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TRENDS OF PRECIPITATION AND TEMPERATURE EXTREMES AND CLIMATE VARIABILITY OVER DONGWAN WATERSHED, HENAN, CHINA

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Climate change profoundly impacts agriculture system by changing variables such as rainfall, temperature, evapotranspiration, soil water content, and water availability. Henan provinece is ranked top among other provincs in China for agricultural production especially the winter wheat. As far, Climate change is affecting agricultural procedures greatly. Therefore, this study was aimed to investigate the variability of climatic extremes and trends of climatic parameters in Dongwan watershed, China. Twelve temperature (max. & min.) and ten precipitation extreme indices were calculated using the RClimDex toolkit. Nonparametric Mann-Kendall trend test and Sen's slope (Q) estimator methods were applied to detect climate change trends and their magnitudes. Inverse distance weighting (IDW) technique was used to patterned the spatial variations in climatic variables. It was observed that the temperature increase showed a significant increase, especially the hot indices. Precipitation indices were not substantial but for few stations and few indexes. In the trend analysis, it was found that the extreme max. The temperature increased significantly during the study period. All through 1998-2014, the maximum temperature has amplified by 1.1°C as compared to 1979-1997. Similarly, precipitation also has increased by 46 mm in the second time step compared to the first. The change in temperature and precipitation may affect the crop water requirement, crop yield, and water availability in the Dongwan river watershed, impacting the Luhun, Sanmenxia, Guxian, and Xiaolangdi reservoir operation downstream.

Keywords: Climate Indices, Climate trend analysis, Mk and Sen's slope method, Precipitation, RClimDex, Temperature.

INTRODUCTION

Acknowledging the modifications and patterns of climate wavering and change that are occurring around us is essential. Globally, the consequences of climate change have been observed. The observation from the last 50 years demonstrates a constant increase in atmospheric carbon dioxide, which has considerably altered the environmental and local climate characteristics (Yu *et al.*, 2002). The climate change impact on the intensity, quantity, and distribution patterns of individual precipitation has affected hydrological processes (Matondo and Msibi, 2001). Climate change in terms of rainfall and temperature have huge effects on the distribution and availability of water resources and the environment. Both precipitation and temperature influence water resources through evapotranspiration. The extreme condition can be understood because decreases in precipitation amount can cause droughts conditions while, its abundance can be responsible for the flooding. In the meantime, an increase in temperature and radiation intensity causes an increase in evaporation (Matondo and Msibi, 2001; Zaman *et al.*, 2015; Hameed *et al.*, 2019a).

Various reports on extreme climate trends were conducted and concluded with clear outcomes of changes in weather frequency and intensity (Frich *et al.*, 2002; Moberg and Jones, 2005; Alexander *et al.*, 2006; Choi *et al.*, 2009; dos Santos *et al.*, 2011). Climate variability affects water resources by altering hydrological factors (temperature, rainfall, evaporation, soil water content, and runoff). The variability in these hydrological factors results in inaccessibility and redistribution of water resources spatially and temporally. These water security issues describe how important it is to study extreme event occurrences and their environmental effects. (Moberg and Jones, 2005; Piao *et al.*, 2010). With over 100 deaths due to the flood in August 2002, Central and Eastern Europe encountered an economic loss of EUR 21.1 billion (Munich Re, 2002).

Rainfall extreme has a significant effect on human societies (Zong and Chen, 2000; Matondo and Msibi, 2001) and agriculture production (Hameed *et al.*, 2019b; Akbar and Gheewala, 2020a). It is determined that the increase in atmospheric temperature ramps up water cycling, resulting in increased precipitation intensity and amount (dos Santos *et al.*, 2011; Molanejad *et al.*, 2014). The variations are so efficient that ETCCDMI is now organizing regional workshops in conjunction with the World Climate Research Program (WCRP) project CCI / CLIVAR, Where indigenous experts and scientists inspect daily precipitation and temperature data for climate change detection (Frich *et al.*, 2002; Easterling *et al.*, 2003; Aguilar *et al.*, 2005; Vincent *et al.*, 2005; Haylock *et al.*, 2006). Precipitation extreme variability over the Black Sea's west coast confirmed significant spatial inconsistency of precipitation patterns in past decades. Human societies and the environment have been significantly disturbed due to fluctuation in extreme climatic events such as heavy precipitation and an increase in hot days frequency (Croitoru *et al.*, 2013).

There are many investigations on climate variability and climate extremes throughout China (Panmao *et al.*, 1999), India (Sen Roy and Balling, 2004), South America (Frich *et al.*, 2002), and the Caribbean region (Peterson *et al.*, 2002). In the last century, western and central Europe experienced a significant decrease in FD, an increase in TR20, and PRCPTOT Wang et al., 2008 evaluated changes in rainfall patterns over the Dongjiang River and found significant changes in monthly extremes (Wang *et al.*, 2008). Middle reaches of the yellow river basin (YRB) also presented a significant decrease in rainfall and an increase in temperature (Zhao *et al.*, 2014). These climate variabilities significantly impact altering crop yield around the globe (Akbar and Gheewala, 2020a).

The present study investigates temperature and precipitation extremes indicators developed by ETCCDMI; many of these indices have already been used in assessing extreme climate events in many parts of Asia and the Middle East (Alexander *et al.*, 2006; Abbas, 2013). These indicators were calculated using RClimDex. It is a powerful statistical tool developed by Zhang and Yang at a climate research branch of Canada. This study aims to find temporal and spatial changes in climatic indices and parameters from 1961-2011 for precipitation (1979-2014 for temperature) and assess the impact of these changes on the area's water resources. This is the first study of extreme precipitation and temperature in this region. The climate variability in the basin contributes significantly to the Luhun and Guxian reservoirs. Investigating climate extremes indices in terms of rainfall and temperature in the basin can help the concerned authorities to raise awareness. Therefore, the present study is helpful for strategic planning and management in the watershed furthermore for better decision making and water resources management, which is essential for agriculture strategy.

MATERIALS AND METHODS

***Study Area*:** Dongwan Watershed is Yihe River's biggest sub-basin in the western province of Henan, China. It is a semi-humid climate zone based on precipitation, land cover, and the flood's hydrographic shape. Watershed longitude and latitude are 111 to 112 East and 33.5 to 34.5 North, respectively, with a total drainage area of 2911 km^2. The watershed topography varies between 365 and 2159 meters; the physical location and elevation of weather stations in the watershed are shown in Figure 1. The average annual maximum temperature (minimum temperature) varies from 15.3 to 19.4°C (5.22 to 7.64°C). The average precipitation varied from 756 to 886 mm per year in Dongwan.

***Data Acquisition*:** Daily temperature and precipitation data were collected from the Yellow River Conservancy Commission (YRCC) different stations. The data was collected from YRCC from 1963 to 2011. Data include daily precipitation data from eight stations and daily temperature data from only one station. The temperature data deficiency was fulfilled by obtaining the temperature data from the National Centers for Environmental Prediction's Climate Forecast System Reanalysis (CFSR) for 36 (1979-2014) years, for six stations. Its spatial resolution was 30 x 30 km (Fuka *et al.*, 2013). The geographical location and station elevation are shown in Table 1. Data length precipitation analysis covers data from 1963- 2011, and the temperature analysis cover period from 1979 to 2014.

***Methodology*:** Many trend analysis tools are available, which can broadly be categorized into two main types, non-*parametric* and parametric. Data should be normally distributed and free form outliers for the parametric approach and there is no such compulsion for the non-parametric approach. That is why the Mann-Kendall (MK) test is one of the non-parametric approaches most widely used. Test is a rank-based approach that relates each unique value with remaining values in sequential order. The standardized test statistic (Z_{mk}) is calculated as mentioned in Equation 1.

$$\text{Zmk} = \begin{bmatrix} \frac{S-1}{\sqrt{Var(S)}} & if\ S > 0 \\ \frac{S+1}{\sqrt{Var(S)}} & if\ S < 0 \\ 0 & if\ S = 0 \end{bmatrix} \qquad (1)$$

Where the (Var) is the Variance, the S is the test statistic and the value of Z_{mk} is the test statistic that follows a standard normal distribution with mean 0 and variance 1. This Z_{mk} value can be related to a p-value of a specific trend. A p-value is a measure of evidence against the null hypothesis of no change to identify significant level in trends (Akbar and Gheewala, 2020b).

Many researchers have estimated the slope of the time series data by applying Sen's slope method as an advantage of insensitive response to outliers. Here slopes are calculated for each pair of the ordinate time points and then the median of slopes is used as an estimate of the overall slope. The estimate of the trend "Q" (change per unit time) is given in Equation 2.

$$\mathrm{Q} = \mathrm{median}\left(\frac{A_j - A_k}{j-k}\right) \forall \mathrm{k} < \mathrm{j} \qquad (2)$$

Where; A_j is the data value at time j, A_k is the data value at time k and j is the time after k (j > k).

Table 1. Metrological stations and their attributes across the watershed.

ID	Stations	Latitude (E)	Longitude (N)	Elevation (m)
1	Miaozi	33.78	111.73	769
2	Luanchuan	33.78	111.60	776
3	Taowan	33.83	111.47	998
4	Heyu	33.85	111.90	622
5	Tantou	33.98	111.73	715
6	Baishi	34.02	111.55	782
7	Dongwan	34.05	111.98	490
8	Baitu	34.05	111.43	1077
9	Station 1	33.88	111.25	1080
10	Station 2	33.88	111.56	1040
11	Station 3	33.88	111.87	618
12	Station 4	34.19	111.56	1292
13	Station 5	34.19	111.87	592

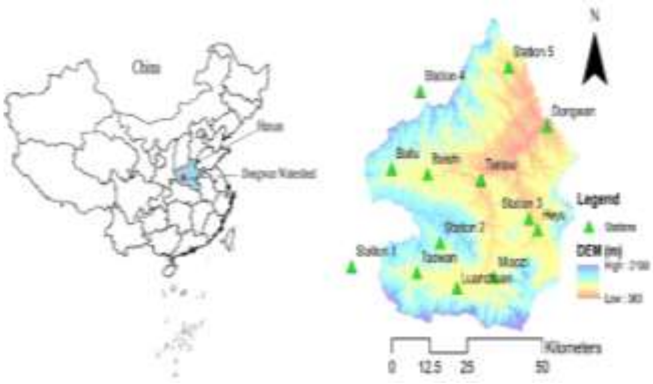


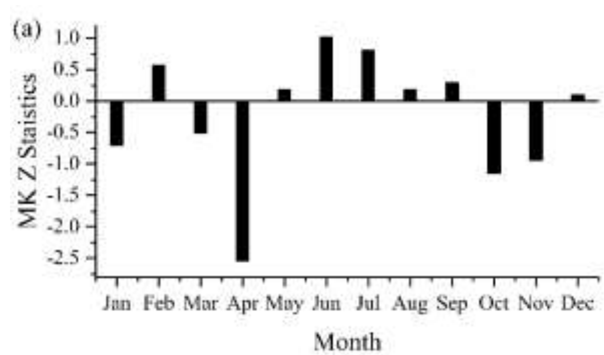
Figure 1. Dongwan Watershed topography map and geographical position.

The RClimDex was used to check the changes in the climatic indices. RClimDex was also used for quality control as well as quality assurance. QC/QA are the prerequisites for index calculation, which is done by the RClimDex Software QC tool. Checking QA / QC is an essential task in any statistical data analysis to find actual results. Data quality was checked by the QA/QC tool of RClimDex the purpose of this test is to identify unpractical values and outliers in data; for example, the minimum temperature is more than maximum temperature and precipitation values less than zero. The definitions and units of all the indices are presented in Table 2.

***Spatial Distribution Analysis*:** To examine hydro-climatic parameters spatial distribution, a spatial analysis tool in Arc GIS was used. Spatial deviations in the climatic parameters were determined by interpolating data between the stations. The Inverse Distance Weighted (IDW) tool was used for the interpolation of climatic parameters.

RESULTS AND DISCUSSION

In this work, two different types of analysis were carried out. At first, the trend analysis of statistical significance for temperature and precipitation time series was performed using the non-parametric MK trend test and Sen Slope method. Secondly, the RClimDex model was used to calculate climate indicators. Trend analysis of the climatic Tmax, Tmin, and PPT was carried out with the help of the Mann-Kendall test. Change in maximum temperature was dominant, especially in the spring and summer seasons and annual basis. However, the trends of Tmin and PPT are not significant. Trends of Tmax, Tmin, and PTT, along with their significance level, are given in Table 3. Monthly trend statistics of Z and Q are shown in figure 2 and 3. The overall analysis results for precipitation are insignificant and inconsistent due to the uneven distribution of rainfall across the watershed.



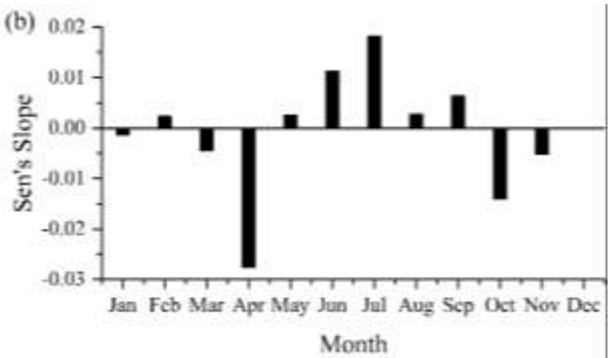


Figure 2. Mann Kendall Z Statistics and Sen's Slope Q on monthly basis for precipitation

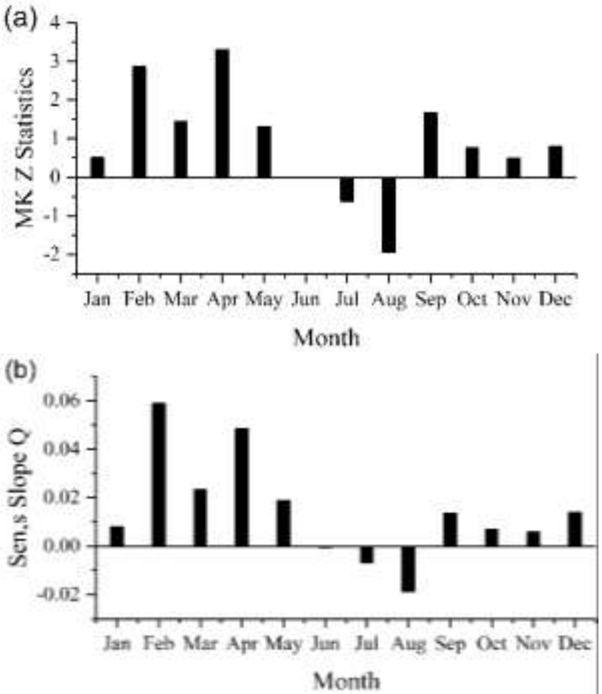


Figure 3. Mann-Kendall Z Statistics and Sen's Slope Q on monthly basis for temperature

***(**only luncheon were used for average temperature because CFSR do not have average temperature data**).**

***Climatic Extremes*:** Extremes indices (hot, cold, and precipitation) trend in the watershed were studied using RClimDex. Changes in the climatic extremes and their significance level were obtained by using the RClimDex tool. Some temperature indices are directly based on percentile; these indicators assist in determining regional warming patterns called **rare climate trends** (Abbas, 2013). These indicators are TN10p, TN90p, TX10p, and TX90p. TN90p and TX90p indicators show that the frequency of warm night and days increases, whereas, cold nights and days are decreasing; calculated indices values are presented and presented in table 4 and Fig. 4.

General Climate Trends: (TXx, TNx, TNn, TXn), these indices are obtained from temperature change during nights and days, that present variations in local weather based on days and nights temperature. Warm day's temperature (TXx) showed an increasing trend of 0.086, while warm night temperature showed a decreasing trend with a slope value of -0.027. However, cold nights and temperature is decreasing in the watershed. Some indicators are calculated depending on a specified threshold and limits. These indices are known for frequency termed as **prevailing climate trends (PCTs)** (Abbas, 2013)**.** These indicators are ID, SU25, WSDI, and CSDI. Among all PCTs, SU25 results depict significant trends for all stations and watershed, confirming that the number of summer days is increasing yearly. WSDI and ID0 also confirm watershed is getting warmer.

Table 2. ETCCDMI extreme indices associated with temperature.

Index	Name	Description
Hot Extremes		
SU25	Summer (hot) days	Annual total number of days with $T_X > 25°C$
TXx	Warm day	Monthly maximum value of daily T_X (°C)
TNx	Warm night	Monthly maximum value of daily T_N (°C)
TX90p	Warm days	Percentage of days with Tx > 90th percentile
TN90p	Warm nights	Percentage of days with T_N > 90th percentile
WSDI	Warm spell duration index	Annual count of days with at least six consecutive days with TX>90th percentile
Cold Extremes		
ID0	Ice (cold) days	Annual total number of days with $T_X < 0°C$
TNn	Coldest night	Monthly minimum value of daily T_N (°C)
TXn	Coldest day	Monthly minimum value of daily T_X (°C)
TN10p	Cool nights	Percentage of days with T_N < 10th percentile
TX10p	Cool days	Percentage of days with T_X < 10th percentile
CSDI	Cold spell duration index	Annual count of days with at least 6 consecutive days when TN<10th percentile
Precipitation Extremes		
R10mm	Heavy PR day	Annual number of days with PR >=10mm
R20mm	Very Heavy PR days	Annual number of days with PR >=20mm

R25mm	Extremely heavy PR days	Annual number of days with PR >=25mm
RX1day	Max 1-day PR amount	Monthly maximum of one day PR (mm)
RX5day	Max 5-day PR amount	Monthly maximum of consecutive five days PR (mm)
CDD	Consecutive dry days	Maximum number of consecutive dry days
CWD	Consecutive wet days	Maximum number of consecutive wet days
R95p	Very wet days PR	Annual sum of PR with PR > 95th percentile (mm)
R99p	Extremely wet days PR	Annual sum of PR with PR > 99th percentile (mm)
PRCPTOT	Wet day PR	Annual total PR from wet days (mm)

* T_N (T_X) = Minimum (Maximum) temperature, PR= Precipitation

Table 3. Annual and Seasonal value of MK and Sen's Slope results.

Para-meters	Stations	Annual		Spring		Summer		Autumn		Winter	
		Z	**Q**	**Z**	**Q**	**Z**	**Q**	**Z**	**Q**	**Z**	**Q**
Tmax	St.1	**3.53**	0.07	**3.75**	0.09	**3.85**	0.10	**2.67**	0.07	1.57	0.04
	St.2	**3.26**	0.06	**3.42**	0.08	**3.61**	0.08	**2.29**	0.05	1.27	0.03
	St.3	**3.04**	0.06	**3.26**	0.08	**3.20**	0.07	**2.21**	0.05	1.16	0.03
	St.4	**3.20**	0.06	**2.87**	0.07	**3.17**	0.08	**1.83**	0.05	0.89	0.02
	St.5	**3.20**	0.06	**3.09**	0.07	**3.28**	0.09	**1.96**	0.04	0.94	0.02
	L.Chuan	**3.31**	0.03	**3.20**	0.05	3.20	0.00	2.10	0.02	**1.10**	0.04
	Watershed	**3.21**	0.05	**3.44**	0.08	**3.25**	0.08	1.98	0.05	**1.13**	0.04
Tmin	St.1	0.75	0.01	**2.27**	0.04	**-1.65**	-0.02	-0.22	0.00	0.45	0.01
	St.2	0.75	0.01	**1.87**	0.03	**-2.00**	-0.02	-0.68	-0.01	0.37	0.01
	St.3	0.75	0.01	**1.73**	0.03	**-1.78**	-0.02	-0.93	-0.02	0.61	0.01
	St.4	0.37	0.01	**1.89**	0.03	-1.57	-0.02	-0.82	-0.01	-0.10	0.00
	St.5	0.67	0.01	**1.81**	0.03	-1.13	-0.02	-0.93	-0.02	0.18	0.00
	L.Chuan	0.73	0.01	1.85	0.01	-1.56	-0.01	-0.99	0.00	0.33	**0.02**
	Watershed	0.73	0.01	1.83	0.03	-1.59	-0.01	-0.89	-0.01	0.43	**0.01**
PPT	Baishi	-0.48	-0.002	-0.95	-0.006	0.02	0.001	-0.95	-0.007	1.12	0.002
	Baitu	-0.32	-0.002	-1.62	**-0.011**	0.64	0.008	-1.57	-0.012	**1.65**	**0.003**
	Dongwan	0.18	0.001	-1.29	-0.009	0.72	0.009	-0.75	-0.007	1.02	0.002
	Heyu	1.47	0.006	-0.74	-0.007	0.95	0.010	0.05	0.001	0.99	0.002
	L.Chuan	0.18	0.001	**1.67**	**0.009**	-1.67	-0.013	0.72	0.005	**3.76**	**0.044**
	Tantou	0.89	0.004	-0.385	-0.003	1.01	0.013	-0.70	-0.005	0.48	0.001
	Miaozi	0.25	0.002	-1.22	-0.011	0.79	0.009	-0.31	-0.003	0.84	0.002
	Taowan	0.55	0.002	-1.34	-0.010	1.02	0.011	-0.75	-0.007	0.32	0.001
	Watershed	0.25	0.038	-1.04	-0.215	0.70	0.256	-0.76	-0.169	0.76	0.049

*The highlighted and bold values indicate significance at 5% level ($p < 0.05$), and bolded values represent significance level of 10% ($0.05 < p < 0.10$).

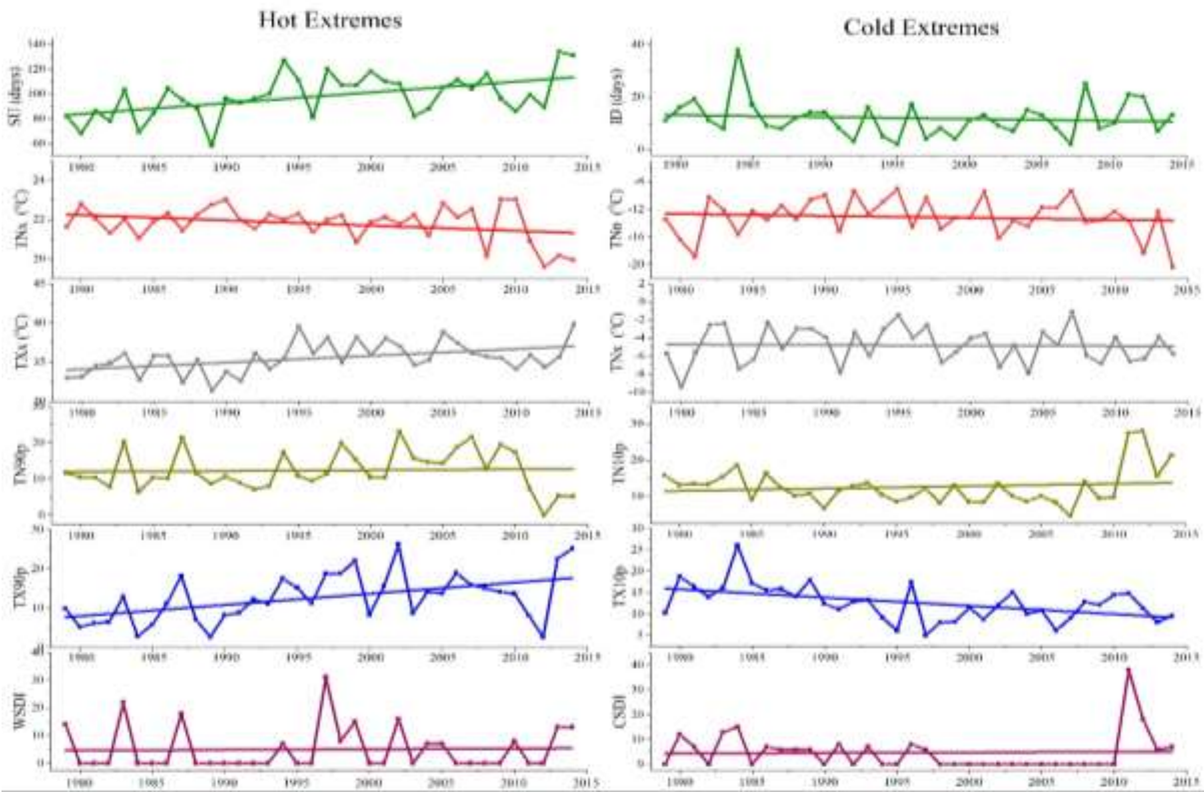


Figure 4. Temperature related indices in Dongwan watershed

Table 4. Hot and cold extremes in the Dongwan watershed

Stations	Luanchuan	Station3	Station4	Station5	Station8	Station9	Watershed
Hot Extremes							
Su25	***0.*293**	**1.211**	**1.019**	**0.920**	**0.895**	**0.833**	**0.869**
TXx	0.013	**0.135**	**0.109**	**0.089**	**0.108**	**0.085**	**0.086**
TNx	-0.001	**-0.030**	***-0.029***	**-0.025**	-0.021	-0.028	-0.027
TX90p	**0.190**	**0.409**	**0.326**	**0.279**	**0.255**	**0.268**	**0.285**
TN90p	0.087	0.040	0.010	0.024	0.021	0.020	0.024
WSDI	0.070	0.174	0.086	0.054	0.080	0.021	0.022
Cold Extremes							
ID0	-0.111	-0.162	-0.139	-0.135	-0.098	-0.065	-0.072
TXn	**0.040**	0.005	0.010	0.018	-0.010	0.000	-0.006
TNn	0.010	-0.043	-0.045	-0.011	0.003	-0.004	-0.028
TX10p	-0.085	**-0.227**	**-0.181**	**-0.209**	**-0.174**	**-0.173**	**-0.193**
TN10p	-0.085	-0.009	0.071	0.093	0.069	0.077	0.066
CSDI	-0.015	-0.029	0.011	0.029	-0.055	-0.092	0.022

*The highlighted and bold values indicate significance at 5% level ($p < 0.05$), and bolded values represent significance level of 10% ($0.05 < p < 0.10$)

Results for the climatic hot and cold extremes for each station along with watershed are presented in Table 4. Changes in the hot extremes were significant as compared to the cold and precipitation extremes. Su25, TXx and TX90p were the three hot indices that showed a significant increase in the Dongwan watershed. In the case of cold extremes, the change in the cold extreme indices was not significant except Tx10p. Tx10p was showing a decrease in trend significantly almost at the entire Dongwan watershed. The details of hot and cold extremes are given in Table 4.

The precipitation extremes, some indicators depict precipitation intensity, and some are associated with

Table 5. Precipitation extremes in the Dongwan watershed.

Index	Dongwan	Miaozi	Taowan	Heyu	Baishi	Tantou	Baitu	Luanchuan	Watershed
R10mm	-0.03	**-0.11**	-0.06	-0.03	-0.05	0.01	-0.04	**-0.11**	-0.04
R20mm	0.02	0.05	0.02	0.05	-0.01	**0.08**	0.02	0.03	0.02
R25mm	0.04	0.02	0.05	0.03	0.01	**0.08**	0.04	**0.06**	0.04
Rx1day	0.38	-0.14	0.17	0.28	0.01	0.11	0.03	0.33	0.03
Rx5day	0.15	-0.48	-0.07	0.16	-0.30	-0.01	0.07	0.12	0.07
R95p	**2.09**	2.09	1.58	**2.61**	0.11	**2.88**	0.63	**2.35**	0.63
R99p	0.39	0.93	0.47	1.03	-0.19	0.53	0.38	**1.47**	0.38
CDD	0.05	0.12	-0.02	0.12	0.17	0.18	0.11	0.13	0.11
CWD	-0.01	-0.03	0.01	-0.01	-0.03	0.01	-0.01	-0.01	-0.01
PRPTOT	0.45	-0.36	-0.77	0.75	-1.27	1.52	-0.90	0.17	-0.91

*The highlighted and bold values mean significance at 5% level ($p < 0.05$), and values only bolded represent significance at 10% level ($0.05<p<0.1$)

precipitation amount and frequency. Indices related to intensity include RX1day, RX5day, R10mm, R20mm, R25mm, and SDII. R10mm, R20mm, and R25mm calculation based on the fixed threshold value according to climate conditions available in the local area, while RX1day and RX5day are indicators for a fixed period (Hundecha and Bárdossy, 2005). All these intensity related indicators showed a positive trend, except R10mm. RX1day showed positive trend at all stations excluding Miaozi station. The annual average trend for RX1day was 0.025mm per year. RX5day depict an increasing trend over 50 percent stations. Overall, RX1day and RX5day trends results were insignificant. R10mm is decreasing, while R20mm and R25mm showed positive trends. Trends results and percent of significant/insignificant results for each station and watershed are presented in Table 5, while Figures 5, 6 and 7 represent the annual trend for overall watershed.

For frequency related Indices, CDD showed a moderate positive trend while CWD showed a negative trend for all stations except for Taowan station. However, the results were insignificant. However, for amount-related indices, R95p showed an increasing trend at all stations from which 50% results were significant, and the other 50% were insignificant R99p demonstrates nearly the same spatial distribution as R95p. PRCPTOT experienced an increasing trend at 50% station, but all stations showed insignificant trend values. It was discovered that stations at high altitude reflect a decreasing trend for indices.

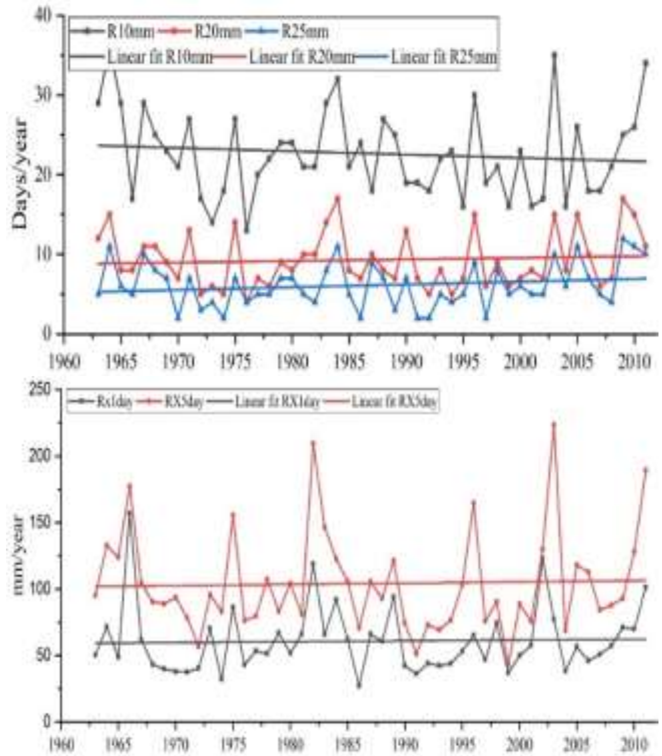


Figure 5. Intensity related indices in Dongwan watershed.

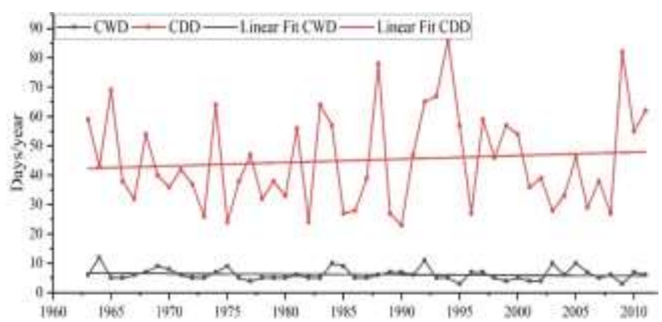


Figure 6. Frequency related indices in Dongwan watershed

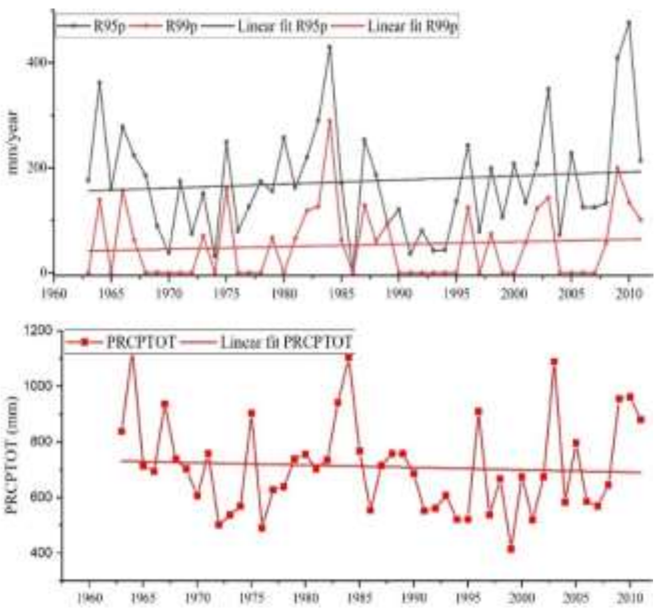
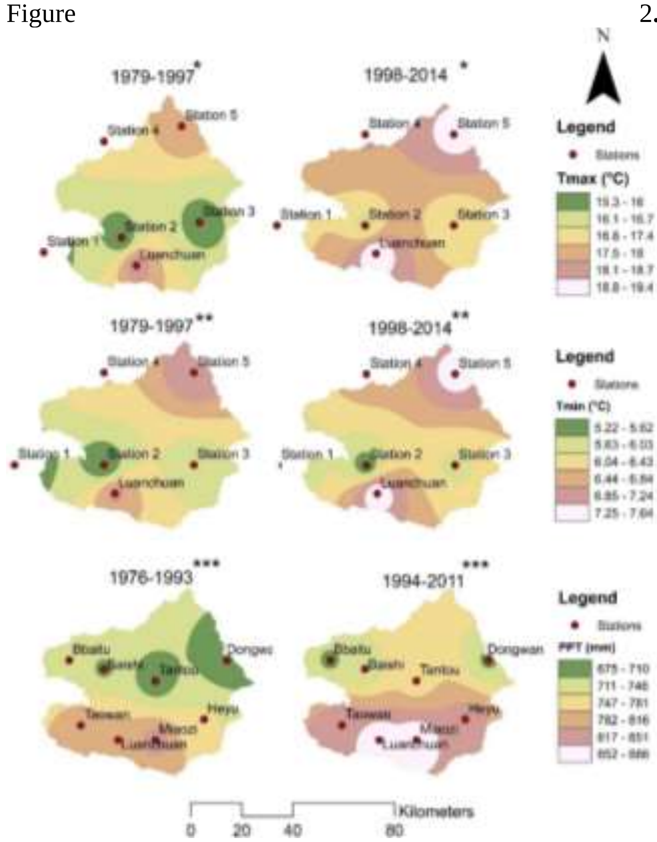


Figure 7. Amount related indices in Dongwan watershed

***Spatial and Temporal Variations*:** The precipitation, maximum and minimum temperatures were analyzed on a spatial and temporal basis. It was observed that the PPT, Tmax, and Tmin were higher in the second time interval than the first-time step in the Dongwan watershed. The spatial and temporal variations in the climatic parameters are shown in Figure 2.



*Tmax, **Tmin and ***PPT

Figure 8. Spatial and temporal changes in climatic parameters in the Dongwan watershed

It was observed that the average annual precipitation increased by 46 mm as compared to the first-time step. Similarly, the average annual maximum and minimum temperatures were increased by 1.1°C and 0.26°C, respectively, in the recent time step. The changes in the climatic parameters are given in Table 6.

Table 6. Variations in the climatic parameters with respect to time

Parameters	1979-1997	1998-2014	Change
Tmax (°C)	16.64	17.74	1.10
Tmin (°C)	6.13	6.39	0.26
*PPT (mm)	747.00	793.00	46.00

*first-time step 1976-1993 and second-time step is 1994-2011

The results clearly show that the climatic parameters vary significantly. The significant increase in hot extremes (SU25, TXx, and TX90) indicates an increase in the summer season length. On the other hand, cold days were showing a significant decrease in trends. It also supports the results of hot extremes. Both the hot and cold extremes changes indicate that winter season was contracting and summer season was expanding. Mainly, the season's expansion and contractions were due to the increase in Tmax. Moreover, during trend analysis, Tmax showed a significant increase while Tmin not. The expansion of the summer season and shrinkage of winter season may trigger the issues related to the increase in evapotranspiration, change the crop water requirement, and change in streamflow, etc.

Furthermore, the change in precipitation indices was showing mixed trends. The numbers of days with precipitation more than 25mm (R25mm) are increased, indicating an increased precipitation intensity. Consecutive wet days and consecutive dry days were decreasing and increasing, respectively. That suggests a decrease in precipitation frequency. However, overall, the average annual rainfall was increasing. It can be summarized that the precipitation extremes (frequency and intensity) may lead to floods and droughts. This study may prove a gateway to check the future climate changes and their impact on stream flow, crop water requirement, Floods, and droughts. This study also provides valuable material for the policymakers of the climate change, agriculture, and water resources departments for better decision making and to cope with the climate change impacts, water resources management, which is essential for agriculture strategy.

Conclusion: This study was conducted to detect changes in climatic (precipitation and temperature) extremes and how these changes affect the watershed. RClimDex, MK, and Sen's Slope method were used for trend analysis. Outcomes indicated that the average annual and maximum seasonal temperature increased significantly compared to the minimum temperature. Temperature indices results also confirm watershed is getting warmer, which in turn has a significant effect on hydrology and agriculture yield of the watershed. Indices related to precipitation were indicating the more intensive and less frequent precipitation events. Overall, the average annual rainfall was increased by 46 mm in the second time step compared to the first. MK trends also verify the increase in the rainfall for the overall watershed. However, most precipitation results showed insignificant trends in the area.

Moreover, the Southern part of the Dongwan watershed was receiving more precipitation than any other side. The changes in climatic indices and parameters, especially the shift in rainfall, intensity, and frequency, will affect the intensity and frequency of runoff and flood in this region. That is why preventive measures must be taken to protect the Dongwan watershed based on these results. Further research could aim at temperature and precipitation forecast in the catchment for better water resource planning and governance.

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REFERENCES

Abbas, F. 2013. Analysis of a historical (1981-2010) temperature record of the Punjab Province of Pakistan. *Earth Interact.* 17:1-23.

Aguilar, E., T.C. Peterson, P.R. Obando, R. Frutos, J.A. Retana, M. Solera, J. Soley, I.G. García, R.M. Araujo, A.R. Santos, V.E. Valle, M. Brunet, L. Aguilar, L. Álvarez, M. Bautista, C. Castañón, L. Herrera, E. Ruano, J.J. Sinay, E. Sánchez, G.I.H. Oviedo, F. Obed, J.E. Salgado, J.L. Vázquez, M. Baca, M. Gutiérrez, C. Centella, J. Espinosa, D. Martínez, B. Olmedo, C.E.O. Espinoza, R. Núñez, M. Haylock, H. Benavides and R. Mayorga. 2005. Changes in precipitation and temperature extremes in Central America and northern South America, 1961–2003. J. Geophys. Res. 110:D23107.

Akbar, H. and S.H. Gheewala. 2020a. Effect of climate change on cash crops yield in Pakistan. Arab. J. Geosci. 13(11).

Akbar, H. and S.H. Gheewala. 2020b. Changes in hydroclimatic trends in the Kunhar River Watershed Changes in hydroclimatic trends in the Kunhar River Watershed. doi:10.13140/RG.2.2.12517.42725.

Alexander, L. V., X. Zhang, T.C. Peterson, J. Caesar, B. Gleason, A.M.G. Klein Tank, M. Haylock, D. Collins, B. Trewin, F. Rahimzadeh, A. Tagipour, K. Rupa Kumar, J. Revadekar, G. Griffiths, L. Vincent, D.B. Stephenson, J. Burn, E. Aguilar, M. Brunet, M. Taylor, M. New, P. Zhai, M. Rusticucci and J.L. Vazquez-Aguirre. 2006. Global observed changes in daily climate extremes of temperature and precipitation. J. Geophys. Res. 111:D05109.

Choi, G., D. Collins, G. Ren, B. Trewin, M. Baldi, Y. Fukuda, M. Afzaal, T. Pianmana, P. Gomboluudev, P.T.T. Huong, N. Lias, W.-T. Kwon, K.-O. Boo, Y.-M. Cha and Y. Zhou. 2009. Changes in means and extreme events of temperature and precipitation in the Asia-Pacific Network region, 1955-2007. Int. J. Climatol. 29:1906-1925.

Croitoru, A.-E., B.-C. Chiotoroiu, V.I. Todorova and V. Torică. 2013. Changes in precipitation extremes on the Black Sea Western Coast. Glob. Planet. Change. 102:10-19.

Dos Santos, C.A.C., C.M.U. Neale, T.V.R. Rao and B.B. da Silva. 2011. Trends in indices for extremes in daily temperature and precipitation over Utah, USA. Int. J. Climatol. 31:1813-1822.

Easterling, D.R., L. V. Alexander, A. Mokssit, V. Detemmerman, D.R. Easterling, L. V. Alexander, A. Mokssit and V. Detemmerman. 2003. CCI/CLIVAR

Workshop to Develop Priority Climate Indices. *Bull. Am. Meteorol. Soc.* 84:1403-1407.

Frich, P., L. V. Alexander, P. Della-Marta, B. Gleason, M. Haylock, A.M.G. Tank Klein and T. Peterson. 2002. Observed coherent changes in climatic extremes during the second half of the twentieth century. Clim. Res. 19:193-212.

Fuka, D.R., M.T. Walter, C. Macalister, A.T. Degaetano, T.S. Steenhuis and Z.M. Easton. 2013. Using the Climate Forecast System Reanalysis as weather input data for watershed models. , doi: 10.1002/hyp.10073.

Hameed, F., J. Xu, S.F. Rahim, Q. Wei, A. ur R. Khalil and Q. Liao. 2019a. Optimizing nitrogen options for improving nitrogen use efficiency of rice under different water regimes. Agronomy.pp.1- 9.

Hameed, F., J. Xu, S.F. Rahim, Q. Liao, A.U.R. Khalil and S. Ahmed. 2019b. Rice growth and nitrogen uptake simulation by using oryza (V3) model considering variability in parameters. Pak. J. Agric. Sci. 56:245-259.

Haylock, M.R., T.C. Peterson, L.M. Alves, T. Ambrizzi, Y.M.T. Anunciação, J. Baez, V.R. Barros, M.A. Berlato, M. Bidegain, G. Coronel, V. Corradi, V.J. Garcia, A.M. Grimm, D. Karoly, J.A. Marengo, M.B. Marino, D.F. Moncunill, D. Nechet, J. Quintana, E. Rebello, M. Rusticucci, J.L. Santos, I. Trebejo, L.A. Vincent, M.R. Haylock, T.C. Peterson, L.M. Alves, T. Ambrizzi, Y.M.T. Anunciação, J. Baez, V.R. Barros, M.A. Berlato, M. Bidegain, G. Coronel, V. Corradi, V.J. Garcia, A.M. Grimm, D. Karoly, J.A. Marengo, M.B. Marino, D.F. Moncunill, D. Nechet, J. Quintana, E. Rebello, M. Rusticucci, J.L. Santos, I. Trebejo and L.A. Vincent. 2006. Trends in Total and Extreme South American Rainfall in 1960–2000 and Links with Sea Surface Temperature. *http://dx.doi.org/10.1175/JCLI3695.1*, doi: 10.1175/JCLI3695.1.

Hundecha, Y. and A. Bárdossy. 2005. Trends in daily precipitation and temperature extremes across western Germany in the second half of the 20th century. *Int. J. Climatol.* 25:1189-1202.

Matondo, J.I. and K.M. Msibi. 2001. Estimation of the Impact of Climate Change on Hydrology and Water Resources in Swaziland. Water Int. 26:425-434.

Moberg, A. and P.D. Jones. 2005. Trends in indices for extremes in daily temperature and precipitation in central and western Europe, 1901-99. Int. J. Climatol. 25:1149-1171.

Molanejad, M., M. Soltani and A.R. Saadatabadi. 2014. Changes in precipitation extremes in climate variability over northwest Iran. Int. J. Agric. Policy Res. 2:334-345.

Panmao, Z., S. Anjian, R. Fumin, L. Xiaonin, G. Bo and Z. Qiang. 1999. Changes of Climate Extremes in China. *Clim. Change.* 42:203-218.

Peterson, T.C., M.A. Taylor, R. Demeritte, D.L. Duncombe, S. Burton, F. Thompson, A. Porter, M. Mercedes, E. Villegas, R. Semexant Fils, A. Klein Tank, A. Martis, R. Warner, A. Joyette, W. Mills, L. Alexander and B. Gleason. 2002. Recent changes in climate extremes in the Caribbean region. *J. Geophys. Res. Atmos.* 107:ACL 16-1-ACL 16-9.

Piao, S., P. Ciais, Y. Huang, Z. Shen, S. Peng, J. Li, L. Zhou, H. Liu, Y. Ma, Y. Ding, P. Friedlingstein, C. Liu, K. Tan, Y. Yu, T. Zhang and J. Fang. 2010. The impacts of climate change on water resources and agriculture in China. *Nature.* 467:43-51.

Sen Roy, S. and R.C. Balling. 2004. Trends in extreme daily precipitation indices in India. *Int. J. Climatol.* 24:457-466.

Vincent, L.A., T.C. Peterson, V.R. Barros, M.B. Marino, M. Rusticucci, G. Carrasco, E. Ramirez, L.M. Alves, T. Ambrizzi, M.A. Berlato, A.M. Grimm, J.A. Marengo, L. Molion, D.F. Moncunill, E. Rebello, Y.M.T. Anunciação, J. Quintana, J.L. Santos, J. Baez, G. Coronel, J. Garcia, I. Trebejo, M. Bidegain, M.R. Haylock, D. Karoly, L.A. Vincent, T.C. Peterson, V.R. Barros, M.B. Marino, M. Rusticucci, G. Carrasco, E. Ramirez, L.M. Alves, T. Ambrizzi, M.A. Berlato, A.M. Grimm, J.A. Marengo, L. Molion, D.F. Moncunill, E. Rebello, Y.M.T. Anunciação, J. Quintana, J.L. Santos, J. Baez, G. Coronel, J. Garcia, I. Trebejo, M. Bidegain, M.R. Haylock and D. Karoly. 2005. Observed Trends in Indices of Daily Temperature Extremes in South America 1960–2000. *J. Clim.* 18:5011-5023.

Wang, W., X. Chen, P. Shi and P.H.A.J.M. Van Gelder. 2008. Detecting changes in extreme precipitation and extreme streamflow in the Dongjiang River Basin in southern China. *Hydrol. Earth Syst. Sci. Discuss.* 12:207-221.

Yu, P.S., T.C. Yang and C.K. Wu. 2002. Impact of climate change on water resources in southern Taiwan. *J. Hydrol.* 260:161-175.

Zaman, M., G. Fang, K. Mehmood and M. Saifullah. 2015. Trend Change Study of Climate Variables in Xin ' anjiang-Fuchunjiang Trend Change Study of Climate Variables in Xin ' anjiang-Fuchunjiang Watershed , China. doi: 10.1155/2015/507936.Zhao, G., P. Tian, X. Mu, J. Jiao, F. Wang and P. Gao. 2014. Quantifying the impact of climate variability and human activities on streamflow in the middle reaches of the Yellow River basin, China. J. Hydrol. 519:387-398.

Zong, Y. and X. Chen. 2000. The 1998 Flood on the Yangtze, China. Nat. Hazards .22:165-184.

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