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PARAMETRIC AND NON-PARAMETRIC TIME SERIES TREND ANALYSIS OF TEMPERATURE AND RAINFALL IN SRINAGAR KASHMIR

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ABSTRACT

A number of global studies have been conducted for identification and quantification of climate change impact on socio-economic divisions and ecosystems. Climate change also has a very pronounced effect on agriculture of a region. The present study was carried out with the aim of analyzing the local climate change trends in Srinagar, Kashmir. The time series of temperature and rainfall trends were analyzed using parametric linear regression and non-parametric Mann-Kendall tests at 5 % significance levels. The magnitude of the trend was quantified using Sen Slope index. Temporal trend analysis was performed for annual and monthly time series of Shalimar weather station for a period of 31 years (1985-2015). No significant variation was observed in annual maximum temperature (Z = 1.979), annual precipitation (Z = 0.48) and annual number of rainy days (Z = 0.194). A very small significant decreasing trend was observed in the annual mean minimum temperature by both linear regression (Z = -2.492) and Mann-Kendall methods (Z = -2.02). The annual minimum temperature showed a decrease by 0.02°C yr^{-1}. The minimum mean temperature exhibited a decreasing trend for the month of September (SSE = -0.050), while the monthly precipitation (SSE = 1.25) and number of rainy days (SSE = 0.074) for this month exhibited a significant increasing trend.

KEY WORDS
Parametric
Non-parametric
Linear Regression, Man-Kendall Test, Sen-Slope Estimate, Trend Analysis

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INTRODUCTION

The present study was aimed to study the trends exhibited by rainfall, rainy days and temperature over Srinagar, Kashmir. Sen's non-parametric estimator of slope was used to estimate the magnitude of trend. The statistical significance of the trends was assessed by the Mann–Kendall test. Trend analysis of a time series consists of the magnitude of trend and its statistical significance.

Global climate change has been the center of attention of scientific research efforts for more than three decades. These efforts aim at creating an awareness and addressing the problems of detrimental impacts on earth's environment as a result of human activities (Mohapatra, 2012). Climatic variability can be understood by examining the behavior climatic parameters, chiefly air temperature and precipitation. Climatic variability may be described as the annual disparity in the values of some particular climatic variables within an average period such as a 30-year period (Melillo et *al*., 1990). Climatic variation over both long and short time scales is exhibited by a number of regions globally (Houghton, 1995; Gardner et *al*., 1996). Agricultural and aquatic resources of agrarian countries are adversely affected by climate change and variation in climatic parameters (Sinha et *al*., 1998; Kumar et *al*., 2004; Mall et *al*., 2006). Animal and plant species have also been affected by the global climate change, especially in the recent past. The negative impacts of climate change have also been witnessed in aquatic flora and fauna (Saikia, 2013).

Precipitation is a crucial constituent of rainfall-runoff relations, and effects the assessment of floods and droughts in addition to the measures for their mitigation. Temperature has a very significant role in evaporation, transpiration and water requirement for plants animals and humans. Precipitation and air temperature are primary elements of weather systems. This necessitates the analysis of their behavior in order to understand climate variability. The spatial and temporal variation for both variables is also high at different local and worldwide levels. The range of variability for these climatic variables must be studied in order to predict forthcoming climatic conditions (Karabulut et *al*., 2008).

A number of meteorological studies have been conducted out for analyzing the trends in temperature and precipitation in different regions of the Himalayas. Warming temperature trends have been observed for many mountain ranges of South Asia comprising the Hindu Kush, Karakoram Himalaya belt (Viviroli et *al*., 2007). Seasonal temperatures of the Himalayas also exhibit a strong warming trend (Immerzeel et *al*., 2010). Increase in temperature also results in early runoff from snow and ice (Kaser et *al*., 2010; Siderius et *al*., 2013). Projected climate change models like SDSM (Statistical Downscaling Model) and ANN (Artificial Neural Network) have also predicted a warming trend in future (Parvaze et *al*., 2016).

Changes in the climate of the region can have a significant impact on vegetation and agriculture of the area. Temperature and precipitation changes also affect the storage and melting of snow which is very essential for the region. Agriculture and related sectors along with sectors of food and energy security are crucially dependent on the availability of timely and sufficient quantity of water. These sectors are also dependent on the climate of the place. Change in climate of a place has an effect on the rainfall and temperature patterns. This in turn has an impact on the water resources and increases the occurrence of extreme events like floods and drought.

In view of the above, the study aimed to investigate the trend of climatic variables for the Srinagar region of Kashmir Valley. The study was carried out using temperature and precipitation data from SKUAST-K weather station located in the Srinagar for a period of 31 years.

Study Area

The state of Jammu and Kashmir has a unique situate as far as its geographic location and topography are concerned. The topography is very undulating having an altitude range of 300-8400 m above mean sea level. This uneven altitude results in a severe climatic variability in the region. The summer capital of Jammu and Kashmir, Srinagar is located between 33º18¹ and 34º45¹ North and 74º56¹ and 75º79¹ East with an altitude of about 1586 m above mean sea level. Summer season is hot and humid while freezing cold is a characteristic of winter season. Heavy rainfall is experienced during spring season while snowfall occurs in winter. Temperature ranges from a minimum of about -13ºC in winter to a maximum of 36º C in summer. Annual Temperature and precipitation data of Srinagar District for 31 years (1985-2015) is presented in Figure 1.

MATERIALS AND METHODS

Observed daily maximum temperature, minimum temperature and precipitation data for a period of 31 years (1985-2011) obtained from Agromet field Unit -Srinagar weather station were reduced to annual time series of cumulative precipitation and average maximum and minimum temperature. The numbers of rainy days per year for the same period were also computed. The time series were then analyzed for presence of trends using parametric and non-parametric approaches.

In order to detect trends in climatic and hydrological variables, several statistical methods have been put to practice (Wang et *al*., 2009; Sonali and Kumar, 2013, Sayemuzzaman et *al*., 2015). These methods may be parametric or non-parametric. Parametric methods suppose a fundamental distribution (generally Normal) for the variables of interest; whereas non-parametric methods do not. The parametric trend analysis was performed using linear regression method while Mann-Kendall test was used for non-parametric trend analysis. The magnitude of the trend was quantified using another index, Sen Slope which is also non-parametric.

Linear Regression Trend

A straight line is fitted to the data and tested in order to determine whether the slope is different from zero or not. For a straight line of the form $y = a + bx$ the test statistic t is calculated and then tested using "Student's t-test".

Mann-Kendall Test

The Mann-Kendall statistic S of a series x is calculated as (Mann, 1945; Kendall, 1975):

$$s = \sum_{i=1}^{n-1} \sum_{j=i+1}^{n} \operatorname{sgn}(x_j - x_i)$$

Where,

$$\operatorname{sgn}(Xj - xi) = f(x) = \begin{cases} 1 \text{ if } (x_j > x_i) \\ 0 \text{ if } (s_j = x_i) \\ -1 \text{ if } (x_j < x_i) \end{cases}$$

The variance associated with the test static S is calculated as.

$$\operatorname{Var}(S) = \frac{n(n-1)\,2n+5) - \sum_{k=1}^{m} t_k\,(tk-1)\,2t_k+5)}{18}$$

Where,

m	=	No. of tied groups.
t_k	=	No. of data points in group k.

If the sample size is more than 10 (n > 10), the test statistic is calculated as.

$$ZMK = \begin{cases} \frac{S-1}{\sqrt{\operatorname{Var}(S)}} \text{ if } S > 0 \\ 0 \quad \text{if } S = 0 \\ \frac{S+1}{\sqrt{\operatorname{Var}(S)}} \text{ if } S < 0 \end{cases}$$

A trends is considered significant if |Z(S)| is more than the standard normal deviate ($Z_{(1-á/2)}$)for the chosen value of á. á is the significance level of the test (á = 0.05 and $Z_{(1-á/2)} = 1.96$in this study).

Sen-Slope Estimate

The Thiel-Sen slope (Sen, 1968; Thiel, 1950) is a non-parametric substitute to the Thiel-Sen slope can exceed up to 1.7 times than that of standard linear regression (Helsel and Hirsch, 1992; Sheskin, 2007; Sprent and Smeeton, 2007). The slope â between any two values of a time series x can be calculated as.

$$\beta = \frac{x_j - x_i}{j - i}, \; j \neq i$$

For 'n' observations, N = n (n-1)/2 values of â are possible. The median of these values is taken as the overall estimator of â. An 'upward trend' is indicated by a positive value of â indicates, while a 'downward trend' is specified by a negative value of â (Xu *et al.,* 2007).

RESULTS

Annual Trend

The maximum mean annual temperature was 21ºC and the

Table 1: Annual temperature and precipitation trends in Srinagar district

Time series	Linear Regression		Mann-Kendall Trend		Sen's Slope Estimate		
	Test Z	Result	Test Z	Result	Â	$â_{min95}$	$â_{max95}$
Maximum Temperature (ºC)	1.979	NS	1.67	NS	0.033	-0.005	0.072
Minimum Temperature (ºC)	-2.492	S	-2.02	S	-0.020	-0.036	0
Rainfall (mm)	0.48	NS	-0.27	NS	-1.486	-9.054	11.462
Rainy Days	0.194	NS	0.36	NS	0.091	-0.369	0.6

S = Significant; NS = Non- Significant

Table 2: Monthly temperature and precipitation trends in Srinagar

Month	Time Series	Linear Regression		Mann-Kendall Test		Sen-Slope Estimate		
		Test Z	RESULT	Test Z	RESULT	2	2_{min95}	2_{max95}
JAN	Maximum Temperature (°C)	2.019	NS	1.462	NS	0.097	-0.027	0.228
	Minimum Temperature (°C)	0.26	NS	-0.17	NS	-0.006	-0.079	0.086
	Rainfall (mm)	1.733	NS	1.7	NS	1.513	-0.318	3.199
	Rainy Days	0.772	NS	0.652	NS	0	-0.067	0.167
FEB	Maximum Temperature (°C)	-0.192	NS	-0.17	NS	-0.006	-0.073	0.067
	Minimum Temperature (°C)	0.462	NS	0.578	NS	0.013	-0.031	0.052
	Rainfall (mm)	1.764	NS	1.411	NS	1.371	-0.504	3.661
	Rainy Days	1.784	NS	1.835	NS	0.1	0	0.2
MAR	Maximum Temperature (°C)	1.787	NS	2.278	S	0.102	0.013	0.198
	Minimum Temperature (°C)	-0.595	NS	-0.357	NS	-0.009	-0.053	0.03
	Rainfall (mm)	0.127	NS	-1.054	NS	-1.22	-4.86	1.443
	Rainy Days	-1.403	NS	-1.3	NS	-0.111	-0.25	0.045
APR	Maximum Temperature (°C)	0.631	NS	0.442	NS	0.015	-0.059	0.08
	Minimum Temperature (°C)	-1.272	NS	-0.952	NS	-0.016	-0.047	0.021
	Rainfall (mm)	0.138	NS	0.476	NS	0.396	-2	2.909
	Rainy Days	0.687	NS	0.996	NS	0.067	-0.076	0.2
MAY	Maximum Temperature (°C)	0.921	NS	0.765	NS	0.048	-0.071	0.15
	Minimum Temperature (°C)	-1.519	NS	-1.632	NS	-0.035	-0.071	0.009
	Rainfall (mm)	-1.376	NS	-1.394	NS	-1.2	-2.768	0.538
	Rainy Days	-2.232	S	-2.351	S	-0.118	-0.2	0
JUN	Maximum Temperature (°C)	-0.313	NS	-0.034	NS	-0.001	-0.067	0.058
	Minimum Temperature (°C)	-1.601	NS	-1.088	NS	-0.039	-0.094	0.025
	Rainfall (mm)	0.662	NS	1.02	NS	0.378	-0.631	1.653
	Rainy Days	0.987	NS	1.11	NS	0.037	0	0.143
JUL	Maximum Temperature (°C)	2.006	NS	1.632	NS	0.035	-0.006	0.076
	Minimum Temperature (°C)	-1.954	NS	-1.36	NS	-0.039	-0.08	0.014
	Rainfall (mm)	-0.148	NS	0.272	NS	0.133	-2.091	1.901
	Rainy Days	0.213	NS	-0.352	NS	0	-0.077	0.045
AUG	Maximum Temperature (°C)	2.129	S	1.836	NS	0.041	-0.004	0.075
	Minimum Temperature (°C)	-0.857	NS	-0.714	NS	-0.019	-0.051	0.028
	Rainfall (mm)	1.005	NS	0.816	NS	0.917	-1.261	3.253
	Rainy Days	0.819	NS	0.617	NS	0	-0.088	0.176
SEP	Maximum Temperature (°C)	-1.122	NS	-1.156	NS	-0.031	-0.082	0.018
	Minimum Temperature (°C)	-2.404	S	-2.074	S	-0.05	-0.107	-0.003
	Rainfall (mm)	2.147	S	2.515	S	1.25	0.222	2.508
	Rainy Days	2.496	S	2.032	S	0.074	0	0.158
OCT	Maximum Temperature (°C)	1.783	NS	1.564	NS	0.052	-0.019	0.11
	Minimum Temperature (°C)	-0.342	NS	-0.34	NS	-0.011	-0.065	0.047
	Rainfall (mm)	-1.294	NS	-1.021	NS	-0.576	-1.685	0.554
	Rainy Days	-0.858	NS	-0.364	NS	0	-0.111	0.053
NOV	Maximum Temperature (°C)	-0.026	NS	-0.476	NS	-0.019	-0.077	0.064
	Minimum Temperature (°C)	-0.285	NS	-0.34	NS	-0.005	-0.049	0.04
	Rainfall (mm)	-0.042	NS	0.804	NS	0.33	-0.514	1.2
	Rainy Days	0	NS	0.434	NS	0	-0.059	0.083
DEC	Maximum Temperature (°C)	2.002	NS	1.632	NS	0.044	-0.011	0.108
	Minimum Temperature (°C)	-1.59	NS	-1.428	NS	-0.04	-0.106	0.022
	Rainfall (mm)	-2.291	S	-0.784	NS	-0.7	-2.901	0.575
	Rainy Days	-1.326	NS	-1.001	NS	0	-0.162	0

least mean minimum temperature was 6ºC in the years 2001 and 2013 respectively. The total precipitation in the study area ranged from a minimum of 445 mm in the year 1999 to a maximum of 1754 mm in the year 2015. The variation in annual mean maximum, mean, minimum, total precipitation and annual number of rainy days is shown in Figure 2. The annual statistical parameters are tabulated in Table 1.

A slight increasing trend was observed in the annual precipitation by linear regression method. But, Mann-Kendall test suggests a slight decreasing trend for annual precipitation with Sen Slope of -0.27 mm/year. However, both these trends are statistically insignificant at 5% significance level. Model projections for the same region also indicate a slight increase in precipitation for the region in future (Parvaze et *al.*, 2017).

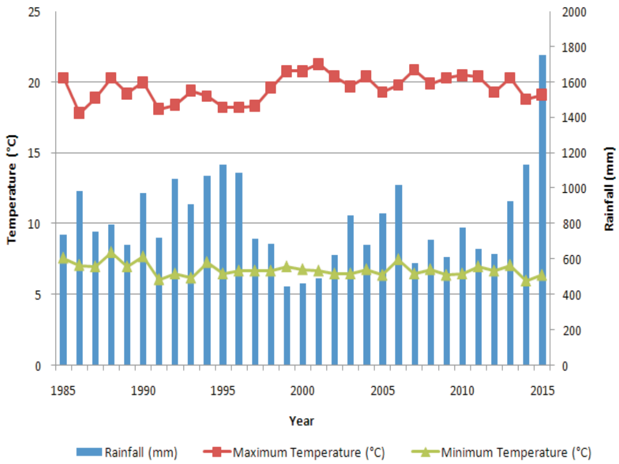

Figure 1: Annual Temperature and precipitation data of Srinagar District for 31 years (1985-2015)

The trends shown by annual mean maximum temperature, rainfall and rainy days were statistically insignificant. A significant decreasing trend was exhibited by annual mean minimum temperature with a Sen-Slope estimate of -0.020ºC/year. The annual number of rainy days also showed a statistically insignificant increasing trend. The trends in annual precipitation and temperature by linear regression method are shown in Figure 2.

The trend exhibited by annual mean maximum temperature and mean minimum temperature, by Mann-Kendall test is shown in Figure 3 and that of total precipitation and annual number of rainy days is shown in Figure 4.

Monthly Trend

The monthly mean maximum temperature, mean minimum temperature, rainfall and number of rainy days did not exhibit statistically significant trends with respect to time for most of the incidences. The results obtained by linear regression analysis are in agreement with those obtained by Mann-Kendall trend analysis except for few instances. The monthly statistical parameters are tabulated in Table 2. A statistically significant

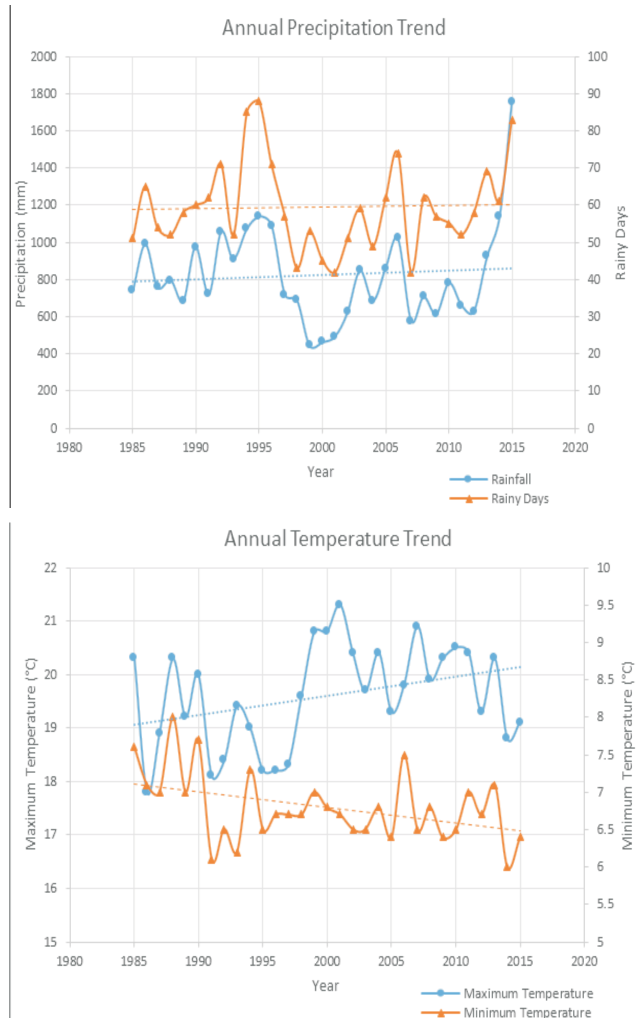

Figure 2: Annual Precipitation and temperature trend in district Srinagar by linear regression method.

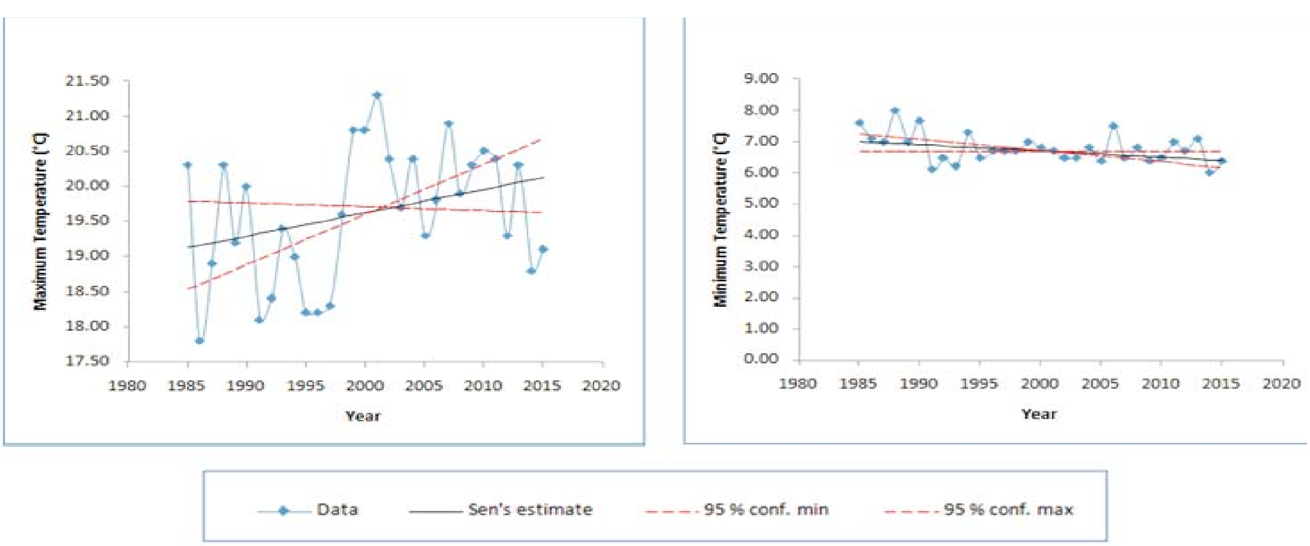

Figure 3 : Annual Temperature trend in Srinagar by Man-Kendall test along with Sen-Slope estimate.

decreasing trend was observed in the number of rainy days in the month of May. The month of September indicated a statistically significant decreasing trend in case of mean minimum temperature decreasing by 0.05°C in the month. A general increasing pattern in the monthly precipitation for September for the region has also been predicted by climate prediction models (Parvaze et *al.*, 2016). The total monthly precipitation and the number of rainy days indicated a statistically significant increasing trend increasing by 1.25mm and 0.074 days respectively in the month of September.

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