SPATIOTEMPORAL TREND OF CLIMATE EXTREMES AND ITS IMPACT ON DROUGHT CONDITION OVER AFGHANISTAN

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1. INTRODUCTION

Climate extreme events, such as heatwaves, heavy precipitation, and prolonged droughts have more severe impacts than average states on both human society and natural ecosystem. Drought, which caused by water shortage and temperature increase, due to climate change showing an increasing trend. Studies have shown extreme climate also have important contribution to the regional drought conditions by impacting to the surface water and evapotranspiration (Shao et al., 2021). Climate extreme indices are usually used to assess the contribution of the extreme climate to drought condition. Though many studies have attempted to use extreme indices to understand the correlation of drought event with climate extreme, there is a luck of studies on the method and selection of extreme indices to ensure that these indices can replicate all information from the spatial and temporal climate extreme events of a region.

Afghanistan, a least developed country in South Asia, where more than 80 % of its population are reliant on agriculture for their livelihoods and wellbeing, are more vulnerable to extreme climate events due to limited capacity for adaptation and mitigation against these extreme events (Jawid & Khadjavi, 2019).

World Meteorological Organization's Expert Team on Climate Change Detection and Indices (ETCCDI) (Zhang et al., 2011) has defined a set of 27 extremes climate indices (ECIs) to explain the changes in frequency and intensity of extreme condition based on temperature and precipitation. The objective of this study is to assess the spatiotemporal trend of climate extremes and its impact on drought condition over Afghanistan. Firstly, a set of optimal ECIs indices were selected. Secondly, non-parametric modified Mann-Kendall test and Sen's slope were applied to analyze the magnitude and significant of trend in ECIs and drought index. Finally, correlation analysis was used to find the influence of each ECIs to the drought condition in Afghanistan.

2. STUDY AREA AND DATASETS

2.1. Study area

Afghanistan a landlocked country encompasses of around 652000 km² areas (Fig 1). Hindu Kush mountains created highly varying topography in this country with complex climate characteristics (Manawi et al., 2020). Afghanistan with a continental dry climate has characterized by little to no precipitation. However, due to dominant topography, the annual rainfall is more than 1000 mm in the northeast and less than 50 mm in the southwest (arid desert) region. To consider the impact of spatial variability of topography and climate, in this study the ECIs selection, trend and correlation analysis was done for two different elevations which is elevation greater than 2000 m and less than 2000 m.

2.2. Datasets

Due to the unavailability of in situ data in Afghanistan, daily rainfall, maximum and minimum temperature data from European Centre for Medium-Range Weather Forecasts (ECMWF) ERA5 reanalysis datasets was derived. The Standardized Precipitation Evapotranspiration Index (SPEI) on a 12-month timescale during 1975-2014 with the 0.5°×0.5° from the global SPEI database was used to assess the inter-annual characteristics of the drought condition. The hourly gridded precipitation and temperature data from ERA5 used to extract daily average precipitation and maximum and minimum temperature.

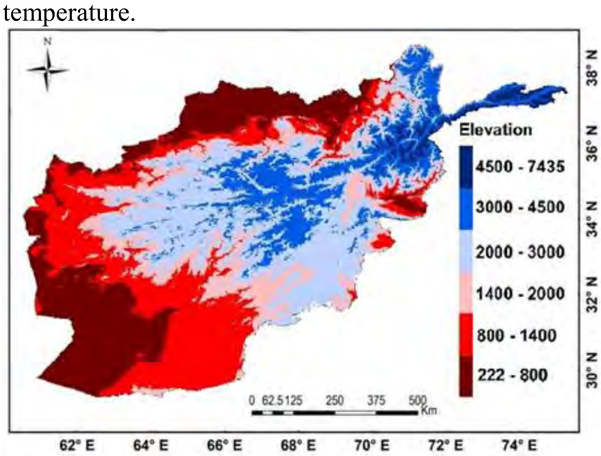

Fig.1 study area: Afghanistan

3. METHODOLOGY

3.1. Selection of key climate extreme indices

We used the cross-correlation to select representative ETCCDI indices for Afghanistan and then used the variance inflation factor (VIF) to detect the multicollinearity in representative indices. We can use the following equation to calculate VIF.

$$VIF = \frac{1}{1-r^2} \quad (1)$$

where, r is the correlation between the ETCCDI indices in multiple regression model.

3.2. Correlation and Trend Analysis

The magnitude of the changes in ECIs and SPEI was estimated using Sen's slope, while the significance of the changes at the 95% confidence level was estimated by the Mann-Kendall (MK) trend test. In the Sen's slope method, time series (Qmed) changes are computed as the median of N slopes estimated from consecutive two points of the series as follows.

$$Q_{med} = \{Q_{|\frac{N+1}{2}|} \; if \; N \; is \; odd \;\; \frac{Q_{|\frac{N}{2}|}+Q_{|\frac{N+2}{2}|}}{2} \; if \; N \; is \; even \quad (2)$$

Mann-Kendall test statistic (S) for a time series, x with n number of data points is calculated as follows.

$$S = \sum_{k=1}^{n-1}\sum_{i=k+1}^{n} sign\,(x_i - x_k) \quad (3)$$

where

$$sign\,(x\_i - x\_k) = \begin{cases} +1 & when\;(x\_i - x\_k) > 0 \\ 0 & when\;(x_i - x_k) = 0 \\ -1 & when\;(x\_i - x\_k) < 0 \end{cases} \quad (4)$$

The significance of the trend is calculated by using Z statistics as follows.

$$Z = \begin{cases} \frac{S-1}{\sqrt{Var\,(S)}} & when\; S > 0 \\ 0 & when\; S = 0 \\ \frac{S-1}{\sqrt{Var\,(S)}} & when\; S < 0 \end{cases} \quad (5)$$

where Var (S) is the variance of S, $|Z| \geq 1.64$ indicates that the confidence level in the current test was >95% ($p < 0.05$).

4. RESULTS

4.1. Selection of key climate extreme indices

Figure 2 shown the cross-correlation of the 27 ETCCDI indices based on daily series of precipitation, maximum and minimum temperature from 1975 to 2014 over Afghanistan. Significant correlations among precipitation extremes indices and lesser correlation between temperature and precipitation extremes indices were found. Some of the temperature extreme indices also reveal significant correlations (e.g., PRCPTOT and R10MM, and TX10P and TN10P). For removing redundant indices, the indices that share a high correlation with others, was selected as representative of indices. Finally, set of eight indices based on their VIF values were selected which shown as bold colour in table (1).

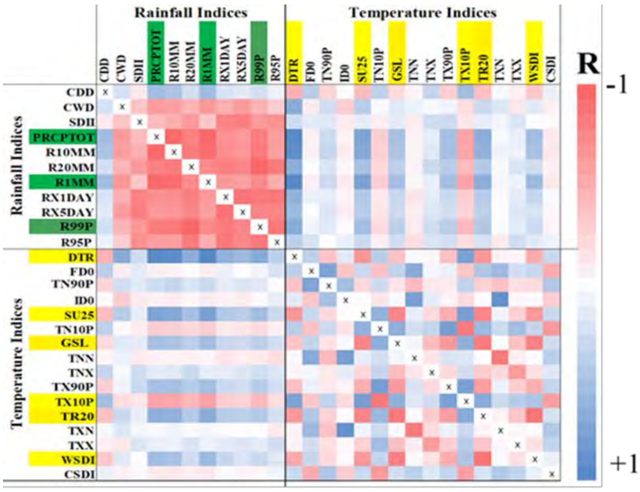

Fig.2 Cross-correlation of the ETCCDI indices for Afghanistan from 1976 to 2015

Table 1- VIF values of pre-selected ETCCDI indices

ETCCDI	Variance inflation factor (VIF) 1st	2nd	3rd	4th
CDD	2.2	1.7	1.6	1.5
R95P	2.2	2.1	1.4	1.3
SDII	4.9	3.1	2.4	removed
R10MM	5.2	3.4	1.8	1.7
RX1DAY	8.6	6.5	removed	removed
RX5DAY	7.3	4.1	2.0	1.5
R20MM	34.5	removed	removed	removed
TN90P	5.1	3.1	1.8	1.3
CWD	3.8	3.5	2.8	removed
TNN	31.5	removed	removed	removed
ID0	27.4	removed	removed	removed
TN10P	51.3	removed	removed	removed
TX90P	5.3	3.5	1.9	1.6
TXN	9.7	3.2	1.8	2.0
FD0	9.3	4.5	4.1	removed
TNX	13.5	7.7	removed	removed
TXX	8.0	4.6	1.8	1.9
CSDI	8.5	5.4	removed	removed

4.2. Correlation between SPEI and extreme indices

Figure 3 represent the spatial characteristics of SPEI drought index during 1975 to 2014 in Afghanistan. it can be seen that aridity is changing from northeast to the southwest of the country. Southwest (desert) region shows significant decreasing trend based on SPEI drought index.

Figure 4 shown the correlation coefficients between SPEI and temperature/precipitation related indices. The result revealed that indices related to temperature were significantly correlated with the SPEI index, but the SPEI index had weak correlations with precipitation related indices. Therefore, the intensification drought condition in Afghanistan during 1975 to 2014 mostly related to increasing temperature rather than to the change in precipitation.

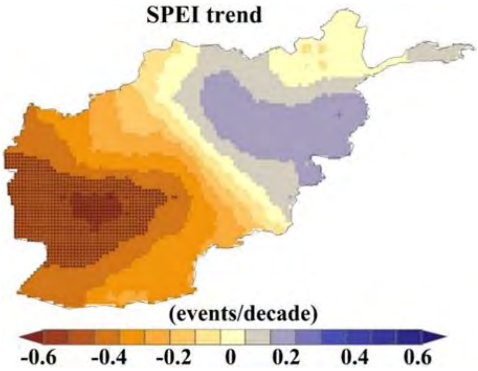

Fig. 3 Trend of SPEI index in Afghanistan from 1975 to 2014.

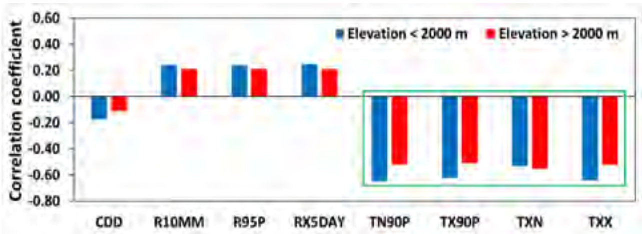

Fig. 4 Correlation between SPEI and climate extreme indices.

5. CONCLUSION

In this study, we identified the suitable set of extreme climate indices to assess the contribution of climate extreme event on changing drought condition. Based on trend correlation analysis of drought index and climate extreme indices we found that increasing aridity in Afghanistan especially in the southwest (desert region) during 1975 to 2014 due to the global warming was directly related to the increasing temperature in the region

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