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Research Article

STUDY ON CHARACTERISTICS OF MAXIMUM AND MINIMUM TEMPERATURES IN THE CONTEXT OF CLIMATE CHANGE IN NINH THUAN PROVINCE

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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 from 0.007^0C per year to 0.03^0C per year, increasing in the remaining months with an increasing amplitude from 0.006^0C per year to 0.05^0C. The lowest minimum temperature also showed that February, July, and August are the three months whose temperature decreases from 0.0025^0C per year to 0.0136^0C per year, and the remaining months increase from 0.01^0C to 0.1^0C per year. In addition, the predicting results of the trend of minimum and maximum temperature that change with the Climate Change scenario are consistent with the low emission scenario (B1) and the RCP 4.5 scenario. The research results have contributed to providing more evidence of the changing trends and predictions in hydrometeorology. This can be beneficial to 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 0.7^0C, 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 1.4^0C to 1.8^0C, the average annual minimum temperature nationwide has a typical increase from 1.4^0C to 1.6^0C by mid-century 21st (Ministry of Natural Resources and Environment, 2016). 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

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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 entire 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 used climate data of Ninh Thuan province from 1992 to 2016 to forecast the future change trends. In this study, a non-parametric approach will be used to assess and predict the trend of changing maximum and minimum temperature in Ninh Thuan in the context of climate change.

2. Methods and research data

2.1. Methods

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

MK_{test} and TS_{slope} methods are the 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 Bacanli, 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). Mullick et al. (2019) 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. A study by Livada et al. (2019) 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. Research by Asfaw et al. (2018) 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.

In Vietnam, many research works related to Meteorology and Hydrology are also used more and more. 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 publications (Ngo et al., 2012). 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; the results also contributed to the development of solutions to contribute limitations and adaptation 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:

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

where:

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

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, Var(S) is calculated by the formula:

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

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 Var(S)>0, then the trend is positive, and 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:

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

The results of Z analysis show that if Z>0, it proves an uptrend, and Z<0, it proves a 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):

$$Q = \frac{x_i' - x_i{}'}{i' - i} \qquad with\ i=1,2,3...\ n \tag{5}$$

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:

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

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-*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 project – Climatic and Hydrological characteristics of Ninh Thuan province by 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

Tables 1 and 2 showed that the T_{max} and T_{min} had a considerable difference, ranging from 14.0^0C to 42.0^0C. Regarding the T_{max}, the highest temperature is 42^0C in Ma Moi area, and the lowest is 31.6^0C in the Phuoc Binh area. Besides, the temperature for the rainy season months is lower than that of the dry season months: with rainy season months from 33.2^0C to 39.0^0C with rainy season months and 31.6^0C to 42.0^0C for the dry season (Table 1). With the T_{min} consistently below 20^0C, it ranges from 14.0^0C to 23.2^0C (Table 2). The average T_{min} varies between regions, with Phan Rang having the highest temperature (16.0^0C-23.3^0C) and Phuoc Binh being the area with the lowest temperature in the region (14.0^0C-18.8^0C).

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

Station	Month (^{0}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

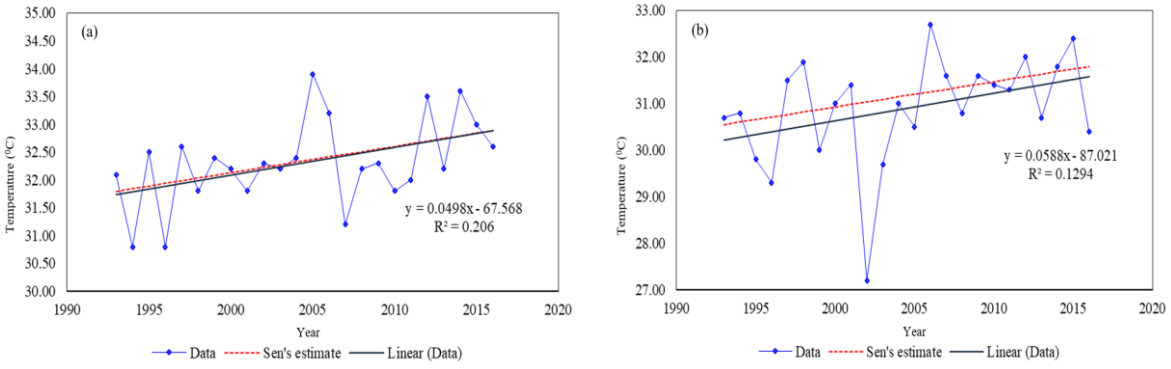
Table 2. *Average minimum temperature (T_{min}) in Ninh Thuan*

Station	Month (^0C)											
	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

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. The TS_{slope}, the T_{max} in May, July, and August decreased by 0.01^{0}C. In May, the temperature drops from 0.01^{0}C to 0.02^{0}C, and this trend continues to decrease. In July, the Tmax decreases from 0.003^{0}C to 0.01^{0}C. In August, the T_{max} tends to decrease from 0.0067^{0}C to 0.01^{0}C. In the remaining months, most of the T_{max} tend to increase from 0.01^{0}C to 0.05^{0}C, of which a slight increase is in January, February, March, April, June, September, October, and November, while December is the highest. In November, the Z(s) index reached 1,800 with a confidence level of 0.04 (p-value < 0.05) and TS_{slope} was 0.05. The results showed that the T_{max} in Ninh Thuan increased by 0.05^{0}C per year (Figure 1b). The calculation results in December are similar, and T_{max} increases by 0.05^{0}C with a p-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^{0}C per year.



(a) *(b)*

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

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 0.0025^0C to 0.0136^0C, 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 0.02^0C per year. The highest increase is about 0.1^0C per year (December), and the lowest decrease is about 0.014^0C per year.

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

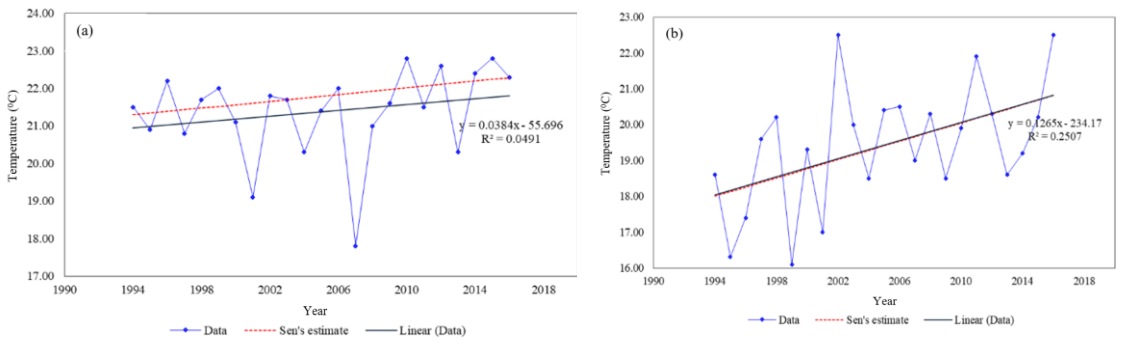
Results		Months											
		1	2	3	4	5	6	7	8	9	10	11	12
Mann-Kendall	N	24	24	24	24	24	24	24	24	24	24	24	24
	M-K Test Value (S)	9	47	16	31	-9	36	-11	-17	47	34	73	73
	Critical Value (0.05)	1.645	1.65	1.645	1.65	-1.65	1.65	-1.645	-1.65	1.65	1.6	1.65	1.65
	Standard Deviation of S	40.22	40.2	40.12	40.2	40.3	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



(a) *(b)*

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

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

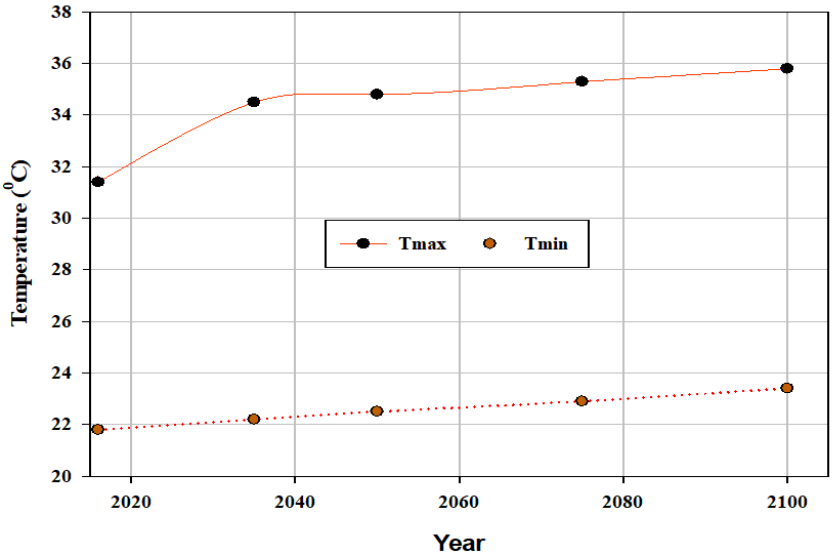


Figure 3. *Prediction trend of change until the end of the 21st century*

The prediction trend 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 2100. Figure 3 shows that the T_{max} increases with each year. In 1992-2016, the T_{max} was 31.4^{0}C, predicted that by 2035, the T_{max} would increase by 0.4^{0}C with a T_{max} of 34.5^{0}C. In 2050 it will increase to 35.8^{0}C. In 2075 it will be 35.3^{0}C, and by 2100 will be 35.8^{0}C. The difference between T_{min} between the prediction period and the year 2100 is from 1.5^{0}C (21.8^{0}C to 23.4^{0}C). In addition, in the middle of the 21st century, the T_{min} is below 23^{0}C, with the temperature in 2035 being about 22.2^{0}C. In 2050 it will be 22.5^{0}C, and in 2075 the temperature could reach 22.9^{0}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^{0}C to the end of the 21st century. January and March are the two months that tend to increase below 1.0^{0}C until the end of the 21st century. In which, January increases from 31.3^{0}C to 31.8^{0}C, and March increases from 33.3^{0}C to 34.1^{0}C. Besides, there are months of increase above 2.0^{0}C are April (2.8^{0}C), June (2.8^{0}C), and September (2.5^{0}C). To the end of the century, April from 34.7^{0}C to 37.5^{0}C, June 36.7^{0}C to 39.5^{0}C, and September 35.70C to 38.2^{0}C. Finally, November and December are the two months with the highest increase above 4.0^{0}C, in which November is 4.1^{0}C and December is 4.6^{0}C (Table 5).

Table 5. *Prediction results of T_{max} change trend according to TS_{slope} (Unit: ^0C)*

Year	Months (^{0}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

Table 6. *Prediction results of T_{min} change trend according to TS_{slope} (Unit: ^0C)*

Year	Months (^{0}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

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} increased from 19.4^{0}C to 29.0^{0}C at the end of the 21st century. Besides, April and November have temperature increase above 2.0^{0}C and March, June, and September, with the forecasted increase ranging from 1.3^{0}C to 1.7^{0}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^{0}C-1.7^{0}C by mid-century to 21 and from 2.0^{0}C-3.2^{0}C by the 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^{0}C-1.8^{0}C T_{max}, T_{min} increased from 1.4^{0}C up to 1.6^{0}C; By the end of the 21st century, increasing from 1.7^{0}C to 2.7^{0}C T_{max}, T_{min} increased from 1.8^{0}C to 2.2^{0}C (Ministry of Natural Resources and Environment, 2016).

Based on the two scenarios and T_{max} and T_{min}, the prediction results are similar to the two scenarios issued by the Ministry of Natural Resources and Environment in 2012 and 2016 (Table 7). Specifically, in the prediction results of T_{max}, the temperature will increase by 1.1^{0}C by the middle of the 21st century. This result is similar to the low emission scenario (B1) from 1.1^{0}C to 1.7^{0}C and tends to increase compared to Scenario RCP4.5. Besides, the forecast value of T_{max} is similar to the scenarios at the end of the 21st century. The T_{max} increase of 2.80C is similar to the low emission scenario (2.0^{0}C-3.2^{0}C) and the RCP4.5

scenario (1.7^0C-2.7^0C). The T_{min} result is similar to the low emission scenarios (1.1^0C to 1.7^0C) and RCP4.5 (1.4^0C-1.6^0C). Finally, at the end of the 21st century, the T_{min} is similar with the two scenarios: 2.6^0C versus 2.0^0C ÷ 3.2^0C (B1) and 1.8^0C ÷ 2.2^0C (RCP 4.5).

Thus, the study of prediction results is similar to the two scenarios of the Ministry of natural resources and environment, yet three differences were found with T_{max} and T_{min}. This difference could be attributed to how the input data were analyzed, solely on temperature, while the two compared scenarios were based on many factors.

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

4. Conclusion

The study evaluated and predicted the trends of the T_{max} and T_{min} in Ninh Thuan through a non-parametric test. The test results show that T_{max} *and* T_{min} tend to increase by 0.02^0C per year during the study period. 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, the results show many similarities. Some forecasts are very consistent with the two scenarios, 2012 and 2016. The T_{max} results are the same as 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^{0}C/năm đến 0,03^{0}C/năm, tăng vào các tháng còn lại với biên độ tăng từ 0,006^{0}C/năm đến 0,05^{0}C/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 dao động từ 0,0025^{0}C/năm đến 0,0136^{0}C/năm và các tháng còn lại tăng dao động từ 0,01^{0}C/năm đến 0,1^{0}C/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