

Vegetation, ecosystem dynamics, and restoration of floodplains in Central Asia – the Tarim River (Xinjiang, NW China) as an example

Vegetation, Ökosystemdynamik und Renaturierung von zentralasiatischen Flussauen am Beispiel des Tarim in Xinjiang, NW-China

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Abstract

Naturally, the floodplains of Central Asian rivers harbour riparian, so-called 'Tugai' forests, reeds with *Phragmites australis*, and shrub communities which form a mosaic depending on the variety of available ground water. In recent decades, these natural ecosystems have been strongly altered anthropogenically or even completely destroyed. In order to restore those ecosystems, knowledge on vegetation, ecosystem dynamics, and natural regeneration processes is essential. In our study, we present results of ecological investigations at the Tarim River. We gathered comprehensive data on soil, vegetation, forest stand age, tree vitality, river course dynamics, and land use and brought it to the landscape level. Thus, recommendations are derived for the maintenance of these floodplain ecosystems, in particular with regard to their biological diversity.

Keywords: Biodiversity, dendrochronology, natural resources, *Phragmites australis*, *Populus euphratica*, succession

Zusammenfassung

Entlang der Flussauen Zentralasiens findet sich natürlicherweise ein Mosaik aus Auenwäldern ('Tugai-Wäldern'), Schilfröhrichten mit *Phragmites australis* und Sträuchern, welches von der Verfügbarkeit des Grundwassers abhängt. In den vergangenen Jahrzehnten wurden diese natürlichen Ökosysteme durch den Menschen stark beeinträchtigt bis hin zu völlig zerstört. Um diese Ökosysteme wiederherzustellen, sind genaue Kenntnisse über die Vegetation, die Ökosystemdynamik und natürliche Regenerationsprozesse unabdingbar. In der vorliegenden Studie berichten wir über Ergebnisse unserer langjährigen ökologischen Untersuchungen am Tarim-Fluss. Diese umfassen Untersuchungen des Bodens, der Vegetation, der Altersstruktur und Vitalität der Tugai-Wälder, der Flusslaufdynamik und der Landnutzung, welche auf Landschaftsebene ausgewertet wurden. Auf dieser Grundlage leiten wir Empfehlungen zum dauerhaften Erhalt dieser Flussauenökosystem ab unter besonderer Berücksichtigung der biologischen Vielfalt.

Schlüsselwörter: Biodiversität, Dendrochronologie, natürliche Ressourcen, *Phragmites australis*, *Populus euphratica*, Sukzession

1 Introduction

Naturally, the floodplains of Central Asian rivers harbour so-called 'Tugai' forests, reeds, shrub communities, and halophyte vegetation which form a mosaic depending on the

ground water level, distance from the main water courses, and groundwater salt content (KUZMINA & TRESHKIN 1997, LAVRENKO 1956, OGAR 2003, TIAN 1991, THEVS et al. 2008a, TRESHKIN 2001). Along the Tarim River in Xinjiang (NW China), the Tugai forests are mainly composed by the two tree species *Populus euphratica* and *P. pruinosa* (LIU et al. 1990, WANG et al. 1996, ZERBE & THEVS 2007). The reeds are built-up by *Phragmites australis* (THEVS et al. 2007). Within the shrub communities, *Tamarix* species are most abundant (LIU et al. 1990, THEVS et al. 2008a). This riparian vegetation performs the major habitat for plants and animals with the highest biodiversity in continental-arid desert regions. Additionally to the environmental benefits like wind protection, sand fixation and soil as well as riverbank stabilization, the floodplain ecosystems are the major resource of natural products for the local people, like timber from poplar and plant material as well as biomass from reed.

As a consequence of various land-use interests and increasing land-use changes, natural Tugai ecosystems have been more and more displaced by agricultural land in recent decades (GIESE et al. 1998). Thus, the area of Tugai forests in the Aral Sea Delta shrunk from 500,000 ha in 1950 to only 70,000 in 1998 (TRESHKIN 2001). Along the Tarim river, the Tugai forest area decreased from 500,000 ha in the 1950ties to 200,000 ha in 1978 (HUANG 1986). In the past decades, excessive use of water resources for cotton farming has led to degradation or even a complete destruction of vast areas of floodplain forests with the consequence of desertification. However, at the Tarim river's middle reaches, we still can find one of the largest contiguous *Populus euphratica* floodplain forest areas worldwide (THEVS 2007).

Since ecological knowledge is essential for the restoration of these valuable and highly threatened ecosystems (cp. ZERBE & WIEGLEB 2009), our research focuses on the differentiation of the floodplain vegetation according to the site conditions. Additionally, ecological ranges, the regeneration as well as the age structure of *Populus euphratica* forests were investigated. Furthermore, the comparison of the growth and the long-term development of natural and anthropogenically strongly influenced floodplain forests are objectives of our research.

2 Study site

Our study site is the 'Tarim Huyanglin Nature Reserve', located in the Tarim Basin, in Xinjiang, north-western China (Fig. 1). The extremely continental climate of the region is reflected by a mean annual precipitation below 50 mm

(THEVS 2007). Consequently, the water supply for the vegetation is exclusively provided by the groundwater (THOMAS et al. 2006, WANG et al. 1996). The water sources of the Tarim river, which has a total length of about 1,300 km, are rivers and melting glaciers from the surrounding mountains (SONG et al. 2000). While along the middle reaches of the river still near-natural forests and reeds with prevailing natural dynamics can be found, the forests along the lower reaches of the Tarim river are already strongly degraded or even completely destroyed (WESTERMANN et al. 2008). Because of increasing water consumption for irrigation farming in the upper and middle reaches of the river, the Tarim lower reaches as well as the former end lakes Lopnor and Taitema fell dry already in 1972 (SONG et al. 2000).

In order to reconstruct the natural vegetation and ecosystem dynamics at the lower reaches of the Tarim, a large-scaled irrigation project was carried out. Water from other river systems in the north of the area under consideration was conducted to the focus region and dykes to channel water towards disturbed areas were built. From 2000 to 2004, artificial flooding was released into the lower reaches of the Tarim River.

These initiated flooding was implemented for 60 up to 131 days in duration. The water originated mainly from Lake Boston, which performs a huge water reservoir, and partly from the middle reaches of the Tarim and from the Daixihaizi water reservoir (ZHU et al. 2006).

3 Methods

In order to analyse the composition and differentiation of the vegetation as well as changes in the forest stand age and tree vitality along the middle and the lower reaches of the Tarim, comprehensive transect studies have been carried out applying phytosociological and landscape ecological (THEVS et al. 2008a) as well as dendrochronological methods (WESTERMANN et al. 2008). River course changes in the past decades have been detected with the help of satellite images and excursion documents from the past century (THEVS et al. 2008b). Furthermore, soil texture, groundwater depth, and salt content of the soil water were analyzed (THEVS 2007). Thus, we gathered comprehensive data on soil, vegetation, forest stand age, tree vitality, river course dynamics, and land use and brought it to the landscape level.

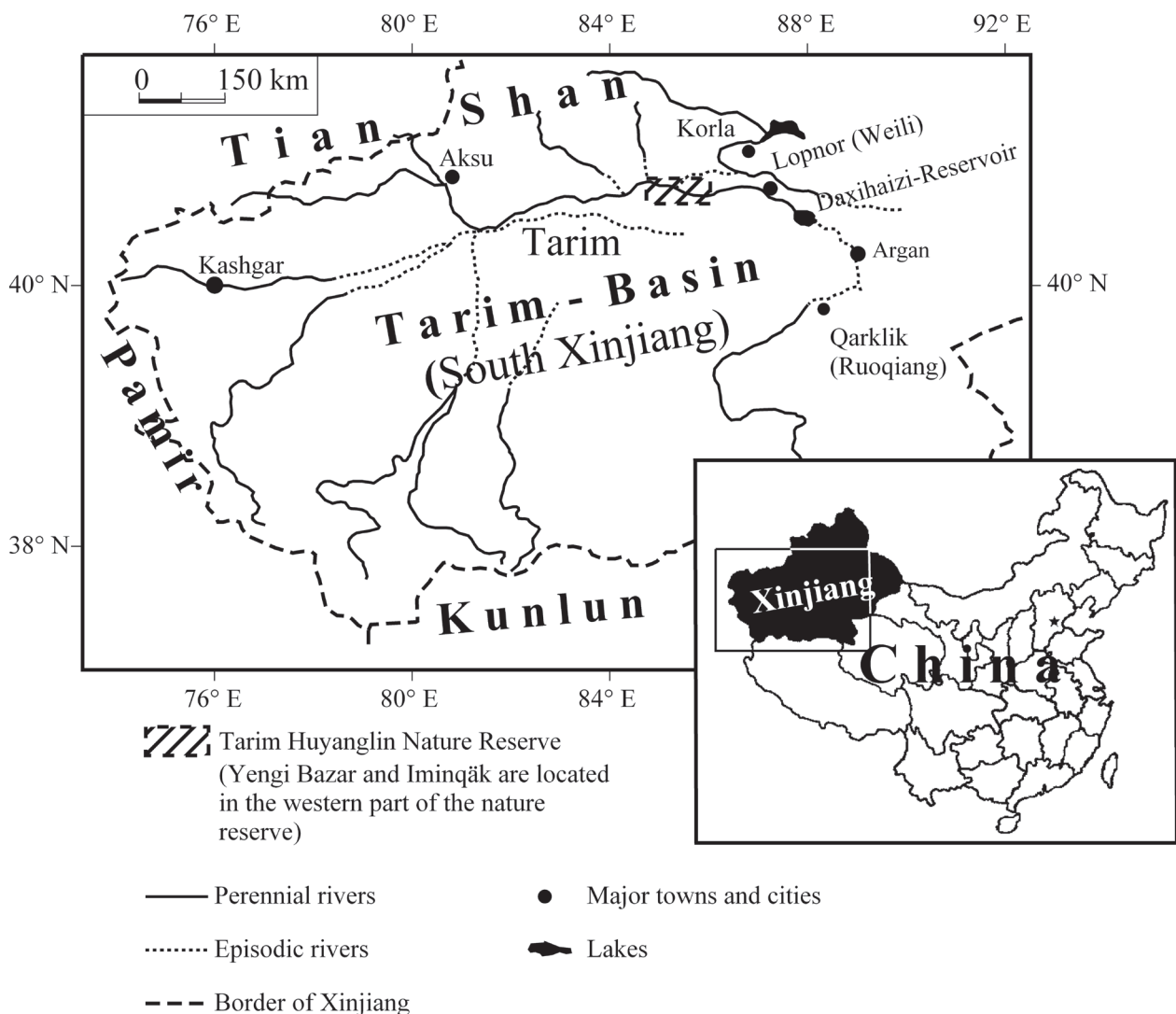


Fig. 1: Study site in NW China (from THEVS et al. 2008a).

Abb. 1: Untersuchungsgebiet in NW-China (aus THEVS et al. 2008a).

4 Results

As a result of the vegetation analysis at the middle reaches of the Tarim, where the floodplain can still be considered as near-natural, a typical zonation (transect shown in Fig. 2) could be detected. At the immediate river banks, we found reeds, followed by *Populus euphratica* shrubs and older Tugai forests (THEVS et al. 2008a, 2008b, ZERBE & THEVS 2007). Reeds with *Phragmites australis* are only found within a distance of up to 350 m from the river course, while *Tamarix* shrubs are growing along the whole transect, their occurrence stretching far into the Taklamakan desert. Generative rejuvenation of poplar was only recorded within a distance of 20–30 m from the river course and on sites which recently have been flooded. Along the transect, the forest stand age showed a considerable variety with mean ages of the trees ranging between ca. 10–60 years (WESTERMANN et al. 2008).

While in near-natural stands, all age classes of the poplar trees occur, in strongly degraded stands, like it is shown for a transect at the lower reaches of the Tarim River (Fig. 3), the youngest age class from 1–20 years is completely missing. The analysis of the annual radial growth from 1954 to 2004 of some dendrochronologically studied trees at the lower reaches of the Tarim River shows a continuous growth decrease. However, strongly related to the artificial flooding of the lower reaches since 2000, an upward trend of the annual radial growth could be revealed (WESTERMANN et al. 2008).

The river course changes in the past century show the extremely high dynamic of the river system (Fig. 4). While along the Tarim middle reaches three main river courses of the Tarim were recorded in 1903 (HEDIN 1905), five ones prevailed in 1949 (ZHONGHUA RENMIN GONGHEGUO GUOJIA TUCIJU 1959). However today, only one main river course is left.

The natural development phases of *P. euphratica* forests can be separated into four stages, like it was shown by WESTERMANN et al. (2008). The stand development begins with the colonization stage with a homogeneous age structure due to recently deposited land and subsequent tree colonization by generative propagation. The age span of the trees is narrow, most trees being younger than 20 years. Multi-aged stands can develop within the second stage because trees can perform clonal growth.

The third stage of stand persistence is characterised by decreasing groundwater levels, increasing soil salinisation and lacking regeneration. In the fourth stage, the process of dying-off begins and tree age span decreases. However, if the groundwater level rises due to the natural river course dynamics, vegetative reproduction can again be expected (WESTERMANN et al. 2008).

5 Discussion and conclusion

Comparing the high river dynamics at the beginning of the 20th century to the current situation, where only one main

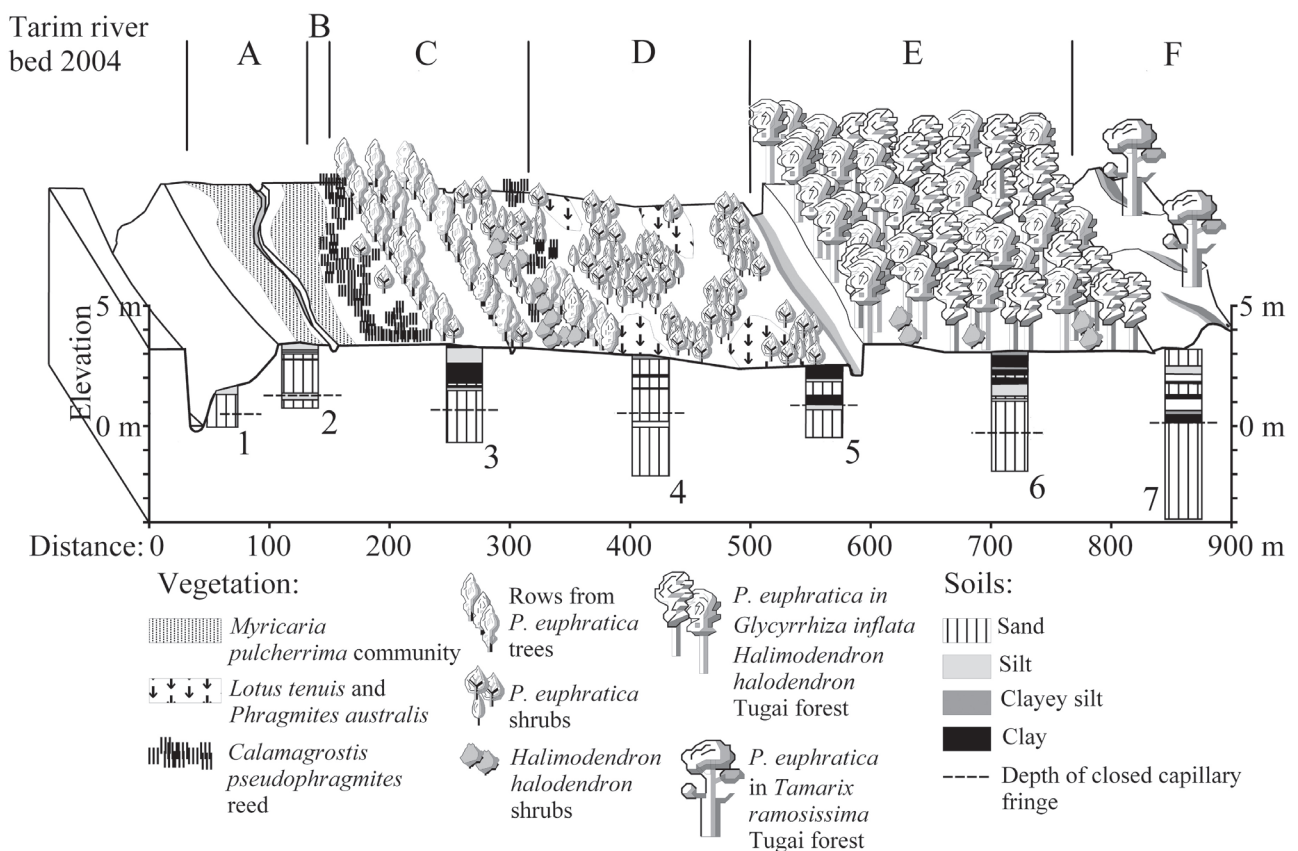


Fig. 2: Transect at the middle reaches of the Tarim river showing the typical zonation of sites and vegetation in a near-natural floodplain forest (from THEVS 2007).

Abb. 2: Transekt am Mittellauf des Tarim-Flusses, welches die typische Zonierung der Standorte und deren Vegetation im naturnahen Flussauenwald darstellt (aus THEVS 2007).

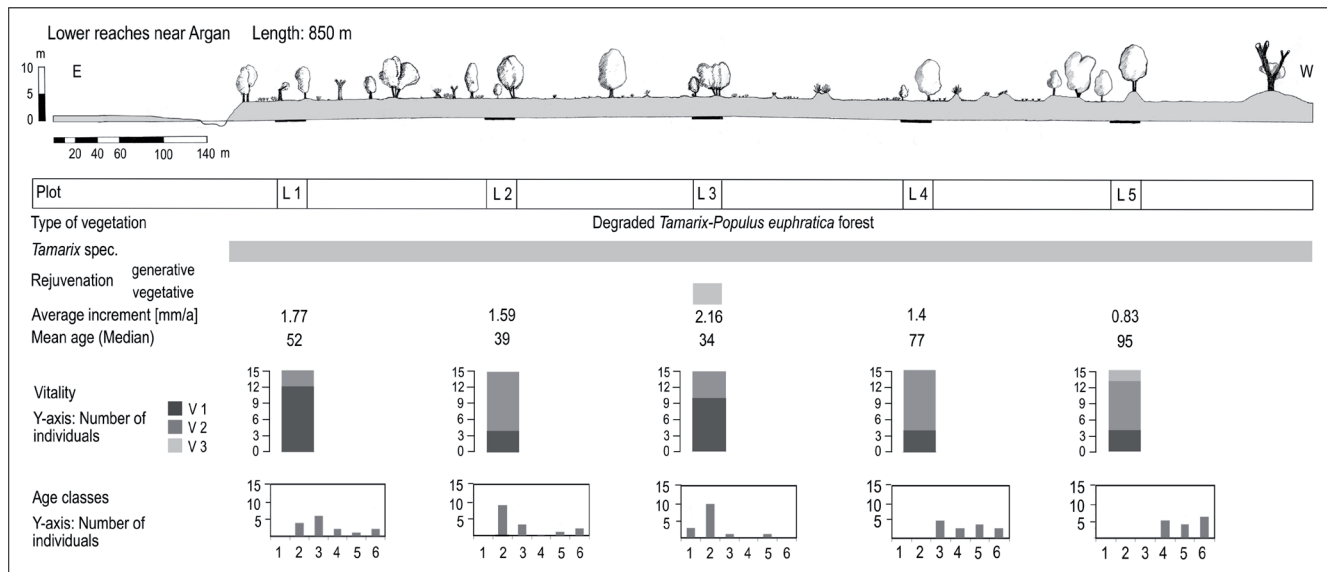


Fig. 3: Transect at the lower reaches of the Tarim river showing the age structure, growth, and vitality of a degraded floodplain forest (from WESTERMANN et al. 2008).

Abb. 3: Transekt am Unterlauf des Tarim-Flusses, welches die Altersstruktur, den mittleren Zuwachs und die Vitalität eines degradierten Flussauenwaldes darstellt (aus WESTERMANN et al. 2008).

stream remains, it is obvious, that the Tarim has lost its natural dynamic, which is important for the preservation of this valuable ecosystem. The fact, that reed patches are forming a mosaic together with groups of young poplar trees indicates the former occurrence of flooding and river channels, respectively. The old-growth poplar stands far away from the current river bed shows a shifting of the river course to the south since 1973, also reflecting the natural dynamics of the floodplain ecosystem.

The rejuvenation and establishment of Tugai forests as well as the maintenance of genetic diversity is, however, based on natural river dynamics. Summer floods, in particular from July to September provide safe sites for germination with moist river banks and a low salt content (< 0.2 %) in the upper soil. Furthermore, an early onset of the flood in the year after germination is important for a successful establishment.

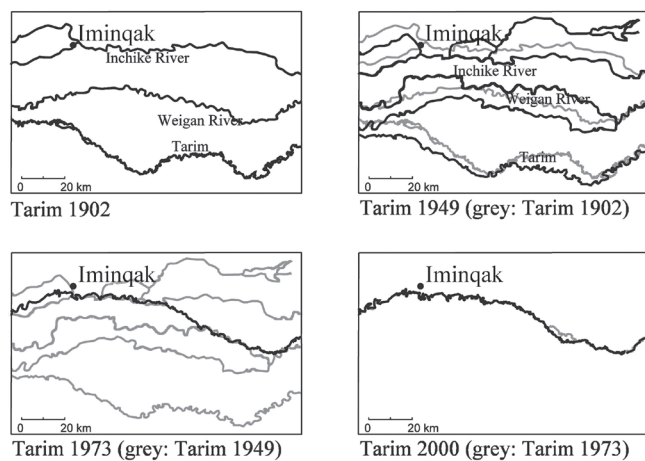


Fig. 4: River course changes of the Tarim River, Xinjiang, NW China in the past century (from THEVS 2007).

Abb. 4: Veränderungen des Tarim-Flusslaufes in Xinjiang (NW-China) im vergangenen Jahrhundert (aus THEVS 2007).

Additionally to poplar, also the majority of the other vegetation-forming plant species can only germinate and establish on flooded sites on the river banks. However, if the natural flood events do not occur any more also rejuvenation is interrupted as was shown for the degraded lower reaches of the Tarim River. Then, the natural succession is also strongly altered.

As a conclusion of our findings, we state that on the short term, controlled flooding may lead to the temporary recovery of the Tugai vegetation. However, on the long term, only the natural dynamics of the river system as well as a sustainable use of the water resources will succeed in the maintenance of the Tugai vegetation as the major biotic resource for the local society.

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