Spatio-temporal Fluctuation of Temperature Using Specific Climate Indices in South Xinjiang, China

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Abstract. Temperature and precipitation are the major variables that can be used to determine the climatic variability in a region. This research study has focused on temperature that is much significant for the study of climatic variability over a long period of time in an area. Temperature has been assessed spatially and temporally in South Xinjiang, China using various climate indices. The temporal data about temperature of seventeen meteorological stations were acquired from Chinese Meteorology Administration (CMA) for the period from 1980–2018. To quantify the magnitude and temporal trend Mann-Kendall (MK) trend test and Sen's Slope (SS) statistical models were used. The monthly and seasonal analysis of temperature reveals significant increasing trend in mean maximum, mean minimum and average temperatures in the study area. The Sen's Slope test results indicate an increasing trend in monthly and seasonal temperature in almost all meteorological stations. The increasing trend in temperature is mainly due to the desert type of climate of the region that are gradually further aggravating with every passing year. These increasing trend of temperature will smoothen the way for perpetual drought in the region in future. Therefore, this research would be beneficial for future planning and management of water resources in the region and to make preventive measures for the mitigation of the impacts of climate change in the study area.

Key words: Climate change, Mann-Kendall Trend, Temperature Variability, South Xinjiang, China.

1. Introduction

Climate change and variation in climatic variables like temperature and precipitation are most important aspect of environment as they influence the ecological balance and agricultural productivity (W. He et al., 2022). Global climate change is currently a debated issue among researchers throughout the world. Climate change is known to have large-scale consequences on human economic and social systems (Y. Wang et al., 2022). Recent research studies recorded a warming trend in climate throughout the world (Zeng et al., 2020). As a result of this climatic imbalance, few cold weather events have been recorded but most of the studies showed warming trend in global climate (Zhang et al., 2021). Due to anthropogenic activities the physical environment has been disturb and as a result both the northern and southern hemispheres are getting warm (R. Li et al., 2020). According to a research finding, increase in greenhouse gases and industrialization have increased the earth's surface temperature have raised up to 0.7°C in last fifty years, with the 1990s being the warmest decade (J. He et al., 2022). Spatio-temporal changes in temperature increase droughts, surface runoff and increase rate of glaciers melting (Xie et al., 2013).

Past research studies in South Asian climate clearly indicate that spatial and temporal fluctuations in temperature are detected in many parts of India (Cao et al., 2022). Most parts of North India show tremendous variation in temperature in terms of maximum, minimum, mean, monthly and daily range of temperature (Jiang et al., 2021). The current statistical data shows increase in temperature and economic damages in past forty years (H. Li et al., 2020). According to published sources of government information on climate change phenomena were detected a 0.13°C per decade rising trend (X. Zhang et al., 2022). This increase in temperature scenario is uneven throughout the world and its harmful devastation are causing water deficiency, which severely influences rainfall regime in any region around the globe (J. Zhang et al., 2022). In last fifty years, the environmental conditions of China indicate more devastated situation due to increase in 0.42°C per decade in average temperature (Moazzam, Rahman, Lee et al., 2022). The more impacts of these unfavorable circumstances are a get way with climatic elements globally with a massive effect throughout the china temperature (S. Wang et al., 2022).

In China, climate change has been experienced severely during 1992 to 2010 causing damage of 16 billion Yuan approximately and above ten million populations suffered from drinking water (H. Li et al., 2019). Due to an increase in temperature, particularly in the Taklimakan desert, Xinjiang becomes hot and dry (Tan et al., 2015). Furthermore, warming and severe changes in the earth's atmosphere cause changes in weather patterns, increased aridity, rising sea levels, and glacier melting (Jamro et al., 2019). These events had a significant impact on Xinjiang's climate, increasing the dry season (Miyan, 2015). Slight temperature variations can have a direct influence on a region's hydrological pattern, as well as a larger impact on the climate (Jia et al., 2022).

The climate trend and its widespread damage are not being given adequate attention. Rainfall and temperature are commonly employed in climatological research to emphasize the amount and pattern of temperature change using different quantitative (Yao et al., 2019). The goal of current research was identifying the temporal and spatial patterns of temperature fluctuation in Xinjiang province 1980 to 2018, as well as for trends using Sen's slope Estimation Model, Mann-Kendall trend test (Khan et al., 2021).

2. Study area

The study area lies in South Xinjiang province, China. Geographical extension of study area is from 34°32' to 41°22' N latitude and 75°31' to 91°30' E longitude. Kunlun, Tianshan, and Himalaya mountain ranges surround the study area from Northern to Southern, while in the East Lop Nor region is situated. On the Western side, Kashgar lies near the border and extend up to the Pakistan boundary. The current population of study area is 7,571,746 persons residing in an area of 803,351 km^2 (Huang et al., 2021). The area has vast desert-like environmental conditions, with regular dunes formation caused by dry dominant winds blowing. Consist on sparse vegetation cover having dry grasslands presents a warm type of climate with a maximum variety of everyday temperature (An et al., 2020). The minimum temperature recorded in South Xinjiang is -5.6°C, maximum up to 26.1°C, and the average temperature are 10-15°C. The yearly precipitation is less than 158 millimeters. Hotian and Aksu are main rivers in the region (Liang et al., 2021).

The major source of water in the area is Hotian River originating from Kunlun Mountain in Southern part, Aksu River origin from North of Tianshan Mountains runs toward the south joining with main Tarim River and ultimately drained Tiatema Lake. The Kashgar River originating from Himalayan ranges that runs from Southern to North and finally draining into the Tarim River (Luo et al., 2020).

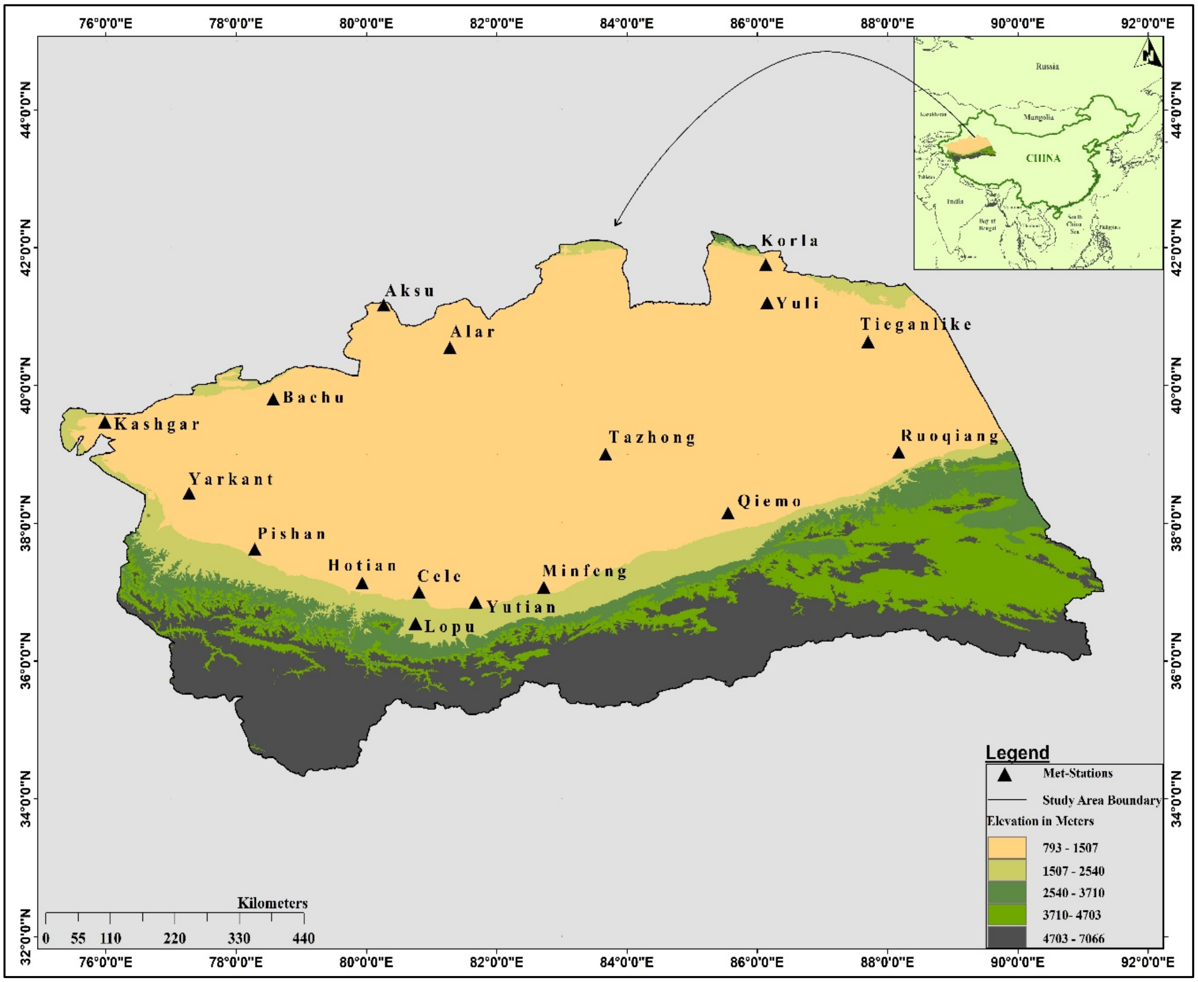


Figure 1. Locational Map of Met Station in South Xinjiang, China [Source: This map arranged from SRTM Data 2022].

In the piedmont area of Tianshan Mountains, many oases be responsible for water supply for agricultural activities, social, and economical purposes. The collective vegetation of region comprises *Tamarix* plants. There are 12 different species of *Tamarix* found in China, along with eighty-four percent of them found in Xinjiang. *Tamarix* is a shrub plant growing in river reaches, muddy fans, oasis areas, and areas between wind-blown sand dunes region. Due to the predominant intense dry environment, remaining perennial plants are hardly to persist that type of harsh environment (Khan et al., 2013).

2.1. Sources and collection of data

The important outcomes of research related to climatic change influence by availability and reliable source of data. For current research, we have selected significant parameter such as monthly mean temperature, minimum temperature and maximum temperature. For this research study temperature data of selected met stations were obtained from Chinese Meteorological Administration (CMA) for period of 1980 to 2018. Due to altitudinal variation in the study area, the monthly mean, maximum, and minimum temperature also varies from area to area. The geographical characteristics of proposed meteorological stations in the study region are given in Table 1.

2.2 Research methodology

From a historical perspective, time series data plays an important role in detection of change in a climatological parameters. This is utmost important for utilization and management of natural resources (Kisaka et al., 2015). For this research study, monthly maximum, minimum, and average temperature data of 17 meteorological stations have examined using Mann-Kendall test (MKT) and Sen's slope (SS). The computed statistical analysis results of MK test and SS model further evaluated for authentication through IDW technique in ArcGIS.

2.3 Serial correlation effect

In climate research sometime only Mann-Kendall trend test not ensures a precise results of trend study. Although in various cases long term data has downward trend and its computed results determine positive direction (Xie et al., 2022). The omitted assessment in lengthy data has an impact in Mann-Kendall trend test for a suitable substantial consequence.

2.4 Mann-Kendall and Kendall tau (τ) statistics

Various statistical tools and model are applying by researchers in climate research studies for reliable results in different decades. Most appropriately in climate research precipitation and temperature data, as well as in environment social sciences MKT is commonly using this model provides better results with spatial temporal context (Xia & Zhao, 2014). Data is put in a serial column and on the other way years, care of missing variables is essential and effectively in the XLSAT program by using various formula proposed consequences are obtained. Furthermore by applying software and various calculations show trend of temperature in different decades (Chipman et al., 2016). Statistical analysis is very important to compute change in a climatological parameter in spatial and temporal context. Through by Mann-Kendall test easily predicating, generally increase and decreasing trend of a variable (Alghannam & Al-Qahtnai, 2012):

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

where

$$sgn(xj - xi) = \begin{Bmatrix} +1, & xj > xi \\ 0, & xj = xi \\ -1, & xj < xi \end{Bmatrix} \quad (2)$$

The variance of statistics is found as

$$Var(S) = \frac{n(n-1)(2n+5)\sum_{i=1}^{n} t_i i(i-1)(2i+5)}{18} \quad (3)$$

Mann-Kendall test mostly determine with calculated results and two Hypothesis are using for its differentiation. In climate research study, when the *p-value* level is greater that of significant value (α = 0.05) significant trend of temperature is considered. In this regard, it shows lower level of significant change in data series we accept null Hypothesis (Mar et al., 2018). Mostly the Kendall tau is taken in statistical analysis for the measurement of climatic parameter intensity. The ascending rate of tau shows positive, while downward level indications negative temperature trend (Allred et al., 2016). All the calculated results like (τ) value, statistical variance will be interpreting in middle portion of research paper.

2.5 Sen's slope Method

In climate research study Sen's slope (SS) method extensively applicable to detect direction and magnitude of temperature at various spatial and temporal context. This demarcate the direction and intensity of temperature magnitude. By the same ways it is calculated in XLSTAT software. This is rank based non-parametric test consistently functional on space detected among the data series (Brilly et al., 2014). This selected technique widely applicable and meteorological data for detecting linear and non-linear temperature data trends, however it is ascending or descending pattern (Ullah et al., 2020). Whole data pairs the slope (T_i) as detect Sen's slope to re-present estimation and its perpetual rate.

$$f\ (t) = Q_t + B \quad (4)$$

In equation (4), shows estimation and its permanent value of Sen's slope level. To detect the slope approximation equation (5) first the rate of totally data was considered.

$$Q_i = \frac{X_i - X_j}{j - k} \quad (5)$$

Furthermore, to discover the approximaty of slope first value of whole data was deliberate. However, calculated figure occurred is odd N, then Sen's slope value is lower, if rate of N is calculated even number shows positive slope, it shows there is upward change (Rahman et al., 2018). When Q_i is decreasing it represents descending pattern trend in the evaluation of lengthy data time series.

In equation (5), i = 1,3,5……. N in which time j and k ($j > k$), Xj and X_k is pairs data value. N value of T_i median is expressing as Sen's slope estimation, as following method.

$$Q_{med} = \begin{cases} Q_{\left[\frac{N+1}{2}\right]}, & if\ N\ is\ odd \\ \frac{Q_{\left[\frac{N}{2}\right]} + Q_{\left[\frac{N+2}{2}\right]}}{2}, & if\ N\ is\ even \end{cases} \qquad (6)$$

When computed level zero specifies no significant trend (Rahman & Dawood, 2017) . The upward pattern of β value displays increasing trend Spatial and temporal context, however descending of β shows less trend.

2.6 Inverse Distance Weighted

This technique is frequently applying for rainfall and temperature climate time series data. In interpolation technique we used approximate values of different cell through around of known points data in the locality of every dispensation cells for prediction of indefinite value to any environmental ground. The averages of mean monthly temperature calculated in Microsoft excel and in ArcGIS further interpolated. Various tones and shades are used to highlight severity of temperature in a region. Although climate research data are presented through this technique using different colors. We differentiate red for cold and blue for warm zone in the area.

$$\hat{Z}(S_o) = \sum_{i=1}^{N} \lambda_i Z(S_i) \qquad (7)$$

In this method the distance is rise and weightage is lessening. The following equation are used for weight calculation.

$$\lambda_i = \frac{d_{i0}^{-P}}{\sum_{i=1}^{N} d_{i0}^{-P}} \qquad (8)$$

This technique was particularly applying on reverse route of mathematical form (p) which fully controller the significance level situated on a defined direction. The focal rate can be considered through (RMSPE). The validity of square root mean is a predictive error in time of calculation.

3. Results

3.1 Monthly and Seasonal Temperature Characteristics

Generally, in climate research studies, data accuracy is the most important indicator in quantification of climatic parameters. Spatial distribution of meteorological stations plays an important role in the provision of accurate data for research studies. The current research is conducted using temperature data acquired from seventeen meteorological stations equally distributed in the study area to get appropriate picture of the changing climate scenario. The acquired data of temperature analyzed through various climatic indices reveals that temperature distribution is uneven from center to South, greater temperature gradation and climate change pattern are found Northern to Southern part of the region (Moazzam, Rahman, Munawar et al., 2022). Table1 depicts spatial distribution of temperature as maximum, minimum and average monthly temperature of the selected meteorological stations. Average monthly temperature of all meteorological stations reveals that Yuli Met station is the highest as 25.33°C while Tazhong Met station show -4.20°C the lowest monthly averages. Other Met stations show intermediate position in between 9°C to 13°C monthly averages.

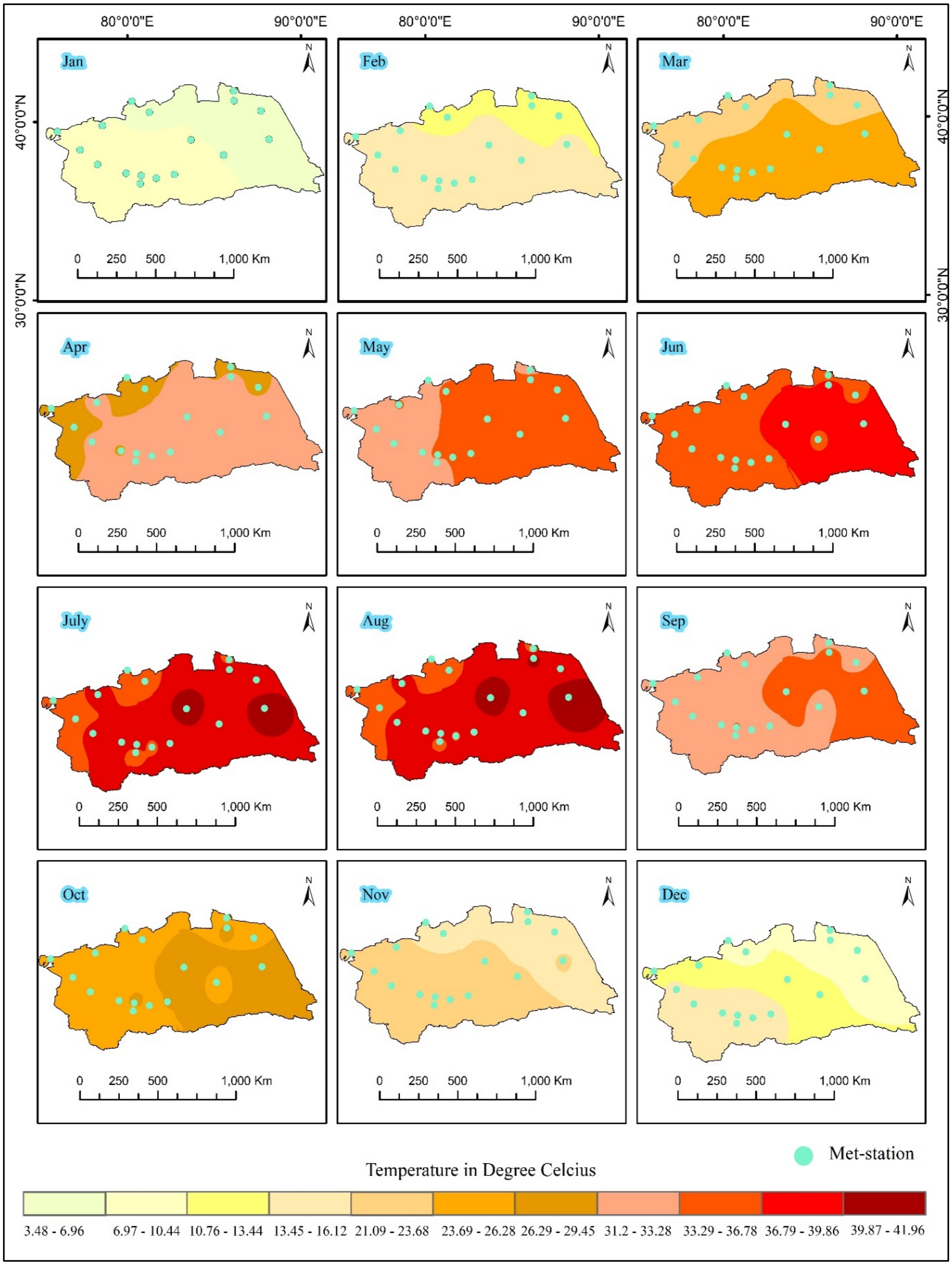
Topographical location plays an important role in temperature distribution of a region. Analysis statistical data in Table 1 reflects that Yuli met station show more warming trend of temperature while Tazhong met station located at higher altitude is the colder met-station in the region. Most notable appearances of Yuli station are that located in east side having more accessibility to natural resources like oil, coal, and gas abundant reserves. Excavation of mining resources are utmost driving forces for increasing lengthy spell of summer temperature although winter season is condensing gradually in spatial and temporal context (Rahman et al., 2018). Moreover, utilization of heavy machinery by Government agencies for the extraction of mineral resources in the area enhancing climatic variability. Due to the high densities of economic activities in the region, the mean minimum temperature show upward trend and climate of the region going to be warmer than normal. This increase in minimum temperature is a big dilemma for the survival of living organism and harshly affecting flora fauna of the region (Hu et al., 2021).

Beside variation in minimum and maximum temperature the seasonal climatic pattern is also changing. Summer becomes more enlarge while winter is condensing with spatial and temporal context. These monthly and seasonal variation in climate of the region make environment unfavorable for the growth and existence of flora and fauna in the study area (An et al., 2020). As the research area receive less precipitation approximately lies in shadows of rainfall, resulting in a shorter monsoon season spell (Dawood et al., 2021). In present condition, the temperature minimum has an ascending route through fluctuation in spatial-temporal context. The interpolated analysis of temperature data through GIS Software's as shown in Figure 2, indicate a highly spatial and temporal trend in minimum temperature over the area.

Table 1. Statistical description and Geographical location of temperature (degree °C) in whole study area.

Station	**Latitude (Nord)**	**Longitude (East)**	**Altitude**	**Maximum Temp.**	**CV %**	**Minimum Temp.**	**CV %**	**Average Monthly. Temp.**	**CV %**
Kashgar	39° 46′	75° 90′	1289	39.40	38.90	-22.30	-45.22	12.40	86.35
Bachu	39° 80′	78° 50′	1116	42.60	44.02	-25.10	-43.61	13.00	94.99
Cele	36° 99′	80° 80′	1394	42.10	37.35	-21.80	-47.85	12.96	82.92
Yutian	36° 85′	81° 67′	1422	40.60	36.6	-22.80	-43.51	10.38	87.04
Hotian	37° 13′	79° 90′	1375	41.40	38.12	-21.00	-47.93	13.29	79.30
Lopu	36° 54′	80° 75′	1189	41.90	38.75	-23.90	-45.03	12.12	84.94
Aksu	41° 16′	80° 26′	1103	39.70	48.14	-11.80	-44.38	11.01	100.84
Pishan	37° 62′	78° 28′	1375	41.60	37.51	-22.80	-46.15	12.52	86.42
Yarkant	38° 43′	77° 27′	1231	40.70	38.45	-24.10	-41.88	12.19	87.82
Alar	40° 54′	81° 28′	1012	40.60	46.37	-25.40	-43.92	9.91	121.30
Korla	41° 75′	86° 13′	931	40.80	49.19	-23.70	-43.66	11.24	100.79
Ruoqiang	39° 03′	88° 17′	887	43.90	46.21	-22.60	-48.62	12.03	101.40
Qiemo	38° 15′	85° 55′	1247	41.60	43.01	-27.30	-40.69	11.08	105.24
Minfeng	37° 07′	82° 17′	1409	41.80	37.81	-25.80	-40.95	12.19	89.39
Tazhong	39° 00′	83° 19′	1099	45.60	44.09	-32.70	-40.84	-4.20	-317.31
Yuli	41° 72′	86° 15′	903	42.20	47.55	-25.50	-45.74	25.33	47.55
Tieganlike	40° 63′	87° 70′	846	43.90	47.66	-25.00	-47.27	11.46	109.95

Source: Meteorology Department, Government of China.



80°0'0"E
90°0'0"E
40°0'0"N
30°0'0"N
Jan
Feb
Mar
Apr
May
Jun
July
Aug
Sep
Oct
Nov
Dec
N
0 250 500 1,000 Km
Met-station
Temperature in Degree Celcius
3.48 - 6.96
6.97 - 10.44
10.76 - 13.44
13.45 - 16.12
21.09 - 23.68
23.69 - 26.28
26.29 - 29.45
31.2 - 33.28
33.29 - 36.78
36.79 - 39.86
39.87 - 41.96

Figure 2. Interpolation of Mean monthly maximum temperatures for 12 months of 17-Met Station [Source: Interpolated Temperature Data of Sixteen Met Station through ArcGIS].

Mean monthly temperature particularly in June, July and August remain high and daily range of temperature is maximum in summer season due to desert surface. In Figure 2 the red color indicates high temperature in the months of June, July and August while other months remain low highlighted with light pink or yellow colors. The northern side has less temperature pattern and remains cool throughout the year due to highland type of climatic pattern. While the south and east-west side of the region remain hot often temperature reached up to 41°C.

Most of met stations are located in southern and central Xinjiang, therefore these station show large variation in temperature both in summer and winter spatially and temporally. Due to this tremendous spatial and temporal fluctuation in climatic patterns and diver's topographic condition of the area, the local environment is continuously damaging. In addition, the ruthless utilization of natural resources, population growth and infrastructure development increasing the severity of climate change in the region and the effects will be faced widespread from national to global level.

Table 2. Mann-Kendall test results of trend detection in maximum, monthly, and minimum temperature.

Station	**Maximum Monthly temperature**	**Monthly temperature Minimum**	**Average Monthly temperature**
Kashgar	8 (-), 1	1(-),1,8	1(-)
Bachu	1, 6,8	1,8	1, 8 (-), 7
Cele	3, 5	…. no significant change	5 (-)
Yutian	…… no significant change	1	…… no significant change
Hotian	5 (-), 8(-), 4, 6	1	…… no significant change
Lopu	…… no significant change	1(-), 2, 12	…… no significant change
Aksu	1 (-)	1	…… no significant change
Pishan	6 (-), 8(-), 4	1 (-)	1
Yarkant	1, 6	1 (-),11,12	1 (-)
Alar	1	5,6,7,8,1 (-), 11,12	1,5,7,8,9,10(-)

Korla	1 (-), 5(-), 8(-), 9(-), 10(-),7	1,4,5,6,7,8,10,11,12 (-)	1,5,7,8,9,10,11,(-), 2,6
Ruoqiang	8	1 (-), 5,12	1,5,8,10,(-), 9
Qiemo	11	1	1
Minfeng	9, 12	… no significant change	… no significant change
Tazhong	4, 6, 8, 9, 11(-), 1, 10	1 (-)	2,4,6,8,10,12, (-)
Yuli	5, 8, 9, 10, (-) 1	… no significant change	1 (-), 5,8,9,10
Tieganlike	1	1 , 5,(-), 9,12	1 (-), 5

Note: Negative symbols show descending temperature trend.

3.2 Mann-Kendall test Results

The MK trend test model applied over the temperature data of selected meteorological stations. Various months are evaluated for clear understanding of temperature fluctuation. For instance, such as 1 shows Jan 4 for Apr, 8 for August and 12 for December. Furthermore, negative symbols indicate decreasing trend and months with no symbol exhibits determine increasing trend of temperature in respective month. For convenience, different numerical values for various temperatures pattern are highlighted. Mostly in Table 2 months show a downward temperature trend, and dots on the table indicate no considerable change in corresponding months. Notable changes are found in the minimum and monthly average temperatures in various stations in Table 2. Northern and southern Xinjiang have more differences in temperature pattern maximum ratio denoted in northern Xinjiang. Due to these unevenness climatic conditions are severely affected and its impacts are harsh on flora growth. Comparatively all meteorological stations, a significant downward trend has been detected in Korla region located on higher altitude. Otherwise Hotian and Tazhong met-stations are low lying having descending trend found in monthly maximum temperatures. Besides this Yarkant met-station have a negative trend in case of minimum monthly temperature.

Table 3. Annually MK test results for the maximum, mean, and minimum temperatures for proposed meteorological stations.

	Annual average Maximum. Temp.	Annual average Minimum	Annual monthly Average Temp.

	Temp.								
Station	value of Kendall (τ)	probability -value	Q_{med}	Kendall (τ) value	probability -value	Q_{med}	value of Kendall (τ)	probability -value	Q_{med}
Kashgar	0.28	0.00	0.03	0.44	0.00	0.07	0.46	0.00	0.04
Bachu	0.34	0.00	0.03	0.60	0.00	0.05	0.45	0.00	0.03
Cele	0.45	0.00	0.05	0.64	0.00	0.08	0.51	0.00	0.05
Yutian	0.51	0.00	0.06	0.57	0.00	0.06	0.52	0.00	0.05
Hotian	0.43	0.00	0.05	0.65	0.00	0.08	0.60	0.00	0.06
Lopu	0.54	0.00	0.07	0.16	0.13	0.02	0.64	0.00	0.06
Aksu	0.58	0.00	0.06	0.59	0.00	0.06	0.67	0.00	0.06
Pishan	0.36	0.00	0.04	0.62	0.00	0.06	0.35	0.00	0.03
Yarkant	0.47	0.00	0.05	0.48	0.00	0.06	0.53	0.00	0.03
Alar	0.46	0.00	0.04	0.07	0.49	-0.00	0.14	0.35	0.00
Korla	0.35	0.01	0.03	-0.27	0.01	0.02	-0.07	0.48	0.00
Minfeng	0.42	0.01	0.04	0.66	0.01	0.08	0.61	0.01	0.05
Qiemo	0.51	0.01	0.07	0.55	0.01	0.05	0.53	0.53	0.04
Ruoqiang	0.48	0.01	0.06	0.31	0.05	-0.03	0.35	0.01	-0.02
Tazhong	0.14	0.35	0.01	-0.55	0.01	0.15	0.47	0.01	0.08
Tieganlike	0.53	0.01	0.06	0.32	0.01	0.03	0.60	0.01	0.05
Yuli	0.42	0.05	0.04	0.58	0.01	0.08	0.42	0.01	0.04

The calculated statistical results in Table 3 of MK models Sen's slope shows magnitude of trend in various proposed met-stations using maximum, minimum, and monthly temperatures. 5% significant probability value out of sixteen in seventeen meteorological stations, the most significant trend is detected in average maximum temperature. Moreover, with this regard, significant trend in annual average minimum temperature is found in fifteen out of seventeen meteorological stations, while a significant change in monthly average temperature is found in fourteen out of seventeen met-stations in the whole region. The rest of six stations (Tazhong, Lopu, Ruoqiang, Qiemo, Alar, and Korla) are excluded, with nominal trend in maximum, minimum, or monthly temperature. The significant trend in temperature denotes a gradual increase in temperature pattern in the study region. Furthermore, Kendall tau value is calculated for more information about temperature severity. Positive values indicate as descending trend, and negative values showing a downward trend in a particular time span. As per analysis of data temperature show a particular upward pattern of rising trend and their detail values are given in Table 3. Among all met stations except Korla and Tazhong region value of Kendall is negative showing downward trend of temperature. Korla is high altitude station but with passage of time more fluctuation occurred in climate condition located in Tianshan mountain belt. Tazhong is lower altitude and located in warm climatic zone shows tremendous variation. Such type of drastic may cause more severe environmental conditions and making surrounding area warm. Furthermore, in statistical analysis Figure 3 and 4 interpolation through idw have applied to find tendency of temperature in various months of selected meteorological stations. The consequences of temperature different ranges from -15.20°C to -23.70°C and 3.48°C to 41.96°C in monthly, minimum and maximum temperature.

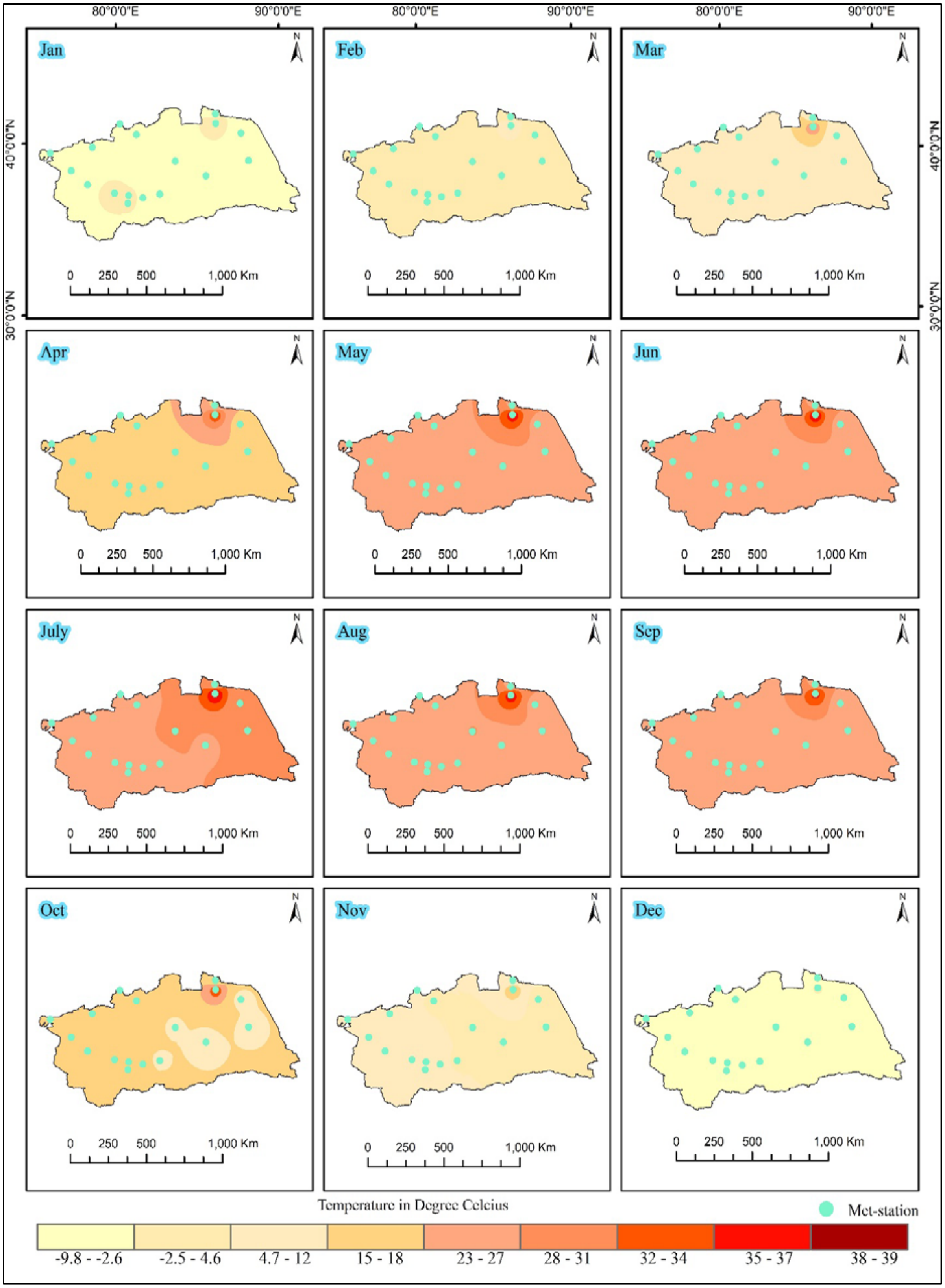


Figure 3. Maps shows mean monthly temperature interpolation (1 to 12 months) in selected met-stations.

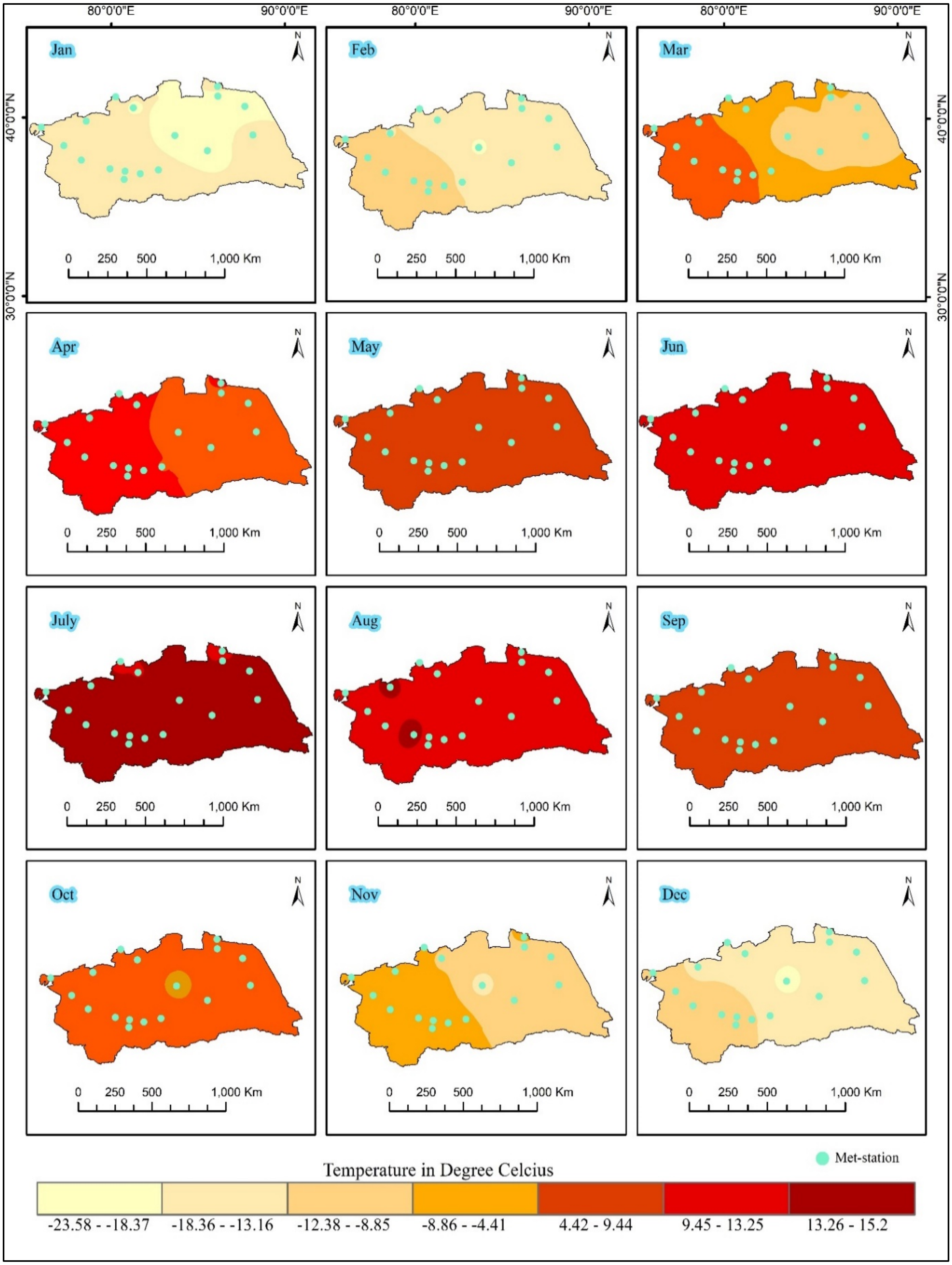


Figure 4. Maps shows interpolation of mean monthly minimum temperature (1 to 12 months) of selected met-stations.

As per computed statistical analysis mostly minimum temperature increasing in various months. Most of rainfall occurring months in winter season indicate an increasing trend of temperature. Although most climatic data, a massive change was detected in south Xinjang showing more severe warm conditions of temperature as demarcated by different shades in maps. Moreover, rate of temperature is maximum in summer season months like June, July and August and rainfall occurring months are detected dry in spatial temporal context (Shang et al., 2019). This become source of water for irrigation purposes in other parts of the region. Due to lower altitude, Tazhong, Qiemo, Ruoqiang stations have most significant higher temperature range among the whole station in the region. These stations are located in lower altitude and have proximity of natural resources, therefore, here climate is more severe. These warming pattern of climatic conditions effects on survival of flora in the region. Such type of warming climate severely affected the surrounding region with spatial and temporal context.

3.3 Sen’s slope

This research deals with spatial and temporal variation of temperature through different indices so it is very essential to detect magnitude of trend in temperature. Calculated statistical results of Sen’s slope show a more positive trend and magnitude of temperature. There is more spatial and temporal variation found in all temperature time series data which shows significant trend. Furthermore, negative estimation of Sen's slope denotes descending trend, and the positive value shows an upward trend in interpolation maps.

Furthermore, in Figures 5 and 6, Sen's slope value are interpolated to find out the distribution of trend magnitude of temperature. The monthly average temperature ranged from -0.08 to 0.06, highest temperature ranged from 0.01 to 0.07, and the lowest temperature ranged from -0.015 to 0.08 in calculated value of Sen's slope. Moreover, intensity of temperature is high in Tazhong, Tieganlike and Lopu met-station in plain area of South Xinjiang. Although various positive values in the map demonstrate an expanding trend pattern while negative show a downward direction of temperature in the selected meteorological-stations in the region.

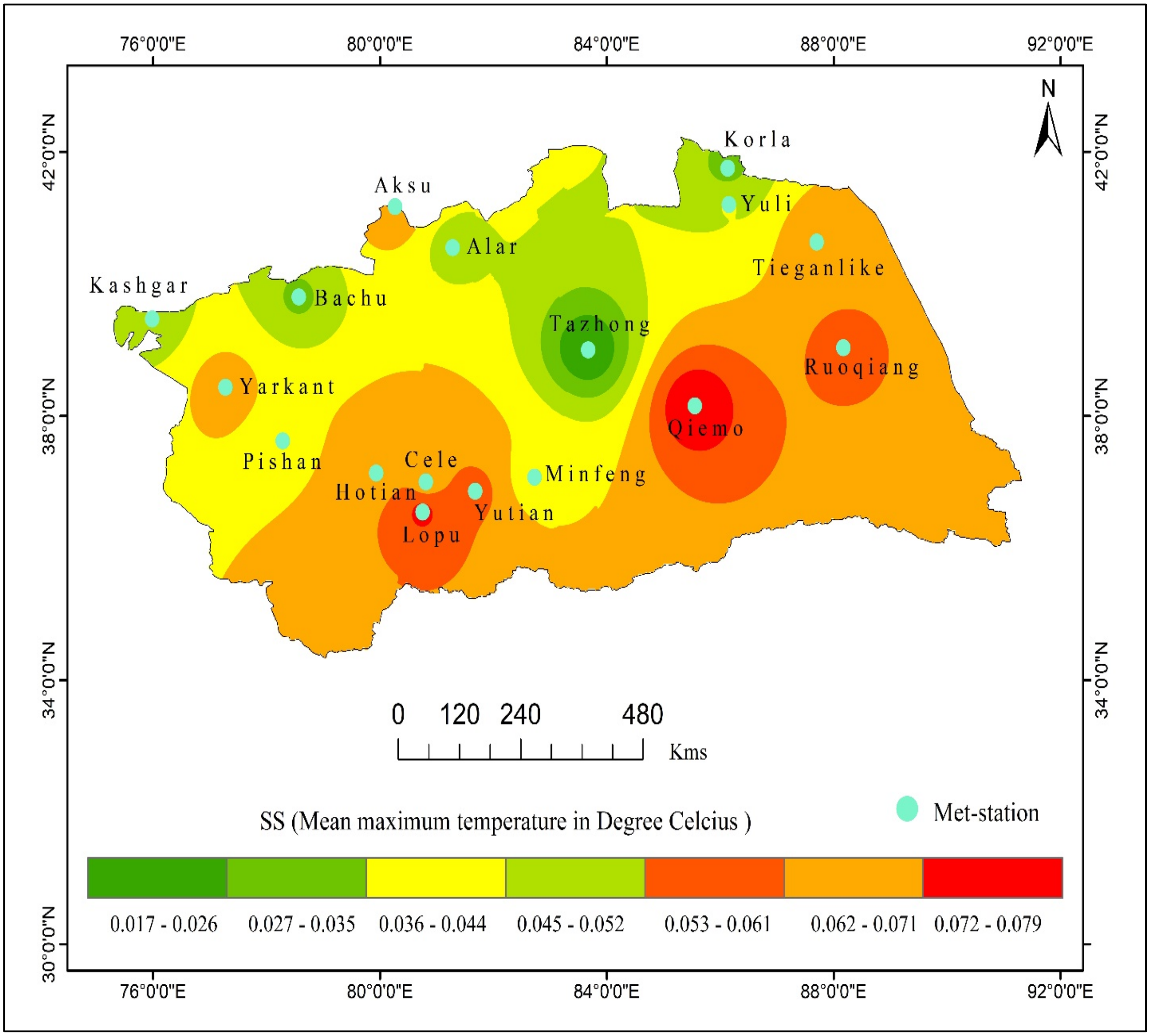


Figure 5. Sen's slope values Interpolation of mean monthly maximum temperature.

Same in case of maximum temperature which is getting increase. Mostly higher altitude area has tremendous variation like Alar and Yarkant. Summer season have maximum range of temperature and in south Taklamakan desert making climate pattern severe. A vast desert landform with barren vegetation cover making physical environment harsh. Spatial and temporal change is minimum temperature is noteworthy and it is a worried situation for survival of flora. As in IDW maps it represent completely red color represent severity of temperature in the region.

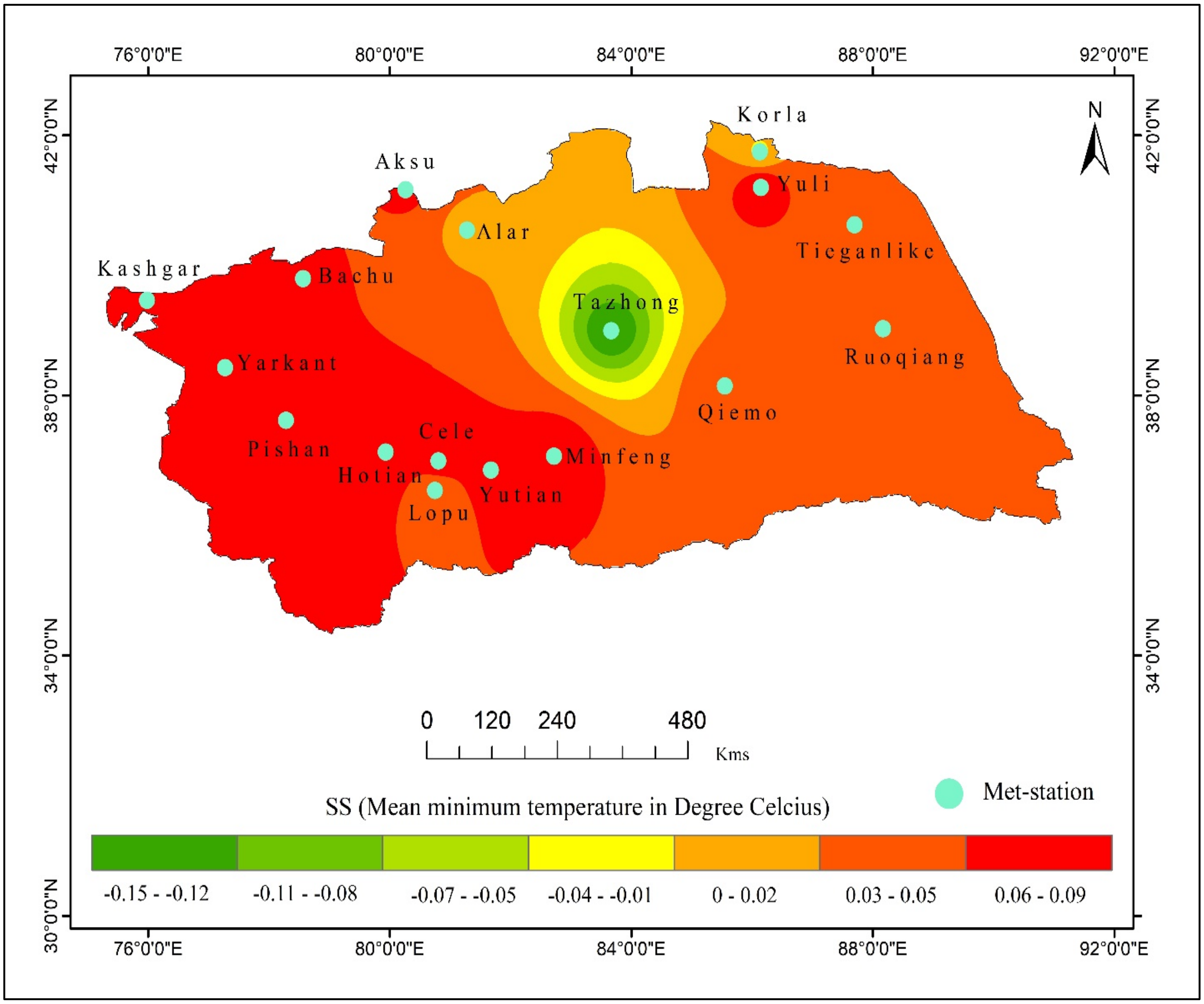


Figure 6. Interpolation of Sen's slope values mean monthly minimum temperature.

Furthermore, in Figure 7 Sen's slope analysis denotes month wise temperature of various selected meteorological stations. Average monthly temperatures shows more tremendous variation in various stations. Monthly temperature in higher altitude station also going in upward direction like Aksu, Korla and in interpolation maps denoted mainly with red colors. Already summer season is enlarging and harsh so whole region indicates more spatial and temporal variation. In south Xinjiang winter season is almost have so severe impacts and due to lack of vegetation cover daily range of temperature is maximum. Mostly rainfall occurring months are found dry in both season with less amount of rainfall.

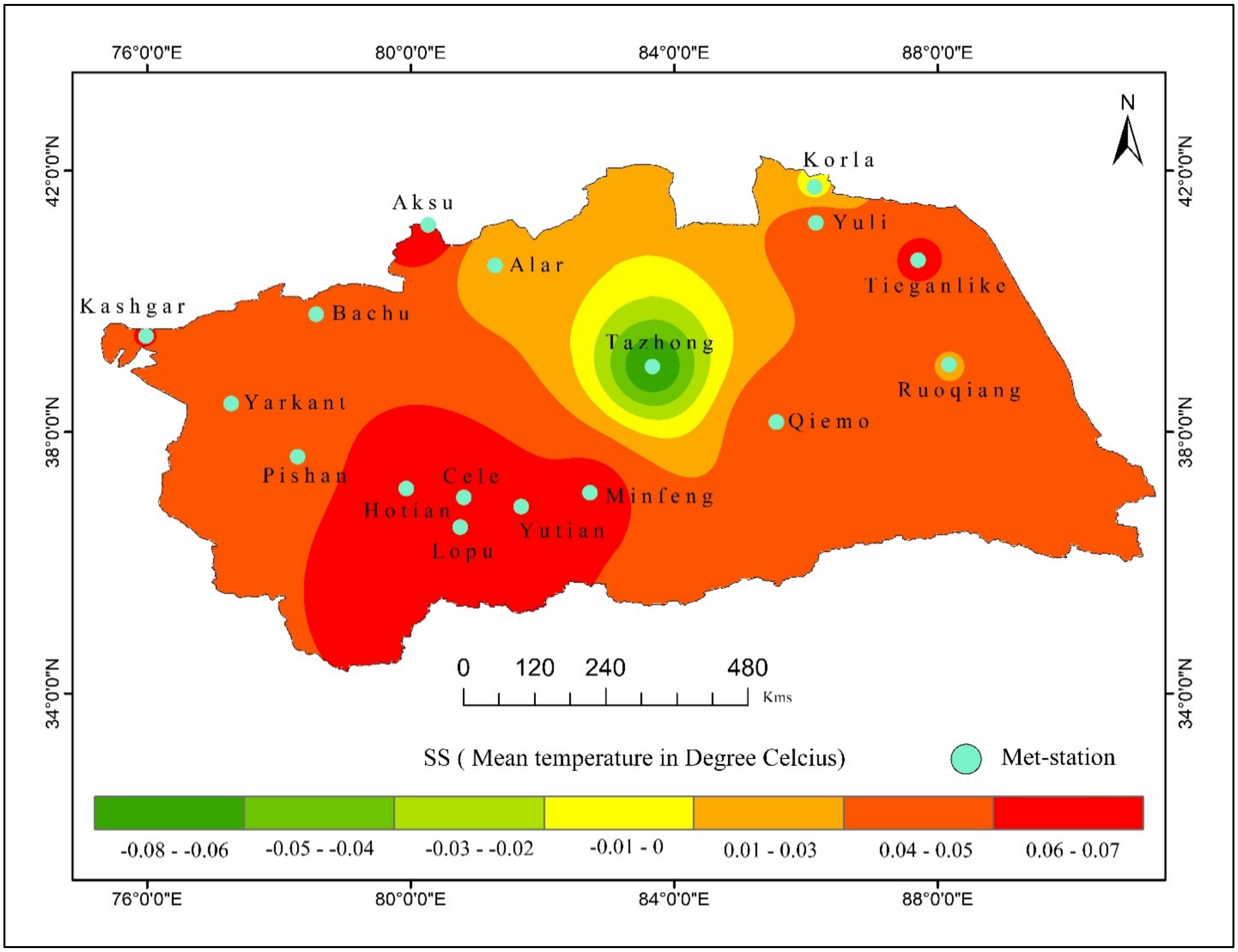


Figure 7. Interpolation of Sen's slope values mean monthly temperature.

These uncertainties make the atmospheric situation to more critical and difficult for survival of flora in the region. Gradual this going towards global warming and scarcity of hydrological resources in the region.

Table 4. Points of significant change annually in maximum, minimum, and monthly temp of proposed meteorological stations.

	Average maximum.		Average minimum.		Average monthly	
Station	change point	Direction	change point	Direction	change point	Direction
Kashgar	2013	rising trend	2003	rising trend	2015	rising trend

Bachu	1983	down trend	2008	rising trend	2012	rising trend
Cele	2013	rising trend	2002	rising trend	2015	rising trend
Yutian	2018	rising trend	2011	rising trend	2015	rising trend
Hotian	2013	rising trend	2002	rising trend	2015	rising trend
Lopu	2013	rising trend	1993	down trend	2015	rising trend
Aksu	2017	rising trend	2017	rising trend	2015	rising trend
Pishan	1997	rising trend	2015	rising trend	2015	rising trend
Yarkant	2005	rising trend	1994	rising trend	2015	rising trend
Alar	1983	rising trend	2017	down trend	2014	down trend
Korla	2000	rising trend	2002	rising trend	1986	down trend
Minfeng	1997	rising trend	2010	rising trend	2015	rising trend
Qiemo	2001	rising trend	2018	rising trend	2015	down trend
Ruoqiang	2016	rising trend	1998	rising trend	2004	rising trend
Tazhong	1997	rising trend	2001	rising trend	2002	rising trend
Tieganlike	2017	rising trend	2107	rising trend	2015	rising trend
Yuli	2000	down trend	2017	rising trend	2000	rising trend

Furthermore, significant points of change were detected to specify particular decades of climate change. Although above Table 4 indicate different values and changing year of temperature in the selected meteorological station. This calculated table clearly give an understanding of gradual change in various decades. Globally variability leads to more severe conditions and its harmful impacts are intensely noteworthy. This computed results indicate changes occurred in the area at end of 1980 decades (Rahman, Rahman, Munawar et al., 2022). Due to increasing anthropogenic, urbanization, agriculture activities, and industrial revolution are the triggers causes of climate change in the region. Although beginning of 21 century situation is totally change existing pattern of physical environment into harsher climate. According to statistical results from the lengthy time series data, much variation is found in the beginning of 2000 due to mineral extraction and infrastructure development in south Xinjiang. South Xinjiang has a large amount of coal, gas, and oil reserves. Currently, China government is trying making more industrialization which modify total physical environmental conditions of the area (Rahman et al., 2021).

Table 5. Seasonality and Mann-Kendall test results application on average minimum and maximum temperature of selected meteorological-station in the study area.

	Autumn		*Spring*		*Summer*		*Winter*	
Station	*Maxi.*	*Mini.*	*Maxi.*	*Mini.*	*Maxi.*	*Mini.*	*Maxi.*	*Mini.*
Aksu	0.12	0.06	0.19	0.00	0.09	0.00	0.93	0.00
Alar	0.41	0.17	0.55	0.00	0.56	0.14	0.97	0.00
Bachu	0.59	0.00	0.44	0.00	0.82	0.00	0.75	0.00
Cele	0.07	0.00	1.00	0.00	0.61	0.00	0.52	0.00
Hotian	0.28	0.00	0.85	0.00	0.96	0.00	0.74	0.00
Kashgar	0.61	0.00	0.33	0.00	0.70	0.00	0.81	0.00
Korla	0.92	0.33	0.52	0.00	0.73	0.12	0.62	0.00
Lopu	0.12	0.00	0.29	0.00	0.28	0.00	0.92	0.00
Minfeng	0.95	0.00	0.55	0.00	0.38	0.00	0.99	0.00
Pishan	0.62	0.00	0.84	0.00	0.88	0.00	0.81	0.00
Qiemo	0.25	0.01	0.50	0.00	0.22	0.00	0.73	0.00
Ruoqiang	0.53	0.05	0.83	0.00	0.97	0.00	0.97	0.00
Tazhong	0.81	0.00	0.32	0.00	0.55	0.03	0.83	0.00
Tieganlike	0.63	0.01	0.47	0.00	0.37	0.00	0.98	0.00
Yarkant	0.34	0.00	0.48	0.00	0.87	0.00	0.95	0.00
Yuli	0.93	0.00	0.87	0.00	0.90	0.00	0.60	0.00
Yutian	0.23	0.00	0.27	0.00	0.56	0.00	0.75	0.00

3.4 Seasonal analysis of temperature

In the above Table 5 seasonal analysis of minimum and maximum temperature reveals high fluctuation in seasonal temperature. The seasonal division has been done as spring season including March, April and May while the autumn season including September and October months. Similarly the summer season consists of June, July and August while the winter includes November, December, January and February months. According to the above Table 5 analysis a dramatic trend detected in summer, spring and winter in minimum temperature. The diversification of temperature is more noteworthy in spring season due to insufficient amount rainfall received from normal distribution (Long et al., 2020). Due to these repercussions a notable modification is detected in length of seasons particularly the summer are enlarging while winter season is condensing and alter with spatial- temporal context (Rafiq et al., 2022).

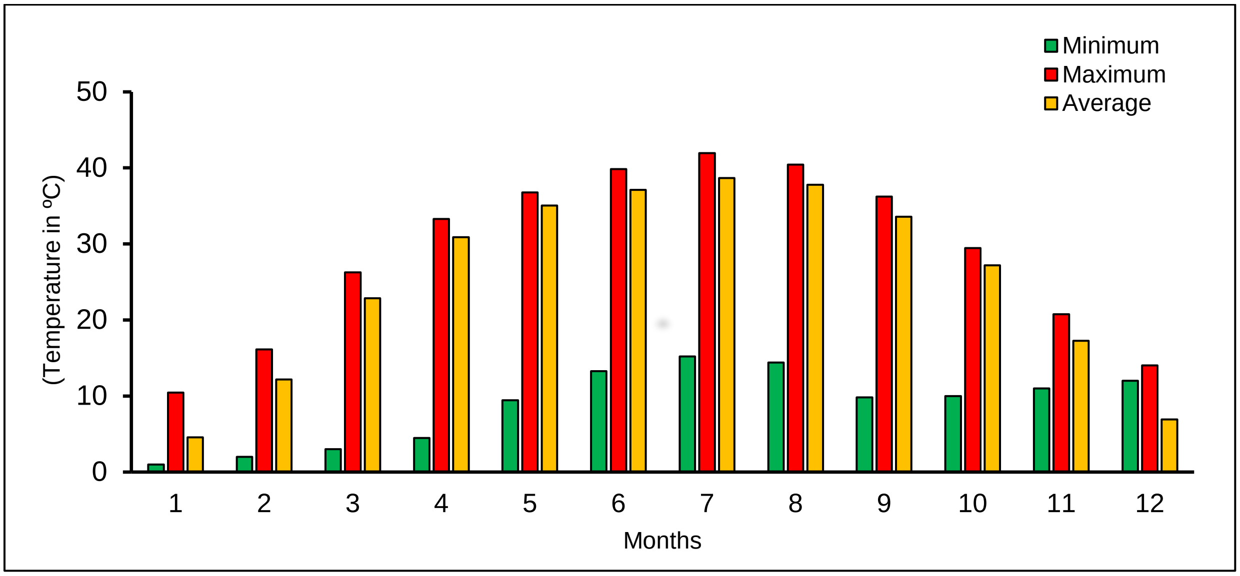


Figure 8. Graph shows variation of maximum, minimum and mean monthly temperature [Source: Temperature Data Acquired from Meteorology Department, China].

According to the representation of Figure 8 the entire region show highest temperature range detected in the month of July that is 41.97ºC. While lowest rate of temperature is found in utmost exciting notable months are January and December. Although other months such as March, April and May and September, October and November reveals slightly changes in minimum, maximum and average temperature throughout the study periods.

Furthermore, a notable downward change is found in minimum temperature from Jan to Feb and Nov to Dec. although, temperature slowly rising in other months with summer season. Decadal representation of temperature data shows that monthly temperature is rising, while in regions near Tianshan mountains range, severe cold months such as Jan., Feb., Nov, and Dec has been recorded. Besides the highest temperature are gradually rising, with the highest proportion recorded in July at 41.97ºC. similarly the seasonal occurrence of monsoon precipitation is also nominal from usual as predicted in the climate data (Yue et al., 2022). The main triggering forces behind these drastic variations in temperature are ruthless utilization of natural resources that have great negative impacts on the physical environment of the area. Therefore, south Xinjiang getting more warming trend than northern due to severe tropical climate environment.

4. Discussion

Generally, altitudinal and longitudinal distributions have a dominant role in controlling prevailing weather conditions and physical environment of an area (Rahman, Rahman, Anwar et al., 2022). This research study deals with temperature variation and its climatic implications in south Xinjiang, China over a period of 30 years. The study areas is mostly spread on desert called the Taklimakhan desert located in southern Xinjiang China. There are seventeen meteological stations installed in the study area. The data about temperatue were collected from Meteorological Department, China. Climate indeces such Man-Kendal and Sen's Slope were applied for statistical analysis to find out the minimum, maximum and average trend of temperature in monthly basis and seasonal variation were also calculated.

Statistical analysis of the time series data of temperatue indicates tremendous fluctuation having severe impacts on social and economic conditions of the area (Khan et al., 2021). At south of Xinjiang the famous Taklimakan desert is located which is mostly barren that making climatic pattern more arid and severe especially in summer season. Summer season is lengthy and high intensity of temperature enhances rate of evapotranspiration throughout the year (Ullah et al., 2020). Generally severe climatic trend began in late 1980 due to increase in population and infrasturcture development in the region. The indices based research study in climate data shows that aridity occured in south Xinjiang in late 1997 and a deficiency also detected in precipitation pattern over the region.

As temperature and precipitation are the most important climatological parameters are good indicators of climatic conditions over the earth surface. Variations in one parameter trigger other parameter to change in an area. The present research analysis reveals that the maximum temperature will reach up to 45ºC, especially in Tazhong and Tieganlike station (Rahman, Rahman, Anwar et al., 2022). This region has sufficient mineral resources and government agencies started exploration with heavy machinery and chemicals blasting which causing daily range of temperature to rise rapidly. Moreover, with these massive variation minimum temperature going towards lower levels that are harmful impacts on ecological equilibrium for living organism (J. He et al., 2022).

The past and current analysis of all types of temperature through Mann-Kendall test applications shows many trends, detected except in Alar and Korla met stations. In the beginning of 2000, a large scale increase has happened in temperature, and before that, due to rainfall occurrences, the climate was up to some extent moderate. The Sen's slope is different in each met-station depending on altitude and maximum variations is found across all types of climatological data (X. Zhang et al., 2022). Overall analysis of statistical results indicates a positive trend and a negative trend are found in a few met-stations. Compared to previous studies, many changes have been found in July, August, January, February and September to November. Large scale fluctuation is found in the Tazhong, Qiemo and Tieganlike regions due to severe tropical climate (Rahman et al., 2021). The annual temperature range is at its peak, and gradually situation is going towards global warming due to these drastic environmental changes.

Furthermore, seasonal analysis of time series data shows that duration of summer is enlarging and remains hotter than past while winter is condensing gradually. Drought conditions prevail in most part of the area that hinder the growth and persistence of flora and fauna in the region. The changing climatic pattern towards hot in summer and colder in winter is attributed to high densities anthropogenic activities and resource extractions(Cao & Gao, 2022).

5. Conclusion

The changing pattern of climate over south Xinjiang province China is alarming threat to flora, fauna and entire biophysical environment of the area. This research study has evaluated spatial and temporal fluctuations in temperature at southern Xinjiang province China for the last four decades. Analysis of previous information's and prediction of future trend in climatic variables is utmost important for appropriate planning and effective policies formulation for various hydro-meteorological responses in a region. These variations in environmental parameters such as temperature and precipitation sometime come to the surface in disastrous situation in various part of the world and threaten flora, fauna, agriculture, hydrology, biodiversity and diminished life of numerous living organisms over the area.

Temperature data of seventeen meteorological stations equally distributed in the region from 1980-2018 analyzed through statistical methods such as Mann-Kendall (MK) trend test and Sen's Slope (SS) statistical models. These statistical models give more comprehensive results in respond to various climatic changes for a long period of time occurred in the study area. The results of analyzed time series data evaluation shows tremendous upward trend in temperature, only maximum temperature indicates approximately 95% of spatial temporal trend. This changing pattern in temperature reveals that the climate of the area is gradually changing from normal to severe that could be more dangerous for the survival of flora and fauna in the area.

Seasonal fluctuation in temperature becomes more critical with the spatial context for life existing in the region. Most winter cold months found with more fluctuation that brings drastic changes in the physical environment. In case of seasonal analysis most rising trend were detected in summer season months like June, July, and August warming ratio reach up to eighty-nine percent. The rising tendency of temperature is a driving way for abrupt climate change. The severity of temperature pattern is more harmful for ecological equilibrium especially in south Xinjiang. These gradual variations occurred in monthly and seasonal temperatures are due to certain reasons. The most important are latitudinal and altitudinal variations in the region have more diverse impacts on climate of the surrounding area. Climate change mainly alter with infrastructure development, network of transportation belt, improve ways of economic conditions, gas and oil extraction, severely effect on fauna and flora survival.

This changing pattern of climate change ultimately causing harsh environmental conditions. The research in every aspect of climatological parameter is vital important to highlight these burning issues and to make futuristic planning to overcome its unnatural impacts on flora and fauna. High level authorities have to take more consideration for preventive measures of this devastation. More stress has been given on reforestation and protective steps for current physical environment. From local to national level public awareness program should be implemented for maintaining existing environmental resources. Through by these ways to more extent we can overcoming the current changes in the environment. This changing pattern may Leads to global warming and diminishing of vegetation cover in the region gradually.

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