Hydrothermal Resource Changes and Future Trend Prediction in the Red Jujube Cultivation Area of the Northern Shaanxi Loess Plateau (Postprint)

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Abstract

To reveal the variation characteristics of hydrothermal resources in the jujube planting areas of the Loess Plateau of Northern Shaanxi and provide a scientific basis for the local jujube industry to adapt to climate change, this study utilized temperature and precipitation data from 8 meteorological stations in the jujube planting areas of the Loess Plateau of Northern Shaanxi from 1971 to 2019, as well as projected climate change data for 2021–2050 under medium (RCP4.5) and high (RCP8.5) emission scenarios, and analyzed the variation characteristics of temperature and precipitation using linear trend estimation, Mann-Kendall (M-K) test, and Morlet wavelet analysis. The results show that over the past 49 years, the annual and growing-season average temperatures in the jujube planting areas exhibited a significant increasing trend, with abrupt changes occurring in 1991 and 1993, respectively, and a periodic variation of 44 years. The annual and growing-season precipitation showed a non-significant increasing trend, with a periodic variation of approximately 31 years, and no abrupt change occurred. During 2021–2050, under both RCP4.5 and RCP8.5 scenarios, the annual and growing-season average temperatures showed an increasing trend, with more significant warming under the RCP8.5 emission scenario, and the annual average temperature underwent an abrupt change in 2027. Under both emission scenarios, the annual and growing-season average temperatures exhibited a periodic variation of approximately 31 years. The annual and growing-season precipitation showed a non-significant decreasing trend under the RCP4.5 emission scenario and a non-significant increasing trend under the RCP8.5 emission scenario; no abrupt change in precipitation occurred. Under the RCP4.5 scenario, the annual and growing-season precipitation exhibited a periodic variation of 23–31 years; under the RCP8.5 scenario, a periodic variation of 7 years was observed. The jujube planting areas of Northern Shaanxi

should actively adapt to climate change, adjust planting layouts, select suitable jujube varieties, and promote the sustainable and healthy development of the jujube industry in Northern Shaanxi.

Full Text

Change and Trend Prediction of Water and Heat Resources in Jujube Planting Areas of the Loess Plateau in Northern Shaanxi

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Abstract

To reveal the variation characteristics of water and heat resources in jujube planting areas of the Loess Plateau in northern Shaanxi and provide a scientific basis for the local jujube industry to adapt to climate change, this study analyzed temperature and precipitation data from 1971 to 2019 and projected climate data from 2021 to 2050 under medium (RCP4.5) and high (RCP8.5) emission scenarios. Linear trend estimation, Mann-Kendall abrupt change test, and Morlet wavelet analysis were employed to examine the climatic characteristics. The results show that from 1971 to 2019, both annual mean temperature and growth-season mean temperature exhibited significant increasing trends, with abrupt changes occurring in 1991 and 1993, respectively, and displayed a quasi-periodic oscillation of approximately 44 years. Annual precipitation and growth-season precipitation showed non-significant increasing trends with a periodicity of about 31 years, without abrupt changes. Under both RCP4.5 and RCP8.5 scenarios for 2021-2050, annual and growth-season mean temperatures are projected to continue rising with a 31-year periodic cycle. Precipitation is projected to decrease under RCP4.5 but increase under RCP8.5, though neither trend is statistically significant. Both scenarios indicate periodic variations of 23-31 years for precipitation. With increasing heat resources, the suitable jujube cultivation zone may expand northward, and phenological periods will shift. While warming improves winter survival of jujube trees, it also facilitates overwintering of pests and diseases. Increased precipitation may alleviate drought stress but elevate fruit cracking risks during the maturation stage. It is recommended to optimize climate resource utilization, adjust planting layouts, and select crack-resistant varieties to ensure sustainable development of the jujube industry in northern Shaanxi.

Keywords: climate scenario; change trend; growth season; Loess Plateau of northern Shaanxi

1 Introduction

Jujube is a light- and temperature-loving, drought-resistant crop with strong adaptability, often called "iron crop." The Yellow River coast of the Loess Plateau in northern Shaanxi represents a primary cultivation region for high-quality dried jujube (Zhongyang Muzao). With a planting area of approximately 19$×10^{4}$ hm^2 and annual output of 74.87$×10^{4}$ t, the jujube industry has become a leading agricultural sector in the Loess Plateau region of northern Shaanxi, delivering substantial economic, social, and ecological benefits. The region belongs to arid and semi-arid zones, constituting a typical ecological transition belt with fragile ecosystems, poor soil fertility, and scarce water resources. Global climate change has significantly impacted climatic conditions in the jujube planting areas, posing severe pressures on the ecological environment and presenting various challenges to jujube production.

In recent years, numerous scholars have employed various research methods to investigate past and future trends of climate elements such as temperature and precipitation across different regions. Many domestic scholars have used different statistical analysis methods to examine climate resource changes during crop growth periods in Northwest China, temperature and precipitation variations in Northeast and North Central China, and spatiotemporal changes in temperature and precipitation on the Loess Plateau. Some scholars have also utilized different climate change projection models to simulate future trends of water and heat resources in various regions. Regarding climate change impacts on jujube planting areas along the Shaanxi-Shanxi Yellow River coast, Shaanxi meteorological workers have conducted extensive research, revealing spatiotemporal variation characteristics of climate resources (light, temperature, water) over the past 40 years and their effects on jujube phenology and meteorological disasters. Fine-scale climate suitability zoning for Zhongyang Muzao and impact assessments of climate change on dried jujube suitable areas have also been performed. However, research on jujube planting areas in the Loess Plateau of northern Shaanxi remains relatively limited, particularly regarding water and heat resource changes and predictions under climate scenario projection models, as well as comparative analyses between past and future conditions. This study addresses this gap by analyzing eight representative counties in the region.

1.1 Study Area and Data Sources

This study selected eight jujube-producing counties in Yulin and Yan' an cities of northern Shaanxi as the research area: Fugu, Shenmu, Jiaxian, Wubu, Suide, Qingjian, Yanchuan, and Yanchang. Daily meteorological data including average temperature and precipitation from 1971 to 2019 for these counties were obtained from the Shaanxi Meteorological Information Center. Future climate projection data were derived from the RegCM4 regional climate model, using outputs from the BCC_{CSM1}.1 global climate system model under RCP4.5 and RCP8.5 emission scenarios for 2021-2050. The model has a horizontal resolution of 50 km × 50 km. Bilinear interpolation was applied to convert grid data to meteorological stations in the study area, generating monthly temperature and precipitation time series. By comparing model outputs for 1971-2005 with observed data, a difference transfer function was established and applied to correct the projected dataset, yielding a bias-corrected monthly temperature and precipitation dataset for the jujube planting area.

1.2 Research Methods

Linear trend fitting, Mann-Kendall abrupt change test, and Morlet wavelet function were used to analyze interannual variation trends, abrupt changes, and periodic patterns of annual and growth-season (April-October) average temperature, monthly temperature, annual precipitation, growth-season precipitation, and monthly precipitation in the jujube planting area along the Yellow River coast of northern Shaanxi.

2 Results and Analysis

2.1 Historical Climate Change Characteristics

2.1.1 Temperature Changes From 1971 to 2019, the multi-year mean values of annual average temperature and growth-season average temperature in the planting area were 9.8°C and 19.5°C, respectively, with climate tendency rates of $0.45°C \cdot (10a)^{-1}$ and $0.38°C \cdot (10a)^{-1}$. Both showed increasing trends, with the highest values reaching 18.4°C. Monthly average temperatures displayed upward trends, with the highest tendency rate and most significant warming in July, followed by June, and the lowest in January (Table 1). Mann-Kendall test indicated abrupt changes from cold to warm periods for annual and growth-season average temperatures in 1991 and 1993, respectively, with temperature differences of 0.6°C and 0.5°C before and after the abrupt changes. Morlet wavelet analysis revealed that the annual average temperature sequence had a large-scale center around 44 years, with the oscillation center not closing, indicating continued warming. The temperature experienced cold-warm alternations, with the maximum energy at the 44-year scale representing the main period, and small-scale centers mainly at 4-9 years. The wavelet variance diagram showed three obvious peak points, with the main period being 44 years and secondary periods of 8 years and 4 years (Figure 2). The wavelet transformation of growth-season average temperature was similar, with a large scale at 44 years and small-scale centers mainly at 4-9 years, with a main period of 44 years and secondary period of 8 years.

[Figure 1: see original paper]

[Figure 2: see original paper]

2.1.2 Precipitation Changes Annual precipitation and growth-season precipitation showed non-significant increasing trends, with climate tendency rates of $10.2 \text{ mm} \cdot (10a)^{-1}$ and $15.0 \text{ mm} \cdot (10a)^{-1}$, respectively ($P > 0.05$). Monthly precipitation showed varying trends, with some months increasing and others decreasing non-significantly (Table 1). Mann-Kendall tests revealed no significant abrupt changes in annual or growth-season precipitation. Wavelet analysis indicated that annual precipitation had a primary period of approximately 31 years, with secondary periods of 7-12 years and 3-9 years (Figure 3).

[Figure 3: see original paper]

2.2 Future Climate Projection

2.2.1 Projected Heat Resource Trends Under Future Climate Scenarios Under the medium emission scenario (RCP4.5), the annual average temperature in the jujube planting area of northern Shaanxi is projected to be 11.4°C, an increase of 1.2°C compared to the past, with a maximum interannual difference of 13.0°C. The growth-season average temperature is projected to be 19.5°C, an increase of 1.1°C. No abrupt changes are projected. A 31-year oscillation period exists, showing regional characteristics and cold-warm alternations. The large-scale oscillation center is located around 2000, with maximum energy representing the main period. Small-scale centers are mainly at 4-9 years, with main and secondary periods of 31 years and 8 years, respectively (Figure 4). Monthly average temperatures show increasing trends, with only May passing significance tests ($P < 0.05$). The growth-season temperature shows a non-significant increasing trend with a climate tendency rate of $0.14°C \cdot (10a)^{-1}$ ($P > 0.05$).

Under the high emission scenario (RCP8.5), the annual average temperature is projected to be 11.7°C, representing increases of 1.5°C and 0.3°C compared to the historical period and RCP4.5 scenario, respectively. The maximum interannual difference reaches 13.2°C. The growth-season average temperature is projected to be 20.0°C, with increases of 1.6°C and 0.5°C compared to the historical period and RCP4.5 scenario, respectively. The annual average temperature shows a significant increasing trend with a climate tendency rate of $0.38°C \cdot (10a)^{-1}$ ($P < 0.05$), with more pronounced warming than under RCP4.5. All monthly temperatures increase, with May and July showing significant upward trends. The growth-season temperature increases at a rate of $0.47°C \cdot (10a)^{-1}$ ($P < 0.05$). Mann-Kendall tests show an abrupt change in annual average temperature around 2031, with a mean difference of 0.6°C before and after the change. No abrupt change is projected for growth-season temperature. Both annual and growth-season temperatures exhibit a primary period of 31 years and secondary periods of 11 years and 9 years, experiencing cold-warm alternations.

2.2.2 Projected Water Resource Trends Under Future Climate Scenarios Under the RCP4.5 scenario, annual precipitation is projected to range from 223 to 765 mm, showing a non-significant decreasing trend with a climate tendency rate of $-5.61\ mm \cdot (10a)^{-1}$ ($P > 0.05$). Precipitation during the growth season is projected to be 207-691 mm, also showing a non-significant decreasing trend. Monthly precipitation shows mixed trends, with some months increasing and others decreasing non-significantly. Mann-Kendall tests indicate no significant abrupt changes in annual or growth-season precipitation. Both annual and growth-season precipitation exhibit a primary period of 23-31 years, with secondary periods of 7-12 years and 3-9 years.

Under the RCP8.5 scenario, annual precipitation is projected to range from 343 to 899 mm, showing a non-significant increasing trend with a climate tendency rate of 19.66 mm $\cdot$ $(10a)^{-1}$ ($P > 0.05$). Growth-season precipitation is projected to be 280-809 mm, with an increasing trend. Monthly precipitation shows varying trends, with May and July exhibiting significant increases. Mann-Kendall tests show no significant abrupt changes. Both annual and growth-season precipitation display a primary period of 22-30 years and secondary periods of 7-12 years and 3-9 years.

3 Conclusions

This study reveals that from 1971 to 2019, both annual mean temperature and growth-season mean temperature in the jujube planting area of the Loess Plateau in northern Shaanxi showed significant increasing trends, with abrupt changes occurring in the early 1990s. Monthly average temperatures increased, with July showing the most significant warming. Annual and growth-season precipitation showed increasing trends, indicating a warming-wetting climate characteristic. Temperature exhibited a primary period of approximately 44 years, with cold-warm alternations and unclosed curves suggesting continued warming. Precipitation showed a primary period of about 31 years, with wet-dry alternations and unclosed curves indicating persistent wet conditions.

Under the RCP4.5 scenario, both annual and growth-season mean temperatures are projected to increase, while precipitation is projected to decrease. Under the RCP8.5 scenario, temperatures will increase more significantly, and precipitation will also increase, though not significantly. Both emission scenarios project increasing heat resources, with more pronounced warming under RCP8.5.

4 Discussion

The rising temperatures in the jujube planting area of northern Shaanxi will extend the growth period and delay dormancy. The warming rate in spring (March-May) exceeds the annual average, which will advance the budding period. While warming improves winter survival rates of jujube trees, it also facilitates overwintering of pest eggs, increasing the potential threat of diseases and pests. Effective measures are needed to prevent and control jujube pests and diseases.

Under the RCP8.5 scenario, precipitation shows an increasing trend, which can alleviate drought stress on jujube growth. However, increased precipitation during the maturity period will also increase the risk of fruit cracking, severely affecting yield and quality. Overall, changes in water and heat resources in the jujube planting area of northern Shaanxi present more opportunities than challenges. It is essential to fully exploit climate resource potential, appropriately adjust planting layouts and scales, and select crack-resistant varieties to promote sustainable and healthy development of the jujube industry.

References

[1] Wang Xing, Zhu Delan, Yang Ronghui, et al. Study on crack resistance of northern Shaanxi jujube on mountain land[J]. Journal of Fruit Science, 2011, 2(1): 82-85.

[2] Li Xingang, Tong Jinxia, Wang Hongzhe, et al. Ecological adaptability of Ziziphus jujuba Mill. in north Shaanxi[J]. Journal of Northwest Forestry University, 2000, 15(2): 13-18.

[3] Li Xingang. Research on status of jujube region in north Shaanxi[J]. Journal of Northwest Forestry University, 2003, 18(1): 80-83.

[4] Yang Xiaoguang, Li Yong, Dai Shuwei, et al. Changes of China agricultural climate resources under the background of climate change: . Spatiotemporal change characteristics of China agricultural climate resources[J]. Chinese Journal of Applied Ecology, 2011, 22(12): 3177-3188.

[5] Sun Qianqian, Liu Jingmiao. Temporal spatial change of temperature and precipitation based on CAST in northeast China[J]. Journal of Meteorology and Environment, 2014, 30(3): 59-65.

[6] Wang Mingchang, Liu Tan, Jiang Yuan, et al. Temperature and precipitation changes in north central China in the last 50 years[J]. Journal of Beijing Normal University (Natural Science), 2015, 51(6): 631-635.

[7] Li Zhenchao, Wei Zhigang, Wen Jun, et al. Analyses on climate variation characteristics over the Loess Plateau in recent 50 years[J]. Journal of Arid Land Resources and Environment, 2008, 22(3): 57-62.

[8] Li Zhi, Zhao Xin, Tang Haiping. Spatiotemporal analysis of meteorological elements on the Loess Plateau during 1961—2009[J]. Journal of Natural Resources, 2013, 28(2): 287-299.

[9] Gu ChaoJun, Mu Xingmin, Gao Peng, et al. Characteristics of temporal variation in precipitation and temperature in the Loess Plateau from 1961 to 2014[J]. Journal of Arid Land Resources and Environment, 2017, 31(3): 136-143.

[10] Liu Zhaofei, Wang Rui, Yao Zhijun. Air temperature and precipitation over the Mongolian Plateau and assessment of CMIP5 climate models[J]. Resources Science, 2016, 38(5): 956-969.

[11] Lu Xiaofei, Ren Chuanyou, Wang Yanhua, et al. Spatial difference characteristics on simulation capability of seasonal variation of air temperature simulated by three global climate models in China[J]. Arid land Geography, 2018, 41(5): 972-983.

[12] Wang Jing, Liu Hailong, Wang Ling. Suitable oasis scale in Manas River Basin in the context of climate change[J]. Arid land Geography, 2019, 42(1): 113-120.

[13] Xu Min, Gao Ping, Xu Jingwei, et al. Variation characteristics and future climate scenario prediction of maize climate resources in Jiangsu[J]. Journal of Jiangsu Agricultural Sciences, 2014, 42(10): 95-100.

[14] Li Hongying, Gao Zhenrong, Wang Sheng, et al. Extreme temperature variation of Hexi Corridor in recent 60 years[J]. Arid Land Geography, 2015, 38(1): 1-9.

[15] Xue Haili, Zhang Xin, Tang Haiping. Extreme temperature and drought events in four different grassland areas of Inner Mongolia in recent 60 years[J]. Arid Land Geography, 2018, 41(4): 701-711.

[16] Qin Rong, Li Linchao, Yang Xian, et al. Change of pan evaporation in Xinjiang and its periods based on wavelet analysis[J]. Arid Land Geography, 2018, 41(5): 90-98.

[17] Zhang Weimin, Wang Jinghong. Variation characteristics of air temperature and its impact on jujube in hilly region of the Loess Plateau in recent 40 years[J]. Chinese Agricultural Science Bulletin, 2016, 32(10): 139-144.

[18] Liang Yi, Wang Jinghong, Qu Zhenjiang, et al. Climate suitability regionalization for Zhongyang jujube in the hilly area of Loess Plateau[J]. Chinese Agricultural Science Bulletin, 2016, 32(10): 132-138.

[19] Liang Yi, Zhang Yong, Wang Jinghong, et al. Potential impacts of climate change on suitable area of dried jujube in hilly area of the Loess Plateau[J]. Journal of Northwest A & F University (Natural Science Edition), 2017, 45(1): 90-98.

[20] Liu Lu, Wang Jinghong, Zhang Weimin, et al. Climatic change characteristics and its impaction on phenophase of jujube in northern Shaanxi during 1971–2010[J]. Journal of Arid Meteorology, 2016, 34(5): 841-846.

[21] Li Yanli, Wang Jinghong, Liang Yi. Variation characteristics of main meteorological disasters of jujube in the hilly Loess Plateau under climate change[J]. Chinese Agricultural Science Bulletin, 2016, 32(5): 118-124.

Note: Figure translations are in progress. See original paper for figures.