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RESEARCH PAPER

Annual rainfall analysis of historical and projected weather for South Interior Karnataka, India

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Abstract: The interannual and intraseasonal variations in the ISMR expand has the significant impact on agricultural sector.The daily gridded rainfall data for the past 40 years (1981-2020) and the climatic projections for the next 20 years (2021- 2040) were analysed at district level across South Interior Karnataka (SIK). Basic statistics such as maximum, minimum, mean, standard deviation (SD), coefficient of variation (CV), and percentage (%) contribution to yearly rainfall were computed. Further, the Mann-Kendall test was used to find the trend in rainfall (RF) and rainy day (RD). The results indicated that RF and RD have a positive trend in the both historical and projected periods. In the past 40 years, the highest annual means of RF and RD were observed in Kodagu district (2031.95 mm and 121) followed by Mandya district (1115.97 mm and 71), and the lowest means of RF and RD were observed in Chitradurga district (482.37 mm and 36) followed by Chikkaballapur district (590.20 mm and 41). For the projected 20 years, the highest annual mean RF is expected in Kodagu and Hassan districts (1693.88 mm) and the lowest in Chitradurga, Chikkaballapur and Tumukur districts (1308.12 mm). High number of RD is expected in Bengaluru Rural, Bengaluru Urban, Chamarajanagar, Kodagu, Hassan, Kolar, Mandya, Mysore, Ramanagar districts (127) and low RD in Chikkamagaluru, Davangere and Shivamogga districts (118).

Key words: Mann-Kendall test, Rainfall, Rainy days, Variability

Introduction

Rainfall is one of the most important meteorological phenomena that affects agriculture and allied business sectors.Timely arrival and distribution of rainfall is very much important for the crop growth. Monsoons are defined as the near-reversal of wind pressure system over a huge geographical area between summer and winter. Although the monsoon is defined by the prevalent direction of wind during the season (June to Sept), it is represented in India by the amount of rainfall received. Over India, the SWM season is also called as the summer monsoon season, and the NEM season is the winter monsoon season. The SWM season, rainfall contributed more than 75% of total annual rainfall, but is irregular in both time and space. The lowest annual rainfall in Karnataka ranges from less than 500 mm in the dry zones to the highest of 3456 mm in the coastal and hilly zones.

South Interior Karnataka (SIK) meteorological subdivision of the state of Karnataka which includes many zones namely the Central Dry Zone, Eastern Dry Zone, Southern Transition Zone, and Southern Dry Zone contains 15 districts namely Bengaluru Rural, Bengaluru Urban, Chamarajanagar, Chikkaballapur, Chikkamagaluru, Chitradurga, Davangere, Hassan, Kodagu, Kolar, Mandya, Mysore, Ramanagara, Shivamogga and Tumukur (Fig.1). The SWM is the primary source of water for agriculture in Karnataka, which is followed by the NEM in a few regions. Other than that, Karnataka has the second largest dry land area in the country. Any change in the climate throughout monsoon months has a considerable impact on agricultural output, the economy, and water availability in non-monsoon months, hence the regional rainfall variability requires a special attention.

In SIK, drought-tolerant crops like as pigeon pea, finger millet, and others are grown, however local varieties are not very productive. Poor yields and high variability, which are exacerbated by fast population increase, are the root causes of recurring food crises. Crop yields in such locations are low and fluctuate widely in space and time for a number of reasons. One of the most crucial risk factors is the high geographical and temporal variability in rainfall across the region, which is exacerbated by poor soil fertility. From April until November, the rainy season continues, with rainfall varying between 528 to ~1374 mm (average 914). A very recent study (Subimal *et al.,*2016) explains an increased spatial variability of extreme rainfall events over India during SW season. Seasonal rainfall amount, intra-seasonal distribution of rainfall, and rain onset/ cessation periods are key climatic factors that influence crop yields and determine the agricultural calendar. Because it determines the planting season, the commencement of the rainy season appears to be the most essential piece of information for agricultural management.

Material and methods

Description of the study area

Karnataka is located between 11.40°-18.27° N latitudes and 74.25°-78.50° E longitudes, and covers an area of 19.1 m. ha that accounts for 5.8% of the total area of the country and has tropical monsoon characterized by hot and moist summers and cool and dry winters. There is a diversity in the climate of the state, influenced by geographical location, oceans, physical features, vegetation and monsoon winds. Hence, the annual temperature and distribution of rain are not the same all over the state. The state has a net cultivated area of 10.5 m ha, net irrigated area of 3.49 m ha and net rainfed area of 7.01 m ha.

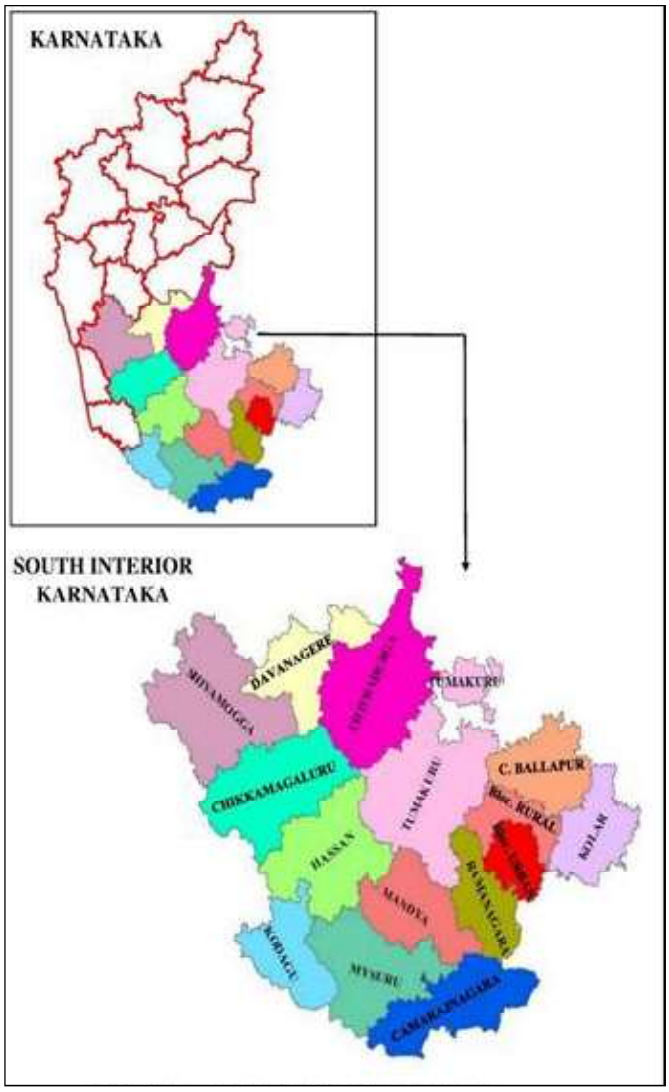

Fig 1. Map showing study area of South Interior Karnataka (SIK)

Nature and Source of data

The daily historical rainfall data for 40 years (1981-2020) were collected from India Meteorological Department (IMD) gridded data platform. IMD provides new highspatial resolution (0.25x0.25 degree) long period (1901-21) daily gridded rainfall data set over India. The unit of rainfall is in millimetre (mm). Data available for 121 years (1901 to 2021). Data is arranged in 135x129 grid points. The first data in the record is at 6.5N and 66.5E, the second is at 6.5N and 66.75E, and so on. The last data record corresponds to 38.5N and 100.0E. The yearly data file consists of 365/366 records corresponding to non-leap/ leap years (Pai *et al*., 2014).

The study periods

The data contains information of rainfall weather parameter which was collected on daily basis for 15 districts of SIK. Historical data was collected for 40 years from 1981 to 2020 from IMD data source. Projected data from the period of 2021-2040 (20 years) was collected from CMIP6 and then processed in ferret and cdo programming languages using Ubuntu (Madolli *et al.,* 2015).

Other descriptive statistics on rainfall such as Maximum, Minimum, Standard Deviation (SD), Standard Error (SE) and Coefficient of Variation (CV), were computed and analysed the variation in rainfall over a period of time. Spatial analysis of the same was also performed and presented.

Daily rainy day calculation

If the recorded rainfall in a day (24 hrs) was more 2.5 mm, then it is called as one rainy day (IMD).

Rainy day = if (RF ³ 2. 5, 1,)

Where, RF = daily rainfall

Mann- Kendall trend test: Adopted for testing the significance of trend.

Mann Kendall test is a statistical test widely used to analyse the trend in climatologic and hydrologic time series data. There are two advantages of using this test. First, it is a nonparametric test and does not require the data to be normally distributed. Second, the test has low sensitivity to abrupt breaks due to in homogeneous time series (Mann,1945). All the trends of rainfall will be determined by using the non-parametric trend test. The null hypothesis 'H0' for these tests is that there is no trend in the series, the alternative hypothesis 'H1' that is a negative, non-null or positive trend can be chosen and which was tested for the significance at 95% level (Kendall, 1975).

The Mann-Kendall S -Statistic was computed as follows:

$$S_0 = \Sigma_{k=1}^{N-1} \Sigma_{j=k+1}^{N} \text{sign}(xj - xk)$$

Where, n is the number of observed data series, xj and xK are the values in period j and K respectively, j>K.

Auto correlation

It refers to the relationship between the successive values of the same variables.

Test for Auto Correlation - The Durbin-Watson Test

This test is appropriate for the first – order autoregressive scheme, the null hypothesis is Ho: p=0 or Ho: the 'u' s is not autocorrelated with a first-order scheme. This hypothesis was tested against the alternative hypothesis H1: p`"0 or H1: the 'u' and was autocorrelated with a first order scheme. To test the null hypothesis, Durbin -Watson statistic was used.

$$d = \frac{\Sigma_{t=1}^{n}(\varepsilon_t - \varepsilon_t - 1)^2}{\Sigma_{t=1}^{n} \varepsilon_t^2}$$

For large samples this reduces to

Where, $d = 2(1 - \hat{\rho})$

Since $\hat{\rho}$ lies between -1 and 1, d varies from 0 to 4

$$\hat{\rho} = \frac{\Sigma_{t=1}^{n}(\varepsilon_t - \varepsilon_t - 1)^2}{\Sigma_{t=1}^{n} \varepsilon_t^2}$$

Durbin Watson have established upper (dU) and lower (dL) limits for the significance levels of the 'd'.

If d > 4-dL then there is negative autocorrelation

If du < d< 4 – du then there is no autocorrelation

If dL < d < du or 4-du < d < 4-dL the test is inconclusive.

Variability patterns of rainfall and rainy days

Variability pattern of rainfall and rainy days were analysed through ten years moving average. The CV was considered for the variability classification *i.e.*, < 20% less variability, 20% to 30% moderate variability, > 40% high variability and if it is > 70% then was classified under rather heavy variability.

Mapping of spatio-temporal variations in rainfall using GIS

It is a geographic information system (GIS) application developed and maintained by the American company Esri (Environmental Systems Research Institute). Monthly, annual and seasonal rainfall, and rainy days data were used for mapping by Arc GIS 10.4.1 software and thereby Spatio-Temporal variations of rainfall and rainy days maps were created.

Results and discussion

Characteristics of annual rainfall and rainy days at district level across SIK during historical period.

Table 2 and 3 showed the numerical representation of annual characteristics of the rainfall and rainy days, respectively at the district level across SIK over a 40-years historical period (1981-2020). Fig 2 and 3 shows the graphical presentation of annual rainfall and rainy days characteristics, respectively at district level across SIK. Fig 6 and 7 shows the map of annual rainfall and rainy days variation spatially, respectively across SIK.

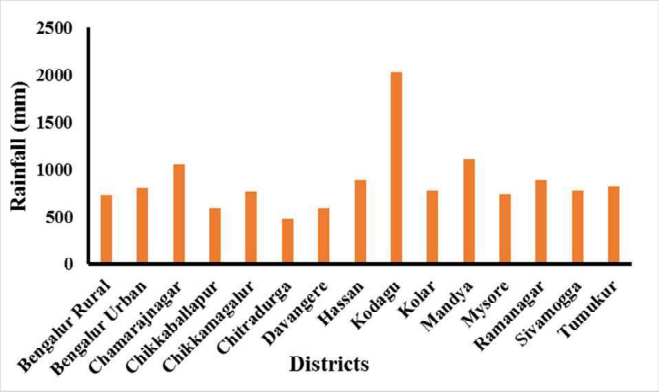

Fig. 2. Characteristics of annual rainfall across SIK over historical period (1981-2020)

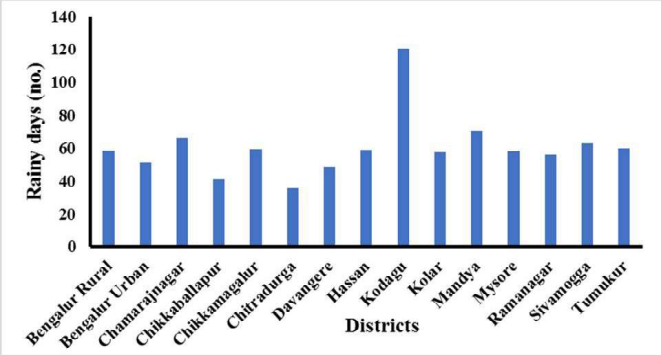

Fig. 3. Characteristics of annual rainy days across SIK over historical period (1981-2020)

During historical 40 years (1981-2020), in Bengaluru rural district, the maximum rainfall of 1095.4 mm, maximum number of 89 rainy days, the lowest rainfall of 212.2 mm and the lowest

Table 1. Agroclimatic zones of study area

Zones	Area (m ha)	Elevation (m)	Rainfall (mm)	Districts
Central dry zone	1.943	450-900	454 -718	Chitradurga,Davanagere, Tumakuru
Eastern dry zone	1.808	800-900	679- 889	Bengaluru Urban, Bengaluru Rural, Chikkaballapur, Kolar Ramanagara
Southern dry zone	1.739	450-900	671 -889	Chamarajanagar, Mysuru, Mandya, Kodagu
Southern transition zone	1.218	450-900	612 -1054	Chikkamagalur, Hassan, Shivamogga

Table 2. District wise annual rainfall characteristics across SIK over historical 40 years (1981-2020)

Districts	Mean RF (mm)	Maximum RF (mm)	Minimum RF (mm)	SD	CV (%)
Bengaluru Rural	736.96	1095.4	212.2	210.09	28.50
Bengaluru Urban	804.53	1380.4	209.2	242.55	30.14
Chamarajanagar	1052.83	1897.7	403.6	377.02	35.81
Chikkaballapur	590.20	1155.4	141.0	239.13	40.51
Chikkamagaluru	768.30	1337.1	129.1	260.58	33.91
Chitradurga	482.37	808.4	155.2	150.04	31.10
Davangere	595.40	1005.3	151.7	192.08	32.26
Hassan	886.31	1983.8	122.5	417.48	47.10
Kodagu	2031.95	3648.3	612.4	711.51	35.01
Kolar	780.30	1451.4	96.80	245.99	31.52
Mandya	1115.97	2746.4	456.2	445.61	39.93
Mysore	738.23	1209.9	367.7	200.59	27.17
Ramanagara	886.09	1327.5	350.1	238.23	26.88
Shivamogga	779.79	2219.0	108.6	393.12	50.41
Tumukur	826.34	1228.0	143.6	230.23	27.86

Table 3. District wise annual rainy days characteristics across SIK over historical 40 years (1981-2020)

Districts	Mean RD(no.)	Maximum RD(no.)	Minimum RD(no.)	SD	CV (%)
Bengaluru Rural	59	89	23	14.46	24.69
Bengaluru Urban	51	88	17	13.31	26.01
Chamarajanagar	66	109	34	17.26	26.13
Chikkaballapur	41	83	7	20.14	49.13
Chikkamagaluru	60	98	18	21.59	36.13
Chitradurga	36	57	16	10.10	28.40
Davangere	49	91	10	16.34	33.29
Hassan	59	107	15	20.65	34.92
Kodagu	121	154	49	19.65	16.30
Kolar	58	89	12	13.18	22.92
Mandya	71	104	24	17.11	24.25
Mysore	58	81	32	12.01	20.61
Ramanagara	56	87	22	14.40	25.62
Shivamogga	63	144	14	23.05	36.76
Tumukur	60	92	15	15.62	26.02

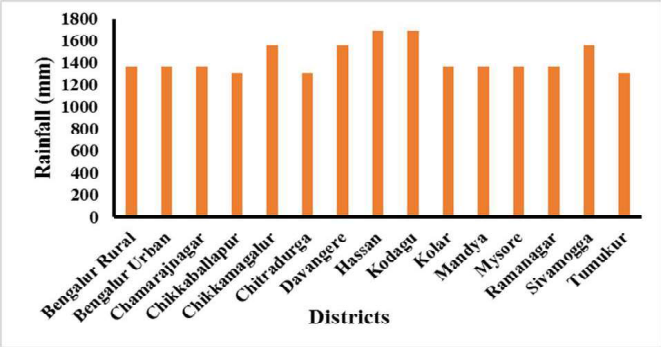

Fig. 4. Characteristics of annual rainfall across SIK over projected period (2021-2040)

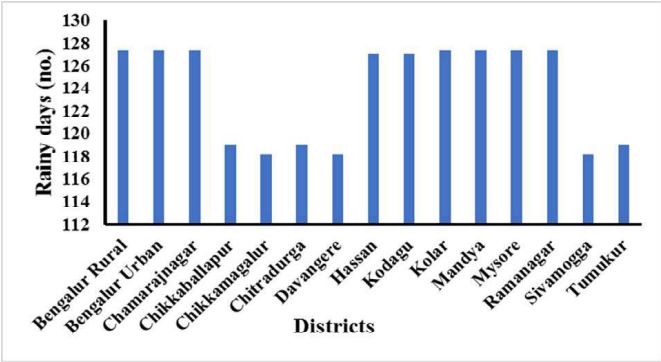

Fig. 5. Characteristics of annual rainy days across SIK over projected period (2021-2040)

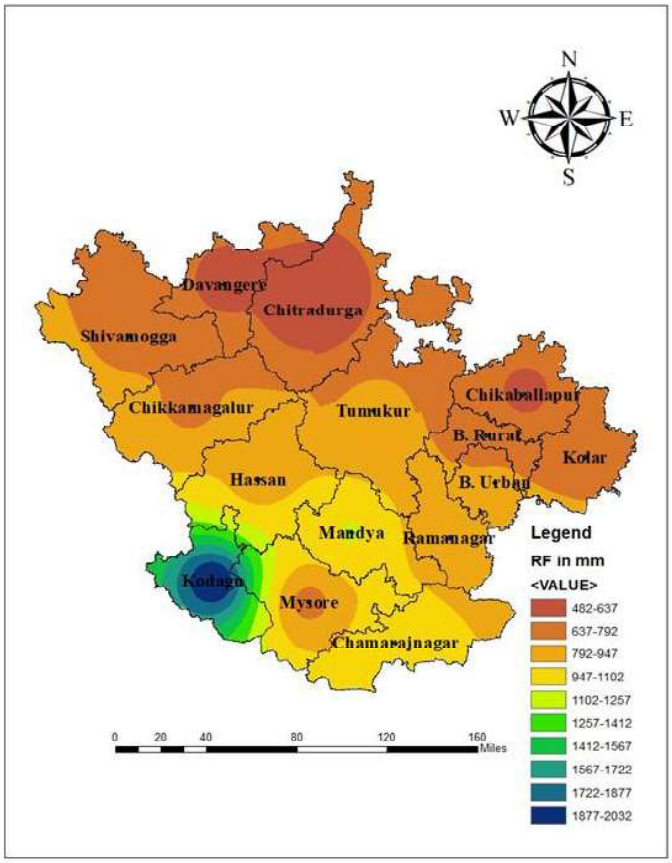

Fig. 6. Spatio-temporal variation of annual rainfall across SIK over historical 40 years (1981-2020)

number of 23 rainy days was observed with the annual mean rainfall of 736.96 mm and 59 of average rainy days. In Bengaluru urban district the maximum rainfall of 1380.4 mm, maximum number of 88 rainy days, the lowest rainfall of 209.3 mm and the lowest number of 17 rainy days were observed with the annual mean rainfall of 804.53 mm and 51 of average rainy days. In Chamarajanagar district the maximum rainfall of 1897.7 mm, maximum number of 109 rainy days, the lowest rainfall of 403.6 mm and the lowest number of 34 rainy days were observed with the annual mean rainfall of 1052.83 mm and 66 of average rainy days. In Chikkaballapur district the maximum rainfall of 1155.4 mm, maximum number of 83 rainy days, the lowest rainfall of 141 mm and the lowest number of 7 rainy days were observed with the annual mean rainfall of 590.20 mm and 41 of average rainy days. In Chikkamagaluru district the maximum rainfall of 1337.1 mm, maximum number of 98 rainy days, the lowest rainfall of 129.1 mm and the lowest number of 18 rainy days were observed with the annual mean rainfall of 768.30 mm and 60 of average rainy days. In Chitradurga district the maximum rainfall of 808.4 mm, maximum number of 57 rainy days, the lowest rainfall of 155.2 mm and the lowest number of 16 rainy days were observed with the annual mean rainfall of 482.37 mm and 36 of average rainy days. In Davangere district, the maximum rainfall of 1005.3 mm, maximum number of 91 rainy days, the

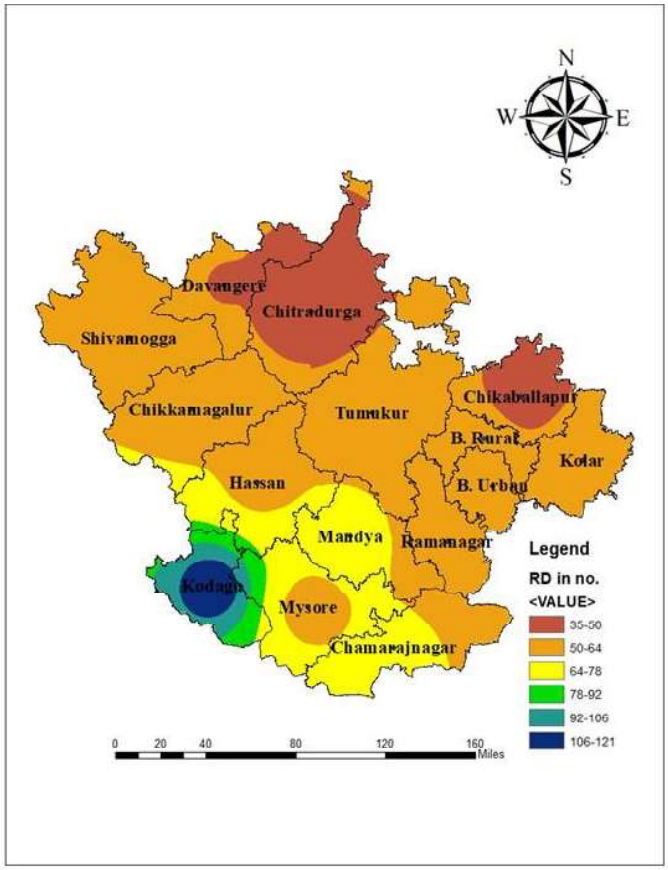

Fig. 7. Spatio-temporal variation of annual rainy days across SIK over historical 40 years (1981-2020)

lowest rainfall of 151.7 mm and the lowest number of 10 rainy days were observed with the annual mean rainfall of 595.40 mm and 49 of average rainy days. Similarly Hassan district the maximum rainfall of 1983.8 mm, maximum number of 107 rainy days, the lowest rainfall of 122.5 mm and the lowest number of 15 rainy days were observed with the annual mean rainfall of 886.31 mm and 59 of average rainy days. In Kodagu district the maximum rainfall of 3648.3 mm, maximum number of 154 rainy days, the lowest rainfall of 612.4 mm and the lowest number of 49 rainy days were observed with the annual mean rainfall of 2031.95 mm and 121 of average rainy days. In Kolar district, the maximum rainfall of 1451.4 mm, maximum number of 89 rainy days, the lowest rainfall of 96.08 mm and the lowest number of 12 rainy days were observed with the annual mean rainfall of 780.30 mm and 58 of average rainy days. In Mandya district, the maximum rainfall of 2746.4 mm, maximum number of 104 rainy days, the lowest rainfall of 456.2 mm and the lowest number of 24 rainy days were observed with the annual mean rainfall of 1115.97 mm and 71 of average rainy days. In Mysore district the maximum rainfall of 1209.9 mm, maximum number of 81 rainy days, the lowest rainfall of 367.7 mm and the lowest number of 32 rainy days were observed with the annual mean rainfall of 738.23 mm and 58 of average rainy days.In Ramanagar district the maximum rainfall of 1327.5 mm, maximum number of 87 rainy days, the lowest rainfall of 350.1 mm and the lowest number of 22 rainy days were observed with the annual mean rainfall of 886.09mm and 56 of average rainy days. In Shivamogga district the maximum rainfall of 2219 mm, maximum number of 144 rainy days, the lowest rainfall of 108.6 mm and the lowest number of 14 rainy days were observed with the annual mean rainfall of 779.79 mm and 63 of average rainy days.In Tumukur district the maximum rainfall of 1228 mm, maximum number of 92 rainy days, the lowest rainfall of 143.6 mm and the lowest number of 15 rainy days were observed with the annual mean rainfall of 826.34 mm and 60 of average rainy days.

Characteristics of annual rainfall and rainy days at district level across SIK during projected period

Table 4 and 5 shows the numerical representation of annual characteristics of the rainfall and rainy days, respectively at the district level across SIK over a 20-years projected period (2021-2040). Figure 4 and 5 shows the graphical presentation of annual rainfall and rainy days characteristics, respectively at district level across SIK. Figure 8 and 9 shows the map of annual rainfall and rainy days variation spatially, respectively across SIK. Because of the 0.5 x 0.5 degree data resolution, values for few districts were identical.

During upcoming 20 years (2021-2040), in Bengaluru rural, Bengaluru urban, Chamarajanagar, Kolar, Mandya, Mysore and

Table 4. District wise annual rainfall characteristics across SIK for projected 20 years (2021-2040)

Districts	Mean RF (mm)	Maximum RF (mm)	Minimum RF (mm)	SD	CV (%)
Bengaluru Rural	1367.70	1922.40	1002.9	249.06	18.21
Bengaluru Urban	1367.70	1922.40	1002.9	249.06	18.21
Chamarajanagar	1367.70	1922.40	1002.9	249.06	18.21
Chikkaballapur	1308.12	1737.12	951.54	214.51	16.39
Chikkamagaluru	1559.07	2079.30	1159.80	229.32	14.70
Chitradurga	1308.12	1737.12	951.54	214.51	16.39
Davangere	1559.07	2079.30	1159.80	229.32	14.70
Hassan	1693.88	2319.69	1257.73	260.59	15.38
Kodagu	1693.88	2319.69	1257.73	260.59	15.38
Kolar	1367.70	1922.40	1002.9	249.06	18.21
Mandya	1367.70	1922.40	1002.9	249.06	18.21
Mysore	1367.70	1922.40	1002.9	249.06	18.21
Ramanagara	1367.70	1922.40	1002.9	249.06	18.21
Shivamogga	1559.07	2079.30	1159.80	229.32	14.70
Tumukur	1308.12	1737.12	951.54	214.51	16.39

Table 5. District wise annual rainy days characteristics across SIK for projected 20 years (2021-2040)

Districts	Mean RD (no.)	Maximum RD (no.)	Minimum RD (no.)	SD	CV (%)
Bengaluru Rural	127	160	105	14.94	11.7
Bengaluru Urban	127	160	105	14.94	11.7
Chamarajanagar	127	160	105	14.94	11.7
Chikkaballapur	119	149	89	16.23	13.64
Chikkamagaluru	118	143	95	12.98	10.98
Chitradurga	119	149	89	16.23	13.64
Davangere	118	143	95	12.98	10.98
Hassan	127	148	106	11.88	9.35
Kodagu	127	148	106	11.88	9.35
Kolar	127	160	105	14.94	11.7
Mandya	127	160	105	14.94	11.7
Mysore	127	160	105	14.94	11.7
Ramanagara	127	160	105	14.94	11.7
Shivamogga	118	143	95	12.98	10.98
Tumukur	119	149	89	16.23	13.64

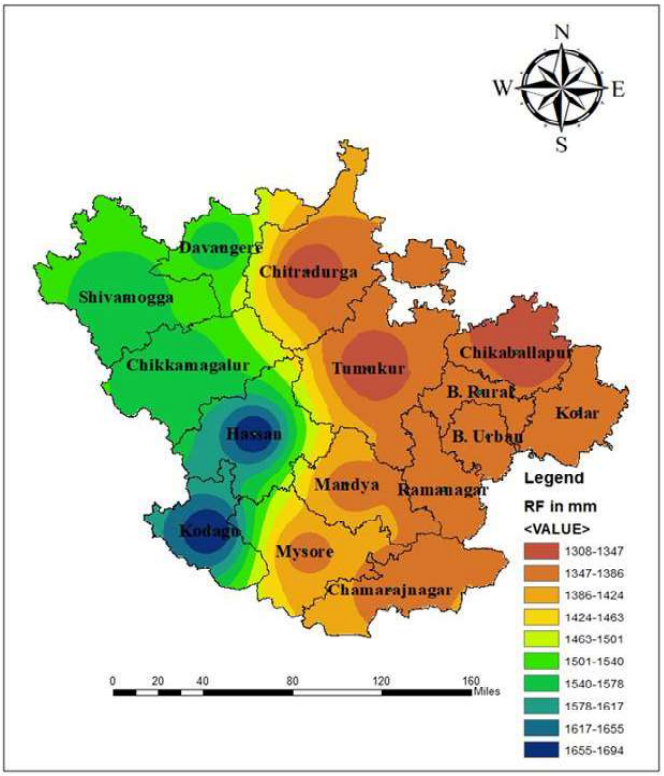

Fig. 8. Spatio-temporal variation of annual rainfall across SIK over projected 20 years (2021-2040)

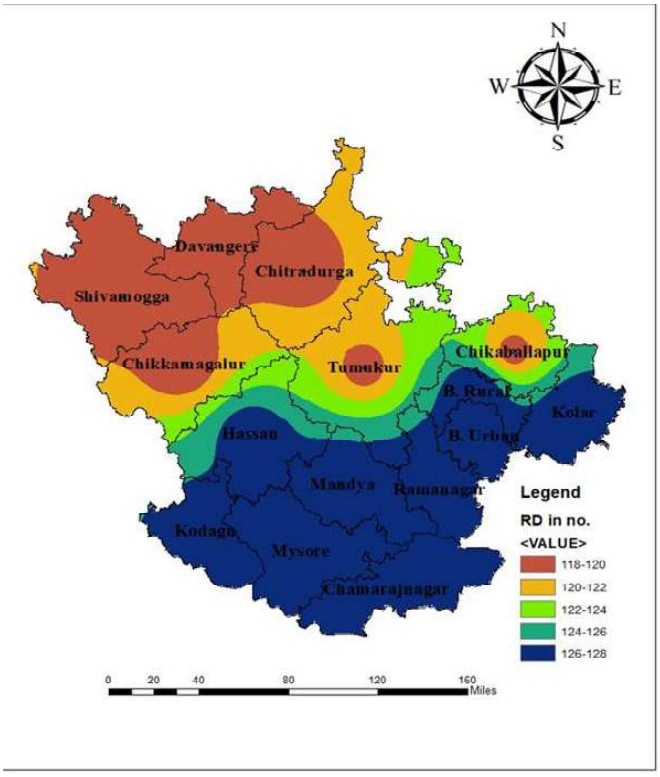

Fig. 9. Spatio-temporal variation of annual rainy days across SIK over projected 20 years (2021-2040)

Ramanagar districts, the maximum rainfall of 1922.40 mm, maximum number of 160 rainy days, the lowest rainfall of 1002.9 mm and the lowest number of 105 rainy days is expected with the annual mean rainfall of 1367.70 mm and 127 of average rainy days. In Chikkaballapur, Chitradurga and Tumukur districts, the maximum rainfall of 1737.12 mm, maximum number of 149 rainy days, the lowest rainfall of 951.54 mm and the lowest number of 89 rainy days is expected with the annual mean rainfall of 1308.12 mm and 119 of average rainy days. In Chikkamagaluru, Davangere and Shivamogga districts, the maximum rainfall of 2079.30 mm, maximum number of 143 rainy days, the lowest rainfall of 1159.80 mm and the lowest number of 95 rainy days is expected with the annual mean rainfall of 1559.07 mm and 118 of average rainy days. In Hassan and Kodagu districts, the maximum rainfall of 2319.69 mm, maximum number of 148 rainy days, the lowest rainfall of 1257.73 mm and the lowest number of 106 rainy days is expected with the annual mean rainfall of 1693.88 mm and 127 of average rainy days.

Annual trend of rainfall and rainy days across SIK during historical period

The results of trend analysis by Mann-Kendall test for annual rainfall and rainy days are shown in Table 6. Out of 15 districts of SIK for historical 40 years (1981-2020), Bengaluru rural district showed a non-significant positive trend for both annual rainfall and rainy days at 5% level. Bengaluru urban, Chitradurga, Kolar, Ramanagara and Tumukur districts showed a non-significant positive trend for annual rainfall at 5% level

Table 6. Trend significance and coefficientforannual rainfall and rainy day at district level across SIK over historical 40 years (1981-2020)

District	Annual RF		Annual RD	
	p value	Z-stat	p value	Z-stat
Bengaluru Rural	0.324	0.011	0.162	0.155
Bengaluru Urban	0.111	0.177	0.012*	0.281
Chamarajanagar	0.004*	- 0.318	0.017*	- 0.265
Chikkaballapur	0.018*	0.260	0.000*	0.393
Chikkamagaluru	0.003*	0.323	0.001*	0.362
Chitradurga	0.067	0.203	0.015*	0.271
Davangere	0.002*	0.330	0.002*	0.343
Hassan	0.000*	0.392	0.009*	0.289
Kodagu	< 0.0001*	0.515	0.001*	0.362
Kolar	0.348	0.105	0.044*	0.224
Mandya	0.281	- 0.121	0.727	- 0.039
Mysore	0.935	- 0.010	0.124	0.171
Ramanagara	0.291	0.118	0.001*	0.368
Shivamogga	0.001*	0.346	0.003*	0.325
Tumukur	0.064	0.205	0.002*	0.346

*Significant at 5% level

but a significant positive trend for annual rainy days at 5% level. Chamarajanagar district showed a significant negative trend for annual rainfall and rainy days at 5% level. Chikkaballapur, Chikkamagaluru, Davangere, Hassan, Kodagu and Shivamogga districts showed a significant positive trend for both annual rainfall and rainy days at 5% level. Mandya district showed a non-significant negative trend for both annual rainfall and rainy days at 5% level. Mysore district showed a non-significant negative trend for annual rainfall but a non-significant positive trend for annual rainy days at 5% level and also the similar work done by Bhagawati *et.al* in the year 2018.

Annual trend of rainfall and rainy days across SIK during projected period

The results of trend analysis by Mann-Kendall test for annual rainfall and rainy days at district level across SIK over upcoming projected 20 years (2021-40) was shown in Table 7. Here because of coarse resolution (0.5*0.5 degree) the values were identical among 15 districts. Out of 15 districts, Hassan and Kodagu districts shows non-significant negative trend for rainy day but non-significant positive trend for rainfall at 5% level. Other 13 districts (Bengaluru rural, Bengaluru urban, Chamarajanagar, Chikkaballapur, Chikkamagaluru, Chitradurga, Davangere, Kolar, Mandya, Mysore, Ramanagara, Shivamogga, Tumukur) shows non-significant positive trend for both rainfall and rain days at 5% level.

Time series analysis of annual rainfall and rainy days across SIK over historical period

The results of time series analysis of annual and seasonal rainfall and rainy days by using Durbin-Watson (Auto correlation) test for historical 40 years (1981-2020. Here the whole 40 years data sets were divided into 2 groups of 20 years in each group. First group included 20 years from 1981-2000 and second group included 20 years from 2001-20. The first order correlation was tested between these two groups and was done to see if there is any relation in rainfall of previous 20 years (1981-2000) with the next 20 years (2001-20). The test was conducted district wise and out of 15 districts of SIK, all districts showed a DW values of < 2, which means a significant positive

Table 7. Trend significance and coefficientforannual rainfall and rainy day at district level across SIK for projected 20 years (2021-2040)

District	Annual RF		Annual RD	
	p value	Z-stat	p value	Z-stat
Bengaluru Rural	0.319	0.168	0.922	0.016
Bengaluru Urban	0.319	0.168	0.922	0.016
Chamarajanagar	0.319	0.168	0.922	0.016
Chikkaballapur	0.288	0.179	0.283	0.176
Chikkamagaluru	0.677	0.074	0.649	0.074
Chitradurga	0.288	0.179	0.283	0.176
Davangere	0.677	0.074	0.649	0.074
Hassan	0.924	0.021	0.948	- 0.011
Kodagu	0.924	0.021	0.948	- 0.011
Kolar	0.319	0.168	0.922	0.016
Mandya	0.319	0.168	0.922	0.016
Mysore	0.319	0.168	0.922	0.016
Ramanagara	0.319	0.168	0.922	0.016
Shivamogga	0.677	0.074	0.649	0.074
Tumukur	0.288	0.179	0.283	0.176

*Significant at 5% level

correlation for annual rainfall and rainy days along with seasonal (PM, SWM and NEM) rainfall and rainy days. This showed that there is a relation between those two groups.

Time series analysis of annual rainfall and rainy days across SIK over projected period

The results of time series analysis of annual and seasonal rainfall and rainy days by using Durbin-Watson (Auto correlation) test for projected 20 years (2021-40). Here the whole 20 years data sets were divided into 2 groups of 10 years in each group. First group included 10 years from 2021-30 and second group includes 10 years from 2031-40. The first order correlation was tested between these two groups and the tested for if there is any relation in rainfall of future 10 years (2021-30) with the next 10 years (2001-40). The test was conducted district wise and out of 15 districts of SIK, all districts showed a DW values of < 2, which means a significant positive correlation for annual rainfall and rainy days along with seasonal (PM, SWM and NEM) rainfall and rainy days. This showed that there is a relation between those two groups.

The variability of annual rainfall and rainy days across SIK for both historical and projected period

The variability of annual and seasonal, rainfall and rainy days was classified based on the CV values obtained from each district of SIK for historical 40 years (1981-2021) and also the similar work done by Chandrashekar *et al.,*in the year of 2017.The result of annual rainfall variability is showed in Fig. 10, where three classifications were found *i.e*., moderate, high and very high variability, and for mapping three groups were made with 10% interval which ranges from 20% to 50% and annual rainy days variability was showed in Fig. 11, where four

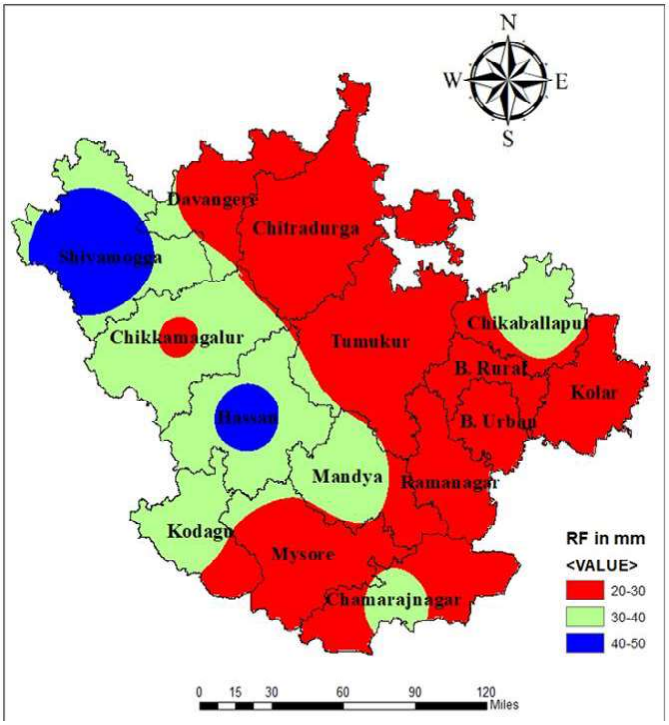

Fig. 10. Annual rainfall variability across SIK over historical 40 years (1981-2020)

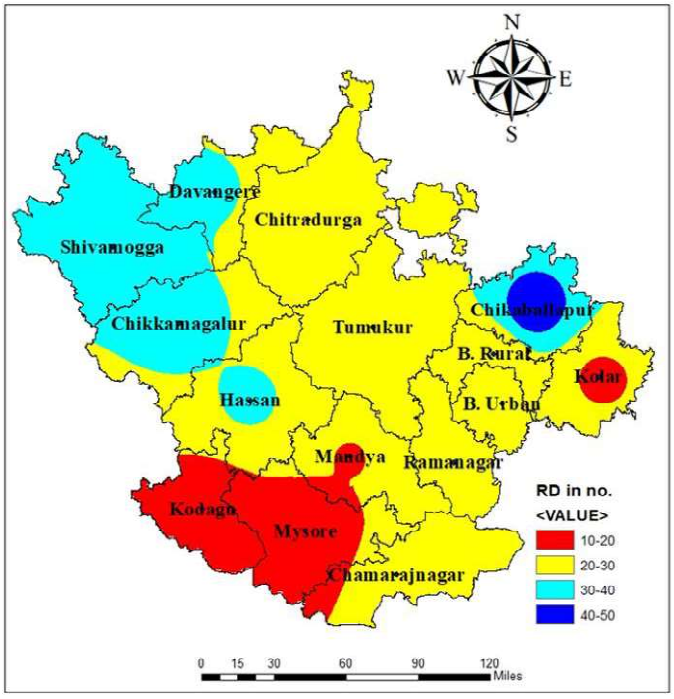

Fig. 11. Annual rainy days variability across SIK over historical 40 years (1981-2020)

classifications were found *i.e*., less, moderate, high and very high variability and for mapping four groups were made with 10 % interval which ranges from 10% to 50%.

The variability of annual and seasonal, rainfall and rainy days was classified based on the CV values obtained from each district of SIK for projected 20 years (2021-2040).The result of annual rainfall variability is shown in Fig. 12, *i.e*., less variability and for mapping four groups were made with 1% interval which ranges from 14% to 18% and annual rainy days variability is shown in Fig. 13, which was considered as less variability and for mapping four groups were made with 1% interval which ranges from 9% to 13%.

Conclusion

District wise database was developed for historical 40 years from 1981 to 2020. From daily rainfall data rainy days were calculated and annual rainfall and rainy days were calculated for study period and major findings from the result, Out of 15 districts of SIK, high annual mean rainfall for historical 40 years was observed in Kodagu (more than 1700 mm) and low annual mean rainfall was observed in Chikkaballapur, Chitradurga and Davangere (less than 700 mm). The greater number of annual mean rainy days were observed in Kodagu followed by Mandya and least annual mean rainy days were observed in Chitradurga, Chikkaballapur and Davangere. The high variability in rainfall was observed in districts of Bengaluru rural, Bengaluru urban, Chitradurga, Davangere, Kolar, Mysore and Ramanagar, Chamarajanagar, Chikkaballapur, Chikkamagaluru, Kodagu and Mandya, Shivamogga and Hassan district. The high variability in rainy days were observed in Chikkaballapur district less variability was observed in Kodagu, Mysore and Kolar, moderate

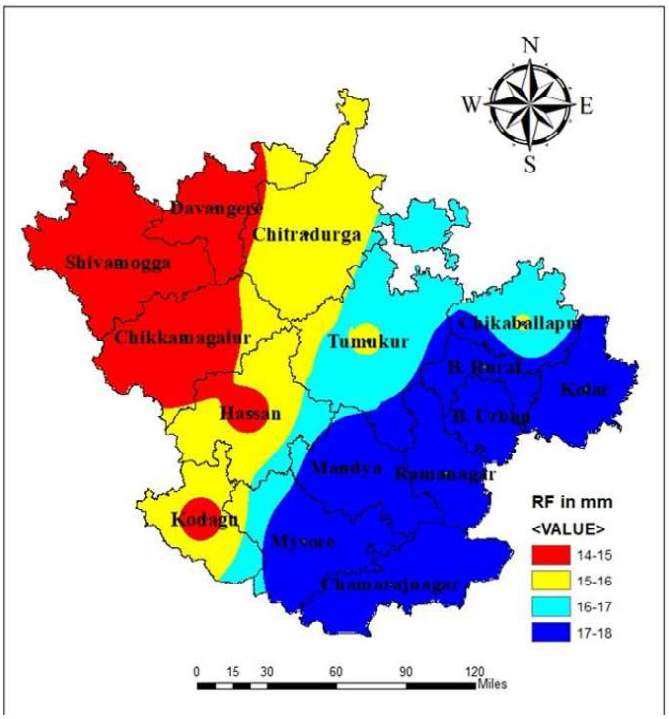

Fig. 12. Annual rainfall variability across SIK over projected 20 years (2021-2040)

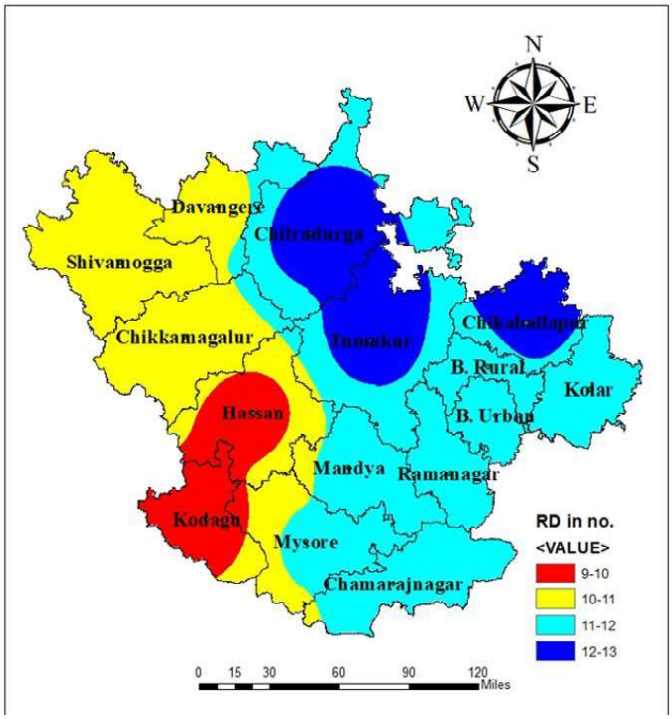

Fig. 13. Annual rainy days variability across SIK over projected 20 years (2021-2040)

variability was observed in the districts of Chikkamagaluru, Davangere, Hassan and Shivamogga. SIK as a total, out of 40 years in historical period, highest mean rainfall was observed in the year 2005 (1266 mm) and lowest mean rainfall was observed in the year 1985 (272 mm) and very heavy variability in rainfall was observed in the years 1997 and 2006, less variability was observed in the years 1987, 2009 and 2010. For projected 20 years from 2021 to 2040.Out of 15 districts of SIK, high annual mean rainfall is expected in Hassan and Kodagu district, and low annual mean rainfall is expected in Chikkaballapur, Chitradurga and Tumukur districts.The greater number of annual mean rainy days are expected in Bengaluru rural, Bengaluru urban, Chamarajanagar, Kolar, Mandya, Mysore and Ramanagar district and least annual mean rainy days were expected in Chikkamagaluru, Davangere and Shivamogga district.The less variability in rainfall and rainy days is expected in all districts of SIK. The Mann-Kendall test was used to find the trend in RF and RD. The RF and RD have a positive trend in the both historical and projected periods.There is a positive auto correlation between rainfall of two groups (1981-2000 and 2001-20) in historical period and projected period (2021-30 and 2031-40).

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