

Research on the climate change in Anyang, China

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Abstract: With climate change and the COVID-19, the world is experiencing serious food shortages. China, as a major production country, also has a serious food security problem. As the main grain-producing base in China, the North China Plain is seriously affected by climate change. Moreover, Anyang City is located in the North China Plain with complex and diverse topography. Due to its warm-temperate continental monsoon climate, the main crops in Anyang City are wheat, corn and peanut. Therefore, the city of Anyang is selected as the research object of this paper. The daily temperature and precipitation data of Anyang from 1991 to 2020 were obtained through NOAA website, and the Manner-Kendall trend test and R/S analysis were used to process and study the climate of Anyang in the past 30 years and to predict the future climate development trend. Eventually, the future climate of Anyang is characterized by a decrease in precipitation and an increase in temperature.

Keywords: temperature, precipitation, Manner-Kendall trend test, R/S analysis.

1. Introduction

On March 20, 2023, the United Nations Intergovernmental Panel on Climate Change (IPCC) released its Sixth Assessment Report, Synthesis Report, in Interlaken, Switzerland, which points to a global surface temperature increase of 1.1°C from 2011-2020 compared to 1850-1900 [1]. With unequal historical and future contributions from unsustainable energy use, land use and land-use change, lifestyles and consumption and production patterns across regions, between countries, within countries, and among individuals, global greenhouse gas emissions continue to increase. Anthropogenic climate change is already affecting many extreme weather and climate events in every region of the globe. This has resulted in widespread adverse impacts on nature and people, as well as associated loss and damage. Vulnerable groups that have historically contributed the least to climate change are being disproportionately affected.

Over the past few decades, in the context of global climate change, China, as one of the country's most vulnerable to its changes, has experienced more significant changes in its forests and natural ecosystems, agriculture and livestock, coastal zones, and water resources [2].

Compared to natural ecosystems, agroecosystems are less stable and more vulnerable to climate change as anthropogenic disturbances. In the past 30 years, the overall temperature in China has been rising at a rate significantly higher than the average rate in the northern hemisphere, especially in the North China Plain, where the number of days of rainfall has been decreasing [3]. As one of the most severe drought areas in China, the extremely high rate of spring drought in the North China Plain seriously affects the agroecosystem of the region. In view of the recent New Crown epidemic and the

world food crisis, China is facing serious challenges in food production, and knowing the impact of climate change on crop yields and exploring the corresponding countermeasures are crucial to China's national political stability and food security, sustainable economic development and social harmony [4].

As one of the typical representatives of the North China Plain, this paper takes Anyang City, Henan Province, as an example, to explore its climate change from 1991 to 2020, try to predict future climate change, and make corresponding measures in response to the prediction.

Climate change can have a direct impact on the productive lives of local people. Through the study and prediction of climate change in Anyang, the local agricultural production activities can be adjusted. It can also adjust the economic and industrial development accordingly.

2. Research Area

Anyang City, is located in the northern part of Henan Province, east-central China, between 35°41' and 36°21'N, 113°38' and 114°59'E. The altitude is high in the west and low in the east. With the eastern foothills of the Taihang Mountains in the west and the Yellow Huaihai Plain in the east, the topography of Anyang is complex and diverse, including plains, mountains, hills and other types of landforms [5]. Anyang City is located in a semi-humid area and has a warm temperate continental monsoon climate with cold winters, little rain and snow, dry and windy springs, and hot summers with lots of rain and heat. This climatic feature determines that the crops in Anyang City are mainly wheat, corn and peanuts.

3. Methodology

3.1. The Mann-Kendall Nonparametric Test

The Mann-Kendall nonparametric test does not require a time series. The data obey normal distribution, and the results are not affected by a few outliers. Therefore, it is widely used in time series trend analysis of meteorological and hydrological factors. For a time, series with variable $X = (x_1, x_2, \dots, x_n)$, n being the length of the time series, define S as follows:

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

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

The x_i and x_j represent the values of year i and year j in the time series. Sign is the sign function, and the variance is calculated as:

$$\text{Var} = \frac{n(n-1)(2n+5)}{18} \quad (3)$$

Standardize S to obtain the statistical test value Z_{MK} :

$$Z_{MK} = \begin{cases} \frac{S-1}{\sqrt{Var(S)}} & S > 0 \\ 0 & S = 0 \\ \frac{S+1}{\sqrt{Var(S)}} & S < 0 \end{cases} \quad (4)$$

The final data is the statistical test value Z_{MK} , which is a normally distributed statistic. When $Z_{MK} > 0$, it shows that the time series shows an upward trend. When $Z_{MK} < 0$, it indicates that the time series shows a downward trend. A larger absolute value of Z_{MK} indicates a more significant change. The error rate $\alpha = 0.05$ is generally taken, which corresponds to $Z = 1.96$.

3.2. R/S Analysis

R/S analysis, also known as Scalar Difference Analysis, is a method proposed by the hydrologist Hurst on the basis of a large number of empirical studies, which was further supplemented and refined by Mandelbro and others to develop it into a fractal theory for studying time series. The main calculation process is as follows:

Consider a time series $\{\xi(t)\}$, $t = 1, 2, \dots$, for any positive integer $\tau \geq 1$, and obtain the mean series, cumulative deviation, extreme deviation and standard deviation:

$$\langle \xi \rangle_\tau = \frac{1}{\tau} \sum_{t=1}^{\tau} \xi(t) \quad (5)$$

$$X(t, \tau) = \sum_{\mu=1}^{\tau} (\xi(\mu) - \langle \xi \rangle_\tau) \quad (6)$$

$$R(\tau) = \max_{1 \leq t \leq \tau} X(t, \tau) - \min_{1 \leq t \leq \tau} X(t, \tau) \quad (7)$$

$$S(\tau) = \left[\frac{1}{\tau} \sum_{t=1}^{\tau} (\xi(t) - \langle \xi \rangle_\tau)^2 \right]^{\frac{1}{2}} \quad (8)$$

The following scalar relationship was found:

$$\frac{R(\tau)}{S(\tau)} = K \left(\frac{\tau}{2} \right)^H \quad (9)$$

The K is the scaling factor. The final H obtained is the Hurst exponent. The mathematical meaning of the Hurst index can be reflected by its relationship with the autocorrelation coefficient of the difference series. The value of autocorrelation coefficient determines that the Hurst index must be between 0 and 1. When $H = 0.5$, it indicates that the time series differential autocorrelation coefficient is 0. The changes before and after the time series are unrelated. When $H < 0.5$, it indicates that the time series differential autocorrelation coefficient is less than 0. The changes in the time series are negatively correlated before and after. Such series have inverse persistence. When $H > 0.5$, it indicates that the time series differential autocorrelation coefficient is less than 0. The changes in the

time series are positively correlated before and after. This kind of series has persistence. When H is closer to 0.5, the correlation is weaker, and the possibility of data fluctuation is greater.

3.3. Data Source

This article uses the Mann-Kendall Nonparametric test and R/S analysis to study and predict the climate of Anyang City, Henan province, in the past 30 years. The climate data used in the analysis of this article are mainly selected from the daily temperature and precipitation data of Anyang, Henan, from 1991 to 2020. The specific data are taken from the surface meteorological data (web) provided by the NOAA website [6].

3.4. Result

The data analysis of the temperature in Anyang City from 1991 to 2020 was obtained by M-K test with R/S analysis method as shown in Fig.1 and Fig.2.

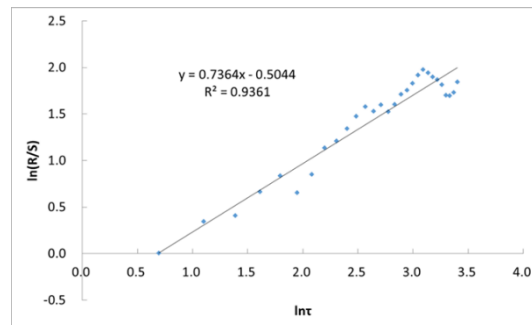


Figure 1: Historical temperature data R/S analysis

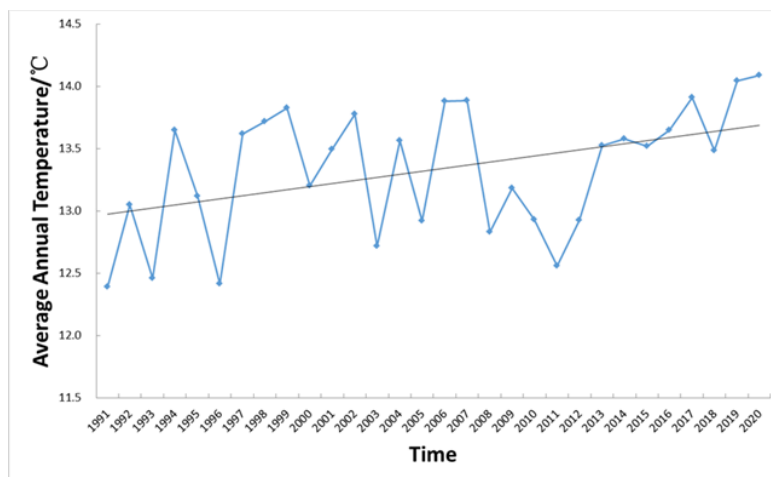


Figure 2: The average annual temperature in Anyang from 1991 to 2020

Specific values are obtained that $Z_{MK} = 2.44 > 1.96$, $H = 0.74$. The data are credible, and the future trend is consistent with the past trend, which are both upward and less volatile.

The data analysis of the precipitation in Anyang City from 1991 to 2020 was obtained by M-K test with R/S analysis method as shown in Fig.3 and Fig.4.

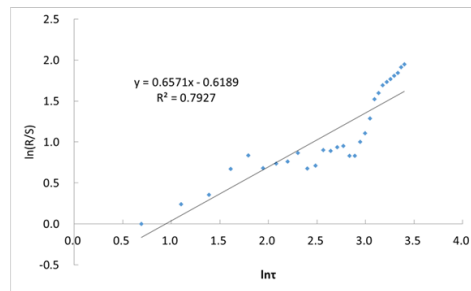


Figure 3: Historical precipitation data R/S analysis

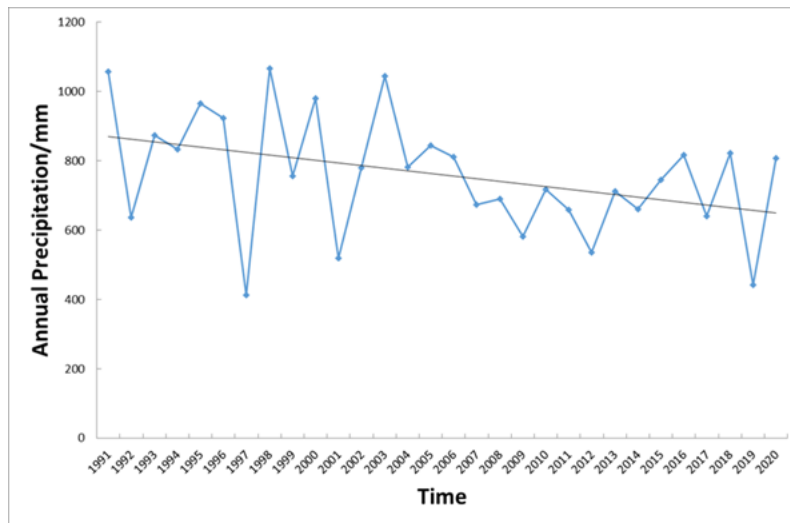


Figure 4: The average annual precipitation in Anyang from 1991 to 2020

Specific values are obtained that $Z_{MK} = -2.00$, $|Z_{MK}| > 1.96$, $H = 0.66$. The data are credible, and the future trend is consistent with the past trend, which are both decreasing. However, the future precipitation values are more volatile because the Hurst index is biased towards 0.5.

The results of both methods show that the climate change in Anyang over the past 30 years has been roughly characterized by a slow increase in temperature and a yearly decrease in rainfall. And this climate change will continue in the recent coming years.

4. Analysis

4.1. Reasons

According to above data, the climate change in Anyang during this 30-year period has been characterized by a continuous increase in temperature and a continuous decrease in precipitation. This climate change in Anyang has been studied from different perspectives and categorized into two factors, natural and perceived.

4.1.1. Natural Factors.

In recent decades, the sun's activity has been intensifying and the energy radiated to the earth has been increasing, leading to an increase in global warming and changes in many aspects of climate conditions. Anyang is not an exception. In the context of global warming, the average temperature of Anyang and the entire North China Plain is rising. The temperature rise is roughly the same for each seasonal influence section. Moreover, the frequent occurrence of El Niño phenomenon, together with

global warming, and the continuous northward shift of high pressure in the western Pacific Ocean have led to a continuous decrease of precipitation in Anyang in summer, and the possibility of drought occurring every year is increasing.

4.1.2. Human Factors.

The deforestation of deep forests on the Taihang Mountains in western Anyang and the increasing industrial activities of digging mountains for sand and stones have led to the destruction of land, severe soil erosion and a significant reduction in the absorption capacity of greenhouse gases such as carbon dioxide. The construction of cities has increased the heat island effect, leading to a greater than average increase in temperature where people live. Moreover, the expansion of Anyang City and the increasing number of concrete roads have decreased the ability and capacity of the land to preserve moisture, and the air humidity and precipitation are decreasing. Moreover, the increase of factories and the emission of exhaust gases in recent years have caused serious damage to the atmospheric environment of Anyang itself, and the climate's ability to self-regulate has decreased.

4.2. Effects

Over the past 30 years, the average temperature in Anyang has increased by 0.5°C and the annual precipitation has decreased by nearly 200mm [7], which has a great impact on human life and agricultural production.

4.2.1. Human Life.

Water resources, as an essential component of human daily life and a key factor limiting agricultural development, are also directly related to China's food security. In the past decades, global climate change has had a significant impact on China's total water resources and their spatial and temporal distribution patterns, exacerbating the instability of agricultural water resources and the contradiction between supply and demand, as well as affecting people's daily life.

On the living side, the city's major rivers are drying up every day, with the number and timing of rivers drying up increasing each year, and even some rivers drying up all year round. The river situation in Anyang City in the past years is shown in the Table.1, including the data with regard to precipitation, the runoff depth, the runoff and the runoff coefficient from 1956 to 2008.

Table 1: Data of Anyang River basin from 1956 to 2008 [8]

Time (Year)	Precipitation(mm)	Runoff Depth(mm)	Runoff(10^8 mm)	Runoff Coefficient
1956-1968	628.0	241.0	3.577	0.383
1969-1978	574.3	170.2	2.526	0.294
1979-1988	566.9	148.4	2.203	0.270
1989-1998	551.5	144.7	2.147	1.255
1999-2008	530.7	101.5	1.505	0.191

Summer high temperatures continue to break records, and hot weather is appearing earlier, leading to an increasing probability of heat stroke. And the increase in average temperatures and the decrease in air humidity are providing better conditions for the spread of the virus. The COVID -19 also has also rapidly increased the speed of transmission and the scope of its influence. In addition, it will also increase the number of people suffering from respiratory diseases every winter, and the situation is not optimistic.

4.2.2. Agricultural Production.

In agricultural production, increase in temperature and decrease in precipitation have both led to a constant change in agricultural production patterns and a slow decrease in the crop maturity cycle [8]. As a result of the study, the mu and total yield of wheat in Anyang are increasing. The wheat production in Anyang City from 2000-2015 is shown in the fig.5. However, the increase in total yield is significantly lower than the increase in mu yield, indicating that the land available for agricultural production is shrinking in the face of decreasing precipitation, which may be the result of the expansion of industry. Moreover, the significant decrease in precipitation during the summer has resulted in having to divert water from outside for irrigation, which also increases production costs. Also, both the increased temperatures and reduced precipitation in winter increase the potential for winter egg hatching, directly leading to an increased risk of pest infestation.

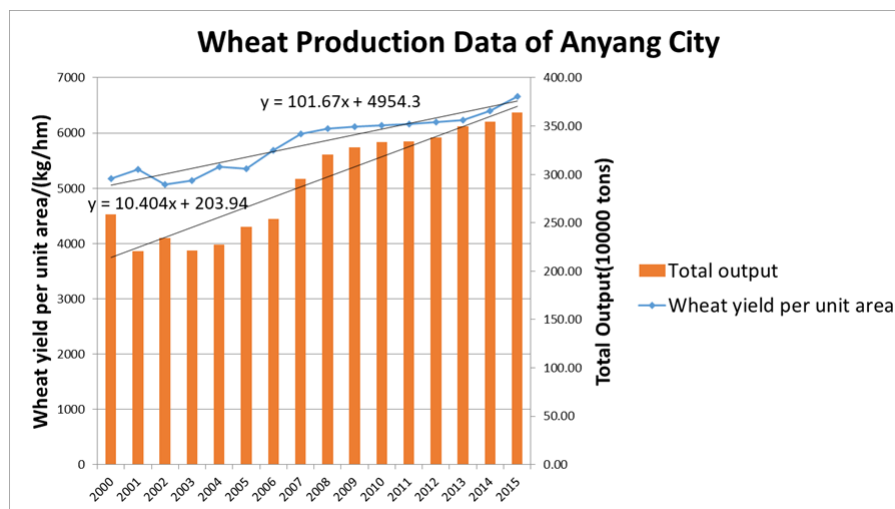


Figure 5: Wheat production data of Anyang from 2000 to 2015 [9]

5. Suggestions

In response to Anyang's changing abnormal climate in recent years, the government may consider slowly adjusting the pace of agricultural production or selecting some crops that are more adapted to today's climate conditions for cultivation in order to reduce agricultural losses. Since it is impossible to change the trend of global warming, it should try its best to slow down its rate of change. There is a lot of abandoned land on top of barren mountains and around cities. Moreover, the government can use it to plant trees to improve land conditions and increase the capacity to deal with greenhouse gases, slowing the trend of rising temperatures and decreasing precipitation. Finally, technology should not be ignored. The government should vigorously develop the level of science and technology for weather forecasting. Increase the accuracy and predictability of early warnings for abnormal and extreme weather so that the government and people can be better prepared for unpredictable events. At the same time, reduce the number of oops events to reduce non-essential spending.

6. Conclusion

By studying and summarizing the precipitation and temperature data of Anyang City from 1991 to 2020, we found that the overall trend of temperature is increasing and precipitation is decreasing in Anyang over 30 years. Among them, the trend of future changes in temperature is closer to the trend of the previous 30 years. And the trend of future changes in precipitation is overall consistent with the previous ones, but specifically, the data will fluctuate. There may be several years of small

increases or large decreases in precipitation. These can adversely affect adjusted agricultural production and people's lives, including reduced food production, increased disease, and economic losses.

This article focuses on the summary prediction of some meteorological data of Anyang in the past 30 years by Mann-Kendall test and R/S analysis. However, human factors are not taken into account in the prediction, which may cause a certain degree of bias. Moreover, only the main meteorological data are discussed in this paper. Some factors that may affect production and life have not been considered, and there may be a lot more that can be added in the targeted recommendations section.

References

- [1] oran Rouven, Ogunbode Charles A., Böhm Gisela, Gregersen Thea. *Exposure to and learning from the IPCC special report on 1.5 °C global warming, and public support for climate protests and mitigation policies*[J]. *npj Climate Action*, 2023, 2(1).
- [2] Zhanping Mi. *Research on industrial water demand prediction in Shanxi Province*[J]. *Shanxi Science and Technology*, 2012, 27(1): 6-7.
- [3] Yudian Feng. *Analysis of precipitation, crop reference evapotranspiration and drought risk during winter wheat fertility in the North China Plain*[D]; Chinese Academy of Meteorological Sciences, 2015.
- [4] Ping Li. *Impacts of climate change on China's food security and coping strategies*[D]. Guangdong: Guangdong Ocean University, 2015.
- [5] Wang, R. *Results of Digital Anyang Geospatial Framework Construction Project Released, Resources Guide*, (23), 42-42, 2017.
- [6] NOAA website, *The daily temperature and precipitation data of Anyang, Henan*, <https://www.ncei.noaa.gov/>
- [7] Chen X. *Impact assessment of climate change on irrigation water demand in Henan Province*[D]. North China University of Water Resources and Hydropower, 2017.
- [8] Jianhua Xu. *Mathematical methods in modern geography* [M]. Beijing: Higher Education Press, 2022: 414-417.
- [9] Li Qingji. *Analysis of climate change in Anyang in the last 57a*[J]. *Anhui Agronomy Bulletin*, 2015, 21(05): 131-133.