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Study of Weather Parameters at Malaprabha Command Area (MCA): A Trend Approach

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A B S T R A C T

Climate change and agriculture are interrelated processes, both of which take place on a global scale. The study was undertaken to identify the trend in weather parameters in Malaprabha Command Area (MCA). The research was based on secondary data of nineteen years (1999 to 2017) on different weather parameters such as precipitation, temperature, relative humidity and potential evapotranspiration obtained from the Irrigation Water Management Research Centre, Belavatgi under UAS, Dharwad. The statistical tools namely trend analysis, Mann Kendall trend test and Sen's slope estimator were employed. The trend analysis shown cubic and quadratic models are suitable for most of the parameters. Mann Kendall trend test revealed that most of the months showed no trend for precipitation, temperature and potential evapotranspiration at Belavatagi Farm, except for few months, temperature showed the decreasing trend respectively in more months. At MCA, temperature and relative humidity showed decreasing and increasing trend in most of the months. Precipitation showed no trend in almost all months.

Introduction

Climate change and agriculture are interrelated processes, both of which take place on a global scale. Climate change affects agriculture in a number of ways, including changes in average temperatures, rainfall, and climate extremes changes in pests and diseases. Climate change is a long-term change in the statistical distribution of weather patterns over periods of time that range from decades to millions of years (Abdulharias *et al.*, 2010). It may be a change in the average weather conditions or a change in the distribution of weather events with respect to an average, for example, greater or fewer extreme weather events. Karnataka state has a pleasant weather. The state is known to have a moderate summers and pleasant winters (Raje Gowda *et al.*, 2012). Global average air temperature near the earth's surface raised 0.74 ± 0.18 °C (1.33 ± 0.32 °F) during the twentieth century. Climate change may be limited to a specific region, or may occur across the whole earth (Sureshbabu, 2013).

The entire coastal belt of Karnataka has the tropical monsoon climate. The climate in the coastal is hot with excessive rainfall during the monsoon. The southern part of Karnataka experiences hot, seasonally dry tropical savanna climate. The Northern Karnataka experiences hot, semi-arid, tropical; steppe type of climate. The winter begins from January and ends in February. It is followed by summer from March to May. Post monsoon season begins in October and lasts till December. The months April and May are really very hot and dry. Weather tends to be harsh during June due to high humidity (Sureshbabu, 2013).

In order to study the trend of weather parameters in Malaprabha Command Area (MCA), we have collected the data from the Irrigation Water Management Research Centre, Belavatgi under UAS, Dharwad. Malaprabha Command Area covers Belgavi, Bagalkot, Gadag, and Dharwad districts. Malaprabha project comprises the area of a dam across the river Malaprabha, near Navilutheertha in Belgaum district. The districts benefited under the Malaprabha project are Belagavi, Gadag and Bagalkot. The taluks benefited are Bailahongal, Saudatti, Badami, Navalagund, Hubli, Naragund, Ron and Gadag.

The statistical investigation on trend of weather parameters was conducted based on secondary data. The statistical techniques such as, trend analysis and Mann Kendal tests were carried out. Trend analysis was done by fitting polynomial and well known non-linear models separately for each parameter over the years. The suitable prediction models were selected based on R^2 values and the least meansquare error. (Swetha, 2009)

Materials and Methods

Trend analysis

Trend analysis was done by fitting the regression equation separately for each parameter over the years for the period of 1999-2017. Further, the trend line presented using graphs of Free hand curve fitting to know the trend of weather parameter over time.

Mann-Kendall test

The trend values for each weather parameter were determined using non-parametric Mann-Kendall test, which were tested for the significance at 95% level. Since there is fluctuation presents in the weather parameters, non-parametric Mann-Kendall test is useful because its statistic is based on the sign of differences, not directly on the values of random variable and therefore trends determined is less affected by the fluctuations. Mann-Kendall test is applicable to the detection of monotonic trend in time series (Sureshbabu, 2013).

The test statistic S is calculated using the formula

$$S = \sum_{k=1}^{n-1} \sum_{k+1}^{n} sgn\,(x_j - x_k)$$

$$sgn\,(x_j - x_k) = \begin{cases} +1 & if\, x_j - x_k > 0 \\ 0 & if\, x_j - x_k = 0 \\ -1 & if\, x_j - x_k < 0 \end{cases}$$

Where n is the number of observed data series, x_j and x_k are the values in periods j and k respectively, j>k. The sampling distribution of S is as follows,

$$Z = \begin{cases} \dfrac{s-1}{\sqrt{VAR(S)}} & if\, S>0 \\ 0 & if\, S=0 \\ \dfrac{s+1}{\sqrt{VAR\,(S)}} & if\, S<0 \end{cases}$$

Where VAR(S) is determined as

$$\text{VRS}(s) = \frac{1}{18}\left[n(-1)(2n+5) - \sum_{p=1}^{q} t_p (t_p - 1)(2t_p + 5)\right]$$

Where q is the number of tied groups, and t_p is the number of data values in the p^{th} group. The probability associated with this normalized test statistic. The probability density function for a normal distribution with a mean of 0 and a deviation of 1 is given by the following equation:

$$d(z) = \frac{1}{\sqrt{2\pi}} e^{z^2/2}$$

Microsoft Excel function, NORMSDIST (), was used to calculate this probability. The trend is said to be decreasing if Z is negative and the computed probability is greater than the level of significance.

The trend is said to be increasing if the Z is positive and the computed probability is greater than the level of significance. If the computed probability is less than the level of significance, there is no trend.

Sen's slope estimator test

The magnitude of trend is predicted by the Sen's estimator. Here, the slope (T_i) of all data pairs is computed as *(Sen, 1968)*

$$T_i = \frac{x_j - x_k}{j - k} \quad \text{for } i = 1,2,\ldots\ldots,N$$

Where x_j and x_k are considered as data values at time j and k (j>k) correspondingly. The median of these N values of T_i is represented as Sen's estimator of slope which is given as:

$$Q_i = \begin{cases} T_{\frac{N+1}{2}} & N \text{ is odd} \\ \frac{1}{2}\left(T_{\frac{N}{2}} + T_{\frac{N+2}{2}}\right) & N \text{ is even} \end{cases}$$

Sen's estimator is computed as $Q_{med} = T_{(N+1)/2}$ if N appears odd, and it is considered as $Q_{med} = [T_{N/2}+T_{(N+2)/2}]/2$ if N appears even. At the end, Q_{med} is computed by a two sided test at 100 (1-α) confidence interval and then a true slope can be obtained by the non-parametric test. Positive value of Q_i indicates an upward or increasing trend and a negative value of Q_i gives a downward or decreasing trend in the time series.

Results and Discussion

Prediction models

Eleven different non-linear and polynomial models were used for predicting the trend of weather parameters at Belavatagi farm is presented in Table 1 and 2 for temperature, precipitation and potential evapotranspiration. For investigating the suitable model for trend of temperature, 7^{th} degree polynomial model was found to be significant and proved to be the best with (R^2=0.746) i.e. 74.6 per cent variation in trend is accounted by temperature. In case Potential evapotranspiration two models were found to be significant.

Among these models, quadratic and cubic models were found to be significant. Among these models, cubic model was proved to be best with highest (R^2 = 0.589) followed by quadratic model (R^2 = 0.492). With the cubic model 58.9 per cent of the variation in PET was explained by trend. For precipitation none of the non-linear and polynomial model were significant, indicating variation in precipitation was not accounted because of presence of trend. Similarly, for the weather data of Malaprabha command area, the different models used, is presented in Table 3 and 4 for temperature, precipitation and relative humidity. For investigating the suitable model for trend of temperature at MCA, all models were found to be significant except inverse and S model.

Table.1 Comparison of models for investigating the suitable model for trend of weather parameters at Belavatagi Farm of MCA

	Temperature			PET			Rainfall		
Equation	**Coefficient**	**MSE**	**R Square**	**Coefficient**	**MSE**	**R Square**	**Coefficient**	**MSE**	**R Square**
Linear	-0.041	2.395	0.023	9.222	24442.19	0.104	4.892	36663.88	0.021
Logarithmic	-0.451	2.311	0.057	33.583	26515.31	0.029	45.439	36040.84	0.038
Inverse	1.514	2.325	0.051	-57.311	27113.99	0.007	-158	36098.8	0.036
Quadratic	-0.476	2.144	0.177	-63.557	14742.06	0.492**	41.965	36042.06	0.095
	0.022			3.639			-1.854		
Cubic	-0.513	2.286	0.177	30.706	12724.84	0.589**	-13.735	37397.38	0.119
	0.026			-7.847			4.933		
	0			0.383			-0.226		
Compound	0.999	0.004	0.019	1.006	0.012	0.085	1.011	0.153	0.024
Power	-0.017	0.004	0.053	0.019	0.013	0.019	0.086	0.152	0.033
S	0.058	0.004	0.05	-0.028	0.013	0.003	-0.265	0.153	0.024
Growth	-0.001	0.004	0.019	0.006	0.012	0.085	0.011	0.153	0.024
Exponential	-0.001	0.004	0.019	0.006	0.012	0.085	0.011	0.153	0.024
Logistic	1.001	0.004	0.019	0.994	0.012	0.085	0.989	0.153	0.024
7th degree Polynomial	-21.91421	0.964	0.746*	- Not fitted -			(No Significant fit up to 12^{0} Polynomial equation)		
	12.32798								
	-3.07705								
	0.38983								
	-0.02623								
	0.00089								
	-0.00001								

* = significance at 5 per cent, ** = significance at 1 per cent, MSE=mean square error, R Square = coefficient of determination, PET= Potential Evapotranspiration

Table.2 Suitable models selected for prediction of trend of weather parameters at Belavatagi Farm of MCA

Parameter	Model	Equation	MSE	R^2
Temperature	7th degree Polynomial	$\hat{Y} = 40.01-21.914^{*}(t)+12.328^{**}(t^2) -3.077^{**}(t^3)+ 0.389^{**}(t^4)- 0.026^{**}(t^5)+ 0.0009^{**}(t^6)-0.00001^{*}(t^7)$	0.964	0.746*
PET	Quadratic	$\hat{Y} = 1610.481^{**}-63.557^{**}(t)+3.639^{**}(t^2)$	14742.06	0.492**
	Cubic	$\hat{Y} = 1433.594+30.706(t)-7.847(t^2)+0.383^{**}(t^3)$	12724.84	0.589**
Precipitation	No significant fit	-	-	-

* = significance at 5 per cent, ** = significance at 1 per cent, MSE=mean square error, PET= Potential Evapotranspiration

Table.3 Comparison of models for investigating the suitable model for trend of weather parameters at MCA

	Temperature			Relative Humidity			Precipitation		
Linear	-0.046	0.117	0.427**	0.487	8.287	0.537**	2.01	51599.585	0.003
Logarithmic	-0.278	0.149	.267*	3.224	10.569	0.409**	-3.846	51752.843	0.0001
Inverse	0.509	0.191	0.065	-7.796	14.793	0.173	108.1	5.1169.356	0.019
Quadratic	0.001	0.117	0.454**	0.254	8.607	0.544**	-6.951	54259.463	0.007
	-0.002			0.011			0.407		
Cubic	0.052	0.123	0.459*	0.843	8.97	0.551**	-63.661	56116.921	0.03
	-0.008			-0.055			6.704		
	0.0001			0.002			-0.191		
Compound	0.998	0.0001	0.428**	1.008	0.002	0.538**	1.002	0.042	0.004
Power	-0.011	0.0002	0.268*	0.054	0.003	0.412**	-0.004	0.042	0.004
S	0.02	0.0001	0.065	-0.129	0.004	0.173	0.109	0.042	0.014
Growth	-0.002	0.0001	0.428**	0.008	0.002	0.538**	0.002	0.042	0.004
Exponential	-0.002	0.0001	0.428**	0.008	0.002	0.538**	0.002	0.042	0.004
Logistic	1.002	0.0001	0.428**	0.992	0.002	0.538**	0.998	0.42	0.004
6th degree Polynomial	- Not tested -			- Not tested -			856.7128	29427.84	0.581*
							-393.291		
							68.82417		
							-5.51112		
							0.204487		
							-0.00285		

* = significance at 5 per cent, ** = significance at 1 per cent, MSE=mean square error, R Square = coefficient of determination, PET= Potential Evapotranspiration

Table.4 Suitable models selected for prediction of trend of weather parameters at Belavatagi Farm of MCA

Parameter	Model	Equation	MSE	R^2
Temperature	Quadratic	$\hat{Y} = 26.293^{**}+0.001(t)-0.002(t^2)$	0.117	0.454**
	Cubic	$\hat{Y} = 26.189^{**}+0.052(t)-0.008(t^2)+0.0001(t^3)$	0.123	0.459*
Relative Humidity	Quadratic	$\hat{Y} = 55.667^{**}+0.254(t)+0.011(t^2)$	8.607	0.544**
	Cubic	$\hat{Y} = 54.463^{**}+0.843(t)-0.055(t^2)+0.002(t^3)$	8.97	0.551**
Precipitation	6th Degree Polynomial	$\hat{Y} = 717.7926+856.7128(t)-393.291(t^2) +68.82417(t^3)-5.51112(t^4)+0.204487^{**}(t^5)-0.00285^{**}(t^6)$	29427.84	0.581*

* = significance at 5 per cent, ** = significance at 1 per cent, MSE=mean square error

Table.5 Results of Mann Kendall test on weather parameters of Belavatagi farm

Month	Precipitation	Temperature	PET
January	⇔	⇔	⇔
February	⇔	⇓	⇔
March	⇔	⇔	⇔
April	⇔	⇓	⇔
May	⇔	⇔	⇔
June	⇔	⇔	⇔
July	⇔	⇔	⇔
August	⇔	⇔	⇔
September	⇔	⇓	⇔
October	⇔	⇔	⇔
November	⇔	⇔	⇔
December	⇔	⇔	⇔

⇑ Increase in trend ⇓ Decrease in Trend ⇔ No Trend

	Precipitation			Temperature			PET		
Month	**K tau**	**Sen's slope**	**p value**	**K tau**	**Sen's Slope**	**p value**	**K tau**	**Sen's slope**	**p value**
Jan	0.07	0.00	0.78	-0.29	-0.09	0.086	0.27	1.88	0.12
Feb	0.01	0.00	1.00	-0.44	-0.17	0.009	0.18	0.85	0.29
Mar	0.23	0.00	0.23	-0.33	-0.13	0.054	0.02	0.14	0.92
Apr	0.14	0.56	0.42	-0.40	-0.10	0.019	0.09	0.73	0.60
May	0.00	0.00	1.00	0.01	0.00	0.972	0.08	0.60	0.65
Jun	-0.02	-0.27	0.92	-0.14	-0.04	0.440	-0.17	-0.70	0.33
Jul	-0.01	-0.03	0.97	0.12	0.03	0.483	0.01	0.06	0.97
Aug	-0.12	-0.87	0.48	0.13	0.03	0.462	0.08	0.48	0.62
Sep	0.18	4.00	0.31	-0.34	-0.06	0.045	-0.21	-1.14	0.22
Oct	-0.08	-1.28	0.65	-0.05	-0.02	0.806	-0.26	1.05	0.13
Nov	0.10	0.00	0.58	0.02	0.01	0.916	0.11	0.38	0.55
Dec	0.01	0.00	1.00	0.25	0.05	0.140	0.27	1.13	0.11

Table.6 Results of Mann Kendall test on weather parameters at MCA

Month	Precipitation	Temperature	Relative Humidity
January	⇔	⇓	⇑
February	⇔	⇓	⇑
March	⇑	⇓	⇑
April	⇔	⇓	⇑
May	⇔	⇔	⇑
June	⇔	⇔	⇔
July	⇔	⇔	⇑
August	⇔	⇔	⇑
September	⇔	⇓	⇑
October	⇔	⇓	⇑
November	⇔	⇓	⇑
December	⇔	⇓	⇑

⇑ Increase in trend ⇓ Decrease in Trend ⇔ No Trend

	Precipitation			Temperature			Relative Humidity		
Month	K tau	Sen's slope	p value	K tau	Sen's slope	p value	K tau	Sen's slope	p value
Jan	0.14	0.00	0.49	-0.44	-0.10	0.0003	0.48	0.59	0.0001
Feb	-0.10	0.00	0.58	-0.28	-0.04	0.0220	0.34	0.36	0.0055
Mar	0.41	0.59	0.02	-0.45	-0.06	0.0003	0.38	0.32	0.0019
Apr	0.30	2.00	0.16	-0.30	-0.08	0.0143	0.32	0.55	0.0087
May	0.09	1.03	0.61	-0.20	-0.05	0.0996	0.25	0.43	0.0437
Jun	-0.29	-3.88	0.07	0.00	0.00	0.9882	0.03	0.02	0.8240
Jul	-0.16	-2.51	0.35	-0.15	-0.01	0.2214	0.25	0.11	0.0379
Aug	0.19	2.97	0.26	-0.21	-0.01	0.0923	0.37	0.20	0.0026
Sep	0.08	2.06	0.63	-0.42	-0.04	0.0006	0.47	0.43	0.0001
Oct	-0.25	-1.86	0.12	-0.54	-0.09	0.0000	0.53	0.90	0.0000
Nov	0.27	1.10	0.11	-0.51	-0.09	0.0000	0.46	1.00	0.0001
Dec	0.02	0.00	0.95	-0.59	-0.09	0.0000	0.30	0.61	0.0122

Among these models cubic model proved to be the best with R^2. (R^2 = 0.459) i.e. 45.9 per cent variation in temperature was explained by trend, followed by quadratic model (R^2 = 0.454). In case of relative humidity except inverse and S models all other models were found to be significant. Among these models, cubic model was proved to be best with highest R^2. (R^2 =0.551) i.e. 55.1 per cent variation in relative humidity was explained by trend, followed by quadratic model (R^2 =0.544). For precipitation 7th degree polynomial model was found to be significant and the model was proved to be the best with (R^2 =0.581) i.e. 58.1 per cent variation precipitation was explained by trend.

The result was in conformity with the findings of Shwetha (2009), she worked on the impact of rain water harvesting on farming economy, who used nine models. The R square was used to compare and choose the best fit model. Polynomial model of fifth order was selected since it was having high R^2. (R^2 = 0.631). Similarly, Sreekanth *et al.,* (2009), who reported that a reliable forecasting model for predicting the ground water level using weather parameter was proved to be best fit with (R^2 = 0.93).

Mann Kendall trend test and Sen's slope estimates MCA

Table 5 showed that there were no significant trend for precipitation and potential evapotranspiration at Belavatagi farm of MCA in all months with none of the significant Kendall Tau and Sen's slope estimates. There was significant decreasing trend found for the temperature in February (K Tau =-0.44, Sen's Slope = -0.17), April (K Tau = -0.40, Sen's Slope = -0.10) and September (K Tau = -0.34, Sen's Slope = -0.06). There was no trend found in the rest of months. Similar result observed with Karnataka State precipitation pattern studied by Rajegowda *et al.,* (2012).

Table 6 showed that there were no significant trend for precipitation except in the month of March (K Tau = 0.41, Sen's Slope = 0.59) at overall MCA and all other months were with insignificant Kendall Tau and Sen's slope estimates. There was significant decreasing trend found for the temperature from September to April. The Kendall tau was highest and significant in the month December (-0.59) and lowest and significant in the month of February (-0.28) in magnitude and sen's slope was highest and significant in February (-0.17) and lowest and significant in November (0.01) in magnitude. There was no trend found from the month May to August. For relative humidity, no trend was observed in the month of June, in all other month there was increasing trend. The Kendall tau was highest and significant in the month October (0.53) and lowest and significant in May and July (0.25) in magnitude and sen's slope was highest in November (1.00) and lowest in July (0.11) in magnitude. Murthy *et al.*, 2008 also found the declining trend of maximum temperature at Ranichauri. Abdulharis (2010) also found similar results.

The cubic model was found to be significant and best suitable model for trend of relative humidity of overall Malaprabha Command Area (MCA), followed by quadratic model. For trend of temperature at MCA 7^{th} degree polynomial model was found to be significant and best suited. At Belavatagi Farm the cubic model was found to be significant and best suitable model for trend of temperature and potential evapotranspiration, followed by quadratic model. For trend of precipitation 6^{th} degree polynomial was found to be significant and best suited model. The results of Mann-Kendall test presented indicate that most of the months showed no trend for precipitation, temperature and potential evapotranspiration at Belavatagi Farm, except for few months, temperature showed that decreasing trend respectively in more months. At MCA, temperature and relative humidity showed decreasing and increasing trend in most of the months. Precipitation showed no trend in almost all months

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