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# Negative feedback adjustment challenges reconstruction study from tree rings: A study case of response of *Populus euphratica* to river discontinuous flow and ecological water conveyance

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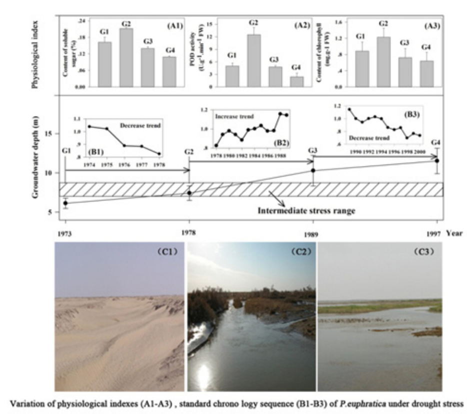
## HIGHLIGHTS

- Ecological water conveyance promotes the increase of tree-ring width owing to lifting groundwater depth.
- The response of the tree-ring growth to the variation of groundwater depth has cumulative and time-lag characteristics.
- A hypothesis that intermediate drought stress results in a negative feedback adjustment is validated.
- Negative feedback adjustment converts the declining growth trend of tree rings during the river cutoff.
- Negative feedback adjustment breaks the homogenization theory of tree ring reconstruction.

## GRAPHICAL ABSTRACT




Variation of physiological indexes (A1–A3), standard chronology sequence (B1–B3) of *P. euphratica* under drought stress and the landscape changes of the inlet of Taitema Lake before (CI), during (C2), and after (C3) ecological water conveyance.

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## ABSTRACT

Drought stress changes the relationship between the growth of tree rings and variations in ambient temperature. However, it is not clear how the growth of trees changes in response to drought of varying intensities, especially in arid areas. Therefore, Tree rings were studied for 6 years in *Populus euphratica* to assess the impacts of abrupt changes in environment on tree rings using the theories and methods in dendrohydrology, ecology and phytophysiology. The width of tree rings increased by 8.7% after ecological water conveyance downstream of Tarim River compared to that when the river water had been cut off. However, during intermediate drought, as the depth of the groundwater increases, the downward trend in the tree rings was reversed because of changes in the physiology of the tree. Therefore, the growth of tree rings shows a negative feedback to intermediate drought stress, an observation that challenges the homogenization theory of tree ring reconstruction based on the traditional methods. Owing to the time lag, the cumulative effect and the negative feedback between the

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Ecological water conveyance
Tarim River

growth of tree rings and drought stress, the reconstruction of past environment by studying the patterns of tree rings is often inaccurate.
Our research sets out to verify the hypothesis that intermediate drought stress results in a negative feedback adjustment and thus to answers two scientific questions: (1) How does the negative feedback adjustment promote the growth of tree rings as a result of intermediate drought stress? (2) How does the negative feedback adjustment lower the accuracy with which the past is reconstructed based on tree rings? This research not only enriches the connotations of intermediate disturbance hypothesis and reconstruction theory of tree rings, but also provides a scientific basis for the conservation of desert riparian forests worldwide.
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## 1. Introduction

Environmental changes influence the evolution and distribution of plant ecosystems (Flantua et al., 2007; Lavoie et al., 2003). An adaptive feedback mechanism enhances the ability of an organism to combat stress (Rose, 1960; Tranchina et al., 1984; Yu et al., 2014). However, the degree of intensity of environmental stress that will produce a positive or a negative feedback is uncertain (Pisaric et al., 2007; Deryng et al., 2014). Although researches have shown that an intermediate intensity of environmental disturbance leads to greater diversity in a plant community (Connell, 1978; Buckling et al., 2000; Molino and Sabatier, 2001), rare researches have been conducted focusing on individual plants. As a carrier of environmental information in forest ecosystem, the pattern of tree rings not only reflects the environmental conditions during the formation of those rings (Baes and Mclaughlin, 1984; Miyake et al., 2012) but is also extremely sensitive to changes in environmental conditions (Briffa et al., 1998; Stine and Huybers, 2014). Therefore, the variation of ring trees can reflects the impact of intermediate environmental disturbance on growth of individual tree.

Because of its accuracy, high resolution, and continuity, the tree ring technology is widely used in reconstructing past climate and hydrological processes (Baes and Mclaughlin, 1984; Esper et al., 2002; Moberg et al., 2005; Liu et al., 2010; Yang et al., 2014). The homogenization theory in tree ring reconstruction maintains that it is possible to reconstruct environmental changes in the past (Fritts, 1976; Frank and Esper, 2005). However, in the context of global warming, when a tree's physiological threshold to temperature is crossed, stress in the form of drought caused by continuous increase in temperature restricts the growth of tree rings (D'Arrigo et al., 2004). During such a period, the relationship between the growth of tree rings and rise in temperature shows a pattern of non-linear divergence, typically in the shape of an inverted “U” (corresponding to the ‘temperature threshold effect’ on the growth of a tree) (Jacoby and D'Arrigo, 1995; Ulf et al., 2008; D'Arrigo et al., 2008). Therefore, the homogenization theory is by no means universally accepted (Watanabe et al., 2000). Moreover, if global temperatures continue to rise in some regions, drought stress would be even more intense. However, it is unclear how trees adapt to drought stress of varying intensity, especially in arid areas. It was against this background that we put forward the following hypothesis: if there is a negative feedback adjustment induced by intermediate drought stress, the growth of tree rings will take a turn for the better; i.e., the variation in the distance between successive tree rings shows an increase trend to environmental stress.

We chose *Populus euphratica*, a constructive species in desert riparian forests, to analyse how the growth of tree rings reflects the negative feedback adjustments induced by intermediate level of drought stress. *Populus euphratica* is a rare, ancient, and endangered species (Meher-Homji, 1973; Zhou et al., 2010). The Tarim River basin, in China's Xinjiang province, has the largest area under *P. euphratica*, which accounts for 54% of the global area under *P. euphratica* forests (Chen et al., 2003). However, Tarim River basin is one of the world's most ecologically vulnerable areas. In the 1950s, excessive development of water and land resources resulted in river water being cut off downstream of Tarim River and, in turn, perishing of large patches of desert riparian *P. euphratica* forests since 1972 (Xu et al., 2010). To restore the damaged ecosystem, the Chinese government has spent 10.7 billion yuan on the Ecological Water Conveyance Project (EWCP) since 2000. Actually, these two abrupt changes in the environment, namely the river water being cut off and the conveyance of ecological water downstream of Tarim River, have made this region not only one of the most prominent areas where an ecosystem has been seriously disturbed by anthropogenic activity, but also a rare and typical site in the world where disturbed ecology has been restored by ecological water conveyance. Therefore, this region offers an ideal location to examine the relationship between the growth of tree rings and environmental stress. This research not only enriches the connotations of intermediate disturbance hypothesis and reconstruction theory of tree rings, but also provides a scientific basis for the conservation of desert riparian forests worldwide.

## 2. Study area

The Tarim River basin (34.20°–43.39° N, 71.39°–93.45° E) is surrounded by nine river systems and 144 rivers. It covers 1.02 million km$^2$ and is the largest inland river basin of China. In terms of administrative units, the region comprises five prefectures (with 45 counties and cities) and four divisions of the Production and Construction Corps (with 56 farms) in southern Xinjiang. The population is 9.84 million. The Tarim River, the longest inland river in China, has a total length of 1321 km. The main river receives no run-off water but is fed by many source streams. In the past, nine great rivers (Aksu, Yarkant, Dina, Kaxgar, Hetian, Weigan, Keriya, Kaidu–Kongque, and Qarqan) flowed into Tarim River. However, because of climate change and human activity, only Hetian, Yarkant, Kaidu–Kongque, and Aksu continue to be the tributaries of Tarim River (Ling et al., 2014).

Areas downstream of Tarim River have experienced water cut-offs since 1972; water scarcity has shrunk the area under *P. euphratica* forests and aggravated environmental degradation (Ling et al., 2015). To restore the ecology of the area downstream of Tarim River and to regenerate and protect the desert riparian forests, the Chinese government launched the EWCP in 2000. The project has brought water from the Kongque River to downstream of Tarim River, which drains into Taitema Lake. As the EWCP proceeds, river flooding will expand to cover both banks of the river, which will raise the groundwater depth and help in regeneration of the damaged desert riparian forests (Ling et al., 2015).

Our study area was downstream of the Daxihaizi reservoir, fed by Tarim River, and covered a total of 2191 km$^2$ (Fig. 1). This region is one of the most arid areas in China with a mean annual precipitation of 40 mm and mean annual potential evaporation of 2590 mm (Ling et al., 2015). Therefore, the precipitation has little effects on groundwater recharge, which is mainly attributed to river and reservoir infiltration, as well as side run-off, with conversion rate 58% (Yang et al., 2007). So, the ecological water of desert riparian *P. euphratica* forests is mainly in the form of groundwater originating from the river (Ling et al., 2015). The flow direction of groundwater is in accordance with

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