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TREND ANALYSIS OF METEOROLOGICAL VARIABLES USING MANN KENDAL & SEN’S SLOPE ESTIMATOR: A CASE STUDY OF LASBELA (BALOCHISTAN)

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Abstract

This study is focused on to determine the district Lasbela's rainfall and temperature trends as a sign of the region's climatic variability. Nonparametric Mann-Kendall test and Sen’s slope estimation techniques are used to analyses trends for monthly rainfall and temperature data for 21 years (1999-2020). In terms of rainfall, only the month of December exhibits a negative tendency; the other months fall into a positive trend. In terms of temperature, eight months exhibit a negative trend; the remaining four exhibit a positive trend. Neither a statistically significant trend in rainfall nor a trend in temperature are seen. While Sen's slope for temperature shows no change for five months, February, June, July, August, and September, the remaining months—January, March, April, May, October, November, and December show a negative trend. Sen's slope also shows no change in the size of the trend for rainfall.

Keywords: Climate change, Mann-Kendall test, Rainfall, Sen’s slope estimator, Temperature, Trend analysis.

INTRODUCTION

Disasters regarding climate are affecting our natural ecosystem, society, economy, water resources, and many more. The research community in every country has paid close consideration to how climate change is affecting rainfall and air temperatures. Numerous studies have been conducted to demonstrate that these variations in rainfall and temperature are becoming visible on a worldwide scale (Karmeshu & Neha 2015).

According to studies, the rate of global surface warming from 1906 to 2005 was 0.74 to 0.18 °C (IPCC, 2007). The main cause of the greenhouse gas emissions that cause environmental change in many regions of the world is thought to be human activity. The changing amount, kinds, and spatial and temporal fluctuation of rainfall, which is

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increasing worse in some regions of the world, is one of the best effects of environmental change (Zamani et al. 2018). According to IPCC assessments, the impact of climate change will be severe in the future and will result in a decrease in the availability of freshwater. Additionally, a projected 0-30% drop in annual average runoff has been identified for the middle of the twenty-first century (IPCC, 2007). With long-term data, numerous scholars have added to the study of climate change (Serra et al., 2001; Marengo, 2004). The analysis of various time series data has demonstrated that both the trend in temperature and rainfall are either declining or growing. Due to the effects of agriculture and irrigation techniques on land usage, human involvement is also contributing to climate change (Kalnay and Cai, 2003). The global climate is changing because of differences in temperature and rainfall. Because trend detection of hydrological variables like discharge, direct runoff, and precipitation provides useful information on the likelihood of change in the variables' tendency in the future, trend analysis has proven to be an excellent technique for water resources planning, design, and management (Hamilton et al. 2001; Yue and Wang 2004; Dinpashoh et al. 2014). Understanding the characteristics of local precipitation and temperature variations is particularly important for determining how environmental change affects agriculture, the environment, the hydrologic cycle, and human society. (Karl, 1998; Piao et al., 2014; Friedlingstein et al., 2010; Chen et al., 2014; Yu et al., 2014; Wang et al., 2017).

District Lasbela (Balochistan) was devastated by floods in 2022, so it also needs to be investigated by researchers to find the factors behind such havoc. In such a scenario of climatic change, this study will be helpful to understand the temperature and rainfall variations and trends for better planning in an agricultural country like Pakistan.

MATERIAL & METHODS

Study Area

District Lasbela in Balochistan (Pakistan) is located on the coast. Having an area of 18.254 km2, it is located at 25°47'11" N and 66°36'12" E (Wikipedia, 2022). Lasbela is renowned for its distinctive geographic makeup, which includes hilly areas and an amazing beach. The weather at Lasbela is hot, dry, and desert-like. Several degrees above the Tropic of Cancer. However, because of the sea breezes, the weather is less severe than in interior Balochistan, where summertime temperatures can approach 50 °C (Wikipedia2022). Huge rainfall variations were experienced here, and flash floods in summer 2022 damaged the whole district that is why this area is selected for study.

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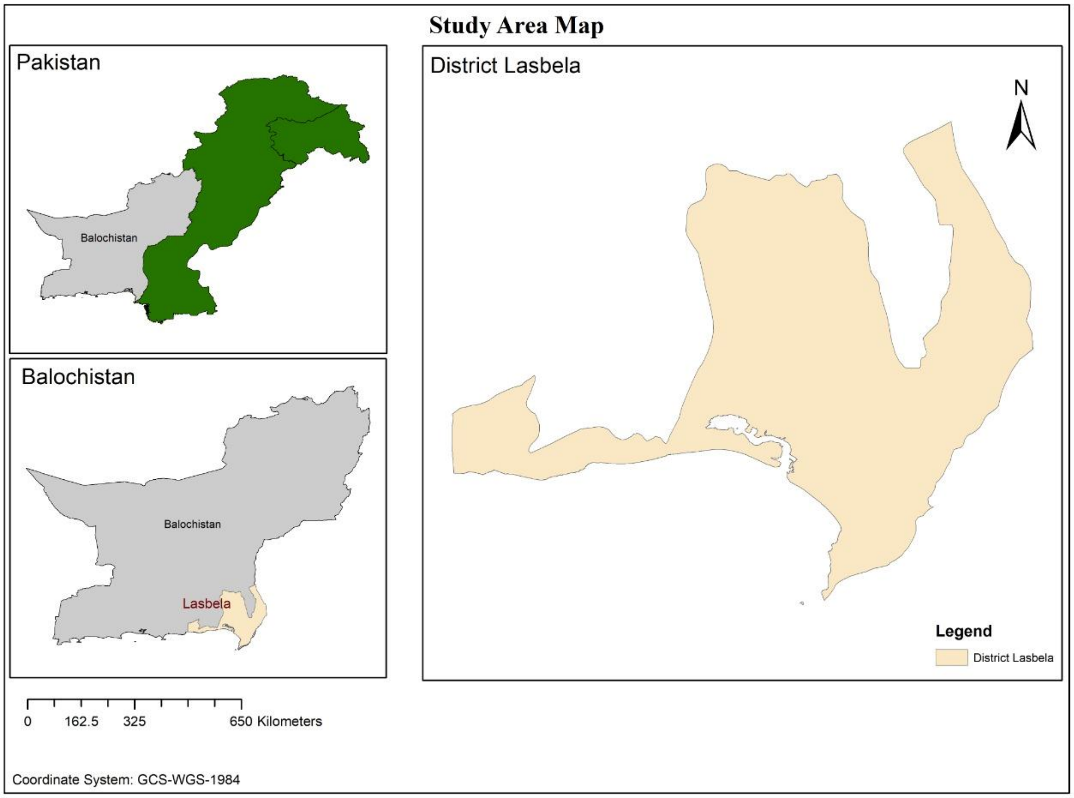

Figure 1: Map of the study area

Data Used

For Lasbela (Balochistan), rainfall and temperature data from 1999 to 2020 have been used. The Pakistan Metrological Department (PMD) provided the data. All statistics are performed using EXELSTAT.

Trend Analysis

Trend analysis has been done with the help of the Mann-Kendall test. The Mann-Kendall test (Mann 1945; Kendall 1975) is a popular test. Even the World Meteorological Organisation (Mitchell et al., 1966) has advised. It is used to determine whether there is a substantial upward or downward trend in a set of data over time.

Mann Kendall Test

It is a non-parametric test and does not need the data set to have a normal distribution. This test can have two outcomes: the null hypothesis for this test is given as H0 = there is no trend, and the alternative hypothesis is H1 = there is a significant trend. The Mann-Kendall test is calculated as shown below.

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$$S = \sum_{k=1}^{n-1} \sum_{j=k+1}^{n} \operatorname{sgn}(xj - xk) \qquad \begin{aligned} \operatorname{sgn}(xj - xk) &= 1 \quad \text{if } xj - xk > 0 \\ &= 0 \quad \text{if } xj - xk = 0 \\ &= -1 \quad \text{if } xj - xk < 0 \end{aligned}$$

Where xj and xk are values of years, j > i to avoid negative values, and N is the number of data points. The sign (xj-xk) is computed as shown above. A high value of S is a marker for an increasing trend, while a very low negative value shows a decreasing trend. The Z values indicate the presence of a statistically significant trend.

Sen's Slope Estimator

The scale of a trend over a time series can be quantified using Sen's estimator. It is a non-parametric method that gives out a positive value for an increasing trend, a negative value for a decreasing trend, and a zero value for no trend.

RESULTS & DISCUSSIONS

Numerous researchers choose the nonparametric M-K test when analysing trends (Jain & Kumar 2012). To determine the magnitude of trends in the data time series, a non-parametric technique (Sen, 1968) is applied.

Rainfall

A non-parametric Mann-Kendal test is applied to 21-year rainfall data from Lasbela station (Balochistan, Pakistan). Trend analysis for every individual 12 months is done.

For trend analysis, two assumptions were established to interpret the results:

- H0: There is no monotonic trend in the series.
- H1: There is a trend in the series. Therefore, we must accept the null hypothesis H0 if the estimated p-value is higher than the level of significance alpha = 0.05. First, using the null hypothesis that there is no trend, we determined the 5% criterion, and then we evaluated the trend using this threshold. (Kasri, et.al.)

Table 1 shows the analysis of rainfall data and depicts that there is no significant trend. The positive Z-value for indivisible 12 months for 21 years indicates an increasing trend for all months except December. December is in the negative, which means a decreasing trend.

Table 1 also shows Sen's slope, which indicates the slope magnitude for each month from January to December for 21 years. From January to December, there is no variation in Sen's slope.

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Table 1: Mann Kendall's test and Sen's slope estimator on rainfall data

Months 1999-2020)	Z-Value (M-K test)	Sen's Slope	P-Value (Spearman)	Test Interpretation
January	0.104	9.091	0.530	H0 Accept
February	O	0	1.00	H0 Accept
March	0.212	0.002	0.189	H0 Accept
April	0.313	0.271	0.049	H0 Reject
May	0.214	0.723	0.175	H0 Accept
June	0.123	0.05	0.411	H0 Accept
July	0.113	0.308	0.480	H0 Accept
August	0.276	0.93	0.079	H0 Accept
September	0.283	0.003	0.084	H0 Accept
October	0.277	0	0.122	H0 Accept
November	0.512	0	0.003	H0 Reject
December	-0.028	0	0.895	H0 Accept

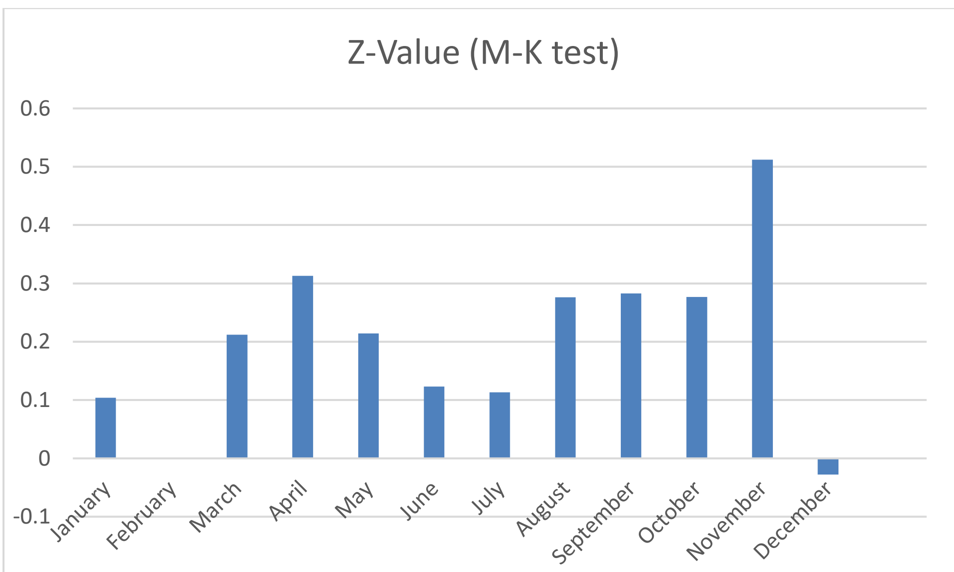

Figure 2: Rainfall trend for individual months for 21 years

Temperature

A non-parametric Mann-Kendal test is applied to 21-year rainfall data from Lasbela station (Balochistan, Pakistan). Trend analysis for every individual 12 months is done.

For trend analysis, two assumptions were established to interpret the results:

- H0: There is no monotonic trend in the series.
- H1: There is a trend in the series. Therefore, we must accept the null hypothesis H0 if the estimated p-value is higher than the level of significance alpha = 0.05.

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First, using the null hypothesis that there is no trend, we determined the 5% criterion, and then we evaluated the trend using this threshold. (Kasri, et.al.)

The study of the temperature data is shown in Table 2, which demonstrates that there is no discernible trend. Only three of the 21 years' positive Z-values suggest a growing trend, while the eight other years' negative Z-values indicate a falling trend.

Table 2 also displays Sen's slope, which represents the slope magnitude for each month from January to December over a 21-year period. Five months—February, June, July, August, and September—show no change in Sen's slope, but the remaining months show a downward trend.

Table 2: Mann Kendall's test and Sen's slope estimator on temperature data

Months 1999-2020)	Z-Value (M-K test)	Sen's Slope	P-Value (Spearman)	Hypothesis
January	-0.123	-0.025	0.445	H0 Accept
February	0.052	0.02	0.756	H0 Accept
March	-0.204	-0.069	0.194	H0 Accept
April	-0.193	-0.05	0.224	H0 Accept
May	-0.035	-0.007	0.843	H0 Accept
June	-0.004	0	1.00	H0 Accept
July	0.123	0.027	0.445	H0 Accept
August	0	0	1.000	H0 Accept
September	0.170	0.04	0.283	H0 Accept
October	-0.270	-0.064	0.085	H0 Accept
November	-0.305	-0.075	0.054	H0 Accept
December	-0.258	-0.05	0.101	H0 Accept

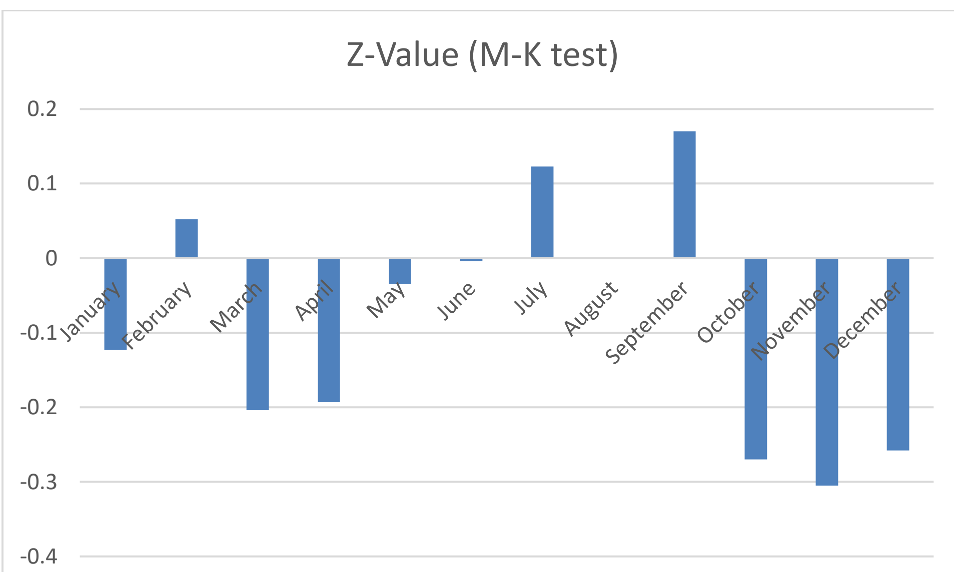

Figure 3: Temperature trend for individual months for 21 years

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CONCLUSION

Sen's slope estimators and the MK test were applied to the District Lasbela (Balochistan) rainfall and temperature data. For trend analysis, data for 12 months spanning a 21-year period from 1999 to 2020 is provided by the Pakistan Meteorological Department (PMD).

However, only the month of December exhibits a negative trend, with the remaining eleven months exhibiting positive values and a positive trend, according to the results for rainfall data, which indicate that there is no discernible pattern. The trend's size is also unchanged according to Sen's slope.

The same test is applied to temperature data for 21 years, from 1999 to 2020, for 12 months. The results for temperature also show no significant trend. Eight months show negative trend and four months show zero values. Sen's slope show no change for five months February, June, July, August, and September and remaining months of January, March, April, May, October, November and December showing negative trend.

In case of rainfall both negative and positive trends are observed, but they are not very significant. Still the eleven months, with an increasing trend along with increasing slope magnitude and decreasing trend with decreasing magnitude depict changes in the trend of the study area. Further investigation may turn up additional factors that will aid in preventing floods from destroying this area.

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