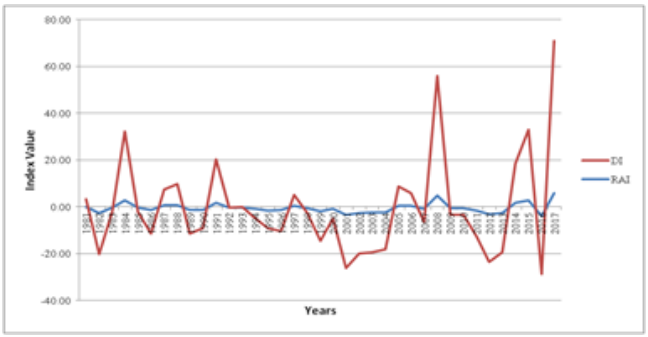

Fig. 5. Comparison of two drought indices

Keeriparai location in the basin is noted as the highest drought index value of -10.67 during the study period. The graphical representation of the average values of two drought indices is plotted inFigure 5. Both indices are almost similar (Table 3).

Conclusion

The main aim of the study is to analyze the drought character using DI and RAI index. The results obtained in this study give almost identical results while comparing the drought years. The two-drought index reveals more or less similar results in the drought years. The common drought years between two indexes are notes as 1986, 2003, 2013, and 2016 during the study period. So, both the index is useful to identify the drought condition in the study area. Even though the study area is not affected by severe and extreme drought but the recent years indicate most of the stations are under moderate drought conditions. It shows that the basin slowly experiencing drought conditions. So, a proper drought management plan is required to mitigate before it goes to

extreme conditions.

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