



TREND ANALYSIS OF CLIMATIC VARIABLES AT MULDE LOCATION OF MAHARASHTRA STATE

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ABSTRACT

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The present study comprises the seasonal & annual trends of different climatic variables for Mulde location of Maharashtra state. The trend analysis for different climatic variables such as maximum temperature (T_{Max}), minimum temperature (T_{Min}), rainfall (RF), morning relative humidity (RH I), afternoon relative humidity (RH II), evaporation (EVP), wind speed (WS) and sunshine hours (BSS) was carried out for 25 years from 1991-2015. The trend of T_{Max} was tested and indicated that the trend was significantly increasing except southwest monsoon while in case of T_{Min} trend was non significantly increasing during different periods. In case of rainfall trend was increasing during annual, winter and summer but statistically non-significant at 95 % level of significance and during southwest monsoon and northeast monsoon decreasing trend but statistically non-significant at 95 % level of significance. The trend analysis for RH I indicated that during annual, summer and northeast season the trend was significantly increasing at 95 % level of significance and while RH II, linear regression analysis indicated for all periods the trend was significantly increasing. In case of evaporation, analysis indicated that trends of all periods increasing and statistically significant at 95 % level of significance except summer and northeast monsoon while for BSS, indicated that trend was decreasing and statistically significant at 95 % level of significance except southwest monsoon. In case of WS, analysis showed that trend was significantly decreasing for all periods at 95 % level of significance.

Contribution/Originality: The present work on trend analysis using non-parametric test such as MK test was carried out for Mulde Maharashtra. The work was based upon the historical data about 25 years. Very few attempts were made earlier regarding the trend analysis of climatic parameters using MK test. The study will be very useful for water resources planing, crop planning and for precision agriculture.

1. INTRODUCTION

Trend analysis found great significance for analysing the repeated extreme weather events during last decade. Due to castophic changes and climate change the adverse effect and change in the natural phenomenon was occurred during the recent time. The trend analysis tool found very supervisor to study the trends, change and detection of pattern of these changes. The changes such as floods and drought, extreme heat weaves etc. along with trends in various hydrometeorological variables. The study of these events is very essential for future planning, optimization of resources and adaptation strategies for the sustainable utilization of natural resources (Huang, Pang, & Edmunds, 2013; Kampata, Parida, & Moalafhi, 2008; Some'e, Ezani, & Tabari, 2012). Without

studying the trends, adoption of farming system to an area might be unsuccessful with the future climatic conditions. Many researchers work on the trend analysis according to Longobardi and Villani (2009) that trend appeared predominantly negative, both at annual and seasonal scale, except for the summer period in southern Italy and shown high significance of study in the resources planning. Karaburun, Demirci, and Kara (2012) reported that there is a significantly increasing trend in temperature during the spring, summer and autumn; positive trends in the annual mean and mean maximum temperature with 90 % and 99 % significance level in the Marmara region. Khushu, Singh, Sharma, Sharma, and Kaushal (2012) studied the temperature of five selected locations Jammu region and concluded that warming trend in the region. The study also found that the rate of increase in temperature had adverse effect on most the crops in the region in terms of productivity and ultimately the total production of the state. Based on these review it also observed that the very little work has been done for south Konkan region of Maharashtra specially for Mulde weather station. By viewing the importance of the study an attempt was made for analyzing the different climatic parameters of Mulde station.

2. MATERIAL AND METHODS

The Konkan region is distinguished from the rest of Maharashtra State by virtue of its distinct agroclimatic conditions, soil types, topography, its location between the Sahyadri ranges and the Arabian sea. Geographically Mulde located between 16.02° North Latitude, 73.42° East Longitude and 18 m Altitude from mean sea level. The data of maximum temperature (T_{Max}), minimum temperature (T_{Min}), rainfall (RF), morning relative humidity (RH I), afternoon relative humidity (RH II), evaporation (EVP), wind speed (WS) and sunshine hours (BSS) were collected from Agricultural Research Station, Mulde, Dist. Sindhudurg (M.S.), Dr. Balasaheb sawant konkan Krishi Vidyapeeth, Dapoli. Meteorological data for a period of 25 years (1991-2015) were used in the study.

2.1. Trend Analysis

A trend refers to an association or correlation between concentration and time or spatial location, but can also refer to any population characteristic changing in some predictable manner with another variable. Trend takes various forms, such as increasing, decreasing, or periodic (cyclic).

2.2. Linear Regression

Linear regression consists of finding the best fitting straight line through the points. The best fitting line is called a regression line. The formula for a regression line is $y = mx + C$, Where, y = Predicted score, m = Slope of the line, x = regression coefficient, C = Intercept.

2.3. Mann-Kendall test (MK Test)

To identify the trends of different climatic variables the non parametric, MK Test was used. The test was tested with tau coefficient (τ) and sen slope estimator (s). Kendall (τ) is a ratio between actual rating score of correlation, to the maximum possible score. To obtain the rating score for a time series, the dataset is sorted in ascending order according to time and formulated as:

$$S = \sum_{j=1}^{j=n-1} \sum_{i=j+1}^{i=n} \text{Sign}(X_i - X_j)$$

Where, s = rating score (also called the Mann-Kendall sum), x = data value, i and j = Counters, n = Number of data values in the series, Sign = A function having values of +1, 0, -1 if ($X_i - X_j$) is positive, zero, or negative, respectively.

The normal distribution parameter (called the Mann-Kendall statistic, Z) is calculated as follows:

$$z = \begin{cases} \frac{1}{\alpha} (s - 1) \dots s > 0 \\ 0 & \dots s = 0 \\ \frac{1}{\sigma} (s + 1) \dots s < 0 \end{cases}$$

2.4. Sen Slope Estimator Test

Sen's statistic is the median slope of each point-pairslope in a dataset (Sen, 1968). To perform the complete Sen's test, several rules and conditions should be satisfied; the time series should be equally spaced, i.e. the interval between data points should be equal. However, Sen's method considers missing data. The data should be sorted ascending according to time, and then apply the following formula to calculate Sen's slope estimator (Q) as the median of Sen's matrix members:

$$Q = \text{Median} \left\{ \left[\left[\frac{X_i - X_j}{i - j} \right]_{j=1}^{j=n-1} \right]_{i=j+1}^{i=n} \right\}$$

Where, Q = Sen's slope estimator, x = data value i and j = Counters, n = Number of data values in the series.

3. RESULTS AND DISCUSSION

3.1. Trends of Weather Parameters at Mulde Location

The trend analysis of different climatic variables such as maximum temperature (T_{Max}), minimum temperature (T_{Min}), rainfall (RF), morning relative humidity (RH I), afternoon relative humidity (RH II), evaporation (EVP), wind speed (WS) and sunshine hours (BSS) was carried out for 25 years data period the analysed mean annual data for aforesaid parameters are presented in Table 1.

3.2. Maximum Temperature (T_{Max})

The trend of maximum temperature was tested using linear regression method and it indicated that, it ranged from 0.01°C to 0.07°C for different periods.

The trend were made confirmed by MK test analysis and revealed that the trend of maximum temperature for different periods was significantly increasing except southwest monsoon. The conformity of trend for maximum temperature was tested at 95% level of significance and indicated that the trend was increasing at Annual ($z = 3.28$), Winter ($z = 3.28$), Summer ($z = 3.57$) and Northeast monsoon ($z = 2.75$). The magnitude of trend also estimated using sen's slope estimator and found that, it ranged from 0.01°C/year for south-west monsoon to 0.07°C/year for summer season and 0.04°C annually. The magnitude of maximum temperature was depicting in Table 1. The trends of annual maximum temperature using linear regression method and MK test are shown in Figure 1.

Table-1. Mann Kendall trend analysis and Sen's slope estimator of climatic variables for Mulde Maharashtra.

Parameters	Period	Z-statistics	Trend	Trend at 95 % significance level	Sen's slope	Confidence limits for slope at 95 % significance level	Linear regression slope
Tmax	Annual	3.28**	Increasing	Yes	0.046	Lower limit=0.025; Upper limit=0.065	0.0401
	Winter	3.28**	Increasing	Yes	0.057	Lower limit= 0.030; Upper limit= 0.090	0.0536
	Summer	3.57***	Increasing	Yes	0.069	Lower limit= 0.040; Upper limit= 0.100	0.0695
	Southwest monsoon	0.75	Increasing	No	0.014	Lower limit= -0.020; Upper limit= 0.044	0.0128
Tmin	Northeast monsoon	2.75**	Increasing	Yes	0.054	Lower limit= 0.014; Upper limit= 0.089	0.0495
	Annual	0.00	Increasing	No	0.000	Lower limit= -0.040; Upper limit= 0.060	0.0037
	Winter	0.07	Increasing	No	0.000	Lower limit= -0.075; Upper limit= 0.049	0.0048
	Summer	-0.30	Decreasing	No	-0.008	Lower limit= -0.062; Upper limit= 0.042	-0.0122
Rainfall (mm)	Southwest monsoon	-0.94	Decreasing	No	-0.013	Lower limit= -0.038; Upper limit= 0.020	-0.0148
	Northeast monsoon	0.80	Increasing	No	0.023	Lower limit= -0.040; Upper limit= 0.100	0.0334
	Annual	0.44	Increasing	No	9.456	Lower limit= -28.284; Upper limit= 45.375	4.4928
	Winter	0.44	Increasing	No	0.000	Lower limit= 0.000; Upper limit= 0.000	0.054
RH-I (%)	Summer	2.17*	Increasing	Yes	1.756	Lower limit= -1.407; Upper limit= 6.111	2.3609
	Southwest monsoon	-0.02	Decreasing	No	-1.700	Lower limit= -31.703; Upper limit= 33.576	0.8113
	Northeast monsoon	-0.26	Decreasing	No	-1.629	Lower limit= -8.732; Upper limit= 4.641	1.2666
	Annual	2.08*	Increasing	Yes	0.164	Lower limit= 0.001; Upper limit= 0.253	0.1745
RH-II (%)	Winter	1.80 ⁺	Increasing	No	0.253	Lower limit= -0.018; Upper limit= 0.400	0.2674
	Summer	2.17*	Increasing	Yes	0.196	Lower limit= 0.027; Upper limit= 0.363	0.2047
	Southwest monsoon	1.03	Increasing	No	0.051	Lower limit= -0.047; Upper limit= 0.134	0.0715
	Northeast monsoon	2.64**	Increasing	Yes	0.179	Lower limit= 0.061; Upper limit= 0.284	0.2112
Evaporation (mm)	Annual	3.69***	Increasing	Yes	0.457	Lower limit= 0.251; Upper limit= 0.621	0.4595
	Winter	3.53***	Increasing	Yes	0.679	Lower limit= 0.390; Upper limit= 1.037	0.6617
	Summer	2.03*	Increasing	Yes	0.285	Lower limit= 0.012; Upper limit= 0.530	0.3025
	Southwest monsoon	4.46***	Increasing	Yes	0.417	Lower limit= 0.269; Upper limit= 0.586	0.4016
Evaporation (mm)	Northeast monsoon	2.50*	Increasing	Yes	0.493	Lower limit= 0.106; Upper limit= 0.833	0.4592
	Annual	-2.27*	Decreasing	Yes	-13.697	Lower limit= -20.607; Upper limit= -2.162	-9.1902
	Winter	-2.34*	Decreasing	Yes	-2.536	Lower limit= -5.054; Upper limit= -0.459	-1.9142
	Summer	-1.0	Decreasing	No	-3.505	Lower limit= -5.961; Upper limit= 1.705	-1.6887
	Southwest monsoon	-2.87**	Decreasing	Yes	-5.687	Lower limit= -9.226; Upper limit= -2.484	-3.2823

	Northeast monsoon	-1.87 ⁺	Decreasing	No	-2.347	Lower limit= -4.921; Upper limit= 0.199	-2.305
Bright sunshine hours (hrs)	Annual	-2.25 [*]	Decreasing	Yes	-0.030	Lower limit= -0.060; Upper limit= -0.001	-0.0271
	Winter	-3.66 ^{***}	Decreasing	Yes	-0.050	Lower limit= -0.069; Upper limit= -0.025	-0.0463
	Summer	-2.81 ^{**}	Decreasing	Yes	-0.050	Lower limit= -0.093; Upper limit= -0.019	-0.0552
	Southwest monsoon	-1.69 ⁺	Decreasing	No	-0.040	Lower limit= -0.075; Upper limit= 0.000	-0.0236
	Northeast monsoon	-3.15 ^{**}	Decreasing	Yes	-0.042	Lower limit= -0.067; Upper limit= -0.019	-0.0436
Wind speed (Kmph)	Annual	-4.15 ^{***}	Decreasing	Yes	-0.118	Lower limit= -0.166; Upper limit= -0.073	-0.1138
	Winter	-3.93 ^{***}	Decreasing	Yes	-0.100	Lower limit= -0.133; Upper limit= -0.060	-0.092
	Summer	-4.49 ^{***}	Decreasing	Yes	-0.120	Lower limit= -0.165; Upper limit= -0.080	-0.1172
	Southwest monsoon	-3.53 ^{***}	Decreasing	Yes	-0.144	Lower limit= -0.192; Upper limit= -0.080	-0.1335
	Northeast monsoon	-3.30 ^{***}	Decreasing	Yes	-0.095	Lower limit= -0.147; Upper limit= -0.040	-0.0932

Note : Winter: Jan-Feb, Summer: Mar-May, Southwest monsoon: Jun-Sep, Northeast monsoon: Oct-Nov.

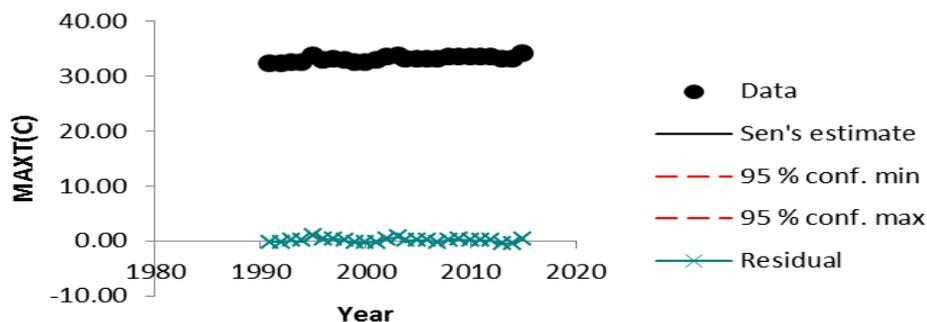


Figure-1. Annual trend analysis of maximum temperature (oC) at Mulde.

3.3. Minimum Temperature (T_{Min})

The linear regression analysis showed increasing trend for minimum temperature except summer and south west monsoon season. To confirmed the trend MK test was carried out with 95 % level of significance and indicated that the trend was non significantly increasing during different periods. The annual trend of minimum temperature using linear regression method given in Table 1 and shown in Figure 2.

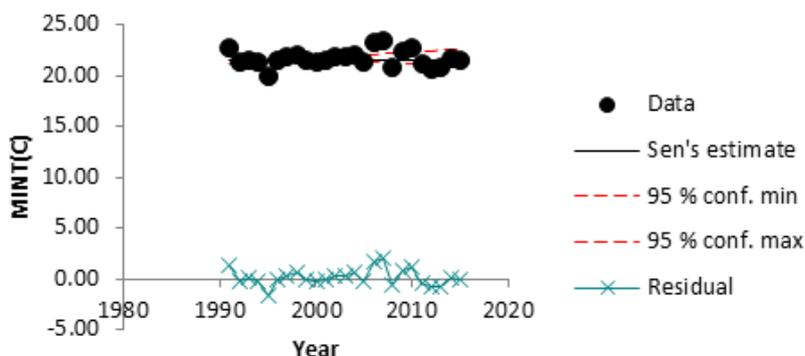


Figure-2. Annual trend analysis of minimum temperature (oC) at Mulde

3.4. Rainfall (RF)

The trend analysis for rainfall using linear regression analysis indicated that the trend was increasing for all periods except southeast and northwest monsoon season. For confirmation of trend, MK test was carried out and found that during annual, winter and summer trend was increasing but statistically non-significant at 95 % level of significance and during southwest mansoon and northeast monsoon decreasing trend but statistically non-significant at 95 % level of significance. The magnitude of trend was also estimated using sen slope and found within that rainfall increasing at the rate of 9.46 mm per year. The trends are shown in Figure 3 and details are given in Table 1.

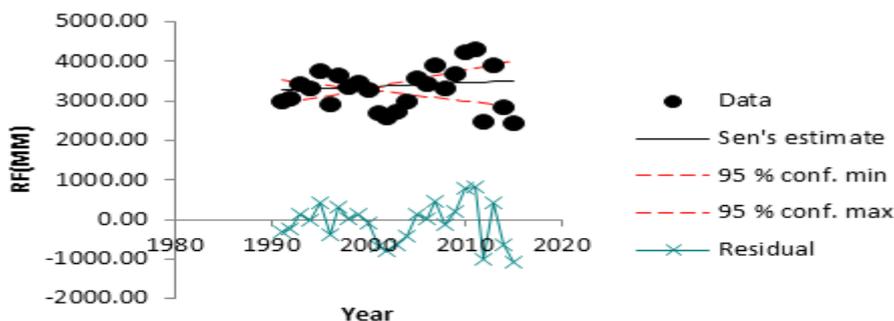


Figure-3. Annual trend analysis of rainfall (mm) at Mulde

3.5. Morning Relative Humidity (RH-I)

The trend analysis for morning relative humidity using linear regression analysis indicated that the trend was increasing for all periods. For confirmation of trend, Mann-Kendall test was carried out and found that during annual, summer and northeast season the trend was significantly increasing at 95 % level of significance. The magnitude of trend was also estimated using sen slope and found within limit at the rate of 0.05 % to 0.25 % per year for different periods. The trends are shown in Figure 4 and details are given in Table 1.

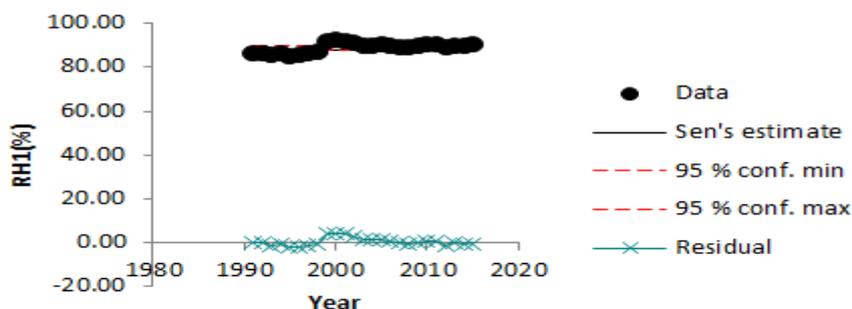


Figure-4. Annual trend analysis of morning relative humidity (RH-I) at Mulde

3.6. Afternoon Relative Humidity (RH-II)

The linear regression trend analysis was carried out for afternoon relative humidity and found that the trend was increasing for all periods. For confirmation of trend, MK test was carried out and found that for all periods the trend was increasing and statistically significant at 95 % level of significance. The magnitude of trend was also estimated using sen slope and found within limit at the rate of 0.28 % to 0.68 % per year for different periods. The details of statistical parameters are shown in Table 1 and Figure 5.

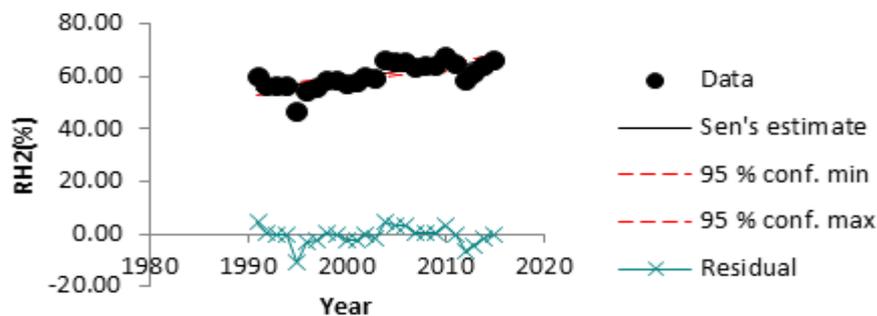


Figure-5. Annual trend analysis of afternoon relative humidity (RH-II) at Mulde

3.7. Evaporation (EVP)

The trend analysis for evaporation using linear regression analysis indicated that the trend was decreasing for all periods. For confirmation of trend, MK test was carried out and found that trends of all periods increasing and statistically significant at 95 % level of significance except summer and northeast monsoon. The magnitude of trend was also estimated using sen slope and found that evaporation decreasing annually by 13.69 mm. The trends are shown in Figure 6 and details are given in Table 1.

3.8. Bright Sunshine Hours (BSS)

The trend analysis for bright sunshine hours using linear regression analysis indicated that the trend was decreasing for all periods. For confirmation of trend, MK test was carried out and found that trend was decreasing and statistically significant at 95 % level of significance except southwest monsoon. The magnitude of the bright sunshine hours showing that bright sunshine hours decreasing at the rate of 0.03 hours per year. The trends are shown in Figure 7 and details are given in Table 1.

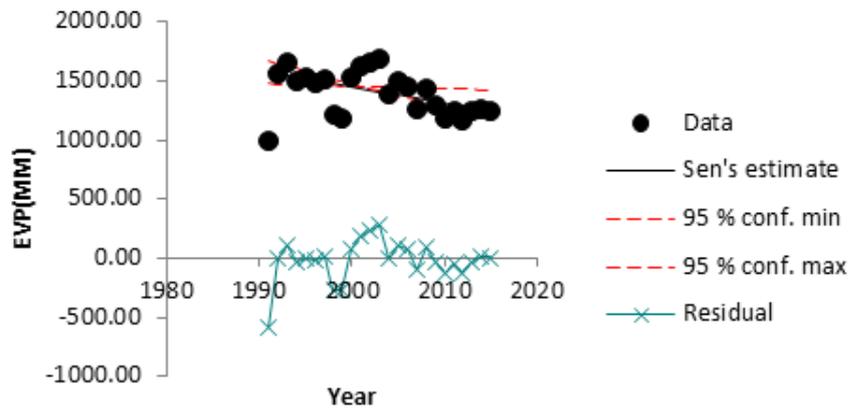


Figure-6. Annual trend analysis of evaporation (mm) at Mulde

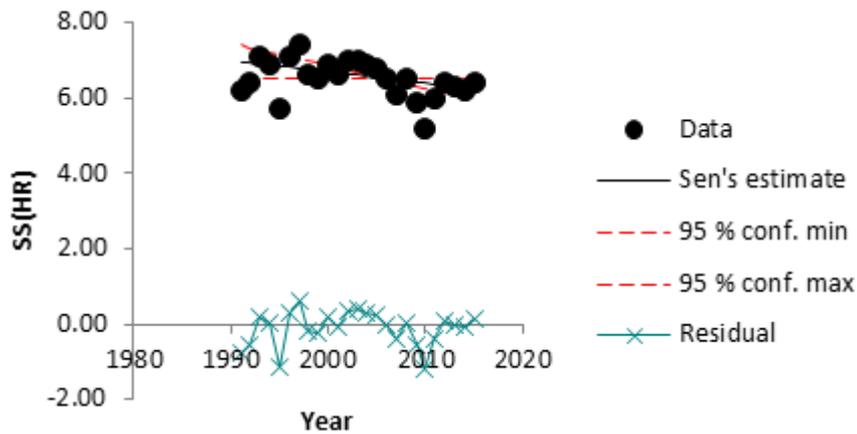


Figure-7. Annual trend analysis of bright sunshine hours (hr) at Mulde

3.9. Wind Speed (WS)

The linear regression trend analysis was carried out for wind speed for different period. The analysis showed that trend was decreasing for all periods. For confirmation of trend, MK test was carried out and found that during different periods trend was significantly decreasing at 95 % level of significance. The magnitude of wind speed was decreasing at the rate of 0.12 kmph per year. The detailed z values and sen slope estimator are presents in Table 1 and corresponding trend is shown in Figure 8.

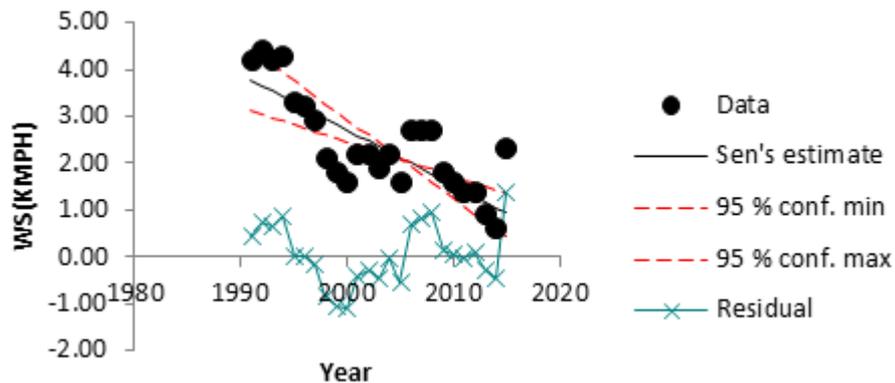


Figure-8. Annual trend analysis of wind speed (kmph) at Mulde

4. CONCLUSION

The trend of maximum temperature was tested and indicated that the trend was significantly increasing except southwest monsoon while in case of minimum temperature trend was non significantly increasing during different periods. In case of rainfall trend was increasing during annual, winter and summer but statistically non-significant at 95 % level of significance and during southwest monsoon and northeast monsoon decreasing trend but

statistically non-significant at 95 % level of significance. The trend analysis for morning relative humidity indicated that during annual, summer and northeast season the trend was significantly increasing at 95 % level of significance and while afternoon relative humidity, linear regression analysis indicated for all periods the trend was increasing and statistically significant at 95 % level of significance. The trend analysis using linear regression analysis for evaporation indicated that trends of all periods increasing and statistically significant at 95 % level of significance except summer and northeast monsoon while for bright sunshine hours indicated that trend was decreasing and statistically significant at 95 % level of significance except southwest monsoon. In case of wind speed, analysis showed that trend was significantly decreasing for all periods at 95 % level of significance.

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