

Research Article

**STUDY ON CHARACTERISTICS OF MAXIMUM AND MINIMUM
TEMPERATURES IN THE CONTEXT OF CLIMATE CHANGE
IN NINH THUAN PROVINCE****Nguyen Hoang Tuan, Truong Thanh Canh***University of Science, Vietnam National University Ho Chi Minh City, Vietnam***Corresponding author: Nguyen Hoang Tuan – Email: nhtuansg@gmail.com**Received: November 15, 2020; Revised: July 25; Accepted: August, 2021...***ABSTRACT**

The study aims to analyze change characteristics and predict the maximum and minimum temperature in Ninh Thuan in climate change. In this study, the author used non-parametric statistics with, Mann-Kendall and Theil-Sen. The results show the maximum temperature decreased in May, July, and August in the range of 0.007°C per year to 0.03°C per year, increasing in the remaining months with an increasing amplitude from 0.006°C per year to 0.05°C . The results with the lowest minimum temperature also showed that July, August, and three months tended to decrease with the temperature range from 0.0025°C per year to 0.0136°C per year, and the remaining months increased from 0.01°C per year to 0.1°C per year. In addition, the results of prediction the trend of minimum and maximum temperature change with the Climate Change scenario show that it is consistent with the low emission scenario (B1) and the RCP 4.5 scenario. The research results have contributed to supplementing the scientific basis of changing trends and predictions in hydrometeorology, helping develop adaptation options and solutions in climate conditions.

Keywords: Climate Change; Mann-Kendall; Non-parametric statistics; Theil-Sen.

1. Introduction

Over the past five decades, the air temperature has increased by about 0.7°C , and climate phenomena such as El Niño and La Niña have increased natural disasters in Vietnam (Ministry of Natural Resources and Environment, 2008). Based on the Climate Change scenario RCP 4.5 (Representative Concentration Pathway), in the middle of the 21st century, the average annual maximum temperature will increase from 1.4°C to 1.8°C , the average annual minimum temperature nationwide has a typical increase from 1.4°C to 1.6°C by mid-century 21st (Ministry of Natural Resources and Environment, 2016).

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Climate change is affecting Vietnam, causing enormous loss of life and properties. Ninh Thuan is one of the provinces of Vietnam also strongly affected by climate change. Ninh Thuan is considered a province with a harsh climate (Nguyen et al., 2012; Ngo et al., 2016), an area at risk of desertification, and severe degradation of land resources in Vietnam (Nguyen, 2008; Ngo et al., 2016). Identifying, evaluating, and analyzing the trend of changing climate factors is essential for Ninh Thuan and the whole country. According to IPCC, to assess climate change, the study is based on observed data from the past and build future scenarios based on climate models in the world (IPCC, 2007). Therefore, the study uses historical climate data of Ninh Thuan province for the period 1992-2016 and uses that result to forecast the future change trend. In this study, a non-parametric approach will be used to assess and predict the trend of changing mean maximum and minimum temperature in Ninh Thuan in the context of climate change.

2. Methods and research data

2.1. Methods

The author uses non-parametric analysis to study Ninh Thuan province's average maximum (T_{max}) and minimum temperature (T_{min}) variation in this study. Mann-Kendall (MK_{test}) and Thei-sen (TS_{slope}) analysis are two methods used in this research.

MK_{test} and TS_{slope} methods are two popular methods in Hydro-Meteorological studies in the world (Addisu et al., 2015; Atilgan et al., 2017; Chattopadhyay & Edwards, 2016; Chaudhuri & Dutta, 2014; Güner Bacanlı, 2017; Khavse et al., 2015; Krishnan et al., 2018; Kumar et al., 2018; Mavromatis & Stathis, 2011; Silva et al., 2015; Toros et al., 2017). Some typical studies, such as Da'u Abba Umar et al., studied the trend of temperature change and precipitation to assess climate change in the semi-arid region of tropical Nigeria. The results illustrate that the annual variation trend can be used as a basis for planning activities to respond to climate change (Umar et al., 2019). Study on the variation T_{max} and T_{min} of the economic corridor between Pakistan and China by Safi Ullah research group. The results show the T_{max} and T_{min} trend, which is also the basis for temperature variation in space and time (Ullah et al., 2019). Research by Reaz Akter Mullick has used the trend study of temperature and precipitation change in Bangladesh. The results of the trend study are used to design and develop climate-related policies for many other areas (Mullick et al., 2019). A study of Livada in Australia used linear regression to calculate the trend of air temperature change in the time series 1970-2016 and evaluated the trend of temperature change for urban planning related to climate issues (Livada et al., 2019). Research by Asfaw in the North of Ethiopia in analyzing the trend of temperature and precipitation change in the Woleka basin shows that the MK_{test} analysis has shown increasing temperature and precipitation in the research area (Asfaw et al., 2018).

In Vietnam, many research works related to Meteorology and Hydrology are also used more and more. The study of Ngo Duc Thanh and Phan Van Tam used non-

parametric statistical methods to test the changing trend of some meteorological factors in Vietnam in 1961 - 2007 based on the study of 7 meteorological factors. The research results showed that temperature and precipitation changes were consistent with previous scientific publications (Ngo et al., 2012). Research by Nguyen Minh Ky analyzed and assessed rainfall in climate change trends from 1979-2011 of Da Nang. In this study, the author used the EPA's ProUCL 4.1 calculation tool, and the results predicted that rainfall could increase by about 1.04% in 2100 and the results also contributed to the development of solutions to contribute limitations and adaptation to climate change (Nguyen, 2016).

Mann-Kendall method

The method was developed by Mann and used in the non-parametric analysis in 1945 and modified in 1975 by Kendall (Mann, 1945; Kendall, 1975). Accordingly, the non-parametric method MK_{test} (S) is calculated according to the formula:

$$S = \sum_{i=1}^{N-1} \sum_{j=i+1}^N \text{sgn}(x_j - x_i) \quad (1)$$

where:

$$\text{Sgn}(x_j - x_i) = \begin{cases} +1 & \text{if } (x_j - x_i) > 0 \\ 0 & \text{if } (x_j - x_i) = 0 \\ -1 & \text{if } (x_j - x_i) < 0 \end{cases} \quad (2)$$

If $S > 0$, the trend is up, and $S < 0$, the trend is down.

However, in order to have more reliable and accurate trend analysis results, the research needs to calculate the variance (VAR) of S. Therefore, $\text{Var}(S)$ is calculated by the formula:

$$\text{VAR}(S) = \frac{1}{18} \left[n(n-1)(2n+5) - \sum_{p=1}^g t_p(t_p-1)(2t_p+5) \right] \quad (3)$$

Where t_p is the number of relationships with sample p , g is the number of groups with the same data value. If the value $\text{Var}(S) > 0$, then the trend is positive, and $\text{Var}(s) < 0$ the trend is negative. To obey a normal distribution, mean 0, variance 1, MK_{test} index (Z) is calculated by the formula:

$$\begin{aligned} Z &= \frac{S-1}{[\text{VAR}(S)]^{1/2}}, \text{ when } S > 0 \\ Z &= 0, \text{ when } S = 0 \\ Z &= \frac{S+1}{[\text{VAR}(S)]^{1/2}}, \text{ when } S < 0 \end{aligned} \quad (4)$$

The results of Z analysis show that if $Z > 0$, it proves an uptrend, and $Z < 0$, it proves a trend in the downtrend.

Theil-Sen estimator

The Theil-Sen estimation (TS_{slope}) was developed in 1950 by Theil and modified by Sen in 1968 (Theil, 1950; Sen, 1968). The formula calculates the estimated slope of Sen (Q):

$$Q = \frac{x'_i - x_i}{i' - i} \quad \text{with } i=1,2,3...n \quad (5)$$

Where Q is the slope between two points x_i and x'_i , x'_i is measurement data at the time i' , x_i measurement data at the time i , i' is the time after time i . The slope estimate of the single Sen is due to the mean slope (Q'), expressed by the formula:

$$Q' = \begin{cases} Q \left\lceil \frac{N+1}{2} \right\rceil & \text{if } N \text{ is odd} \\ \frac{Q[N+1] + Q[N+2]}{2} & \text{if } N \text{ is even} \end{cases} \quad (6)$$

Q' was calculated using a two-sided test with a 100 (1 - α) % confidence level. Calculation results show that if $Q' > 0$ increases, and if $Q' < 0$, it decreases. It should be noted in the use of MK_{test} and TS_{slope} analyses that the lack of data was still acceptable and that the results were not affected by missing or incorrect data measurements (Atilgan et al., 2017; Silva et al., 2015). Besides, the fact that the analytical values are not statistically significant ($p\text{-value} < 0.05$) is still accepted and used depending on the purpose of the study (Umar et al., 2019).

2.2. Research data

The research data used for 1992-2016 is the T_{max} and T_{min} data in Ninh Thuan province. The data was collected from National Center for Hydro- Meteorology on typical data of temperature and monthly rainfall in Ninh Thuan province, Scientific research topic – Climatic and Hydrological characteristics of Ninh Thuan province of the Southern Meteorological Institute, and Additional study on hydro-climate characteristics of Ninh Thuan province of the Hydro-meteorological station in the South Central.

3. Results and discussion**3.1. Temperature characteristics in Ninh Thuan**

The table 1 and 2 showed that the T_{max} and T_{min} had a considerable difference, ranging from 14.0°C to 42.0°C. Regarding the T_{max} , the highest temperature is 42°C in Ma Moi area, and the lowest is 31.6°C in the Phuoc Binh area. Besides, the rainy season months are lower than the dry season months, with rainy season months ranging from 33.2°C to 39.0°C while the dry season average temperature ranges from 31.6°C to 42.0°C (Table 1). With the T_{min} consistently below 20°C, it ranges from 14.0°C to 23.2°C (Table 2). The value of average T_{min} varies between regions, with Phan Rang having the highest temperature (16.0°C-23.3°C) and Phuoc Binh being the area with the lowest temperature in the region (14.0°C-18.8°C).

Table 1. Average maximum temperature (T_{max}) in Ninh Thuan

Station	Month ($^{\circ}\text{C}$)											
	1	2	3	4	5	6	7	8	9	10	11	12
Phan Rang	33.1	33.8	36.5	37.4	39.4	38.8	38.7	38.6	37.1	35.1	33.9	32.7
Nha Ho	34.3	35.2	37.9	38.8	40.9	40.5	40.2	40.1	38.5	36.4	35.2	34.0
Ma Moi	33.4	34.6	38.2	39.4	42.0	41.5	41.1	41.0	39.0	36.3	34.6	32.9
Phuoc Binh	32.0	33.2	36.9	38.2	41.0	40.5	40.0	39.9	37.7	34.9	33.2	31.6

Source: Research data collection

Table 2. Average minimum temperature (T_{min}) in Ninh Thuan

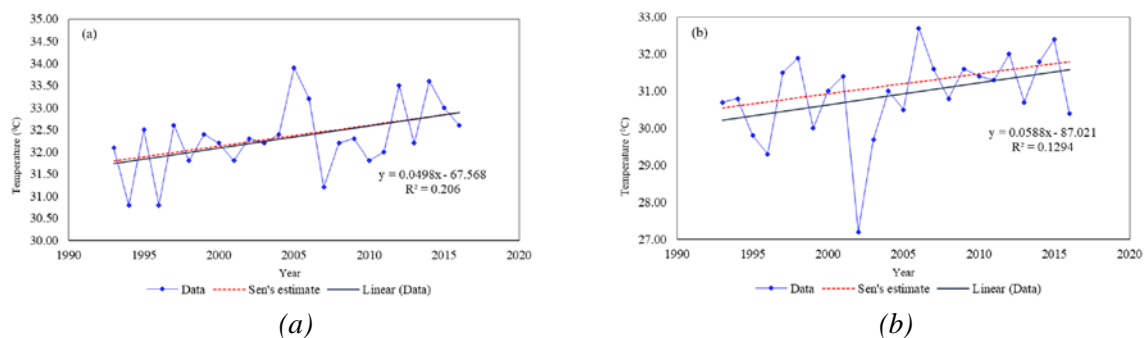
Station	Month ($^{\circ}\text{C}$)											
	1	2	3	4	5	6	7	8	9	10	11	12
Phan Rang	16.2	17.8	18.1	21.0	22.1	22.6	23.2	17.5	22.0	21.0	17.8	16.1
Nha Ho	14.6	16.6	17.2	20.3	19.9	21.1	21.3	16.5	20.8	19.3	16.8	14.8
Ma Moi	14.9	16.8	17.3	19.9	19.7	20.6	20.8	16.7	20.4	19.2	17.0	15.0
Phuoc Binh	14.0	15.4	15.9	18.1	17.9	18.8	18.9	15.4	18.5	17.4	15.6	14.1

Source: Research data collection

3.2. Changes and trends in maximum and minimum temperature

The trend of average maximum temperature change (T_{max})

The MK_{test} and TS_{slope} analysis results show that T_{max} in Ninh Thuan tends to decrease in May, July, and August, the remaining months of the year tend to increase (Table 3). Specifically, in May, July, and August, the $Z(s)$ values were -0.200, -0.249, and -0.400, respectively. Considering the TS_{slope} , the T_{max} in May, July and August decreased by 0.01°C . In May, the temperature drops range from 0.01°C to 0.02°C , and this trend continues to decrease. July, the T_{max} decreases in the range of 0.003°C to 0.01°C . In August, the T_{max} tends to decrease in the range of 0.0067°C to 0.01°C . In the remaining months, most of the T_{max} tend to increase with an increase ranging from 0.01°C to 0.05°C , of which a slight increase is in January, February, March, April, June, September, October, and November, while December is high increase. In November, the $Z(s)$ index reached 1.800 with a confidence level of 0.04 ($p\text{-value} < 0.05$) and TS_{slope} was 0.05, the results showed that the T_{max} in Ninh Thuan increased by 0.05°C per year (Figure 1b). The calculation results in December are similar, and T_{max} increases by 0.05°C with a $p\text{-value}$ close to 0.04 (Figure 1b). In summary, based on the results of TS_{slope} analysis, T_{max} in Ninh Thuan tends to increase by 0.02°C per year.

**Figure 1.** Trend of T_{max} variation in November (a) and December (b) in Ninh Thuan

Source: Research results

The trend of average maximum temperature change (T_{min})

Based on MK_{test} and TS_{slope} results, the T_{min} value in Ninh Thuan fluctuates with different increasing and decreasing trends (Table 4). Specifically, T_{min} tends to decrease in February, July, and August. In the remaining months, the T_{min} is increasing. Accordingly, February, July, and August are the months with a decreasing trend with the temperature range ranging from 0.0025°C to 0.0136°C , and the $Z(s)$ coefficient is -0.238, -1.002, -0.526, respectively. TS_{slope} coefficients of February, July, and August are 0.014, 0.0143, 0.00611, respectively. November and December are two statistically significant months with p-values are 0.035 and 0.019, TS_{slope} index of 0.05, 0.113, and traditional values (S) of 40.24 and 40.25, respectively (Figures 2a, 2b). With the results of the TS_{slope} , the T_{min} increase in Ninh Thuan is about 0.02°C per year. The highest increase is about 0.1°C per year (December), and the lowest decrease is about 0.014°C per year.

Table 3. Results of trend analysis of T_{max} variation in Ninh Thuan by MK_{test} and TS_{slope}

Results		Months											
		1	2	3	4	5	6	7	8	9	10	11	12
Mann-Kendall	N	24	24	24	24	24	24	24	24	24	24	24	24
	M-K Test Value (S)	9	47	16	31	-9	36	-11	-17	47	34	73	73
	Critical Value (0.05)	1.645	1.65	1.645	1.65	-1.65	1.65	-1.645	-1.65	1.65	1.6	1.65	1.65
	Standard Deviation of S	40.22	40.2	40.12	40.2	40.3	40.2	40.19	40.1	40.2	40	40.1	40.3
	Standardized Value of S	0.199	1.150	0.374	0.750	-0.200	0.87	-0.249	-0.400	1.150	0.800	1.800	1.790
	p-value	0.421	0.126	0.354	0.228	0.421	0.192	0.402	0.345	0.126	0.206	0.0363	0.0368
Theil-Sen	Number of Slopes	276	276	276	276	276	276	276	276	276	276	276	276
	Theil-Sen Slope	0.006	0.021	0.009	0.033	-0.011	0.033	-0.001	-0.007	0.029	0.020	0.048	0.054
	Theil-Sen Intercept	18.93	-9.4	15.99	-32	57.9	-30	51.56	50.5	-22	-6.7	-63	-78

Source: Research results

Table 4. Results of trend analysis of T_{min} variation in Ninh Thuan by MK_{test} and TS_{slope}

Results		Months											
		1	2	3	4	5	6	7	8	9	10	11	12
Mann-Kendall	N	23	23	23	24	24	24	24	24	24	24	24	24
	M-K Test Value (S)	7	-10	16	26	21	37	-41	-22	47	4	74	85
	Critical Value (0.05)	1.645	-1.645	1.645	1.645	1.645	1.645	-1.645	-1.645	1.645	1.645	1.645	1.645
	Standard Deviation of S	37.69	37.82	37.82	40.21	40.12	39.91	39.93	39.9	40.11	40.14	40.24	40.25
	Standardized Value of S	0.159	-0.238	0.397	0.622	0.498	0.902	-1.002	-0.526	1.147	0.0747	1.814	2.087
	p-value	0.437	0.406	0.346	0.267	0.309	0.184	0.158	0.299	0.126	0.470	0.035	0.019
Theil-Sen	Number of Slopes	253	253	253	276	276	276	276	276	276	276	276	276
	Theil-Sen Slope	0.000	-0.014	0.020	0.023	0.011	0.015	-0.014	-0.006	0.017	0.000	0.050	0.113
	Theil-Sen Intercept	18.8	47.84	-19.3	-23.91	0.873	-6.187	52.44	35.8	-10.31	22.45	-78.68	-206.1

Source: Research results

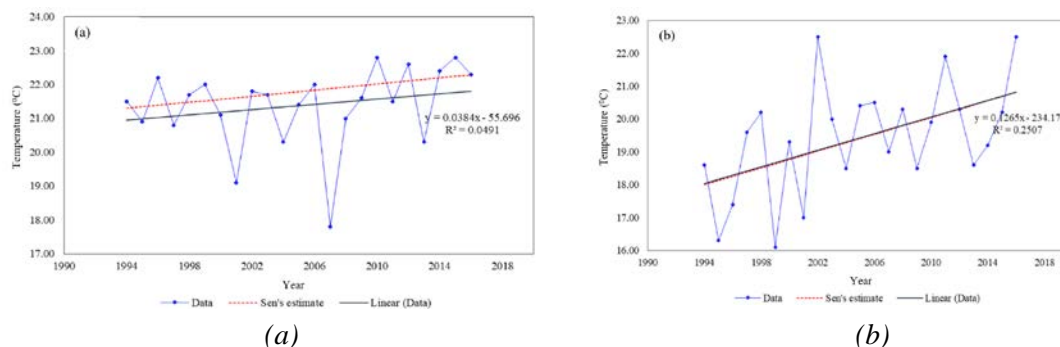


Figure 2. Trend of change in T_{min} in November (a) and December (b) in Ninh Thuan

Source: Summary of research results

3.3. Prediction trends of T_{max} and T_{min} in the context of climate change

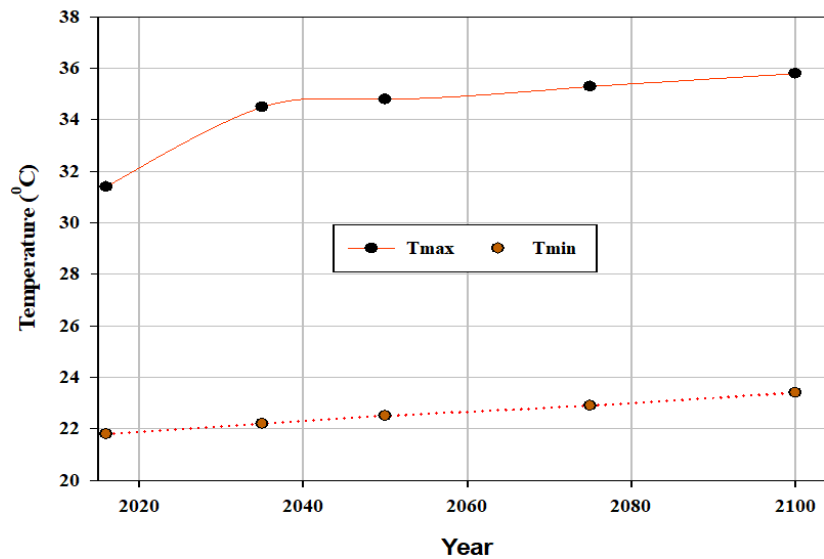


Figure 3. Prediction trend of change until the end of the 21st century

Source: Research results

The trend prediction results of T_{max} and T_{min} are based on the temperature increase trend of the TS_{slope} result (Table 3.4). The results show that the T_{max} and T_{min} increase until the end of the 2100 year. According to Figure 3, the T_{max} increases with each prediction year. In 1992 - 2016, the T_{max} was 31.4°C, predicted that by 2035, the T_{max} would increase by 0.4°C with a T_{max} of 34.5°C. In 2050 it will increase to 35.8°C. In 2075 it will be 35.3°C, and by 2100 will be 35.8°C. The difference between T_{min} between the prediction period and the year 2100 is from 1.5°C (21.8°C to 23.4°C). In addition, in the middle of the 21st century, the T_{min} is below 23°C, with the temperature in 2035 being about 22.2°C. In 2050 it will be 22.5°C, and in 2075 the temperature could reach 22.9°C (Figure 3).

The month prediction results show that the T_{max} tends to decrease in July and August to the end of the 21st century, while the remaining months increase (Table 5). Specifically, in July and August, the T_{max} tends to decrease by 0.6°C to the end of the 21st century. January and March are two months that tend to increase below 1.0°C until the end of the 21st century. In which, January increases from 31.3°C to 31.8°C, and March increases from 33.3°C to 34.1°C. Besides, there are months of increase above 2.0°C are April (2.8°C), June (2.8°C), and September (2.5°C). To the end of the century, April from 34.7°C to 37.5°C, June 36.7°C to 39.5°C, and September 35.70C to 38.2°C. Finally, November and December are the two months with the highest increase above 4.0°C, in which November is 4.1°C and December is 4.6°C (Table 5).

Table 5. Prediction results of T_{max} change trend according to TS_{slope} (Unit: $^{\circ}C$)

Year	Months ($^{\circ}C$)											
	1	2	3	4	5	6	7	8	9	10	11	12
1992-2016	31.3	32.1	33.3	34.7	36.8	36.7	36.1	36.5	35.7	33.5	32.3	30.9
2035	31.4	32.5	33.5	35.3	36.6	37.3	36.0	36.4	36.3	33.9	33.3	32.0
2050	31.5	32.8	33.6	35.8	36.4	37.8	35.9	36.3	36.7	34.2	34.0	32.8
2075	31.6	33.3	33.8	36.7	36.1	38.7	35.7	36.1	37.4	34.7	35.2	34.1
2100	31.8	33.8	34.1	37.5	35.9	39.5	35.5	35.9	38.2	35.2	36.4	35.5

Source: Research results

Table 6. Prediction results of T_{min} change trend according to TS_{slope} (Unit: $^{\circ}C$)

Year	Months ($^{\circ}C$)											
	1	2	3	4	5	6	7	8	9	10	11	12
1992-2016	18.8	19.4	20.4	22.7	23.8	23.8	23.8	23.2	23.2	22.3	21.3	19.4
2035	18.8	19.2	20.8	23.2	24.0	24.1	23.5	23.1	23.5	22.3	22.3	21.6
2050	18.8	19.0	21.1	23.5	24.1	24.3	23.3	23.0	23.7	22.3	23.0	23.3
2075	18.8	18.6	21.6	24.1	24.4	24.7	23.0	22.8	24.2	22.3	24.3	26.1
2100	18.8	18.3	22.1	24.7	24.7	25.1	22.6	22.7	24.6	22.3	25.5	29.0

Source: Research results

The prediction for the T_{min} variation (Table 6) has a variation within the year, with January and October showing no sign of an increase or decrease. In comparison, the T_{min} of February, August, and September are predicted to decrease to the end of the century (2100). In December, the T_{min} increase from $19.4^{\circ}C$ to $29.0^{\circ}C$ at the end of the 21st century. Besides, April and November have temperature increase above $2.0^{\circ}C$, March, June, and September, with the forecasted increase ranging from $1.3^{\circ}C$ to $1.7^{\circ}C$.

Evaluation of prediction results with climate change scenario

The study used two scenarios of the Ministry of Natural Resources and Environment in 2012 and 2016 to evaluate the prediction. According to the 2012 emission scenario B1, T_{max} and T_{min} increase $1.0^{\circ}C$ - $1.7^{\circ}C$ by mid-century to 21 and from $2.0^{\circ}C$ - $3.2^{\circ}C$ late 21st century (Ministry of Natural Resources and Environment, 2012). The RCP 4.5 scenario (2016), in the middle of the 21st century, increasing $1.4^{\circ}C$ - $1.8^{\circ}C$ T_{max} , T_{min} increased from $1.4^{\circ}C$ up to $1.6^{\circ}C$; By the end of the 21st century, increasing from $1.7^{\circ}C$ to $2.7^{\circ}C$ T_{max} , T_{min} increased from $1.8^{\circ}C$ to $2.2^{\circ}C$ (Ministry of Natural Resources and Environment, 2016).

Based on two scenarios and T_{max} and T_{min} , the research prediction results are like two scenarios issued by the Ministry of Natural Resources and Environment in 2012 and 2016 (Table 7). Specifically, with the prediction results of T_{max} , the temperature will increase by $1.1^{\circ}C$ by the middle of the 21st century. This result is like the low emission scenario (B1) from $1.1^{\circ}C$ to $1.7^{\circ}C$ and tends to increase compared to Scenario RCP4.5. Besides, the forecast value of T_{max} is like the scenarios at the end of the 21st century. The T_{max} increase of $2.80^{\circ}C$ is like the low emission scenario ($2.0^{\circ}C$ - $3.2^{\circ}C$) and the RCP4.5 scenario ($1.7^{\circ}C$ -

2.7⁰C). The T_{min} result is similar with low emission scenarios (1.1⁰C to 1.7⁰C) and RCP4.5 (1.4⁰C-1.6⁰C). Finally, at the end of the 21st century, the T_{min} is similar with two scenarios: 2.6⁰C versus 2.0⁰C ÷ 3.2⁰C (B1) and 1.8⁰C ÷ 2.2⁰C (RCP 4.5).

Thus, the study of prediction results with two scenarios of the Ministry of natural resources and environment has many similarities, but there are only three differences in T_{max} and T_{min} . This difference is because the study's input data were based solely on temperature, while the comparative study of the two scenarios was based on many factors, many components leading to disparate prediction results.

Table 7. Comparison of prediction results with scenario B1 (2012) and RCP 4.5(2016)

Temperature (⁰ C)	Prediction results		Scenario: B1		Scenario: RCP 4.5	
	mid-21st century	end of the 21st century	mid-21st century	end of the 21st century	mid-21st century	end of the 21st century
T_{max}	1.1	2.8	1.1÷1.7	2.0 ÷ 3.2	1.4 ÷ 1.8	1.7÷2.7
T_{min}	1.0	2.6	1.1÷1.7	2.0 ÷ 3.2	1.4 ÷ 1.6	1.8 ÷ 2.2

Source: Summary of research results

4. Conclusion

The study evaluated and predicted the trends of the T_{max} and T_{min} in Ninh Thuan through the non-parametric test. The test results show that T_{max} and T_{min} tend to increase by 0.02⁰C per year during the study period. In terms of the month factor, T_{max} tends to decrease in July and August, while T_{min} decreases in August and September.

Comparing the prediction with the two emission scenarios show many similarities, and some forecasts are very consistent with the two scenarios 2012 and 2016. The T_{max} results are equivalent to scenarios B1 and RCP. 4.5 in the mid and late 21st century, and T_{min} fits two scenarios at the end of the 21st century.

In summary, the research results show that non-parametric analysis is an essential tool in trend research, especially in climate. The research is an essential basis to help localities analyze and assess climate change trends in climate change to propose adaptation solutions. However, for a more complete and accurate assessment, it is necessary to diversify the data and combine several other parametric methods to aggregate the results.

❖ **Conflict of Interest:** Authors have no conflict of interest to declare.

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NGHIÊN CỨU ĐẶC ĐIỂM BIẾN ĐỔI NHIỆT ĐỘ TỐI CAO VÀ TỐI THẤP TRONG BỐI CẢNH BIẾN ĐỔI KHÍ HẬU TỈNH NINH THUẬN

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TÓM TẮT

Mục tiêu của nghiên cứu là phân tích đặc điểm biến đổi và dự báo nhiệt độ tối cao và tối thấp tại Ninh Thuận trong bối cảnh Biến đổi khí hậu. Để thực hiện nghiên cứu này, chúng tôi đã sử dụng thống kê phi tham số (non-parametric statistics) với hai phân tích là Mann-Kendall và Theil-Sen. Kết quả cho thấy nhiệt độ tối cao giảm vào tháng 5, 7, 8 giảm trong khoảng $0,007^{\circ}\text{C}/\text{năm}$ đến $0,03^{\circ}\text{C}/\text{năm}$, tăng vào các tháng còn lại với biên độ tăng từ $0,006^{\circ}\text{C}/\text{năm}$ đến $0,05^{\circ}\text{C}/\text{năm}$. Kết quả với nhiệt độ tối thấp cũng chỉ ra được tháng 2, 7 và 8 là 3 tháng có xu hướng giảm với biên độ nhiệt giao động từ $0,0025^{\circ}\text{C}/\text{năm}$ đến $0,0136^{\circ}\text{C}/\text{năm}$ và các tháng còn lại tăng dao động từ $0,01^{\circ}\text{C}/\text{năm}$ đến $0,1^{\circ}\text{C}/\text{năm}$. Bên cạnh đó, kết quả dự báo xu thế biến đổi nhiệt độ tối thấp và tối cao với kịch bản Biến đổi khí hậu cho thấy phù hợp với kịch bản phát thải thấp (B1) và kịch bản RCP 4.5. Kết quả nghiên cứu đã đóng góp thêm một cơ sở khoa học để đánh giá xu thế biến đổi và dự báo trong lĩnh vực Khí tượng Thủy văn, giúp cho việc xây dựng những kế hoạch, và giải pháp thích ứng trong bối cảnh Biến đổi khí hậu.

Từ khóa: biến đổi khí hậu; Mann-Kendall; phân tích phi tham số; Theil-Sen