Interdecadal variation in rainfall patterns in South West of Western Australia

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Abstract

The South West of Western Australia (SWWA) has experienced a significant decrease in rainfall since the 1970s which has adversely affected the agricultural and water supply sector in this region. The decreasing trend has been attributed to lesser interactions between cloud bands and cold fronts and the major changes in the large scale atmospheric circulation in the Indian Ocean region. Though many studies have been carried out to understand the decline of rainfall in SWWA, the total quantitative change of rainfall in the study area in terms of volume and area still remains uninvestigated. The objective of this study is to examine the change in total rainfall volume and wet areas in SWWA. Daily gridded rainfall data from 1930 to 2009 from the Bureau of Meteorology were used in this study. The method used is linear regression which identifies how the rainfall volume and wet area has varied over the years. Three rainfall categories were considered for this study namely, rainfall greater than 0.2mm (total rain), rainfall greater than 10 mm (heavy rain) and rainfall less than or equal to 10 mm (light rain). The results indicated that although rainfall volume has showed a decreasing trend, it is not statistically significant. The area receiving highest number of rain days per year showed a significant decreasing trend in all three rainfall categories. It was also noted that the area receiving higher number of rain days has been reduced and the area receiving lower number of rain days per year has expanded.

Keywords: SWWA, rainfall, trend, wet days.

1. INTRODUCTION

The South West of Western Australia (SWWA) has been showing a significant decreasing trend in winter rainfall as stated by Pittock (1983), Yu and Neil (1993), Hennessey et al (1999), Smith et al (2004) and Gallant et al (2007). SWWA receives most of its rainfall during the winter months of June, July and August. A decrease in mean winter rainfall was observed by Pittock (1983). This is found to be contributed by a decrease in the winter rainfall intensity and frequency of occurrence (Yu and Neil (1993) and Hennessy et al (1999)). A decrease in frequency and intensity of extreme rainfall was also noted by Haylock and Nicholls (2000). Smith (2004) explained the decreasing trend as a recent feature rather than a part of any long term trend.

The climate of SWWA is governed by various factors like the frontal systems, Southern Annular Mode (SAM), Indian Ocean Dipole (IOD), subtropical ridge, cut off lows and west coast trough (IOCI (2002)). SAM is found to be inversely related to SWWA winter rainfall (Hope et al (2006) and Juan et al (2015)). The decreasing frequency of westerly fronts during the winter months is also stated to be the reason for the declining winter rainfall (Hope et al (2006)). The change point of statistically significant decreasing trend is noticed to be around the time 1965-1970 (Li et al (2004) and Fu et al (2010)). This step change closely correlates with the Sea Surface Temperature (SST) anomalies during the 1970s (Samuel et al (2006)) and to a positive SAM in a neutral ENSO phase which was associated with a reduced rainfall from westerly fronts (Raut et al (2014)). The concept of a monsoon like atmospheric circulation, South West Australian Circulation, suggested by Juan et al (2014) explains the interannual variability of rainfall in SWWA and the long term drying trend.

Agriculture and water supply are the two major sectors that have been adversely affected by the rainfall decline. Wheat production in the area could decline drastically due to lower rainfall as suggested by the Climate Council (2011). Likewise, the decrease of inflow into the dams due to lower rainfall has led to lower water levels in the dams of this region where the demand of water has been continuously rising (Climate Council (2015)). The decrease in annual inflow into the dams is found to be associated with decrease in amount and frequency of daily precipitation (Bates et al (2010)).

Most studies in SWWA have explained decreasing trend as a result of decrease in extreme events or heavy rainfall (Hennessy et al (1999) and Fu et al (2010)). The decline has also been related to various weather drivers like a positive SAM (Hope et al (2010) and Juan et al (2014)), warmer SSTs (Samuel et al (2006)) and decrease in interaction between the cloudbands and the cold fronts (IOCI (2002)). The aim of this study to take a quantitative approach on the total rainfall decline in SWWA. This is achieved by evaluating the change in rainfall volume and the change in area receiving rainfall in the study area.

2. DATA AND METHODOLOGY

The region in SWWA which has greater than 10mm/decade of decline in rainfall has been chosen as the study area as shown in Figure 1. This area lies between 30.5˚S and 35˚S in latitude and 114.5˚E and 120˚E in longitude. The data used in the study is 0.05˚daily rainfall gridded data, obtained from the Bureau of Meteorology for the duration 1930 to 2009. From the gridded data available for Australia as a whole, daily layers were cropped to coincide with the study area. Each grid point represents a rectangular area with sides 0.05˚latitude by 0.05˚longitude. The study area covers an area of 197062.4 km^2.

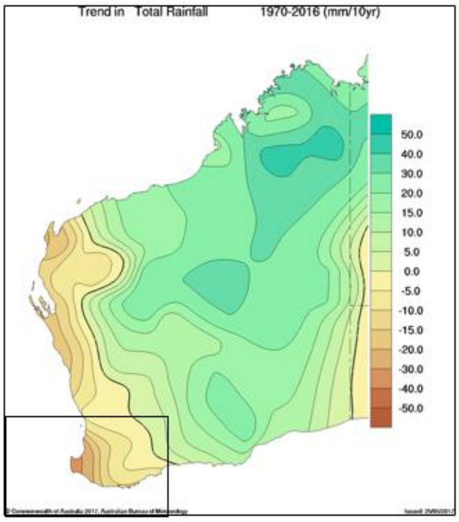

Figure 1. Study area in Southwest of Western Australia (Source: http://www.bom.gov.au)

A day with rainfall greater than 0.2 mm is considered as a rain day as per the Bureau of Meteorology. Likewise, the maximum daily potential evapotranspiration is 10mm. For this study rainfall greater than or equal to 0.2 mm (total rain), greater than 10 mm (heavy rain) and less than or equal to 10mm (light rain) are considered. The total depth of rainfall multiplied by the area of each grid cell will give the volume of rainfall for a day. Linear regression was used to examine the presence of trend on the annual rainfall volume time series. P value was calculated at a significance level of 0.05. The goal of regression analysis is to understand how the values of Y change as X is varied over its range of possible values (Sanford Weisberg, 1980). Equation 1 gives the linear regression equation.

$$y = \beta_0 x + \beta_1 \quad (1)$$

Where β_1 and β_0 are the intercept and slope, estimated by the Equations 2 and 3.

$$\beta_1 = \left(\sum_i^n (x_i \; y_i) - n\,\bar{x}\,\bar{y} \right) / \left(\sum_i^n x_i^2 - n\bar{x}^2 \right) \quad (2)$$

$$\beta_0 = \bar{y} - \beta_1 \bar{x} \quad (3)$$

Spatial maps were plotted to understand and visually represent the changes in area receiving rainfall in the three categories over the decades. Total area is obtained by adding the number of grid cells in each frequency class and multiplying by the area of one grid cell. The area of each grid cell was found to be 25.868 km^2. Trend analysis was carried out on the area time series and p value calculated to identify the significant trend.

3. RESULTS AND DISCUSSION

Linear regression was conducted on the three volume time series of the three rainfall categories. It was observed that all three time series show a decreasing trend as shown in Figure 2. The trend was found to be not significant at 0.05 significance level. Table 1 shows the volume trend for all three rainfall categories considered.

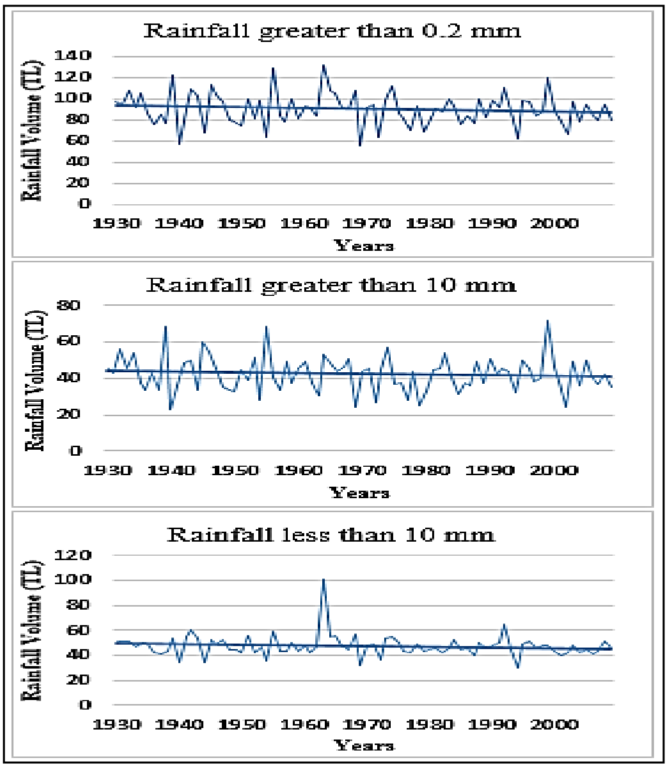

Figure 2: Volume time series

Table 1. Results of trend analysis of volume

Rainfall categories	Trend (TL/decade)	p value
Rainfall >= 0.2mm	-0.82	p >0.05
Rainfall > 10mm	-0.36	p >0.05
Rainfall <= 10mm	-0.46	P >0.05

The spatial maps shown in figures 3, 4 and 5, demonstrates the change in area receiving wet days over the years.

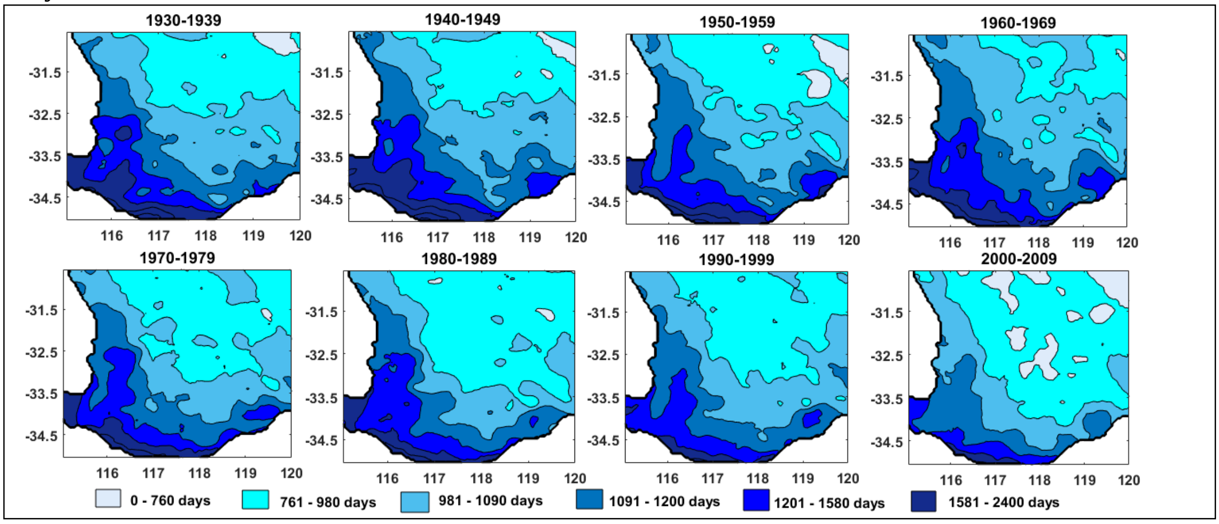

Figure 3. Number of days when rainfall was greater than or equal to 0.2 mm

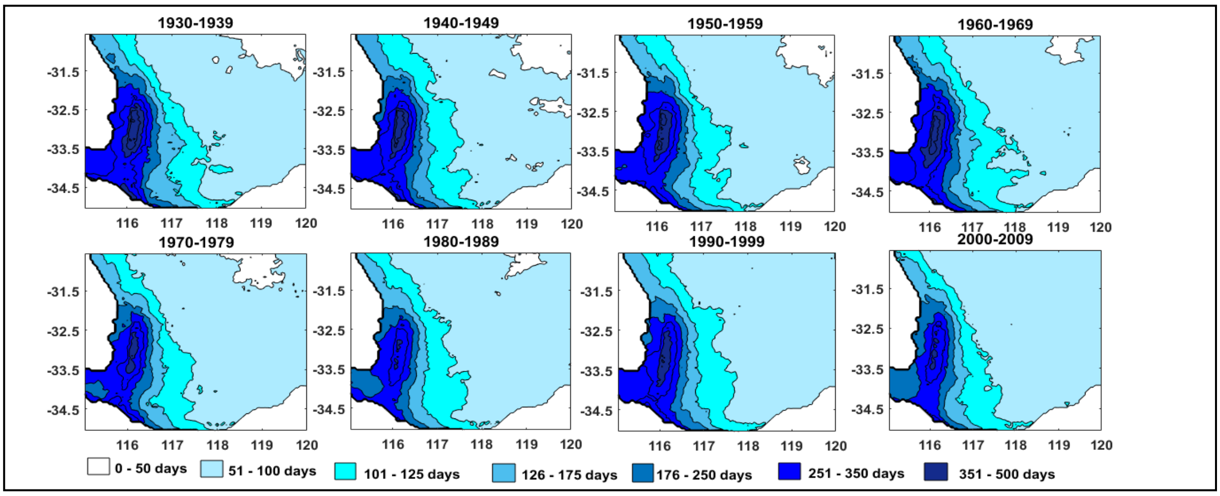

Figure 4. Number of days when rainfall was greater than 10 mm

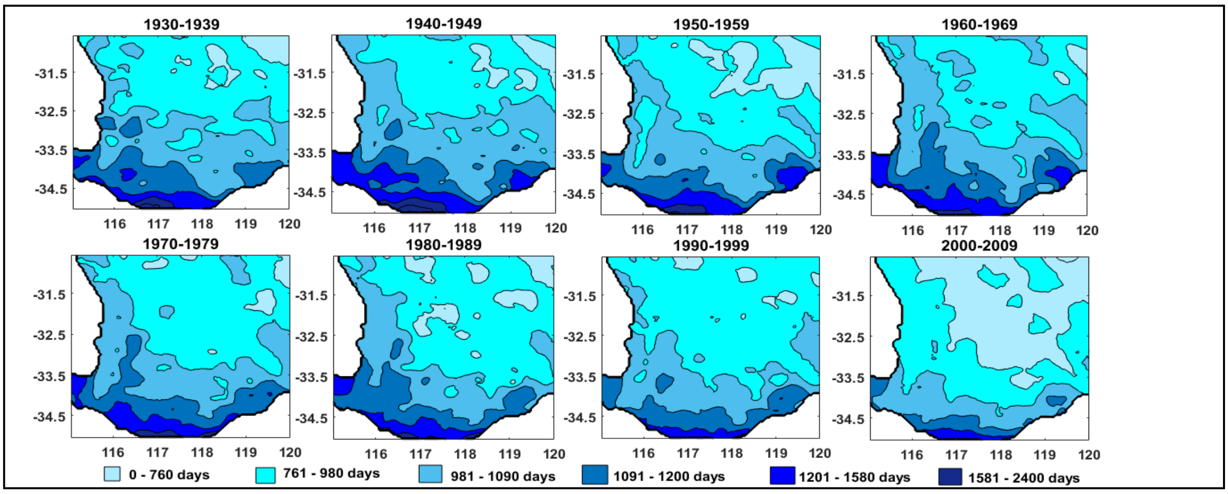

Figure 5. Number of days when rainfall less than or equal to 10 mm

Figure 3 shows the change in area receiving rainfall greater than equal to 0.2 mm for the last eight decades. The total area that received greater than 98 rain days per year (71% in 1930s) has reduced to a small area (43.5% in 2000s) that occupies the south western corner of the study area. In case of rainfall greater than 10 mm as shown in Figure 4, the region which received the least number of rain days (0- 5 days/year) in the upper right corner of the study area diminishes to zero by the end of the 2000s. Figure 5 shows the spatial maps for rainfall less than or equal to 10 mm. The region that receives rainfall less than 76 days per year has increased by 22% in the last eight decades.

The percentage of total area of each frequency class in the three rainfall categories for the 1930s and the 2000s is given in Table 2. Trend analysis was carried out on area in each frequency class of the three rainfall categories and the results are shown in Table 3. Significant decreasing trend in the area receiving highest number of rain days was observed in all the three rainfall categories considered. A general decreasing trend in the regions receiving higher number of rain days and an increasing trend in the regions receiving lower number of rain days was oberved in all three categories (Table 3).

Table 2. Percent of the total area (197,062.4 km^2) in SWWA for each frequency class

Daily rain >= 0.2mm			Daily rain > 10mm			Daily rain <= 10mm		
Frequency (raindays/ yr)	Percentage area (%)		Frequency (raindays/ yr)	Percentage area (%)		Frequency (raindays/ yr)	Percentage area (%)	
	1930s	2000s		1930s	2000s		1930s	2000s
0-76	1	4	0-5	7	0	0-76	3	25
76-98	28	52.5	5-10	54	66	76-98	42	50
98-109	16	13	10-12	7	7	98-109	23	11
109-120	18.5	10	12-17	10	9	109-120	12	7
120-158	27	19	17-25	8	11	120-158	19	7
158-240	9.5	1.5	25-35	11	7	158-240	1	0
			35-50	3	0			

Table 3. Trend in wet areas ('*' denotes significant trend at 0.05 significance level)

Rainfall >= 0.2mm		Rainfall > 10mm		Rainfall <= 10mm	
Frequency (raindays/yr)	Trend (km^2/yr)	Frequency (raindays/yr)	Trend (km^2/yr)	Frequency (raindays/yr)	Trend (km^2/yr)
0-76	107.64	0-5	-221.2	0-76	298.8*
76-98	402.2*	5-10	942.2	76-98	362.6*
98-109	77.1	10-12	38.4	98-109	-110.4
109-120	-96.2	12-17	47.01	109-120	-147.9*
120-158	-274.3*	17-25	27.1	120-158	-339.2*
158-240	-216.4*	25-35	-46.3	158-240	-63.7*
		35-50	-77.3*		

4. CONCLUSION

Trend analysis of rainfall volume and wet area in SWWA for three rainfall categories (rainfall >= 0.2mm, rainfall > 10mm and rainfall <= 10mm) using the daily gridded rainfall from 1930 to 2009 was undertaken in this study. Previous investigations in the study area have shown a significant decreasing trend in rainfall. The current study showed that although rainfall volume shows a decreasing trend, the rate of decrease is not significant statistically. Maps were used to visually represent the change in areas receiving different frequency of rainfall. Significant decreasing trend in the area receiving the highest number of rain days was observed for all three categories. In addition, an overall increasing trend was observed in area receiving lower number of rain days and a decreasing trend in area receiving higher number of rain days.

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