International Journal Of Advance Research, Ideas And Innovations In Technology

ISSN: 2454-132X
Impact factor: 4.295
(Volume3, Issue2)
Available online at www.ijariit.com

Trend Analysis Of Precipitation Data And Its Spatio-Temporal Assessment in West Flowing River Basin Of Kutch, Saurashtra, And Marwar (WFR-KSM) Basin, India

Ila Agnihotri
Regional Remote Sensing Centre-West (Rrsc-W/Nrsc), Indian Space Research Organization, Jodhpur, Rajasthan, India.
ilaagni@gmail.com

Dr. M. P. Punia
Birla Institute of Technology, Jaipur, Rajasthan, India.

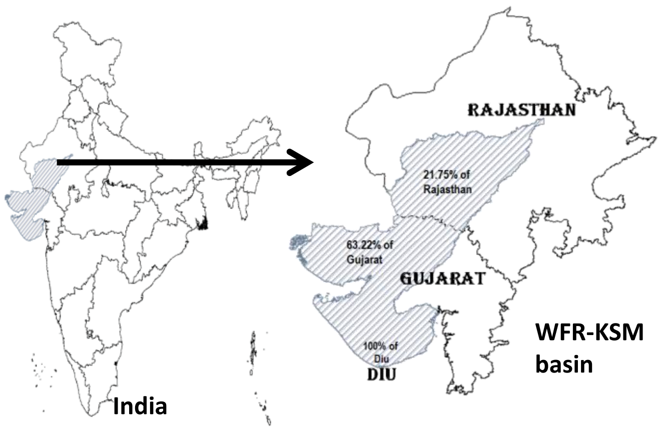
Dr. J. R. Sharma
National Remote Sensing Centre (NRSC), Indian Space Research Organization, Jodhpur, Rajasthan, India.

Abstract: The society and economy of India are crucially dependent on monsoon rains for its agriculture needs. The assessment of spatial and temporal aspects of trends in precipitation is critical for this region of India as the basin has areas which frequently experience draughts and water scarcity. The purpose of this research was to investigate the spatiotemporal variations in precipitation in terms of month wise, monsoon and annual trends in West Flowing River Basin of Kutch, Saurashtra and Marwar (WFR-KSM basin).The trend was calculated and assessed in ProUCL5.0.00 and ArcMap 10 software using Indian Meteorological Department (IMD) Precipitation grid data (0.25° x 0.25°) with a temporal resolution of 1964-2013 representing 50 years daily data. The direction and magnitude of annual, monsoon and month wise trends in long-term precipitation data were calculated for every grid using Mann-Kendall (MK) test and Theil- Sen's (TS) slope.Annually and in monsoon season, the increasing trend in precipitation was exhibited by the major part of the basin. The decreasing trend was confined to northern and north-eastern regions. The month wise trend analysis indicated either no grid or few grids exhibited a trend in non-monsoon months. The June, July, August, September (monsoon) months exhibited spatial variation in trends. The majority of the grids in June, July and August months exhibited increasing trends and a few grids with declining trend were clustered mainly in western and north-eastern part of the basin.

Keywords: Trend, Climate, Precipitation, Rainfall, Remote Sensing, GIS, Spatial, Mann-Kendall test, Theil- Senslope.

I. INTRODUCTION

Precipitation constitutes an important component of the water cycle. The variation in precipitation influences the amount of water flowing through the water cycle, and consequently the water availability in a region. The precipitation becomes even more important when it is an important driver of socio-economic life of a country. The society and economy of India are crucially dependent on rains for its agriculture needs. The amount and distribution of monsoon season (June to September) rains determine the economy as well as influence the livelihood of the majority of the agriculture-dependent rural population of India. The vulnerability to small variations in monsoon rainfall is very high for the society. The impending threats of climate change are going to further increase the vulnerability of this population. Thus for ensuring the food security and keeping pace with the economy, it is essential to provide scientific outputs to the planners in terms of annual, seasonal and month wises patio-temporal analysis of rainfall. The assessment of spatial and temporal aspects of trends in precipitation is critical for this region of India as the basin has areas which frequently experience draughts and water scarcity. The purpose of this research was to investigate the spatiotemporal variations in precipitation in terms of month wise, monsoon and annual trends.



Map 1: Location of WFR-KSM Basin

II. STUDY AREA

The study area is West Flowing River Basin of Kutch, Saurashtra, and Marwar (WFR-KSM basin)[1]. This basin is located in western India and is defined by the rivers flowing westwards towards the Arabian Sea with their respective drainage areas. The basin has an area 1,84,865.96 Sq. Km and is located in the states of Rajasthan (13 Districts), Gujarat (13 Districts), and Daman & Diu (1 District). The area represents a wide diversity of relief features and variability in terms of topography. In the west lie shallow wetlands of Rann of Kutch; the eastern area is bounded by river Banas and hilly terrain of Aravalli hills; northern part is represented by Luni river which is an active tectonic-sedimentary basin and southern part is covered by other important smaller rivers such as Shetrunji, Machhu, Ruben, and Bhader.

III. LITERATURE REVIEW

The studies by eminent organizations indicated an increase in global precipitation [2, 3, 4, 5, 6] and predicted an increase in the number of heavy precipitation events in a number of regions [7, 8, 9]. World Bank [3] mentioned an increase in the frequency & intensity of draughts in the Asian region. Rathore, Attri, and Jaswal [10] found out an increasing trend in Gujarat and declining trend over Rajasthan monsoon season rainfall. There are guidelines suggested by WMO [11] indicating the use of none- parametric tests with datasets having high variability. The use of Mann–Kendall (MK) trend test [12] combined with Theil-sen slope [13] as robust estimators of trend in the analysis of precipitation data is demonstrated by several authors Hirsch et al. [14], Lettenmaier et al. [15], Burn and Hag-Elnur [16], Alexander et al. [17], Frichet al.[18], Domroes and El-Tantawi [19], Hundecha and Bardossy [20] and Shen et al. [21].

IV. SOFTWARE, DATA AND ANALYTICAL METHODS

The trend was calculated and assessed in ProUCL5.0.00 and ArcMap 10 software using Indian Meteorological Department (IMD) Precipitation grid data (0.25° x 0.25°) with a temporal resolution of 1964-2013 representing 50 years daily data. The trends in long-term precipitation data were calculated for every grid in every month, monsoon season and annually using Mann-Kendall (MK) test and Theil- Sen's (TS) slope for the estimation of direction and magnitude of trends.

The Mann-Kendall (MK) trend test is a nonparametric test for the determination of the direction of the trend and it does not require the data to follow any specific distribution [12], [13], [22].The MK test indicates the presence of potential increasing or decreasing trends based on test statistic, S, which is computed by analyzing all pairs of the time series data and scoring & adding the score of each pair. For a dataset of size, n, there are n(n-1)/2 distinct pairs.

The test statistic, S is given as

$$S = \sum_{i=1}^{n} \sum_{j=i+1}^{n} \text{sgn}(y_j - y_i)$$

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

Based on the value of S, the conclusions about the presence or absence of trend are derived.

The TS trend test is used to determine the magnitude of the trend over time. The TS trend test has no assumption regarding the normal distribution of residuals and their homoscedastic (having equal variance over time) nature. The TS trend line estimates the changes in the median value of the variable with time. In this test, simple slopes are calculated for each pair of data, and the median slope value is extracted as TS slope. Let y_1, y_2,…, i_n represent ordered measured observations. For each successive observation for every j which is greater than I, the pairwise slope was calculated as

$$m_{ij} = \frac{(y_j - y_i)}{j - i}$$

The calculated pairwise slopes are ordered from smallest to largest and relabeled as m(1), m(2)… m(n). The median slope (Q) or TS slope can be computed depending on whether the sample has even or odd observations as follows.

$$Q = \begin{cases} m_{([N+1]/2)} \text{ if N = odd} \\ \frac{(m_{([N/2])} + m_{([n+2])/2})}{2} \text{ if N = even} \end{cases}$$

V. METHODOLOGY

IMD daily precipitation data was extracted from grid format to 0.25-degree grids. The grids in WFR-KSM basin were clipped in ArcMap environment. The month wise, monsoon and annual rainfall for every year were calculated and assigned to each grid. The MK test statistic and TS slopes for the month wise, monsoon and annual precipitation for every grid was calculated in ProUCL5. The calculated slopes were arranged using MS-excel and ASAP utilities and were attached to the grids. The spatial maps were generated and interpreted using ArcMap.

VI. RESULTS

The trends in annual, monsoon and month wise precipitation are presented grid-wise, where 348 grids covered the entire basin. The spatial interpretation of annual, monsoon and month wise trends are as follows.

The trend in annual rainfall (Map 2) indicated an increasing trend in most of the basin except some northern and north-eastern grids which exhibited decreasing trend. MK test statistics suggested that 91.09% grids indicated the presence of potential increasing trend over time, 8.91% grids suggested the presence of a potential decreasing trend over time. TS slope estimates detected that overall slope ranges from -3.9 to 9.6 mm/yr and 87.93% of all grids exhibit a positive slope. The higher end of slope range (>8mm/yr) is clustered around southern and south-western part of our study area. The declining trend was associated with north-eastern grids of the basin.

The monsoon season trend (Map 2) also indicated an increasing trend in most of the basin except some northern and north-eastern grids which exhibited decreasing trend. MK test statistics indicated that 92.53% grids indicated the presence of potential increasing and 7.18% grids suggested the presence of a potential decreasing trend with time. TS slope estimates indicated that 96.55% of all grids exhibited upward/downward trend ranging from -3.2 to 9.6 mm/yr. 89.37% of all grids exhibited a positive slope with higher slope (>8mm/yr) clustering in southern and south-western part of the basin and higher declining slope in the north-eastern part of the basin.

The trend in month wise precipitation (Map 3) was analyzed in all the grids for all the months. The trend calculations in terms of MK test indicated a presence of potential increasing/decreasing trend in the grids but TS slope indicated the absence of a trend in most of the months except in monsoon months.

In MK test analysis, some grids indicated potential increasing trend (29.89% in January, 81.61% in February, 48.56% in March, 94.25% in April, 50.86% in May, 83.05% in June, 60.06% in July, 85.34% in August, 100% in September, 84.48% in October, 6.03% in November, 67.24% in December). Potential decreasing (66.95% in January, 15.52 % in February, 47.99% in March, 4.60% in April, 47.7% in May, 16.09% in June, 39.94% in July, 14.66% in August, 14.94% in October, 90.80% in November, 30.17% in December).

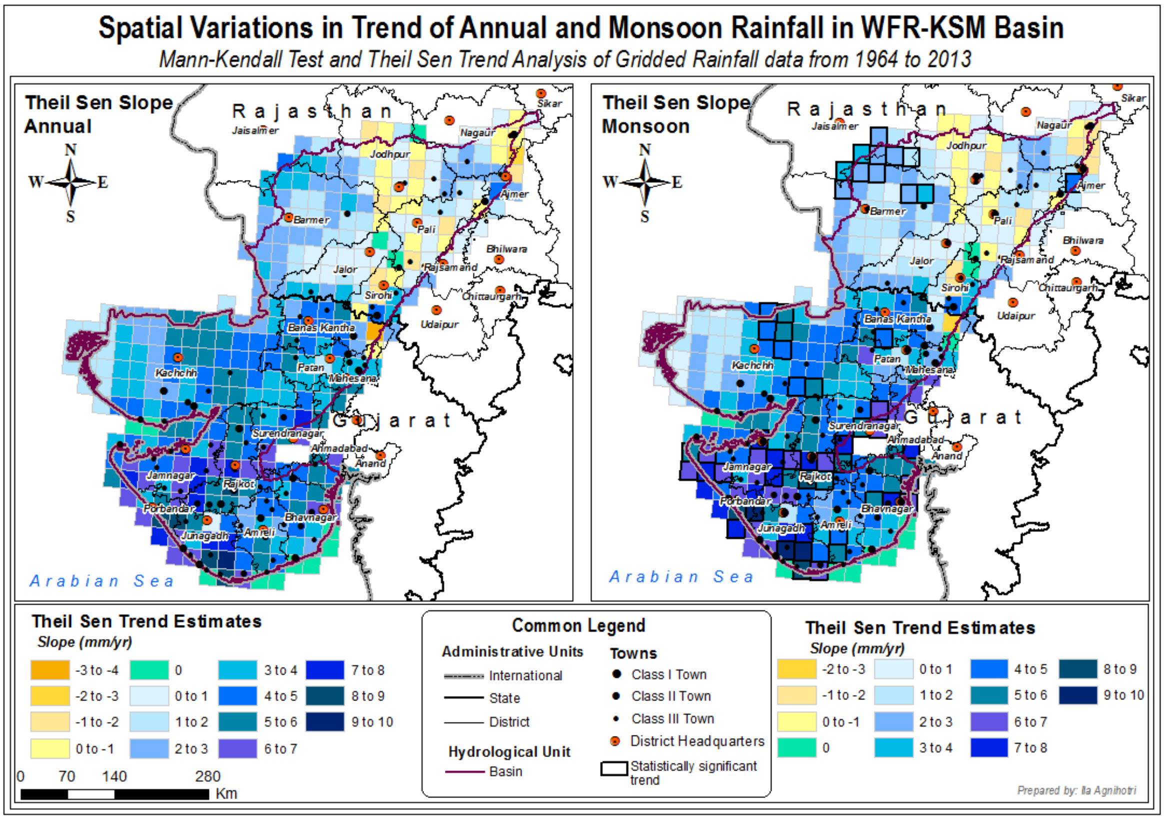
TS slope indicated the absence of a trend in any of the grids in the months of January, February, March, November and December. A few grids indicated the presence of a trend in April, May, and October. Three grids with increasing trend (0.1 mm/yr) in the north-western part of the basin in April, One grid (-0.1 mm/yr) in the north-eastern part of the basin in May. In October, few grids (4.89%) exhibited increasing trend by 0.1 mm/yr in the southern part of the basin.

The monsoon months from June to September exhibited spatial variations in precipitation trend. TS trend variations were exhibited by 80.75% of all grids in June ranging from -0.7 to 1.7 mm/yr, with the dominantly increasing trend throughout the basin and clustering of declining trend in north-eastern part of the basin. In July, 91.95% of all grids exhibited spatial variations in trend ranging from -1.7 to 3.1 mm/yr, with the dominantly increasing trend and clustering of declining trend in western and northern (including north-eastern and north-western) part of the basin. In August, 93.39% of all grids exhibited spatial variations in trend ranging from -2 to 2.4 mm/yr, with the dominantly increasing trend and clustering of declining trend in western and northern part of the basin. In September, 96.55% of all grids exhibited increasing trend ranging from 0.1 to 2.3 mm/yr, no grid exhibited declining trend.

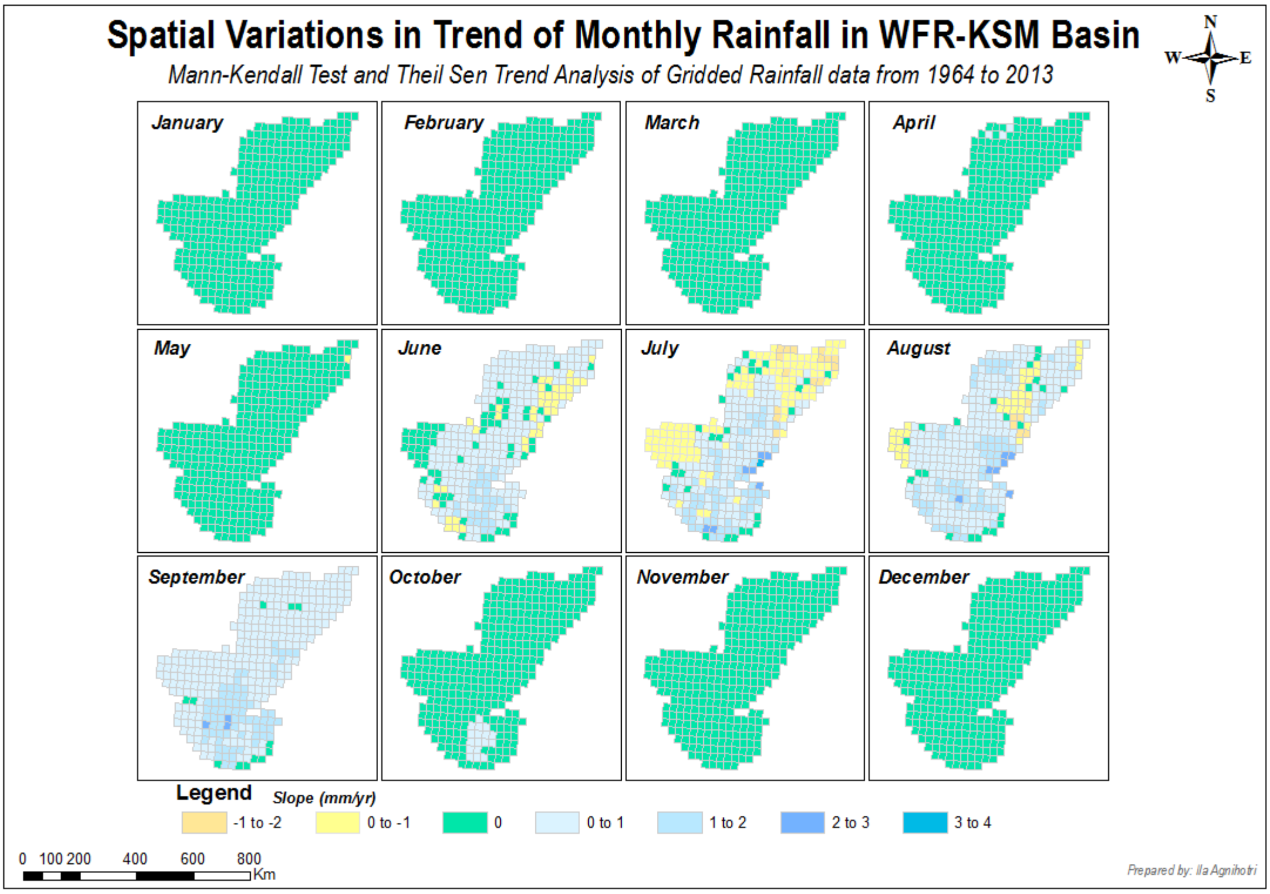
CONCLUSION

Spatial analysis of 50 years daily annual and monsoon rainfall (grid wise analysis) indicated increasing trend in major part of the basin. The decreasing trend was observed in northern and north-eastern grids in Jodhpur, Pali, Sirohi, and Nagaur districts of Rajasthan. The analysis indicated an increasing trend with a movement towards a wetter climate in precipitation in the majority of the basin. The month wise spatial analysis indicated that none to few grids indicated a precipitation trend in non-monsoon months. The June, July, August, September (monsoon) months exhibited spatial variation in trends. The majority of the grids exhibited increasing trends in rainfall and a few grids with declining trend were clustered in June, July, and August months. In June, the declining trend clustering was exhibited by the grids in the north-eastern border in Pali district of the basin. In July the clustering was observed in western (Kutch district) and north-eastern border (Jodhpur, Pali, Nagaur, some part of Barmer districts) of the basin. In August the clustering was observed in the western border (Kutch district) and northern part (Jalor, Sirohi and some part of Jodhpur districts) of the basin.

Map 2: Spatial Variations of trend in Annual and monsoon rainfall in WFR-KSM Basin



Map 3: Spatial Variations of month wise trend of rainfall in WFR-KSM Basin



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