

Tree-Ring Based Study on the Impact of Ecological Water Conveyance on *Populus euphratica* Growth Characteristics in the Lower Reaches of the Tarim River (Postprint)

Authors: Zhou Honghua

Date: 2021-06-17T00:00:00+00:00

Abstract

Using tree-ring and stable isotope techniques, this study analyzed the impacts of ecological water conveyance from 2000–2015 on the tree-ring width index and tree-ring stable carbon isotope ratio ($\delta^{13}\text{C}$) of *Populus euphratica* in the lower reaches of the Tarim River, and explored the relationship between ecological water conveyance and poplar growth. The results indicate that: (1) Poplar growth is closely related to the volume of ecological water conveyance. Affected by ecological water conveyance, the tree-ring width index and tree-ring $\delta^{13}\text{C}$ of poplars at the Yingsu cross-section in the upper part of the lower Tarim River underwent three stages: during the initial four years (2000–2003) of water conveyance, poplar growth response was highly sensitive, with the tree-ring width index and tree-ring $\delta^{13}\text{C}$ showing an increasing trend, with average values of 1.52 and -26.70% , respectively; however, during 2004–2009, as the volume of ecological water conveyance gradually decreased, the tree-ring width index and tree-ring $\delta^{13}\text{C}$ gradually declined, decreasing by 28.83% and 2.41% on average compared with 2000–2003, respectively; when ecological water conveyance stabilized during 2010–2015, the tree-ring width index and tree-ring $\delta^{13}\text{C}$ also gradually increased and stabilized. (2) The timing of water conveyance is closely related to poplar growth. Poplar growth showed the highest correlation with ecological water conveyance during the growth year (previous September–current August), growing season (April–August), and previous growth year (previous April–current March), while the correlation with ecological water conveyance during the calendar year (January–December) was not significant. Specifically, no ecological water was discharged during the 2008 calendar year (January–December). Although water was conveyed in 2009 (January–December), because there was no ecological water replenishment during the 2009 growing season, growth year, or previous growth year, the tree-ring width index and tree-ring

$\delta^{13}\text{C}$ of poplars dropped to their lowest values for 2000–2015 in 2009, at 0.76 and -27.50% , respectively, representing decreases of 61.18% and 3.14% compared with 2003. (3) Based on the research results, the mechanism by which ecological water conveyance promotes poplar growth was deduced: ecological water conveyance in the lower reaches of the Tarim River effectively raised the groundwater level, improved the water environment for poplar growth, enhanced poplar water use efficiency, thereby increasing photosynthetic accumulation products and ultimately promoting tree growth. However, ecological water conveyance has a lagged effect on groundwater depth and poplar growth, with a lag time of approximately one year. To maintain effective restoration and reconstruction of desert riparian forests, it is recommended that ecological water conveyance in the lower reaches of the Tarim River be implemented during the plant growing season.

Full Text

Effects of Ecological Water Conveyance on the Growth Characteristics of *Populus euphratica* in the Lower Reaches of the Tarim River Based on Tree Rings

ZHOU Honghua, CHEN Yapeng, YANG Yuhai, ZHU Chenggang
(State Key Laboratory of Desert and Oasis Ecology, Xinjiang Institute of Ecology and Geography, Chinese Academy of Sciences, Urumqi, Xinjiang, China)

Abstract

This study employed tree-ring and stable isotope techniques to analyze the impacts of ecological water conveyance from 2000 to 2015 on the tree-ring width chronology and stable carbon isotope ratios ($\delta^{13}\text{C}$) of *Populus euphratica* in the lower reaches of the Tarim River, and to explore the relationship between ecological water conveyance and poplar growth. The results indicate: (1) *P. euphratica* growth is closely related to the amount of ecological water conveyance. Under the influence of water conveyance, the tree-ring width chronology and $\delta^{13}\text{C}$ values in the Yingsu section of the upper lower reaches showed three distinct stages. During the continuous water conveyance period (2000–2003), poplar growth responded very sensitively, with the tree-ring width chronology and $\delta^{13}\text{C}$ values showing increasing trends, averaging 1.52 and -26.70% , respectively. In the following six years (2004–2009), as water conveyance gradually decreased, the tree-ring width chronology and $\delta^{13}\text{C}$ values decreased by 28.83% and 2.41%, respectively. Although water conveyance resumed during 2010–2015, the tree-ring width chronology and $\delta^{13}\text{C}$ values only gradually increased and stabilized due to the absence of water delivery during the 2009 growing season. (2) The timing of water conveyance is also closely related to poplar growth. Growth responses were not significantly correlated with calendar-year water conveyance (January–December), but showed extremely significant positive correlations with water conveyance during the growth year (previous September–

current August), growth season (April–August), and previous growth year (previous April–current March). After water conveyance stabilized during 2010–2015, the highest correlation was observed between the tree-ring width chronology and $\delta^{13}\text{C}$ values and growth-season water conveyance. Because no ecological water was delivered during the growth season, growth year, or previous growth year of 2009, the tree-ring width chronology and $\delta^{13}\text{C}$ values reached their lowest points in 2009, decreasing by 61.18% and 3.14% compared to 2003, respectively. (3) The mechanism by which ecological water conveyance promotes poplar growth can be derived as follows: water conveyance effectively raises groundwater levels, improves the water environment for poplar growth, enhances water use efficiency, increases photosynthetic product accumulation, and ultimately promotes tree growth. However, a lag effect of approximately one year exists between water conveyance, groundwater depth changes, and poplar growth responses. To maintain effective restoration and reconstruction of desert riparian forests, we recommend that ecological water conveyance in the lower Tarim River be implemented during the plant growing season.

Keywords: ecological water conveyance; tree-ring width chronology; stable carbon isotope; groundwater depth; *Populus euphratica*

Introduction

The severe ecological problems caused by the drying up of the river channel in the lower reaches of the Tarim River are typical both in China and worldwide, attracting considerable attention from the international community and various sectors of society [1-2,10]. Since the implementation of the ecological water conveyance project in the lower Tarim River in 2000, the desert riparian forest dominated by *Populus euphratica* has been saved and rejuvenated. Numerous scholars have conducted detailed studies on the physiological and ecological responses of desert riparian forests to ecological water conveyance [3-5,11-12]. However, existing research has primarily focused on diurnal or intra-annual/seasonal changes in physiological and ecological indicators of natural vegetation in response to water conveyance, or used short-term (≤ 10 a) ecological survey results to assess vegetation restoration benefits under water conveyance. There remains a lack of research on the response of long-term (>10 a) plant growth processes to intermittent water conveyance. Consequently, current studies can hardly accurately evaluate long-term vegetation restoration effects from the perspective of plant growth processes, nor can they propose appropriate water conveyance schemes for maintaining long-term growth of desert riparian forests, which represents the key challenge in managing ecological water conveyance projects.

Populus euphratica is the key tree species in the desert riparian forest of the lower Tarim River, witnessing the ecological and environmental changes in the lower reaches during its growth and development. It serves as an excellent “archive” for recording environmental changes and directly reflects regional ecological restoration processes [1-2,10]. This study employed tree-ring and stable isotope techniques to analyze changes in the growth characteristics of *P. euphratica* under

the ecological water conveyance project in the lower Tarim River, to examine the relationship between water conveyance and long-term poplar growth processes, and to explore the mechanisms by which water conveyance promotes poplar growth, providing a scientific basis for the restoration and reconstruction of desert riparian forests and watershed water resource management in the lower Tarim River.

1.1 Study Area

From Daxihaizi Reservoir to Lake Taitema, the lower reaches of the Tarim River extend approximately 428 km, winding between the Kumtag and Taklamakan deserts. The region has a continental warm temperate arid climate, with multi-year average precipitation of 17.4–42.0 mm; multi-year average solar radiation of 5692–6360 MJ · m⁻²; multi-year average potential evaporation of 2500–3000 mm; multi-year average sunshine hours of 2780–2980 h; multi-year average temperature of 13–17 °C; and \$ 10 °C accumulated temperature of 4040–4300 °C [6,9,13]. The lower Tarim River produces no runoff itself. Desert riparian forests dominated by *P. euphratica* develop along the floodplains and riverbanks, dependent on surface runoff and groundwater for survival. After the river channel dried up, channel water conveyance became the main source of groundwater recharge.

1.2 Data Collection and Analysis

In July 2015, tree core samples were collected from *P. euphratica* around groundwater monitoring wells in the lower Tarim River (Yingsu section in the upper lower reaches). An increment borer was used to collect samples at 1–1.5 m height from the tree trunk base, with two cores taken from each tree in the north-south direction. Considering that *P. euphratica* often has hollow trunks and easily decayed xylem, trees with breast-height diameter \$ 5 cm were considered invalid samples [10]. According to this sampling principle, 61 valid cores were obtained. The collected cores were dried, fixed, and polished. Tree-ring widths were measured using a LintabTM 6 tree-ring analyzer (precision 0.001 mm) and cross-dated. The COFECHA quality control program ensured dating accuracy, and individual sequences with poor correlation, overly short sequences, or too many outliers were eliminated. The ARSTAN software calculated the tree-ring width chronology, with growth trends removed using negative exponential functions and spline functions. Chronology reliability was assessed using the signal-to-noise ratio (SNR).

Considering that tree-ring width may be influenced by multiple factors, we also measured tree-ring stable carbon isotope ratios ($\delta^{13}\text{C}$), which are less affected by tree age growth effects and subjective human factors. $\delta^{13}\text{C}$ reflects tree growth characteristics and effectively represents intrinsic water use efficiency (iWUE) during tree growth. After measuring ring widths and cross-dating, samples were peeled annually under a microscope using stainless steel blades, avoiding carbon contamination. Samples from the same year were combined, then crushed and

sieved through a 100-mesh screen. The ampoule organic combustion method prepared CO_2 . Processed samples were measured for $\delta^{13}\text{C}$ using a mass spectrometer. The $\delta^{13}\text{C}$ calculation formula is: $\delta^{13}\text{C} = (R_{\text{sample}}/R_{\text{standard}} - 1) \times 1000$, where R_{sample} is the $^{13}\text{C}/^{12}\text{C}$ ratio in the tree-ring sample and R_{standard} is the $^{13}\text{C}/^{12}\text{C}$ ratio in the standard sample.

Ecological water conveyance data (time, volume, duration) from 2000–2015 were obtained from the Tarim River Basin Administration. Groundwater depth data came from monitoring wells established along the riverbank since 2000. Statistical analysis used SPSS software, and figures were created using Sigmaplot 12.5.

2 Results and Analysis

2.1 Tree Growth Characteristics of *P. euphratica*

In the sampling area, the average breast-height circumference of *P. euphratica* was 203.43 cm, ranging from 157.00–250.00 cm. Trees exceeding 250.00 cm accounted for only 2.70%, while those exceeding 200 cm accounted for approximately 52.70%. Age distribution frequency statistics showed that *P. euphratica* ages mainly concentrated between 50–80 years [Figure 1: see original paper].

Comparative analysis revealed three stages of change after ecological water conveyance implementation (Fig. 2). Under the influence of water conveyance from 2000–2015, the average tree-ring width chronology of *P. euphratica* in the lower Tarim River was 1.18, and the average $\delta^{13}\text{C}$ was -25.87% . Pearson correlation analysis showed that $\delta^{13}\text{C}$ was significantly positively correlated with the tree-ring width chronology ($r = 0.549$, $P < 0.05$), and the tree-ring width chronology of 2000–2009 was extremely significantly positively correlated with that of 2010–2015 ($r = 0.832$, $P < 0.01$). This indicates that $\delta^{13}\text{C}$ is closely related to tree growth, and this relationship exhibits a lag effect.

2.2 Effects of Ecological Water Conveyance on *P. euphratica* Growth

Since 2000, the Tarim River Basin Administration has implemented ecological water conveyance projects, transferring water from the Kongque River and main Tarim stream to the lower reaches to raise groundwater levels and restore riparian vegetation. *P. euphratica* growth in this region depends primarily on groundwater, and channel water conveyance has become the main groundwater recharge source.

From 2000–2015, ecological water conveyance was implemented 22 times (except in 2008), delivering a total of $54.56 \times 10^8 \text{ m}^3$ to the lower Tarim River. Maximum single conveyance reached $8.23 \times 10^8 \text{ m}^3$, while minimum was $0.11 \times 10^8 \text{ m}^3$. The water head reached Lake Taitema 11 times.

2.2.1 Relationship Between Water Conveyance Amount and *P. euphratica* Growth

Considering environmental factors have lag effects on tree

growth, this study separately calculated water conveyance amounts for the calendar year (January–December), growth year (previous September–current August), growth season (April–August), and previous growth year (previous April–current March) based on the general growth period of *P. euphratica*.

Pearson correlation analysis showed that, except for calendar-year water conveyance, the growth year, growth season, and previous growth year water conveyance amounts were all extremely significantly positively correlated with the tree-ring width chronology ($r = 0.655$, $P < 0.01$; $r = 0.749$, $P < 0.01$; $r = 0.610$, $P < 0.05$, respectively). Meanwhile, growth-season water conveyance was significantly positively correlated with tree-ring $\delta^{13}\text{C}$ ($r = 0.610$, $P < 0.05$) [Figure 3: see original paper].

Under the influence of water conveyance from 2000–2015, *P. euphratica* growth experienced three stages [Figure 2: see original paper]. During 2000–2003, continuous water conveyance greatly promoted growth, with tree-ring width chronology and $\delta^{13}\text{C}$ showing increasing trends averaging 1.52 and -26.70‰, respectively. When water conveyance gradually decreased during 2004–2009, the tree-ring width chronology and $\delta^{13}\text{C}$ decreased by 28.83% and 2.41%, respectively. After large-scale water conveyance resumed during 2010–2015, both indices gradually increased and stabilized under annual large-volume conveyance.

2.2.2 Relationship Between Water Conveyance Duration and *P. euphratica* Growth Due to limitations in water availability from upstream, the timing of ecological water conveyance in the lower Tarim River varies annually. Statistical analysis of conveyance duration from 2000–2015 showed that the entire growth year and previous growth year of 2009 had no water input, and the growth seasons from 2006–2009 also lacked ecological water input.

Pearson correlation analysis indicated that calendar-year water conveyance duration was significantly positively correlated with the tree-ring width chronology ($r = 0.610$, $P < 0.05$), while growth-season duration showed an extremely significant positive correlation ($r = 0.749$, $P < 0.01$) [Figure 4: see original paper]. Although some water conveyance occurred in 2009, the tree-ring width chronology and $\delta^{13}\text{C}$ values decreased to their lowest levels since project implementation because the growth season, growth year, and previous growth year of 2009 had no ecological water supply. Compared to 2003, the 2009 values decreased by 61.18% and 3.14%, respectively. Therefore, water conveyance duration also plays a crucial role in *P. euphratica* development. To effectively restore and reconstruct poplar forests, ecological water conveyance should be implemented during the plant growing season.

2.3 Effects of Groundwater Depth Changes on *P. euphratica* Growth

Continuous river channel drying caused groundwater depth along both banks to increase continuously, reaching nearly 12 m in 2000. After water conveyance implementation, groundwater depth gradually decreased [Figure 5: see original

paper], demonstrating that the project effectively improved the water environment.

Correlation analysis showed that groundwater depth was not significantly related to current-year water conveyance but was extremely significantly negatively correlated with previous-year conveyance ($r = -0.749$, $P < 0.01$), indicating a nearly 1-year lag between water conveyance and groundwater depth reduction. Groundwater depth was significantly negatively correlated with both current-year tree-ring width chronology and lagged 1-year $\delta^{13}\text{C}$ values ($P < 0.05$) [Figure 5: see original paper].

Scatter plots of tree-ring width and groundwater depth revealed that *P. euphratica* growth rates at 4–6 m groundwater depth were faster than at other depths. From 2000–2015, *P. euphratica* primarily lived at groundwater depths of 4–8 m, with relatively fast radial growth observed at 4–8 m depth [Figure 6: see original paper], indicating that the suitable groundwater depth range for long-term poplar growth is 4–8 m.

3 Discussion

Most studies on the effects of ecological water conveyance on desert riparian forests in the lower Tarim River have relied on vegetation plot surveys [3-5,11-12] and eco-hydrological model simulations [6,9,13]. Varying data time spans and survey areas often lead to differing results. The impact of water conveyance on vegetation is a long-term, gradual process that short-term analyses may not reveal. Therefore, identifying effective physiological and ecological indicators that can characterize long time series to evaluate water conveyance effects on plant growth has become crucial for assessing project effectiveness.

Numerous studies have confirmed that tree-ring technology is an important tool for studying hydrological processes [1-2,10,15-19]. However, tree growth is easily affected by multiple environmental factors, and tree-ring width records relatively complex environmental information susceptible to tree growth trends. In contrast, tree-ring carbon isotope fractionation mechanisms are clearer and less affected by tree age effects, physiological factors, and subjective human influences [20], making it a more mature and effective indicator for studying long-term tree growth characteristics.

This study used both tree-ring width and stable carbon isotope dual indicators to comprehensively analyze *P. euphratica* growth characteristics in the lower Tarim River, compensating for limitations of single indicators. Results showed that due to ecological water conveyance, the tree-ring width chronology and $\delta^{13}\text{C}$ values changed significantly after the first 4 years of project implementation, especially during 2000–2003 when poplar growth was very sensitive to water conveyance. This indicates that continuous water conveyance has significantly promoted long-term poplar growth, consistent with results from field vegetation surveys and remote sensing interpretation during the conveyance period [3-5,11-12].

Dual-indicator analysis showed that the tree-ring width chronology and $\delta^{13}\text{C}$ values of *P. euphratica* were positively correlated, indicating consistent trends and that both can serve as effective proxy indicators for explaining growth characteristics. Compared to the width chronology, $\delta^{13}\text{C}$ is less affected by growth trends and more stable [20], making it more suitable for studying the relationship between water conveyance and tree growth.

$\delta^{13}\text{C}$, as the ratio of plant carbon assimilation to water transpiration, is an effective tool for tracking long-term changes in plant intrinsic water use efficiency (iWUE) [12]. *P. euphratica* $\delta^{13}\text{C}$ in the lower Tarim River was significantly positively correlated with water conveyance amount and significantly negatively correlated with groundwater depth, indicating that water use efficiency increases with more water conveyance or shallower groundwater. $\delta^{13}\text{C}$ is the ratio of photosynthetic rate to stomatal conductance, and its increase indicates enhanced photosynthesis. Therefore, ecological water conveyance may promote tree growth by improving water use efficiency and increasing photosynthetic products.

Correlation analysis showed that the tree-ring width chronology was not significantly correlated with calendar-year water conveyance but was extremely significantly correlated with growth year and growth season water conveyance. $\delta^{13}\text{C}$ was only significantly correlated with growth-season water conveyance, indicating that tree growth is affected by both water amount and timing. Water conveyance, groundwater depth, and tree growth have about a 1-year lag effect, and trees are most sensitive to water conveyance during their growth year and season. Therefore, to maintain effective restoration of desert riparian forests, water conveyance timing should align with plant growth cycles.

4 Conclusion

In extremely arid areas, water resources are the decisive factor limiting plant growth and development. Although numerous studies have examined the relationship between plants and surface runoff/groundwater in the lower Tarim River, most were based on instantaneous physiological/biochemical characteristics of individual plants, vegetation diversity surveys, or remote sensing NDVI changes. Research on the relationship between long-term plant growth characteristics and water resources remains weak. Based on 16 years of tree-ring width chronology, $\delta^{13}\text{C}$, ecological water conveyance, and groundwater depth data, this study analyzed the effects of surface runoff, groundwater, and water conveyance timing on long-term *P. euphratica* growth.

Results showed that surface runoff from ecological water conveyance significantly changed groundwater depth and promoted *P. euphratica* growth. Water conveyance amount was significantly correlated with both tree-ring width chronology and $\delta^{13}\text{C}$. Water conveyance timing is closely related to tree growth, with growth-season conveyance being most beneficial. After water conveyance, *P. euphratica* can enhance growth by improving water use efficiency and increasing

photosynthetic products. These results provide an important theoretical basis for understanding the relationship between long-term poplar growth processes and water resources in the lower Tarim River.

References

- [1] Zhou Honghua, Li Weihong, Sun Huilan. Reconstruction of groundwater depth using tree ring of *Populus euphratica* in the lower Tarim River[J]. *Scientia Silvae Sinicae*, 2018, 54(4): 11-16.
- [2] Zhou Honghua, Li Weihong, Li Yupeng, et al. Estimation of ecological water demand of a desert riparian forest using tree rings of *Populus euphratica* in the lower Tarim River[J]. *Acta Ecologic Sinica*, 2017, 37(22): 7576-7584.
- [3] Chen Y, Zhang X, Zhu X, et al. Analysis on the ecological benefits of the stream water conveyance to the dried up river of the lower reaches of Tarim River, China[J]. *Science in China (Series D: Earth Sciences)*, 2004, 47(11): 1053-1064.
- [4] Zhu Chenggang, Aikeremu Abula, Li Weihong, et al. Ecosystem restoration of *Populus euphratica* forest under the ecological water conveyance in the lower reaches of Tarim River[J/OL]. *Arid Land Geography*. [2021-03-29]. <https://kns.cnki.net/kcms/detail/65.1103.X.20210328.1831.008.html>.
- [5] Shi Haobo, Chen Yaning, Li Weihong. Interspecific association and stability of vegetation in the lower reaches of the Tarim River[J]. *Arid Zone Research*, 2020, 37(1): 220-226.
- [6] Hanati Gulimire, Wang Guangyan, Zhang Yin, et al. Influence mechanism of intermittent ecological water conveyance on groundwater level and vegetation in arid land[J]. *Arid Land Geography*, 2018, 41(4): 726-733.
- [7] Li Lijun, Zhang Xiaoqian, Chen Changqing, et al. Ecological effects of water conveyance on the lower reaches of Tarim River in recent twenty years[J]. *Arid Land Geography*, 2018, 41(2): 238-247.
- [8] Hao X M, Chen Y N, Li W H. Indicating appropriate groundwater tables for desert river bank forest at the Tarim River, Xinjiang, China[J]. *Environmental Monitoring Assessment*. 2009, 152(1-4): 223-232.
- [9] Deng X, Xu H, Ye M, et al. Impact of long term zero flow and ecological water conveyance on the radial increment of *Populus euphratica* in the lower reaches of the Tarim River, Xinjiang, China[J]. *Regional Environmental Change*, 2015, 15: 13-23.
- [10] Yu P, Xu H, Liu S, et al. Effects of ecological water conveyance on the ring increments of *Populus euphratica* in the lower reaches of Tarim River[J]. *Journal of Forest Research*, 2012, 17(5): 413-420.
- [11] Yan H, Wang Y, Wang Y. The influence of 10 years of water conveyances on groundwater and juvenile *Populus euphratica* of the lower Tarim River[J].

Environmental Earth Sciences, 2014, 71: 2855-2864.

[12] Hao X, Li W. Impacts of ecological water conveyance on groundwater dynamics and vegetation recovery in the lower reaches of the Tarim River in northwest China[J]. Environmental Monitoring and Assessment, 2014, 186: 7605-7616.

[13] Han M, Zhao C, Feng G, et al. An eco-hydrological approach to predicting regional vegetation and groundwater response to ecological water conveyance in dryland riparian ecosystems[J]. Quaternary International, 2015, 380-381: 224-236.

[14] Li Junli, Xiao Hao, Shen Zhanfeng, et al. Vegetation changes during the 2013–2018 period and its response to ecological water transport in the lower reaches of the Tarim River[J]. Arid Zone Research, 2020, 37(4): 985-992.

[15] Sun Tianyao, Li Xuemei, Xu Min, et al. Spatial-temporal variations of vegetation coverage in the Tarim River Basin from 2000 to 2018[J]. Arid Land Geography, 2020, 43(2): 415-424.

[16] Zhang Z. Tree rings, a key ecological indicator of environment and climate change[J]. Ecological Indicators, 2015, 51: 107-116.

[17] St. George S. An overview of tree ring width records across the northern Hemisphere[J]. Quaternary Science Reviews, 2014, 95: 132-150.

[18] Zhou H H, Chen Y N, Hao X M, et al. Tree rings: A key ecological indicator for reconstruction of groundwater depth in the lower Tarim River, northwest China[J]. Ecohydrology, 2019, 12(8): 1250-1380.

[19] Schilling O S, Doherty J, Kinzelbach W, et al. Using tree ring data as a proxy for transpiration to reduce predictive uncertainty of a model simulating groundwater-vegetation interactions[J]. Journal of Hydrology, 2014, 519(B): 2258-2271.

[20] Friedman M J, Stricker A C, Csank Z A, et al. Effects of age and environment on stable carbon isotope ratios in tree rings of riparian *Populus* [J]. Palaeogeography, Palaeoclimatology, Palaeoecology, 2019, 524: 25-32.

[21] Lu Weiwei. Long-term water-carbon coupling mechanism of trees based on tree ring stable carbon isotopes[D]. Beijing: Beijing Forestry University, 2019.

[22] Guan Wenke. Response of leaf $\delta^{13}\text{C}$ and $\delta^{15}\text{N}$ and environmental factors in different habitats of *Populus euphratica* [J]. Acta Botanica Boreali-Occidentalia Sinica, 2020, 40(6): 1031-1042.

[23] Huang Puzhao, Li Dongxing, Wang Bin, et al. Foliar stable carbon isotope composition and water use efficiency of plant in the Karst seasonal rain forest[J]. Chinese Journal of Applied Ecology, 2019, 30(6): 1833-1839.

Abstract: Water is a decisive factor limiting plant growth and development in extremely arid areas. Although numerous studies on the relationship between water resources and plants in the lower reaches of Tarim River, Xinjiang, China have been published, most of them focused on short time changes in the physiological or biochemical characteristics of individual plants, plant diversity, or normalized differential vegetation index. Thus, the relationship between long-term plant growth characteristics and water resources must be examined further. In this study, the responses of the long-term growth characteristics of *Populus euphratica* to ecological water conveyance from 2000 to 2015 in the lower reaches of Tarim River were analyzed using the tree-ring width chronology and stable carbon isotope ($\delta^{13}\text{C}$) characteristics of the species. Results showed that: (1) *P. euphratica* growth was significantly related to the amount of ecological water conveyance, and the tree-ring width chronology and $\delta^{13}\text{C}$ values of *P. euphratica* in Yingsu indicated three stages. Specifically, tree growth was very sensitive to ecological water conveyance in 2000 and -26.70% , respectively. When ecological water conveyance was reduced in 2004–2009, the mean tree-ring width chronology and $\delta^{13}\text{C}$ values of the species decreased by 28.83% and 2.41%, respectively. The values of these indices remained stable when the ecological water conveyance amount was increased and maintained in 2010–2015. (2) *P. euphratica* growth was closely related to the ecological water conveyance time, especially in terms of growth year (from previous September to current August), growth season (from April to August), and previous growth year (from previous April to current March). However, plant growth was not significantly related to ecological water conveyance of the calendar year (from January to December). Because no ecological water conveyance was conducted in the growth season, growth year, and previous growth year of 2009 or in the growth seasons of 2006–2009, the tree-ring width chronology and $\delta^{13}\text{C}$ values of *P. euphratica* of 2009 were lowest in 2015. The tree-ring-width chronology and $\delta^{13}\text{C}$ values of *P. euphratica* in 2009 decreased by 61.18% and 3.14% compared with those in 2003, respectively. (3) Ecological water conveyance decreased the groundwater depth and improved the water environment of *P. euphratica*, thereby enhancing the water use efficiency, accumulated photosynthetic production, and growth of the trees. However, a 1-year lag effect between ecological water conveyance, groundwater depth, and *P. euphratica* growth was also observed. Therefore, ecological water conveyance should be implemented during the plant growth period in the lower reaches of Tarim River to restore and reconstruct the desert riparian forest effectively.

Key words: ecological water conveyance; tree-ring width chronology; stable carbon isotope; groundwater depth; *Populus euphratica*

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

Source: ChinaXiv – Machine translation. Verify with original.