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Full Research Article

Spatial and Temporal Analysis of Drought Characteristics in Parambikulam-Aliyar Sub-basin, Tamil Nadu

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Abstract

Drought assessment in a basin provides useful information for sustainable water resource planning and management. The impacts of drought assessment and projection for the Parambikulam–Aliyar sub-basin was carried out with the aid of Regional Climate Models (RCMs) output (precipitation), using the Representative Concentration Pathways (RCPs) 4.5 and 8.5 scenarios of the Fifth Assessment Report (AR5) of the Intergovernmental Panel on Climate Change (IPCC). A basin was divided into four hydrological sub-basins and monthly precipitation data from four stations were used. This study attempts to develop the spatial and temporal pattern of drought characteristics based on frequency and severity of drought events at 3, 6 and 12 month time scales in the Parambikulam-Aliyar sub-basin. A comparison throughout three future time slices reveals a significant decreasing precipitation trend and increasing drought frequency. The Standardized Precipitation Index (SPI) was calculated in order to evaluate the spatial and temporal distribution of droughts by classifying the stations in terms of severely dry and extremely dry conditions as a time percentage. Intensification of drought events is projected for the central and western part of the basin during the last future period under study (2070−2098) under RCP8.5 scenario. The above findings should be taken into consideration for future strategy planning for drought management and for the development of warning systems.

1. Introduction

Drought is a complex natural phenomenon that affects more people than any other natural hazards causing significant damage both in natural environment and in human lives (Wilhite, 2000). As a normal feature of climate, drought occurs in virtually all climatic zones, such as high as well as low rainfall areas and its occurrence appears inevitable. Mostly droughts are related to the reduction in the amount of rainfall received over an extended period of time, such as a season or a year.

Drought is a frequent phenomenon in India and drought areas are mainly confined to the Peninsular and Western parts of the country and there are only few pockets in the central, eastern, northern and southern parts. Out of 329 mha of total geographical area in India about 107 Mha of lands are subjected to different degrees of water stress and drought conditions (Mishra and Desai, 2005). More than 100 districts spread over 13 states of India have been identified as drought prone districts, out of these, about 8 districts occur Tamil Nadu (Gupta et al., 2011). The western regions of Tamil Nadu (Coimbatore and Tiruppur districts) have suffered with severe droughts at many times in the past. The demand for water has increased several times due to the growth of population and expansion of agricultural, energy and industrial sectors, and almost every year water scarcity has been occurring. Other factors, such as climate change and contamination of water supplies, have further contributed to the water scarcity.

A Regional Climate Models has a high resolution (typically 50 km, compared to 300 km in GCM) and covers a limited area of the globe. It is a comprehensive physical model, usually of the atmospheric and land surface, containing representatives of the important processes in the climate system as are found in GCM. The scenarios emerging from the new set of GCM experiments, are called Representative Concentration Pathways (RCPs) and constitute a set of greenhouse gas concentration and emissions pathways served to support research on the impacts climate change (Riahi et al., 2011; Kim et al., 2013). The Representative Concentration Pathway (RCP) 8.5 corresponds to a high greenhouse gas emissions pathway compared to the scenario literature (Jevrejeva et al., 2012; Kim et al., 2013; IPCC, 2007), and hence to the upper bound of the RCPs. The greenhouse gas emissions and concentrations in this scenario increase considerably over time, leading to a radiative forcing of 8.5 W/m^2 at the end of the century (Riahi et al., 2007). The rest of the pathways represent milder conditions and can be considered as moderate mitigation scenarios.

The threat that drought pose to the climatic change in the sensitive economic sectors in the future has necessitated the assessment of the potential impacts of climate change at various scales to reduce their vulnerability. Few studies of climate change impacts on droughts have employed meteorological drought indices, which require considerably less input data when compared to weather, soil and land use information needed by meteorological, hydrologic, agrohydrologic and water management models as the tools for assessing drought responses (i.e. Kothavala, 1999; Blenkinsop and Fowler, 2007; Mavromatis, 2007). This study is a contribution towards meeting this challenge. It investigates the spatial and temporal analysis of drought characteristics in Parambikulam-Aliyar sub-basin, Tamil Nadu using meteorological drought indices. In this basin, four rain gauge stations (Aliyar Nagar, Top slip, Pollachi and Chinnakallar) were located according to climatological and topographical characteristics. The standardized precipitation index (SPI) was used for the identification and assessment of drought events. Finally the future SPI time series are analyzed to evaluate the effect of drought characteristics in PAP Basin.

2. Materials and Methods

2.1. Study area and data used

Parambikulam-Aliyar basin is located in the south western part of the Peninsular India covering areas in Kerala and Tamil Nadu States (Figure 1), which is considered as the classical bio diversity hotspot of the world that harbours several critically endangered flora and fauna like Tiger, Nilagiri Tahr etc. This basin area lies within the coordinates of North latitude between 10°18′22′′ to 10°42′59′′ and East longitudes 76°48′37′′ to 77°8′7′′. The basin is drained by eight west flowing rivers viz. Valaiyar, Koduvadiaru, Uppar, Aliyar and Palar (tributaries of Bharathapuzha river) and Parambikulam, Solaiyar and Nirar (tributaries of Chalakudi river). The Aliyar River has its source in the Anamalai Hills. It flows towards north-westerly direction for about 37 kms in Tamil Nadu and enters Kerala and finally confluences in Bharathapuzha. Aliyar reservoir is one among the main components in PAP with a surface area of 6.50 km^2 and is formed in the plains across the river with a gross storage capacity of 109.42 mcm. The catchment area of the Aliyar dam is 196.83 km^2. Apart from its own catchment, water can be diverted to this reservoir through the Aliyar Feeder canal and the Contour canal from the Parambikulam group of reservoirs. Total area of sub-basin is 574.75 km^2 and command area is 20,536 ha covering Pollachi (North), Pollachi (South) and Anamalai blocks of Coimbatore district. Crops grown in this sub-basin area are coconut, sugarcane, banana, sapota, mango, fodder, besides annual crops such as paddy, groundnut, cotton, vegetables, pulses, fodder, tomato, gaurds, Maize as I crop, and Paddy and Groundnut as II crop.

Aliyar sub-basin is considered as the study area for this research, since the management of water resources in this basin is important to downstream user for their water requirements and environmental flow. Due to frequent droughts and increasing water demand in recent years, pressure on the water resources management activities have increased within the basin.

The Monthly precipitation data was used to assess the impact of climate change on the Parambikulam-Aliyar sub-basin in terms of occurrence of droughts. The Regional Climate Model (RegCM) has been used to estimate the precipitation changes for the periods 2006‒2039 (Near Century), 2040‒2069 (Mid Century) and 2070‒2098 (End Century) and for the two climate change scenarios (RCP 4.5 and RCP 8.5). The standardized Precipitation index computed at various time scales was used as an indicator of meteorological drought for present and future climatic conditions. The four rain gauge stations namely (Aliyar Nagar, Topslip, Pollachi and Chinnakallar) in Parambikulam-Aliyar sub-basin are considered for the rain fall data and drought analysis by using SPI index with 3, 6 and 12 month time scale.

2.2. Use of the standardized precipitation index (SPI) for drought analysis

The standardized precipitation index (SPI) as a drought assessment tool was developed at Colorado State University, U.S. to quantify the rainfall deficit, and has been used to monitor drought conditions (McKee et al., 1993). A drought event occurs at the time when the value of SPI is continuously negative and the event ends when the SPI becomes positive. The SPI may be calculated at multiple timescales (1-, 3-, 6-, 9-, 12-, 24-, 48-months). The use of multiple timescales allows the effects of a rainfall deficit on different water resource components (groundwater, reservoir storage, soil moisture and stream flow) to be assessed. Table 1 provides a drought

Table 1: SPI Classification of drought characterization

SPI value	Category
2 or more	Extremely wet
1.5 to 1.99	Severely wet
1 to 1.49	Moderately wet
0 to 0.99	Mildly wet
0 to - 0.99	Mildly dry
-1 to -1.49	Moderately dry
- 1.5 to -1.99	Severely dry
2 or less	Extremely dry

characterization based on SPI. Numerous studies have been conducted to analysis the meteorological droughts using SPI (Hughes and Saunders, 2002; Patel et al., 2007; Edossa et al., 2010; Moradi et al., 2011; Pai et al., 2011).

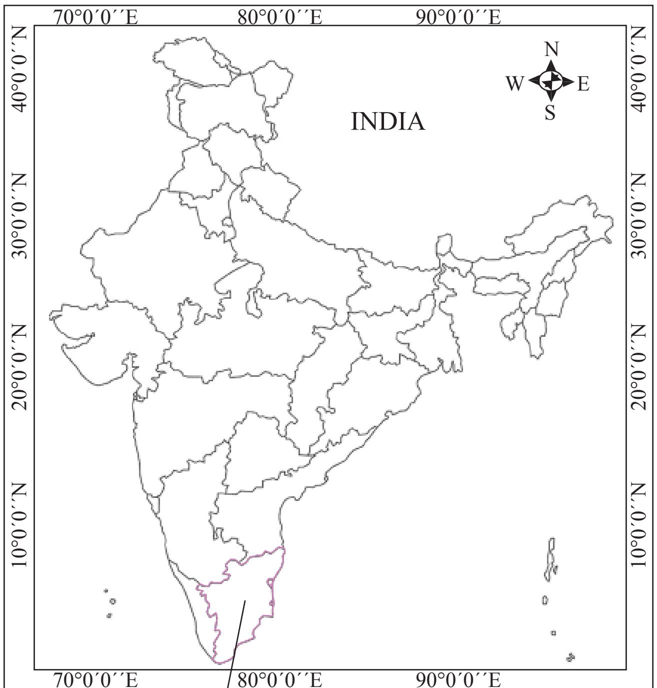
3. Results and Discussion

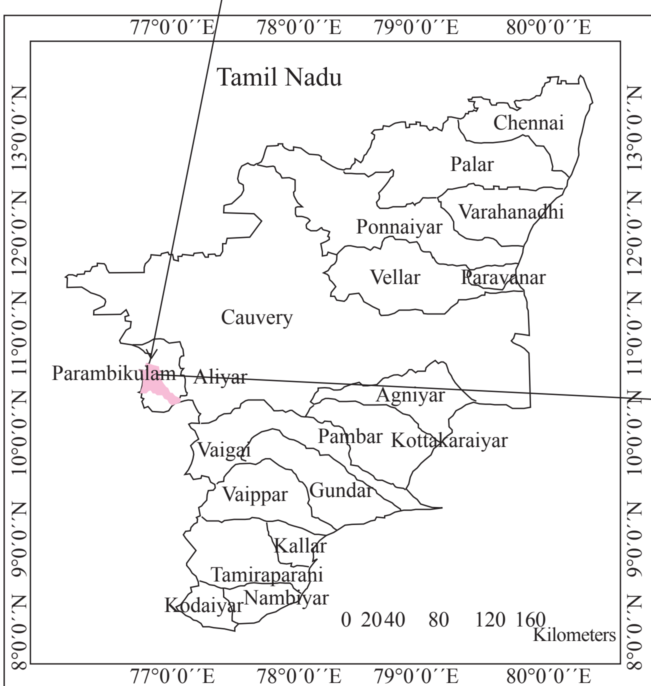
3.1. Spatial and temporal distribution of drought

It shows drought occurrences of Aliyar sub-basin over the study area for near, mid and end centuries under RCP 4.5 and 8.5 scenarios (Table 2). Projected SPI are presented in Figures 2 to 4 for the four rain gauge stations over the study area. Extreme drought is expected to occur in the year of 2017 at Pollachi station (-3.23) under RCP 8.5 scenario at 3 month time step. For the 6 month time step, the severe drought (-3.32) is expected at Pollachi station in the year of 2027 under RCP 4.5 scenario. For the 12 month time step, the severe drought

Table 2: Expected percentage of drought occurrence in Aliyar sub-basin

Catego-ries/Time scale	RCP 4.5			RCP 8.5		
	SPI_3	SPI_6	SPI_12	SPI_3	SPI_6	SPI_12
Near Century						
D_1	34.3	34.5	35.7	34.1	33.0	32.3
D_2	9.7	9.4	8.6	8.9	8.9	9.3
D_3	4.2	4.0	5.5	3.9	4.1	3.2
D_4	2.0	1.7	1.3	1.8	2.3	2.8
Mid century						
D_1	33.5	34.1	31.0	32.9	32.0	32.3
D_2	9.9	8.7	10.5	10.8	10.5	9.0
D_3	5.1	4.9	4.4	4.0	4.4	3.4
D_4	2.2	2.7	2.3	2.2	2.0	3.2
End century						
D_1	37.3	35.9	34.3	37.1	38.3	39.5
D_2	9.4	9.0	9.3	9.6	9.5	8.6
D_3	4.2	3.6	3.0	3.5	4.2	3.5
D_4	1.9	2.6	3.0	2.3	2.2	2.2





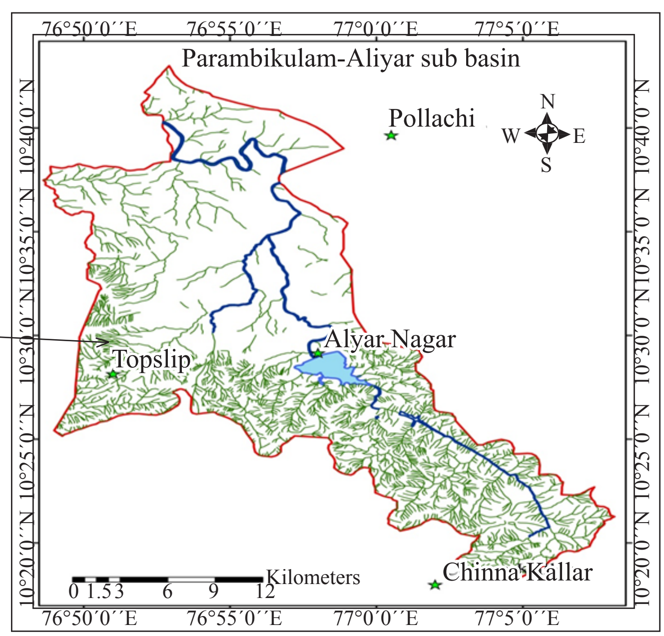


Figure 1: Location map of study area

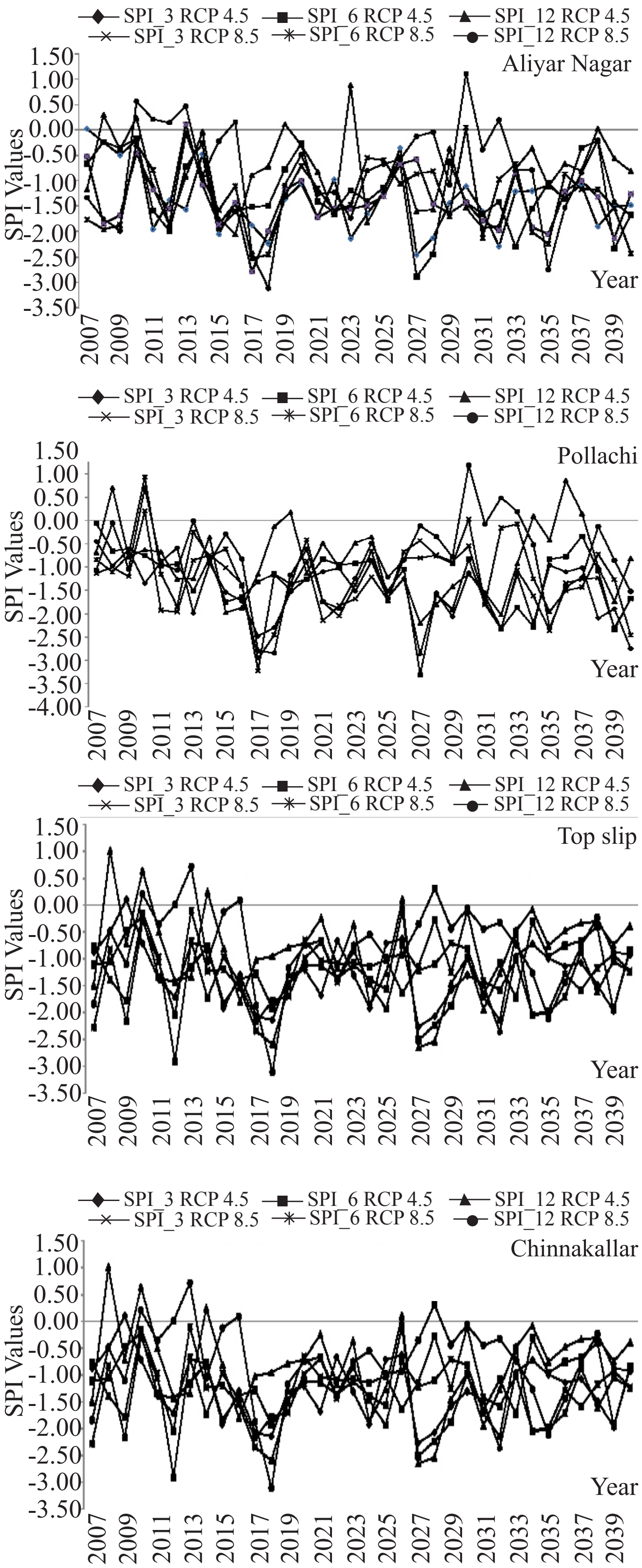


Figure 2: Projected spatial and temporal variation of SPI values at 3, 6 and 12 month time scale for different rainguage station of Aliyar sub basin (Near Century)

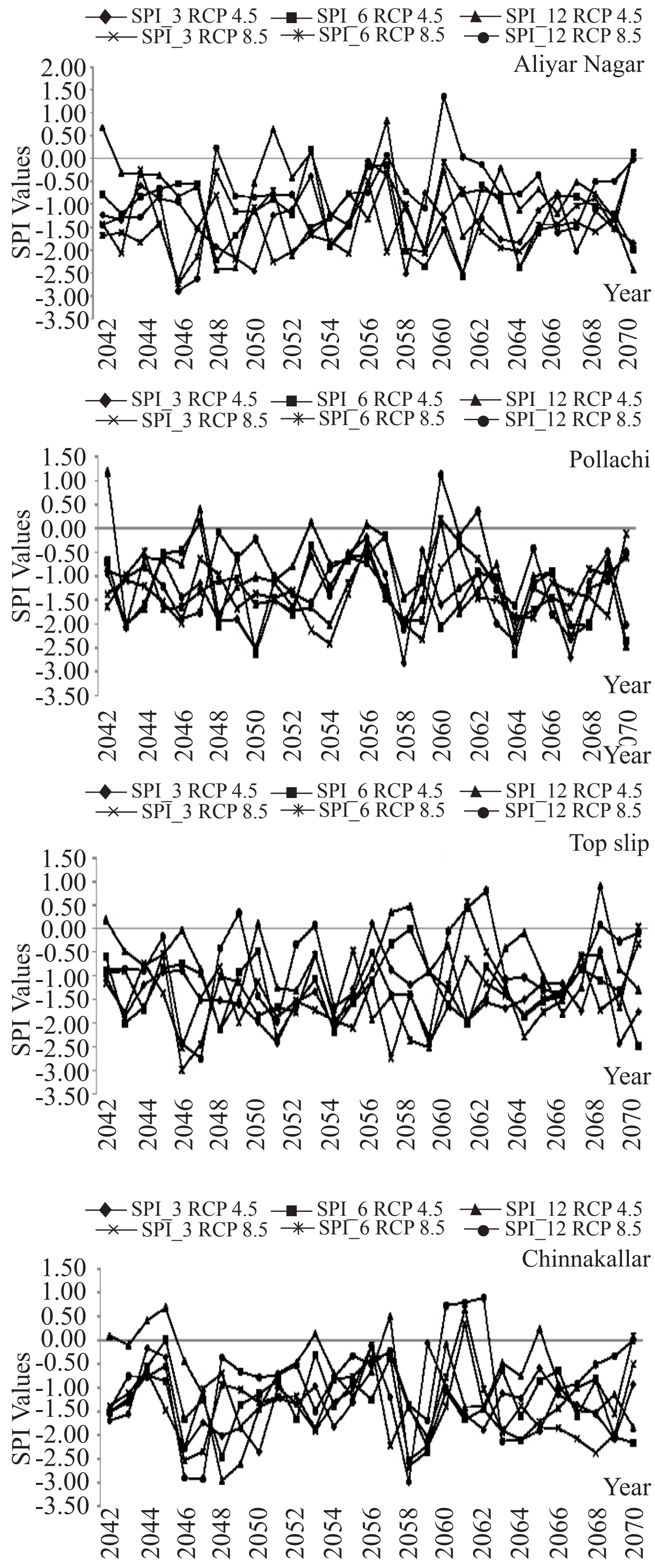


Figure 3: Projected spatial and temporal variation of SPI values at 3, 6 and 12 month time scale for different rainguage station of Aliyar sub basin (Mid Century)

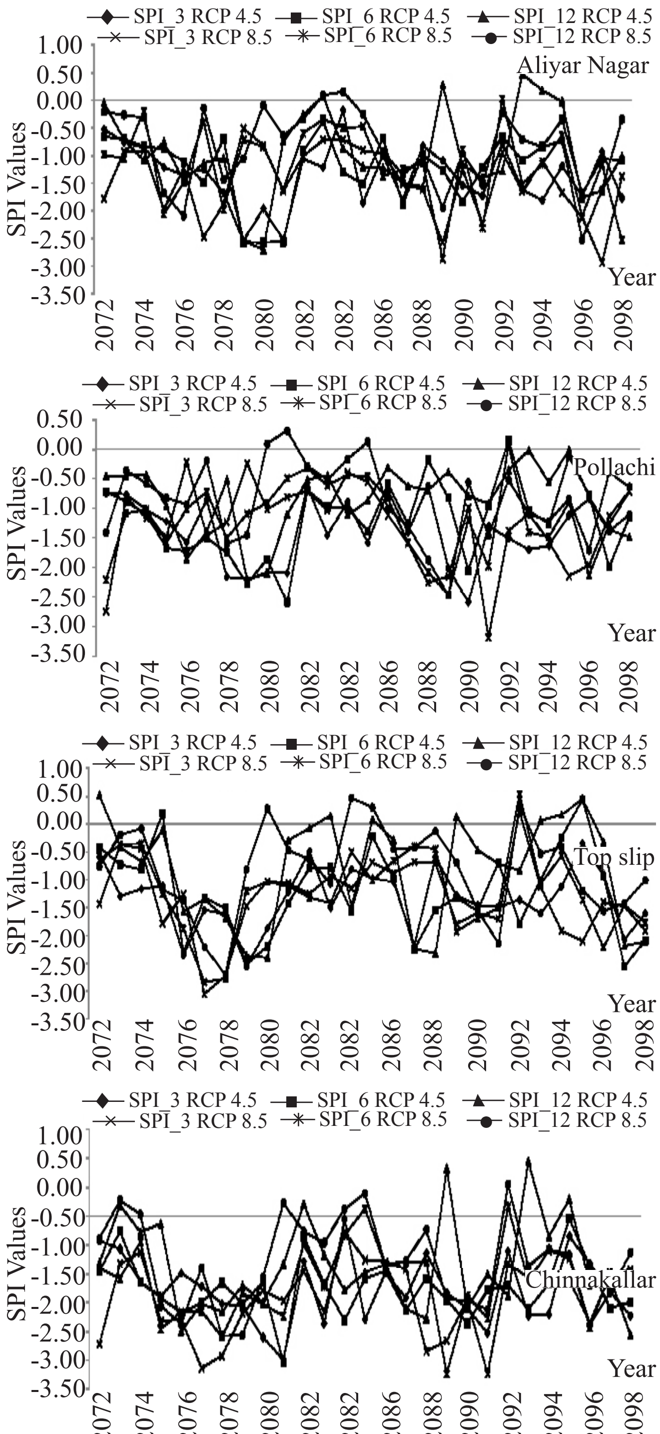


Figure 4: Projected spatial and temporal variation of SPI values at 3, 6 and 12 month time scale for different rainguage station of Aliyar sub basin (End Century)

(-3.12) is expected at Aliyar Nagar station in the year of 2018 under RCP 8.5 scenario. The severity of the drought is mainly due to low rainfall, high temperature, high wind, and low relative humidity. The other reason is that drought becomes more intense when mean precipitation is projected to decrease and wet conditions are completely absent in that region. These results are in harmony with the finding of Sigdel and Ikeda (2010).

From (Table 2) short term and long term (3, 6 and 12 month time step) drought analysis in the near century, the frequency of mild drought is expected higher in RCP 4.5 (34.3, 34.5 and 35.7) scenario compared with RCP 8.5 (34.1, 33.0 and 32.3). Less occurrence of severe and extreme drought is expected under both scenarios in the short and long term drought analysis. For long term analysis the frequency of occurrence in severe drought is higher in RCP 8.5 scenario than RCP 4.5 scenario in the near century. Tayeb et al. (2013) found that, the occurrence of severe drought due to higher intensity of rainfall, higher evapo- transpiration, less amount of ground water contribution, soil type and cropping pattern of that area.

In the mid century for drought analysis of short and long term (3, 6 and 12 month time step), mild drought is expected to decrease in RCP 4.5 (33.5, 34.1 and 31.0) than RCP 8.5 scenario (32.9, 32.0 and 32.3), whereas the severe drought for short and long term analysis is expected to higher frequency in the RCP 8.5 (2.2, 2.7 and 2.3) scenario compared with RCP 4.5 (2.2, 2.0 and 3.2) scenario (Figure 3). As compared to the near century, decreased mild, moderate, severe and extreme drought frequencies are expected in the mid century under the both scenarios.

In the end century from short and long term drought analysis, mild drought is expected to increase in RCP 8.5 (37.1, 38.5 and 39.5) scenario than RCP 4.5 scenario (37.0, 35.9 and 34.3) (Figure 4). Severe and extreme droughts are expected higher frequency in RCP 4.5 scenario compared with RCP 8.5 in the end century. However, under the RCP 8.5 scenario, the magnitude and severity of the drought conditions are noted to reduce as compared to RCP 4.5 scenario is also in line with the result of Ngaina et al. (2014).

Short and long term drought analysis, the frequency of mild drought is expected to decrease in mid century, whereas the severe and extreme droughts are expected to increase in near and end century compared with mid century under the both scenarios. Similar findings are reported by Gosain et al. (2011) who found that moderate and severe droughts are expected to increase under the end century for almost all the river systems, except for the Tapi basin in India.

4. Conclusion

Based on the study, the year 2070 to 2098 will experience severe and extreme drought that projects 39.5% chance of drought occurence under RCP 8.5 scenario. The analysis revealed that the northern part suffered significantly severe drought and the Pollachi rain gauge station was affected by extreme drought events with fluctuated rainfall pattern throughout the study period. Therefore precipitation trends from RCM outputs helps to develop proper drought management plans and provide an additional clue in climate change investigation.

Salient points for my article is

1. This study extensively analyzed the drought & rainfall distribution pattern of Parambikulam-Aliyar sub-basin, which is the lifeline of 20,536 ha of cultivable land that promotes the cultivation of major commercial crops like coconut, banana etc.

2. This study thoroughly analyzes the drought pattern & greatly helps to forewarn the drought occurrence in the basin so as to take precautionary measures and other sustainable water management practices to reduce the environmental damage.

3. This study projects the drought pattern in the Aliyar sub-basin which is one of the biodiversity hotspots of the world and thus helps to take mitigation measures to conserve the precious flora and fauna of this zone.

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