Atmospheric and Climate Sciences, 2021, 11, 697-708
https://www.scirp.org/journal/acs
ISSN Online: 2160-0422
ISSN Print: 2160-0414

The Seasonal Rainfall Forecast in Nanning City in 2019 with the Method of Trend Comparison Ratio (TCR)

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How to cite this paper: Tan, R.Z., Wang, C.Z. and Chen, R. (2021) The Seasonal Rainfall Forecast in Nanning City in 2019 with the Method of Trend Comparison Ratio (TCR). *Atmospheric and Climate Sciences*, **11**, 697-708.
https://doi.org/10.4236/acs.2021.114041

Received: August 23, 2021
Accepted: October 18, 2021
Published: October 21, 2021

Abstract

In this paper, the monthly rainfall statistical data of Nanning City, Capital of Guangxi Zhuang Autonomous Region, China, from 2006 to 2018, were collected. On the basis of qualitative analysis of the rainfall seasonal changing law, the non-linear seasonal rainfall forecast model on Nanning City with the method of Trend Comparison Ratio (TCR) was established by the statistical analysis software Office Excel 2013. The model was used to predict the rainfall in spring, summer, autumn and winter in Nanning in 2019. The results were: 286.41 mm, 695.79 mm, 292.20 mm and 118.11 mm, respectively. It was also found that the predicted results were consistent with the seasonal distribution characteristics, annual distribution characteristics and the trend of historical rainfall time series fluctuation, through the qualitative analysis of figures. Compared with the actual measured rainfall data of Nanning City in 2019 in the China Statistical Yearbook (2020), the predicted values are basically consistent with the measured values.

Keywords

Rainfall, Forecast, Trend Comparison Ratio (TCR), Nanning City

1. Introduction

The time series is a sequence of objective numbers arranged in chronological order. It contains the rule of a certain phenomenon changing with time in the objective material world. The time series analysis is a statistical technique to discover the rule of time series variables and predict them [1] [2].

Usually, time series are influenced by long-term trends, periodic fluctuations and irregular changes. Mostly, the seasonal variation can reflect the periodicity of time series. Seasonal variation analysis has been widely used not only in the field of natural science, such as meteorology, hydrology, seismology, crops diseases and insect pests forecasting, environmental pollution control, ecological system dynamic analysis, astronomy, and oceanography, but also in the field of sociology and economics, such as national economy macro-control, regional comprehensive development planning, enterprise management and market potential prediction [3]-[8]. The Method of Mean Trend Adjustment (MTA), Trend Comparison Ratio (TCR), Sequential Method and Winster's Method are the common methods of seasonal forecasting analysis [9].

The frequent natural disasters, such as flood, drought, landslide and debris flow, seriously threaten life safety and cause huge economic losses. Rainfall is an important factor causing all kinds of natural disasters [10]. Therefore, rainfall prediction is the basis of disastrous weather prediction. How to improve the accuracy of rainfall prediction and to ensure the accurate prediction and timely early warning of disastrous weather has become the focus and difficulty of current research. At present, the data of rainfall prediction are mainly based on ground observation stations and satellite radar meteorological data for short-term and imminent prediction [11] [12]. There are problems such as uneven distribution of stations, inconsistent length and poor continuity of observation data series, which restricts the reliability of prediction and the accuracy of medium and long-term rainfall prediction. In this paper, the monthly rainfall statistical data of Nanning City, Capital of Guangxi Zhuang Autonomous Region, China, from 2006 to 2018, were collected [13] [14] [15] [16]. On the basis of qualitative analysis of the rainfall seasonal changing rule, the non-linear seasonal rainfall forecast model on Nanning City with the method of Trend Comparison Ratio (TCR) was established by the statistical analysis software Office Excel 2013 [17]. And the model was used to predict the rainfall in spring, summer, autumn and winter in Nanning in 2019. This research tries to develop a rainfall prediction tool which is easy to access and can make up for the shortage of meteorological data to a certain extent. At the same time, this tool also can be calibrated in other regions.

2. Study Area

Nanning is located in the south of the Tropic of Cancer, southwest of Guangxi Zhuang Autonomous Region, China, between 107˚45' - 108˚51'E and 22˚13' - 23˚32'N. The climate type of Nanning belongs to the subtropical monsoon humid climate, where is full of light, plenty of rainfall and the summer is longer and the winter is relatively short. Nanning is mild in spring and autumn, hot and humid in summer. And there is no snow in winter. The average annual temperature is 21.6˚C. The extremely maximum temperature is 40.4˚C, and the extremely minimum temperature is −2.4˚C. The average perennial rainfall is between 1241 mm and 1753 mm. Average relative humidity is 79%.

The main rivers in Nanning belong to Xijiang River system of the Zhu drainage. The larger rivers are Yongjiang River, Youjiang River, Zuojiang River, Hongshui River, Wuming River, Bachi River. This means Nanning is rich in water resources. The perennial average groundwater modulus is 1.11×10^5 m^3/km^2. Perennial average shallow groundwater recharge is 2.5×10^9 m^3. Surface runoff is 15.6 billion/m^3. Total water resources are about 55.6 billion/m^3.

3. Study Method

Firstly, the starting and developing time of variables will be reconstructed by the method of Trend Comparison Ratio (TCR) according to the historical data. Secondly, the seasonal trend model will be established generally according with the seasonal statistical variables. Then, the historical trend value of each season (theoretical value) will be calculated by the seasonal trend model above. Thirdly, the seasonal trend comparison ratio of each season according to the difference between the true value and the trend value (theoretical value) will be calculated. Then the seasonal factors of the variations will be obtained. Finally, the trend model will be modified and corrected by the seasonal factors and then can be used to predict the seasonal variables of the future [18] [19]. The detail steps are as follows:

1) Calculate the statistical value of variable y in the same season and different years according to the statistical data of multi-years (the total or the mean, usually). Define them as y_i.

2) Construct the linear regression model according to the statistical value y_i of each season and the customized season order s.

$$\hat{y}_s = A + Bs \tag{1}$$

where, "A" and "B" are the linear correlation coefficients obtained by the least square method. "s" represents the terms of seasons, and the starting season of the reference starting year is the first.

3) Use the above linear regression model to calculate the trend value of variable y in each season and get the theoretical value defined as y_{si}. The ratio between the true value y_i and the theoretical value y_{si} in the same season and different years are defined as the seasonal trend ratio f_i.

$$f_i = \frac{y_i}{y_{si}} \tag{2}$$

4) After eliminating the influence of seasonal variation on variables by using the correction factor θ (see the following for the algorithm detail), the adjustment coefficients F_i of each season are obtained.

$$F_i = f_i * \theta \tag{3}$$

5) Finally, the established seasonal TCR prediction model is as follows:

$$\hat{y}_s = (A + Bs) * F_i \tag{4}$$

where, "*s*" represents the ordinal value of time series with the seasonal ordinal number; "*i*" represents the *i*th season.

4. Data Collection and Analysis

4.1. Data Collection

The rainfall data of Nanning City in this paper are all from the China Statistical Yearbook (2007-2019), but the actual statistical period is from 2006 to 2018, 13 years totally. Annual rainfall data include the month data and the whole year data, and the unit is mm, the accuracy is 0.1 mm (Table 1).

4.2. Data Analysis

4.2.1. Seasonal Statistics

Because of the distinctive characteristics of seasonal cycle, first of all, seasonal rainfall data in Nanning City of each year were analyzed. Additionally, spring (Marked as 1) is in March, April and May. Summer (Marked as 2) is in June, July and August. Autumn (Marked as 3) falls in September, October and November. Winter (Marked as 4) is January, February and December every year. In order to keep up with the yearbook, winter is January, February and December of the same year, not from the December of a year to February of the following year.

According to statistics, the total rainfall in summer of Nanning from 2006 to 2018 is 8398.7 mm, with an average of 646.0 mm. The total rainfall in autumn is 3550.5 mm, with an average of 273.1 mm. The total rainfall in spring is 3483.3 mm, with an average of 267.9 mm. The total rainfall in winter is 1435.3 mm, with an average of 110.4 mm. The total rainfall in summer is higher than that in

Table 1. The rainfall data in Nanning City from 2006 to 2018 (mm).

M./Y.	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
Jan.	1.0	10.4	76.1	7.9	150.7	13.5	75.6	17.0	1.5	37.4	129.1	72.5	32.3
Feb.	63.7	26.9	70.0	2.1	3.8	32.3	18.7	26.4	15.6	22.5	19.0	7.5	16.7
Mar.	36.5	74.7	18.7	37.7	9.1	97.8	33.2	82.2	30.9	42.3	38.6	164.9	69.5
Apr.	24.1	12.2	45.2	114.3	126.8	78.1	35.6	148.5	52.2	43.5	130.8	8.2	60.1
May	119.6	129.2	121.8	149.6	168.4	56.1	159.8	138.6	51.7	99.0	203.8	300.8	169.2
Jun.	169.2	100.3	300.6	150.6	282.1	242.8	97.9	198.0	147.8	79.8	345.2	101.3	223.1
Jul.	461.6	214.8	260.1	241.2	326.1	102.9	109.2	265.3	274.8	235.3	76.0	290.0	337.8
Aug.	225.5	231.1	317.4	125.1	103.8	109.3	253.4	271.2	122.2	242.8	355.2	256.1	151.8
Sep.	7.5	142.6	187.6	42.8	161.5	186.2	56.4	128.5	329.2	131.8	47.2	81.5	99.5
Oct.	5.1	26.6	47.6	75.1	2.5	312.8	148.7	17.6	86.9	56.6	152.8	149.6	67.4
Nov.	45.2	16.0	156.0	8.4	10.1	1.4	53.2	211.2	74.8	98.1	44.6	63.3	16.6
Dec.	0.4	23.3	23.9	8.3	32.0	19.7	45.1	64.8	47.1	133.2	4.1	53.0	30.2
Total	1159.4	1008.1	1625.0	963.1	1376.9	1252.9	1086.8	1569.3	1234.7	1222.3	1546.4	1548.7	1274.2

the other three seasons significantly, 136.5% higher than that in autumn, 141.1% higher than that in spring, and 485.2% higher than that in winter. The difference of perennial rainfall in spring and autumn is not significant, with the difference of 67.2 mm only.

The annual statistical results of rainfall in spring, summer, autumn and winter from 2006 to 2018 are shown in **Table 2**. The annual distribution of seasonal rainfall is shown in **Figure 1**. It can be seen from the figure intuitively that the rainfall in Nanning City is distributed in summer mainly, and the rainfall decreases in the order of summer, autumn, spring and winter.

4.2.2. Trend Comparison Ratio Modeling

Input the monthly rainfall data of Nanning City from 2006 to 2018 into Excel 2013 and calculate the amount rainfall in different seasons and different years [17], then construct the seasonal sequence with spring of 2006 as the starting time (**Table 3**).

A linear regression model was established with the seasonal rainfall as variable y and the seasonal ordinal number as independent variable x (**Figure 2**).

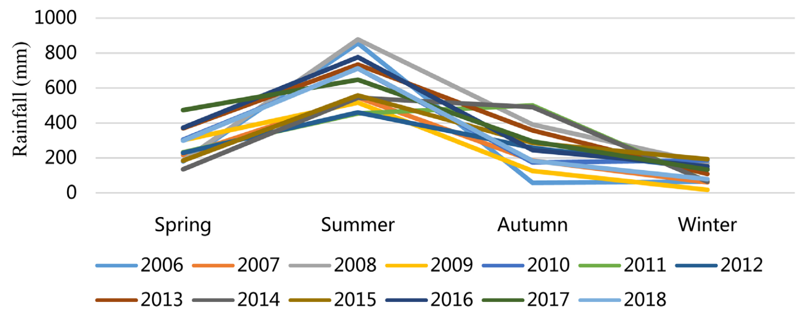

Figure 1. Seasonal rainfall in Nanning City in multi-years.

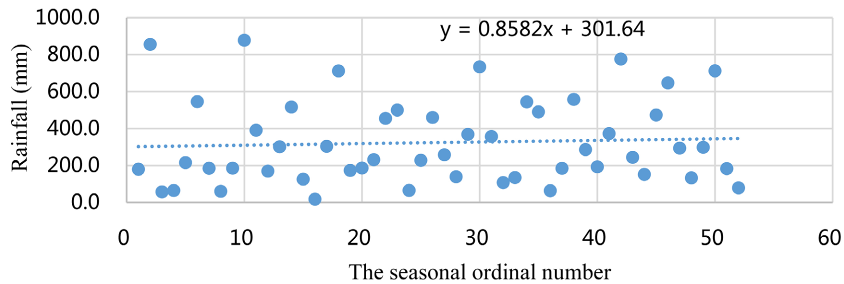

Figure 2. Linear regression model about seasonal rainfall and seasonal ordinal number.

Table 2. The seasonal rainfall in Nanning City from 2016 to 2018 (mm).

S./Y.	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
Spring	180.2	216.1	185.7	301.6	304.3	232	228.6	369.3	134.8	184.8	373.2	473.9	298.8
Summer	856.3	546.2	878.1	516.9	712	455	460.5	734.5	544.8	557.9	776.4	647.4	712.7
Autumn	57.8	185.2	391.2	126.3	174.1	500.4	258.3	357.3	490.9	286.5	244.6	294.4	183.5
Winter	65.1	60.6	170	18.3	186.5	65.5	139.4	108.2	64.2	193.1	152.2	133	79.2

Table 3. The rainfall seasonal series of Nanning City from 2006 to 2018.

Year	Season	Ordinal No.	Rainfall (mm)	Trend Value (mm)	Ratio (fi)
2006	1	1	180.2	302.50	59.57%
	2	2	856.3	303.36	282.28%
	3	3	57.8	304.21	19.00%
	4	4	65.1	305.07	21.34%
2007	1	5	216.1	305.93	70.64%
	2	6	546.2	306.79	178.04%
	3	7	185.2	307.65	60.20%
	4	8	60.6	308.51	19.64%
2008	1	9	185.7	309.36	60.03%
	2	10	878.1	310.22	283.06%
	3	11	391.2	311.08	125.76%
	4	12	170	311.94	54.50%
2009	1	13	301.6	312.80	96.42%
	2	14	516.9	313.65	164.80%
	3	15	126.3	314.51	40.16%
	4	16	18.3	315.37	5.80%
2010	1	17	304.3	316.23	96.23%
	2	18	712	317.09	224.54%
	3	19	174.1	317.95	54.76%
	4	20	186.5	318.80	58.50%
2011	1	21	232	319.66	72.58%
	2	22	455	320.52	141.96%
	3	23	500.4	321.38	155.70%
	4	24	65.5	322.24	20.33%
2012	1	25	228.6	323.10	70.75%
	2	26	460.5	323.95	142.15%
	3	27	258.3	324.81	79.52%
	4	28	139.4	325.67	42.80%
2013	1	29	369.3	326.53	113.10%
	2	30	734.5	327.39	224.35%
	3	31	357.3	328.24	108.85%
	4	32	108.2	329.10	32.88%
2014	1	33	134.8	329.96	40.85%
	2	34	544.8	330.82	164.68%
	3	35	490.9	331.68	148.01%
	4	36	64.2	332.54	19.31%

Continued

2015	1	37	184.8	333.39	55.43%
	2	38	557.9	334.25	166.91%
	3	39	286.5	335.11	85.49%
	4	40	193.1	335.97	57.48%
2016	1	41	373.2	336.83	110.80%
	2	42	776.4	337.68	229.92%
	3	43	244.6	338.54	72.25%
	4	44	152.2	339.40	44.84%
2017	1	45	473.9	340.26	139.28%
	2	46	647.4	341.12	189.79%
	3	47	294.4	341.98	86.09%
	4	48	133	342.83	38.79%
2018	1	49	298.8	343.69	86.94%
	2	50	712.7	344.55	206.85%
	3	51	183.5	345.41	53.13%
	4	52	79.2	346.27	22.87%

Then the linear trend model of seasonal rainfall in Nanning City from 2006 to 2018 was obtained via Formula (5):

$$\hat{y}_s = 0.8582s + 301.64 \tag{5}$$

where: s was measured in quarters. The starting time of the seasonal trend model was spring of 2006 (marked as 1).

The trend value (theoretical value) of seasonal rainfall over the years was calculated by the above seasonal rainfall trend model [20] [21]. And the ratio of the actual value to the trend value was also calculated. The sum of the seasonal ratio should be 400% without the seasonal variation, but it was 399.9941% as showing in **Table 4**.

Therefore, the trend value of each season should be revised. The correction factor θ = 400%/399.9941% = 1.00015. The revised seasonal adjustment coefficients are shown in **Table 4**. After correction, the non-linear seasonal rainfall trend prediction model of Nanning City was obtained as follows [22]:

$$\hat{y}_s = \left(301.64 + 0.8582s\right) * F_i \tag{6}$$

4.2.3. Prediction Results and Evaluation

Based on the method of seasonal Trend Comparison Ratio (TCR), the time starting point of the seasonal rainfall non-linear trend prediction model in Nanning City was the spring of 2006. Thus, it can be inferred that the Ordinal Numbers of the seasons in 2019 are 53 (spring), 54 (summer), 55 (autumn) and 56 (winter), respectively. After substituted the four seasonal ordinals into Formula (6), the forecast rainfall in each season in Nanning City in 2019 was calculated (**Table 5**).

Table 4. The seasonal rainfall ratio and the adjusted seasonal adjustment coefficients.

Year	Seasonal Ratio f_i				Total
	Spring	Summer	Autumn	Winter	
2006	59.5706%	282.2752%	18.9997%	21.3392%	382.1848%
2007	70.6368%	178.0376%	60.1988%	19.6431%	328.5163%
2008	60.0264%	283.0554%	125.7554%	54.4979%	523.3351%
2009	96.4205%	164.7990%	40.1573%	5.8027%	307.1795%
2010	96.2276%	224.5436%	54.7578%	58.4999%	434.0289%
2011	72.5766%	141.9566%	155.7042%	20.3267%	390.5641%
2012	70.7532%	142.1502%	79.5231%	42.8041%	335.2305%
2013	113.0991%	224.3529%	108.8519%	32.8773%	479.1812%
2014	40.8534%	164.6823%	148.0054%	19.3062%	372.8473%
2015	55.4300%	166.9102%	85.4944%	57.4757%	365.3103%
2016	110.7990%	229.9188%	72.2509%	44.8437%	457.8124%
2017	139.2763%	189.7881%	86.0881%	38.7943%	453.9468%
2018	86.9384%	206.8495%	53.1255%	22.8726%	369.7860%
Total	82.5083%	199.9477%	83.7625%	33.7756%	399.9941%
Seasonal Adjustment Coefficient F_i	82.5094%	199.9506%	83.7638%	33.7762%	400.0000%

Table 5. The forecast seasonal rainfall in Nanning in 2019.

Year 2019	Spring	Summer	Autumn	Winter
Season Ordinal No.	53	54	55	56
Predicted Rainfall (mm)	286.41	695.79	292.20	118.11

The predicted rainfall in spring, summer, autumn and winter in Nanning in 2019 are 286.41 mm, 695.79 mm, 292.20 mm and 118.11 mm respectively, according with the annual rainfall decreasing law in Nanning: 1) summer rainfall > autumn rainfall > spring rainfall > winter rainfall; 2) Autumn rainfall is higher than spring rainfall, but only a little.

The seasonal rainfall sequence composed of the predicted results and the known seasonal rainfall sequence over the last 13 years were plotted as a comparison map of seasonal rainfall within a year (**Figure 3**). It can be seen from the red line in the figure that the predicted rainfall value of Nanning in 2019 has the same distribution characteristics basically as the actual rainfall value over the last years [23].

A rainfall time series was made from the predicted rainfall and the actual historical data (**Figure 4**). It can be seen from the figure that there is a consistent fluctuation trend between the predicted value and the historical data [24] [25].

The actually measured rainfall values of each month in Nanning City in China Statistical Yearbook (2020) were converted into the actual rainfall values of each season in Nanning in 2019. The correlation coefficient R^2 between the forecast and the actual values is 0.826. The error analysis results are shown in **Table 6**.

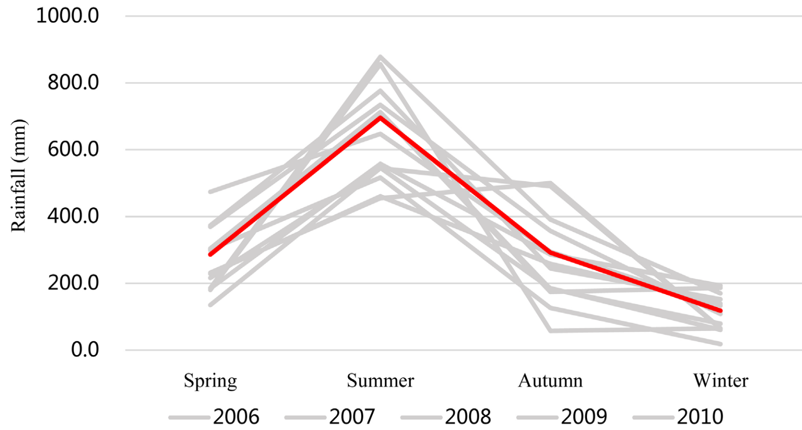

Figure 3. Comparison of the forecast seasonal rainfall and the historical data.

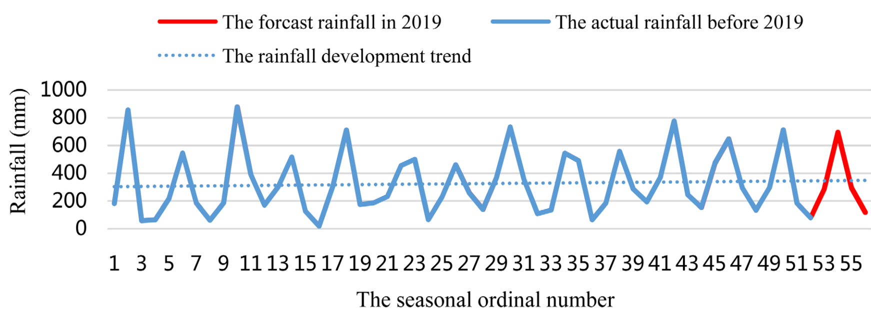

Figure 4. Comparison of the sequence of forecast seasonal rainfall and historical rainfall.

Table 6. The actually measured and the forecast rainfall values and the errors.

Year 2019	Spring	Summer	Autumn	Winter	Whole Year
Actual Rainfall (mm)	334.7	734.8	51.3	101.8	1222.6
Forecast Rainfall (mm)	286.41	695.79	292.2	118.11	1392.5
Absolute Error (mm)	−48.29	−39.01	240.9	16.31	169.9
Relative Error (%)	−14.4%	−5.3%	469.5%	16.0%	13.8%

The forecast rainfall values of spring, summer and winter are consistent with the actual rainfall values basically, while the error of autumn rainfall is larger. It may be affected by the inter-annual variation of various meteorological and hydrological factors, especially by the return period of the extreme variation of rainfall. The reason is very complicated and needs to be analyzed and discussed deeply [26] [27] [28].

5. Conclusions

In this paper, the annual rainfall data of Nanning City from 2006 to 2018 were collected. On the basis of analyzing the general trend of seasonal rainfall over the years, the non-linear prediction model of seasonal rainfall in Nanning with the method of Trend Comparison Ratio (TCR) was constructed. And the model was used to predict the rainfall in each season in 2019. The main conclusions are as follows:

1) The TCR prediction model of seasonal rainfall in Nanning is:

$\hat{y}_s = (301.64 + 0.8582s) * F_i$.

2) The forecast rainfall calculated from the model in each season in Nanning in 2019 are 286.41 mm in spring, 695.79 mm in summer, 292.20 mm in autumn, and 118.11 mm in winter.

3) Through the qualitative analysis from the figures in the context above, it is found that the predicted results have the same seasonal distribution law, annual distribution characteristics and time series fluctuation trend with the rainfall data of Nanning City over the last 13 years, basically.

4) The correlation coefficient R^2 between the forecast and the actually measured values is 0.826. The forecast rainfall values of spring, summer and winter are consistent with the actual values basically, but the error between the forecast and the actual rainfall value of autumn is larger.

Acknowledgements

This study was financially supported by the Strategic Priority Research Program of CAS (Grant No. XDA23090303) and the Sichuan Science and Technology Program (Grant No. 2019YFH0040).

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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