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Research Paper

Innovative trend analysis of rainfall and temperature over Nubra Valley, Ladakh

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ABSTRACT

Climate change impacts on mountains have increased over the past few decades, with evident and significant consequences for people and ecosystems. This study investigates the long-term trend in rainfall and temperature (1951-2022) over Nubra Valley, Ladakh, India employing the Innovative Trend Analysis (ITA) using IMD gridded (0.25^{o} x 0.25^{o}) rainfall and (1.0^{o} x 1.0^{o}) temperature data. The results of ITA indicate a significantly increasing trend in rainfall at various time scales; in contrast, November shows a significantly decreasing trend in the northern region. The minimum temperature (Tmin) and maximum temperature (Tmax) trend reveals an increasing trend in different months, seasons and annual basis, except for a significant decreasing trend during winter season (January and February) and in June. The results are indicative of a rising rainfall and temperature trend in the Nubra Valley.

Keywords: Climate analysis, Trend analysis, Innovative trend analysis, Time series, Ladakh

The IPCC's Sixth Assessment Report states that climate change impacts in the high-altitude region have increased in recent decades; rising temperature, change in onset and offset of seasons, variability in rainfall and loss of glacier mass are a few observed changes (IPCC, 2014). These changes have affected mountain regions' ecosystems, food, agriculture, culture and tourism, and water resources. In Nubra Valley, agricultural practices are vulnerable due to the high altitude, cold climate and exceptionally rugged and isolated terrain. The meagre rainfall supports only one shorter summer agricultural season, from April to September. Thus, the only source of irrigation is melting snow and the demand for water for agricultural purposes is high. Traditionally, crops like wheat and barley had the largest share of total cropped. After the economic shift in the post-1960s, locals increased the production of vegetables for domestic use and as cash crops to fulfil the demand for the military and tourism industry (Bisht, 2008).

The variability and trends in climatic parameters are being studied using various techniques viz. Mann Kendall (MK) test, Sen's slope estimator and innovative trend analysis. Shafiq *et al.,* (2016) examined the precipitation variability in Ladakh (1901 to 2000) using the Mann Kendall (MK) test, showing decreasing summer precipitation and increasing precipitation off late during winter. Kale, (2020) examined the time series of temperature and rainfall data using Sequential Mann-Kendall (SQMK) and ITA methods in the Tapi basin while Ahmad *et al.,* (2023) applied Sen's slope estimator and MK test to identify the variability in climate parameters in Jammu province. Yadav *et al.,* (2014) applied MK and Sen's slope to detect the trend and slope magnitude in Uttarakhand, showing an increasing temperature and precipitation trend. Upadhyaya *et al.,* (2022) analysed the rainfall trends in the North-Western Indian Himalayan Region for 120 years, revealing increasing trends and the southern region districts indicating decreasing trends in rainfall. Chevuturi *et al.,* (2018) analysed climate change over Leh (Ladakh) using the Kendall test, indicating rising temperatures and precipitation patterns in recent decades.

In the present analysis, rainfall and temperature trends of the Nubra Valley were assessed on monthly, seasonal and annual time scales using the innovative trend analysis (ITA). The result draws focus to the patterns of rainfall and temperature in the Nubra Valley, which may have implications for managing water resources in the region in the future.

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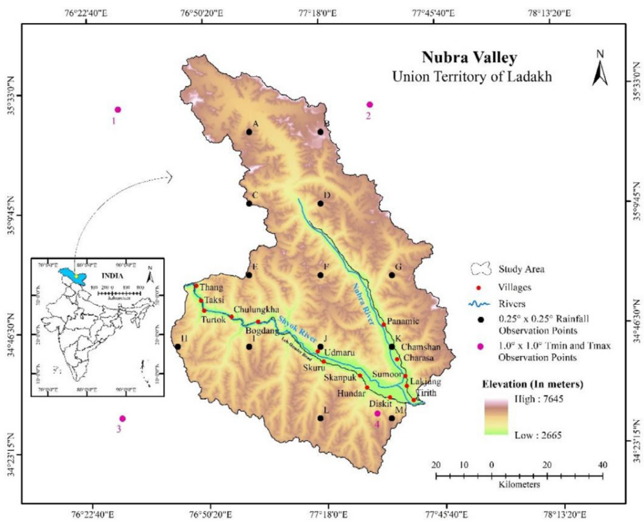

Fig. 1: Location and observation points of the study area

MATERIAL AND METHODS

The Nubra Valley lies between latitudes 34°18'17.976"N to 35°40'26.672"N and longitudes 76°41'41.249"E to 77°48'38.88"E. The Nubra River is originates from the Siachen glacier of the Karakoram range in the Himalayas (Fig. 1). The winters of Nubra Valley are severely cold and prolonged from September to May. We acquired the daily rainfall (0.25° x 0.25°) and temperature (Tmin and Tmax) (1.0° x 1.0°) gridded data for 1951 to 2022 from Indian Metrological Department (IMD) (https://www.imdpune.gov.in/lrfindex.php). This dataset includes thirteen-grid rainfall and four-grid temperature observation points (Fig. 1). The watershed delineation procedure was applied to specify the Nubra Valley region. We use the ArcGIS 10.3 and QGIS 3.18.3 software for different processes, such as pre-processing and watershed delineation.

Innovative trend analysis (ITA)

Şen (2012) introduced an ITA which is a better approach, unlike the other methods, such as MK and m-MK, which rely on certain presumptions. This approach does not follow any assumption and is valid for serial correlation time series data. It compares the two equally divided groups from the original time series data. Both groups' arithmetic averages are calculated; the arithmetic averages of the first and second half are Y1 and Y2, respectively. n denotes the data length and the trend's slope is calculated as

$$E(s) = \frac{2}{n} - [E(\bar{y}_2) - E(\bar{y}_1)]$$

$$\sigma_s^2 = \frac{8}{n^2}\left[E(y_2^{-2}) - E(\overline{y_2 \bar{y}_1})\right]$$

$$p\bar{y}_2\bar{y}_1 = \frac{E(\bar{y}_2\bar{y}_1) - E(\bar{y}_2)\ (\bar{y}_1)}{\sigma_{\bar{y}_2}\sigma_{\bar{y}_1}}$$

$$\sigma_s^2 = \frac{8}{n^2}\frac{\sigma^2}{n}\ (1 - p_{\bar{y}_2\bar{y}_1})$$

$$\sigma s = \frac{2\sqrt{2}}{n\sqrt{n}}\sigma\sqrt{(1 - p_{\bar{y}_2\bar{y}_1})}$$

Here E, p, σ_s^2 and σs represents, the cross-correlation coefficient between two average values and the variance and standard deviation of the slope, respectively. The confidence interval is obtained using following equation.indicates the z value of the chosen significance level. A positive S value exhibits an increasing trend and a negative S value exhibits a decreasing trend. If the slope value is beyond the confidence interval, the data shows a noteworthy trend. Otherwise, there is no trend in data (Ceribasi *et al.,* 2021; Al-Lami *et al.,* 2024).

$$CL\ (1 -_{\alpha}) = 0 \pm S_{cri}\ \sigma_s$$

RESULTS AND DISCUSSION

Spatial variability in rainfall and temperature

The seasonal and annual rainfall and temperature variation over Nubra Valley is presented in Fig. 2. The seasons were classified as pre-monsoon (March-May), monsoon (June-September), post-monsoon (October-December) and winter (January-February) (Dharani *et al.,* 2022). It may be seen that the northern parts of the Nubra Valley receive higher rainfall (>470 mm), and the southern parts receive less rainfall (<430 mm) on an annual basis. Overall, the mean annual rainfall varies between 404 to 490 mm in the valley. During the monsoon season, rainfall ranges between 141mm and 166 mm, with a spatial distribution similar to the annual pattern, with northern parts receiving higher rainfall (>160 mm) and southern parts receiving less rainfall (<150 mm). A similar pattern is observed in all the seasons, with seasonal contributions of 34.1%, 34.4%, 13.0%, and 18.5% during pre-monsoon, monsoon, post-monsoon, and winter seasons respectively (Fig. 2). It reveals that in the Nubra Valley, the pre-monsoon and monsoon seasons are the primary rainy season contributing about 68.5% to annual rainfall and the post-monsoon and winter seasons contribute 31.5% to the annual rainfall.

The minimum temperature (Tmin) in Nubra Valley ranges from 8 to 9 °C on an annual basis, the northern region experiencing is more (> 8.5 °C) Tmin compared to the southern region (<8.01 °C). The minimum temperature during winter season is less than 0°*C* while the highest minimum temperature of more than 16.0 °C is observed during monsoon season. A similar pattern is observed in all the seasons, with the lower Tmin in southern region and higher Tmin values in northern part of Nubra Valley (Fig. 2).

The maximum temperature (Tmax), on an annual basis, ranges from 20 to 21°*C* in the Nubra Valley. In the northern region, Tmax is more (> 20.65 °C) compared to the southern region (<20.84 °C). The lowest maximum temperature of about 10°*C* is observed during winter season while the highest maximum temperature is observed during monsoon season which is highly variable over the space ranging from less than 28°*C* in southern part to more than 39°C in northern part. The pattern of Tmax was similar to Tmin in the Nubra Valley, however, the spatial variation of Tmax was more than Tmin particularly during monsoon seasons (Fig. 2). The northern region receives higher rainfall on both a seasonal and annual basis as well as higher temperature as compared to southern region.

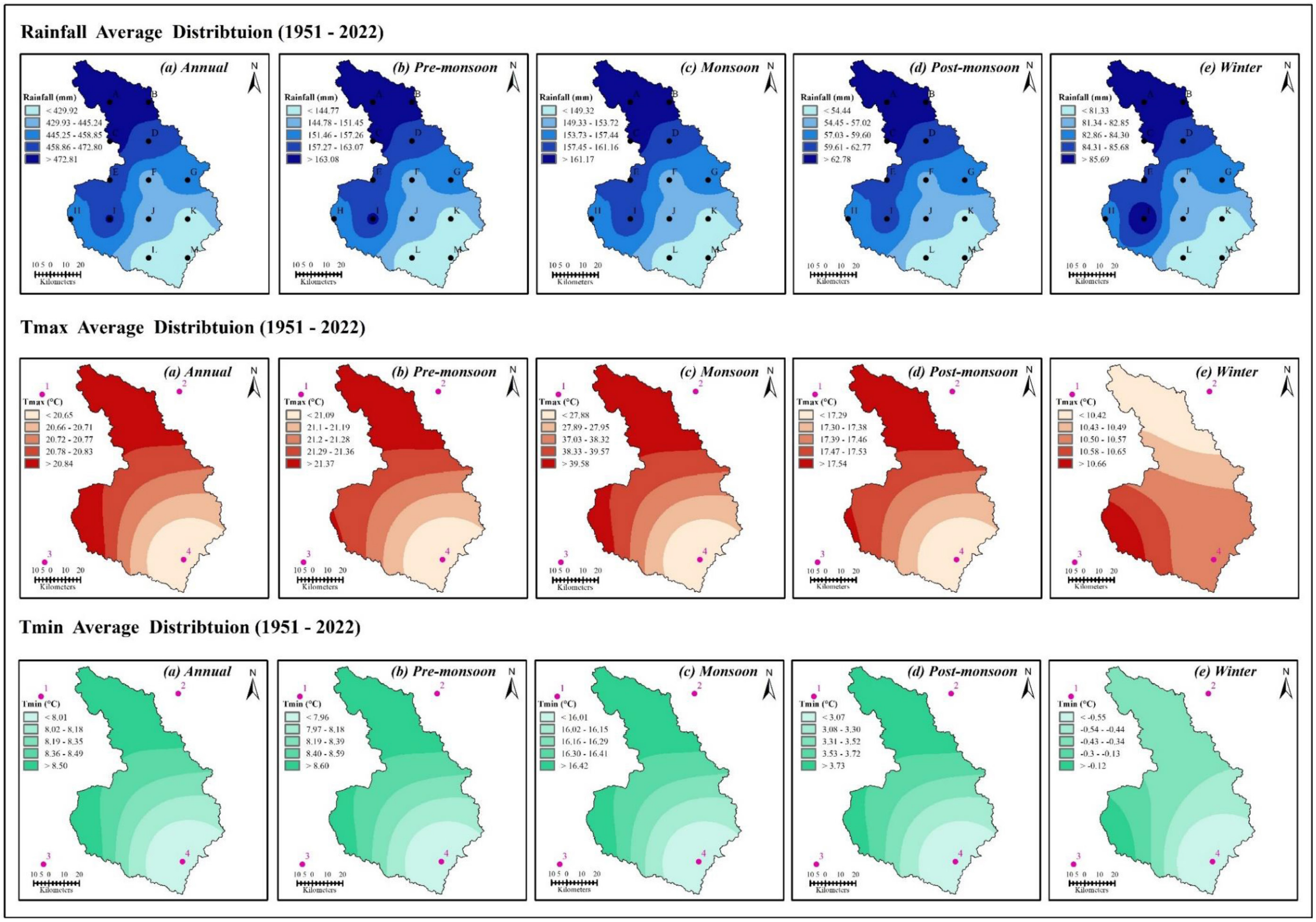

Fig. 2: Spatial distribution of seasonal rainfall, maximum temperature (Tmax) and minimum temperature (Tmin) over Nubra Valley

Innovative trend analysis (ITA) of rainfall

The innovative trend analysis (ITA) of rainfall carried out on monthly, seasonal and annual magnitude for all rainfall grid points are presented in Fig. 3 & 4. It shows a statistically significant increasing trend at a 95% confidence interval for in all the months except in November. The highest increasing slope was recorded at 0.6159 mm/year for January at Point A, 0.6817 mm/year for February at Point M, 0.7508 mm/year for March at Point H and 0.5041 mm/year for April at Point I, respectively. In May, all the observation points show a statistically significant increasing trend except point L, which indicates no trend at a 95% confidence interval. The highest slope was recorded in May for point A was 0.1654 mm/year. In June, the highest increasing slope was 0.4719 mm/year at Point F; in July it was 0.5614 mm/year at Point A; in August it was 1.1480 mm/year at Point M; in September it was 0.8120 mm/year at Point L; in October it was 0.3031 mm/year at Point I, and in December it was 0.2698 mm/year at Point M. In November A both decreasing and increasing trends were observed; decreasing trend in the northern and increasing trend in the southern regions of the study area (Fig. 3). Similar observations have been reported by Chevuturi *et al.,* (2018). The annual and seasonal trend analysis of rainfall reveals that all the observation points show a statistically significant increasing trend at a 95% confidence interval (Fig. 4).

Innovative trend analysis (ITA) of temperatures

Trends of maximum temperature (Tmax) and minimum temperature (Tmin) were analysed for only one observation point due to the available data that falls within the valley. The monthly, seasonal and annual ITA of Tmax and Tmin presented in Table 1 shows statistically significant increasing trends at 95% confidence interval on annual basis as well as in pre-monsoon, monsoon and post-monsoon seasons. The significant decreasing trends in Tmax and Tmin is observed during winter season due to significant decreasing trends observed both in January and February months (Table 1). A significant decreasing trends in Tmax and Tmin is also observed in June month. July is the only month wherein contrasting trend in Tmax and Tmin is observed; for minimum temperature a decreasing but non-significant trend (no trend) while for maximum temperature significant increasing trend (Table 1). The increasing slope for minimum temperature (Tmin) was observed at 0.0081 °C/year for March, 0.0019 °C/year for April, 0.059 °C/year for May, 0.0091 °C/year for August, 0.0127 °C/year for September, 0.0025 °C/year for October, 0.0177°C/year for November and 0.0118°C/year for December, respectively. In case of maximum temperature (Tmax) the increasing slope was recorded at 0.0137 °C/year for March, 0.0164 °C/year for April, 0.0048 °C/year for May, 0.0011 °C/year for July, 0.0127 °C/year for August, 0.0069 °C/year for September and 0.0023 °C/year for October, 0.0065 °C/year for

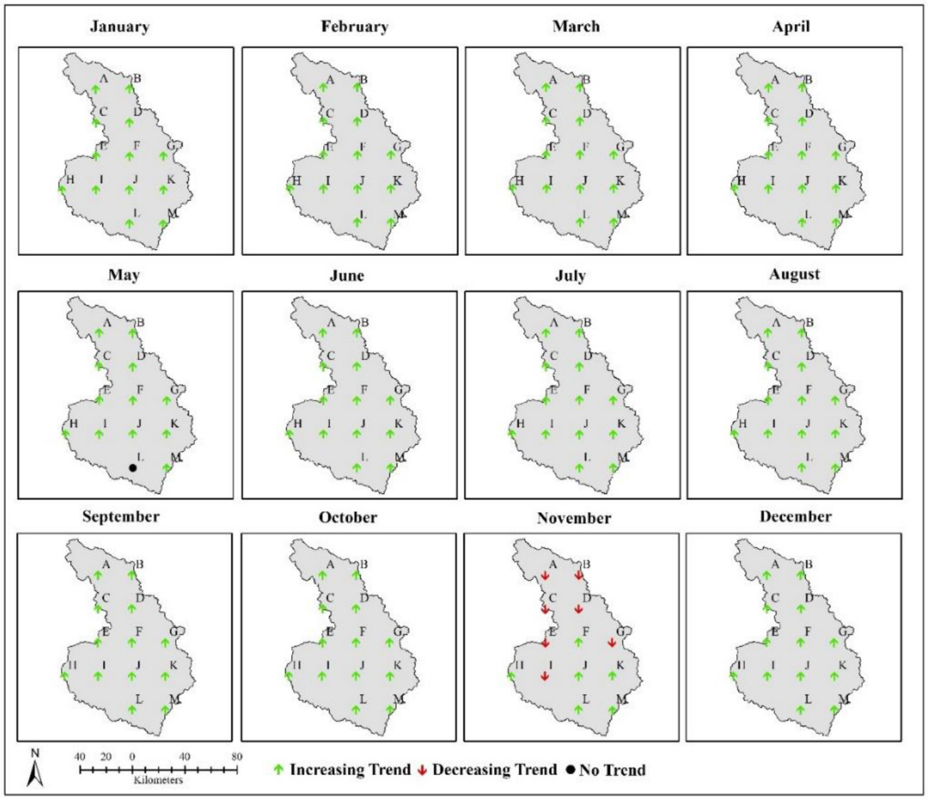

Fig. 3: Monthly rainfall trend analysis over Nubra Valley

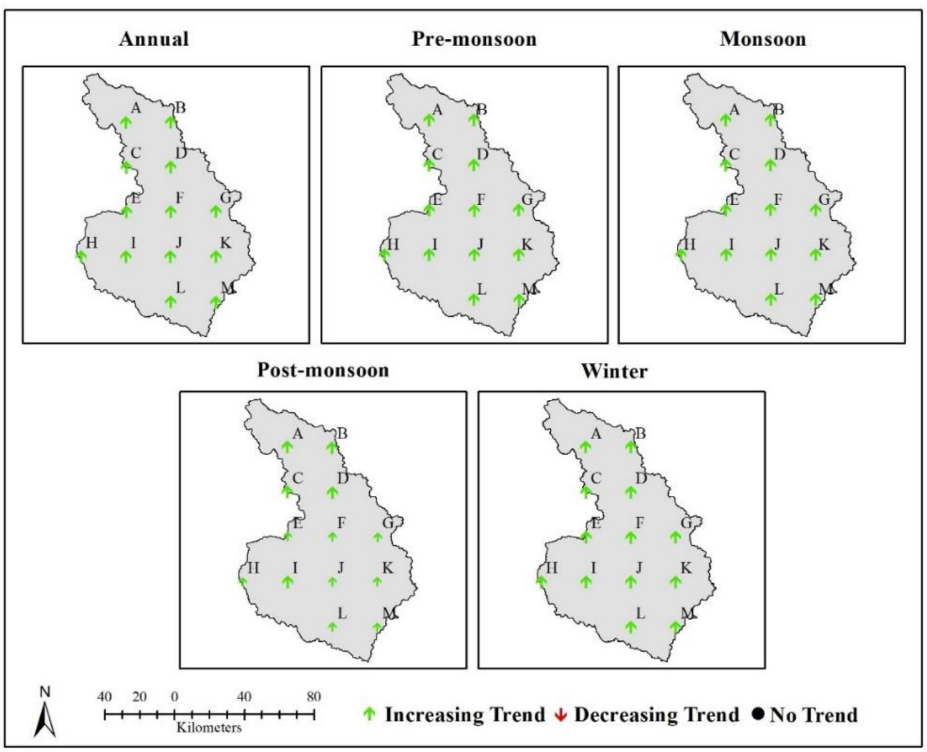

Fig. 4: Annual and seasonal rainfall trend analysis over Nubra Valley

November, 0.0140°C/year for December, respectively (Table 1). Similar trends have been reported by Chevuturi *et al.,* (2018).

Thus, all three variables showed a significant increase in most of the observation points on a monthly, seasonal, and annual basis. If this trend continues to increase in the future, it will lead to various water-related issues in the valley. Agricultural and tourism

Table 1: Monthly, annual and seasonal trend analysis for Tmin and Tmax (95%) in Nubra Valley

Months	Slope	Trend indicator	Lower limit	Upperlimit	Trend
		Minimum temperature (Tmin)			
January	-0.0022	0.4252	-0.0095	0.0095	-
February	-0.0245	-8.2824	-0.0199	0.0199	-
March	0.0081	0.7926	-0.0012	0.0012	+
April	0.0019	0.0892	-0.0011	0.0011	+
May	0.0059	0.1899	-0.0012	0.0012	+
June	-0.0073	-0.1721	-0.0014	0.0014	-
July	-0.0001	-0.0036	-0.0098	0.0098	0
August	0.0091	0.1925	-0.0009	0.0009	+
September	0.0127	0.3492	-0.0015	0.0015	+
October	0.0025	0.1260	-0.0038	0.0038	+
November	0.0177	3.4966	-0.0009	0.0009	+
December	0.0118	-4.1025	-0.0007	0.0007	+
Annual	0.0029	0.1382	-0.0018	0.0018	+
Winter	-0.0133	11.4573	-0.0129	0.0129	-
Pre-monsoon	0.0053	0.2517	-0.0009	0.0009	+
Monsoon	0.0036	0.0818	-0.0030	0.0030	+
Post-monsoon	0.0107	1.4366	-0.0017	0.0017	+
		Maximum temperature (Tmax)			
January	-0.0056	-0.2214	-0.0069	0.0069	-
February	-0.0236	-0.6906	-0.0222	0.0222	-
March	0.0137	0.3149	-0.0028	0.0028	+
April	0.0164	0.2791	-0.0031	0.0031	+
May	0.0048	0.0688	-0.0033	0.0033	+
June	-0.0160	-0.1992	-0.0010	0.0010	-
July	0.0011	0.0143	-0.0102	0.0102	+
August	0.0127	0.1665	-0.0009	0.0009	+
September	0.0069	0.0952	-0.0011	0.0011	+
October	0.0023	0.0366	-0.0038	0.0038	+
November	0.0065	0.1386	-0.0015	0.0015	+
December	0.0140	0.4417	-0.0018	0.0018	+
Annual	0.0027	0.0489	-0.0013	0.0013	+
Winter	-0.0146	-0.4899	-0.0128	0.0128	-
Pre-monsoon	0.0116	0.2022	-0.0027	0.0027	+
Monsoon	0.0012	0.0156	-0.0021	0.0021	+
Post-monsoon	0.0076	0.1612	-0.0023	0.0023	+

activities will be primarily affected by the availability of irrigation water and demand for drinking water will increase as the valley's tourism industry rises day-to-day. Further, it leads to growing concern in agriculture and the region's economy.

CONCLUSION

The ITA trend analysis of rainfall over Nubra Valley indicates a significant increase in most months at a 95% confidence interval, with the highest slope recorded at 1.1480 mm/year for August. A significant decreasing trend for rainfall was observed only in November in the northern region; Tmin and Tmax trend results indicate increasing trends in most of the months and seasons, except in winter season (January and February) wherein decreasing trends were observed for both Tmax and Tmin. In June also the Tmax and Tmin have decreasing trends. The limited availability of meteorological observation stations in the study area restricts understanding of the trends and patterns of climatic parameters, and this circumstance could only be solved by utilizing the dense network of meteorological stations in the study area. Further research is needed to analyse the impacts of climate change in this region, including climatic parameters such as humidity, potential evapotranspiration, soil moisture, and snow cover assessment (Glacier mass balance) to facilitate water resource management in Ladakh.

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Authors Contribution: **Ambrish:** Conceptualization, Methodology, Data collection, Data Analysis, Visualization, Writing-original draft; **B.W. Pandey**: Conceptualization, Resources, Supervision, Review the manuscript; **V.S Negi**: Conceptualization, Resources, Supervision, Proof-reading; **Y.S. Rathore**: Conceptualization and Literature, Proof-reading and review the manuscript.

REFERENCES

Ahmad, M., Kumari, M., Kumar, N., Goswami, G., Shahfahad and Asgher, M.S. (2023). Assessing livelihood vulnerability to climate variability in the Himalayan region: a district-level analysis of Jammu Province, India. *Geo Journal, 88*(4), 3631-3650.

Al-Lami, A.M., Al-Timimi, Y.K., and Al-Salihi, A.M. (2024). Innovative trend analysis of annual rainfall in Iraq during 1980-2021. *J. Agrometeorol.,* 26(2): 196-203. https://doi.org/10.54386/jam.v26i2.2561

Bisht, R. (2008). Agriculture in Ladakh: a status report. Prepared for TATA-LAHDC-Development Support Programme, Mumbai, 34-36.

Ceribasi, G., Ceyhunlu, A. I. and Ahmed, N. (2021). Innovative trend pivot analysis method (ITPAM): a case study for precipitation data of Susurluk Basin in Turkey. *Acta Geophys.,* 69 (4): 1465-1480. https://doi.org/10.1007/s11600-021-00605-6

Chevuturi, A., Dimri, A.P. and Thayyen, R.J (2018). Climate change over Leh (Ladakh), India. *Theor. Appl. Climatol.,* 131: 531-545. https://doi.org/10.1007/s00704-016-1989- 1

Dharani C., Maragatham, N., Geetalakshami, V., Ramanathan, S.P. and Kannan, B. (2022). Rainfall variability analysis and trend assessment in Theni District of Tamil Nadu, India: An implication for crop planning. *J. Agrometeorol.,* 24(3): 305-308. https://doi.org/10.54386/jam.v24i3.1797

IPCC (2014): Climate Change 2014: Synthesis Report. Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Core Writing Team, R.K. Pachauri and L.A. Meyer (eds.)]. IPCC, Geneva, Switzerland, 151 pp

Kale, G. D. (2020). Trend analyses of regional time series of temperatures and rainfall of the Tapi basin. *J. Agrometeorol.,* 22(1): 48-51. https://doi.org/10.54386/jam.v22i1.121

Şen, Z. (2012). Innovative trend analysis methodology. *J. Hydrol. Eng.,* 17(9): 1042-1046.

Shafiq MU, Bhat MS, Rasool R, Ahmed P, Singh H, and Hassan H (2016). Variability of Precipitation regime in Ladakh region of India from 1901-2000. *J. Climatol. Weather Forecast.,* 4: 165. doi:10.4172/2332-2594.1000165

Upadhyaya, A., Rai, A. K. and Kumar, P. (2022). Anomalous rainfall trends in the North-Western Indian Himalayan Region (NW-IHR). *Theor. Appl. Climatol.*, 151 (1-2): 253-272. https://doi.org/10.1007/s00704-022-04280-5

Yadav, R., Tripathi, S. K., Pranuthi, G. and Dubey, S. K. (2014). Trend analysis by Mann-Kendall test for precipitation and temperature for thirteen districts of Uttarakhand. *J. Agrometeorol.,* 16(2): 164-171. https://doi.org/10.54386/jam.v16i2.1507