ORIGINAL ARTICLE

Spatial and Temporal Analysis of Rainfall and Drought Condition in Southwest Xinjiang in Northwest China, Using Various Climate Indices

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Abstract

Variability in precipitation results flooding and drought worldwide. The climate change has a close relationship with the precipitation and temperature pattern as well as river discharge. In this research, spatial and temporal rainfall variability have been analyzed. The rainfall data of seventeen meteorological stations for the period of 1980–2018 was acquired from China Meteorological Administration. To assess drought in the study area, the standardized precipitation index (SPI) was applied and to check the temporal drought trend the Mann–Kendall test was applied, while the data normality was checked through skewness, kurtosis, and standard deviation. The Mann–Kendall results shows decreasing rainfall and increasing drought trend in the study area. The study area southwest Xinjiang is an arid region and the decreasing rainfall trend will further aggravate the conditions of already endangered flora and fauna in the region. This study will provide a platform for decision makers to take proactive actions to mitigate the risk of increasing drought in the study area.

Keywords SPI · Mann–Kendall trend · Meteorological drought · Southwest Xinjiang

1 Introduction

Globally, precipitation is considered as an important driving factor of climate change that trigger various natural hazards such as flood, landslide, soil erosion and drought (Chou and Lan 2012; Ashraf and Routray 2015). Among these devastating natural hazards, drought is a complex and damaging one that have profound impacts on global economy and ecosystems and China has no exception in this regard particularly southwest China (Pauling and Paeth 2007; Shaw et al. 2007; Xiao-jun et al. 2012; Yuan and Quiring,

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2014; Tan et al. 2015). Numerous research studies regarding spatio-temporal variability in precipitation reveals that southwest China is more vulnerable to soil erosion, flood and drought due to increasing anthropogenic and climatic change (Spinoni et al. 2014; Miyan 2015). Regardless of the type, drought has severely affected each continent such as Asia, Africa, Europe, Australia, America and China experiencing longer and intense drought since 18th century (Abramopoulos et al. 1988). Moreover decreasing precipitation and increasing drought has severely affected South Asia and central Asian countries such as India, Pakistan, Iran and Tajakistan, Uzbakistan Afghanistan have reported droughts at least once in every three year period (Miyan 2015). The study of rainfall variability are very important to manage early environmental system from coming threats of global warming (Zhang et al. 2012; Xu et al. 2015).

The climate of china has experienced extreme drought period from 1991 to 2009 leads to loss of 17 billion Chinese Yuan and about more than 11 million peoples face shortage of drinking water and other basic needs of life (Fuchs et al. 2014). The major cause of drought in southwest Xinjiang is the increasing rate of temperature and evapotranspiration, and less amount of precipitation (Tao et al. 2014).

Western China particularly Taklimakan region (a waste desert) in Xinjiang gets up warm and dry rapidly (Wang et al. 2004; Steinemann et al. 2005). This drastic variation leads to changing weather pattern, increasing aridity, contributing to salinity, results in melting of glaciers (Yavuz and Erdoğan 2012). The northern Xinjiang China is semi-arid dry while, southern is absolutely dry having severe type of climatic condition are more inclined to drought heightening. The monthly rainstorm precipitation in (July, August) less is then from typical in southwest Xinjiang. It is found that precipitation intensity is significantly increasing in Xinjiang, while more precipitation amount often leads to heavy flooding from 1980 to 2000 (Duan et al. 2014). Different studies discover that in Xinjiang dry season impacts are increments in the year 1986 (Bayissa et al. 2015).

In climate research meteorologist utilized different tools for the drought estimation in recent past (McKee et al. 1993). For instance, drought severity measurement Palmer Drought Severity Index (PDSI) (Palmer1965), standardized precipitation index (SPI) (McKee et al. 1993), For wet and dry conditions standardized precipitation evapotranspiration index (SPEI) (Vicente-Serrano et al. 2010), soil absorption capacity and vegetation cover soil moisture index (SMI) (Nam et al. 2012), vegetation condition index (VCI) (Kogan 1995) widely used. Among them SPI are overall appropriate technique and simple to figure required precipitation information for, mean monthly precipitation and give better results. In addition World Meteorological Organization (WMO) also used SPI for drought measurement (Chen et al. 2013). SPEI need temperature and precipitation time arrangement data to discover various kinds of drought condition on worldwide Level (Wang et al. 2015).

In this research study we have focused on rainfall variation and drought conditions over the past three decades and its wide spread damages in southwest Xinjiang region in China (Vicente-Serrano et al. 2015). Various indices of the drought measurement also shows that drought rate increase after the year 1986 in history of Xinjiang (Xiao-jun et al. 2012). Spatial–temporal study of precipitation has been assessed using non-parametric Mann–Kendall (MKT) test model and standardized precipitation index (SPI) for the appropriate results (Li et al. 2013; Wang et al. 2014). The fundamental targets of the study are the following:

1. To identify Spatiotemporal and seasonal precipitation pattern by apply Mann–Kendall measurable strategy and its effects.
2. Discover seriousness of drought through SPI index and its annihilation, alleviation ventures for recovery.

2 Data and Methods

2.1 The Study Area

The study area situated in southwest Xinjiang in northwest, China. Topographically, it stretches out from 34°33 ″ to 42°22 ″ N Latitude and 75°30″ to 91°31 ″ E Longitude. Generally, study area is encircled by Tianshan, Himalaya, and Kunlun Mountain goes from north to south, while Lop-nor area lies in the east (Ma et al.2008). The western side is limited by Kashgar in (Fig. 1). Physiographically the region is desert having customary rises development because of blowing winds and dry natural conditions. The northern side are more gainful then southern comprise on sandy and boggy land. population is 577100 and spread more than 803351 square kilometers area (Yearbook 2015).

The base temperature recorded in south Xinjiang is −14 °C, greatest temperature from 10 to 23.5 °C and yearly mean monthly temperature is 11to16°C. The yearly precipitation in south Xinjiang are 96 mm consider as dry area. Absolute per annum precipitation are 130 mm in May 56 stormy days annually and August temperature reach to a maximum (Nendel et al. 2018). Environment is parched and semi-dry. Tianshan Mountains separated Xinjiang into northern and southern Xinjiang practically away from sea lies in Eurasian plate. Geographically Xinjiang is bounded by three Mountain ranges (Altai, Kunlun and Tianshan mountains) with two basin Junggar (south Xinjiang) and Tarim basin (northern Xinjiang). The principle river is Hotian begun from the south of Kunlun Mountain ranges, Kashgar River from Himalayas range run from south to north lastly depleted into the Tarim River. The Aksu River from north of Tianshan Mountains run toward the south Join with primary Tarim River and eventually fall into lake Tiatema (Fan et al. 2013).

In northern part various oasis provide water for agricultural and socio-economic activities. The common flora of the area consists on Tamarix plants in south Xinjiang. Due to the prevailing severe drought conditions other seasonal plants are unable to persist in such harsh environment. It is a shrub plant found in lower river reaches, alluvial fans, oasis and area between wind blowing sand dunes. Some twelve species are in China among that 84% are growing in Xinjiang (Farinotti et al. 2015).

2.2 Framework of Data Set

The precise results of climate change depend on accurate data record at different meteorological stations. The continuation of data length, reliability and serial correlation
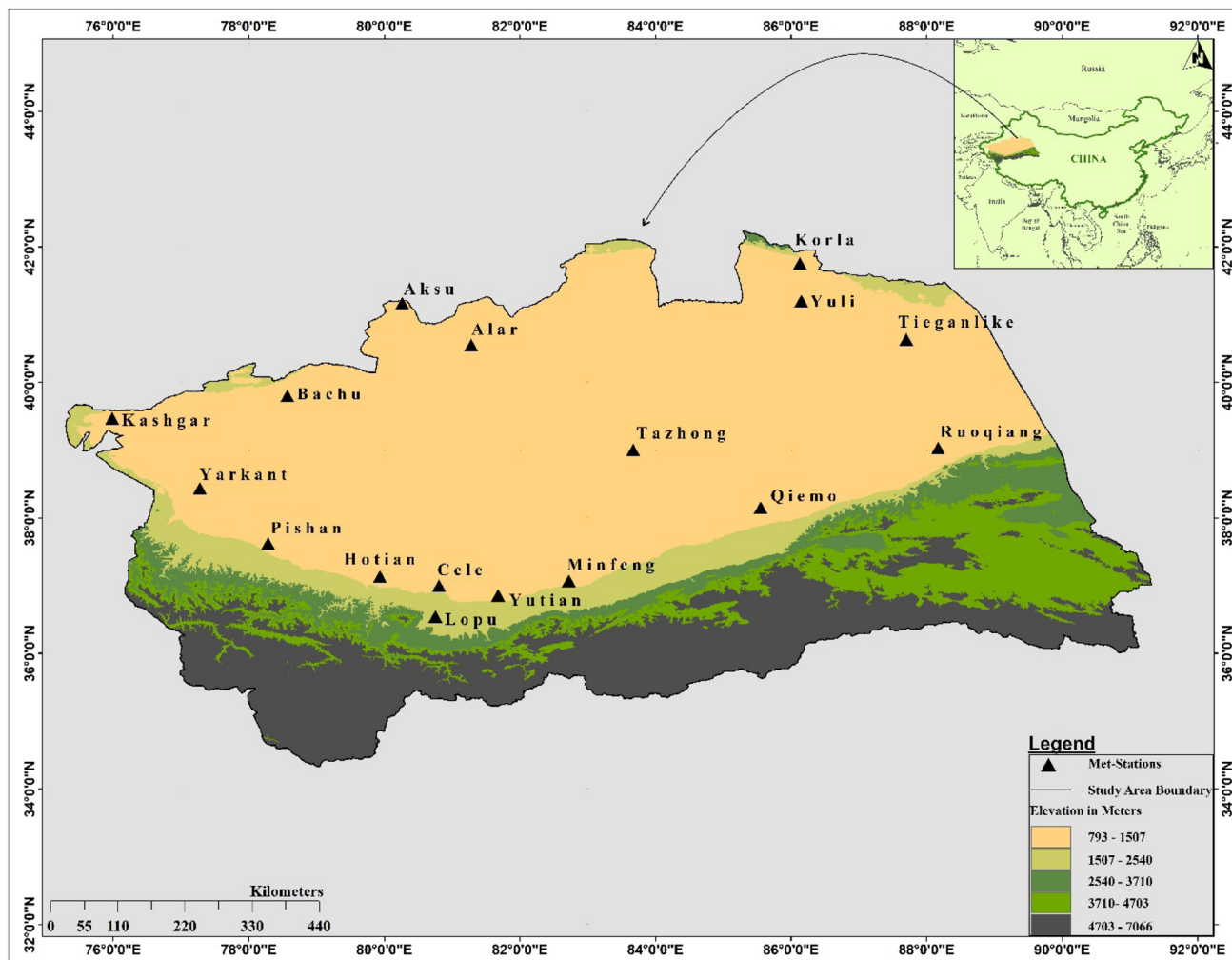
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Fig. 1 Map of study area with meteorological stations. Source: Prepared from SRTM Data 2021

are important aspects of climate research. We have focused on a very important parameter of climate change that is monthly rainfall. The spatial–temporal monthly rainfall data of the selected metrological stations is obtained from China Meteorological Administration (CMA), of different time period. The 16 met-station data available for 39 years (1980–2018), only Tazhong met-station data are for 23 years (1996–2018). All the stations significantly vary in altitudinal extent and details of geographical characteristic of seventeen meteorological stations are given in (Table 1).

2.3 Multiple data analysis indices

Various statistical studies of climatic models in different region of southwest Xinjiang in northwest China shows tremendous spatial and temporal variation. The monthly rainfall of the seventeen met-stations for 4 decades has been analyzed through (SPI) standardized precipitation index and non-parametric Mann–Kendall test (MKT) by accepting or rejecting the null hypothesis (H_0) with a significant level up to 95%. Seasonally analysis also conducted data distributed into four seasons, applying MK test on individual month to obtain appropriate result for wet/dry condition. Their statistical analysis will discuss step wise in detail in middle portion of the paper.

2.4 Inverse Distance Weighted (IDW)

Generally, for the interpolation of rainfall data IDW are widely used for better consequences. The results of Mann–Kendall test were then analyzing through IDW interpolation techniques in ArcGIS software. By this methods calculation of rainfall values are corresponding to the predictable position. The IDW measurement indicates the more weight age of rainfall points that are closed to each other. For trend detection calculated statistical value of rainfall were interpolated to find spatial–temporal measurement with

Table 1 Details of meteorological stations with geographical characteristics in the study area

S. no	Met-station	Time-span	Longitude	Latitude	Elevation in (m) a.m.s.l
1	Aksu	1980–2018	80°26′	41°16′	1103
2	Alar	1980–2018	81°28′	40°54′	1012
3	Bachu	1980–2018	78°51′	39°82′	1116
4	Cele	1980–2018	80°80′	36°99′	1394
5	Hotian	1980–2018	79°90′	37°13′	1375
6	Kashgar	1980–2018	75°91′	39°46′	1289
7	Korla	1980–2018	86°13′	41°75′	931
8	Lopu	1980–2018	80°75′	36°54′	1189
9	Minfeng	1980–2018	82°17′	37°07′	1409
10	Pishan	1980–2018	78°28′	37°62′	1375
11	Qiemo	1980–2018	85°55′	38°15′	1247
12	Ruoqiang	1980–2018	88°17′	39°03′	887
13	Tazhong	1996–2018	83°19′	39°00′	1099
14	Tieganlike	1980–2018	87°70′	40°63′	846
15	Yarkant	1980–2018	77°27′	38°43′	1231
16	Yuli	1980–2018	86°15′	41°72′	903
17	Yutian	1980–2018	81°67′	36°85′	1422

respective location. For this study IDW were selected and calculated the monthly averages of rainfall of all met-stations. This method comprehensively evaluates the warm and cold regions by giving various shades in the map. Through which we classify the different variation of precipitation in various region.

2.5 Standardized Precipitation Index

The SPI is mostly used to find and analyzed various dynamics of climate data (Huang et al. 2015). Moreover, to detect spatial and temporal variability of rainfall (SPI) calculation gives accurate and appropriate results for a broad range of situation. SPI use to find trend intensification of dry and wet condition in time series data. This method is effectively determining rainfall data frequency and its distribution for a point to a specific period of time. The standardized precipitation index is the standard deviations number that observed cumulative rainfall deviated from the climatologically averages. SPI are calculated for annual rainfall, monthly, seasonal and long time series data (Türkeş and Tatlı 2009). The time duration for each met-station is used to find the scaling parameters and rainfall forms, probability, density and function. SPI used for monthly, weekly drought intensification and recommended by world meteorological organization This can be deriving by the following ways.

$$g(x) = \frac{1}{\beta^a \Gamma(a)} x^{a-1} e^{-\frac{x}{\beta}} \quad \text{for } x > 0 \tag{1}$$

In the Eq. (1) α is the parameter and β is parameter scale and x is the rainfall quantity. $\Gamma(a)$ Is the function of gamma and by following ways it defines is?

$$\Gamma(x) = \int_0^\infty x^{a-1} e^{-x} \mathrm{d}x \tag{2}$$

The counting of SPI comprises on gamma thickness to a particular appropriation and all out precipitation recurrence in a meteorological station. The boundaries β and α of probability of gamma work density figure for each met-stations. The time-frame is diverse going from 01 to 4 years. For instance, (1, 3, 6, 9, 12, 15, 18, 21, 24, 4 years). The coefficient gauge of β and α probable function, density of gamma g (x) looking over x and getting articulation for combined probability $G(x)$ which decide specific time-frame of the noticed explicit measure of precipitation

$$G(x) = \int_0^\infty g(x)\mathrm{d}x = \frac{1}{\beta^a \Gamma(a)} \int_0^\infty x^{a-1} e^{\frac{-x}{\beta}} \mathrm{d}x \tag{3}$$

The function of gamma is not defined here $x = 0$ and amount of rainfall will be o. The conversion of cumulative probability as following:

$$H(x) = q + (1 - q)G(x) \tag{4}$$

In this equation value of q shows no rainfall probability. According to (Edossa et al. 2010) conversion of probability value to a standardized normal distribution with unit variance and null average from which SPI is calculated. Further we define SPI in the following ways;

$$\mathrm{SPI} = -(t - \frac{C_0 + C_1 t + C_2 t^2}{1 + d_1 t + d_2 t^2 + d_3 t^3}, \quad \text{for } 0 < H(x) < 0.5 \tag{5}$$

$$\mathrm{SPI} = +(t - \frac{C_0 + C_1 t + C_2 t^2}{1 + d_1 t + d_2 t^2 + d_3 t^3}, \quad \text{for } 0.5 < H(x) < 1 \tag{6}$$

In this equation value of t is follow as

$$t = \sqrt{In\left[\frac{1}{(H(x))^2}\right]}, \quad \text{for } 0 < H(x) < 0.5 \tag{7}$$

$$t = \sqrt{In\left[\frac{1}{(1 - H(x))^2}\right]}, \quad \text{for } 0.5 < H(x) < 1 \tag{8}$$

The drought conditions based on SPI values were categorized in four categories as given in Table 2.

After SPI calculation the drought events were classified as shown in Table 2. The main purpose of this to determine rainfall events of long and short time periods. The positive value of SPI results shows wetting while the negative values shows dry conditions. The long-term SPI is important to

Table 2 Classification of Drought on the basis of calculated (dry and wet) SPI value

SPI Value	Drought category
<0 and >-1	Mild dryness
-1.0 to -1.49	Moderate drought
-1.5 to -1.99	Severe drought
≤ -2.0	Extreme drought

study hydrological resources for example, subsurface and surface water flow and reservoir Level, while short term SPI is used for the study of agriculture resources. In this research study SPI 1-month and 12- months have been calculated.

2.6 Non-Parametric Test for Trend Detection

Different statistical tools and models are used by different scholars extensively for trend detection in climate variables. The time series trend analysis was applying to understand the rainfall changes spatio-temporally. The objectives of the trend analysis study to find out change in a variable with specific duration either increasing or decrease and their reclamation in future.

2.7 Mann–Kendall Test for Trend Detection

Mostly for climate study and hydrological variables, non-parametric Mann–Kendall test is used. This is a rank base test and highly recommended by world meteorological organization for general use (Zhang et al. 2011). Hence, for this study MKTT has been used to detect trend in rainfall data over the last four decades. The null (H_o) hypothesis assume that dataset is free of trend, while alternate hypothesis assumes a significant trend. Results of (MKTT) were determined universally by accepted or rejecting probability value (0.05). The Mann–Kendall test statistics are calculated by the following equations.

$$S = \sum_{i=j}^{n-1} \sum_{j=i+1}^{n} \text{sgn}(xj - xi) \tag{9}$$

$$\text{where } \text{sgn}(xj - xi) = \begin{Bmatrix} +1, & xj > xi \\ 0, & xj = xi \\ -1, & xj < xi \end{Bmatrix} \tag{10}$$

To avoid the same value occurrence, we might be adding evenly small distributed value randomly with interval of (0, $\sigma/100$). This is (S Dev) (σ) sign in time series data. While τ (tau) is used to measure monotonic trend strength and express by following ways.

$$\tau = \frac{2S}{n(n-1)} \tag{11}$$

The S statistics distributed normally when $n \geq 8$, with average value the statistics variance is representing following ways.

$$\text{Var}(S) = \frac{n(n-1)(2n+5) \sum_{i=1}^{n} t_i i(i-1)(2i+5)}{18} \tag{12}$$

Here t_i is the tie of extent i.

(Z) Standardized statistics calculation for two tail test are follow,

$$Z = \frac{x - \mu_0}{\frac{\sigma}{\sqrt{n}}} \tag{13}$$

The (MKT) interpretation are depending on incoming calculated $p \leq 0.05$, the null hypothesis (H_o) is rejected and we accept alternate hypothesis (H_a) means there is a significant trend in the time series data. The calculated $p \geq 0.05$ then alpha levels, (H_o) null hypothesis is accepted means insignificant trend.

3 Results and Discussions

In this portion past climatic variability of precipitation from (1980–2018) and their future outcomes will examine in various subtitles. The measurable consequences of the whole metrological stations are explained by following ways.

3.1 Temporal variation in precipitation

The circulation of precipitation is uneven in southwest Xinjiang, China. For this study, 17 meteorological stations precipitation information (1980–2018) use to distinguish pattern of precipitation, their geographical properties are given detail in (Table 1). In spatial–temporal context and results of various indices and background of global warming cold extreme events are decreasing and warm events are increasing in south Xinjiang. Fundamentally, the south Xinjiang is generally comprising on desert region and have desert environment. Normally, the winds speed is more and have serious climatic conditions. The annual pace of precipitation is less from ordinary and winter season is less, summer season is greater strength and rainstorm precipitation is inadequate. Because of these severe conditions the agriculture area is gravely endured by disastrous characteristic. Expansion in anthropogenic activities completely changed the current situation into an assorted climate. Dryness and shortage of hydrological assets consequences for creation of yields. This is a definitive reason on expanding dry spell circumstance.

For instance, in rise point of view Kashgar, Bachu, Aksu, Alar, Korla and Yuli in northern Xinjiang closeness to Tianshan Mountain. The excess stations Located in the plain zone. In spite of the fact that Yutian, Hotian, and Pishan met-stations on higher height get little measure of precipitation lies on downward shadow areas. Situated on inland surface, away from sea and Tianshan Mountains is a boundary for cool winds. Besides Tibet plateau obstacle on the ways of warm air and higher vanishing. For the most part, the pattern of precipitation is diminishing from east to west. Nearby geography and air course are chief variables of precipitation changeability. The overall reason for low precipitation is high dissipation rate (Dawood 2017).

A territory where precipitation rate is less than 251 mm fall in the dry areas. The locality has precipitation proportion between 251 and 750 mm named semiarid, other have annual mean precipitation is in excess of 750 mm is named as damp regions.

The spatial–temporal analysis of precipitation shows intense climatic changing situation in Xinjiang. From 1960 to center of 1980 precipitation abrupt increment happened in 1987 and 2000 decades considering as warm period in entire China. Again this vital proceeds since 1997–2015 and labeled as dry period. In most recent forty years' dry environment variety has been identified in (Figs. 2, 3). The interpolation maps give an understanding of rainfall severity in various shades in (Figs. 2, 3). For instance, the met-stations are not shown in the maps it decreases visibility. But it details discussion are given in methods and methodology section of the paper. The Tazhong Qiemo, Ruoqiang met-stations receive insufficient amount of precipitation from normal annually. During this time span pace of dry season were higher and vegetation cover are affected. After 1980 the SPI shows an upward pattern floods strengthening is expanding. The significant reason for decline in precipitation are evapotranspiration to the climate and anthropogenic exercises in the actual climate. The measure of occasional rainstorm precipitation decline in July and August, and just Tianshan Mountain have plenitude of precipitation over time uniquely in storm.

The Tamarix are normal bush plants generally in desert and alluvial grounds of Xinjiang. Due the expanding pattern of temperature and less measure of precipitation different species cannot survive in such brutal climate. Alongside this Aksu, Alar, Bachu, Korla, Ruoqiang, Minfeng and Pishan are consider as moist metrological stations get most extreme precipitation in December, January, and July, August. Rest of met-stations fall in the classifications of semi-arid. Moreover, information was examined measurably to discover focal propensity and scattering. The most elevated estimation of (St Dev) shows annual precipitation inconstancy its consistency and assurance. Greater fluctuation is recognized in yearly minimum, and maximum precipitation

in each meteorological station as demonstrated in (Table 3). Among met-station Yarkant have exclusive expectation deviation (40.17 mm), follow by Pishan met-station having (39.70 mm), and indicates most elevated variety of per annum measure of precipitation. For typical appropriation skewness and kurtosis of yearly precipitation information determined. In typical information appropriation estimation of skewness is start from zero show balanced information. All meteorological station shows positive estimation of skewness decides increment in the measure of precipitation than appropriation typical.

Kurtosis is an estimation of tailed-ness of probability (P) appropriation of genuine variable value. Which Shows most noteworthy estimation of kurtosis is towards high peak and close to mean value dataset, while lower estimation of kurtosis is close to mean value. The appropriation of kurtosis in ordinary dataset is zero and typical dissemination of kurtosis does not found in (Table 3). Value of kurtosis signifies level circulation design for instance, Aksu, Cele, Kashgar, Yutian, Yuli, Tieganlike, Ruoqiang and Tazhong met-stations shows high estimation of kurtosis.

3.2 Spatial and Temporal Characteristics of SPI

SPI generally utilizing to discover spatial–temporal connection of environmental change in any area. The SPI were applying to discover dry/wet conditions and it is drawn out effects on the predominant climate.

For long time span SPI is total of brief timeframe. In this analysis SPI were determined for 1 and a year. The SPI results were determined as demonstrated in (Figs. 4, 5). The research study assess that serious dry positive spell found in first many years of 1980 in (Bachu, Hotian, Korla, Minfeng and Qiemo counties) met-stations as demonstrated in Figs. 4, 5. The SPI spatial and temporal evaluation moreover explain that year 1985 in (Bachu, Hotian, Yarkant, Yutian Pishan, Kashgar Cele and Alar) are extreme and less chilly occasions are happened. Other than that, 1986 in (Aksu, Lopu, Cele and Yutian) met-stations and 1984 in (Cele, Korla, and 2001 in Alar, Ruoqiang, Tieganlike and Yutian) are extraordinary dry a very long time as in (Table 4). Shortly in Xinjiang intensity of flood and normalized drought were more common and possibility of severe flooding is highest. From Figs. 4, 5 we examine that SPI values shows a significant trend and on global level wetting trend is increasing. From 1960 to 1980 increase recorded in drought occurrence and as that of flood after that the tendency of flood is increase. Henceforth the value of SPI shows a changing pattern till 2010. The dry condition increase as we go from north to south.

The 1997 decades in Bachu, 1994 in Kashgar, 2009 in Pishan, Korla in 2007, 1999 in Yuli) met-stations have more droughts. The 2000 in (Kashgar) and 2014 in (Alar)
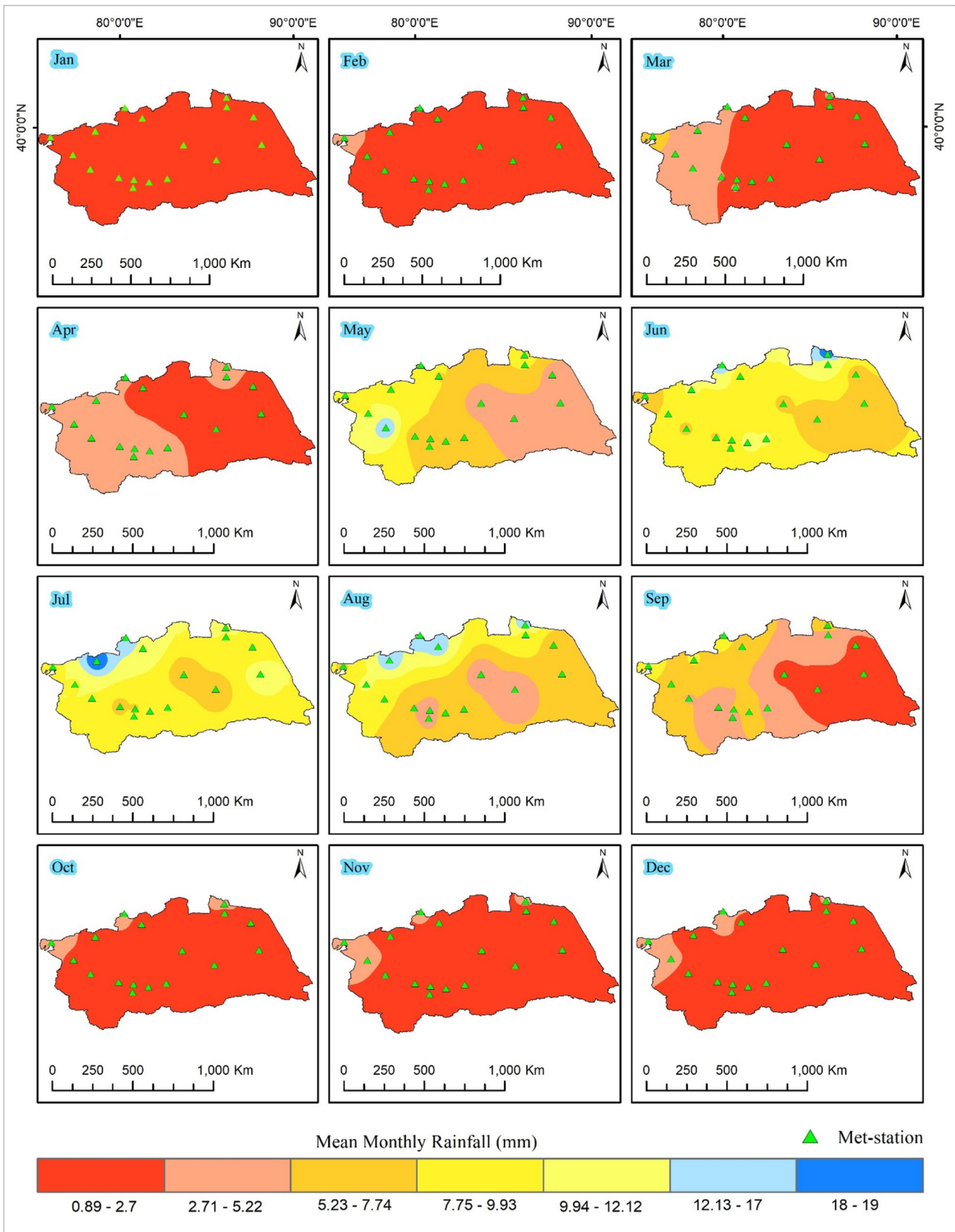
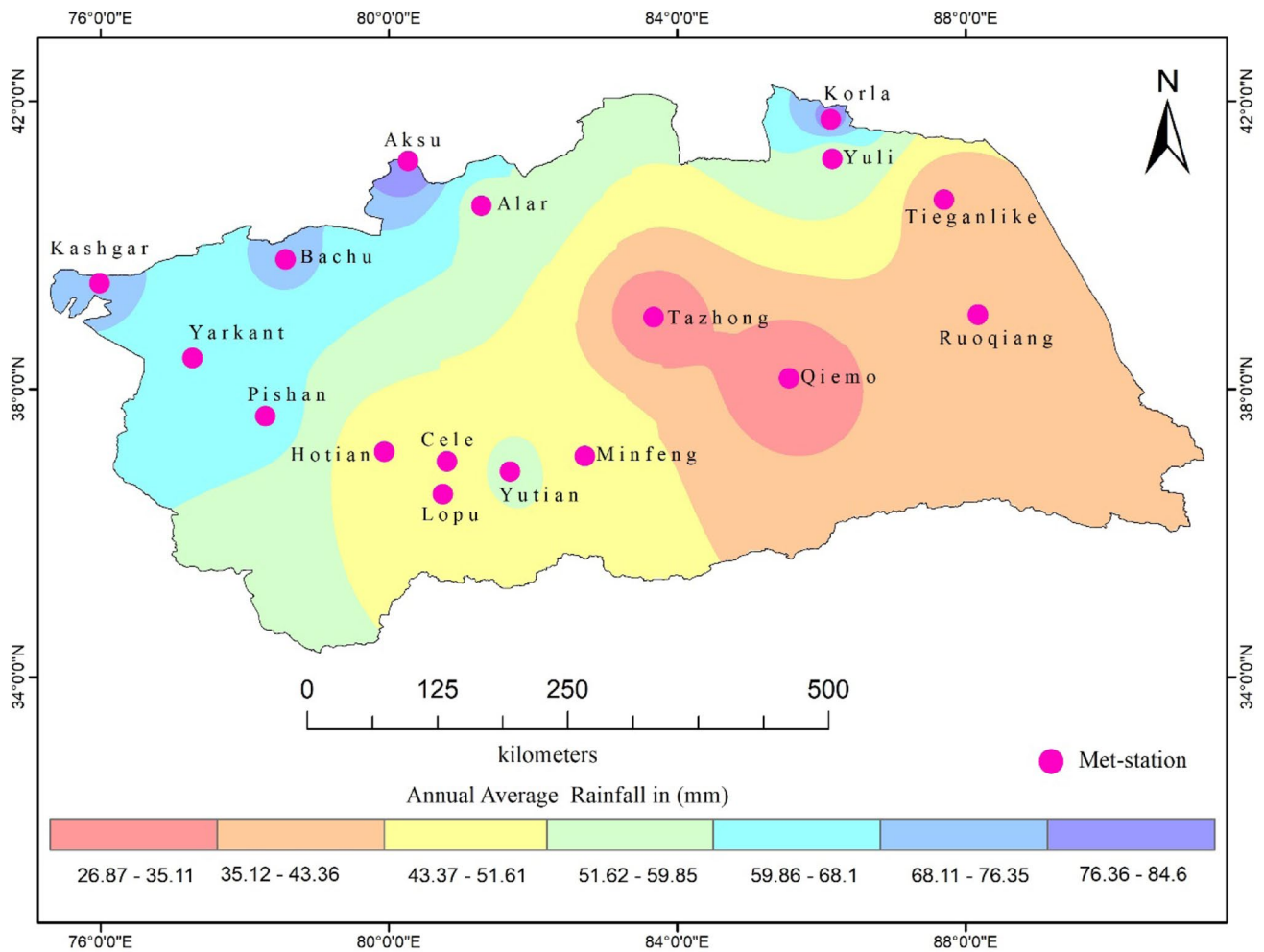**Fig. 2** Spatial and temporal distribution of monthly mean precipitation

Fig. 3 Spatial distribution of annual mean precipitation

Table 3 The Statistical data measurement of annual rainfall in the study area

| Met-station	Minimum (mm)	Maximum (mm)	Monthly (mm)	(SD mm)	Skewness	Kurtosis
Aksu	18.70	186.20	84.60	36.30	0.85	1.24
Alar	21.50	102.40	57.81	21.89	0.09	− 0.94
Bachu	8.64	148.84	70.06	36.06	0.42	− 0.63
Cele	8.20	135.50	44.15	27.52	1.09	2.15
Hotian	3.40	111.90	45.55	27.75	0.73	− 0.26
Kashgar	16	191.77	70.66	37.75	1.13	2.02
Korla	34.8	145.7	80.37	26.36	0.34	0.05
Lopu	8.40	135.40	46.57	31.93	1.10	0.41
Minfeng	6.5	136.9	48.02	29.19	1.15	1.38
Pishan	13.90	162.40	63.15	39.70	0.84	− 0.07
Qiemo	1.9	63.9	26.86	13.62	0.49	0.12
Ruoqiang	5.1	117	35.88	25.01	1.54	2.81
Tazhong	6.8	75.2	28.08	14.71	1.39	3.71
Tieganlike	3.4	125.3	37.73	24.54	1.45	2.87
Yarkant	10.10	153.70	65.79	40.17	0.54	− 0.74
Yuli	14.4	151	51.48	29.45	1.43	2.43
Yutian	6.20	186.90	55.42	36.28	1.46	3.21
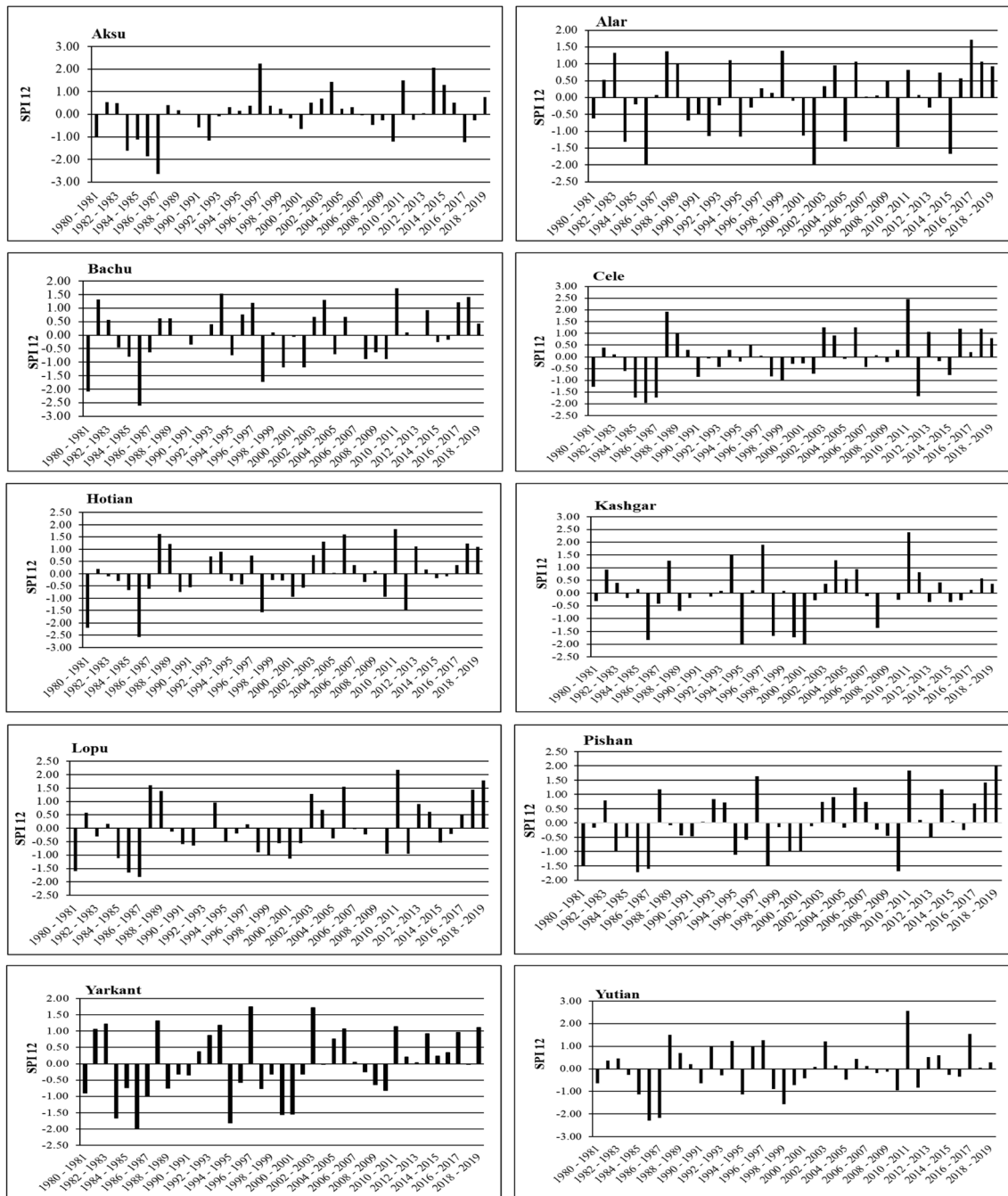
Fig. 4 Twelve months SPI Spatial and temporal results in various meteorological station

met-stations are discovered dry. The most unmistakable dry period runs from 1980 to 1986 and other from 1997 to 2014. Generally, evaluation shows that 1980, 1985, 1986, 1994, 1997, 2001, 2014, 2011 are very dry many years and lack in measure of precipitation has been recorded in the whole area. By and large, the pattern is more in metropolitan zones, in light of high population development and human exercises. The expanding pace of desertification in Xinjiang is because of less measure of precipitation

get annually and ascending of greatest temperature particularly in south Xinjiang. The year 2008 considered is extreme dry season spells in Xinjiang seriously endured domesticated animals and horticulture in the whole district. Aftereffects of SPI confirm dry season exhausted in 1960s, 1970s, 1980s, 2000s and pre-1980s as consider as moist period as in Table 4). The Table 4 give a predominant of dry season seriousness in different station The SPI as based on processed worth in Table 2, where we
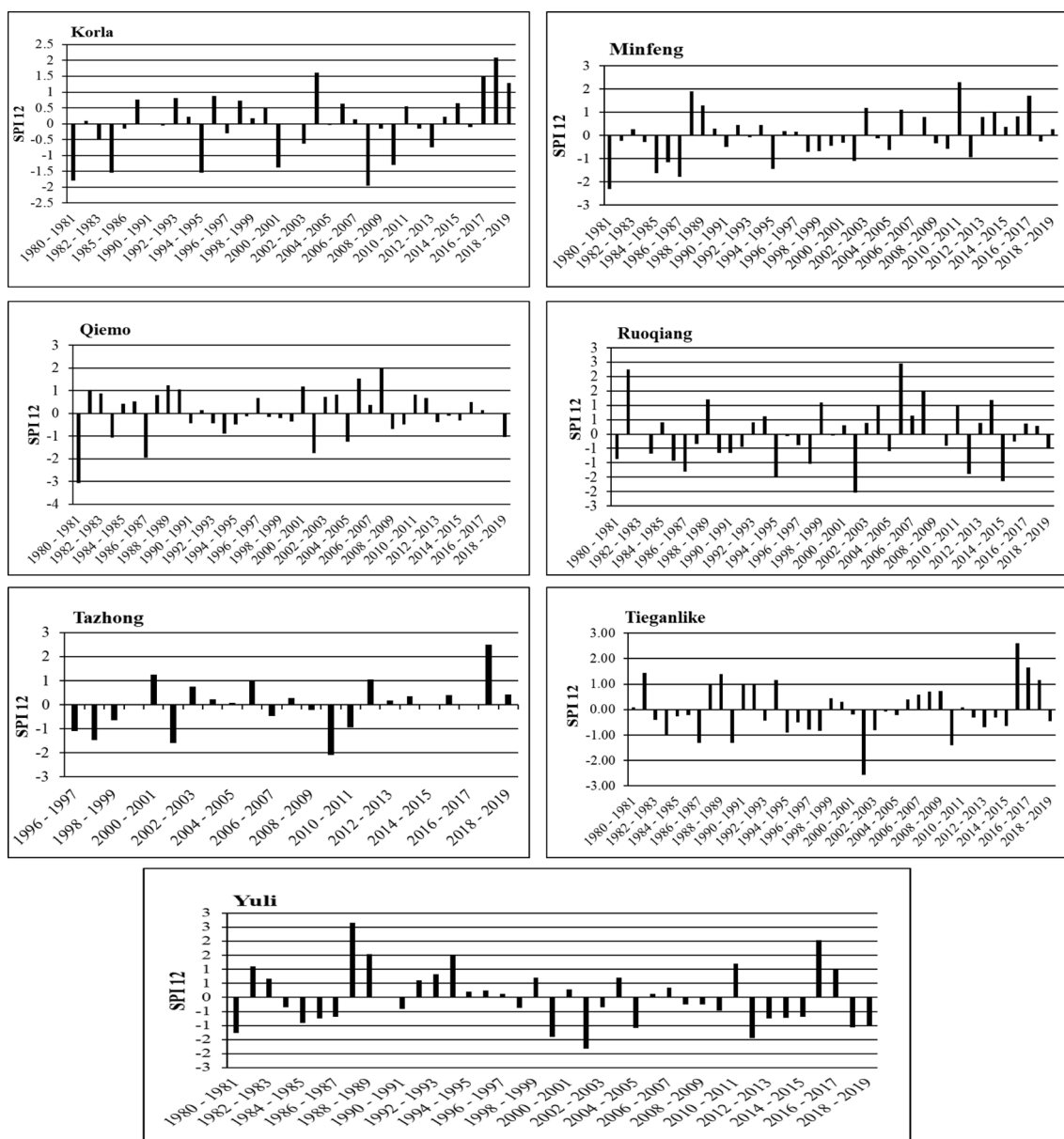
Fig. 5 Twelve months SPI Spatial and temporal results in various meteorological station

ordered wet and dry occasions. As we find out in Table 2 the serious driest conditions are happened in Aksu, Hotian, Bachu, Yutian, Minfeng, Qiemo, Ruoqiang, Tazhong, Yuli, Cele, and Tieganlike stations. Rest of stations such as Kashgar, Pishan, Lopu, and Yarkant have recorded wet conditions. Among the aforementioned met-stations such as, Qiemo, Tazhong, Ruoqiang, Tieganlike, and Yuli confronting warmest conditions in summer and coldest conditions in winter. Mostly, these stations are located in the heart of Taklimakan desert. It is squander desert territory that has scarcity of vegetation and water resources. This desert is rich with valuable natural resources such as minerals, oil and gas etc. High density of human economic

activities and constantly prevailing dry winds enhancing temperature and worst effect precipitation.

3.3 MK Trend Results for Precipitation Changes

The pattern of trend analysis study is vital to distinguish change in a straight factor with time by various parametric and non-parametric devices. The (MKT) test applying to decide pattern in SPI arrangement for both one-month and a year. Further, the Kendall's (τ) value inserted by IDW (Inverse Distance Weighted) technique in Fig. 7. IDW broadly used to explain the connection of precipitation for a particular drought over a territory. The MK test results on

Table 4 Drought frequency occurrence years in 12-month SPI

Station	Extreme drought occurrence year	Severe drought occurrence year	Moderate drought occurrence year
Aksu	1 (1986)	3 (1983, 1985,2010)	1 (1981)
Alar	2 (2001,1985)	4 (1983, 2009,2014,2004)	1 (1990)
Bachu	2 (1985, 1980)	3 (1997, 1999, 2001)	
Cele	1 (1985)	4 (1984, 1986, 2011, 1980)	
Hotian	1 (1985)	3 (1980, 1997, 2009)	1 (2001)
Kashgar	2 (1994, 2000)	3 (1997, 1999, 2007)	
Lopu	1 (1986)	3 (1980, 1998, 2000)	2 (1994, 2014)
Pishan	1 (2009)	3 (1997, 1999, 2000)	1 (1984)
Yarkant	1 (1985)	1 (1983, 1994, 2009)	
Korla	1 (2007)	3 (1981, 1983, 2000)	1 (1992)
Yutian	2 (1985, 1986)	3 (1984, 1994, 1998)	
Minfeng	1 (1980)	2 (1986, 2001)	1 (2011)
Qiemo	1 (1980)	3 (1986, 2001, 2004)	2 (1983, 2018)
Ruoqiang	1 (2001)	3 (1997, 2011, 2014)	1 (2018)
Tazhong	1 (2009)	2 (1996, 2001)	1 (2010)
Tieganlike	1 (2001)	3 (1986, 1989,2009)	1 (1983)
Yuli	1 (2001)	3 (1980, 1999, 2017)	1 (2009)

all meteorological stations information (*p* value) determined for SPI one-month and year at level up to 95%. After that value is introduced to discover precipitation force in different locality by various colors. At the point when the probability value ≤ 0.05 (H$_o$) is dismissed and we acknowledge substitute hypothesis (H$_a$), implies a critical pattern. The positive tau (τ) value shows (wet conditions) expanding pattern, while negative value of Kendall τ uncovers negative pattern (dry condition). Due to decadal changeability dry critical pattern nearly increments in each meteorological station of southwest Xinjiang. The SPI results for the January just in Alar and Ruoqiang met-stations are discovered generally critical (MSTD) and huge pattern identified (STD) in Aksu met-station. Month to month SPI bring about February most huge pattern identified (MSTD) in Hotian and Lopu met-station as demonstrated in Figs. 6, 7. In March (MSTD) discovered Korla and Tazhong met-station, while huge pattern identified (STD) in Lopu station. The period of April (NSTD) with no more pattern and in May (MSTD) found in Tieganlike met-stations. In month of June and July the (MSTD) recorded distinctly in Bachu, Kashgar, Qiemo and Pishan met-stations. August with no critical pattern (NSTD), in September most huge pattern distinguished in Kashgar and Tazhong and huge pattern identified (STD) in met-stations.

The main pattern (MSTD) in October Cele, Kashgar and Significant pattern distinguished (STD) in Lopu met-stations. In the month of November (MSTD) found in Aksu, Alar, Korla, Qiemo, Cele and critical pattern identified (STD) in Ruoqiang met-station. In December the main

pattern recognized (MSTD) in Korla, Minfeng, Qiemo, Tieganlike, Aksu and critical pattern identified in Cele met-station in (Fig. 6).

The main pattern identified Alar and Aksu, Korla, Minfeng, Qiemo and Ruoqiang met-station in October, November, December and January. The Standardized Precipitation Index statistical analysis for May, July, January, December shows critical positive pattern (wet condition). This is a stressed issue for thought the vast majority of the precipitation happens in rainstorm (Jul, Aug), western dispersions (Dec and Jan). The negative (dry pattern) happened in northern and parts at Xinjiang March, Jan and February, are undermine circumstance for dry season heightening. In these months raised region get most extreme measure of precipitation looking like snowfall. In stormy season get together with principle streams satisfying deficiency of farming water in plain zones. The 17 met-stations information not show a total descending example of precipitation in south Xinjiang China. The stations near Tianshan Mountains get more precipitation then plain regions. At some point geomorphology of a zone likewise become a wellspring of changing the situation like flash floods stream, soil disintegration. The present circumstance may straightforwardly leads to diminish of vegetation cover and lack of running water as a wellspring of water system in descending zones.

The results of Standardized Precipitation Index demonstrate in southwest parts of Xinjiang region shows drying condition, while northern and focal parts show wetting condition. A vast Taklimakan desert lies in southern segment a barren surface with no vegetation cover all in all clearing a
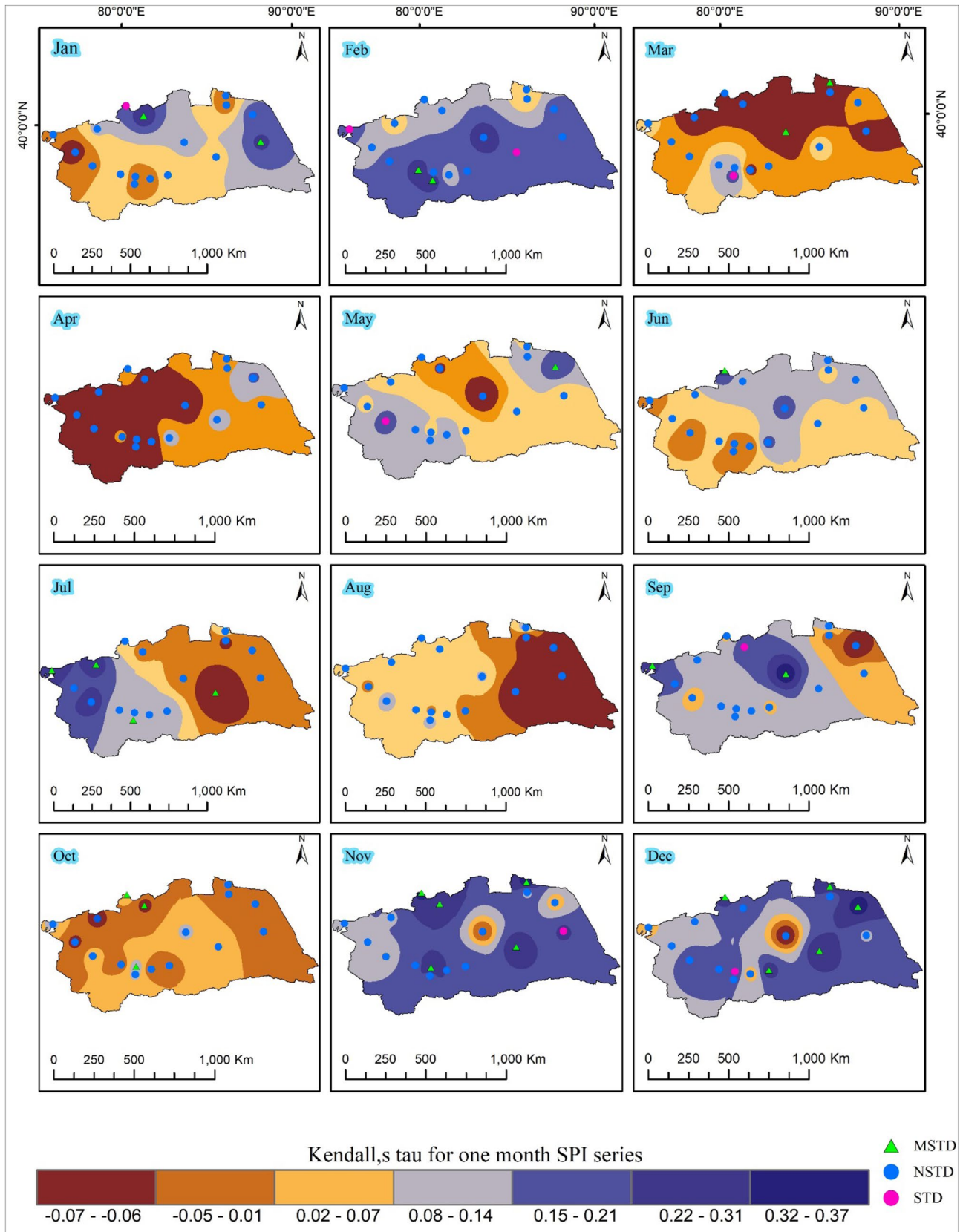
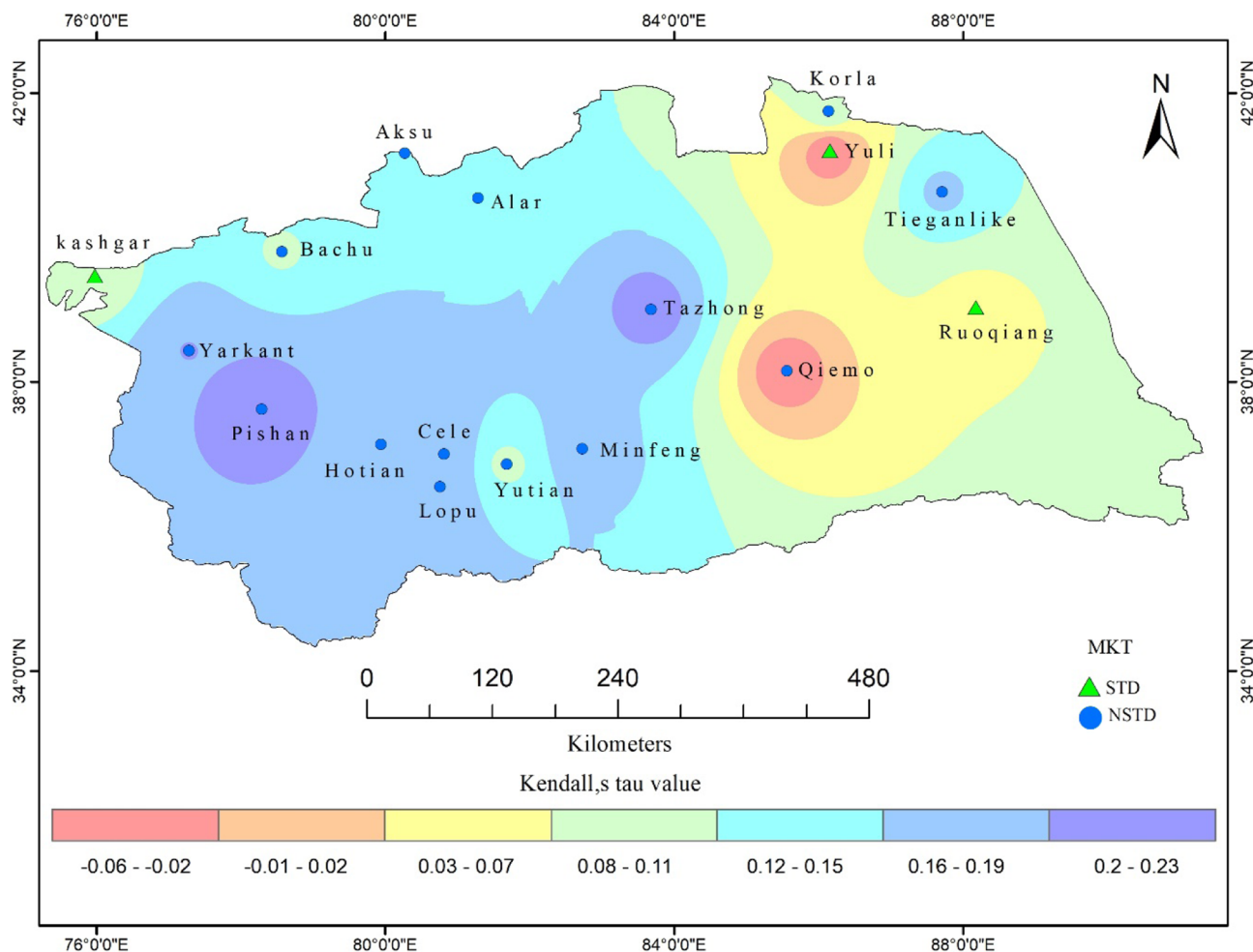**Fig. 6** Interpolation of Kendall, s tau value for 1 month SPI Series

Fig. 7 Spatial and temporal distribution of Kendall (τ) value and Mann–Kendall test results for SPI in southwest Xinjiang in northwest, China

path for desertification. The diminishing pattern of precipitation has seen in southern parts like Kashgar, Yutian, Yarkant, Korla metrological stations. The wetting conditions are found in Cele, Hotian, Aksu, Lopu, Alar met-stations. The main diminishing pattern of precipitation saw in Aksu, Alar and Korla met-stations in these stations as demonstrated in addition (Fig. 7). Interpolation of precipitation in Fig. 7 shows more variation. In Tazhong, Ruoqiang, Qiemo met-station more fluctuation is detected in precipitation regime. The most negative pattern identified in central and southern parts of the focal region. Current research study shows adjust shape from an earlier time, and the territory goes through human and common instigated changes.

The seasonal analysis of precipitation information shows more variation. For this purpose, it divided into four Summer (June, July, August), winter (Nov, Dec, Jan, Feb), Autumn (Sep, Oct), Spring (March, April, May) seasons. In Table 5, MK test applied monthly an upward pattern of trend distinguished in Kendall tau value in Lopu, Qiemo and Minfeng met-station in January. In month of April Aksu,

Korla, Qiemo, Ruoqiang, and Tieganlike have expanding pattern, while most critical pattern found in Yuli, Yarkant, and Cele in June. In August Aksu, Alar, Hotian, Kashgar and Yutian met-station have an expanding pattern of precipitation. The negative pattern recognized in precipitation happening months like Aksu in march, may, while Alar have an April, may, July. The most diminishing pattern discovered in different months like January, June, August, December in various stations. The territory has meagerly vegetation cover and shortage of water assets. The primary decline of precipitation as outrageous vanishing, dry surface and per annum proportion is less from ordinary.

Month-to-month pattern of precipitation was analyzed for consistently. The precipitation was oppressed by nonparametric test. In Table 6 the determined *p* value restricted more fluctuation in different stations. Occasionally, January in Alar, Ruoqiang while February Hotian and Lopu met-stations have rising pattern. The Aksu in June, July Bachu, Kashgar, Qiemo, Ruoqiang, November Aksu, Alar, Cele, Korla, December Aksu, Minfeng, Tieganlike met-station

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Table 5 Season wise Mann–Kendall test results of Kendall (τ) value in various met-stations

Station	Jan	Feb	Mar	April	May	June	July	Aug	Sep	Oct	Nov	Dec
Aksu	0.20	0.11	− 0.14	0.00*	− 0.01	0.24	0.02*	0.03*	0.05*	0.05*	0.32	0.25
Alar	0.28	0.08	− 0.14	− 0.09	− 0.07	0.09	-0.02	0.03*	0.20	0.05*	0.30	0.18
Bachu	0.09	0.01*	− 0.16	− 0.12	0.06	0.07	0.26	0.06	0.08	0.04*	0.13	0.09
Cele	− 0.05	0.19	0.13	− 0.11	0.03*	0.00*	0.12	-0.02	0.11	0.27	0.27	0.22
Hotian	0.08	0.25	0.10	− 0.05	0.10	0.03*	0.08	0.04*	0.09	0.08	0.20	0.14
Kashgar	− 0.06	0.20	0.06	− 0.10	0.08	− 0.06	0.28	0.04*	0.23	0.23	0.10	0.05*
Korla	− 0.01	0.01*	− 0.24	0.00*	0.05*	0.13*	0.09	0.14	0.13	0.13	0.37	0.29
Lopu	0.00*	0.26	0.20	− 0.06	0.13	− 0.03	0.10	0.11	0.16	0.23	0.19	0.14
Minfeng	0.04*	0.18	− 0.03	0.06	0.06	0.17	0.13	− 0.03	0.04	0.12	0.19	0.26
Pishan	0.00*	0.18	− 0.05	− 0.06	0.19	− 0.04	0.29	0.09	0.01*	0.16	0.06	0.18
Qiemo	0.06	0.21	0.06	0.03*	0.05*	0.01*	− 0.23	− 0.16	0.08	0.17	0.27	0.29
Ruoqiang	0.27	0.17	− 0.01	0.02*	0.05*	0.04*	− 0.05	− 0.13	0.09	0.07	0.21	0.11
Tazhong	0.10	0.27	− 0.33	− 0.17	− 0.20	0.18	− 0.05	0.08	0.38	0.23	− 0.07	-0.15
Tieganlike	0.18	0.16	− 0.01	0.05*	0.21	0.10	− 0.07	− 0.14	− 0.12	0.13	0.01*	0.33
Yarkant	− 0.13	0.08	− 0.04	− 0.10	0.06	0.04*	0.17	0.00*	0.18	0.05*	0.13	0.10
Yuli	− 0.06	0.00*	− 0.16	0.05*	0.11	0.00*	− 0.14	− 0.12	− 0.04	0.08	0.08	0.14
Yutian	− 0.02	0.06	− 0.11	− 0.14	0.13	− 0.05	0.10	0.05*	0.15	0.07	0.21	0.00*

*Most significant trend

Table 6 Season wise Mann–Kendall test results of P value in various meteorological stations

Station	Jan	Feb	Mar	April	May	June	July	Aug	Sep	Oct	Nov	Dec
Aksu	0.07	0.31	0.21	0.99	0.90	0.03*	0.84	0.79	0.61	0.61	0.01*	0.03*
Alar	0.02*	0.52	0.25	0.43	0.49	0.40	0.84	0.76	0.08	0.65	0.01*	0.13
Bachu	0.44	0.89	0.19	0.31	0.57	0.54	0.02*	0.59	0.45	0.71	0.31	0.45
Cele	0.64	0.11	0.28	0.36	0.80	0.95	0.29	0.84	0.34	0.03*	0.03	0.07
Hotian	0.48	0.03*	0.37	0.62	0.37	0.77	0.46	0.67	0.43	0.52	0.11	0.23
Kashgar	0.56	0.08	0.55	0.35	0.43	0.60	0.01*	0.69	0.04	0.05	0.39	0.64
Korla	0.87	0.94	0.03*	1.00	0.62	0.23	0.39	0.20	0.24	0.22	0.00*	0.01
Lopu	0.98	0.02	0.08	0.61	0.23	0.75	0.37	0.32	0.17	0.07	0.12	0.25
Minfeng	0.68	0.14	0.98	0.57	0.59	0.11	0.24	0.75	0.74	0.33	0.14	0.03*
Pishan	0.95	0.13	0.65	0.57	0.09	0.71	0.01	0.42	0.90	0.19	0.63	0.12
Qiemo	0.61	0.09	0.63	0.78	0.60	0.91	0.04	0.18	0.48	0.17	0.03*	0.02
Ruoqiang	0.03	0.17	0.91	0.84	0.65	0.72	0.63	0.63	0.47	0.55	0.10	0.38
Tazhong	0.55	0.12	0.05	0.32	0.19	0.23	0.75	0.58	0.02*	0.16	0.69	0.36
Tieganlike	0.14	0.20	0.95	0.65	0.07	0.38	0.49	0.21	0.30	0.29	0.94	0.01*
Yarkant	0.28	0.51	0.71	0.38	0.56	0.68	0.14	0.97	0.10	0.65	0.29	0.38
Yuli	0.58	0.99	0.19	0.62	0.33	0.96	0.22	0.29	0.68	0.51	0.48	0.24
Yutian	0.87	0.58	0.35	0.23	0.24	0.63	0.37	0.62	0.19	0.54	0.10	1.00

*Most significant trend

have critical upward pattern. Over all evaluation the precipitation happening months shows more dry conditions.

The present circumstance causing dry season conditions to a maximum degree. This may make more issues in agriculture area for rancher and water system. Uniquely in beginning of summer season outrageous flooding change the geomorphology decadal and occasional changeability of precipitation shows a diminishing pattern.

4 Summary and Conclusions

Xinjiang face not so much precipitation but rather drier season. The evaluation of spatial–temporal variation of precipitation is extremely high because of its more effects and high degrees of ecological wonders like floods, dry spell event, and decrease of vegetation covers likewise

diminishing of soil dampness. The research study base on Spatial–temporal changeability of precipitation examined by utilizing SPI and Mann–Kendall. Yearly, seasonally and month-to-month precipitation data of 17 meteorological stations utilized geographically located in south Xinjiang, China. The accompanying outcomes were acquiring from the measurable examination.

1. Temperature and precipitation variation in Xinjiang shows a lopsided situation. An extreme upward pattern happened in temperature rate in 1997. A 1987 expanding pattern identified in precipitation. These twenty years decide a rising pattern of both climatic boundaries.
2. The Standardized Precipitation Index results likewise of high value. Assessment shows abrupt changes happened after 1997. During 1997–2015 SPI investigations show that dry season seriousness increment in southern and focal Xinjiang up to 52%. The years 2001, 2014 and 2011 are amazingly dry recorded lacking measure of precipitation, extreme dry spell extension in the territory. Worldwide the precipitation pattern in Xinjiang is wet and event of typical dry spell and flood stream is higher in the region. The dry spell and flood increase in south Xinjiang on this request are 1980s > 1990s > 2 000s > 2010s > .
3. The Mann–Kendall test for SPI results shows there is positive pattern (wetting conditions) in some met-stations Located in north of Tianshan mountains. The met-stations situated on this belt shows a slight expanding measure of precipitation.

The spatial and temporal results of various indices due to regional differences show dissimilarities. Mostly cold events are decreasing in Xinjiang with direction of trend in mountainous and desert regions. The stations show increasing trend especially in south Xinjiang. The complexity in topographical features shows uneven distribution of rainfall. In southern and focal parts have negative pattern (drying conditions). The MK test results were added in (Figs. 6, 7) demonstrates spatial and temporal variance of precipitation. On government level unique consideration ought to be given recognizes the exceptional changes in spatial and transient progress of environmental change. Particularly significant level foundation ought to be established to screen the ecological changes. Certain guidelines are planned to rigorously endure the characteristic resources as timberland cover, horticulture land, streams stream and other actual ecological components. By these additive estimations on nearby also as government side can take legitimate choice and strategy makers to plan future arrangement and improvement.

In southwest Xinjiang monthly SPI and seasonal individual monthly results shows that positive pattern is seen in throughout the months besides in Bachu, met-station

negative pattern distinguished in March. The negative pattern likewise saw in different months. The north of the region demonstrating positive pattern in November, December, January and February, aside from Kashgar met-station have negative pattern in January. The precipitation happening months December nearly discovered dry in SPI 1-month estimation. Finding of the research study demonstrate a huge pattern upward in occasional month-to-month and seasonal precipitation and per annum precipitation is less from typical. Dissipation rate higher up to 11.9 mm/year. Temperature increment with a rate of 1.5 °C. Dry spell seriousness more affects vegetation and release of the waterways. On government level certain measurement should be formulated for check and balance of Spatial and temporal change. Protection of natural assets is essential for survival of physical environment. Drought study is significant for capable specialists, for future arrangement and assets for advancement of the territory.

Declarations

Conflict of interest The authors declare no conflict of interest.

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