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Investigating trend in weather variables of Bidar district of Karnataka: Analysis of 114 years time series data

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Abstract
The climatic variability for an area is refers to the long-term change in rainfall, temperature, humidity, evaporation, wind speed and other meteorological parameters. Trend analysis is carried out to understand pattern or structure of the climatic variability. Without studying the trends, adoption of farming system to an area might be unsuccessful with the future climatic conditions. For the present study, the annual rainfall, annual maximum temperature and the annual minimum temperature of Bidar district for the year 1901 to 2015 was considered to examine the trend in the rainfall, maximum temperature and minimum temperature. The data is collected form IMD, India. The summary statistics and regression analysis revealed no significant trend in rainfall and temperature. In Regression analysis of rainfall data linear, exponential, growth and logistic functions (5 % level of significance) were found to be the best fit and in case of maximum and minimum temperature, cubic function (5 % level of significance) found to be the best fit.

Keywords: Investigating trend, weather, 114 years, Bidar

1. Introduction

Climate change is one of the biggest challenges the present world is facing today. It refers to a long-term change in the state of climate that can be identified by changes in mean or changes in variability of its properties and that persists for an extended period, typically decades or longer. It refers to any change in the climate over time, whether due to natural variability or as a result of human activity (Anonymous, 2007) [1]. The Inter-governmental Panel on Climate Change has projected that increase in temperature is expected to be in the range of 1.8 to 4.0 °C by the end of 21st century. For the Indian region (South Asia) the IPCC projected rise in temperature will be 0.5 to 1.2 °C by 2020, 0.88to 3.16°C by 2050 and 1.56 to 5.44 °C by 2080, depending on the future human activities (Anonymous, 2007) [1]. The various studies show the overall loss in the crop production in the country in the last few years due to the anticipated rise in the temperature. The rise in temperature will be higher during the winter (*Rabi*) than in the rainy season (*Kharif*).These climatic changes are expected to increase the pressure on Indian agriculture as projected that there is a probability of 10-40 per cent loss in crop production in India by 2080-2100 due to global warming (Rosenzweig *et al*. 1994 [10]. and Fischer *et al*. 2002) [2]. Studies also show that in India average annual and monsoon rainfall decreased, while pre-monsoon and winter rainfall increased at the national scale (Kumar *et al*. 2010) [4]. Areas of increasing trend in the monsoon seasonal rainfall are found along the west coast, north Andhra Pradesh and north-west India, and those of decreasing trend over east Madhya Pradesh and adjoining areas, north-east India and parts of Gujarat and

Kerala. The sub seasonal patterns indicate that the excess or deficiency of the monsoon rainfall is more frequently realized in the later half of the season. Monsoon rainfall tends to be more concentrated in August, over the west coast and central India (Kumar *et al.* 1992) [3]. Based on the analysis of last 60 years of gridded data, there is a statistically significant decreasing trend in all India summer monsoon rainfall (Oza and Kishtawal, 2014) [8]. In Karnataka the magnitude of trend in temperature has increased during the period of 1941 to1980 and it extended its severity during the period of 1981-2002. Analysis also showed that increase in trend for annual mean temperature was correlated with an increase in latitude (Madolli *et al.* 2015) [5].

Farmers are practicing agriculture on contextual factors beyond their control. With the new understanding, climate change is real, happening and inevitable. The complexities involved in farming have become manifold. The challenges in agriculture would seriously threaten to push them to face more unpredictable situations. The effect of rising temperatures and unpredictable rainfall patterns are going to test seriously the in formal decisions farmers must make in order to survive in farming and sustain their living. Hence a study was undertaken to examine the trend in the rainfall, maximum temperature and minimum temperature of Bidar district by using 114 years' time series data with different models such as linear, Exponential, growth, logistic, cubic, power, compound, logarithmic, Inverse, Quadratic and S Curve.

2. Methodology

2.1 Study area

The Bidar district is situated between 17°35' and 18°25' North latitudes and 74°42' and 73°39' east longitudes and lies in the extreme north of the state. Its maximum length from east to west is 93.4 km and from north east to south west 11.52 km. The district has geographical area of 5,451 sq.km with 4, 74,224 ha of agricultural land of which 1, 71,807 ha is the cultivable land. The district receives an average rainfall of 890.60 mm per year. It is situated at a height of 618.7 mt above the mean sea level. It is surrounded by Andhra Pradesh and Maharashtra states at North – East and west directions, respectively and Gulbarga district at south direction. The soil type is red laterite and medium to deep black soil. The district receives *kharif* rains from July to September and *rabi* rains in the month of October to December. The major crops in the Kharif season among cereals are Paddy, Jowar etc., among pulses are Redgram, Greengram, Blackgram, Horsegram etc., and among oil seeds are Groundnut, Sunflower, Safflower and with respect to commercial crops Sugarcane and Cotton are being grown. For the present study, the annual rainfall, annual maximum temperature and the annual minimum temperature of Bidar district for the year 1901 to 2015 was considered to examine the trend in the rainfall, maximum temperature and minimum temperature. The data is collected form IMD, India.

2.2 Statistical models

Following statistical growth models were used in the study to diagnose and analyze the pattern present in the considered variables;

2.2.1 Trend models

Trend analysis

Trend analysis is carried out to understand the Pattern or structure of the data setor time series under consideration. Broadly speaking, trends occur in two ways: agradual change over time that is consistent in direction (monotonic) or an abrupt shift ata specific point in time (step trend). For time series trend analysis the dependent and independent variable are need to define. Usual for a time series data, the time is considered as independent variable and time series under consideration as dependent variable.

Procedure of selecting a trend model

1. Choose one or more curve estimation regression models.
2. Plotting of data
3. If the variables appear to be related linearly, use a simple linear regression model.
4. If variables are not linearly related, then try for transforming your data. When atrans formation does not help, then one is needing to go for complicated model. For trend analysis following models are popular used as these are from family of regression models (Motulsky and Christopoulos, 2004 [7]. Montgomery and Peck, 1982) [6].

2.2.1 A: Linear model

The series values are modeled as a linear function of time.

.

$$Y = b_o + (b_1 * t) \quad \text{………… (1)}$$

Where,

Y is dependent variable or time series under consideration

b_0 is intercept of the model

b_1 is the first regression coefficient

t is the time period

2.2.1 B: Logarithmic Model

The series values are modeled as a linear function of logarithmic values time.

$$Y = b_o + (b_1 * ln(t)) \quad \text{…………………. (2)}$$

Where,

Y is dependent variable or time series under consideration

b_0 is intercept of the model

b_1 is the first regression coefficient

ln is natural log

t is the time period

2.2.1 C: Inverse Model

The inverse model is as follows

$$Y = b_o + (b_1/t) \quad \text{………….. (3)}$$

Where,

Y is dependent variable or time series under consideration

b_0 is intercept of the model

b_1 is the first regression coefficient

t is the time period

2.2.1 D: Quadratic Model

Quadratic model can be used to model a series that "takes off" or a series that dampens.

$$Y = b_o + (b_1 * t) + (b_2 * t^2) \quad \text{………….. (4)}$$

Where,

Y is dependent variable or time series under consideration

b_0 is intercept of the model

b_1 the first regression coefficient

b_2 is the second regression coefficient
t is the time period

2.2.1 E: Cubic Model

$$Y = b_o + (b_1 * t) + (b_2 * t^2) +) + (b_2 * t^3) \quad \ldots\ldots\ldots\ldots (5)$$

Where,
Y is dependent variable or time series under consideration
b_0 is intercept of the model
b_1 is the first regression coefficient
b_2 is the second regression coefficient
t is the time period

2.2.1 F: Power Model

$$Y = b_o * (t^{b_1}) \quad \ldots\ldots\ldots\ldots (6)$$

Where,
Y is dependent variable or time series under consideration
b_0 is intercept of the model
b_1 is the first regression coefficient
t is the time period

2.2.1 G: Compound Model

$$Y = b_o * (b_1{}^t \quad \ldots\ldots\ldots\ldots (7)$$

Where,
Y is dependent variable or time series under consideration
b_0 is intercept of the model
b_1 is the first regression coefficient
t is the time period

2.2. H: S-curve Model

$$Y = exp^{(b_0} + b_1/t) \quad \ldots\ldots\ldots\ldots (8)$$

Where,
Y is dependent variable or time series under consideration
b_0 is intercept of the model
b_1 is the first regression coefficient
t is the time period
exp is the exponential value

2.2.1 I: Logistic Model

$$Y = \frac{1}{(\frac{1}{u} + (b_0 * (b_1{}^t)))} \quad \ldots\ldots\ldots\ldots (9)$$

Where,
Y is dependent variable or time series under consideration
b_0 is intercept of the model
b_1 is the first regression coefficient
t is the time period
u is the upper boundary value.
After selecting Logistic, specify the upper boundary value to use in the regression equation. The value must be a positive number that is greater than the largest dependent variable value.

2.2.1 J: Growth Model

$$Y = e^{(b_0 + (b_1 * t))} \quad \ldots\ldots\ldots\ldots (10)$$

Where,
Y is dependent variable or time series under consideration
b_0 is intercept of the model
b_1 is the first regression coefficient
t is the time period
exp is the exponential value

2.2.1 K: Exponential Model

$$Y = b_0 * (exp^{(b_1 * t)}) \quad \ldots\ldots\ldots\ldots (11)$$

Where,
Y is dependent variable or time series under consideration
b_0 is intercept of the model
b_1 is the first regression coefficient
t is the time period
exp is the exponential value
The regression coefficient ***b*** explains the amount of or unit of changes in dependent variable as a result of per unit of changes in independent variable.

2.2.3 Coefficient of determination (R^2)
Coefficient of determination explains the variation in the prediction variable (y) by independent variables through the fitted regression equation which is computed as follows

$$R^2 = \frac{RegSSq}{ErrorSSq} \quad \ldots\ldots\ldots\ldots (12)$$

In trend analysis R^2 is used to identify the goodness of fit of the model or to identify the best model among the considered models.

3. Results
3.1 Trend analysis of various weather parameters of climate change
3.1.1 Trend analysis of rainfall of Bidar district for the year 1901 to 2015
For the present study, the annual rainfall (mm) of Bidar district for the year 1901 to 2015 is considered to examine the trend in the rainfall. The time series plot of above dataset has been exhibited in Fig. 1. The summary statistics of rainfall data is given in Table 1 and it indicates that there are 115 observations with the average rainfall of 819.50 mm, maximum rainfall of 1647.6 mm and minimum of 484.14 mm. Coefficient of variation is 22.93 per cent which indicates that the data is highly heterogeneous. Trend analysis of the rainfall series is presented in table 2. Linear (0.033), exponential (0.035), growth (0.035) and logistic (0.035) models are found to be best for this data set based on their R^2value. The regression coefficient of the respective model along with F statistics is also present in the Table 2 which explains the unit of changes in dependent variable as a result of per unit of changes in independent variable. for example, in linearregression model the *b1* is 1.019 which means for every one-unit change in present rainfall depends on every 1.019 unit changes in its lag (earlier years rainfall). For the rainfall of Bidar district the linear (0.053), exponential (0.046), growth (0.046) and logistic (0.046) models are significant at 5 per cent level of significance. The model fitting is also represented through graphical representation which is presented in Fig. 2 which indicates that the above discussed models are fitting better among all the models used in the study. Based on the overall result obtained for trend analysis of annual rainfall (mm) of Bidar district, none of the model is

fitted correctly as the R2 value is very low. The reason may be due to presence of set is highly nonlinear, complex and unidentified patterns in the series. The above results were in line with the findings of Rachel *et al.* (2014) [9].

Table 1: Summary statistics of rainfall time series of Bidar district

Statistic	Series	Statistic	Series
Observation	115	Variance	35331.50
Mean	819.50	Standard Deviation	187.96
Median	792.42	Kurtosis	2.20
Maximum	1647.6	Skewness	1.00
Minimum	484.14	Coefficient of Variation (%)	22.93

Table 2: Model summary and parameter estimates

Model	Model Summary					Parameter Estimates			
	R Square	F	df1	df2	Sig.	Constant	b1	b2	b3
Linear	0.033	3.817	1	113	0.053	760.469	1.019		
Logarithmic	0.021	2.398	1	113	0.124	710.141	29.000		
Inverse	0.007	0.782	1	113	0.379	826.109	-141.11		
Quadratic	0.034	1.971	2	112	0.144	776.125	0.216	0.007	
Cubic	0.034	1.303	3	111	0.277	778.258	0.000	0.012	0.0000026
Compound	0.035	4.066	1	113	0.046	744.670	1.001		
Power	0.023	2.669	1	113	0.105	698.707	0.036		
S	0.007	0.840	1	113	0.361	6.692	-0.171		
Growth	0.035	4.066	1	113	0.046	6.613	0.001		
Exponential	0.035	4.066	1	113	0.046	744.670	0.001		
Logistic	0.035	4.066	1	113	0.046	0.001	0.999		

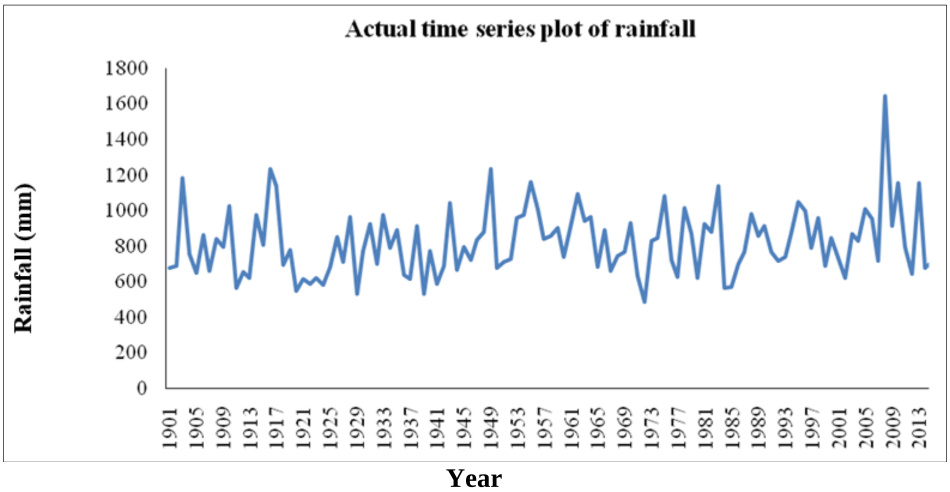

Fig 1: Actual time series plot of rainfall (Bidar district)

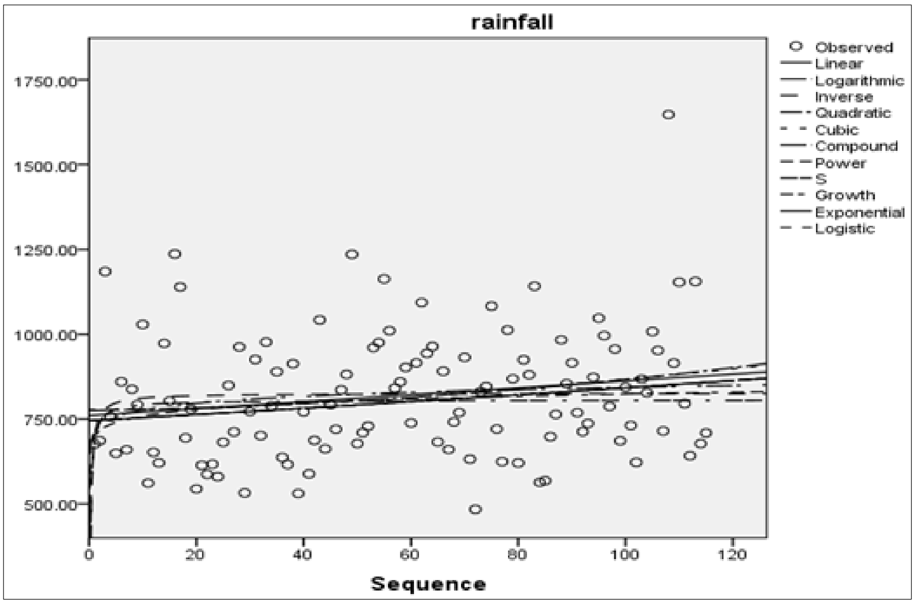

Fig 2: Actual v/s Fitted plot (Bidar district)

3.1.2 Trend analysis of maximum temperature of Bidar district for the year 1901 to 2015

For the present study, the annual maximum temperature of Bidar district for the year 1901 to 2015 is considered to examine the trend in the maximum temperature. The time series plot of above dataset has been exhibited in Fig. 3. The summary statistics of temperature data is given in Table 3 and it indicates that there were 114 observations with mean temperature of 32.95 ^{0}C and maximum temperature of 34.23 ^{0}C and minimum of 31.20 ^{0}C with coefficient of variance of 1.81 per cent. Trend analysis of the maximum temperature series is presented in table 4. Based on the R^2 value obtained one can depict that among the various models used cubic model (0.468) is fitting best for this data set. In maximum temperature data, the cubic (0.000) models are significant at 5 per cent level of significance. The model fitting is also represented through graphical representation which is presented in Fig. 4. Which indicates that the above discussed model is fitting better among all the models used in the study.

Table 3: Summary statistics of Maximum Temperature series (Bidar district)

Statistic	Series	Statistic	Series
Observation	115	Variance	0.35
Mean	32.95	Standard Deviation	0.59
Median	32.97	Kurtosis	0.16
Maximum	34.23	Skewness	-0.39
Minimum	31.20	Coefficient of Variation (%)	1.81

Table 4: Model summary and parameter estimates

Equation	Model Summary					Parameter Estimates			
	R Square	F	df1	df2	Sig.	Constant	b1	b2	b3
Linear	0.009	0.982	1	113	0.324	32.854	0.002		
Logarithmic	0.020	2.356	1	113	0.128	32.605	0.091		
Inverse	0.006	0.686	1	113	0.409	32.970	-0.421		
Quadratic	0.152	10.034	2	112	0.000	32.337	0.028	0.000	
Cubic	0.468	32.588	3	111	0.000	33.270	-0.066	0.002	0.000016
Compound	0.007	0.828	1	113	0.365	32.856	1.000		
Power	0.019	2.169	1	113	0.144	32.614	0.003		
S	0.006	0.645	1	113	0.424	3.495	-0.012		
Growth	0.007	0.828	1	113	0.365	3.492	4.659E-5		
Exponential	0.007	0.828	1	113	0.365	32.856	4.659E-5		
Logistic	0.007	0.828	1	113	0.365	0.030	1.000		

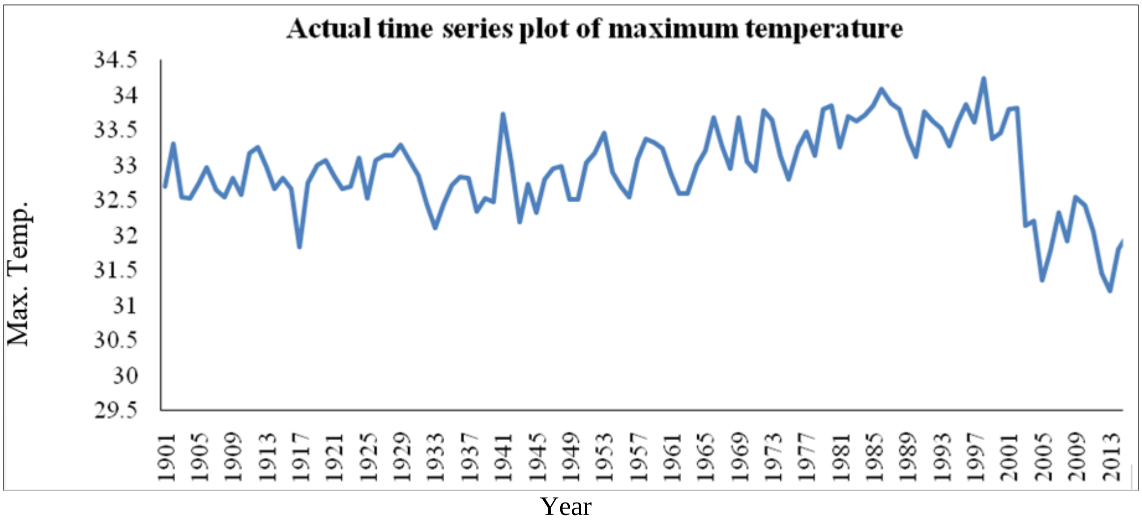

Fig 3: Actual time series plot of Maximum Temperature time series of Bidar district

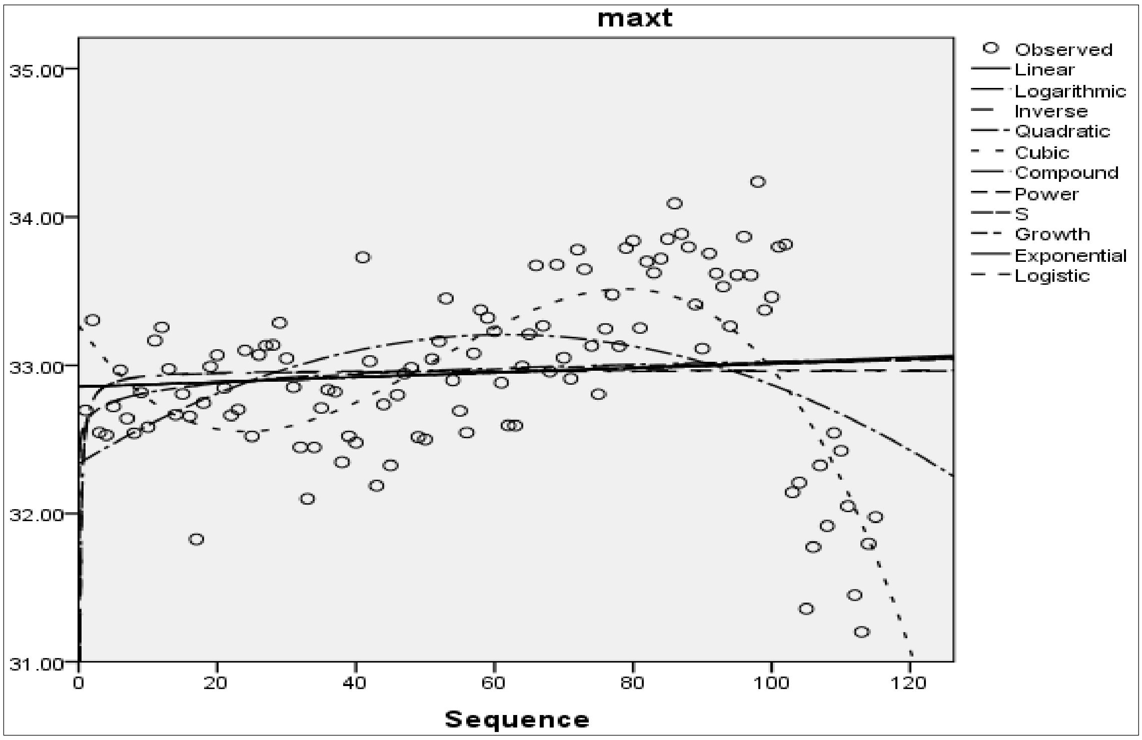

Fig 4: Actual v/s Fitted plot (Bidar district)

3.1.3 Trend analysis of minimum temperature of Bidar district for the year 1901 to 2015

For the present study, the annual minimum temperature of Bidar district for the year 1901 to 2015 is considered to examine the trend in the minimum temperature. The time series plot of above dataset has been exhibited in Fig. 5. The summary statistics of temperature data is given in Table 5 and it indicates that there were 115 observations with mean minimum temperature of 20.68 ^{0}C and maximum temperature of 21 ^{0}C and minimum of 19.15 ^{0}C with coefficient of variance of 2.66 per cent. Trend analysis of the minimum temperature series is presented in Table 6. Based on the R^2value obtained one can depict that among the various models used, the cubic model (0.470) is best for this data set. The model fitting is also represented through graphical representation which is presented in Fig.6. which indicates that the above discussed model is fitting better among all the models used in this study.

Table 5: Summary statistics of Minimum Temperature series (Bidar district)

Statistic	Series	Statistic	Series
Observation	115	Variance	0.30
Mean	20.68	Standard Deviation	0.55
Median	20.68	Kurtosis	-0.11
Maximum	21.93	Skewness	-0.17
Minimum	19.15	Coefficient of Variation (%)	2.66

Table 6: Model summary and parameter estimates

Equation	Model Summary					Parameter Estimates			
	R Square	F	df1	df2	Sig.	Constant	b1	b2	b3
Linear	0.034	4.023	1	113	0.047	20.506	0.003		
Logarithmic	0.044	5.246	1	113	0.024	20.216	0.124		
Inverse	0.011	1.219	1	113	0.272	20.708	-0.515		
Quadratic	0.147	9.656	2	112	0.000	20.084	0.025	0.000	
Cubic	0.470	32.793	3	111	0.000	20.952	-0.063	0.002	-0.00001
Compound	0.031	3.619	1	113	0.060	20.508	1.000		
Power	0.041	4.892	1	113	0.029	20.227	0.006		
S	0.010	1.151	1	113	0.286	3.030	-0.024		
Growth	0.031	3.619	1	113	0.060	3.021	0.000		
Exponential	0.031	3.619	1	113	0.060	20.508	0.000		
Logistic	.031	3.619	1	113	.060	.049	1.000		

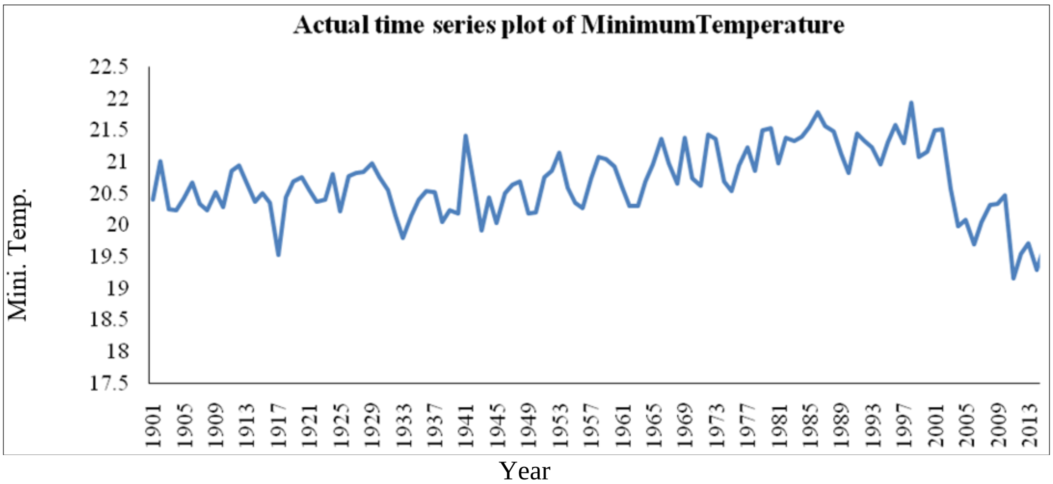

Fig 5: Actual time series plot of Minimum Temperature time series of Bidar district

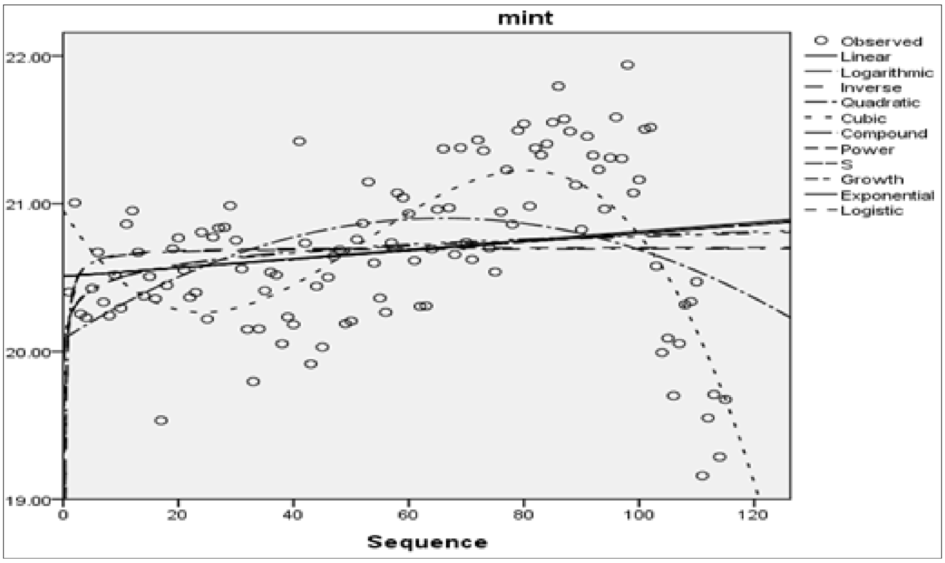

Fig 6: Actual v/s Fitted plot (Bidar district)

4. Conclusion

In trend analysis of rainfall of Bidar district for the year 1901 to 2015, Coefficient of variation of the rainfall data was 22.93 per cent which indicates that the rainfall is highly heterogeneous. In linear regression model the *b1* was 1.019 which means for every one unit change in present rainfall depends on every 1.019 unit changes in its lag (earlier years rainfall). Similarly, In trend analysis of maximum temperature, based on R^2 value obtainedcubic model was fitting best for the temperature data set at 5 per cent level of significance. *b1* was.002 which means for every oneunit change in present emperature depends on every 0.002 unit changes in its lag (earlier years temperature) and for minimum temperature based on R^2 value obtainedcubic model was fitting best for the temperature data set at 5 per cent level of significance. *b1* was -.063 which means for every one unit change in present temperature depends on every -.063 unit changes in its lag (earlier years temperature).

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