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Long term spatial and temporal rainfall trend analysis using GIS and statistical methods in Lower Bhavani basin, Tamil Nadu, India

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The present study aims to identify the long term spatial and temporal distribution of rainfall, using the methods from GIS and statistical tools, in Lower Bhavani basin. For this attempt, the spatial distribution of rainfall pattern was studied, by using 33 years of rainfall data (1983 – 2015), from 22 rain gauge stations. The rainfall pattern was interpolated by Inverse Distance Weighted (IDW) method using Arc GIS 10.2.1 on the monthly, seasonal and annual basis. The mean annual rainfall of the region was 666.84 mm. The increasing monthly rainfall was reported in the month of October (164 mm) and decreasing rainfall was observed in the month of January (4.99 mm). The seasonal rainfall changes were prominent during the north east Monsoon season. From 1983 to 2015, 2010 witnessed the highest rainfall pattern in the area. The statistical analysis of Mann Kendall (MK) Test was used, to detect the monotonic increasing and decreasing trend over time, on a monthly basis. A significant level ($\alpha = 0.05$) was used to detect the positive and negative trend that existed over the basin. To be precise, the positive trend existed during the October over 10 rain gauge stations and it was located on the upper northern part of the basin. The negative trend was observed, over six rain gauge stations in southern part of the basin, in the month of January. The result indicated that spatial distribution of rainfall and trend pattern ensured influences in the topography, agriculture productivity and groundwater management across the basin.

[Keywords: Groundwater Management, Lower Bhavani Basin, Mann-Kendall Test, Rainfall, Spatial fluctuation]

Introduction

Water is a vital source for the sustenance of human life. India is a tropical country and naturally it is dependent on rainfall, for water resources planning and management[1]. Precipitation is an important factor, in the various systems of applications in the field of hydrology, vegetation and water quality and it is also important for agriculture at productivity. The precipitation is varied in nature such as liquid, freezing or frozen and mixed. It is a form of water from the sky such as rain, snow, hail and sleet. The liquid precipitation itself is classified into two groups, namely drizzle and rainfall. It is called drizzle when the water particle is below 5 mm in size and when it is above 5 mm size it is rainfall. The rainfall may be a saviour to the environment or a threat to it depending on its intensity. Rainfall may be called a key climatic variable, as it decides the regional hydrological cycle or the water resources. It is the most complex element in the hydrological cycle, as it has wide range of scales in space and time[2]. The recent reports on climate change are alarming and the extreme severity is attributed to the temporal and spatial distribution of rainfall. For planning and management of water resources one should have a clear understanding of these temporal and spatial distribution of rainfall and the water basins. The knowledge on rainfall and water basins would help agricultural planning, flood frequency analysis, hydrological modelling, flood hazard mapping, water resource assessment, climate change impact and other environmental aspects. India has four climatic seasons Post-Monsoon (January and February), Pre-Monsoon (March- May), South West Monsoon (June-September) and North East Monsoon (October-December). The North East Monsoon is partially distributed all over India. Extensive studies have been done on the rainfall distribution pattern, using GIS and statistical techniques[3-8]. In Twentieth Century, the rainfall trend analysis, attempted through GIS and MK statistical analysis, examined the long term rainfall fluctuation were identified over the Cauvery River basin, during the period from 1901-2002[9]. The seasonal rainfall behaviour was analysed, in Lower bhavani basin, over nine raingauge stations.

The spatial rainfall analysis indicated Isohyet line. Further regression analysis revealed the relationship between annual rainfall and total monsoonal rainfall to be the best fit[10]. The MK Test was employed, to predict the rainfall trend in the eastern part of Cuttack District[11]. Geostatistical techniques such as Thiessen Polygon, Inverse Distance Weighted [IDW] linear regression, ordinary kriging and simple kriging methods were adopted, to estimate the rainfall[12,13]. Compared to other techniques, linear regression method and IDW reported lesser errors[14]. The spatio-temporal trend analysis was done, with the help of GIS interpolation technique, to understand and construct rain harvesting structures in the study area[15]. Rainfall fluctuation analysis, used for designing spatial distribution maps with the help of GIS tool, indicated the rainfall variation in the study area[16]. Spatial and temporal variability of rainfall was studied, over fourty nine years, in Sheonath sub-basin of Chhattisgarh[17]. The MK Test, modified MK Test and Spearman's Rho Test were adopted to track the trends, reported in the study area. Cumulative Summation Technique [CUSUM] was applied to note the change points. The changing trends, over the Tamirabarani basin in Tamil Nadu, were studied. MK test and CUSUM method were used, to delineate the beginning of the season from the calculation of monthly rainfall data[18]. MK test and linear regression technique were performed to pinpoint significant changes in the area[19-23]. Based on the findings of these research exercises, the study of rainfall trend analysis was formulated for the Lower Bhavani basin. A statistical based spatio-temporal rainfall analysis was used for this study, to obtain a refined rainfall data. The data from 22 rain gauge stations were analysed for the study, which was not considered in the past by any researcher. The non-parametric statistical technique of Mann-Kendall Test was adopted, to investigate the monotonic trends in rainfall pattern of the study area, which recorded the mean and maximum rainfall. The trend analysis was deemed essential for the Lower Bhavani basin because irregular rainfall of the region caused serious threat to agricultural activities of the basin. The declining and increasing trend had to be identified over a long period of time and to understand the rainfall pattern of region, for proper management in agriculture, watershed, irrigation and all other groundwater related activities of the basin. The basin composed of hard rock terrain with the formation of alluvial materials in river flowing area. Moreover, the basin continuously experienced semi-arid climate. Hence it was considered essential to overcome the situation, by analysing long term multi temporal rainfall datasets for the following objectives (1) to find out the spatial distribution pattern (monthly, seasonal and annual) rainfall over 33 years (1983-2015) and (2) to estimate the statistical based seasonal trend pattern by using the MK test.

Materials and methods

Study area

Bhavani River is one of the largest tributaries of Cauvery River. Cauvery river basin has three sub-basins such as upper, middle and lower basins. The Lower Bhavani basin is situated in the middle of the sub-basin of Cauvery river. Bhavani river originates from the silent valley in Kerala and enters through Bhavani Sagar dam, from west to east, for 234 kms and joins the Cauvery river near Bhavani town. The study area lies between 11°15' to 11°45' N latitude and 77°00' to 77°35' E longitude. The total area covers 2424 kms^2 as shown in Figure 1. Lower Bhavani basin is located in the District of Erode and the altitude varies from 1487 m maximum to 215 m minimum above the MSL. The annual average rainfall varies from 575.55 mm to 840.64 mm and the temperature of the area varies from maximum of 40 °C to a minimum of 22 °C. The Indian Meteorological Department (IMD) categorizes the year into four seasons: (1) the relatively dry, cool winter from December to February. (2) the dry hot summer from March to May (3) the Southwest Monsoon from June to September and (4) the northeast or retreating monsoon of October and November[24]. The study area is spread over 22 rain gauge stations, namely, Anainasuvampalayam, Anthiyur, Athani, Bhavanisagar PWD, Bhavanisagar FCS, Bhavani Revenue SRG_NHP, Chennampatti, Chennimalai, Chittode, Erode, Gopichettipalayam, Gounderipallam, Kavunthapadi, Kodiveri Anaicut, LBP (Lower Bhavani Project) canal 33/7, LBP canal 54/1, Nambiyur, Perundurai, Puliyampatti, Sathyamangalam, Thalavadi and Varattupallam. The study area experiences monsoon rainfall seasons from both southwest and northeast monsoons. Northeast monsoon contributes more rainfall compared to the Southwest monsoon. But in winter and summer, the rainfall is scanty. The study area covers major blocks such as Bhavanisagar, Sathyamangalam,

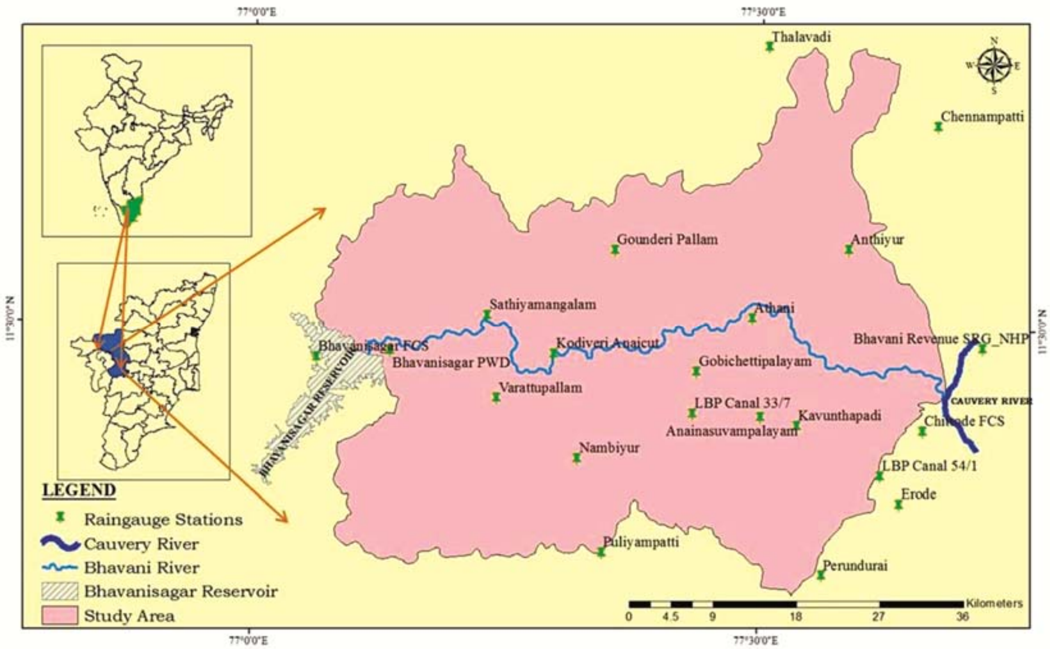

Fig. 1 — Location map of the study area

Gopichettipalayam, Erode, Anthiyur, Nambiyur and Bhavani town etc. The past studies reported that Gopichettipalayam and Erode receive good rainfall over the seasons[10]. Crops such as banana, sugarcane, groundnuts and paddy are cultivated in the study area. Therefore, the rainfall from the northeast monsoon is quiet helpful to farmers and irrigators, to improve the agricultural activities, in the Lower Bhavani basin.

Data collection

The Rainfall data for the study area were acquired from the State Ground and Surface Water Resources, Data Centre, Tamil Nadu. The monthly rainfall data, obtained at 22 rain gauge stations, covered a period of 33 years (1983 – 2015). The acquired data were in the format of a worksheet.

Data analysis

Simple Arithmetic Mean method

The data series, from 22 rain gauge stations, were arranged from 1983 to 2015. There are different issues, related to the arrangement of the rainfall data. For instance, due to the failure of the rainfall recording instrument, there were missing values, offered for data interpretation. The missing data were estimated by the method of arithmetic mean method, for the purpose of the linear arrangement of rainfall data. The equations (1) and (2) were as follows:

$$Px = 1/n \sum_{i=1}^{i=n} Pi \quad \ldots (1)$$

$$P_x = (Pa+Pb+Pc)/3 \quad \ldots (2)$$

Here 'n' represents the number of nearby stations located on the basin. 'Pi' was the rainfall (mm) recorded in a particular station and 'P_x' was the missing rainfall value. Then, a, b and c denoted as stations.

Inverse Distance Weighted (IDW) method

Inverse Distance Weighted (IDW) is an interpolation technique in which interpolated estimates are made based on the values at nearby locations, weighted only by distance from the interpolation location. IDW does not make the assumption about spatial relationships, except for the basic assumption that nearby points ought to be more closely related than distant points to the value at the interpolated location. This method determines cell values, using a linearly weighted combination of a set of sample points[25,26]. The weight is a function of inverse distance. IDW allows the user to control the significance of recognized points upon the interpolated values, based on their distance from the output point.

Isohyet method

Isohyet is a line or contour joining an area at the equal interval of rainfall over the basin. It is a method used to discriminate the spatial rainfall distribution of the particular area by the isohyet. In the present study, it accounted for the rainfall reported in the relative areas of the Lower Bhavani basin.

Mann – Kendall Test

The Mann – Kendall (MK) Test is a statistical test, widely used for the analysis of the trend in climatologic and hydrologic time series[27-29]. The MK Test statistically assesses the concept of monotonic upward or downward trend of the variable over the time[30]. According to the test statistic, a time series of x_i was denoted and ordered from i = 1, 2, ….., n-1 and another time series of value x from j = 1, 2,…..n, where n is the number of annual values, taken from the rainfall data series. The data series of x_i was used as a reference factor and compared with other data series in x_j (j > 1). Therefore the value of sign of comparison was obtained from Eq (3)

$$\operatorname{sgn}(x_j - x_i) = \begin{Bmatrix} +1 & if & x_j > x_i \\ 0 & if & x_j = x_i \\ -1 & if & xj < xi \end{Bmatrix} \quad \ldots (3)$$

The Kendall's statistic of S is calculated by using the Equation (4)

$$S = \sum_{i=1}^{n-1} \sum_{j=i+1}^{n} \operatorname{sgn}(x_j - x_i) \quad \ldots (4)$$

Here, n is the number of observed time series data. For n > 10, the statistic of S is normally distributed with the zero mean. The value of S is computed, by the equation of (5):

$$VAR(S) = \frac{1}{18}\left[n(n-1)(2n+5) - \sum_{p=1}^{q} (t_p - 1)(2t_p + 5) \right] \quad \ldots (5)$$

Here q is the number of tied groups and t_p is the number of data values in the p^{th} group

The MK test Z - Statistic is computed by the Equation (6):

$$Z = \begin{cases} \frac{S-1}{\sqrt{Var(S)}} & if\ S > 0 \\ 0 & if\ S = 0 \\ \frac{S+1}{\sqrt{Var(S)}} & if\ S < 0 \end{cases} \quad \ldots (6)$$

The presence of statistically significant trend was evaluated, by using the Z value and the statistics Z recorded the normal distribution. Significance level α was used for observing, either an upward or downward monotonic trend (a two – tailed test). If Z appears greater than Zα/2, where α illustrates the significance level, then the trend is considered to be significant[9]. The value of Zα/2 was obtained from the standard normal cumulative distribution tables, for the significance levels (α) 0.001, 0.01, 0.05 and 0.1.

Results and Discussion

Rainfall characteristics of Lower Bhavani basin

The rainfall characteristics of Lower Bhavani basin were explored, with the help of pragmatic methodology. The rainfall statistics of the Lower Bhavani basin was calculated, for the period from 1983 to 2015. The average annual rainfall of the basin was 666.84 mm, with the standard deviation of 168.06 mm and the coefficient of variation of annual rainfall at 25.20 %. According to the Table 1, the rainfall during the month of October was in the highest range of 164 mm, with 24 % contribution from annual rainfall of 666.84 mm. But rainfall during November (18 %), September (14 %), May (9.9 %) and August (9.3 %) was low. The results of seasonal wise rainfall statistics revealed the annual highest rainfall to be 46 %, during the North east monsoon, followed by 33 % at the South West monsoon, 18 % at the Pre-monsoon and declined to one percent during the Post monsoon period. According to this characteristic of rainfall in the study area, the least amount of rainfall of 4.99 mm was recorded in the month of January, with the annual rainfall contribution of 0.74 %. The annual rainfall contributions of 1.1 % and 2 % were received in the months of February and March respectively. The coefficient of variation of rainfall was the highest in January (95.75 %) followed by February (54 %), March (47 %) and the value was found to be the lowest in the month of August (17.45 %).

Rainfall spatial distribution of Lower Bhavani basin

The spatial distribution of monthly rainfall was computed, with the help of interpolation techniques. The rainfall pattern was equally distributed during the period of October to December in the areas of Gounderipallam, Gopichettipalayam and Erode. The northern part of the basin experienced maximum rainfall of 237 mm and south eastern part of the basin also had received the rainfall of 212 and 188 mm respectively, as shown in Figure 2. The Lower Bhavani basin received the highest rainfall, during the North east monsoon (311.22 mm). The map reveals lower to the higher gradient of rainfall, in the basin. While maximum rainfall was reported in the month of August, September and May recorded minimum rainfall over the area. The moderate rainfall was experienced in the month of May which was due to the influence of rainfall from the Western Ghats which partially covered basin area. Months of January, February, March, July and June witnessed limited experience rainfall due to the dry season.

Seasonal rainfall distribution

The seasonal rainfall of the basin has been differentiated based on the amount of rainfall spatially distributed with the equal spacing, displayed by the

Table 1 — Mean, seasonal and annual statistics of rainfall over Lower Bhavani basin (1983 – 2015)

Months/Seasons	Rainfall (mm)	Standard deviation	Coefficient of variation (%)	% of contribution to annual rainfall
January	4.998898	4.78658	95.7527	0.749635
February	7.556915	4.149111	54.9048	1.133236
March	13.66763	6.512329	47.6478	2.049599
April	41.19676	9.902067	24.036	6.17787
May	66.49176	18.12954	27.2658	9.97111
June	32.50313	8.888689	27.3472	4.874172
July	31.07208	9.206079	29.6281	4.659572
August	62.4718	10.90275	17.4523	9.368277
September	95.65556	18.86564	19.7225	14.34452
October	164.0448	29.69896	18.1042	24.60017
November	122.1318	21.53609	17.6335	18.3149
December	25.03678	9.694653	38.7217	3.754518
Post-Monsoon (January - February)	12.57377	7.555864	60.0923	1.885564
Pre-Monsoon (March - May)	121.3444	30.76273	25.3516	18.19682
SW Monsoon (June - September)	221.7041	36.08988	16.2784	33.24677
NE Monsoon (October - December)	311.2218	54.64626	17.5586	46.67085
Annual	666.84407	168.0604	25.20235	100

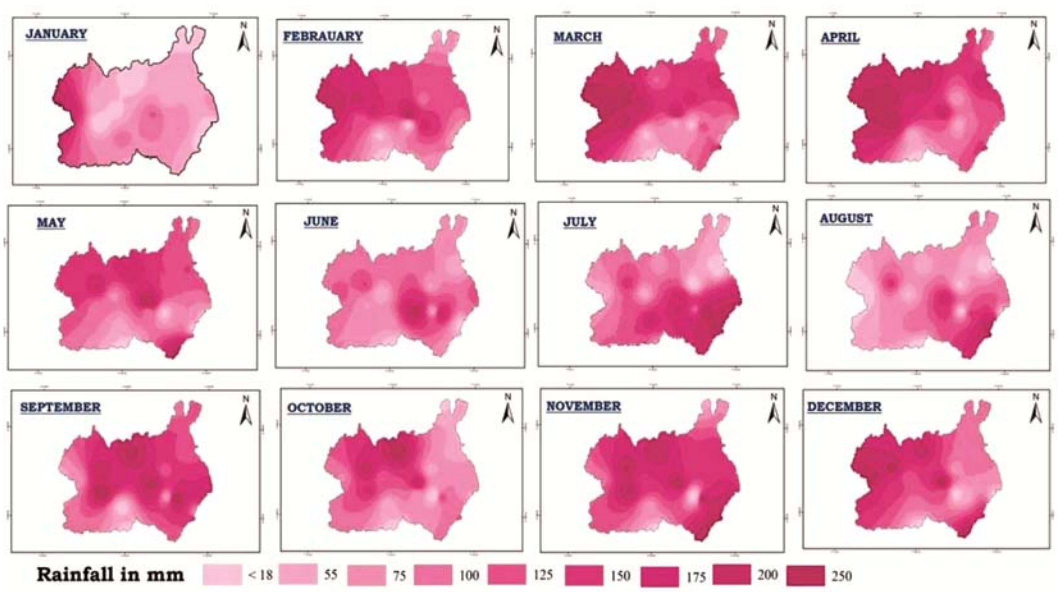

Fig. 2 — Spatial distribution of mean monthly rainfall over Lower Bhavani basin (1983 – 2015)

Isohyetal method, shown in Figure 3. According to Figure 3, the post-monsoon season of rainfall (4 mm – 32 mm) was the lowest seasonal rainfall of the basin. The isohyet indicated the elevation of distribution of post monsoon rainfall, with an interval of 5 mm. During the pre-monsoon, isohyet revealed rainfall ranges of low rainfall of elevation (55 mm – 162 mm), located in the southern part of the basin and isohyet with 150 mm indicated higher rainfall area. The south west monsoon brought an annual rainfall contribution of 33 % and it varied from 157 – 275 mm. It reached the maximum in the month of September and isohyet indicated higher rainfall in the central part of the basin and lowest in the southern part. The north-east monsoon is a retreating monsoon, which withdraws from the peninsula by October and reaches its peak in the month of December. The north-east monsoon recorded the highest rainfall of 204 – 403 mm in Lower Bhavani basin. The Figure 3 illustrates the 20 m interval difference of isohyet lines, which indicated good rainfall in the northern and northeastern part of the basin.

Annual rainfall distribution pattern

Spatial distribution of annual rainfall (1983 – 2015) revealed the overall rainfall pattern of the basin. The southern parts of the basin recorded a decreasing rainfall and the isohyet displayed low to high rainfall elevation, as shown in Figure 4. The northern part and south west part of the basin received a good quantity of rainfall throughout the year. Lower Bhavani basin reported gradual increasing rainfall from the north-east monsoon and moderate rainfall from the south-west monsoon. The southern part of the Lower Bhavani basin received very low rainfall and it was prone to drought during pre-monsoon and post-monsoon periods.

Deviation in rainfall from mean level

The deficient or excess rainfall years are defined as when the rainfall of years departs from the mean

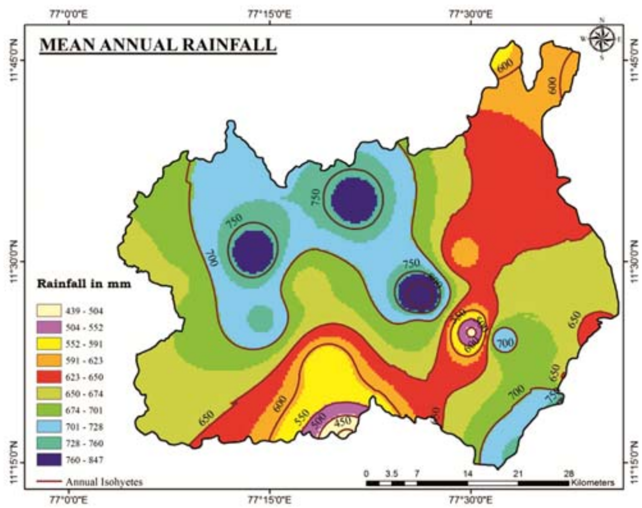

Fig. 4 — Spatial distribution of mean annual rainfall over Lower Bhavani basin (1983 – 2015)

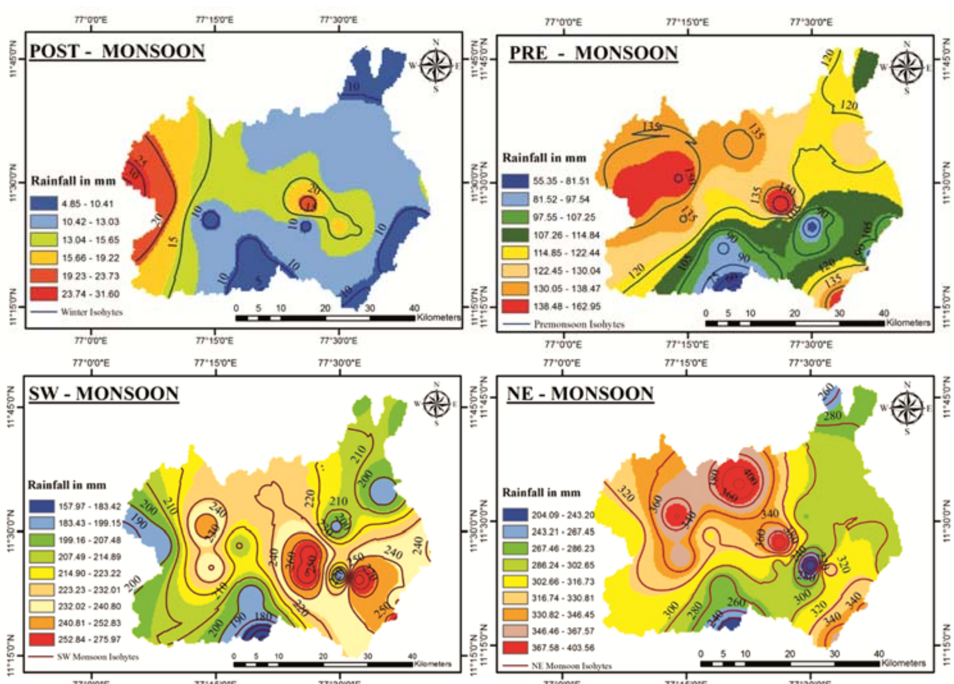

Fig. 3 — Spatial distribution of mean seasonal rainfall over Lower Bhavani basin (1983 – 2015)

rainfall[9]. The annual rainfall of the Lower Bhavani basin (1983 – 2015), over a period of 33 years, had decreased in about 19 years, from the mean rainfall. Therefore, the remaining 14 years reported positive deviation from the mean rainfall as shown in Figure 5. The rainfall of the basin had decreased from 1983 up to 1999 and afterwards there was gradual increase in the rainfall till 2015. Similarly, the seasonal rainfall pattern was also calculated. In the post monsoon period, the basin experienced negative deviation, particularly in the period of 1987 – 1993. In contrast, pre-monsoon witnessed 13 years of positive deviation and 20 years of negative deviation from the mean rainfall. Though southwest and northeast monsoon were equally distributed, there was 14 and 15 years of positive deviation from the mean rainfall respectively. In other words, there was positive deviation (98 mm Southwest monsoon) and (> 250 mm for North east Monsoon) and there was negative deviation also for about 19 years.

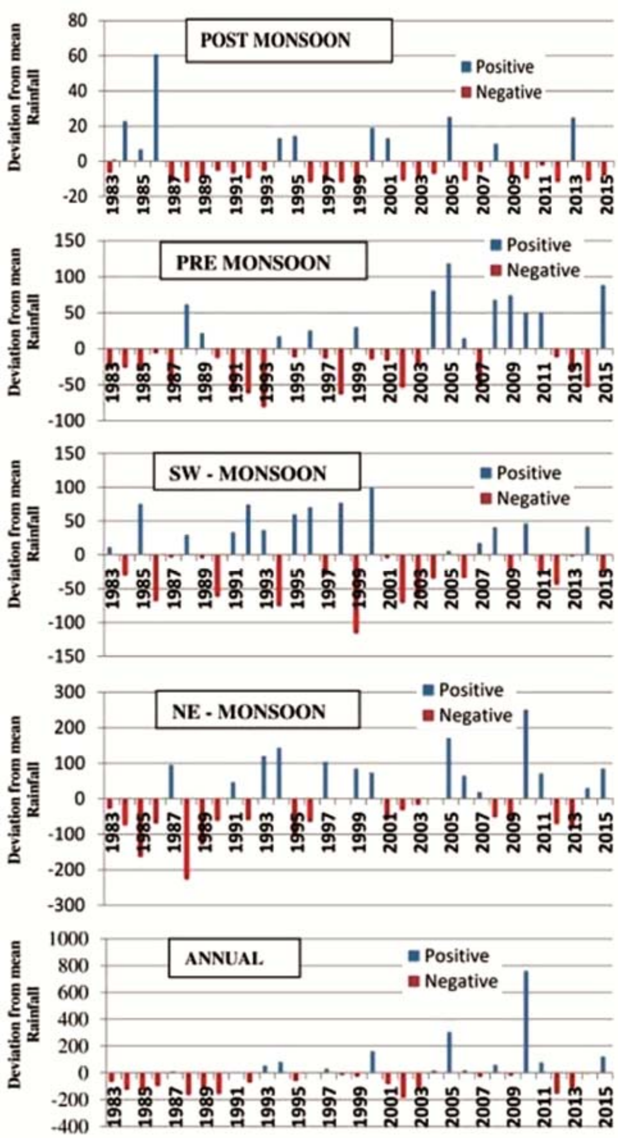

Fig. 5 — Deviation of seasonal and annual rainfall from mean (1983 – 2015)

Mann Kendall Trend analyses

Mann – Kendall Trend test was used, to study the significance of the rainfall pattern over the basin. The results of Mann - Kendall Test for monthly rainfall trend analysis, from the 22 rain gauge stations of the Lower Bhavani basin are shown in Table 2. Two hypothesis were formulated to be tested in the study one was a Null hypothesis (H_0) and another was an Alternate hypothesis (H_a). According to H_0, there is no trend in the data series and H_a states that there is a trend in the data series. As mentioned in the formula, if the computed p-value is lower than the significance level of $\alpha = 0.05$, one should reject the null hypothesis (H_0) and if the p-value is greater than the significance level $\alpha = 0.05$, one should not reject the null hypothesis H_0. The Table 2 displays the trends of the basin. If the trend value were to be positive, there will be positive increase or monotonic upward trend in the particular month of the specific area. On the other hand, negative value shows decreasing or monotonic downward trend of the area. The MK test significance level was computed as 95 %, for the data series, to analyse the fluctuation or anomaly over the basin. The results revealed increasing trend in areas such as Anthiyur (October), Athani (October), Bhavanisagar PWD (March, August, October), Bhavanisagar FCS (August, October), Bhavani NHP (December), Chithode (December), Erode (October), Gounderi (August, October), LBP Canal 54/1 (October, November), Sathyamangalam (August) and Thalavadi (April, May, July, August). In other words, the impact of rainfall was very high in the month of October because northeast monsoon brought good amount rainfall over the basin. The negative trend was reported in area such as Anainasuvampalayam for the months of (January, April, May, June, July, August, September, November), Bhavani NHP (March), Erode (January), LBP Canal 54/1 (January), Nambiyur (January), Puliyampatti (January, April, June) and hence they were denotes drought-prone areas in the basin.

Table 2 — Statistically significant trends of rainfall for individual months (January 1983 – December 2015)

NAMES \MONTHS	JAN	FEB	MAR	APR	MAY	JUN	JULY	AUG	SEP	OCT	NOV	DEC
ANANINASUVAMPALAYAM	-0.383	-0.082	-0.155	-0.353	-0.288	-0.377	-0.418	-0.505	-0.617	-0.217	-0.317	-0.225
ANTHIYUR	0.023	0.259	0	0.17	0.152	0.017	0.023	0.161	0.173	0.293	0.173	0.096
ATHANI	0.023	0.237	0	0.071	0.034	-0.01	0.056	0.108	0.047	0.267	0.129	-0.008
BHAVANISAGAR_PWD	-0.087	0.083	0.284	0.231	0.176	0.032	0.064	0.357	0.146	0.258	0.188	-0.05
BHAVANISAGAR_FCS	-0.019	0.062	0.257	0.128	0.066	0.074	0.091	0.261	0.093	0.261	0.1	-0.124
BHAVANI_NHP	-0.296	0.071	0.193	-0.032	0.129	-0.159	0.017	-0.023	-0.216	0.195	0.114	0.271
CHENNAMPATTI	0.003	0.105	-0.009	0.071	0.019	-0.076	-0.027	0.188	0.03	0.168	0.08	0.034
CHENNIMALAI	0.061	-0.141	0.028	0.021	0.008	-0.147	0.017	0.095	-0.188	0.082	0.125	-0.082
CHITTODE	0	0.11	0.151	-0.075	-0.004	0.038	-0.074	-0.189	-0.207	0.152	0.182	0.278
ERODE	-0.36	0.052	-0.013	0.12	0.068	-0.042	0.072	0.22	-0.167	0.243	0.207	-0.112
GOPICHETTIPALAYAM	-0.171	0.079	0.068	0.196	0.223	0.042	-0.027	0.193	-0.085	0.121	0.059	-0.071
GOUNDERI	-0.217	0.121	-0.102	0.153	0.114	0.103	-0.179	0.411	-0.066	0.295	-0.021	0.118
KAVUNTHAPADI	-0.263	0.083	0.169	-0.019	0.15	-0.046	-0.044	0.11	-0.146	0.216	0.193	0.248
KODIVERI_ANAICUT	-0.259	-0.095	-0.156	0.098	0.068	-0.054	-0.245	0.161	-0.191	-0.064	-0.067	-0.211
LBP_CANAL_33/7	-0.247	0.159	0.124	-0.138	0.138	0.015	-0.152	-0.07	-0.098	0.226	0.082	0.204
LBP_CANAL_54/1	-0.352	-0.055	-0.239	0.058	-0.163	0.028	0.198	0.142	-0.025	0.402	0.248	-0.046
NAMBIYUR	-0.339	0.003	-0.15	-0.161	0.038	-0.209	-0.085	-0.002	-0.123	0.131	0.019	-0.002
PERUNDURAI	-0.084	0.029	0.042	0.127	0.008	-0.157	0.002	0.074	-0.22	0.133	0.116	-0.061
PULIYAMPATTI	-0.376	-0.11	-0.107	-0.341	-0.202	-0.277	-0.198	-0.215	-0.023	0.006	-0.1	-0.025
SATHIYAMANGALAM	-0.195	0.04	-0.022	0.156	0.051	0.104	-0.036	0.267	-0.216	0.061	0.036	0.006
THALAVADI	-0.079	0.11	0.051	0.318	0.298	0.117	0.25	0.367	0.19	0.059	0.059	0.068
VARATTUPALLAM	-0.199	0.235	0.074	0.131	0.241	0.119	-0.048	0.226	-0.015	-0.011	-0.028	-0.047

MK Test Z Value

Conclusion

In the present study, the spatial distribution of rainfall pattern and rainfall trend pattern was investigated, over a period of 33 years, with rainfall data from 22 rain gauge stations of Lower Bhavani basin. The arithmetic method was adopted for the study, to arrange rainfall data continuously and resolved the missing values of the data series. The IDW and isohyet methods were applied for the purpose of identification of the spatial rainfall pattern of the basin. The analysis revealed that rainfall was very high in the month of October (237 mm) and northeast monsoon (< 380 mm) reported increasing amount of rainfall, especially in the areas of Gounderi Pallam, Erode, Thalavadi and Gopichettipalayam. However, the decreasing rainfall was observed in Chithode, Puliyampatti, Anainasuvampalayam and Chennampatti. The annual rainfall (< 780 mm) was high in Erode, Gopichettipalayam and scanty in Puliyampatti, Anainasuvampalayam. The basin received the highest rainfall in 2010 (1442 mm), during the study period. Then the MK Test was used, to analyse the rainfall trend over the basin. The MK Test indicated significant observation of positive and negative trends over the study area. Increasing or positive trend was found in the months of October, November, December and it was less positive during April, May and July. The negative or decreasing rainfall trend was observed in the month of January. Therefore, the study identified that the northern part of the basin as the virtuous rainfall area. But eastern part of the basin received very little rainfall in monthly, seasonal and annual observations. The reason behind was some significant changes in the trends of rainfall, over the study period of 33 years and this area was severely prone to drought. This part of the area was also adversely affected by the agriculture efficiency and growth. This analysis of rainfall data could be used by agricultural managers, to improve the groundwater management practices, effectively and sustainably in the basin.

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