



# Innovative trend analysis of total annual rainfall and temperature variability case study: Yesilirmak region, Turkey

Uğur Serencam<sup>1</sup>

Received: 25 May 2019 / Accepted: 11 October 2019 / Published online: 19 November 2019  
© Saudi Society for Geosciences 2019

## Abstract

It is well known that any kind of ordinary hydrometeorological parameter trend may have increasing or decreasing tendency systematically. Various methodologies are developed for possible trend identification such as the well-known Mann-Kendall test and recently Şen innovative trend analysis (ITA) approaches. The former has a set of assumptions, whereas the latter is almost without any restrictive assumption. The main purpose of this paper is to present precipitation and temperature trend behaviors by applying ITA in Yesilirmak drainage basin. Selected observation stations are mainly located at the Black Sea confluence region of Yesilirmak while few others at the middle and upper drainage basins. ITA provided visual inspection with quantitative trend slopes distinctively for low, medium, and high sub-levels with physical interpretations. Based on categorization, precipitation records have significant decreasing trends in low, medium, and high levels as an average  $-3.4\%$ ,  $-3.8\%$ , and  $-2.4\%$ , respectively. In contrary to precipitation trend, and consistent to global expectation in climate change, temperature records have significantly strong increasing tendency along the basin. In sub-level of temperature, this strong trend tendencies are detected  $+4.6\%$ ,  $+4.8\%$ , and  $+7.2\%$  from low to high ranges, respectively.

**Keywords** Innovative trend analysis (ITA) · Rainfall · Temperature · Yesilirmak · Turkey

## Introduction

Global warming due to the Green House Gas (GHG) concentration increases leading to climate change tendencies, which attracted researchers' and people's attention due to the unexpected and adverse results on sectoral damages (Hobbs 2003). According to the observed global average temperature trends in previous records, the global average temperature has increased by about  $0.74\text{ }^{\circ}\text{C}$  since comparing pre-industrial time (UNFCCC 2007). In the same period, although the precipitation on the land surface has decreased in the tropics, increases are observed especially in the middle and high latitudes (IPCC 2007). These variabilities are often and intensively beginning to occur as extreme precipitation and high summer temperatures (Dabanli 2019). Recent climate modeling studies are

conducted with identification of these change effects and gained an improved ability to simulate many aspects of climate change, variability, and extreme events (IPCC 2014).

In climate change and hydrology studies, rainfall and temperature parameters are accepted as the major factors underlying unexpected adverse effects on nature, agriculture, and society (Cheung et al. 2008). As told by Riddle and Cook (2008), these parameters have crucial importance for spatio-temporal analysis of climate change to sustain logical analysis output. Mathematical model for climate change impacts and predictions is helpful to prevent adverse impacts of extreme rainfall and high temperatures (Tabari and Talaei 2011). Trend analysis for water resources has significant importance over drought, water scarcity, and extreme precipitations, which may result in flooding. In the northern Mediterranean region, there are frequent water-stressed basins due to climate change impacts. Vulnerable populations to unexpected impacts on these regions are estimated to be from 1.4 to 2.1 billion (Arnell 2004; Alcamo et al. 2006).

While total precipitation amount increases, precipitation variability has been changed in mid-latitudes. Frequency of intensive precipitations tends to increase in those regions (Dabanli 2019). In particular, Turkey has witnessed several

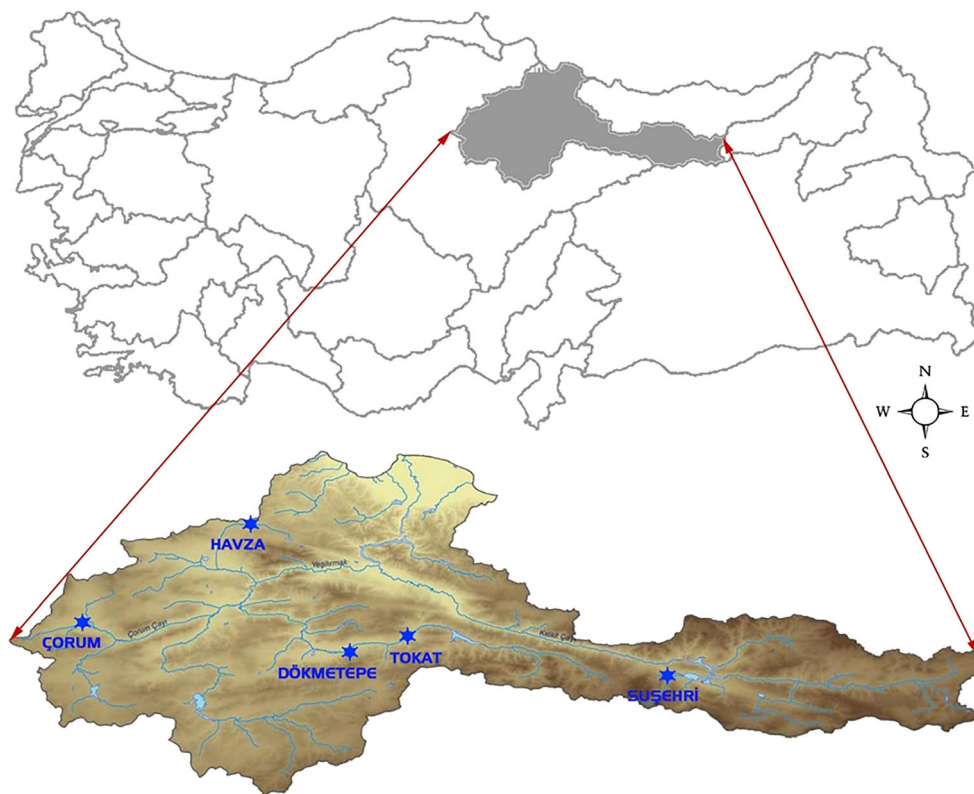
---

Responsible Editor: Abdullah M. Al-Amri

✉ Uğur Serencam  
userencam@bayburt.edu.tr

<sup>1</sup> Engineering Faculty, Civil Engineering Department, Bayburt University, 69000 Bayburt, Turkey

**Fig. 1** Study area and observation stations in Yesilirmak basin



flooding on Black sea regions due to intensive rainfall. In July 2019, more than six people disappeared after flooding in Duzce province in the northern region. Prevention against flood disaster, riverbed restoration, and watershed planning are essential. In this planning, rainfall and temperature trend magnitude should be considered while calculating risk and other precautions. In most cases, observed data is evaluated by calculating the average values by ignoring the extreme events. Consideration of extreme data instead of average values may help to decide on qualitative scientific definitions and predictions in factual practices (Şen 2010; Dabanli et al. 2017).

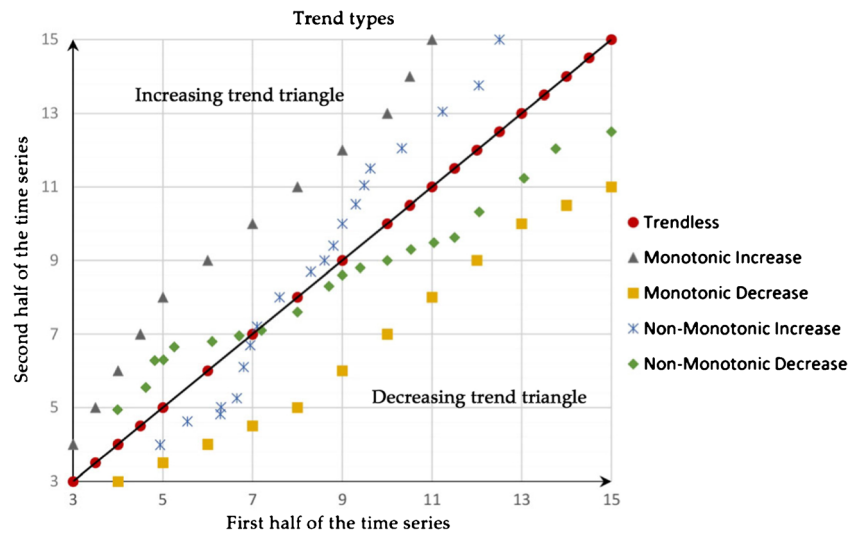
Similarly, temperature records are expected to increase, while monthly average precipitation records decrease in mid-latitudes (Gocic and Trajkovic 2013). Jiang et al. (2014)

revealed that precipitation decrease due to climate change may also reduce the flow rates around 20%. The limitations in the spatial and temporal scopes of the monitoring networks cause uncertainty in hydrologic variables' trends (Huntington 2006). Trends of monthly and annual record values have been examined by many researchers and organizations depending on various parameters and different methods (Kottegoda 2015; Hirsch and Slack 1984; Loftis et al. 1991; Lettenmaier et al. 1994; Dabanli et al. 2017; Mortsch et al. 2009; Zhang et al. 2001; Helsel and Hirsch 2002; Libiseller and Grimvall 2002; Önöz and Bayazit 2003; Kahya and Kalaycı 2004; IPCC 2007; Pujol et al. 2007; Kumar et al. 2010; Tabari and Talae 2011; UNDP 2012; Şen 2013; Sonali and Nagesh Kumar 2013).

**Table 1** Observation stations and related information in Yesilirmak basin

Rainfall and temperature observation gauges' codes and names	Height above sea level (m)	Drainage area (km <sup>2</sup> )	Average rainfall (mm/year)	Highest-average-lowest temperature values (°C/Year)
D14A030 (Susehri)	838	305.30	684.6	39.2; 10.4; -26.2
D14A169 (Tokat)	652	652.00	651.4	45.0; 12.5; -23.4
D14A157 (Dokmetepe)	545	3550.00	193.0	41.0; 11.3; -22.2
D14A090 (Corum)	727	3669.00	444.6	42.6; 10.7; -27.2
D14A019 (Havza)	615	52.60	695.0	38.7; 10.3; -23.1

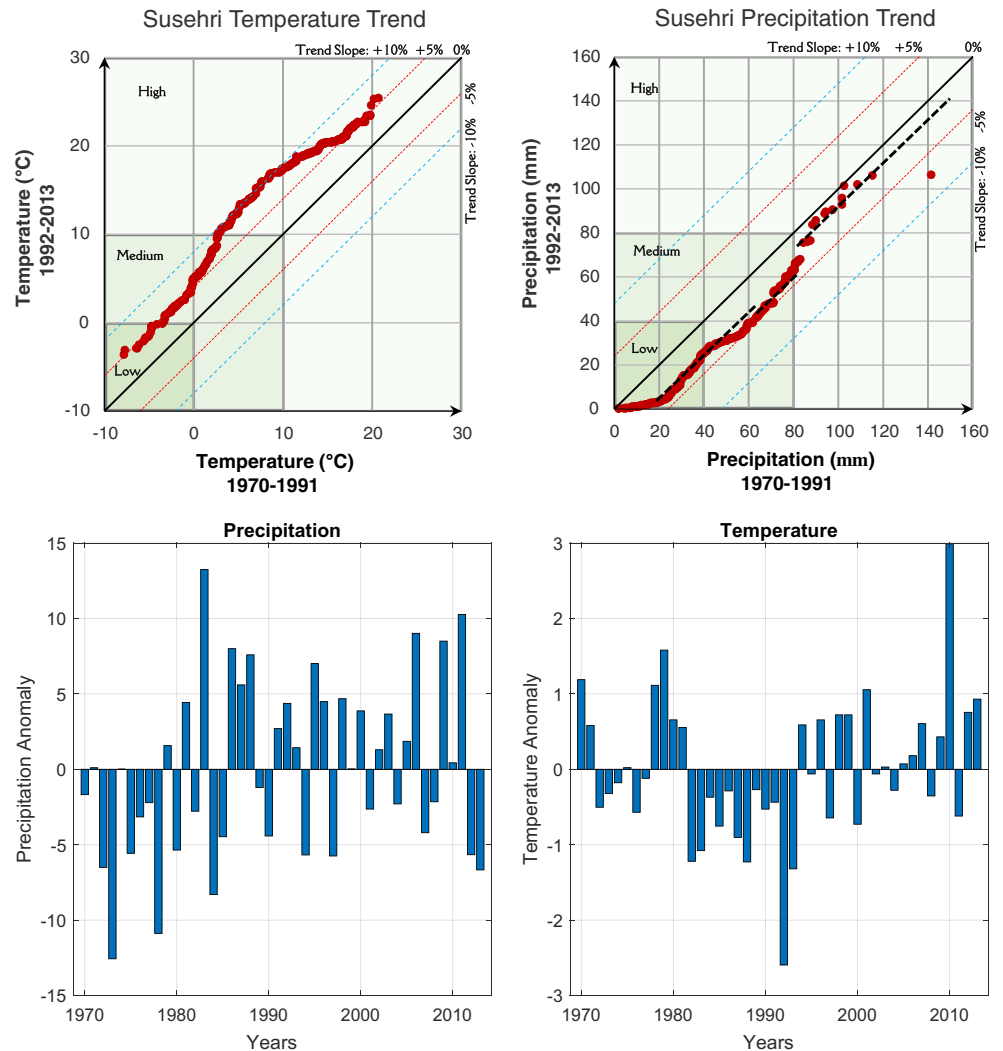
**Fig. 2** Illustration of decreasing, increasing, and trendless regions (Dabanli et al. 2016)



In this study, meteorological variables (temperature and precipitation) are analyzed by Şen's 1:1 (45°) innovative

trend assessment (ITA) method by consideration of data from the Yesilirmak basin (based on historical observation

**Fig. 3** Precipitation and temperature trends and anomalies in the Susehri station Figures 3–7 contain poor-quality text inside the artwork. Please do not re-use the file that we have rejected or attempt to increase its resolution and re-save. It is originally poor; therefore, increasing the resolution will not solve the quality problem. We suggest that you provide us the original format. We prefer replacement figures containing vector/editable objects rather than embedded images. Preferred file formats are eps, ai, tiff, and pdf. Figure 2 contains text below the minimum required font size of 6pts inside the artwork, and there is no sufficient space available for the text to be enlarged. Please provide replacement figure file. Please see attachment. All figures have been changed in high quality and saved as PDF file.



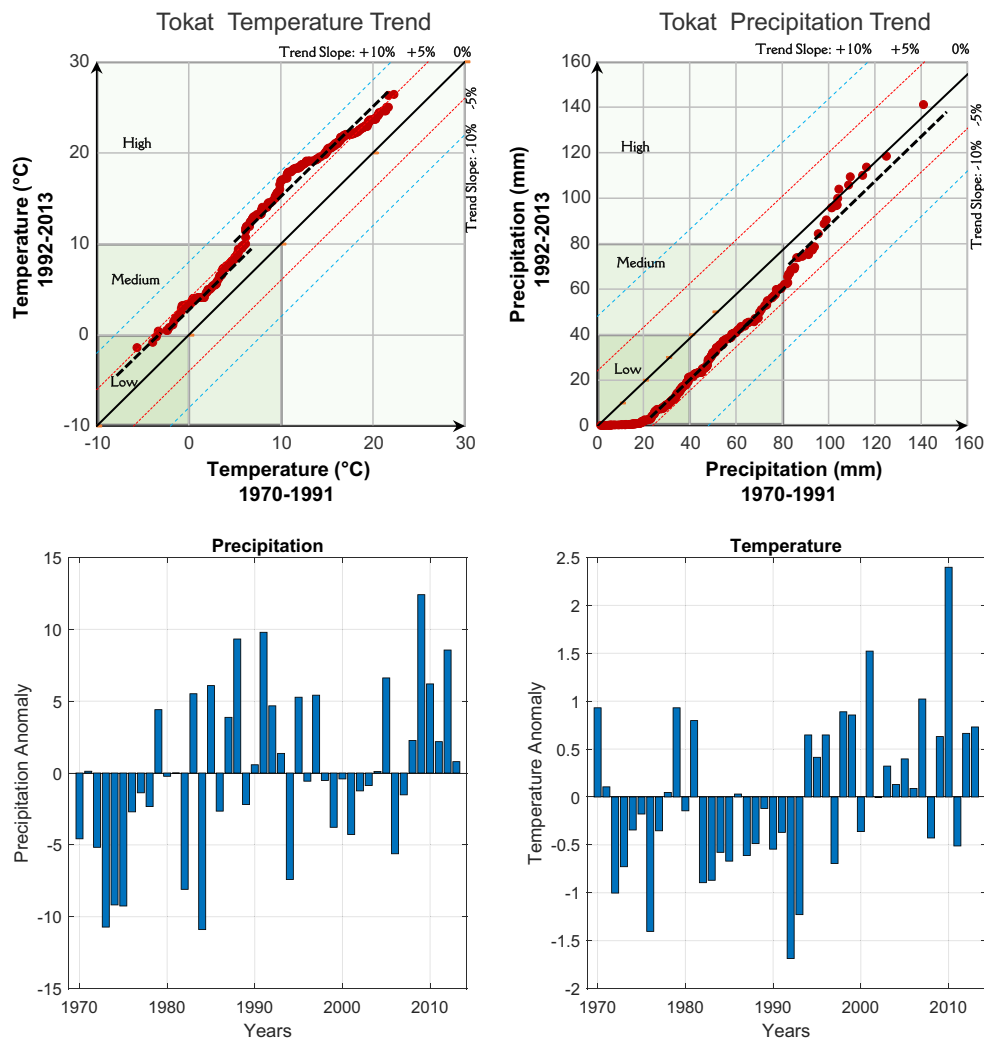
**Table 2** Trend analysis results summary

Parameters	Precipitation (mm)			Temperature (°C)		
	Low	Medium	High	Low	Medium	High
Reference interval	< 60	60–80	> 80	< 0	0–10	> 10
Stations	Average trend slope (%)			Average trend slope (%)		
Susehri	-3	-4	-1	+5	7	8
Tokat	-4	-4	-3	+5	4	7
Dokmetepe	-4	-4	-3	3	4	7
Corum	-3	-3	-3	5	4	7
Havza	-3	-4	-2	5	5	7
Average	-3.4	-3.8	-2.4	+4.6	+4.8	+7.2

of 1970–2013 years) in the north part of Turkey. Subsequently, climate change impacts on meteorological variables are also interpreted under the light of the same approach.

### Study area and data

Yesilirmak river basin is located in the northern part of Turkey with approximately 39,595 km<sup>2</sup> area. The basin is covered by Eastern Black Sea, Coruh, Firat, and Kizilirmak basins as presented in Fig. 1. The Yesilirmak river (519 km length) originates from Köse mountains to the southwest of Sivas province. From the upstream to the downstream, it passes through the plains of Tokat, Turhal, and reaches to Amasya and Carsamba plains. The Yesilirmak basin covers a part of Tokat, Samsun, Amasya, Çorum, Sivas, Yozgat, Gümüşhane, Giresun, Erzincan, Ordu, and Bayburt provinces with the main branches of the river as Kelkit, Cekerek, and Tersakan Streams. The Yesilirmak basin is divided into 32 sub-basins by the General Directorate of State Hydraulic Works (DSI). Temperature and precipitation data obtained from General Directorate of Meteorology (MGM) are given in Table 1. In the basin, average



**Fig. 4** Precipitation and temperature trends and anomalies in the Tokat station

annual precipitation is 646 mm and average annual flow is 5.80 km<sup>3</sup>/year for Yesilirmak river.

### Methodology

Yesilirmak basin is selected for the trend application studies due to its utmost importance for water resource sustainability and management studies. For this purpose, five regularly measured temperature and precipitation data at different sites are selected to show the present situation.

A recorded hydro-climatic time series data is divided into two equal length groups from the beginning date to the end and both sub-series are separately sorted into ascending order. The first sub-series (Xi) is located on the X-axis and the other sub-series (Xj) on the Y-axis as seen in Fig. 2. If data plots appear on the 1:1 (45°) straight line or near to it, it implies that there is no trend

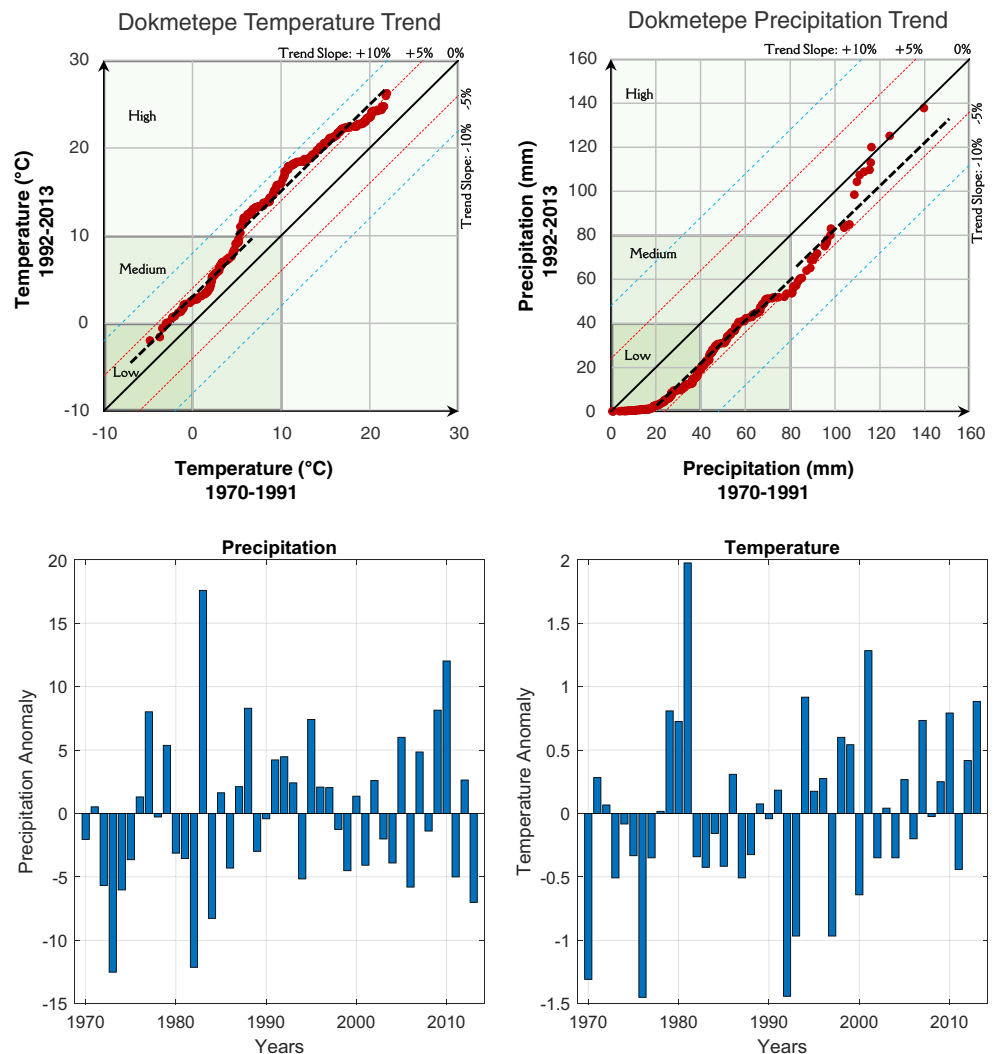
(Dabanlı et al. 2016). It is obvious that in the case of increasing (decreasing) monotonic trend, the scatter points fall above (below) the 1 : 1 straight line.

In this study, trend envelope lines are applied for significant assessments of possible trends. These envelope lines are generated as parallels to 1:1 (45°) straight line. Thus, numerical trend assessments can be achieved easily by consideration of ± %5 or ± %10 trend envelopes.

### Result and discussion

Six observation stations are selected for the trend analysis study. Figure 3 shows the results for the precipitation and temperature trend and anomalies for Susehri station. It is possible to see that the precipitation data have a significant decreasing trend. This figure also illustrates that temperature trend has increasing character, especially at the medium range, where average precipitation values have a - 4% decrease. In

Fig. 5 Precipitation and temperature trends and anomalies in the Dokmetepe station



the same figure, temperature records have ascending trends (5–10%). In particular, one can see those medium temperatures between 0 and 10 °C, which are expected to increase (+7%) more rapidly in future. All trend slopes are illustrated in the figures and numerical values are presented in Table 2. Precipitation and temperature anomaly limits are detected as  $\pm 14$  mm and  $\pm 3$  °C, respectively.

Tokat is located in the southeastern cost of the Yesilirmak sub-basin. Figure 4 shows that precipitation innovative template scatters have a descending trend for all range data values. In precipitation, -4% decreasing trend is detected for low and medium ranges. In high ranges, this decreasing trend is calculated as -3%. Temperature observations at this station have a significant increase in all ranges. They are calculated as +5%, +4%, and +7% for low, medium, and high ranges, respectively. Precipitation and temperature anomaly limits are detected as  $\pm 12$  mm and  $\pm 2.5$  °C, respectively.

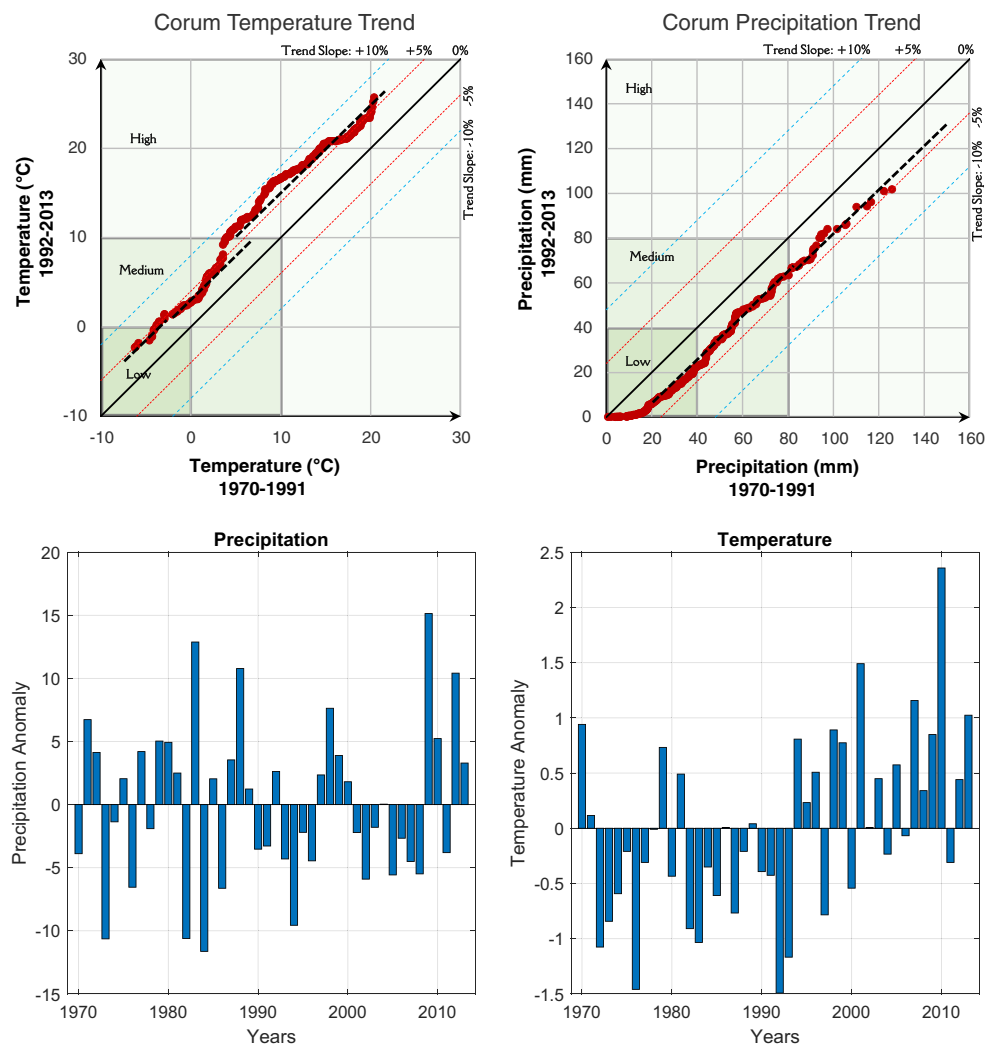
Dokmetepe is located in the southeastern part of the Yesilirmak sub-basin. Figure 5 shows that precipitation innovative template scatters have a descending trend for all data

range. In precipitation, -4% decreasing trend is detected for low and medium ranges. In high ranges, this decreasing trend is calculated as -3%. Temperature observations at this station have significant increase in all sub-groups. These rates are calculated as +3%, +4%, and +7% for low, medium, and high ranges, respectively. Precipitation and temperature anomaly limits are  $\pm 17$  mm and  $\pm 2$  °C, respectively.

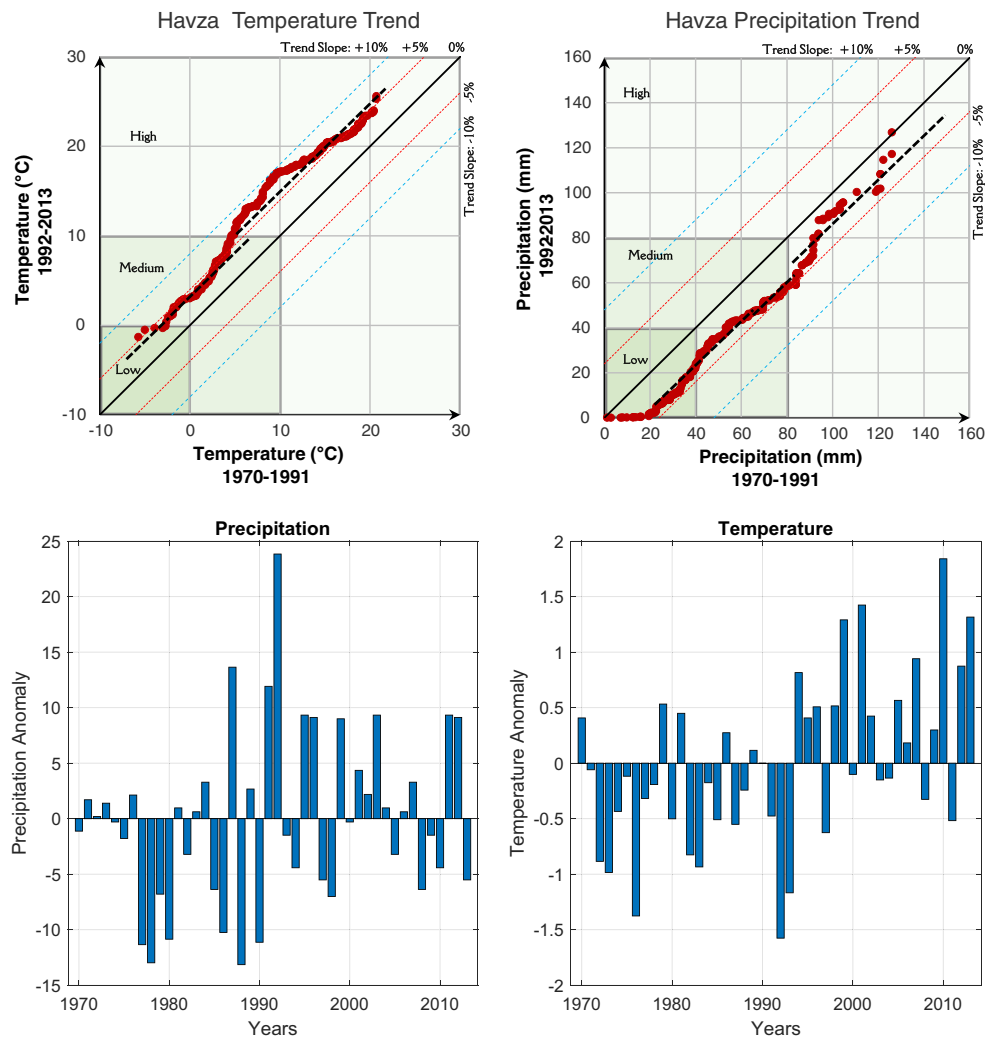
Corum station trend templates for precipitation and temperatures are presented in Fig. 6, where precipitation scatters have descending trend (-3%) for all data ranges with the exception that 2 data records are out of this behavior and they can be treated as possible extreme values. Temperature records at this station have significant increase around +5% trend envelope lines. Especially, around 10 °C, +10% strong trend behavior is seen. Average trend slopes are calculated for low, medium, and high ranges as +5%, +4%, and +7%, respectively. Precipitation and temperature anomaly limits are detected as  $\pm 15$  mm and  $\pm 2.5$  °C, respectively.

Havza is located in the northwestern cost of the Yesilirmak basin. Figure 7 indicates that precipitation

**Fig. 6** Precipitation and temperature trends and anomalies in the Corum station



**Fig. 7** Precipitation and temperature trends and anomalies in the Havza station



innovative trend template scatters have significant decrease as presented for precipitation at the Tokat station. According to figure, precipitation records can be split up with 80 mm. Besides, temperature records at this station have significant increase in all ranges. Strong consistency of trend is easily detectable between the Havza and Tokat stations. The precipitation and temperature characteristics are almost similar for these two stations. Precipitation and temperature anomaly limits are detected as  $\pm 25$  mm and  $\pm 2$  °C, respectively.

In precipitation, low, medium, and high ranges are considered at low levels than 40 mm, at a medium level between 40 and 80 mm, and at high level ranging more than 80 mm, respectively. These limits are determined based on expert judgment considering average values. Detected trend slopes are presented in Table 2 based on trend envelope lines. In this table, significant decreasing trends are valid for precipitation in all ranges. Results prove that although basin has high precipitation above country average, precipitation trends tend to

decrease. Precipitation anomalies are fluctuating around 15–20 mm average in basin level.

In a similar manner, temperature sub-group limits are determined as  $< 0$  °C, 0–10 °C, and  $> 10$  °C for low, medium, and high ranges, respectively. From the graphs, temperature anomalies are fluctuating on the average around 2 °C in basin level. Increasing trends are calculated for temperature records. These outputs strengthen climate change expected in the Yesilirmak basin by increasing temperatures.

**Conclusions**

In this study, the innovative trend analysis (ITA) method is employed for meteorological time series trend detections. The ITA approach provides categorical trends within the low, medium, and high data ranges, whereas other popular trend methods do not provide categorical trends, but single monotonic trend component within the time series. For the

implementation, monthly precipitation and temperature records are considered over the 44-year duration from Yesilirmak basin for trend analysis and anomaly presentation. It is observed that the ITA trend test provides significantly decreasing trend tendencies for precipitation in low, medium, and high levels on an average  $-3.4\%$ ,  $-3.8\%$ , and  $-2.4\%$ , respectively. In contrast, precipitation trends are consistent with global climate change expectations and, temperature records have significantly increasing trends. In sub-levels of temperature, this strong trend tendencies are detected as  $+4.6\%$ ,  $+4.8\%$ , and  $+7.2\%$  from low to high ranges, respectively. Moreover, the trends can be detected at different categories with consideration of the trend envelope lines. Combination of these envelope lines with the existing ITA method provides a supportive analysis way for trend identification categorically. It also provides reliable interpretations for drought (low) and flood (high) values to manage climate change effects on water resources in future studies.

**Acknowledgments** The authors are grateful to The State Water Works (DSI) of Turkey for supplying precipitation and flow data.

**Data availability** Authors do not have permission to share data.

## Compliance with ethical standards

**Conflict of interest** The authors declare that they have no conflict of interest.

## References

- Alcamo J, Döll P, Henrichs T, Kaspar F, Rösch T, Siebert S (2006) Development and testing of the WaterGAP 2 global model of water use and availability. *Hydrolog Sci* 48(3):317–337. <https://doi.org/10.1029/2001WR000355> Amell
- Amell NW (2004) Climate change and global water resources: SRES emissions and socio-economic scenarios. *Glob. Environ. Chang* 14:31–52. <https://doi.org/10.1016/j.gloenvcha.2003.10.006>
- Cheung WH, Senay GB, Sing A (2008) Trends and spatial distribution of annual and seasonal rainfall in Ethiopia. *Int J Climatol* 28:1723–1734. <https://doi.org/10.1002/joc.1623>
- Dabanlı I (2019) Temperature difference relationship among precipitation, dry days, and spells in Turkey. *Theor Appl Climatol* 135(1–2):765–772. <https://doi.org/10.1007/s00704-018-2649-4>
- Dabanlı İ, Şen Z, Yeleğen MÖ, Şişman E, Selek B, Güçlü YS (2016) Trend assessment by the innovative-Şen method. *Water Resour Manag* 30(14):5193–5203. <https://doi.org/10.1007/s11269-016-1478-4>
- Dabanlı İ, Mishra AK, Şen Z (2017) Long-term spatio-temporal drought variability in Turkey. *J Hydrol* 552:779–792. <https://doi.org/10.1016/j.jhydrol.2017.07.038>
- Gocic M, Trajkovic S (2013) Analysis of changes in meteorological variables using Mann-Kendall and Sen's Slope Estimator Statistical Tests in Serbia. *Global and Planetary Change* 100:172–182. <https://doi.org/10.1016/j.gloplacha.2012.10.014>
- Helsel, D. R., & Hirsch, R. M. (2002). *Statistical methods in water resources*. Techniques of water resource investigations. US Geological Survey, Book 4, 522 pp (Chapter A3). Retrieved from <http://water.usgs.gov/pubs/twri/twri4a3/>
- Hirsch RM, Slack JR (1984) A nonparametric trend test for seasonal data with serial dependence. *Water Resour Res* 20(6):727–732. <https://doi.org/10.1029/WR020i006p00727>
- Hobbs SE (2003) Climate change 1992: the supplementary report to the IPCC scientific assessment. *J Atmos Terr Phys* 58(10):1189. [https://doi.org/10.1016/s0021-9169\(96\)90059-8](https://doi.org/10.1016/s0021-9169(96)90059-8)
- Huntington TG (2006) Evidence for intensification of the global water cycle: review and synthesis. *J Hydrol* 319(1–4):83–95. <https://doi.org/10.1016/j.jhydrol.2005.07.003>
- IPCC. (2007). *Climate change 2007: impacts, adaptation and vulnerability*. (M. Parry, O. Canziani, J. Palitkof, P. van der Linden, & C. Hanson, Eds.), Cambridge University Press (Vol. 1, p. 976). Cambridge: Cambridge University. <https://doi.org/ISSN:02767783>
- IPCC. (2014). *Climate change 2014: impacts, adaptation, and vulnerability: part a: global and sectoral aspects*. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University
- Jiang R, Xie J, He H, Luo J, Zhu J (2014) Use of four drought indices for evaluating drought characteristics under climate change in Shaanxi, China: 1951–2012. *Nat Hazards* 75(3):2885–2903. <https://doi.org/10.1007/s11069-014-1468-x>
- Kahya E, Kalayci S (2004) Trend analysis of streamflow in Turkey. *J Hydrol* 289(1–4):128–144. <https://doi.org/10.1016/j.jhydrol.2003.11.006>
- Kottegoda, N. T. (2015). *Stochastic water resources technology*. Stochastic Water Resources Technology. Palgrave Macmillan UK <https://doi.org/10.1007/978-1-349-03467-3>
- Kumar V, Jain SK, Singh Y (2010) Analysis of long-term rainfall trends in India. *Hydrol Sci J* 55(4):484–496. <https://doi.org/10.1080/02626667.2010.481373>
- Lettenmaier DP, Wood EF, Wallis JR (1994) Hydro-climatological trends in the continental United States, 1948–88. *Journal of Climate* 7(4):586–607.
- Libiseller C, Grimvall A (2002) Performance of partial Mann-Kendall tests for trend detection in the presence of covariates. *Environmetrics* 13(1):71–84. <https://doi.org/10.1002/env.507>
- Loftis JC, Taylor CH, Chapman PL (1991) Multivariate tests for trend in water quality. *Water Resour Res* 27(7):1419–1429. <https://doi.org/10.1029/90WR01802>
- Mortsch L, Hengeveld H, Lister M, Wenger L, Lofgren B, Quinn F, Slivitzky M (2009) Climate change impacts on the hydrology of the Great Lakes-St. Lawrence system. *Can Water Resour J* 25(2):153–179. <https://doi.org/10.4296/cwrj2502153>
- Önöz B, Bayazit M (2003) The power of statistical tests for trend detection. *Turk J Eng Environ Sci* 27(4):247–251
- Pujol N, Neppel L, Sabatier R (2007) Regional tests for trend detection in maximum precipitation series in the French Mediterranean region. *Hydrol Sci J* 52(5):956–973. <https://doi.org/10.1623/hysj.52.5.956>
- Riddle EE, Cook KH (2008) Abrupt rainfall transitions over the greater horn of Africa: observations and regional model simulations. *J Geophys Res* 113:D15109. <https://doi.org/10.1029/2007JD009202>
- Şen, Z. (2010). *Fuzzy logic and hydrological modeling*. Fuzzy Logic and Hydrological Modeling. CRC Press <https://doi.org/10.1201/9781439809402>
- Şen Z (2013) Trend identification simulation and application. *J Hydrol Eng* 19(3):635–642. [https://doi.org/10.1061/\(asce\)he.1943-5584.0000811](https://doi.org/10.1061/(asce)he.1943-5584.0000811)
- Sonali P, Nagesh Kumar D (2013) Review of trend detection methods and their application to detect temperature changes in India. *J Hydrol* 476:212–227. <https://doi.org/10.1016/j.jhydrol.2012.10.034>
- Tabari H, Talaei PH (2011) Temporal variability of precipitation over Iran: 1966–2005. *J Hydrol* 396(3–4):313–320. <https://doi.org/10.1016/j.jhydrol.2010.11.034>



- UNDP (2012) Environment for the future we want. Population and Development Review, vol 24. United Nations Environment Programme, p 407. <https://doi.org/10.2307/2807995>
- UNFCCC, (2007). Climate change: impacts, vulnerabilities and adaptation in developing countries. United Nations Framework Convention on Climate Change (UNFCCC), Bonn, Germany.
- World Meteorological Organization. (2009). Management of Water Resources and Application of Hydrological Practices. In Guide to Hydrological Practices (Vol. II, pp. 1–302)
- Zhang X, David Harvey K, Hogg WD, Yuzyk TR (2001) Trends in Canadian streamflow. *Water Resour Res* 37(4):987–998. <https://doi.org/10.1029/2000WR900357>