Jilin Daxue Xuebao (Gongxueban)/Journal of Jilin University (Engineering and Technology Edition)
ISSN：1671-5497
E-Publication Online Open Access
Vol: 41 Issue: 09-2022
DOI 10.17605/OSF.IO/XT2R4

RAINFALL TREND ANALYSIS USING MAN-KENDAL TEST AND THE SEN'S SLOPE ESTIMATOR IN ZHOB DISTRICT OF BALOCHISTAN

ROMANA IFTIKHAR[1*], SAID QASIM[1], GHULAM MURTAZA[2], SABIHA MENGAL[1], UZMA MUKHTAR[3] and JAMAL-UD-DIN[2]

[1]Department of Geography & Regional Planning, University of Balochistan, Quetta Pakistan.
E-mail: ambgeog@gmail.com
*(Corresponding author)
[2]Department of Disaster Management and Development Studies, University of Balochistan, Quetta.
[3]Commerce Department, University of Balochistan, Quetta.

Abstract

This research is mainly based on rainfall variability in Zhob district of Balochistan. Balochistan is the largest province of Pakistan as far as area is concerned. A drought is the most frequently faced disaster in Zhob district. Zhob not only receives the winter rainfall from western depression but also receives some rainfall from the summer monsoon as well. For sustainable growth and better management of water resources, it is highly recommended to use resources wisely. Rainfall variability is one of the effects of climate change. That is why spatial and temporal analysis of rainfall is getting huge attention from scientists internationally. Rainfall data for district Zhob of 22 years (1999- 2020) was analyzed to find the annual trend of rainfall. The trend analysis was done through the Man-Kendal test & Sen's slope estimator. The results indicate that there are positive and negative trends but are not statistically significant. High rainfall variability is also found.

Keywords: Rainfall Variability, Man-Kendal Test, Sen's Slope Estimator, Temporal, Rainfall Trend.

INTRODUCTION

Climate change due to global warming is the main issue in recent times. Global warming is creating variations in rainfall patterns at both global as well as regional scales. (Shahid 2012). The extreme environmental conditions will get more strength in future due to climate change (Kaushik and Sharma 2015; Lembi et al. 2020; Yokomatsu et al. 2020). The change in the amount of rainfall is the deviation in rainfall from average or the ratio of the standard deviation of rainfall from the mean of rainfall or the variability of coefficient of variation (Priyan 2015). Useful planning and management of floods and droughts need a complete record of rainfall fluctuations (Hussain & Lee 2016). The poor Asian countries will face worse effects of climate variability in the near future (IPPC 2007). Spatial-temporal variability in January precipitation is also observed in Pakistan. (Ahmad et al. 2014).

Balochistan is primarily covered by hyper- and semi-arid regions, with annual rainfall ranging from 30 to 397 mm. (Ahmed et al. 2014). Balochistan province is an arid area which gets 210 mm of annual rainfall. Usually, the monsoon did not reach Balochistan. The province has some monsoon rainfall in the summer season (Ch et al. 2009). The

Jilin Daxue Xuebao (Gongxueban)/Journal of Jilin University (Engineering and Technology Edition)
ISSN：1671-5497
E-Publication Online Open Access
Vol: 41 Issue: 09-2022
DOI 10.17605/OSF.IO/XT2R4

rough terrain of Balochistan together with high rainfall variability may affect it dangerously and will produce more droughts (Ashraf et al. 2021). Rainfall in areas of Balochistan shows a high coefficient of variability (Naheed & Rasool 2011). Due to high number of dry episodes, Zhob with some other parts of Balochistan could face worst climate change effects. (Naz et al. 2020).

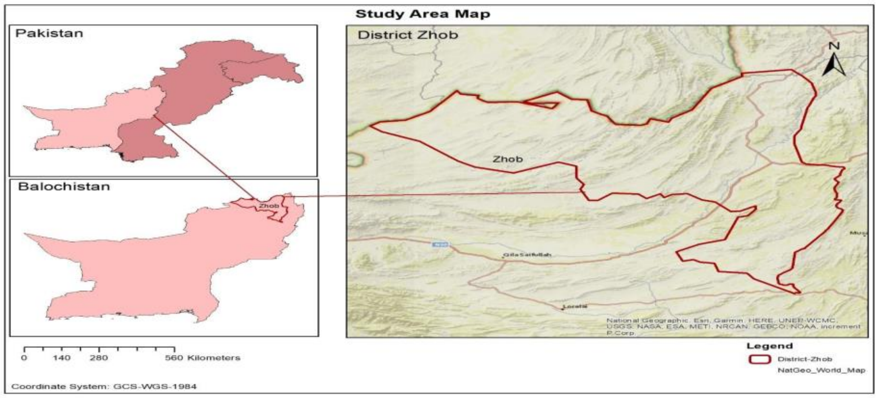
In Balochistan, the Zhob District has experienced climate variability in the last few decades (Baber & Baber 2019) Proper management is needed to deal with rainfall variations and drought, especially in the arid and semiarid climate of Balochistan (Rafiq et al. 2022) Food production from agricultural farms has decreased due to variation in rainfall and temperature (Baber & Baber 2019). Such variations result in floods and drought. Drought is one of the high-risk disasters (Tirivarombo et al. 2018). Drought effects are economic, social and environmental also (Sharma et al. 2009). Understanding the temporal pattern of rainfall trends examined in this work is a fundamental and crucial prerequisite for managing water resources and ensuring food security.

Introduction of the Study Area

District Zhob was selected for the research purpose. The purpose of selecting this area lies in its interesting location as it lies in the monsoon region and receives rainfall from the monsoon winds, unlike other Balochistan. Zhob district lies between 69°44'43" east longitudes and 31°57'32" at north latitudes, and covers an area of 12,400 square kilometres, and 4,659 ft. Elevation (Figure 1).

The topography within 2 miles of Zhob contains significant variations in elevation, with a maximum elevation change of 515 feet and an average elevation above sea level of 4,661 feet. Within 10 miles it contains significant variations in elevation (3,494 feet). Within 50 miles also contains extreme variations in elevation (10,062 feet). The province's topography is made up of high mountains, low mountains, plains, and deserts. Depending on the geography, different temperatures and rainfall patterns exist.

Figure 1: Study area



METHODOLOGY

Rainfall data for each month was collected from Pakistan meteorological department in the Zhob region for a time period of 22 years from 1999 to 2020. Rainfall analysis was carried out each month for all years. Maximum, minimum, mean, standard deviation, coefficient of variation (%), skewness and kurtosis for rainfall data were calculated for all 22 years. The data were statistically analyzed using XLSTAT software. Trends were identified via the Mann-Kendall test and the extent was estimated using Sen's slope estimator. All data were processed using XLSTAT software studying the spatiotemporal changes in rainfall for the area of Zhob.

Mann-Kendall test

The Mann-Kendall test (Mann 1945; Kendall 1975) is a widely used test even recommended by World Meteorological Organization (Mitchell et al. 1966) to compute a significant trend for a data set over a time period, which shows an upwards or downwards trend. It is a non-parametric test and does not require the data set to have a normal distribution. This test can have two outcomes,

The null hypothesis for this test given as H_0 = there is no trend; and

Alternative hypothesis H_1 = there is a significant trend.

Mann-Kendall test is calculated as shown below.

$$S=\sum_{k=1}^{n-1}\sum_{j=k+1}^{n}\operatorname{sgn}(xj-xk)$$

$$\begin{aligned}\operatorname{sgn}(xj-xk)&=1 \quad \text{if } xj-xk>0\\ &=0 \quad \text{if } xj-xk=0\\ &=-1 \quad \text{if } xj-xk<0\end{aligned}$$

Where xj and xk are values of years, j > i to avoid negative values and N is the number of data points. Sign (xj-xk) is computed as shown above. A high value of S is a marker

Jilin Daxue Xuebao (Gongxueban)/Journal of Jilin University (Engineering and Technology Edition)
ISSN：1671-5497
E-Publication Online Open Access
Vol: 41 Issue: 09-2022
DOI 10.17605/OSF.IO/XT2R4

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 and Discussion

Statistics for rainfall data is done from 1999 to 2020 for 22 years for district Zhob (Balochistan) is shown in the table 1. It shows Annual Rainfall, Maximum, Minimum, Mean, Standard Deviation, and Coefficient of Variance in percentage, Skewness and Kurtosis.

Table 1: Precipitation data, Zhob

Year	Annual	Max	Min	Mean	SD	CV (%)	Skewness	Kurtosis
1999	199.80	57.90	0.00	16.65	19.72	118.42	1.10	0.19
2000	163.40	82.00	0.00	13.62	23.19	170.27	2.72	7.99
2001	117.70	30.50	0.00	9.81	9.44	96.29	1.04	0.65
2002	276.60	48.00	0.00	23.05	16.49	71.54	-0.06	-0.96
2003	243.30	87.00	0.00	20.28	28.61	141.09	1.51	1.46
2004	184.90	38.30	0.00	15.41	13.48	87.50	0.92	-0.56
2005	359.80	118.20	0.00	29.98	37.46	124.94	1.43	1.49
2006	303.60	62.20	0.00	25.30	22.00	86.96	0.58	-1.18
2007	357.40	81.50	0.00	29.78	32.38	108.73	0.85	-0.96
2008	304.70	122.00	0.00	25.39	36.32	143.03	2.20	4.51
2009	269.50	99.40	0.00	22.46	28.86	128.51	1.94	4.24
2010	301.80	118.40	0.00	25.15	43.95	174.74	1.95	2.35
2011	109.60	35.50	0.00	9.13	12.62	138.14	1.61	1.42
2012	262.60	53.50	0.00	21.88	20.40	93.23	0.39	-1.36
2013	220.90	52.50	0.00	18.41	20.05	108.90	0.76	-1.14
2014	191.00	33.00	0.00	15.92	12.59	79.10	-0.13	-1.79
2015	368.10	117.00	5.00	30.68	30.47	99.33	2.37	6.35
2016	120.00	43.00	0.00	10.00	15.67	156.73	1.60	1.35
2017	194.70	47.00	0.00	16.23	17.12	105.51	0.70	-0.90
2018	181.00	44.00	0.00	15.08	14.60	96.80	0.90	-0.22
2019	389.00	94.00	0.00	32.42	30.10	92.86	0.82	-0.22
2020	299.00	108.00	0.00	24.92	28.74	115.33	2.46	7.21

Jilin Daxue Xuebao (Gongxueban)/Journal of Jilin University (Engineering and Technology Edition)
ISSN：1671-5497
E-Publication Online Open Access
Vol: 41 Issue: 09-2022
DOI 10.17605/OSF.IO/XT2R4

According to table 1. Maximum Mean rainfall is 32.42mm in the year 2019 while Minimum is 9.1mm in 2011. Coefficient of Variance (CV) indicates the degree of variability, with less variability (CV 20%), moderate variability (20 CV 30%), high variability (CV > 30%), extremely high variability (CV > 40%), and extremely high variability (CV > 70%) of rainfall between years. (Ashraf & Routray 2015). It is observed that all the months had above 70% of CV which means that extremely high variability of precipitation in district Zhob. It ranges from71.5% for the year 2002 to 174.7%, in 2010.As in the previous studies also (Ashraf & Routray 2015)

To check the normal distribution of rainfall skewness and kurtosis is done (Thenmoshi & Kottiswaran 2016). According to table no.1 the data was asymmetrical and was right tailed, some is left tailed and the rest was symmetrical or normally distributed. Kurtosis is highest for the year 2000 which indicates that data is highly peaked near mean, while 2016 have lowest value of kurtosis. Only some of the years have standard normal distribution.High values of kurtosis and skewness show that the data set is asymmetric while low value means symmetric. The highest year of rainfall is 2019 and the lowest year is 2011, which is 389 mm and 109 mm.

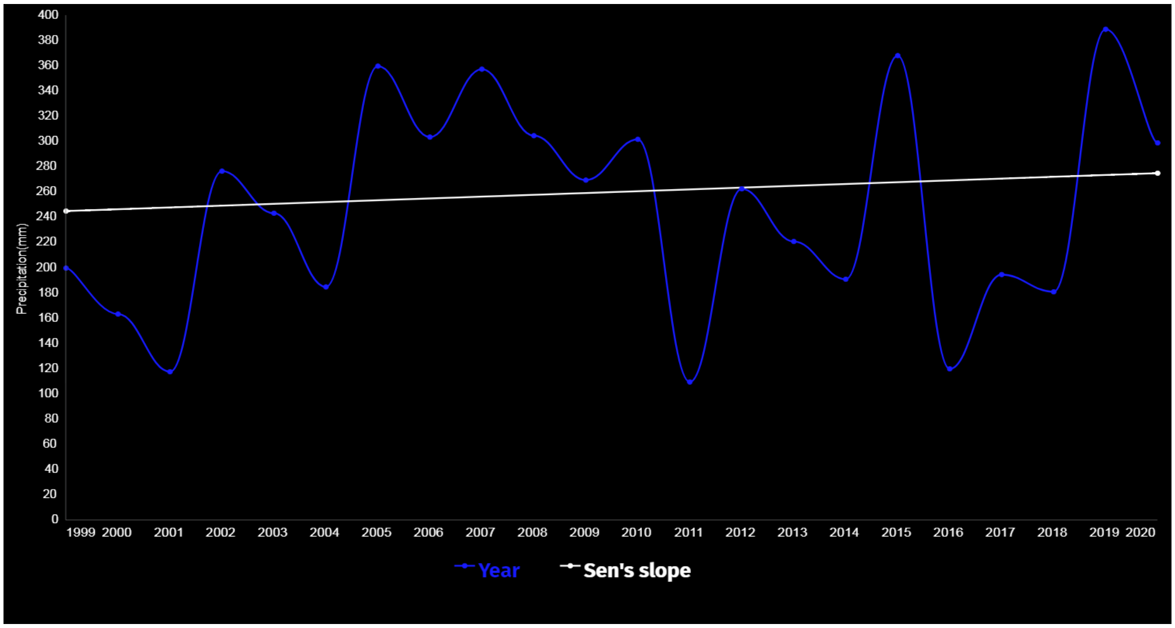
Men Kenda l& San’s Slope Estimator

Table 2: Statistical test results

Month (1999-2020)	Z-Value (M-K test)	Sen's Slope	P-Value (Spearman)	Hypothesis
Jan	0.088	0.217	0.591	H_0
Feb	-0.075	-0.375	0.651	H_0
Mar	-0.061	-0.207	0.714	H_0
Apr	0.279	1.000	0.075	H_0
May	0.268	0.500	0.090	H_0
Jun	0.087	0.160	0.592	H_0
Jul	-0.108	-0.910	0.499	H_0
Aug	0.200	0.873	0.204	H_0
Sep	-0.169	-0.200	0.293	H_0
Oct	-0.034	0.000	0.877	H_0
Nov	0.237	0.118	0.154	H_0
Dec	-0.114	0.000	0.500	H_0

Jilin Daxue Xuebao (Gongxueban)/Journal of Jilin University (Engineering and Technology Edition)
ISSN：1671-5497
E-Publication Online Open Access
Vol: 41 Issue: 09-2022
DOI 10.17605/OSF.IO/XT2R4

Figure 2: Sen's Slope (1999-2020)



M-K test is nonparametric test for analysis of trend; it is chosen by many investigators (Jain & Kumar 2012). So, M-K Test and San's Slope estimator were applied on monthly data of 22-year for District Zhob (Balochistan), results of which are shown in table2. M-K test is applied to detect monotonic trend either upward or downward.

In the observations, no statistically significant trend appeared at 95% confidence level by all trend tests, as depicted in table 2. Generally, for the whole study area, six months had positive trends while the remaining six had negative ones. Although, no month for the time series showed a statistically significant trend in precipitation. Only 2 months of October and December showed a Sen's slope of 0 while the rest had a positive or a negative value, indicating a statistically non-significant trend (Figure 2). Furthermore, in all cases, the results of Mann-Kendall and Sen's T-tests were successfully verified by Spearman's method as shown in table 2. All 12 P-values were greater than 0.005 significance hence the null hypothesis cannot be ignored.

M-K test and Sen's slope for all years were calculated and the M-K value is 0.065 while the Sen's slope value is 1.244. Even though both show a slightly positive trend throughout the 21-year data collection period as the values are positive, the P-value is greater than 0.005 at 0.693 hence the null hypothesis cannot be ignored and the tests are statistically insignificant.

ISSN：1671-5497
E-Publication Online Open Access
Vol: 41 Issue: 09-2022
DOI 10.17605/OSF.IO/XT2R4

CONCLUSION

Annual rainfall trend was calculated through Man Kendal's Test and San's Slope Estimator. For such investigation rainfall data for the 22years from 1999 to 2020 of 12 months were analyzed. The results indicated a slight increase in trend statistically insignificant. A higher value of the coefficient of Variance shows extremely high inter-annual variability of rainfall which depicts high rainfall variability in the study area, more than 70% for all years. Uncertainties in the deepness of rainfall are explained by CV (Farhana and Rahaman 2011). Almost all Balochistan falls in arid region having annual rainfall less than250mm (Rafiq et al.2022)

It is expected that climate variability could be a serious challenge then climate change, if it increasing trend is on the same pace spatially and temporally. (Naheed & Rasool 2011) From the above studies, it is observed that district Zhob of Balochistan (Pakistan) is facing high rainfall variability. Zhob was one of the affected areas of drought in Balochistan several times. (Ashraf et al. 2021) Early 1985, mid-1999, late 2000, late 2010, mid-2013, and mid-2016 were the driest periods for Zhob. (Naz et al. 2020) The population here is very poor and already have shortage of food. High rainfall variation would lead to more severe droughts, which will affect the food security. Serious steps need to be taken abut climate related issues because population is increasing and provision of food is at stake.

Serious measures have to be taken to manage water resources which is important for sustainable development. In order to save the study area from the shortage of food production in the form of fruits and vegetables. District Zhob is connecting KPK with Balochistan. It not only fulfils its local demand but also sends fruits and vegetables to the rest of the country. It should be taken very seriously by the policy makers.

References

Ahmad, I., Ambreen, R., Sultan, S., Sun, Z.B. and Deng, W.T. (2014). Spatial-Temporal Variations in January Precipitation over the Period of 1950-2000 in Pakistan and Possible Links with Global Teleconnections, Geographical Perspective. American Journal of Climate Change: 3: 378-387.

Ahmed, K., Shahid, S., Harun, S. (2016). Characterization of seasonal droughts in Balochistan province, Pakistan. Stochastic Environmental Research Risk Assessment. 30:747–762.

Ashraf, M., Arshad, A., Patel, P.M., Khan, A., Qamar, H., Sundari, R.S., Ghani, M.U., Amin, A., Babar, J.R. (2021). Quantifying climate-induced drought risk to livelihood and mitigation actions in Balochistan, Natural Hazards. 109: 2127–2151.

Ashraf M., Routray J. K. (2015) Spatio-temporal characteristics of precipitation and drought in Balochistan Province, Pakistan, Natural Hazards. 77:229–254

Baber, J., Baber, N. (2019). Climate change impacts on agriculture productivity in district Zhob. A time series analysis International Journal of Biosciences, 5:41-49.

ISSN：1671-5497
E-Publication Online Open Access
Vol: 41 Issue: 09-2022
DOI 10.17605/OSF.IO/XT2R4

Farhana, S. and M.M. Rahaman. (2011). “Characterizing rainfall trend in Bangladesh by temporal statistics analysis.” ISBN: 978-984-33-4363-5.

Hussain M. S., Lee S. (2016). Investigation of summer monsoon rainfall variability in Pakistan Meteorology and Atmospheric Physics. 128: 465–475.

IPCC AR4 SYR (2007), Core Writing Team; Pachauri, R.K; and Reisinger, A. (ed.), Climate Change 2007 :Synthsis Report Contribution of Working Groups I, II and III to the Fourth assessment report of the Intergovernmental Panel on Climate Change, IPCC, ISBN 92-9169-122-4.

Jain, S.K. and Kumar, V. (2012) Trend Analysis of Rainfall and Temperature Data for India. Current Science, 102, 37-49.

Kaushik, G., Sharma, K.C. (2015). Climate change and rural livelihoods-adaptation and vulnerability in Rajasthan. Global Nest Journal, 17(1):41-49.

Kendall MG (1975) Rank correlation measures. Charles Griffin, London

Lembi, R.C., Cronemberge, C., Picharillo, C. (2020). Urban expansion in the Atlantic forest: applying the nature futures framework to develop a conceptual model and future scenarios. Biota Neotropica, 20.

Mann HB (1945) Non-parametric tests against trend. Econometrica 13:245–259

Mitchell JM, Dzerdzeevskii B, Flohn H, Hofmeyr WL, Lamb HH, Rao KN, Walle´n CC (1966) Climate change, WMO technical note No. 79, World Meteorological Organization, Geneva.

Naheed, G. & Rasul G., (2011). Investigation of Rainfall Variability for Pakistan. Journal of Meteorology, 7(14): 25-32.

Naz F, Dars GH, Ansari K, Jamro S, Krakauer NY(2020). Drought Trends in Balochistan. Water. 12(2):470.

Priyan, k. (2015). Spatial and Temporal Variability of Rainfall in Anand District of Gujarat State. Aquatic Procedi, 4: 713 – 720.

Rafiq, M., Li, Y.C., Cheng, Y., Rahman, G., Ikram Ullah, Ali, A. (2022). Spatial and temporal fluctuation of rainfall and drought in Balochistan province, Pakistan. Arabian Journal of Geosciences, 15:214.

Shahid, S., (2012). Rainfall variability and changes in Bangladesh during the last fifty years. Rainfall Behavior for casting and distribution, 1-24.

Sharma A, Dadhwal VK, Jeganathan C, Tolpekin V (2009) Drought monitoring using the Standardized Precipitation Index: a case study for the state of Karnataka, India. Geospatial Appl Pap Environ 6

Solomon, S., Qin, D., Manning, M., Chen, Z., Marquis, M., Averyt, K.B., Tignor, M. and Miller, H.L., Eds., IPCC (2007). Climate Change 2007, The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment. Report of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge, New York, 996.

Tirivarombo S, Osupile D, Eliasson P (2018) Drought monitoring and analysis: Standardized Precipitation Evapotranspiration Index (SPEI) and Standardized Precipitation Index (SPI). Phys Chem Earth, Parts A/B/C 106:1–10. https://doi.org/10.1016/j.pce.2018. 07.001

Yokomatsu, M., Ishiwata, H., Sawada, Y. (2020). A multi-sector multi-region economic growth model of drought and the value of water. A case study in Pakistan. International J Journal of Disaster Risk Reduction, 43:1-18.