International Journal of Engineering &Technology, 8 (2) (2019) 110-119

SPC

International Journal of Engineering & Technology

Website: www.sciencepubco.com/index.php/IJET

Research paper

Trend analysis using mann-kendall, sen's slope estimator test and innovative trend analysis method in Yangtze river basin, china: review

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Abstract

Trend analysis of mean monthly flows is fundamental for better water resources management and planning in this study, Mann Kendall (MK), Sen's Method and Şen's Innovative trend method (ITM) were utilized so as to analyze the possible trends of annual and seasonal flows. In this study, trends of flow of the Yangtze River were reviewed on in seasonal and annual time series utilizing the Mann-Kendall (MK) test, Sen's slope estimator, and innovative trend method (ITM). That is why, the monthly flow information will gather in the stations of Yangtze River Basin. In any case, the seasonal and annual warming magnitudes showed large regional differences, and a higher warming rate was identified in the eastern YRB and the western source area of the Yangtze River on the Qinghai-Tibetan Plateau (QTP). In general, a warming wetting trend was identified in the south-eastern and north-western YRB, while there was a warming-drying trend in a middle region. The developed maps of spatial variability of flow trends may help the stakeholders and/or water resource managers to figure out the risk and vulnerability related to climate change in the study region.

Keywords: *Flow; Mann Kendall (MK); Sen's Method and Şen's Innovative Trend Method (ITM); Yangtze River; China.*

1. Introduction

Environmental change and factors of anthropogenic unfavorably influence the hydro meteorological procedure in a consistent way, and their effects show up in the types of trends or unexpected bounces (Şen 2012). The examines demonstrate that the air temperature mean worldwide has expanded roughly by 0.6 °C during twentieth century because of increase in atmospheric greenhouse gases (Nazeri Tahroudi et al. 2018). Human activity is considered as the principle reason of expanding the greenhouse gases, which prompts environmental change in various districts over the world. A standout amongst the best outcomes of environmental change is changing of sum, kinds, spatial and temporal variation of rainfall, which is increasingly serious in certain pieces of the earth (Zamani et al. 2018) The worldwide reaction to environmental change and the activities required to alleviate its belongings upon most parts of the regular biological systems and human activities (Ali et al. 2017). Rainfall is a climate fundamental factor, and its varieties directly affect farming profitability, event of floods, or dry season (Abdi et al. 2017). Consequently, examination on variety of rainfall is a fundamental issue in arranging and overseeing water resources and furthermore planning appropriate designs to adapt to floods and dry season conditions. Perception of the flows information is a standout amongst the most significant issues in water resources management, planning related projects and designing. There are numerous components, for example, environmental changing and anthropogenic exercises which are powerful on time-subordinate flow information. Recognizing potential trends in historical flow information is one of the primary strides in water resources. Choice on water the executives and arrangements is essentially influenced by an identification of a trend significant in flow (Yenigun et al. 2008).

As indicated by the Intergovernmental Panel on Climate Change dependent on fifth evaluation (IPCC 2013), the Global Mean Surface Temperature (GMST) was expanded by 0.89 °C during 1901–2012. It is certain that the maximum and minimum temperatures over land surface have been expanded on worldwide scale since 1950, yet the change greatness fluctuated in both reality (Zhang et al.2008). (IPCC2013) likewise exhorted that diminishing in increment in evapotranspiration and precipitation result in droughts. Rainfall is one of the dynamic parameter of the hydrological cycle, which for the most part shifts in spatial and temporal patterns because of the expansion in the centralization of atmospheric gases. The examination of worldly and spatial fluctuation of rainfall is significant for hydrologists, agriculturalists, meteorologist, and industrialists in the part of maintainable usage of water resources and droughts and control of floods, and the detailed information on the spatio-fleeting dispersion of rainfall is vital for exact displaying of flood control utilizing detainment basins (Brunsell et al. 2010; Bellu et al. 2016) or surface water storage utilizing rainwater harvesting systems (Terêncio et al. 2017, 2018). (Kumar and Jain 2010) detailed the adjustment in rainfall distribution could impact both spatial and worldly circulations of overflow, soil dampness, and groundwater holds and could change the recurrence of floods and draughts. Subsequently, it is essential to distinguish the variety of trends at spatio-fleeting scales far and wide (Pingale et al. 2014; Wang et al. 2013; Cui et al. 2017).

In late decades, environmental change portrayed by expanding changing precipitation properties and air temperatures has created overall consideration (Shen and Varis, 2001; Gerten et al., 2008; Kurane, 2010; Tian et al., 2016). Examinations of the qualities of varieties in local precipitation and temperature are especially understanding the effects of environmental change on the agriculture, eco-environment, atmospheric/hydrologic cycle, and human society and significant for distinguishing (Karl, 1998; Piao et al., 2014; Friedlingstein et al., 2010; Chen et al., 2014; Yu et al., 2014; Wang et al., 2017). Subsequently, it is basic to identify the variety trends of precipitation and temperature at various spatial and scales fleeting the world over. However, the magnitude of the changes varied greatly in space and time (Zhang et al., 2008; Sun et al. 2014) expressed the biggest trends warming were seen in Antarctica and Middle Africa during 1948–2010. (Jin et al. 2015) demonstrated that most urban areas in China experienced warming during 1955–2012, however the warming trend was higher in the north than in the south (Ge et al., 2013). In the interim, various examinations have been centered around varieties in precipitation utilizing different indices precipitation (Gemmer et al., 2011; Sun et al. 2014) demonstrated that 62.26% of the world wound up wetter in the previous 60 years, with the biggest precipitation increment happening in Northern Europe, while 22.01% of the world indicated drying trends, with the quickest drying happening in Western Africa. (Ren et al. 2015) demonstrated that trend no significant in yearly precipitation during 1956–2013 was found in China; however evident provincial contrasts were identified. Diminishes in precipitation chiefly happened in North China, focal and Southern Northeast China and Southwest China, and increments in rainfall mainly happened in the mid-and lower compasses of the Yangtze River, the south-eastern beach front district, the Qinghai-Tibetan Plateau (QTP) and Northwest China (Ren et al., 2015). There are enormous contrasts in the spatial-transient varieties of precipitation and air temperature in the various of China climates or different districts, which should be quantitatively and qualitatively investigated.

An expansion in recurrence and force of outrageous climate and climatic occasions has raised across the board worries over worldwide climatic changes (Chen et al., 2017). Being a standout amongst most significant factors in the precipitation changes directly affects floods, drought, water resources and ecosystem services, hydrologic cycle, (Wu et al., 2013). Further, power, precipitation magnitude and recurrence are liable to varieties related with the environmental change (Pal and Al-Tabbaa, 2011) . For the recurrence force of precipitation and similar magnitude of precipitation, might be extraordinary (Trenberth, 2011). The example of the hydrological cycle might be modified by precipitation changes, which can influence the society and environment (Gajbhiye et al., 2016). Henceforth, it is basic to consider the varieties in the precipitation qualities with regards to environmental change. In this manner, precisely anticipating the precipitation patterns is an essential in the water assets wanting to help the local water assets arranging and sustenance trade conceivable outcomes for the manageable financial improvement of society (Ahmad et al., 2015). Fast development of urban area is compromising the watershed. As an outcome water issues, for example, dry season and flood are developing, and afterward the supportability of streaming water is diminishing. A customary methodology including recurrence investigation doesn't mull over the water storage capacity in the watershed as significant parameters to moderate conquer this problem (Ali R, and Heryansyah A,2018)In the substance of environmental change, a hotter climate builds the dissipation rate from land, bringing about more dampness flowing all through the troposphere. Henceforth, it is relied upon to have increasingly extreme precipitation occasions, and more and serious dry spells (Costa et al., 2012; Eslamian et al., 2011; Xu et al., 2006; Zhang et al., 2010). Further, because of warming, more precipitation happens as downpour rather than prior snowmelt, and snow can occur. These progressions may not just improve the danger of flooding in spring, yet additionally increment danger of drought during summer in the snow-sustained basins (Callaghan et al., 2011; Trenberth, 2011).

Trend examination is a standout amongst the most mainstream approaches, which has generally utilized by specialists for investigating the variety of hydro meteorological factors during the most recent two decades. Hereunto, numerous strategies has been created and connected for breaking down the trend of hydro-meteorological factors, which have their very own impediments and favorable circumstances. For the most part, the trend investigation strategies are separated into non-parametric and parametric procedures. In the ongoing years, the nonparametric strategies are favored by scientists for trend examination in light of the fact that these techniques are not delicate to anomalies and can be connected for non-normally circulated arrangement with missing values (Ahmadi et al. 2017) . Among the nonparametric techniques, the Mann-Kendall (MK) test, which proposed by (Mann 1945) and (Kendall 1975), is progressively famous and has recommended by World Meteorological Organization (WMO) for analyzing the trends of hydro meteorological time series (Kumar et al. 2009).

In the ongoing years, various examinations has been led to identify a spatial-transient trends in meteorological (rainfall, evapotranspiration, temperature, humidity and so on.) and hydrological (flow) time series data utilizing non-parametric (Kendall rank relationship, Spearman's rho, Mann-Kendall, adjusted Mann-Kendall, Thiel-Sen's incline) and parametric (simple linear regression) tests all through a world (Tabari et al. 2011; Some'e et al. 2012; Pingale et al. 2014; Gajbhiye et al. 2015; Amirataee et al. 2016; Khatiwada et al. 2016; Sonali and Kumar 2016; Chang et al. 2017; Dhorde et al. 2017; Kumar et al. 2017; Machiwal and Jha 2017; Meshram et al. 2017; Birara et al. 2018; Bisht et al. 2018; Kabanda 2018; Machiwal et al. 2018; Dinpashoh et al. 2019; Ouatiki et al. 2019; Ray et al. 2019; Chakraborty et al. 2013) examined a spatial and worldly fluctuation of precipitation in Seonath basin, Chhattisgarh, India, utilizing Mann-Kendall (MK), altered Mann-Kendall (MMK) and Spearman's rho (SR), and Thiel-Sen's slant (TSS) tests. A spatial example of the trend was examined in ArcGIS condition utilizing Inverse Distance Weighting (IDW) technique. Outcomes demonstrated a descending pattern on yearly also occasional precipitation. (Suryavanshi et al. 2014) examined spatio-fleeting trends in temperature, rainfall, and potential evapotranspiration of the Betwa basin situated in India, utilizing the MK test. The spatial example of a trend was examined in ArcGIS condition utilizing the Thiessen polygon (TP) strategy. Consequences of investigation demonstrated a decreasing trend in yearly and regular precipitation, just as most minimum and maximum temperatures, and trend increasing found in potential evapotranspiration. (Pingale et al. 2014) utilized MK and TSS tests to identify a spatial and mean of the trends (non-monsoon and monsoon annual and seasonal) and extraordinary yearly precipitation and daily temperature for the thirty - three urban focuses of the semi arid and arid province of Rajasthan, India. They announced that positive and negative trends were seen in the extreme and mean occasions of a temperature and precipitation in urban focuses. (Gajbhiye et al. 2015) analyzed the trend in occasional, monthly and yearly precipitation information of the Sindh stream basin, India, utilizing MK and MMK tests. The size of pattern line was recognized utilizing TSS test. The spatial example of its magnitude and trend was added in ArcGIS condition utilizing the kriging strategy. The fundamentally trend increasing found in annual and seasonal rainfall series. (Phuong et al. 2018) researched fleeting and spatial pattern of seasonal and annual rainfall data (1980 –2016) at 14 climate stations situated in Ho Chi Minh City, Vietnam, utilizing linear regression, MK, and TSS tests. The result demonstrated upward trends in the annual and seasonal rainfall over the time of thirty-seven years, however just drought indicated statistical trends significant. The outcomes likewise shown impressive augmentation in the rainfall dry season compared with the season rainy in the vast majority in the stations in the examination locale. In the previous couple of years, a few uses of the ITA strategy has been found for trend detecting in meteorological and hydrological time series data (Şen 2012; Kisi and Ay 2014; Şen 2014; Ay and Kisi 2015; Kisi 2015; Dabanli et al. 2016; Cui et al. 2017; Mohorji et al. 2017; Wu and Qian 2017; Güçlü et al. 2018; Kisi et al. 2018; Wu et al. 2018; Zhou et al. 2018; Balasmeh et al. 2019; Kisi and Ay 2014) trend detecting in water quality parameters in the Kizilirmak River, Turkey, utilizing MK and ITA approaches at 1% and 5% levels of importance. The consequences of examination uncovered the ITA method can

be effectively utilized for analysis trend of parameters water particularly as far as assessment of medium, low, and high of data. (Kisi 2015) identified trends in monthly pan-evaporation data of six stations (Adiyaman, Batman, Diyarbakir, Gaziantep, Kilis, and Siirt) in Turkey, utilizing MK and ITA techniques at 1% and 5% criticalness levels. The results of examination uncovered both increasing and desreasing trends over the investigation stations. He additionally announced that the ITA method is not dependent on serial non-normality, correlation, and sample number, and the trends of medium, high and low data can be easily observed by this method (Dabanli et al. 2016) appliedMKand ITAmethods at 5% level of essentialness for trend detecting in hydro meteorological data from Ergene seepage basin, Turkey. They announced the ITA method trend yields classifications (high, medium, low, extremely low) which aides in future flood (high) and droughts (low) studies. (Cui et al. 2017) analyzed trends in seasonal and annual air temperature and rainfall in the Yangtze River Basin, China, utilizing linear regression (LR), MK, Sen's slope estimator (SSE), and ITA method at 10%, 5%, and 1% levels of significance. They found that the annual and seasonal minimum, maximum and mean temperatures significantly increased. The the seasonal precipitation significantly decreased while annual precipitation significantly increases. Every one of the investigations above utilized the first version of ITA method. Just one examination led by (Zhou et al. 2018) examined trends in seasonal and annual solar radiation at fourty-eight stations in five distinctive climatic zones crosswise over China during (1962–2015), utilizing LR, MK, and ITA approaches with test significance as of late created by (Şen 2017) at 1% and 5% levels significance . The aftereffects of analysis trends indicated decreasing and increasing in seasonal and annual solar radiation over study stations. They likewise detailed that a numerous significance trend that can't be adequately recognized by LR and MK tests can be distinguished utilizing the new ITA method. (Caloiero et al. 2018) researched trend in monthly, annual, andseasonal rainfall data of fifty years in southern Italy, utilizing MK and ITA techniques at 5% level significance. They discovered trends in annual and seasonal rainfall values utilizing the ITA method, while the MK test showed a trend negative in fall and winter rainfall data over the examination region. The evaluation of trends in waterway streams has happened to enthusiasm to established researchers so as to comprehend the changing attributes of stream because of environmental change. In this examination, the trends in stream of Dukan Dam situated in the northern piece of Iraq were evaluated. The appraisal was completed the period 1964 to 2013 utilizing Sen's slope and the Mann – Kendall test (Ali, R et al.2019).

The principle constraint in used MK test on hydro climatological data set is a suspicion of absence of huge auto correlation in considered time series, while a most of hydroclimatological time series are serially correlated (Dinpashoh et al. 2014). The past investigations uncovered that on the off chance that the impact of autocorrelation does not expel from time searies, at that point the negative autocorrelation prompts disparage the significance of trend , while the positive auto correlation positive overestimate the significance of trend (Hamed and Rao 1998 and Koutsoyiannis 2003). So as to defeat this deformity, when the slack 1 auto correlation was critical, it was expelled from time series before used MK test. The huge slack 1 auto correlation coefficient in time series named as momentary perseverance (STP). In any case, in some time series, the auto correlations with more than one slack are noteworthy and can influence on exactness of a MK test (Zamani et al. 2017). The huge auto-connection with mutiple, named as long-term persistence (LTP) (Koutsoyiannis and Montanari 2007). (Hamed 2008) built up a changed variant of MK (RMK) test, which evacuated the impact of all critical auto correlation coefficient from time series before playing out a MK test. This procedure,called trend-free pre-whitening (TFPW) technique. Another form of MK test was proposed by (Hamed 2008), which considers the Hurst marvel. (Kumar et al.2009) looked at the presentation of four adaptations of MK test, i.e., exemplary MK test, MK test subsequent to expelling the slack 1 auto correlation, TFPWmethod, and MKtest considering the Hurst coefficient for distinguishing the patterns in flow time arrangement recorded in thirty one USGS stations in Indiana. The outcomes demonstrated that the auto correlation structure had not huge impact on the rainfall of trend time series. Also, it was discovered that a high streams were less corresponded than low streams in Northern Indiana. To this point, a various examinations has been directed to break down the trend of hydro climatological factors utilizing previously mentioned renditions of MK test (Yue and Wang 2004; Pal and Al-Tabbaa2009; De Martino et al.2013; Jhajharia et al. 2014; Gajbhiye et al. 2016; Amirataee et al. 2016; Zamani et al. 2017; Yan et al. 2017). The main disadvantage of a MK is including a few suspicions, which are free structure of the data length, data distribution, and time series. As of late, another non-parametric premise method was proposed by (Şen 2012) for trend detection of significance in time series, which called as innovative Trend Method (ITM). In a straightforward word, the ITM method considers the area of information focuses in a Cartesian organize framework and contrasts them and the 1:1 line as the benchmark (Tabari and Willems 2015). The ITM method is somewhat basic and isn't liable to any preconditions, for example, autocorrelation, non-normality and data length, and furthermore, this method plainly demonstrates the trend of low, medium, high and data (Tosunoglu and Kisi 2017). Despite the fact that the ITM method is as of late proposed, it immediately pulled in the consideration of specialists, the same number of studies have led by this technique. (Tabari and Willems 2015) utilized the ITM method for investigating the streamflow trend at eight stations in the northwest of Iran and contrasted the consequences of ITM method and MK test. (Demir and Kisi 2016) examined the annual total rainfall in six areas in Turkey by MK and ITM tests. (Dabanlı et al. 2016) looked at the presentation of MK and ITM method for breaking down the trend of relative rainfall, temperature, humidity and runoff variable factors in Ergene Basin, Turkey. (Tosunoglu and Kisi 2017) examined the Annual Maximum Severity (AMS) and Annual Maximum Duration (AMD) utilizing exemplary MK test, RMK test, and ITM test in 9 stations situated at Coruh River Basin, Turkey. The outcomes demonstrated that RMK test gave the ITM distinguished some noteworthy expanding or diminishing trends at these stations while no critical trend to the next 7 stations. (Wu and Qian 2017) dissected the trend in seasonal and annual rainfall time series at fourteen downpour measures in Shaanxi Province, China, applying the ITM, MK, and direct relapse techniques.(Öztopal and Sen 2017) have connected the ITM method for inspecting the rainfall trend at 7stations in Turkey. (Şen 2017a) proposed an over-brightening (O-W) method rather than pre-brightening (P-W) methodology for creating similar trend line slant with a free time arrangement. The past examinations utilized ITM dependent on graphical assessment as it were. (Şen 2017b) as of late built up an importance test for ITM method and connected yearly temperature records of Southern New Jersey, and annual discharge time series of Danube River and on annual total rainfall records of Tigris River Diyarbakir,. In the present investigation, ITM was utilized with noteworthiness test proposed by (Şen 2017b).

The quantitative trends of precipitation and temperature has been investigated utilizing various strategies, for example, a MK test, Sen's slope, Spearman test and LR (Jonsdottir et al. 2008; Ceribasi et al.2013; Kazmierczak et al.2014; Westra et al.2013) utilized a MK test to think about the trends in annual maximum daily precipitation, and noteworthy expanding trends has been recognized in worldwide scale. (Pingale et al.2014) connected a MK test and Sen's slope to examine the spatial-worldly trends of extreme and mean temperature and rainfall in Rajasthan, India, and negative and positive trends were seen in the urban focuses of Rajasthan State. (Martínez-Austria et al. 2015) examined the significant trends increasing for temperature and heat waves in northwest Mexico utilizing LR and the Spearman test. (Wang and Zhou 2005) utilized LR to seasonal and annual mean trends precipitation in China during 1961–2001, and the outcomes demonstrated that expanding trends in eastern China happened for the most part in summer, while the decreasing trends in focal, north and upper east China happened in autumn and spring.(Gemmer et al. 2011) utilized a MK test to investigate the spatial-fleeting attributes of precipitation drifts in the Zhujiang River Basin, South China. The outcomes demonstrated that few stations experienced trend in precipitation lists on a annual basis, however on a monthly basis, critical positive and negative trends were recognized in all months aside

from December. As of late, the ITAmethod, presented by (Sen 2012), have been effectively connected to research trend of meteorological and hydrological factors (Markus et al.,2014; Sen,2014). (Wu and Qian,2016) dissected the annual seasonal and trend precipitation at fourteen stations precipitation in Shanxi Province, China utilizing the MK test, LR and the ITA method. They found that the trend results were in expansive understanding among all tests and in complete understanding among tests with noteworthy patterns, which bolstered the utilization of a ITA method for the examination of trends precipitation. Notwithstanding, not many examinations has concentrated on spatial-fleeting varieties of precipitation and temperature drifts in different districts of China. Utilizing various strategies and thought about the related trends in various periods. (Rawshan Othman Ali et. al.) Decline in the amount of the Basin's water assets because of diminishing precipitation and rising air temperature.

The Yangtze River Basin YRB, the biggest stream Basin in China, have encountered atmosphere warming in previous fifty years (Tian et al.2016). In any case, a spatial appropriation of precipitation over the entire basin are amazingly uneven, which are more probable because of impacts of atmosphere warming on hydrological cycle. The effects of environmental change on a YRB will in general be annihilating because of the thick populace and fast financial improvement. The watershed technique uncovered the impacts of climatic conditions and human activity on water resources. Be that as it may, it is constrained by the consistent variety to land use designs normally littler in huge catchments than in little watersheds (Othman Ali R et al.2018) Therefore, inquire about on a long haul variety trends of precipitation and temperature in aYRB will be of crucial significance for guaging meteorological debacles (like, floods and dry spells) and the board of water assets. Tolerating a Yangtze River as a basic relevant examination, our responsibility gives a feasible and clear system for estimating the impact of human activities on RWT change. Such a novel system will, preferably, add to set coherent guidelines for water resources boss and maritime scientists (Ali RO et al. 2019).

However, for effective and efficient trend analysis,management of water resources at high, middle and low estimations of hydro meteorological time series data are additionally indispensable alongside the monotonic trends after some time identified by conventional trend examination tests, for example, Mann-Kendall , Spearman's rho test , Sen's slope estimator , linear regression , and so on . (Sen, 2012). For this reason, the innovation Trend Analysis (ITA) method, as of late presented by (Sen, 2012; Şen, 2014) have been effectively connected in water resources (Haktanir and Citakoglu, 2014; Kisi, 2015; Markus et al., 2014; Onyutha, 2016; Wu and Qian, 2017). For approval of ITA results, MK test have frequently been utilized on account of it is heartlessness toward exceptions and typical circulation of time series data. Trend examination of absolute monthly precipitation was explored in 6 unique areas at Turkey by utilizing ITA method and discovered noteworthy expanding patterns at Samsun and Trabzon territories, and inconsequential pattern in other four regions (Ay and Kisi, 2015). Warmth and Air temperature wave inclines somewhere in the range of 1960 and 2010 were examined in Northwestern Mexico by utilizing direct information change, Spearman's rho test and ITA method, and discovered trends clear on temperature increment and event of warmth waves (Martínez-Austria et al.,2016) . monthly trends precipitation were inspected for twenty five stations by utilizing ITA method and found a an increasing trend in southern and decreasing trend in the north pieces of Macta watershed in Algeria somewhere in the range of 1970 and 2011 (Elouissi et al., 2016). The patterns of most extreme hydrologic dry season factors for nine stations in Coruh River basin in Turkey were examined and MK test recognized no -pattern; in any case, changed MK test and ITA method demonstrated negative and positive trends at a few stations, and the pattern results was steady with one another (Tosunoglu and Kisi,2017). Consequently, ITA technique has a widespread materialness in contrast with a MK and Spearman's rho tests, which has some prohibitive suspicions, for example, sequentially free information, the typicality of circulation, regular cycle and time allotment arrangement.

China is located in a eastern part of the Eurasian Continent and have mind boggling geology and different climate types including monsoon climate continental (LIU M. et al.,2017). Accordingly, the investigations of trends in China are high significance not just regionally, yet in addition all around as a pointer of reaction to environmental change over differing settings. Like somewhere else, evaporation in a large portion of China has been demonstrated to incline descending. (Qiu et al., 2003) found evaporation was on a critical plunging pattern in a Yellow River Basin. (Guo et al.,2005) achieved the comparable end in the Huang –Huai - Hai Plain, and the crediting variables were believed to wind speed and sun based radiation. Be that as it may, (Liu et al., 2006) discovered cozy connections between dish vanishing and diurnal temperature extend (from now on DTR) and wind speed. (Zuo et al., 2005) found that skillet dissipation had a decent connection with a relative stickiness dependent on the atmosphere pattern investigation for China as the whole. Keeping the above audits as a top priority, this examination was led with the accompanying explicit targets Review rainfall time series data in trend utilizing the MK and new ITA method with test of significance.

2. Case study

The Yangtze River, the third longest on the world and the longest in Asia, begins on a Tibetan Plateau in western China, streams 6300km from the western hilly territory toward a eastern plain, lastly releases in to the East China Sea , with an around 5000 m drop in rise (Milliman and Farnsworth,2011; Yang et al., 2014). The drainage basin located in the range of 91 and 122_ E and 25–35_ N (Fig. 1,Lifang Cui et al.2017), covering 1.8 _ 106km2, which records for almost 20 % of the landmass of China (Li et al.,2011;Guan et al.2015). Aside from some areaslocated on the Tibetan Plateau, the YRB is described by a subtropical monsoon climate (Zhang et al.2005; Zhao et al.2012). The upper and mid-lower YRB are influenced by the Indian summer monsoon and the East Asian summer monsoon, two independent of the Asia monsoon (Ding and Chan, 2005; Chen et al., 2014). Affected by monsoon, the YRB presents a particular yearly cycle of dry and wet seasons in the Qinghai-Tibet Plateau and streams around 6300 km eastwards toward the East China Sea. It moves through eleven regions: Qinghai, Xizang (Tibet), Sichuan, Yunnan, Chongqing, Hubei, Hunan, Jiangxi, Anhui, Jiangsu, and Shanghai, separately. What's more, has a populace of in excess of 400 million (1/3 of the Chinese populace) (Yang et al., 2002). The precipitation designs all through the Yangtze River Basin shift generally, expanding east wards from 850mm/yr in upper Basin to in excess of 1800mm/yr in the mid-lower Basin (Li et al.2011;Yu et al.2012). The TGD began to appropriate water in 2003 and were in full task by 2009. The subsequent repository has a storage capacity of 39.3 km3, about 4.5 % of the Yangtze yearly release. Stream Yangtze is picked as a best example to examine the power impacts of the dams and floodgates upstream on the hydrological regime (Rawshan Othman Ali et al.2019).

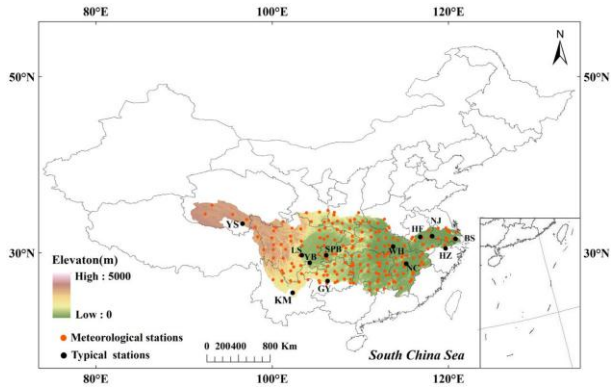

Fig. 1: Yangtze River Basin Map (Cui L. et al.2017).

3. Methodology

The primary thought analysis of trend is to recognize whether an observed estimation of a hydro meteorological time series are trendless, decreased or increased. Distinctive nonparametric and parametric methods were utilized by a several researchers to distinguish a trends in hydro meteorological data time series. The parametric method considered as increasingly ground-breaking over nonparametric methods yet have numerous prohibitive estimates, for example, data should be serially independent and normally distributed, which are infrequently valid in the event of hydro meteorological data time series. Subsequently, nonparametric method have frequently been connected in recognizing the trends in hydro meteorological time series since it doesn't data normally distributed restriction ; be that as it may, the information must be serial correlation free . for the evacuation of serial correlation, (Von Storch1999) proposed a pre brightening method system before the use of MKtest for the trend detecting in a hydro meteorological time series. Nonetheless, (Douglas et al.2000 and Yue et al.2002) contended that the use of the pre-brightening procedure to the data time series may bargain the innovation of time arrangement and evacuates a part of a trend. Along these lines, (Sen2012) proposed an innovative Trend Analysis (ITA) method, which is free from these prohibitive measures and has an all inclusive appropriateness. In this examination, ITAmethod was utilized to identify the trends in the time series. The consequences of ITAmethod was compare and two well known non-parametric tests, i.e., Mann-Kendall and Sen's slope tests to reliability the dependability of ITAmethod. In addition, seasonal and annual rainfall time series was analyzed utilizing the ITAmethod for force based trends classifications. The four seasons were outlined as winter (Dec-Feb), spring or pre-rainstorm (Mar-May), summer or storm (Jun-Sep), and pre-winter or post storm (Oct-Nov). The monthly flow data was added to produce the occasional and annual trends time series (Ahmad et al.2015; Duhan and Pandey.2013). The trends in the flow time series were evaluated at 10 %, 5 %, and 1 % centrality levels by utilizing the ITA, MK and Sen's slope method. A centrality level of 10 % was considered as a indicate trend significant (I. Ahmad et al. 2018).methodology shown in the figure.2

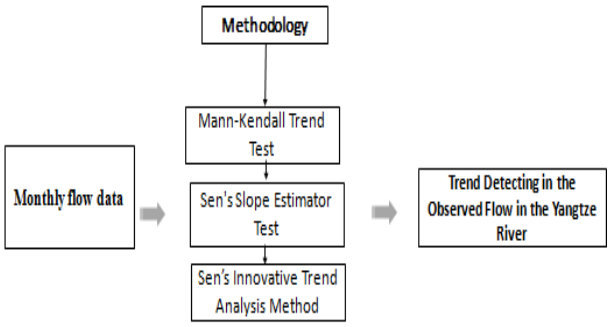

Fig. 2: Research Design.

3.1 Mann-kendall (MK) trend test

The non-parametric Mann-Kendall(MK) test (Kendall,1975;Mann,1945) is most commonly used for trends identifying in hydro meteorological data time series, because of its insensitivity to normal distribution of data time series and outliers (Hamed,2008). The MKtest statistic (S) is given by:

$$S = \sum_{i=2}^{n} \sum_{j=1}^{i-1} \text{Sign}\ (x_i - x_j) \quad (1)$$

$$\text{sign}(x_i - x_j) = \begin{cases} -1 \text{ for } (x_i - x_j) < 0 \\ 0 \text{ for} (x_i - x_j) = 0 \\ 1 \text{ for} (x_i - x_j) > 0 \end{cases} \quad (2)$$

Where n signifies the length of the dataset, X_j and X_i are the successive information esteems on occasion j and i, sgn means the sign capacity that takes on the values 1, 0, or−1; if $X_j > Xi$, $X_j = X_i$ or $X_j < X_k$, individually. S values Positive demonstrate an expanding (upward) trend, and value of S negative uncover the decreasing (descending) trend in the data time series. For tests, n >10, the test is directed utilizing distributional is normal ($\sigma 2 = 1$) and mean ($\mu = 0$) (Helsel and Hirsch, 1992), variance (Var) and with expectation (E) as follows:

$$E[S] = 0 \quad (3)$$

$$V_o(S) = \frac{s(n-1)\,(2n+5)-\sum_{k-1}^{q} tk(t_k-1)(2t_k+5)}{18} \quad (4)$$

Where p is tied roup, t_k a number of observations in a k_{th} group, a sign (Σ) speaks to the summation of all a tied group. Be that as it may, if there are no-tied groups in a data, this outline course might be slighted. In a wake of calculating a variance Var (S) from Eq. (4), a standardized test statistic (Z_{mk}) value calculated by utilizing the following equations.

$$Z_{MK} = \begin{cases} \frac{s-1}{\sqrt{Var(S)}} & \text{if } S > 0 \\ 0 \quad \text{if } S = 0 \\ \frac{s+1}{\sqrt{Var(S)}} & \text{if} S < 0 \end{cases} \quad (5)$$

The determined standardized Z_{mk} values follow distribution normal with variance normal "0"and "1" , it is utilized a measure of trend significance. In fact, this test measurement is utilized to null hypothesis test, H0 if Z_{mk} is morethan $Z_{\alpha/2}$. This value of Z_{mk} is contrasted and standard distribution normal table of two followed test at certainty levels of α=1 %, α=5 % and α=10 %. In a two-followed test, null hypothesis (H0) is accepted for no trend if the determined value of Z_{mk} between – $Z_{1-\alpha/2}$ and $Z_{1-\alpha/2}$, and in this way, H1 is rejected.

3.2. Sen's slope estimator test

Non-parametric method (Sen, 1968) was used to estimate the magnitude of trends in the data time series. The slope of "n" pairs of data can be first estimated by using the following equation:

$$\beta_i = \text{Median}\left[\frac{X_j - X_k}{j-k}\right] \forall\, (k < j) \quad (6)$$

In this equation, X_j and X_k denote values data at time j and k, respectively, and time j is after time k ($k \le j$). The median of "n" values of β_i is the Sen's slope estimator test. A negative β_i value represents a decreasing trend, a positive β_i value represents an increasing trend over time.
If "n" is an even number, then the slope Sen's estimator is computed by using the following equation:

$$\beta_{med} = \frac{1}{2}\left(\beta_{[n/2]} + \beta_{[(n+2)/2]}\right) \quad (8)$$

If "n" is an odd number, then the estimated slope by using the Sen's method can be computed as follows:

$$\beta_{med} = \beta_{[(n+1)/2]} \quad (7)$$

Lastly, β_{med} is tested by a two tailed test at 100 (1−α) % confidence level, and the true slope of monotonic trend can be estimated by using a nonparametric test (Partal and Kahya, 2006).

3.3. Innovative trend analysis (ITA) method

The Innovative Trend Analysis (ITA) method have been utilized in a several studies around the globe trends detect in the climatological ,meteorological and hydrological data time series , and a reliability of ITA were confirmed by comparing its outcomes and results Mann-Kendall (MK) test. This method, the first step is dividing the hydro-meteorological data time series into two equivalent parts and organizes each sub-series in ascending order independently. For example, in the event that there are 54 perceptions in the time-series, then the first 27 observations will be the first half and the next 27 observations will become the second half of the time series. In the second step, the first half (Xi: i=1, 2… n/2) of the sub-arrangement is put on the X-axiz and the second half (Xj: j=n/2+1, n/2+2… n) is set on the Y-axis of a Cartesian coordinate system as appeared in Fig. 3. The range of both axes (vertical and horizontal axis) must be same. The space of variety of each sub-series might be portrayed by a progression of bunches .This kind of plots offers first visual check of the nature of trends in time series. The range of every subgroup might be resolved either qualitative or quantitatively. If the data points in a scatter plot are collected on the 1:1 (45o) straight line, it means that there is no-trend in the hydro-meteorological time series (trendless time series). Something else, if the data point accumulated in the triangular area above or below the 1:1 straight line, it means that the time series shows an decreasing and increasing trends, separately (Sen,2012). The magnitude of a decreasing and increasing trend in the time series can be calculated by the average between the Xi and Xj values at each point. This absolute difference might be taken as the vertical or horizontal distance from the 1:1 straight line. Be that as it may, this average difference should be normalized in comparing trend of two subseries. The trend change is resolved dependent on the first half of the time series. In this manner, the trend indictor is determined by dividing the average difference from the 1:1 straight line to the average of first half of the time series. The ITA trend indictor is multiplied by 10 to represent to a similar scale as that of the MK test and Sen's slope estimator test at 10% significance level and is presented in the following equations

$$B = \frac{1}{n}\sum_{i=1}^{n}\frac{10(X_j - X_i)}{\mu} \quad (9)$$

Where B reprents to the trend indictor, n indicates the length of each subseries, X_i and X_j are the observed data value in the first and second subseries, separately, and μ signifies the mean of the first subseries, a negative or positive value of B demonstrates an increasing or decreasing trend, individually. If the observed data values in the original time series are odd, then the first observation may be ignored before dividing it into two halves to make full use of latest records.

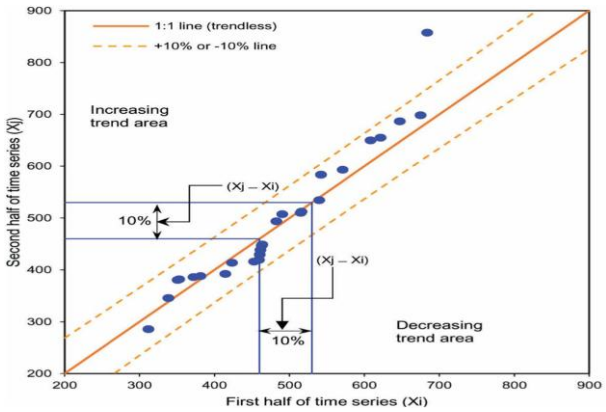

Fig. 3: Illustrate of Trendless, Decreasing and Increasing Regions in the ITA Method (I. Ahmad Et Al. 2018).

4. Conclusion

In the present study, trends in seasonal and annual flow time series were reviewed on for Yangtze River Basin, utilizing Mann Kendall (MK), Sen's method and Şen's innovative Trend Method (ITM). In any case, , a significant trend increasing was just seen in the source region of the Yangtze River and trend decreasing that was not statistically significant were detected over the whole study area. The study showed that the Innovation Trend Method has a few points interest in relative to Sen's and Mann-Kendall trend method. One is that it does exclude any assumptions (such us: test number, serial relationship and non-normality, so forth.) compared with Sen's and MK trend method. The other point is that the trends of high, medium, and low data can be effectively distinguished by Innovation Trend Method. This new method can be used in climate change scenarios and a priori view to the authorities and designers and can give useful information.

Recommendation and suggestion

The technique can give a helpful information and from the earlier view to the specialists and originators and can be utilized in climate change scenarios and an understanding into future improvement ventures; for example, it can display important information and from the earlier view to help the architects and experts to execute the structures to be developed to adapt to the floods and droughts when taking a gander at winning climatic occasions.

Acknowledgements

The authors wish to sincerely thank China Scholarship Council, China Three Gorges University for funding this study.

References

[1] Abdi A, Hassanzadeh Y, Talatahari S, Fakheri-Fard A, Mirabbasi Rn (2017) Regional drought frequency analysis using L-moments and adjusted charged system search. J Hydroinf 19(3):426–442. https:// doi.org/10.2166/hydro.2016.228
[2] Ahmad, I., Tang, D., Wang, T., Wang, M., Wagan, B., (2015). Precipitation trends over time using Mann-Kendall and Spearman's rho tests in Swat River basin, Pakistan. Adv. Meteorol. 2015.
[3] Ahmadi F, Nazeri Tahroudi M, Mirabbasi R, Khalili K, Jhajharia D (2017) Spatiotemporal trend and abrupt change analysis of temperature in Iran. Meteorol Appl 25(2):314–321. https://doi.org/10. 1002/met.1694
[4] Ali, R., Chunju, Z., Yihon, Z., & Nawaz, N. (2018). The Challenges of Water Resources Availability and Development in Huai River Basin, China. Current Journal of Applied Science and Technology, 25(3), 1-13. https://doi.org/10.9734/CJAST/2017/38191
[5] Ali, R., & Heryansyah, A. (2018). WATERSHED RETENTION CAPACITY APPROACH FOR IDENTIFYING WATER RESOURCE PROBLEMS-CASE STUDY FROM MALAYSIA. Polytechnic Journal, 8(1). https://doi.org/10.25156/ptj.2018.8.1.97
[6] Ali, R.; Ismael, A.; Heryansyah, A.; Nawaz, N. Long Term Historic Changes in the Flow of Lesser Zab River, Iraq. *Hydrology* 2019, *6*, 22. https://doi.org/10.3390/hydrology6010022
[7] Ali RO, Abubaker SR, Islam S. Overview effect of three gorges reservoir on the changing water temperature in the Yangtze river, China. Int J Hydro. 2019;3(3):230–237. DOI: 10.15406/ijh.2019.03.00185
[8] Amirataee B, Montaseri M, Sanikhani H (2016) The analysis of trend variations of reference evapotranspiration via eliminating the significance effect of all autocorrelation coefficients. Theor Appl Climatol 126(1–2):131–139
[9] Ay M, Kisi O (2015) Investigation of trend analysis of monthly total precipitation by an innovative method. Theor Appl Climatol 120: 617–629
[10] BalasmehOA, Babbar R, Karmaker T (2019) Trend analysis and ARIMA modeling for forecasting precipitation pattern inWadi Shueib catchment area in Jordan. Arab J Geosci. https://doi.org/10.1007/s12517-018-4205-z
[11] Bellu A, Sanches Fernandes LF, Cortes RMV, Pacheco FAL (2016) A framework model for the dimensioning and allocation of a detention basin system: the case of a flood-prone mountainous watershed. J Hydrol 533:567–580
[12] Birara H, Pandey RP, Mishra SK (2018) Trend and variability analysis of rainfall and temperature in the Tana basin region, Ethiopia. J Water Clim Chang. https://doi.org/10.2166/wcc.2018.080
[13] Bisht DS, Chatterjee C, Raghuwanshi NS, Sridhar V (2018) Spatiotemporal trends of rainfall across Indian river basins. Theor Appl Climatol 132:419–436
[14] Brunsell NA, Jones AR, Jackson TL, Feddema JJ (2010) Seasonal trends in air temperature and precipitation in IPCC AR4 GCM output for Kansas, USA: evaluation and implications. Int J Climatol 30(8): 1178–1193
[15] Callaghan, T.V., Johansson, M., Brown, R.D., Groisman, P.Y., Labba, N., Radionov, V., Bradley, R.S., Blangy, S., Bulygina, O.N., Christensen, T.R., Colman, J.E., Essery, R.L.H., Forbes, B.C., Forchhammer, M.C., Golubev, V.N., Honrath, R.E., Juday, G.P., Meshcherskaya, A.V., Phoenix, G.K., Pomeroy, J., Rautio, A., Robinson, D.A., Schmidt, N.M., Serreze, M.C., Shevchenko, V.P., Shiklomanov, A.I., Shmakin, A.B., Sköld, P., Sturm, M., Woo, M.K., Wood, E.F.,(2011). Multiple effects of changes in arctic snow cover. Ambio 40, 32–45. http://dx.doi.org/10.1007/s13280-011-0213-x.

[16] Caloiero, T., Coscarelli, R., Ferrari, E., Mancini, M., 2011. Trend detection of annual and seasonal rainfall in Calabria (Southern Italy). Int. J. Climatol. 31 (1), 44–56.

[17] Ceribasi, G., Dogan, E., Sonmez, O., (2013). Evaluation of Sakarya River streamflow and sediment transport with rainfall using trend analysis. Fresenius Environ. Bull. 22 (3A), 846–852.

[18] Chakraborty S, Pandey RP, Chaube UC, Mishra SK (2013) Trend and variability analysis of rainfall series at Seonath River basin, Chhattisgarh (India). Int J Appl Sci Eng Res 2(4):425–434

[19] Chang X, Xu Z, Zhao G, Cheng T, Song S (2017) Spatial and temporal variations of precipitation during 1979–2015 in Jinan City, China. J Water Clim. https://doi.org/10.2166/wcc.2017.029

[20] Chen, J., Wu, X.D., Finlayson, B.L., Webber, M., Wei, T.Y., Li, M.T., Chen, Z.Y., (2014). Variability and trend in the hydrology of the Yangtze River, China: annual precipitation and runoff. J. Hydrol. 513, 403–412.

[21] Chen, P.C., Wang, Y.H., You, G.J.Y., Wei, C.C., (2017). Comparison of methods for nonstationary hydrologic frequency analysis: case study using annual maximum daily precipitation in Taiwan. J. Hydrol. 545, 197–211. http://dx.doi.org/10.1016/j.jhydrol.2016.12.001

[22] Costa, A.C., Santos, J.A., Pinto, J.G., (2012). Climate change scenarios for precipitation extremes in Portugal. Theor. Appl. Climatol. 108, 217–234. http://dx.doi.org/10.1007/s00704-011-0528-3.

[23] Cui L, Wang L, Lai Z, Tian Q, Liu W, Li J (2017) Innovative trend analysis of annual and seasonal air temperature and rainfall in the Yangtze River basin, China during 1960-2015. J Atmos Sol Terr Phys 164:48–59

[24] Dabanlı I, Sen Z, Yeleğen MO, 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

[25] De Martino G, Fontana N, Marini G, Singh V (2013) Variability and trend in seasonal precipitation in the continental United States. J Hydrol Eng 18(6):630–640. https://doi.org/10.1061/(ASCE)HE.1943-5584.0000677

[26] Demir V, Kisi O (2016) Comparison of Mann-Kendall and innovative trend method (Şen trend) for monthly total precipitation (Middle Black Sea Region, Turkey). 3rd International Balkans Conference on Challenges of Civil Engineering, 3-BCCCE, 19–21 May 2016, Epoka University, Tirana, Albania

[27] Dhorde AG, Korade MS, Dhorde AA (2017) Spatial distribution of temperature trends and extremes overMaharashtra and Karnataka states of India. Theor Appl Climatol 130:191–204

[28] Ding, Y.H., Chan, J.C.L., (2005). The East Asian summer monsoon: an overview. Meteorol. Atmos. Phys. 89 (1), 117–142.

[29] Dinpashoh Y, Mirabbasi R, Jhajharia D, Abianeh HZ, Mostafaeipour A (2014) Effect of short-term and long-term persistence on identification of temporal trends. J Hydrol Eng 19(3):617–625

[30] Dinpashoh Y, Singh VP, Biazar SM, Kavehka S (2019) Impact of climate change on streamflow timing (case study: Guilan Province). Theor Appl Climatol. https://doi.org/10.1007/s0070401902810-2

[31] Douglas, E.M., Vogel, R.M., Kroll, C.N., 2000. Trends in floods and low flows in the United States: impact of spatial correlation. J. Hydrol. 240, 90–105. http://dx.doi.org/10.1016/S00221694(00)00336-X.

[32] Duhan, D., Pandey, A., 2013. Statistical analysis of long term spatial and temporal trends of precipitation during 1901–2002 at Madhya Pradesh, India. Atmos. Res. 122,136–149.

[33] Elouissi, A., Şen, Z., Habi, M., (2016). Algerian rainfall innovative trend analysis and its implications to Macta watershed. Arab. J. Geosci. 9. http://dx.doi.org/10.1007/ s12517-016-2325-x.

[34] Eslamian, S., L. K., H.R.,(2011). Climate change detection and modeling in hydrology, in: climate change - research and Technology for Adaptation and Mitigation. INTECH. http://dx.doi.org/10.5772/24550.

[35] Friedlingstein, P., Liu, C.Z., Tan, K., Yu, Y.Q., Zhang, T.Y., Fang, J.Y., (2010). The impacts of climate change on water resources and agriculture in China. Nature 467, 4351.

[36] Gajbhiye S, Meshram C, Mirabbasi R, Sharma SK (2016) Trend analysis of rainfall time series for Sindh River basin in India. Theor Appl Climatol 125:593–608. https://doi.org/10.1007/s00704-015-1529-4

[37] Gajbhiye S,Meshram C, Mirabbasi R, Sharma SK (2015) Trend analysis of rainfall time series for Sindh river basin in India. Theor Appl Climatol 125:593–608

[38] Gajbhiye, S., Meshram, C., Singh, S.K., Srivastava, P.K., Islam, T., (2016). Precipitation trend analysis of Sindh River basin, India, from 102-year record (1901-2002). Atmos. Sci. Lett. 17, 71–77. http://dx.doi.org/10.1002/asl.602.

[39] Ge, Q.S., Wang, F., Luterbacher, J., (2013). Improved estimation of mean warming trend of China from 1951-2010 based on satellite observed land-use data. Clim. Change 121, 365–379.

[40] Gemmer, M., Fischer, T., Jiang, T., Su, B., Liu, L.L., (2011). Trends in precipitation extremes in the Zhujiang River basin, south China. J. Clim. 24 (3), 750–761.

[41] Gerten, D., Rost, S., von Bloh, W., Lucht, W., (2008). Causes of change in 20th century global river discharge. Geophys. Res. Lett. 35 (20), 1–5.

[42] Guan, Y.H., Zhang, X.C., Zheng, F.L., Wang, B., (2015). Trends and variability of daily temperature extremes during 1960-2012 in the Yangtze River Basin, China. Glob. Planet. Change 124, 79–94.

[43] Güçlü YS (2018) Multiple Sen-innovative trend analyses and partial Mann-Kendall test. J Hydrol 566:685–704

[44] Guo Jun, Ren Guoyu, (2005). Recent change of pan evaporation and possible climate factors over the Huang–Huai–Hai watershed, China. *Advances in Water Science*, 16(5): 666–672. (in Chinese)

[45] Haktanir, T., Citakoglu, H., (2014). Trend, independence, stationarity, and homogeneity tests on maximum rainfall series of standard durations recorded in Turkey. J. Hydrol. Eng. 19, 05014009. http://dx.doi.org/10.1061/(ASCE)HE.1943-5584.0000973.

[46] Hamed KH (2008) Trend detection in hydrologic data: theMann-Kendall trend test under the scaling hypothesis. J Hydrol 349:350–363

[47] Helsel, D.R., Hirsch, R.M., 1992. Statistical Methods in Water Resources. Elsevier.

[48] Ijaz Ahmad, Fan Zhang, Muhammad Tayyab, Muhammad Naveed Anjum, Muhammad Zaman, Junguo Liu, Hafiz Umar Farid, Qaisar Saddique.(2018). Spatiotemporal analysis of precipitation variability in annual, seasonal and extreme values over upper Indus River basin. Atmospheric Research 213 (2018) 346–360. https://doi.org/10.1016/j.atmosres.2018.06.019

[49] IPCC (2013) Summary for policymakers. In: Stocker TF, Qin D, Plattner GK, Tignor M, Allen SK, Boschung J, Nauels A, Xia Y, Bex V, Midgley PM (eds) Climate change 2013: the physical science basis. Contribution of working group I to the fifth assessment report of the intergovernmental panel on climate change. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA

[50] Jhajharia D, Dinpashoh Y, Kahya E, Choudhary RR, Singh VP (2014) Trends in temperature over Godavari River basin in Southern Peninsular India. Int J Climatol 34(5):1369–1384

[51] Jin, K.J., Wang, F., Chen, D.L., Jiao, Q., Xia, L., Fleskens, L., Mu, X.M., (2015). Assessment of urban effect on observed warming trends during 1955–2012 over China: a case of 45 cities. Clim. Change 132 (4), 631–643.

[52] Jonsdottir, J.F., Uvo, C.B., Clarke, R.T., (2008). Trend analysis in Icelandic discharge, temperature and precipitation series by parametric methods. Hydrol. Res. 39 (5–6), 425–436

[53] Kabanda T (2018) Long-term rainfall trends over the Tanzania coast. Atm. 9(155):1–12

[54] Karl, T.R., (1998). Regional trends and variations of temperature and precipitation. In: Watson, R.T., Zyinyowera, M.C., Moss, R.H. (Eds.),

[55] Kazmierczak, B., Kotowski, A., Wdowikowski, M.,(2014). Trend analysis of annual and The Regional Impacts of Climate Change, an Assessment of Vulnerability. IPCC, Cambridge University Press, pp. 411–437.

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

[57] Khatiwada KR, Panthi J, Shrestha ML, Nepal S (2016) Hydro-climatic variability in the Karnali River basin of Nepal Himalaya. Climate 4(17):1–14

[58] Kisi O, AyM(2014) Comparison of Mann–Kendall and innovative trend method for water quality parameters of the Kizilirmak River, Turkey. J Hydrol 513:362–375
[59] Kisi O, Santos CAG, Silva RMD, Zounemat-Kermani M (2018) Trend analysis of monthly streamflows using Şen's innovative trend method. Geofizika 35(1):53–68
[60] Kisi, O., 2015. An innovative method for trend analysis of monthly pan evaporations. J. Hydrol. 527, 1123–1129. http://dx.doi.org/10.1016/j.jhydrol.2015.06.009.
[61] Koutsoyiannis D, Montanari A (2007) Spatial analysis of hydroclimatic time series: uncertainty and insights. Water Resour Res 43(5): W05429 1-9
[62] Kumar S, Machiwal D, Dayal D (2017) Spatial modelling of rainfall trends using satellite datasets and geographic information system. Hydrol Sci J 62(10):1–18
[63] Kumar S, Merwade V, Kam J, Thurner K (2009) Streamflow trends in Indiana: effects of long term persistence, precipitation and subsurface drains. J Hydrol 374(1):171–183
[64] Kumar V, Jain SK (2010) Rainfall trend in Ganga-Brahmputra-Meghna River basins of India (1951-2004). Hydrol J 33:59–66
[65] Kurane, I., (2010). The effect of global warming on infectious diseases. Publ. Health Res. Perspect. 1 (1), 4–9
[66] Li Q, Yu M, Lu G, Cai T, Bai X, Xia Z. (2011). Impacts of the Gezhouba and Three Gorges reservoirs on the sediment regime in the Yangtze River, China. *Journal of Hydrology* 403(3): 224-233.
[67] Lifang Cui , Lunche Wang, Zhongping Lai , Qing Tian , Wen Liu , Jun Li .(2017). Innovative trend analysis of annual and seasonal air temperature and rainfall in the Yangtze River Basin, China during 1960–2015. Journal of Atmospheric and Solar-Terrestrial Physics 164 (2017) 48 59http://dx.doi.org/10.1016/j.jastp.2017.08.001
[68] Liu Bo. Ma Zhuguo, Ding Yuguo, (2006). Characteristics of the changes in pan evaporation over northern China nduring the past 45 years and the relations to environment factors. *Plateau Meteorology*, 25(5): 840–848. (in Chinese)
[69] LIU Min, SHEN Yanjun, ZENG Yan, LIU Changming. (2010). Trend in pan evaporation and its attribution over the past 50 years in China, J. Geogr. Sci. 2010, 20(4): 557-568 DOI: 10.1007/s11442-010-0557-3
[70] Machiwal D, Gupta A, Jha MK, Kamble T (2018) Analysis of trend in temperature and rainfall time series of an Indian arid region: comparative evaluation of salient techniques. Theor Appl Climatol.https://doi.org/10.1007/s00704-018-2487-4
[71] Machiwal D, Jha MK (2017) Evaluating persistence and identifying trends and abrupt changes in monthly and annual rainfalls of a semi-arid region in Western India. Theor Appl Climatol 128:689– 708
[72] Mann HB (1945) Nonparametric test against trend. Econometrica 13: 245–259
[73] Markus, M., Demissie, M., Short, M.B., Verma, S., Cooke, R.A., (2014). Sensitivity analysis of annual nitrate loads and the corresponding trends in the lower Illinois River. J. Hydrol. Eng. 19, 533–543. http://dx.doi.org/10.1061/(ASCE)HE.1943-5584.
[74] Martínez-Austria, P.F., Bandala, E.R., Patino-G_omez, C., 2015. Temperature and heat wave trends in northwest Mexico. Phys. Chem. Earth 91, 20–26.
[75] Martínez-Austria, P.F., Bandala, E.R., Patiño-Gómez, C., (2016). Temperature and heat wave trends in Northwest Mexico. Phys. Chem. Earth 91, 20–26. http://dx.doi.org/ 10.1016/j.pce.2015.07.005.
[76] Meshram SG, Singh VP, Meshram C (2017) Long-term trend and variability of precipitation in Chhattisgarh State, India. Theor Appl Climatol 129:729–744
[77] Milliman, J.D., Farnsworth, K.L., (2011). River Discharge to the Coastal Ocean: a Global Synthesis. Cambridge University Press, Cambridge.
[78] Mohorji AM, Şen Z, Almazroui M (2017) Trend analyses revision and global monthly temperature innovative multi-duration analysis. Earth Syst Environ. https://doi.org/10.1007/s41748-017-0014-x
[79] Nazeri Tahroudi M, Khalili K, Ahmadi F, Mirabbasi R, Jhajharia D (2018) Development and application of a new index for analyzing patterns and temporal variability of dryness/wetness in the Yangtze River Basin, China. Quat. Int. 282, 5–13.
[80] Onyutha, C., (2016). Identification of sub-trends from hydro-meteorological series. Stoch. Env. Res. Risk A. 30, 189–205. http://dx.doi.org/10.1007/s00477-015-1070-0
[81] Othman Ali R, Chunju Z, Yihon Z, et al. The effects of human activities, climatic conditions and land-use factors on water resources development in huai river basin northeast china. Int J Hydro. 2018;2(2):107–114. DOI: 10.15406/ijh.2018.02.00059.
[82] OuatikiH, Boudhar A, Ouhinou A, AriouaA, Hssaisoune M, Bouamri H, Benabdelouahab T (2019) Trend analysis of rainfall and drought over the Oum Er-Rbia River basin in Morocco during 1970–2010. Arab J Geosci. https://doi.org/10.1007/s12517-019-4300-9
[83] Öztopal A, Sen Z (2017) Innovative trend methodology applications to precipitation records in Turkey. Water Resour Manag 31(3):727– 737. https://doi.org/10.1007/s11269-016-1343-5
[84] Pal I, Al-Tabbaa A (2009) Trends in seasonal precipitation extremes: an indicator of climate change in Kerala, India. J Hydrol 367(1–2):62–69
[85] Pal, I., Al-Tabbaa, A., (2011). Assessing seasonal precipitation trends in India using parametric and non-parametric statistical techniques. Theor. Appl. Climatol. 103, 1–11. http://dx.doi.org/10.1007/s00704-010-0277-8
[86] Partal, T., Kahya, E., 2006. Trend analysis in Turkish precipitation data. Hydrol. Process. 20, 2011–2026. http://dx.doi.org/10.1002/hyp.5993.
[87] Phuong DND, Linh VT, Nhat TT, Dung HM, Loi NK (2018) Spatiotemporal variability of annual and seasonal rainfall time series in Ho Chi Minh City, Vietnam. J Water and Clim Change. https:// doi.org/10.2166/wcc.2018.115
[88] Piao, S.L., Ciais, P., Huang, Y., Shen, Z.H., Peng, S.S., Li, J.S., Zhou, L.P., Liu, H.Y., Ding, Y.H., Pingale, S.M., Khare, D., Jat, M.K., Adamowski, J., (2014). Spatial and temporal trends of mean and extreme rainfall and temperature for the 33 urban centers of the arid and semi-arid state of Rajasthan, India. Atmos. Res. 138, 73–90.
[89] Pingale SM, Khare D, JatMK, Adamowski J (2014) Spatial and temporal trends ofmean and extreme rainfall and temperature for the 33 urban centers of the arid and semi-arid state of Rajasthan, India. Atm Res 138:73–90
[90] Qiu Xinfa, Liu Changming, Zeng Yan, (2003). Changes of pan evaporation in the recent 40 years over the Yellow River Basin. *Journal of Natural Resources*, 18(4): 437–442. (in Chinese)
[91] Rawshan Othman Ali, Arez Mohammed Ismael, Muhammad Arif Mengal, Nadeem Nawaz and Arien Heryansyah, (2019). Influences of Three Gorges Dam on Flow Regime of Yangtze River, China. Journal of Engineering and Applied Sciences, 14: 5899-5905. DOI: 10.3923/jeasci.2019.5899.5905
[92] Rawshan Othman Ali, Arien Heryansyah, Nadeem Nawaz.(2018). Impact of climatic change on water resources in Huia river basin, China. International Journal of Engineering & Technology. 2018;7(4):2225–2230. DOI: 10.14419/ijet.v7i4.15788
[93] Ray LK, Goel NK, Arora M (2019) Trend analysis and change point detection of temperature over parts of India. Theor Appl Climatol. https://doi.org/10.1007/s00704-019-02819-7
[94] Ren, G.Y., Ren, Y.Y., Zhan, Y.J., Sun, X.B., Liu, Y.J., Chen, Y., Wang, T., 2015. Spatial and temporal patterns of precipitation variability over mainland China: Ⅱ. recent trends. Adv. water Sci. 26 (4), 451–465 (in Chinese).
[95] Şen Z (2012) An innovative trend analysis methodology. J Hydrol Eng 17(9):1042–1046
[96] Şen Z (2014) Trend identification simulation and application. J Hydrol Eng 19(3):635–642
[97] Şen Z (2017) Innovative trend significance test and applications. Theor Appl Climatol 127:939 947
[98] Şen Z (2017a) Hydrological trend analysis with innovative and overwhitening procedures. Hydrol Sci J 62(2):294–305. https://doi.org/10.1080/02626667.2016.1222533
[99] Şen Z (2017b) Innovative trend significance test and applications. Theor Appl Climatol 127:939–947. https://doi.org/10.1007/s00704-015- 1681-x
[100] Şen Z (2018) Crossing trend analysis methodology and application for Turkish rainfall records. Theor Appl Climatol 131:285–293
[101] Sen, P.K., 1968. Estimates of the regression coefficient based on Kendall's tau. J. Am. Stat. Assoc. 63, 1379–1389.
[102] Sen, Z., (2012.) Innovative trend analysis methodology. J. Hydrol. Eng. 17, 1042–1046. http://dx.doi.org/10.1061/(ASCE)HE.1943-5584.0000556.

[103] Şen, Z., (2014). Trend identification simulation and application. J. Hydrol. Eng. 19, 635–642. http://dx.doi.org/10.1061/(ASCE)HE.1943-5584.0000811.
[104] Shen, D., Varis, O., 2001. Climate change in China. Ambio 30 (6), 381–383.
[105] Some'e BS, Ezani A, Tabari H (2012) Spatiotemporal trends and change point of precipitation in Iran. Atmos Res 113:1–12
[106] Sonali P, Kumar DN (2016) Spatio-temporal variability of temperature and potential evapotranspiration over India. J Water Clim Chang 7(4):810–822
[107] Sun, Q., Kong, D., Miao, C., Duan, Q., Yang, T., Ye, A., Di, Z., Gong, W., (2014). Variation in global temperature and precipitation for the period of 1948 to 2010. Environ. Monit. Assess. 186 (9), 5663–5679. temperature concentration for Iran's climate. Int J Environ Sci Technol. https://doi.org/10.1007/s13762-018-1739-2
[108] Suryavanshi S, Pandey A, ChaubeUC, JoshiN(2014) Long-termhistoric changes in climatic variables of Betwa Basin, India. Theor Appl Climatol 117:403–418
[109] Tabari H, Willems P (2015) Investigation of streamflow variation using an innovative trend analysis approach in Northwest Iran. The 36th IAHR World Congress, 28 June–3 July, 2015, The Hague, the Netherlands
[110] Tabari, H., Marofi, S., Aeini, A., Talaee, P.H., Mohammadi, K., 2011. Trend analysis of reference evapotranspiration in the western half of Iran. Agric. For. Meteorol. 151 (2), 128–136.
[111] Terêncio DPS, Sanches Fernandes LF, Cortes RMV, Moura JP, Pacheco FAL (2018) Rainwater harvesting in catchments for agro-forestry uses: a study focused on the balance between sustainability values and storage capacity. Sci Total Environ 613-614:1079–1092
[112] Terêncio DPS, Sanches Fernandes LF, CortesRMV, Pacheco FAL (2017) Improved framework model to allocate optimal rainwater harvesting sites in small watersheds for agro-forestry uses. J Hydrol 550:318– 330
[113] Tian, Q., Prange, M., Merkel, U., (2016). Precipitation and temperature changes in the major Chinese river basins during1957-2013 and links to sea surface temperature. J. Hydrol.536, 208–221.
[114] Tosunoglu, F., Kisi, O., (2017). Trend analysis of maximum hydrologic drought variables using Mann-Kendall and Şen's innovative trend method. River Res. Appl. 33, 597–610. http://dx.doi.org/10.1002/rra.3106.
[115] Trenberth, K.E., (2011). Changes in precipitation with climate change. Clim. Res. 47, 123–138. http://dx.doi.org/10.3354/cr00953.
[116] Von Storch, H., 1999. Misuses of Statistical Analysis in Climate Research. In: Analysis of Climate Variability. Springer, pp. 11–26.
[117] Wang SJ, Jiao ST, Xin HJ (2013) Spatio-temporal characteristics of temperature and precipitation in Sichuan Province, southwestern China, 1960-2009. Quat Int 286:103–115
[118] Wang, L., Chen, Y., Niu, Y., Salazar, G., Gon, W., (2017). Analysis of atmospheric turbidity in clear skies at Wuhan, Central China. J. Earth Sci. 28 (4), 729–738.
[119] Wang, Y.Q., Zhou, L., (2005). Observed trends in extreme precipitation events in China during 1961-2001 and the associated changes in large-scale circulation. Geophys. Res. Lett. 32, L09707.
[120] Westra, S., Alexander, L.V., Zwiers, F.W., (2013). Global increasing trends in annual maximum daily precipitation. J. Clim. 26 (11), 3904–3918.
[121] Wu H, Li X, Qian H (2018) Detection of anomalies and changes of rainfall in the Yellow River basin, China, through two graphical methods. Water. https://doi.org/10.3390/w10010015
[122] Wu H, Qian H (2017) Innovative trend analysis of annual and seasonal rainfall and extreme values in Shaanxi, China, since the 1950s. Int J Climatol 37(5):2582–2592. https://doi.org/10.1002/joc.4866
[123] Wu, H., Qian, H., 2016. Innovative trend analysis of annual and seasonal rainfall and extreme values in Shanxi, China, since the 1950s. Int. J. Climatol. http://dx.doi.org/ 10.1002/joc.4866.
[124] Wu, P., Christidis, N., Stott, P., (2013). Anthropogenic impact on Earth's hydrological cycle. Nat. Clim. Chang. 3, 807–810. http://dx.doi.org/10.1038/nclimate1932.
[125] Xu, C. yu, Gong, L., Jiang, T., Chen, D., Singh, V.P., (2006). Analysis of spatial distribution and temporal trend of reference evapotranspiration and pan evaporation in Changjiang (Yangtze River) catchment. J. Hydrol. 327, 81–93. http://dx.doi.org/10.1016/j.jhydrol.2005.11.029.
[126] Yan T, Shen Z, Bai J (2017) Spatial and temporal changes in temperature, precipitation, and streamflow in the Miyun Reservoir Basin of China. Water 9(2):78. https://doi.org/10.3390/w9020078
[127] Yang S, Zhao Q, Belkin IM. (2002). Temporal variation in the sediment load of the Yangtze River and the influences of human activities. *Journal of Hydrology* 263(1): 56-71.
[128] Yang, S.L., Milliman, J.D., Xu, K.H., Deng, B., Zhang, X.Y., Luo, X.X., 2014. Downstream sedimentary and geomorphic impacts of the three gorges dam on the Yangtze River. Earth Sci. Rev. 138, 469–486.
[129] Yenigün, K., Gümüş, V. and Bulut, H. (2008): Trends in streamflow of the Euphrates basin, Turkey, Water Management, 161, 189–198, DOI: 10.1680/wama.2008.161.4.189.
[130] Yu D, Chen L, Sun S, Rao C, Chen C. 2012. Temporal and Spatial Feature of Area Rainfall in the Upper Reaches of the Yangtze River. *Arid Meteorology* 30(4): 563-569.
[131] Yu, M., Li, Q., Hayes, M.J., Svobodab, M.D., Heim, R.R., (2014). Are droughts becoming more frequent or severe in China based on the Standardized Precipitation Evapotranspiration Index: 1951–2010? Int. J. Climatol. 34 (3), 545–558.
[132] Yue S, Wang C (2004) The Mann-Kendall test modified by effective sample size to detect trend in serially correlated hydrological series. Water Resour Manag 18:201–218
[133] Yue, S., Pilon, P., Cavadias, G., 2002. Power of the Mann–Kendall and Spearman's rho tests for detecting monotonic trends in hydrological series. J. Hydrol. 259, 254–271
[134] Zamani R, Mirabbasi R, Abdollahi S, Jhajharia D (2017) Streamflow trend analysis by considering autocorrelation structure, long-term persistence and Hurst coefficient in a semi-arid region of Iran. Theor Appl Climatol 129(1–2):33–45. https://doi.org/10.1007/s00704-016-17474
[135] Zamani R, Mirabbasi R, Nazeri M, Gajbhiye Meshram S, Ahmadi F(2018) Spatio-temporal analysis of daily, seasonal and annual precipitation concentration in Jharkhand state, India. Stoch Env Resn Risk A 43(4):1085–1097. https://doi.org/10.1007/s00477-017-1447-3
[136] Zhang Q, Xu CY, Zhang Z, Chen YD, Liu CL (2008) Spatial and temporal variability of precipitation maxima during 1960-2005 in the Yangtze River basin and possible association with large-scale circulation. J Hydrol 353(3):215227
[137] Zhang, Q., Jiang, T., Gemmer, M., Becker, S., (2005). Precipitation, temperature and runoff analysis from 1950 to 2002 in the Yangtze basin, China. J. Hydrol. Sci. 50 (1), 65–80.
[138] Zhang, Q., Xu, C.-Y., Tao, H., Jiang, T., Chen, Y.D., (2010). Climate changes and their impacts on water resources in the arid regions: a case study of the Tarim River basin, China. Stoch. Env. Res. Risk A. 24, 349–358. http://dx.doi.org/10.1007/s00477-009- 0324-0.
[139] Zhang, Q., Xu, C.Y., Zhang, Z., Chen, Y.D., Liu, C.L., (2008). Spatial and temporal variability of precipitation maxima during 1960-2005 in the Yangtze River basin and possible association with large-scale circulation. J. Hydrol. 353 (3), 215–227.
[140] Zhao, G.J., Mu, X.M., H€ormann, G., Fohrer, N., Xiong, M., Su, B.D., Li, X.C., 2012. Spatial patterns and temporal variability of dryness/wetness in the Yangtze River Basin, China. Quat. Int. 282, 5–13.
[141] Zhou Z, Wang L, Lin A, Zhang M, Niu Z (2018) Innovative trend analysis of solar radiation in China during 1962–2015. Renew Energy 119:675–689
[142] Zuo Hongchao, Li Dongliang, Hu Yinjiao, (2005). Change trend of climate in China over the past 40 years and its relationship with the change of pan evaporation. *Chinese Science Bulletin*, 50(11): 1125–1130. (In Chinese).