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Rainfall variation in Lakshadweep Islands

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An analysis has been carried out to determine the monthly, seasonal and annual rainfall variations, trend and its magnitude for Amini, and Minicoy islands of Union Territory of Lakshadweep for the period 1951-2004. Most of the monsoon and post monsoon months have positive trend while other months in general negative trend even though they are insignificant. The analysis of rainfall for different time spans failed to show any significant trend.

[**Keywords:** rainfall variation, trend, Mann-Kendall test, Theil-Sen's slope]

Introduction

It has been reported from different parts of India as well as the world that annual and seasonal (especially monsoon) rainfall is showing variability and trend, either increasing or decreasing[1, 2, 3, 4, 5, 6, 7, 8]. Besides, there are large intra seasonal variations of monsoon rainfall[9] which means lesser dependable monsoon rainfall. Studies on rainfall pattern in India[10, 1, 11, 7, 12, 9, 13], mainly focusing on the monsoon rainfall, have been initiated to assess the trends in rainfall. Treating India as one homogeneous units, while analyzing the rainfall, often fails to capture the diversity of trends since there are regions of positive and negative trends in different parts of India[14]. Thus, researchers also have analyzed rainfall variability and trend at regional scale[15, 16] as well as for meteorological subdivisions of India[17, 18]. Most of these studies are carried out at the annual and seasonal scale, especially for southwest and northeast monsoon seasons, to understand the trend and pattern of distribution[10, 19, 17, 12, 13] and many studies failed to identify any specific trend. Analysis of percentage contributions of monthly rainfall to annual rainfall at all India level13 also failed to detect any trend. But increasing or decreasing trends were found in monthly rainfall in different regions of India [20, 15, 16, 17, 18]. The above review of literature are for rainfall analysis was carried out for stations located within the mainland of India.

It is imperative to examine the spatial and temporal rainfall pattern to comprehend the fresh water availability conditions in small islands[21]. The aquifer depth of Lakshadweep Islands varies between 0.4 m to 1.5 m below ground level[22]. In areas of over exploitation of groundwater there is seasonal salt water incursion[23] and consequent disturbance to hydrostatic equilibrium[24]. The year round unhindered availability of freshwater and the sustainability of the freshwater aquifer systems depends upon the normality in rainfall distribution during a hydrological year. Present study evaluated the rainfall distribution pattern in the Lakshadweep, its trend and magnitude during the latter half of the last century.

Materials and Methods

The rainfall pattern has been analyzed for Lakshadweep islands in Arabian Sea. Islands of India are poorly monitored for the climatological parameters resulting in sparse rainfall data availability for these locations. Continuous monthly rainfall data for sufficiently long period (more than 30 years) are available only for Amini and Minicoy islands of the Union Territory of Lakshadweep. The geographical area of these islands are less than 5 sq. km and rainfall data of these islands well represent the pattern of rainfall in Lakshadweep islands since there is no orographic effect. The monthly total rainfall for Amini and Minicoy Islands of

Lakshadweep for the period 1951-2004 were obtained from the India Meteorological Department (IMD). In the present study the rainfall analysis was carried out for monthly, seasonal (following the IMD scheme of classification[25]) and annual time spans.

In order to study the variability of rainfall various descriptive statistical techniques such as mean, standard deviation and coefficient of variation used by researchers[19, 1, 26] have been used in this study. The trend in rainfall distribution in the above temporal scales were analyzed for the selected island locations using non-parametric Mann-Kendall test[27, 28] for the entire study period. This method calculates the relative magnitude of the rainfall rather than the absolute values themselves[29]. The Mann-Kendall test is the most widely used technique for the analysis of trends in meteorological studies, especially to identify the climatic variability[21].

The magnitude of trend in rainfall can be computed either by a parametric or nonparametric approach[30]. Theil-Sen's slope estimator[31, 30], a distribution free non-parametric regression slope which assumes a linear trend, was used to determine the magnitude of trend in the monthly, seasonal and annual rainfall in the present study. It is less sensitive to outlying (extreme) rainfall events and hence robust than the least-squares estimator. This method is extensively used in determining the magnitude of trend in time series data[30, 32]. Theil-Sen's slope was estimated to determine the magnitude of the trend in rainfall in Lakshadweep islands.

Results

The results of the monthly, seasonal and annual rainfall analysis for Minicoy and Amini stations of the Lakshadweep islands are presented in following sections.

Monthly Rainfall

All months receive rainfall in both islands even though summer and winter months have very less rainfall contribution to the annual. Monthly distribution of rainfall showed large fluctuations which is in tune with the rainfall pattern in other part of India. Percentage distribution of monthly rainfall varied among these two islands (Fig. 1). Minicoy, which is having a southern most location among the Lakshadweep group of islands, is receiving higher amount of rainfall in all months except monsoon (Table 1 and Table 2). During monsoon months Amini receives higher average monthly rainfall. It indicates that the Amini, which is having a northerly location than Minicoy, has greater influence of southwest monsoon circulation

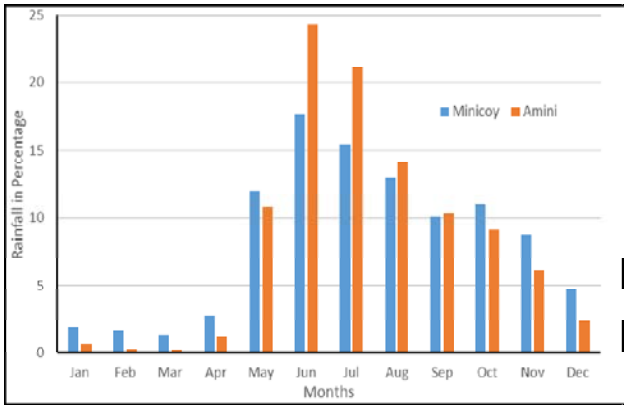

Fig. 1. Average monthly rainfall distribution during 1951-2004 at Minicoy and Amini islands

while Minicoy is receiving more rainfall from northeast monsoon season. Further, being located near to equator, convectional rainfall is predominant during other months, that is during winter and pre-monsoon (summer) months in Minicoy than Amini. Thus, during these seasons Minicoy has higher amount of rainfall than Amini. Amini has very low rainfall, around 0.51 % of the annual, during January to March while it is over 1 % for Minicoy. In both islands highest monthly average rainfall occurs in June followed by July and August while March followed by February and January receives the least (Fig. 1). In contrast to this, an analysis of all India monthly averages showed that July has the highest percentage of rainfall (24.2 %) followed by August[13]. There is significant difference in percentage of rainfall distribution between Minicoy and Amini during monsoon months. During June to September Amini receives more rainfall and the monthly percentage share to the annual rainfall is higher than that of Minicoy. In contrast, Minicoy receives more rain than Amini (Fig. 1) during this the pre-monsoon

Table 1 Descriptive statistics and trend of rainfall (in mm) at Amini, Lakshadweep

Time Span	Mean Rainfall	Coefficient of Variation (%)	MK test (Z)	Sen's Slope (mm/yr)
Jan	9.83	262.2	0.69	0.00
Feb	3.85	311.9	0.12	0.00
Mar	2.98	336.27	-0.62	0.00
Apr	17.19	135.81	-1.20	0.00
May	163.10	111.99	-0.98	-1.01
Jun	366.88	36.78	0.37	0.35
Jul	319.25	51.44	0.16	0.35
Aug	213.41	52.90	1.39*	1.43*
Sep	156.14	61.34	0.31	0.29
Oct	137.15	61.7	-0.14	-0.08
Nov	93.11	108.0	0.53	0.24
Dec	34.34	153.8	-0.45	0.00
Winter	13.17	203.17	0.51	0.00
Pre-monsoon	182.90	101.65	-0.91	-1.09
Monsoon	1052.78	25.5	0.81	1.87
Post Monsoon	261.41	58.4	0.10	0.10
Annual	1510.27	22.49	1.06	3.26

*Significant at 0.1 level

Table 2 Descriptive statistics and trend of rainfall (in mm) at Minicoy, Lakshadweep

Time Span	Mean Rainfall	Coefficient of Variation (%)	MK Test (Z)	Sen's Slope (mm/yr)
Jan	29.90	123.20	0.35	0.06
Feb	25.48	161.37	-1.23	-0.10
Mar	20.55	150.16	0.48	0.00
Apr	43.85	61.08	-0.31	-0.08
May	195.17	51.69	-0.96	-0.83
Jun	286.20	36.84	0.49	0.45
Jul	249.96	44.88	1.02	1.16
Aug	209.92	45.02	0.70	0.71
Sep	164.01	54.79	-0.94	-0.58
Oct	178.57	50.11	-0.48	-0.43
Nov	141.30	60.36	1.50*	0.91*
Dec	76.07	134.05	-0.91	-0.27
Winter	55.38	113.54	-0.37	-0.13
Pre-Monsoon	259.57	41.48	-0.88	-0.91

Monsoon	910.10	21.80	0.91	1.98
Post Monsoon	395.94	33.86	0.36	0.46
Annual	1620.99	13.63	0.10	0.27

Significant at 0.1* level

months, even though pre-monsoon convectional thunder showers are prominent in both islands. A spread out distribution of rainfall throughout the year at Minicoy than Amini results in better water availability conditions at Minicoy.

The variability of monthly rainfall is very high in these stations (Table 1 and Table 2). Lowest variability of rainfall is observed in June while highest is in March followed by February. Among these two stations Minicoy reported lower monthly variability in rainfall than Amini. At Amini variability of rainfall were as high as 336 and 311 per cent respectively during March and February (Table 1). Minicoy also have variability in rainfall during these months. It is to be noted that Minicoy have less than half of Amini's monthly rainfall variability during these months (Table 2). This again reiterates the role of convective rainfall at Minicoy. Normally June receives most dependable rainfall (only 36 per cent variability) in this area followed by July while March and February have most undependable rainfall showing upto 300 per cent variability in monthly distribution. Seven months, November to May, have more than 100 per cent variation in monthly rainfall indicating the uncertainty in occurrence of rainfall in these months.

The monthly distribution of rainfall has both positive and negative trends at Minicoy and Amini islands. But these trends are not significant in any of the months, except during August at Amini and in November at Minicoy. At Amini 7 months have positive trend in rainfall indicating an increase in rainfall over the study period while other months have negative trend indicating a decline in rainfall. These trends are not significant except in August. August has significant positive trend (at 0.1 level). As per Theil-Sen's slope estimate the increase in rainfall 1.4 mm per annum. The negative trends are observed either in pre-monsoon and post monsoon seasons while winter and monsoon months have positive trends. A comparable trend was also observed at Minicoy except in February and September during which negative trend was observed at Minicoy in contrast to a positive trend at Amini. The negative trends were observed in 6 months at Minicoy mainly during pre-monsoon and post monsoon months while rest of months had positive trend. Both positive and negative trends are not significant at Amini except in November during which a significant positive trend at 0.1 significance level was observed (Table 1 and 2). Theil-Sen'slope estimate showed a positive trend in rainfall during November at Amini resulting in 0.91 mm annual increase in rainfall. In general, monsoon months had positive trend, even though statistically insignificant, at both stations. This is in contrast to trends reported for Kerala coast[33].

Seasonal Rainfall

The seasonal rainfall distribution pattern and trends were analyzed for monsoon, post-monsoon, winter and pre-monsoon seasons for the selected island stations for the period 1951-2004. Seasonal concentration of rainfall is observed in these two islands similar to other regions of India. However, the seasonal concentration of rainfall varies significantly in these two island stations despite the fact that they are located in close proximity. About 69% and 56% of annual rainfall is received during the monsoon season at Amini and Minicoy respectively. It should be noted that southernmost island Minicoy, located closer to the equator, receives less rainfall while Amini receives more during monsoon season. In contrast to this Minicoy (24%) receives more rainfall than Amini (17%) during northeast monsoon (post monsoon season). Winter season has least rainfall at both stations and it is less than 1 % at Amini while around 3 % at Minicoy. Summer rainfall is 12 % and 16% at Amini and Minicoy respectively (Table 1 and 2). Around 80% of annual rainfall is received during monsoon and post monsoon seasons indicating very high seasonal concentration of rainfall. Minicoy has relatively higher spread in distribution of rainfall across different seasons than Amini. Southwest monsoon winds have lesser influence on rainfall distribution at Minicoy compared to Amini as well

as the locations at Kerala coast. The variability of seasonal rainfall was highest during winter and lowest during monsoon season. It can be concluded that monsoon and post monsoon seasons rainfall distribution is determinant for fresh water availability condition at Lakshadweep islands.

The positive and negative trends in rainfall were ensued, in both stations, during different seasons. Pre-monsoon season at both islands and winter season at Amini has negative trend while positive trend is observed during monsoon and post monsoon seasons at both islands and also at Minicoy during pre-monsoon season. However, these trends are statistically insignificant. In contrast to this, significant decreasing trend during further verified.

Annual Rainfall

The Amini and Minicoy islands received rainfall throughout the year with a mean annual rainfall of 1510 and 1621 mm (Table 1 and 2) respectively during the analysis period (1951 to 2004). The corresponding normal rainfall for the 1961-90 period is 1545 and 1634 mm. This indicates that over the longer time span the annual rainfall received by these islands are decreasing. At Amini the maximum annual rainfall during the analysis period was 2634 mm while 947 mm was the southwest monsoon was reported along adjoining Kerala coast during a larger time span of 1871-2005[33]. At the same time during post monsoon season both islands and Kerala coast were showing similar pattern. Theil-Sen's slope estimates showed that monsoon rainfall is increasing at the rate of 1.9 mm per year at both islands (Table 1 and 2). Pre-monsoon (summer) rainfall is decreasing by about 1 mm per annum at both islands which is a concern for the water availability for these islands. This is in tune with the declining trend of Kerala coast. In contrast this winter and post monsoon season rate of changes are negligible (< 0.5 mm per annum). This can be considered as sign of intensification of monsoon rainfall in the region which need to be minimum reported (Fig. 2). The occurrence of extreme annual rainfall was common in Amini island than in Minicoy where relative more even distribution of rainfall across the study period was observed. This shows a very high range of 1686 mm in annual rainfall distribution which is higher than the mean annual rainfall for the study period indicating the high variability in annual rainfall. At Minicoy the maximum rainfall was 2205 mm while minimum was 1089 mm during the study period (Fig. 3) and the range in rainfall distribution is 1115 mm. The inter annual distribution of rainfall showed that 1961 received highest while lowest rainfall

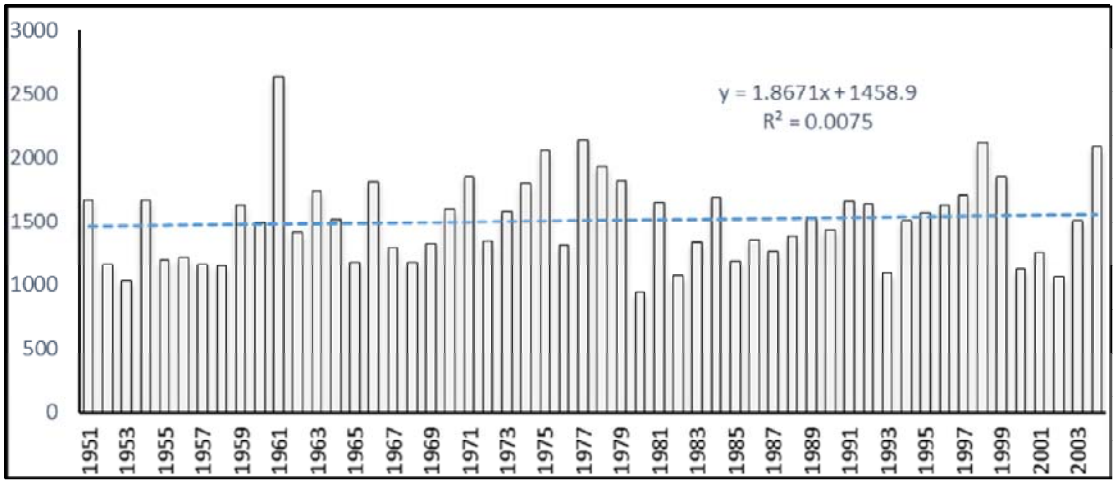

Fig. 2 Annual rainfall distribution during 1951-2004 at Amini island

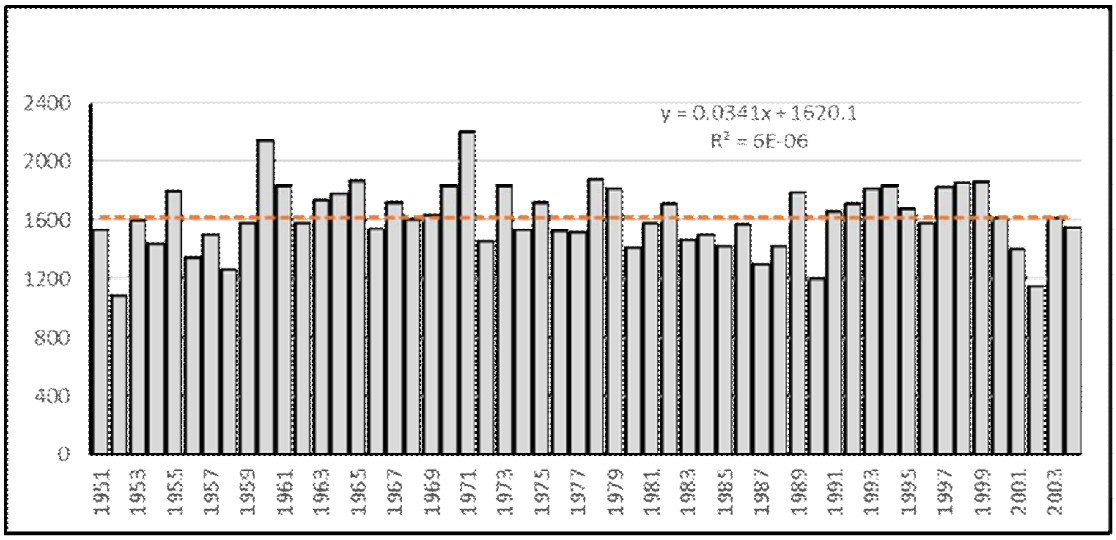

Fig. 3 Annual rainfall distribution during 1951-2004 at Minicoy island

was recorded in 1980. The coefficient of variation in annual rainfall is over 22% at Amini and nearly 14% at Minicoy indicating a lesser consistency in rainfall distribution at Amini than Minicoy. In general, annual variability of rainfall is high at Amini, nearly 2/3rd of Minicoy, because of high variability in rainfall during winter and pre-monsoon months. Compared to Amini, Minicoy has low variability of rainfall throughout the year (Table 1 and 2).

The trend analysis using Mann-Kendall test showed that the annual rainfall has positive trend at Amini and Minicoy islands (Table 1 and Table 2). However, these positive trends are not significant. Mann-Kendall Z score is higher at Amini while it is very negligible at Minicoy. The Theil-Sen's slope estimate showed 3.3 mm per year increment in annual rainfall at Amini while it is only 0.27 mm per year at Minicoy. The higher increment reported at Amini is probably due to the regime changes in southwest monsoon circulation system

Discussion

The annual rainfall and its monthly distribution shows significant differences among Minicoy and Amini islands irrespective of geographic proximity in the Southern Arabian sea. Minicoy island has least variability in rainfall both monthly and annual basis owing to its proximity to equator where more convectional rainfall is dominant than the monsoon circulation. Hence at this location rainfall variability will be comparatively less than Amini and other northern islands that are located along the path of monsoon circulation.

Analysis of trend in rainfall showed insignificant positive trend during monsoon and post-monsoon seasons in both islands. Annual rainfall received remained more or less same, with least variation. However, there is a variation in the monthly rainfall received. Some of the months during southwest monsoon showed an increasing trend while October, during retreating monsoon season, showed a declining trend. The increasing trend in rainfall, even though less in magnitude, is relatively high during latter part of the monsoon season in comparison with earlier monsoon months. This is probably an earlier sign of strengthening of monsoons during later part of the season. The extreme annual rainfall is common in these islands which indicates the vulnerability to water availability in these islands.

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