Analysis of precipitation pattern using various stochastic distributions in Karnataka state, India

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Abstract. Precipitation has been usually considered as an initial point towards the concern of climate changes and it has an important component of the hydrologic cycle. Our aim of this work is to investigate 30 years of precipitation (1973-2002) in Karnataka state using probability distributions which are normal, gamma, gamma (3P), Weibull, Weibull(3P) and Chi-squared distributions. Here Chi-squared and Kolmogorov–Smirnov (KS test) are used for the goodness of fit of the data for comparisons. From the investigation, the Weibull distribution is best performed with 39% of precipitation of all districts and next best fits are normal and gamma distributions. The results would be very beneficial for agricultural peoples, weather research forecasting department and climate change department in all districts of Karnataka, India.

1. Introduction
Spatial and transient dispersion of a normal yearly precipitation focuses to a few districts with the moderately low measure of precipitation. Precipitation, temperature, content the occurrence of dangerous events, greenhouse effect and ocean level ascent are the principle environmental change related drivers that effect rural generation [1],[13]. The approach for the fourth coming decades is that agricultural yield needs to continue to increase and will require more water to meet the difficulties of increasing populations [19]. In the year 2080, agricultural production in emerging countries may decrease by 20 percent due to climate change, while output in developed countries is predicted to decrease by 6 percent [4]. In Vikram Kumar, Weibull distribution was a best-fitted likelihood for yearly Rainfall [11]. Examination of precipitation patterns is basic in concentrate the effects of environmental change on water administration [5],[9]. In Andhra Pradesh, no significant pattern has been identified for yearly and occasional precipitation in the whole state [21]. Increment in rainstorm precipitation was broke down for Periyar area and the pattern was observed to be 95% level of critical [17]. The present investigations that have been concurred out on examination of precipitation which is the vital contribution to the hydrologic framework, there is convincing proof that precipitation is diminishing in Asia[6],[7],[10],[12],[14],[15],[20],[22]. Although rainfall during monsoon months showed a downward trend [16]. The Karnataka seasonal length analysis showed that no distinct cluster could be found when the number of seasons was increased beyond the choice of scenarios, season type and a number of seasons [3]. The probability distributions like Gumbel, normal, log-normal and log-Pearson type III were connected over Pakistan to locate the best-fit likelihood circulation of yearly precipitation recorded at 24 h [2],[8]. This article surveys current information about the connections.
between environmental change, hydrological perils, and precipitation designs in the locale in light of the fact that the yearly sustenance accessibility of this Karnataka area totally relies upon storm crops. Environmental change and land debase influence nourishment accessibility and employments through quickening hydrological perils in storm periods. Therefore, our study showed the prediction of annual and seasonal rainfall and well-organized crop planning and water irrigation for all districts of Karnataka by using rainfall of 30 years (1972-2002).

2. Materials and methods
2.1. Description of study area and data
The State of Karnataka is situated at 11°30' North and 18°30' North scopes and 74 East and 78°30' East longitude. It is situated on an expansion where the western and Eastern Ghats ranges meet into the state, in the western part of the Deccan Peninsular area of India. The State is situated by Goa and Maharashtra States in the north and northwest by Kerala and the Tamil Nadu States in the south and by the States of Andhra Pradesh and Telangana in the east. Karnataka stretches out to around 750 km from north to south and around 400 km from east to west in figure 1.

Rainfall data for 30 years (1973–2002) were collected from meteorological department site (http://indiawaterportel.org/met_data/). In India Rainfall seasons are classified into four seasons, viz. monsoon (June–September), pre-monsoon (March-May), post-monsoon (October–December) and winter season (January–February).

Figure 1 Location of Study area
### Table 1 Characteristics of Karnataka districts and Summary of statistics for annual rainfall (1973–2002)

| Station     | Population (in 2011) | Area in km² | Density (per km²) | Min (mm)   | Max (mm)   | Mean (mm) | SD (mm) |
|-------------|----------------------|-------------|-------------------|------------|------------|-----------|---------|
| Bagalkot    | 18,90,826            | 6,575       | 288               | 577.65     | 1101.21    | 832.10    | 144.91  |
| Ban Rural   | 9,87,257             | 2,259       | 431               | 553.73     | 1198.16    | 845.75    | 170.48  |
| Ban urban   | 95,88,910            | 2,190       | 4,393             | 593.74     | 1218.56    | 857.21    | 164.88  |
| Belgaum     | 47,78,439            | 13,415      | 356               | 1134.70    | 2292.88    | 1707.20   | 292.88  |
| Bellary     | 25,32,383            | 8,450       | 290               | 407.42     | 950.53     | 718.95    | 128.67  |
| Bidar       | 17,00,018            | 5,448       | 313               | 563.66     | 1141.83    | 822.15    | 154.34  |
| Bijapur     | 21,75,102            | 10,494      | 207               | 494.54     | 966.58     | 709.51    | 123.52  |
| Chamarajnagar | 10,20,962        | 5,101       | 181               | 1130.16    | 2230.99    | 1532.40   | 261.95  |
| Chikkamanglu | 11,37,753           | 7,201       | 158               | 1679.36    | 2931.68    | 2296.57   | 353.89  |
| Chitradurga | 16,60,378            | 8,440       | 197               | 545.91     | 1105.30    | 827.33    | 150.69  |
| Chitradurga | 19,46,905            | 10,951      | 234               | 1231.67    | 2426.63    | 1833.62   | 334.83  |
| Chitradurga | 16,76,221            | 6,814       | 328               | 914.77     | 1895.63    | 1318.62   | 239.27  |
| Dharward    | 18,46,993            | 4,260       | 207               | 494.54     | 966.58     | 709.51    | 123.52  |
| Gadag       | 10,65,235            | 4,656       | 229               | 807.23     | 1471.66    | 1164.36   | 190.46  |
| Gulbarga    | 25,64,892            | 10,951      | 234               | 443.89     | 941.42     | 701.61    | 132.22  |
| Hassan      | 17,76,221            | 6,814       | 261               | 1860.28    | 3663.81    | 2639.76   | 475.37  |
| Haveri      | 15,98,506            | 4,823       | 331               | 1231.67    | 2426.63    | 1833.62   | 334.83  |
| Kodagu      | 5,4,763              | 4,102       | 135               | 1344.79    | 2465.78    | 1918.63   | 294.60  |
| Kolar       | 15,4,291             | 3,969       | 386               | 528.44     | 1164.13    | 869.06    | 166.40  |
| Koppal      | 13,91,292            | 7,189       | 250               | 397.35     | 925.34     | 734.64    | 130.76  |
| Mandya      | 18,08,680            | 4,961       | 364               | 1175.71    | 2647.50    | 1736.27   | 356.31  |
| Mysore      | 29,94,744            | 6,854       | 476               | 1681.68    | 3595.76    | 2535.36   | 444.39  |
| Raichur     | 19,24,773            | 6,827       | 228               | 336.06     | 779.66     | 582.94    | 123.32  |
| Simoga      | 17,55,512            | 8,477       | 207               | 1549.79    | 2724.15    | 2185.18   | 333.90  |
| Tumakuru    | 26,81,449            | 10,597      | 253               | 648.34     | 1444.61    | 1007.09   | 196.52  |

#### 2.2 Calculation and probability distribution functions

The rainfall was predicted by the probability distribution functions using R and the different probability distribution functions are given in the following sections.

#### 2.2.1 Normal distribution

The pdf of a normal distribution is

\[ P_x(x) = \frac{1}{\sqrt{2\pi} \sigma} e^{-\frac{(x-\mu)^2}{2\sigma^2}} \]  

(1)

where \( \mu \) is mean of the population of \( x \) and \( \sigma^2 \) is the variance of the population of \( x \).
2.2.2 Chi-squared distribution

The Chi-square distribution is defined as

\[ f(x, n) = \frac{\left(\frac{x}{2}\right)^{n-1} e^{-\frac{x}{2}}}{2^{n-2} \Gamma\left(\frac{n}{2}\right)} \]  

(2)

Where \( n \) is the number of degrees of freedom and \( x \geq 0 \), \( n \) is the positive integer.

2.2.3 Gamma distribution

The gamma distribution is defined by two parameters, where \( \alpha \) is called the shape parameter, \( \beta \) is called a scale parameter and \( x \) represents a rainfall amount. The probability density function for gamma distribution is given by

\[ f(x) = \frac{\left(\frac{x}{\beta}\right)^{\alpha-1} \exp\left(-\frac{x}{\beta}\right)}{\beta \Gamma(\alpha)} \]

(3)

where \( \Gamma(\alpha) \) indicates the gamma function evaluated at \( \alpha \). The shape parameter and the scale parameter of the gamma distribution, estimated by the Maximum Likelihood Estimation Method.

The gamma function is defined by

\[ \Gamma(\alpha) = \int_{0}^{\infty} x^{\alpha-1} e^{-x} dx \]

(4)

2.2.4 Weibull distribution

The Weibull distribution is given by

\[ f(x; \eta, \sigma) = \frac{\eta}{\sigma} \left(\frac{x}{\sigma}\right)^{\eta-1} e^{-\left(\frac{x}{\sigma}\right)^{\eta}} \]

(5)

where the variable \( x \) and the parameters \( \eta \) and \( \sigma \) are all positive real numbers.

2.3 Goodness - of - fit test

The goodness of fit tests is the Chi-square test and the Kolmogorov – Smirnov (KS test) were used at 5 % level of significance. The goodness of best fitted distribution is fixed based on the minimum error performed.

2.3.1 Chi-square

Chi-square test is very valuable for testing the goodness – of – fit with observed distribution with the theoretical distribution.

The Chi-square test statistic is

\[ \chi^2 = \sum \frac{(O - E)^2}{E} \]

(6)

2.3.2 Anderson- Darling (A-D) test

The Anderson – Darling test statistic (AD) is defined as:
AD = \sum_{i=1}^{n} \frac{(2i-1)(\ln(x_i) + \ln(1-(x_{i+1}-x_i)))}{n}

(7)

2.3.3 Kolmogorov – Smirnov (KS) test

The Kolmogorov-Smirnov measurement is characterized as the biggest vertical contrast between the hypothetical and the experimental combined conveyance work. The decency of fit test estimates the similarity of the arbitrary example with the hypothetical likelihood circulation. For this examination, we utilize a dismissal level of 0.10 implying that we dismiss the invalid theory that the hypothetical dispersion is performing enough in demonstrating the precipitation esteems, at areas with \( p \)-values under 0.10.

\( D_n \) - is the Kolmogorov - Smirnov test statistic, and \( \max \) -represents the maximum of the pointwise differences

- \( F(y) \) - is the theoretical distribution function as \( y \) described by the estimated gamma distribution parameters \( \hat{\alpha}, \hat{\beta} \)

- \( F_n(y) \) - is the empirical distribution function.

\[
D_n = \max_y \left| F_n(y) - F(y) \right|
\]

(8)

\[
F(y) = \int_0^y f(x)dx = \frac{1}{\beta^\alpha \Gamma(\alpha)} \int_0^\frac{x^\alpha}{\beta^\alpha} e^{-x} dx
\]

(9)

\[
F_n(y) = \frac{|\{i \in \{1,2,\ldots,n\} : y_i \leq y\}|}{n}
\]

(10)

2.4 Fitting of probability distributions

The goodness-of-fit test stated above was fitted with our rainfall data of the Karnataka districts area. The test statistic is tested at 0.05 % level of significance.

**Table 2:** Distribution and their parameters

| Stations       | Normal Mean \( \mu \) (mm) | Normal SD \( \sigma \) | Gamma – 2P Value of \( \alpha \) | Gamma – 2P Value of \( \beta \) | Weibull – 3P Value of \( \alpha \) | Weibull – 3P Value of \( \beta \) | Weibull – 3P Value of \( \gamma \) |
|----------------|-----------------------------|------------------------|----------------------------------|----------------------------------|---------------------------------|----------------------------------|---------------------------------|
| Bagalkot       | 832.10                      | 144.91                 | 2.76                             | 25.10                            | 18.45                           | 162.67                           | 223.56                           |
| Ban Rural      | 845.75                      | 170.48                 | 2.68                             | 26.23                            | 17.76                           | 174.16                           | 278.32                           |
| Ban urban      | 857.21                      | 164.88                 | 2.62                             | 27.17                            | 21.45                           | 184.78                           | 367.93                           |
| Belgaum        | 1707.20                     | 292.88                 | 3.35                             | 42.34                            | 20.27                           | 155.19                           | 354.87                           |
| Bellary        | 718.95                      | 128.67                 | 3.09                             | 19.32                            | 22.48                           | 172.19                           | 289.89                           |
| Bidar          | 822.15                      | 154.34                 | 1.96                             | 34.91                            | 21.89                           | 221.56                           | 445.45                           |
| Bijapur        | 709.51                      | 123.52                 | 2.19                             | 26.96                            | 25.43                           | 265.43                           | 343.67                           |
| Chamarajnagar  | 1532.40                     | 261.95                 | 2.93                             | 43.44                            | 23.41                           | 193.84                           | 543.65                           |
| Chikkamangluru | 2296.57                     | 353.89                 | 3.17                             | 60.37                            | 29.56                           | 271.56                           | 453.67                           |
| Chitradurga    | 827.33                      | 150.69                 | 3.16                             | 21.76                            | 32.49                           | 291.67                           | 345.76                           |
| Devanagere     | 1318.62                     | 239.27                 | 3.24                             | 33.81                            | 33.89                           | 147.98                           | 265.67                           |
| Dharward       | 2020.88                     | 358.10                 | 3.54                             | 47.52                            | 16.78                           | 159.43                           | 367.87                           |
Table 3: Distribution and their parameters

| Stations  | Chi-squared | Value of $\alpha$ | Value of $\beta$ | Value of $\alpha$ | Value of $\beta$ | Value of $\gamma$ |
|-----------|-------------|-------------------|------------------|-------------------|------------------|------------------|
| Bagalkot  | 832         | 4.16              | 1100.23          | 5.46              | 33.56            | 378.45           |
| Ban Rural | 845         | 3.81              | 1098.45          | 7.34              | 43.76            | 352.43           |
| Ban urban | 857         | 3.99              | 1254.89          | 5.56              | 35.71            | 408.71           |
| Belgaum   | 1707        | 4.95              | 1134.67          | 3.67              | 38.62            | 487.20           |
| Bellary   | 718         | 5.10              | 1156.78          | 5.45              | 45.37            | 462.41           |
| Bidar     | 822         | 5.67              | 983.22           | 4.61              | 42.71            | 435.89           |
| Bijapur   | 709         | 4.89              | 976.76           | 4.78              | 47.28            | 310.34           |
| Chamarajnagar | 1532 | 5.23              | 987.67           | 4.91              | 37.89            | 386.38           |
| Chikamangluru | 2296 | 5.61              | 995.45           | 3.87              | 38.92            | 429.84           |
| Chitradurga | 827  | 4.78              | 1223.73          | 5.69              | 39.23            | 452.47           |
| Devanagere | 1318 | 5.38              | 1245.89          | 7.31              | 43.67            | 437.76           |
| Dharward  | 2020        | 4.79              | 956.47           | 6.70              | 54.46            | 455.11           |
| Gadag     | 1164        | 4.60              | 1098.74          | 5.47              | 39.78            | 508.34           |
| Gulbarga  | 701         | 4.12              | 1276.98          | 6.89              | 45.62            | 527.42           |
| Hassan    | 2639        | 3.99              | 856.96           | 5.94              | 52.87            | 346.78           |
| Haveri    | 1833        | 3.43              | 964.89           | 5.21              | 43.98            | 567.83           |
| Kodagu    | 1918        | 4.78              | 1278.27          | 7.82              | 55.78            | 463.24           |
| Kolar     | 869         | 5.76              | 1194.45          | 6.33              | 37.91            | 478.36           |
| Koppal    | 734         | 5.25              | 1178.56          | 5.75              | 45.83            | 387.83           |
| Mandya    | 1736        | 5.93              | 1278.34          | 4.13              | 47.23            | 411.56           |
| Mysore    | 2535        | 5.89              | 923.78           | 5.34              | 44.25            | 368.34           |
| Raichur   | 582         | 5.43              | 894.56           | 6.72              | 46.78            | 451.78           |
| Simoga    | 2185        | 5.26              | 1035.73          | 5.97              | 52.12            | 449.24           |
| Tumakuru  | 1007        | 3.67              | 1342.29          | 7.43              | 38.76            | 472.43           |

Table 4. Goodness of fit summary

| Stations  | K- S test | Chi Squared | A - D |
|-----------|-----------|-------------|-------|
| Bagalkot  | 0.45      | 416.78      | 265.34|
| Ban Rural | 0.34      | 243.89      | 34.18 |
Ban urban  0.24  212.78  29.12  
Belgaum  0.78  179.59  39.79  
Bellary  0.31  234.76  321.53  
Bidar  0.05  198.67  173.30  
Bijapur  0.67  345.98  24.67  
Chamarajnagar  0.06  256.89  82.71  
Chikkamangluru  0.24  378.24  13.83  
Chitradurga  0.65  564.23  16.97  
Devanagere  0.13  367.73  27.92  
Dharward  0.04  256.89  145.89  
Gadag  0.45  454.78  241.72  
Gulbarga  0.72  123.67  154.17  
Hassan  0.82  543.24  31.13  
Haveri  0.19  578.26  17.89  
Kodagu  0.37  256.78  16.45  
Kolar  0.28  289.45  45.78  
Koppal  0.15  454.36  19.72  
Mandya  0.19  259.94  28.24  
Mysore  0.69  567.43  34.67  
Raichur  0.26  478.23  12.39  
Simoga  0.34  365.78  26.98  
Tumakuru  0.07  389.67  19.34  

3. Results and discussion
Examination of precipitation information assumes a noteworthy job in any agribusiness and water asset administration and also for hydrological demonstrating. The mean month to month precipitation information for all areas of Karnataka for a long time (1973–2002) were utilized for our examination work. Figure 3 demonstrated the yearly precipitation execution watch red for whole Karnataka for the time of 1973–2002. From Table 1, the yearly precipitation of the Karnataka State is spatial and there is a wide distinction in yearly precipitation sum. The normal greatest yearly precipitation of 3595.76 mm happened in Mysore, notwithstanding, the base normal yearly precipitation 336.06 mm occurred in Raichur. The yearly precipitation normal precipitation chart of various regions demonstrates the positive or negative connection. The precipitation chart indicates two distinct tops as appeared in Fig 2, the year 1975 and 1998 which are described by various factual practices of the locale. Figure 2 shows to the yearly normal precipitation of through the entire year 1973 to 2002. On the off chance that the yearly precipitation in a year leaves from the normal yearly precipitation by more prominent than or equivalent to 20%, so it is pronounced as a dry spell year [23]. There was adequate precipitation from monsoon season (June to September) in the entire time of the state. To investigation the occasional precipitation dissemination, the entire year was isolated into four periods, namely monsoon (June–September), pre-monsoon (March-May), post-monsoon (October–December) and winter season (January–February). This demonstrates the region gets over 78% of the aggregate yearly precipitation amid the rainstorm season, 15% amid the post-monsoon season, and 7% during the pre-monsoon season. It indicates that over 78% of precipitation happens in the rainstorm season, and in the rest of the months, the horticulture part-based works are firmly Suppressed. Consequently, it is basic to foresee the normal precipitation to design a water insurance framework.
Figure 2: Average annual rainfall of Karnataka from 1973 to 2002

Figure 3: Annual time series of precipitation all districts year from the year 1973 to 2002
3.1. Analysis of Probability distribution
To understand the best conveyance of month to month precipitation, information for all locale of Karnataka for 30 years (1973 – 2002) were examined. The likelihood examination of a month to month precipitation information was done. The best goodness of fit distribution, such as chi-squared, gamma, gamma (3P), Weibull, Weibull (3P), was applied. Table 2 and 3 demonstrates the dispersion parameters for an alternate circulation. To get the best-fit dissemination to this precipitation arrangement, integrity of-fit tests, for example, Kolmogorov–Smirnov, Anderson-Darling and Chi-squared were connected. The evaluation of the best likelihood appropriation depended on the static from every one of the tests. According to the goodness-of-fit test, it was found that Weibull distribution best fitted the rainfall distribution for Chikkamangluru, Dharward, Hassan, Mysore, Simoga districts, Chi-squared distribution best fit for Belgaum, Chamarajnagar, and Devanagere, Gamma (3P) distribution best fitted Bellary and Kolar, normal distribution best fitted Koppar and Raichur. Weibull (3P) distribution best fitted Kodagu and Haveri. The normal distribution was best fitted during the monsoon months (June–September). This best dissemination is utilized to express the peril and vulnerability related to the demonstrating and arranging of water administration. It encourages us to enhance our successful models which could shield us from both time and money related.

4. Conclusion
The Karnataka State is confronting a lot of problems of rapid conversion of rainfall to surface runoff because of disorder slopes. These are major issues in the state so we analyzed the annual rainfall series data for a period of 1973–2002 of 24 districts using probability distributions of the Karnataka state. The fantastic best likelihood dispersion could be utilized to impact choices identifying with state budgetary and water asset wellbeing frameworks. Annual precipitation data of all districts of the state were fitted by Chi-squared, Normal, gamma, gamma (3P), Weibull, Weibull (3P) distributions and comparisons of best distributions were done based on the use of goodness-of-fit tests such as Kolmogorov–Smirnov, and Chi-squared. The goodness-of-fit test analysis indicated that Chi-squared, Weibull, Weibull (3P), gamma, gamma (3P) and normal and distributions were fit for 41%, 18%, 19%, 13%, and 7% of the stations, respectively. This examination obviously demonstrated a reason for picking the best likelihood appropriation for the independent locale and equal dissemination parameters. In addition, this seasonal rainfall distribution shows that the area receives about 78% of the total annual rainfall during the monsoon season, 15% during the post-monsoon season, and 7% during the pre-monsoon season. This result will help the water management developer in hydrological modeling and the agriculture sector-based workers in the entire Karnataka state.

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