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Research Article

Global climate variability driven rainfall and temperature increases in the southwestern of Nghe An province, Vietnam

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Abstract

Climate change is a pressing global issue that affects various regions around the world, including Vietnam. The southwestern districts of Nghe An province, Vietnam, are particularly vulnerable to climate change due to their unique geography and climate. This study investigates the impact of global climate change (GCC) on rainfall and temperature variation in the southwestern region of Nghe An province, Vietnam, using rainfall and temperature series from 1998 to 2020. The study employed the Mann-Kendall test and Sen's slope estimator to detect trends in rainfall and temperature series. The results show that there is a statistically significant upward trend in annual temperature, with a slight increase of 0.075°C per year. In contrast, the trends in rainy season and dry season temperature are not statistically significant. The analysis of rainfall data reveals no statistically significant trend in the annual, rainy season, and dry season rainfall. The study contributes to the understanding of the impact of GCC on rainfall and temperature variation in the southwestern region of Nghe An province, Vietnam. The findings of this study have important implications for water resources management, agricultural planning, and climate change adaptation strategies in the region.

Keywords: *Global, temperature, rainfall, drought, flooding, trend.*

1. INTRODUCTION

Climate change, particularly the change in the temperature and rainfall, has received a great deal of attention worldwide [1,3]. Global climate changes may influence the availability of water, along with the risk potential of increasing occurrences of droughts and floods [2,6]. Rainfall and temperatures are the most important fundamental physical parameters among the climate as these parameters determine the environmental condition of the particular region which affects the agricultural productivity [4,5]. They are key parameters that influence the environmental conditions of a region, affecting many aspects of life, especially agricultural and forestry activities [7,9]. Variability in rainfall and temperature plays a crucial role in providing water for crops [8,10]. Extreme events like floods and droughts are linked to fluctuations in rainfall and temperature, underscoring the significance of understanding these trends in the context of climate change [8,14]. Studies on past and recent climate change have received considerable attention, improving our understanding of the impacts of GCC [11,13]. Agriculture and other related sectors, food security and energy security of any region are crucially dependent on the timely availability of adequate amounts of water and a conducive climate [14, 15]. The rainfall received in an area is an important factor in determining the amount of water available to meet various demands such as agricultural, industrial, domestic water supply [16,18].

Understanding trends in climatic variables at local and regional scales is vital for developing adaptation strategies to mitigate the negative effects of climate change [16,17]. Studies on the impact of GCC on changing trends in rainfall and temperature has received attention from scientists in recent decades [17,19,20]. For instance, an analysis of temperature and rainfall trends in the Tana Lake sub-basin, Ethiopia investigated by Addisu et al. (2015) [1]; a study on precipitation and temperature trend analysis in Mekelle city Northern Ethiopia conducted by Beyene (2015) [2]; an investigation of trends in indices for extremes in daily temperature in the Utah, USA employed by Dos Santos et al. (2011) [4]; a study on

long-term trends in rainfall and temperature in East Africa designed by Gebrechorkos et al. (2019) [8] and a study on extreme rainfall trends in the Mekong Delta under the impacts of climate change conducted by Lee and Dang (2019) [13].

This study focuses on investigating rainfall and temperature variability in the southwestern district of Nghe An province, Vietnam, to provide insights for better management of agriculture, irrigation, and water-related activities in the area. The findings of this study will provide valuable insights into the impacts of climate change on agricultural production and water resources management in the study area and will inform the development of strategies to mitigate these impacts.

2. Materials and methods

2.1 Describe the study area and data collection

The study area, the southwestern districts of Nghe An province (Figure 1). The Nam Dan district is located between 18°30’ to 18°47’N latitude and 105°24’ to 105°37’E longitude [12]. It borders Do Luong district and a part of Nghi Loc district to the North, Huong Son district and Duc Tho district of Ha Tinh province to the South, Hung Nguyen district and a part of Nghi Loc district to the East, and Thanh Chuong district to the West [12]. Do Luong district is situated in the plain region, bordering the northern mountainous region of Nghe An province [12]. Its geographical coordinates are between 18º55' to 19º10'N latitude and 105º15’ to 105º45’E longitude [12]. The district has a total natural area of 35,009.25 ha, characterized by semi-mountainous terrain.

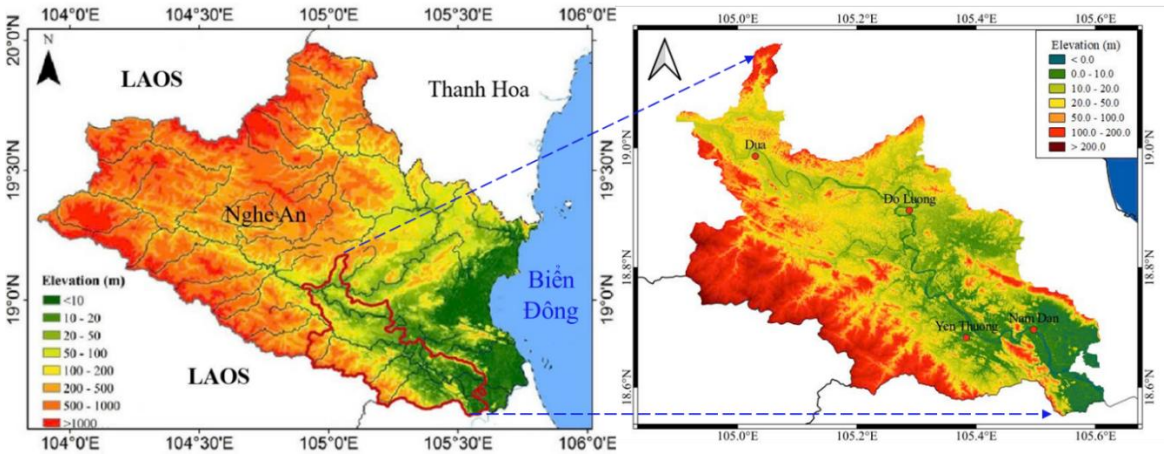

Fig. 1 The map of the study area with rainfall observation stations [12]

The study area is located in the tropical monsoon region, subject to the influence of numerous weather systems [12]. Annually, the dry season lasts from January to August, while the rainy season spans from September to December. The annual rainfall is highest up to more 2000 mm, lowest at 1400 mm, and averages approximately 1700 mm (Figure 2).

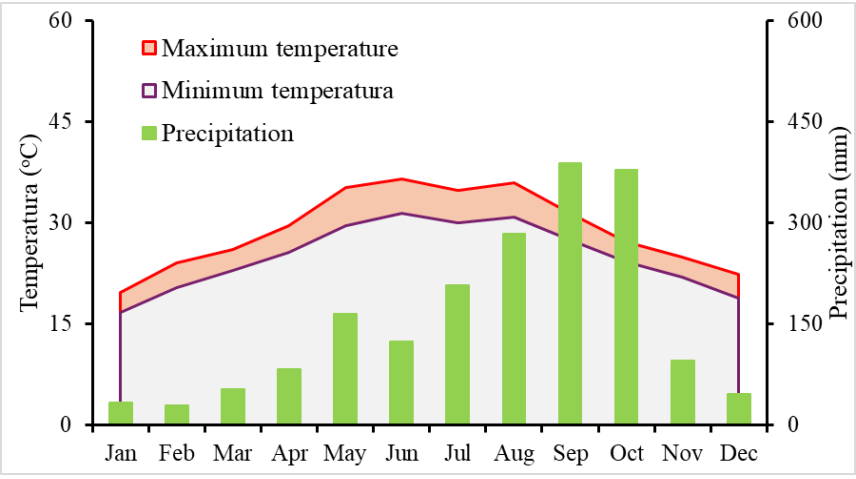

Fig.2 Distribution of monthly rainfall and temperature at observation stations across the study area during the period of 1998-2020

2.2 Statistical methods for detecting rainfall trends

The monthly rainfall and temperature data at Do Luong station have been collected from the Nghe An Hydrometeorological Station during the period 1998-2020. The data series were first quality verified through the Standard Normal Homogeneity test (SNHT) to ensure their reliability and accuracy. Subsequently, the basic characteristics of rainfall and temperature, including the standard deviation (SD), coefficient of variation (CV), skewness, and kurtosis, were analyzed to gain a deeper understanding of the data. Finally, the changing trends of rainfall and temperature were evaluated using the Mann-Kendall test and Sen's slope estimator.

This study used the SNHT to assess the quality of input rainfall and temperature data series. The SNHT is provided as formula (1):

$$T_s = \max T_m,\ with\ 1 \le m\ \le n \quad (1)$$

To define the discontinuity values relates to the points when Ts approaches the maximum value in the surveyed rainfall and temperature data series. When the Tm is calculated by formular (2):

$$T_m = \bar{m}z_1 + (n-m)\bar{z_1},\ with\ m = 1, 2, 3, \ldots\ldots, n \quad (2)$$

With z_1 is defined by formular (3):

$$z_1 = \frac{1}{m}\sum_{1=1}^{n}\frac{(M_i - \bar{M})}{s} \quad (3)$$

Where m, s in formular (3) present for the mean value and standard deviation of input rainfall and temperature data series.

3. Results and discussion

3.1 Statistical features of monthly rainfall and temperature

The data presented in Table 1 provides a comprehensive overview of the statistical features of monthly rainfall at Do Luong station during the period 1998-2020. This analysis aims to delve deeper into the characteristics of the rainfall data, highlighting the minimum, maximum, mean, standard deviation (SD), coefficient of variation (CV), skewness, and kurtosis for each month. The minimum rainfall recorded during the study period was 0.30 mm in January, while the maximum rainfall was 1108.9 mm in October. These values indicate that the rainfall at Do Luong station can vary significantly throughout the year, with some months experiencing extremely low rainfall and others experiencing heavy rainfall events. The mean rainfall for each month is calculated by averaging the rainfall data from the corresponding month over the 24-year period. The mean rainfall values range from 30.9 mm in February to 369.2 mm in September, with an overall average of 151.8 mm. This indicates that the rainfall at Do Luong station is generally moderate, with some months experiencing above-average rainfall and others experiencing below-average rainfall.

Table 1 Statistical features of rainfall at Do Luong station during the period 1998-2020

Month	Min	Max	Mean	SD	CV (%)	Skewness	Kurtosis
Jan	0.3	141.1	32.0	28.8	92.1	2.56	7.94
Feb	10.7	105.7	30.9	22.1	73.4	1.99	4.47
Mar	12.3	154.9	53.4	34.3	65.5	1.34	1.78
Apr	14.8	315.6	82.3	64.5	80.2	2.07	6.06
May	28.7	398.6	177.9	103.6	59.5	0.57	-0.53
Jun	0.6	404.8	118.5	107.6	92.7	1.40	1.16
Jul	46.9	701.0	189.8	147.2	79.2	2.06	5.01
Aug	69	743.4	262.7	142.2	55.3	1.69	4.14
Sep	82.6	646.5	369.2	173.5	48.0	0.13	-1.26
Oct	15.1	1108.9	368.3	295.3	81.9	1.10	0.79
Nov	14.5	207.5	92.5	62.7	69.2	0.70	-0.95
Dec	7.8	253.9	43.9	46.9	109.1	3.92	17.3
Ave.	*25.3*	*431.8*	*151.8*	*102.4*	*74.0*	-	-

The SD is a measure of the amount of variation of a set of values. The SD for each month ranges from 22.1 mm in February to 295.3 mm in October, with an overall average of 102.4 mm. The CV is a normalized measure of dispersion of probability distribution or frequency distribution. The CV values range from 48.0% in September to 109.1% in December, with an overall average of 74.0%. This indicates that the rainfall at Do Luong station is characterized by a relatively high degree of variability, with some months experiencing extreme rainfall events. Skewness is a measure of the asymmetry of the probability distribution of a real-valued random variable. The skewness values range from 0.13 in

September to 3.92 in December and this indicates that the rainfall at Do Luong station is generally skewed to the right, with some months experiencing more extreme rainfall events on the right tail of the distribution. Kurtosis is a measure of the "peakedness" of the probability distribution of a real-valued random variable. The kurtosis values range from -1.26 in September to 17.3 in December. It implies that the rainfall at Do Luong station is generally leptokurtic, with some months experiencing more extreme rainfall events than would be expected under a normal distribution.

Table 2 provides a comprehensive overview of the statistical features of monthly temperature at Do Luong station during the period 1998-2020. The minimum temperature recorded during the study period was 13.3°C in February, while the maximum temperature was 20.9°C in June. These values indicate that the temperature at Do Luong station can vary significantly throughout the year. The mean temperature values range from 17.8°C in January to 30.5°C in June, with an overall average of 17.8°C. The SD for each month ranges from 0.72°C in September to 2.86°C in February, with an overall average of 1.25°C. The CV values range from 2.6% in August and September to 15.4% in February, with an overall average of 5.7%. This indicates that the temperature at Do Luong station is characterized by a relatively low degree of variability, with some months experiencing more extreme temperature events. The skewness values range from -1.07 in March to 1.14 in August, and this indicates that the temperature at Do Luong station is generally skewed to the left, with some months experiencing more extreme temperature events on the left tail of the distribution. The kurtosis values range from -1.15 in July to 2.71 in August. This implies that the temperature at Do Luong station is generally platykurtic, with some months experiencing less extreme temperature events than would be expected under a normal distribution.

Table 2 Statistical features of temperature at Do Luong station during the period 1998-2020

Month	Min	Max	Mean	SD	CV (%)	Skewness	Kurtosis
Jan	14.1	20.9	17.8	1.50	8.7	-0.30	1.18
Feb	13.3	23.1	19.0	2.86	15.4	-0.62	-0.38
Mar	17.2	23.8	21.6	1.65	7.8	-1.07	1.47
Apr	23.1	28.4	25.1	1.23	5.0	0.81	1.93
May	26.6	31.1	28.6	1.26	4.5	-0.06	-0.88
Jun	29.0	32.4	30.5	0.90	3.0	0.54	-0.01
Jul	28.5	31.3	29.6	0.79	2.7	0.80	-1.15
Aug	27.6	30.8	28.7	0.73	2.6	1.14	2.71
Sep	26.6	28.9	27.6	0.72	2.6	0.47	-0.90
Oct	23.8	26.8	25.2	0.88	3.5	-0.03	-1.10
Nov	20.4	24.9	22.8	1.20	5.4	0.05	-0.36
Dec	16.2	20.8	19.0	1.35	7.3	-0.49	-0.78
Ave.	*22.2*	*26.9*	*17.8*	*1.25*	*5.7*	-	-

3.2 Change trends in rainfall and temperature features

Table 3 presents the results of the Mann-Kendall test and Sen's slope estimator for detecting trends in annual, rainy season, and dry season rainfall at Do Luong station during the period 1998-2020. The value of the Mann-Kendall test for annual rainfall is 0.239, with a p-value of 0.108. This indicates that the trend in annual rainfall is not statistically significant, as the p-value is greater than 0.05. However, the Sen's slope estimator shows an increase of 16.011 mm per year, suggesting that there may be a slight upward trend in annual rainfall (Figure 3). The value of the Mann-Kendall test for rainy season rainfall is 0.009, with a p-value of 0.964, indicating the trend in rainfall season rainfall is also not statistically significant ($p > \alpha = 0.05$). The Sen's slope estimator shows a very slight increase of 0.0002 mm per year, suggesting that there is slight trend in rainfall season.

Table 3: Results of detecting monotony of rainfall and temperature based on the Man-Kendall test and Sen's slope estimator

Variables	Factors	Man-Kendall test	p	Sen's slope
Rainfall	Dry season	0.091	0.566	0.550
	Rainy season	0.009	0.964	0.0002
	Annual	0.239	0.108	16.011
Temperature	Dry season	0.329	0.078	0.177
	Rainy season	0.009	0.964	0.000
	Annual	0.574	0.001	0.075

For rainfall in dry season, the value of the Mann-Kendall test is 0.091 (p = 0.566), implying the trend in dry season rainfall is not statistically significant. However, the Sen's slope estimator shows a slight increase of 0.550 mm per year, suggesting that there may be a slight upward trend in dry season rainfall. In overall, the analysis of trends in rainfall features at Do Luong station reveals that there is no statistically significant trend in annual, rainy season, and dry season rainfall. However, the Sen's slope estimator suggests that there may be slight upward trends in annual, rainy and dry seasonal rainfall. These findings will be useful for further research and applications in fields such as water resources management for agricultural planning.

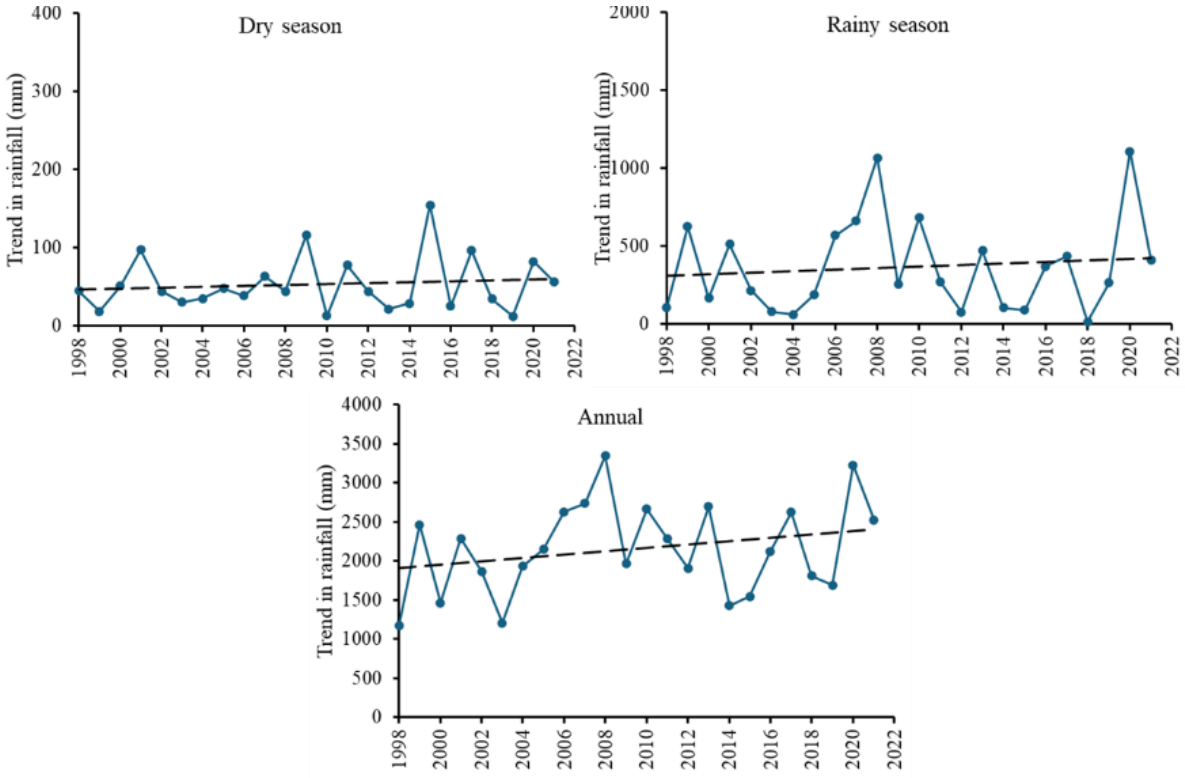

Figure 3: Trends of rainfall across Do Luong station during the period 1998-2022

Table 3 also presents the analyzed results of the Mann-Kendall test and Sen's slope estimator for temperature features at Do Luong station during the period 1998-2022. For annual temperature, the Man-Kendall value is 0.574 (p = 0.001). This implying that the trend in annual temperature is statistically significant, as the p-value is less than 0.05. The Sen's slope estimator shows a slight increase of 0.075°C per year, suggesting that there is a slight upward trend in annual temperature (Figure 4). For dry season temperature, the Mann-Kendall value is 0.009, p-value is 0.964. This reveals that the trend in rainy season temperature is not statistically significant, as the p-value is greater than 0.05. The Sen's slope estimator shows a very slight increase of 0.0002°C per year, suggesting that there is slight uptrend in rainy season temperature. For dry season temperature, the values of Mann-Kendall test, p-critical and Sen's slope estimator are 0.329, 0.078 and 0.177°C per year. This indicates that the trend in dry season temperature is not statistically significant, as the p-value is greater than 0.05 and the Sen's slope estimator shows a slight increase, suggesting that there may be a slight upward trend in dry season temperature.

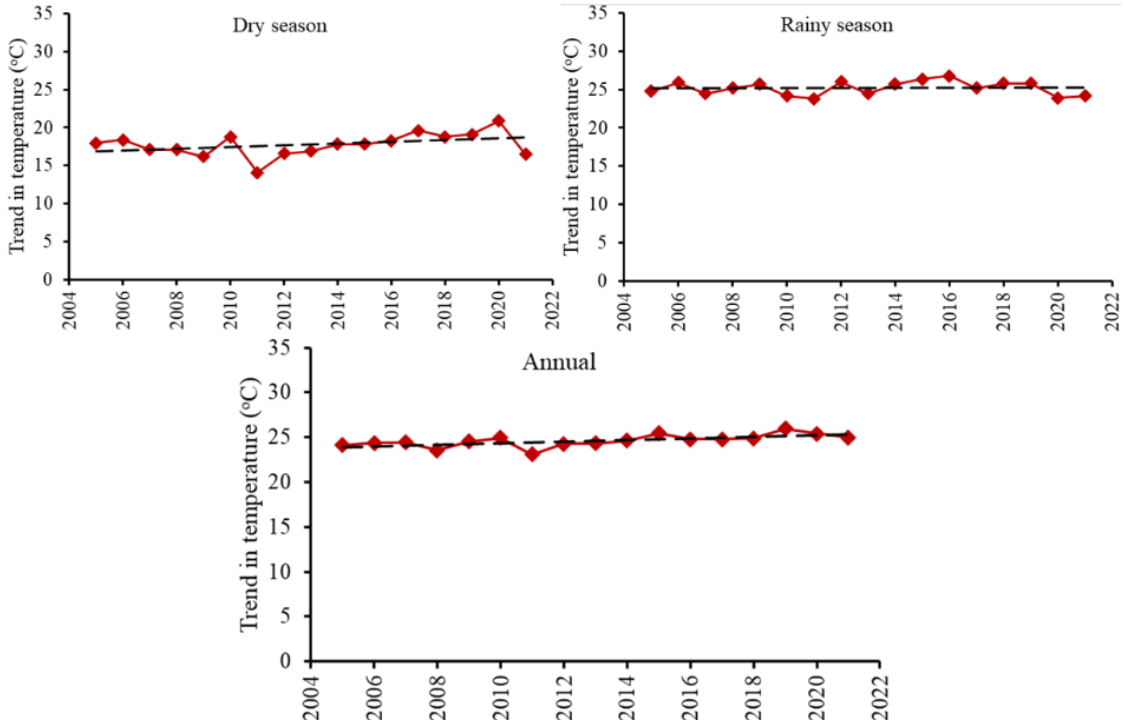

Figure 4: Trends of temperature across Do Luong station during the period 1998-2022

In general, the analyzed results of trends in temperature features at Do Luong station based on the Mann-Kendall test and Sen's slope estimator reveals that there is a statistically significant upward trend in annual temperature. However, the trends in rainy season and dry season temperature are not statistically significant.

4. Conclusion

The study investigated the impact of GCC on rainfall and temperature variation in the southwestern region of Nghe An Province, Vietnam. The analysis of rainfall and temperature data from 1998 to 2022 revealed a statistically significant upward trend in annual temperature, with a slight increase of 0.075°C per year. However, the trends in rainy season and dry season temperature were not statistically significant. The results also showed that there is no statistically significant trend in annual, rainy season, and dry season rainfall.

The findings of this study have important implications for water resources management, agricultural planning, and climate change adaptation strategies in the region. The increasing trend in temperature can have significant impacts on agricultural productivity and water availability. Therefore, it is essential to consider these changes in planning and decision-making processes to ensure sustainable development and adaptation to climate change.

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