Archiv für Naturschutz und Landschaftsforschung

Band 44
Heft 1
März 2005

Inhalt

www.ArchivNatur.de

Tugay vegetation in the middle reaches of the Tarim River – Vegetation types and their ecology

Niels Thevs

Institut für Botanik und Landschaftsökologie, Universität Greifswald, Grimmer Straße 88, 17487 Greifswald, e-mail: Niels.Thevs@uni-greifswald.de

Schlüsselwörter:

Ökologie, *Populus euphratica,* Reproduktionsbiologie, Tarim, Tugay-Vegetation, Vegetationsklassifikation, Xinjiang

Zusammenfassung

Tugay-Vegetation ist die vorherrschende Vegetation an Flüssen Zentralasiens. Tugay-Vegetation besteht aus Wäldern, gebildet von *Populus euphratica* und *P. pruinosa*, *Tamarix*-Busch und Röhrichten. Tugay-Vegetation und Tugay-Wälder sind zum großen Teil zerstört. Der größte, noch intakte Bestand an Tugay-Vegetation liegt am Mittellauf des Tarim in Xinjiang, Nordwestchina. Dort wurde vom Institut für Landschaftsökologie und Botanik der Universität Greifswald ein Forschungsprojekt begonnen, um die Tugay-Vegetation zu verstehen und zu ihrem Schutz beizutragen. Ziele sind: Definition von Vegetationstypen, Abschätzung der ökologischen Ansprüche der Vegetationstypen, Veränderungen der Vegetation durch Nutzung sowie Reproduktion von *P. euphratica* als Schlüsselart. In diesem Artikel wird der Stand des Wissens über Ökologie und Reproduktion von *P. euphratica* sowie die ökologische Amplitude der wichtigsten Pflanzenarten und Vegetationstypen hinsichtlich Wasser und Salz vorgestellt. *P. euphratica* vermehrt sich generativ durch Samen und clonal durch Wurzelsprosse. Die generative Vermehrung findet auf vegetationslosen Uferbänken statt. Einmal etabliert kann *P. euphratica* sich aus einer Grundwassertiefe von 13 m versorgen. *Tamarix ramossissima* geht bis 30 m. Pflanzenbestände etablieren sich vorwiegend in der Nähe des Flusses oder anderer Oberflächengewässer. Die Flussdynamik ist die treibende Kraft der Sukzession. Die Sukzession beginnt mit jungen Wäldern, Busch-Beständen oder Röhrichten in Gewässernähe. Danach folgen Wälder und Busch-Bestände mit guter Wasserversorgung aus dem Grundwasser (Begleitarten sind: *Glycyrrhiza inflata*, *Halimodendron halodendron*. Bei steigendem Salzgehalt setzt sich Halophyten-Vegetation (z.B. *Halostachys caspica* durch. Bei sinkendem Grundwasser bleiben Reinbestände aus *P. euphratica* and *Tamarix ramossissima* übrig.

Keywords:

ecology, *Populus euphratica*, reproduction, Tarim, Tugay vegetation, vegetation typology, Xinjiang

Abstract

Tugay vegetation is the dominant vegetation distributed along rivers in Central Asia. It is composed from forests, i.e. Tugay forests, dominated by *Populus euphratica* and *P. pruinosa*, *Tamarix* bush communities and reeds. Large areas of Tugay vegetation and especially Tugay forests, have been destroyed and the largest still intact site of Tugay vegetation remains at the middle reaches of the Tarim River in Xinjiang, Northwest China. In order to understand and contribute to the conservation of Tugay vegetation from the Institute of Botany and Landscape Ecology of Greifswald University a research project was started. Research objectives are: Define types of vegetation, research the ecological demands of the vegetation types, research on the changes of the vegetation types through utilisation by men, reproduction of the key-species *P. euphratica*. This article introduces the state of knowledge on ecology and reproduction of *P. euphratica*, ecological amplitudes of the main plant species regarding water and salt as the main factors and vegetation types of the Tugay Vegetation. *P. euphratica* reproduces through seeds and root suckers. Generative reproduction depends on barren river banks. Once established, *P. euphratica* can tap the groundwater down to 13 m and *Tamarix ramossissima* down to 30 m. Plant communities establish themselves mostly close to the river or lakes. The river dynamics are the driving forces for succession of vegetation types. The succession starts from young forests, bush-communities or reeds on sites close to surface waters. Then follow forests and bush communities with good water supply from the groundwater (accompanying species: *Glycyrrhiza inflata*, *Halimodendron halodendron*. With increasing salt contents in the groundwater Halophyte (e.g. *Halostachys caspica* vegetation develops. With decreasing groundwater pure stands from *P. euphratica* and *Tamarix ramossissima* remain.

1 Introduction

Tugay is defined in a broad sense as “the recessive vegetation, including forests, bush communities and meadows, relying on flood and phreatic water along river banks, piedmont springs and lake shores in the desert and semi-desert plains in the middle of Asia. In a narrow sense it refers to riverine forests composed mainly of the two species *Populus euphratica*, *Populus pruinosa,* and *Eleagnus* spp. associated with shrubs (*Tamarix* spp.) and herbaceous species, distributed along rivers in Asian deserts (Tian, 1991). In this work the term Tugay vegetation is used for Tugay in broad sense and the term Tugay forests for the narrow sense. Tugay vegetation is then composed of Tugay forests, *Tamarix* bush communities, and reeds (mostly *Phragmites australis* reeds). The natural distribution of Tugay vegetation is from the Mediterranean through the Euphrates and Tigris area, the Lake Aral with its tributaries and the Tarim-Basin into Mongolia (fig. 1). P. euphratica forms stands throughout the area given in fig. 1, while *P. pruinosa* is restricted to more favourable sites in terms of water supply and climate (Liu et al., 1990; Wang et al., 1995).

> Tugay vegetation comes from the Uyghur word “Tugay”, which refers to vegetation along rivers in arid areas in Central Asia. Synonyms for Tugay vegetation are Togai and Tokai, both in English and German and Tougai in French. Chinese literature mostly refers to “Huyanglin”, meaning forests of *Populus euphratica*, but often includes the associated species, too.

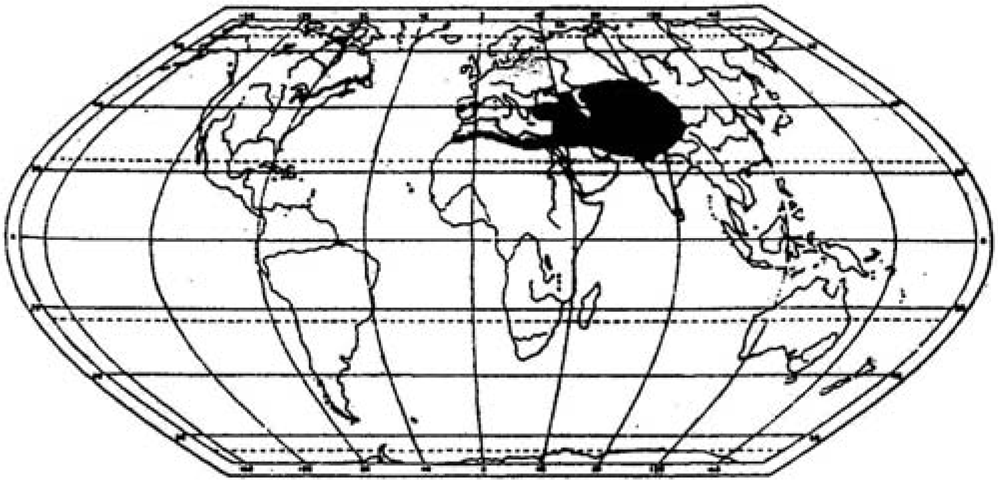

Fig. 1 The natural distribution of *Populus euphratica* as the dominating tree of the Tugay-forests (WANG et al., 1995).

Abb. 1 Natürliche Verbreitung von *Populus euphratica*, der Leitbaumart der Tugay-Wälder (WANG et al., 1995).

The Tugay vegetation is the most important habitat for plant and animal life in the desert regions of Central Asia and harbours most of the biodiversity of these regions. YUAN et al. (1998) report 21 species of mammals, 70 species of birds, and 10 species of reptiles and amphibians for Tugay vegetation in the middle reach of the Tarim. 25 bird species fall under protection according to Chinese law and 27 fall under the CITES Agreement (XINJIANG TALIMU HUYANG ZIRANBAOHUQU GUANLIZHAN, 2002). The Tugay vegetation is furthermore the hotspot of biomass production and accumulation in the Central Asian deserts.

Currently, worldwide most of the Tugay forests have been cut down to give space to agriculture. Especially in the 20th century, most of the Tugay forests in the Soviet Union and China were destroyed. The remaining forests suffered from water shortage as more and more water was used for irrigation. This process still goes on: in the Region Alar at the upper reaches of the Tarim the area under irrigation increased from 1992 to 1996 with nearly 4000 ha while the area of Tugay forests shrunk with nearly 800 ha (ZHAO et al., 2001).

The centre of the worldwide distribution of Tugay vegetation is the Tarim Basin in China (Tab. 1). There the Tarim Huyanglin nature reserve at the middle reach of the Tarim harbours the largest still intact Tugay forests of the world with *Populus euphratica* and other Tugay vegetation. Smaller near natural stands of Tugay forests still can be found in Kazakhstan at the Syr Darya. Data on the worldwide distribution of Tugay forests newer than 1993 apparently do not exist, as authors still refer to the data given in Tab. 1 (HUANG, 2004).

Country	Area [ha]	Share of world wide area [%]
China	395200	60,9
Tarim Basin, Xinjiang	352200	
Inner Mongolia, Gansu, Qinghai, Ningxia	43000	
Kazakhstan and other countries of Central Asia	200000	30,8
Iraq	20000	3,1
Iran	20000	3,1
Syria	5818	0,9
Turkey	4900	0,8
Pakistan	2800	0,4

Tab. 1 Distribution of Tugay forests world wide in 1993 (WANG et al., 1995).

Tab. 1 Weltweite Verbreitung von Tugay-Wäldern 1993 (WANG et al., 1995).

The destruction of Tugay vegetation most severely falls upon the Tugay forests and the reeds, as they are more sensitive to decreasing water supply than the *Tamarix* bush communities. The Tugay vegetation, especially forests of *P. pruinosa* and *P. euphratica*, is a worldwide unique and threatened ecosystem, which is not understood well so far. To contribute to their conservation, the Institute of Botany and Landscape Ecology of Greifswald University and the Institute of Resources and Environmental Sciences of Xinjiang University, China cooperatively study the Tugay vegetation at the middle reach of the Tarim River in Xinjiang. China, with respect to:

- The vegetation types and their ecological demands
- The effects of human utilisation on the vegetation types
- Reproduction of the key-species *Populus euphratica*.

This article presents the state of art knowledge on Tugay forests and vegetation regarding:

- The ecology and reproduction of Populus euphratica
- The ecological amplitudes of the main plant species regarding water and salt as the main factors
- Vegetation types of the Tugay vegetation

2 Study area

The study area is the Tarim Huyanglin Nature Reserve, as the last large intact and undisturbed Tugay vegetation stands with a mosaic of Tugay forests of *Populus euphratica*, reeds of *Phragmites* and *Calamagrostis pseudophragmites*, and *Tamarix* bush formations is located there. The Tarim Huyanglin Nature Reserve covers a rectangle of 100 x 40 km at the middle reach of the Tarim. The Tarim River is located in the Tarim Basin in Xinjiang, Northwest China. The huge inland Tarim Basin is largely occupied by the Taklamakan Desert, according to ZHU (1986) and CHEN et al. (1997) with 337,600 km² the second largest sand desert of the world (cf. fig. 2). The Basin is surrounded by the Pamir, Tianshan, and Kunlun mountains, which intercept all humid air currents. The climate is hyperarid and winter cold

(AGNEW et al., 1992 and SCHULTZ, 1995). A climate diagram of the town Weili, about 100 km east of the study area is given in fig. 3.

Fig. 2 Map of the Tarim Basin with the location of the Tarim Huyanglin Nature Reserve.

Abb. 2 Karte des Tarim-Beckens mit dem Tarim Huyanglin Schutzgebiet.

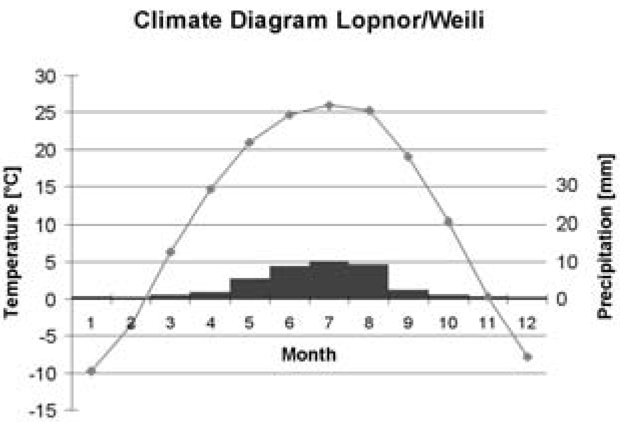

Fig. 3 Climate diagram Weili (Weili Xian Difangzhe Bianzuan Weiyuanhui, 1993).

Abb. 3 Klimadiagramm der Stadt Weili (Weili Xian Difangzhe Bianzuan Weiyuanhui, 1993).

The only source of water for life under such hyper arid conditions is ground- and soil water, which eventually is replenished by the rivers. The largest river of the Tarim Basin is the Tarim, 1321 km long. It is fed by melting water and precipitation in the mountains through its three tributaries Aksu, Hotan, and Yarkant. Increasing water demand for irrigation leads to decreasing runoffs, which in the 1970s led to the end lakes Lop Nor and Lake Taitema as well as 300 km of the Tarim lower course falling dry.

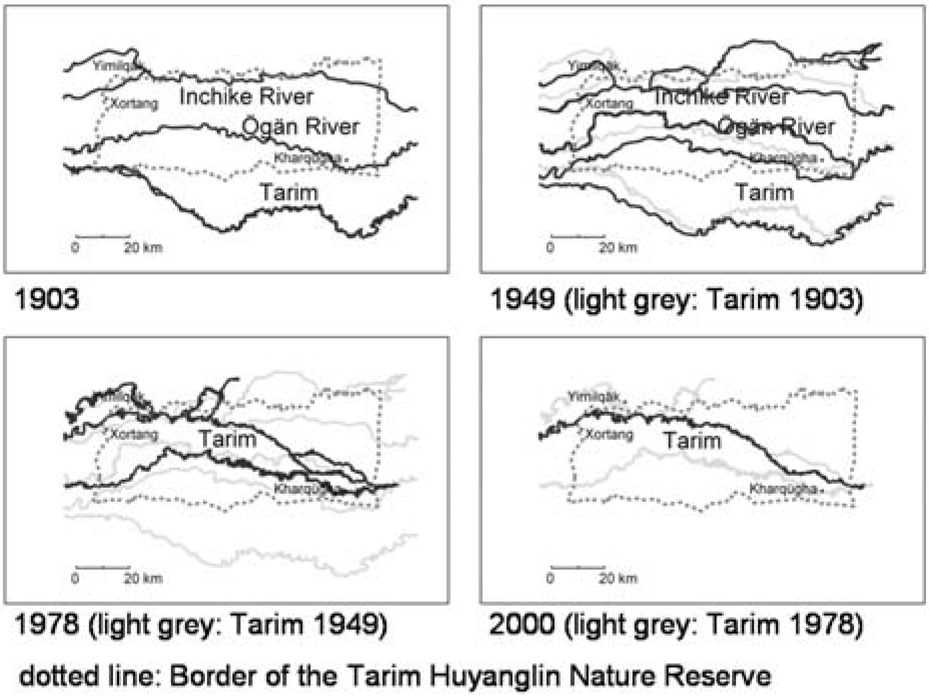

Fig. 4 Changes of the Tarim River in the area of the Tarim Huyanglin Nature Reserve 1903, 1949, 1978, and 2000 (Sources: 1903: HEDIN (1905), 1949: ZHONGHUA RENMIN GONGHEGUO GUOJIA TUCIJU (1959), 1978: GENERALNYJ STAB. (1983), 2000: Satellitenbild Landsat ETM, 06.07.2000).

Abb. 4 Flussverlagerungen des Tarim innerhalb des Tarim Huanglin Schutzgebietes 1903, 1949, 1978 und 2000 (Quellen: 1903: HEDIN (1905), 1949: ZHONGHUA RENMIN GONGHEGUO GUOJIA TUCIJU (1959), 1978: GENERALNYJ STAB. (1983), 2000: Satellitenbild Landsat ETM, 06.07.2000).

About 75% of the annual runoff is concentrated in the months July, August, and September. The water level rises 3 to 4 m and these annual floods replenish the ground- and soil water (HUANG et al., 1998). Each flood brings huge loads of sediments in the large, very slightly inclined alluvial plain, leading to the formation of meanders and an inland delta at the middle reach of the Tarim. Every flood changes the river course, erodes land and forms new river banks, opens new river branches or closes existing ones. Huge floods even change the entire river system (cf. fig. 4). As the river moves away sites change from wet, frequently flooded and fresh via dry (groundwater levels 3-5 m below surface) with some accumulation of salts, to extremely dry with groundwater levels of 8-10 m or even 20 m deep. This flood dynamics has lost much of its former strength, but in parts of the Tarim Huyanglin Nature Reserve still prevails.

In Chinese literature the soils are classified as “meadow soils” with humus accumulation under grass vegetation, “peat soils”, “gley soils”, “*Populus euphratica* forest soils” with an A-horizon under *Populus euphratica* forests, “soils of aeolian sands”, “solonchak” and “takyr soils“ (WEILI XIAN DIFANGZHE BIANZUAN WEIYUANHUI, 1993). According to the FAO classification the soils are Fluvisols, Gleysols, Solonchak, and Arenosols (DRIESSEN et al., 1991).

The figures on the area of Tugay forests in the Tarim Basin vary widely, though all authors agree that the area of Tugay forests has shrunk drastically after the founding of the Peoples Republic of China, when land opening campaigns were launched in Xinjiang (HUANG, 1986; LIU et al., 1990; WANG et al., 1995; XU, 2003). HUANG (1986) presents areas of Tugay forests in the Tarim Basin of 528,600 ha for 1958 and 350,000 ha for 1978.

3 Methods

On the basis of numerous vegetation typologies in literature a preliminary working scheme of vegetation types was derived. Ecological data and data on vegetation typologies were collected from Chinese journals, books, expedition and research reports, and through excursions and personal communication with researchers, administrators, and local people on site. Unfortunately most Chinese publications do not explain, how data on groundwater level, salt content, and vegetation were gathered. As most literature uses Chinese plant names, the scientific names were translated according to HUDABERDI et al. (2000).

4 Ecology and reproduction of *Populus euphratica*

Taxonomically *P. euphratica* OLIV. together with *P. pruinosa* SCHRENK belongs to the *Turanga* group within the genus *Populus*, which has branched off very early in evolution from the other *Populus* species (WANG et al., 1995). *Populus euphratica* (Toghrak in Uyghur, Huyang in Chinese) is the only tree that forms forests along all the Tarim River. It is a phreatophytic plant that taps the groundwater through its ability to grow deep roots and follow sinking groundwater levels. Young trees have elongated leafs, while older trees have round leaves (fig. 5). The different leaf forms can be found on one tree or even on a single twig. Therefore its former scientific name was *P. diversifolia*. *P. euphratica* can grow to a 15 m high tree and is perfectly adapted to the conditions of a dynamic river system under extreme arid climate. The most detailed overall descriptions on *P. euphratica* are given by XINJIANG LINKEYUAN ZAOLIN ZHISHA YANJIUSUO (1989), XINJIANG ZIYUAN KAIFA ZONGHE KAOCHA DUI (1989), CHINA MINISTRY OF FORESTRY (1990), and WANG et al. (1995).

Fig. 5
Leafs, flowers, and seeds of
Populus euphratica.

Abb. 5
Blätter, Blüten und Früchte von
Populus euphratica.

On a site near Yingbaza XINJIANG LINKEYUAN ZAOLIN ZHISHA YANJIUSUO (1989) documented the annual life-cycle of *P. euphratica* during a period of three years (Tab. 2). The groundwater level was deeper than 5 m most of the time.

Stage of annual life cycle	**Time span**
Flower buds swell.	March, 25th to 30th
Flower catkins sprout.	April, 4th to 8th
Begin of the flowering period.	April, 7th to 10th
50% of the flowers pollinate.	April, 9th to 14th
End of the flowering period, 80% of the flowers pollinate and flower catkins start to fall.	April, 11th to 20th
First leaves unfold from the buds.	April, 14th to 20th
Half of the leaves are unfolded.	April, 15th to 25th
Start of the fruiting period. More than 50% of the fruits have turned from green to yellow.	Mid-June to end of July
Seed ripening period, seeds fall out.	End of June to August (late seeds ripe in October)
New twigs sprout.	Beginning of May to mid-June
Leaves turn from green to yellow.	September to October
90% of the leaves have turned yellow.	Sept., 25th to Oct., 25th
Beginning of leaf fall period.	Oct., 10th to Nov., 10th
End of leaf fall period.	Oct., 30th to Nov., 20th

Tab. 2 Annual life cycle of *P. euphratica*, after XINJIANG LINKEYUAN ZAOLIN ZHISHA YANJIUSUO (1989).

Tab. 2 Jährlicher Lebenszyklus von *P. euphratica*, nach XINJIANG LINKEYUAN ZAOLIN ZHISHA YANJIUSUO (1989).

P. euphratica has two strategies to reproduce: generative and clonal. The seeds are light, have pappus like hairs, and are drifted by wind and water. The main fruiting period is during the flooding period of the Tarim River. The seeds depend on freshly sedimented river banks to germinate and establish. There the seeds find empty space, abundant light, and moist soil, where the salt has been leached off and there they germinate in lines or narrow strips marking flood water lines at the river bank. Experiments confirmed that optimal germination conditions are intense light, a temperature of 25-30°C, and level, moist soils. The salt content in the soil may not exceed 0.2%. But LUO et al. (1991) report that *P. euphratica* seedlings are more sensitive to carbonate than to sulphate and least sensitive to chloride. The seedlings do not grow high in the first year, but invest in root growth to follow the sinking groundwater after the flood. On permanently moist sites the roots do not grow deep. Once the seedling has established and still has good groundwater supply it forms lateral roots, which form root suckers, and bush-like stands are formed. Roots parallel to the soil surface can be as long as 50 m (XINJIANG LINKEYUAN ZAOLIN ZHISHA YANJIUSUO, 1989; CHINA MINISTRY OF FORESTRY, 1990; LIU et al., 1990). *Tamarix* spp., *Calamagrostis pseudophragmites* and sometimes *Phragmites australis* germinate on the same sites together with *P. euphratica* (LIU et al., 1986).

The formation of root suckers, i.e. clonal growth, is the second strategy for *P. euphratica* to reproduce. Through clonal growth *P. euphratica* can reproduce rapidly on sites without flooding events, but cannot really enter new sites. Whenever the river changes its course and opens new banks or even a whole new river course, *P. euphratica* can enter these new sites through its seeds and form a new stand there.

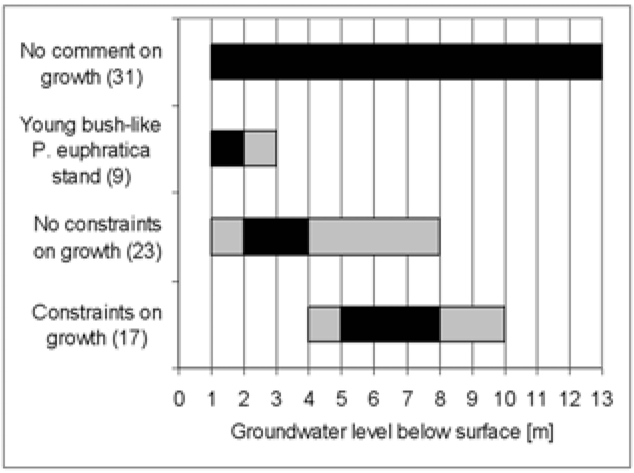

Fig. 6 Groundwater levels under young bush-like *P. euphratica* and *P. euphratica* with and without growth constraints. In brackets: Number of references.

Abb. 6 Grundwasserstände unter jungem *P. euphratica*-Gebüsch sowie *P. euphratica*-Wäldern mit bzw. ohne Wachstumshemmung. In Klammern: Anzahl der Nennungen in der Literatur.

P. euphratica shows its optimal growth at groundwater levels of 3-4 m deep. When the river moves away from a stand and the groundwater level does not sink too fast, *P. euphratica* can follow the groundwater to maintain its water supply. With sinking groundwater level, however, the growth rates decrease, clonal growth stops, and twigs in the tree crowns loose their leafs (cf. fig. 6). The data from fig. 6 were published by QU (1982), LIU (1986), LIU et al.

(1986), HUANG (1986), ZHANG et al. (1988), XINJIANG LINKEYUAN ZAOLIN ZHISHA YANJIUSUO (1989), CHINA MINISTRY OF FORESTRY (1990), LIU et al. (1990), WANG et al. (1995), MA et al. (2000), HAMID et al. (2001), JI et al. (2001), HUDABERDI et al. (2002), HUDABERDI (2003), LI (2003), and LI et al. (2003).

With the river moving away from a *P. euphratica* stand the salt concentration in the groundwater increases. Growing older, *P. euphratica* can withstand a maximum salt concentration in the groundwater of 15 g/l (Ji et al., 2001) (cf. fig. 7). The Data given in fig. 7 were published by QU (1982), XINJIANG LINKEYUAN ZAOLIN ZHISHA YANJIUSUO (1989), JI et al. (2001), and Li (2003). *P. euphratica* is able to exclude salts from soil water to a certain extent by transporting them into the leafs in autumn and getting rid of them, when the leafs fall (WANG et al., 1995 and LIU et al., 1986).

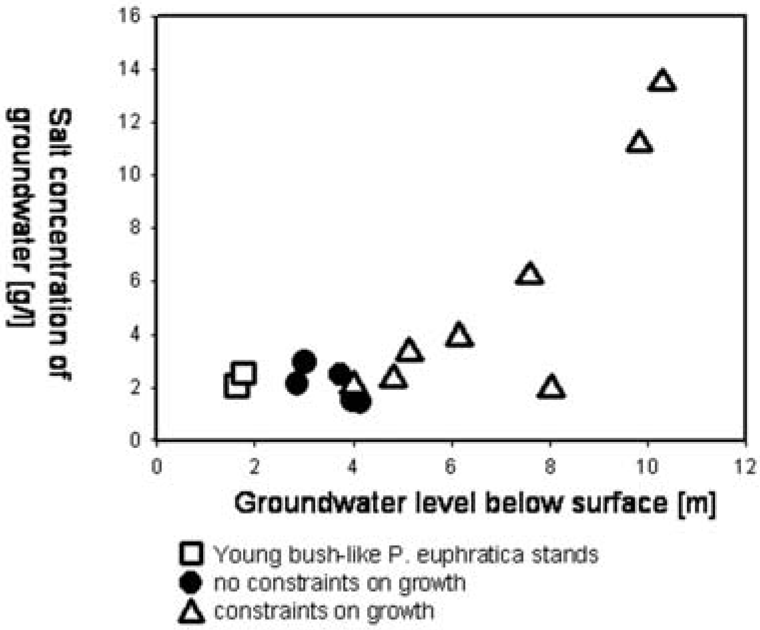

Fig. 7 Groundwater levels and groundwater salt concentrations under young bush-like *P. euphratica* and *P. euphratica* with and without growth constraints.

Abb. 7 Grundwasserstände und Salzgehalte im Grundwasser unter jungem *P. euphratica*-Gebüsch sowie *P. euphratica*-Wäldern mit bzw. ohne Wachstumshemmung.

When dunes invade *P. euphratica* forests, the *P. euphratica* trees can grow upward with the accumulating sand. Figures on the maximum growth in dunes are not available in the literature.

SAITO et al. (2002) showed that the genetic diversity of two populations of *P. euphratica* at the Tarim (Weili and south of Luntai) was higher than that of three populations on sites without river dynamics. They conclude that due to generative reproduction at the Tarim River there is a gene flux, which increases the genetic diversity.

5 Ecology of other common Tugay plant species

HUDABERDI et al. (2002) list 121 plant species for the Tarim Basin. Most of them are mesophytic phreatophytes, that continuously tap the groundwater. In the Tugay vegetation only about 20 plant species are found regularly. *Calamagrostis pseudophragmites*, *Carex* spp., *Cyperus* spp., and *Myricaria pulcherrima* are restricted to the wettest sites. Most species require a groundwater level of higher than 10 m and occur in the range of 2-5 m (fig. 8). *Oxytropis glabra* has a very small amplitude. *Phragmites* can grow from flooded sites to sites with 10 m groundwater level. Only *P. euphratica* and *Tamarix* spp. can grow on sites with deeper groundwater, HAMID et al. (2001) report 30 m below surface for *Tamarix ramossissima*. *T. ramossissima* is the most common *Tamarix* species in the Tarim Basin, but most authors refer to the genus *Tamarix* and not to certain species. The data given in fig. 8 are published in LIU (1986), ZHANG et al. (1988), XINJIANG LINKEYUAN ZAOLIN ZHISHA YANJIUSUO (1989), CHINA MINISTRY OF FORESTRY (1990), LIU et al. (1990), WANG et al. (1995), MA et al. (2000), SONG et al. (2000), HAMID et al. (2001), TASHPOLAT (2001), HUDABERDI et al. (2002), HUDABERDI (2003), and LI (2003).

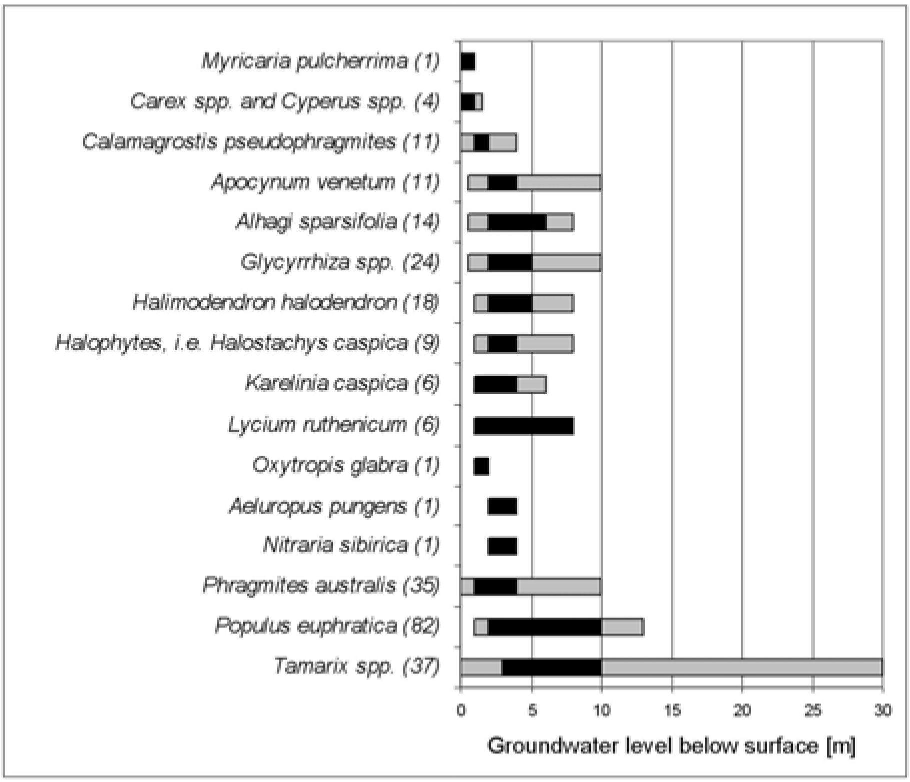

Fig. 8 Groundwater levels under common species of Tugay vegetation. In brackets: Number of references.

Abb. 8 Grundwasserstände unter den verbreiteten Arten der Tugay-Vegetation. In Klammern: Anzahl der Nennungen in der Literatur.

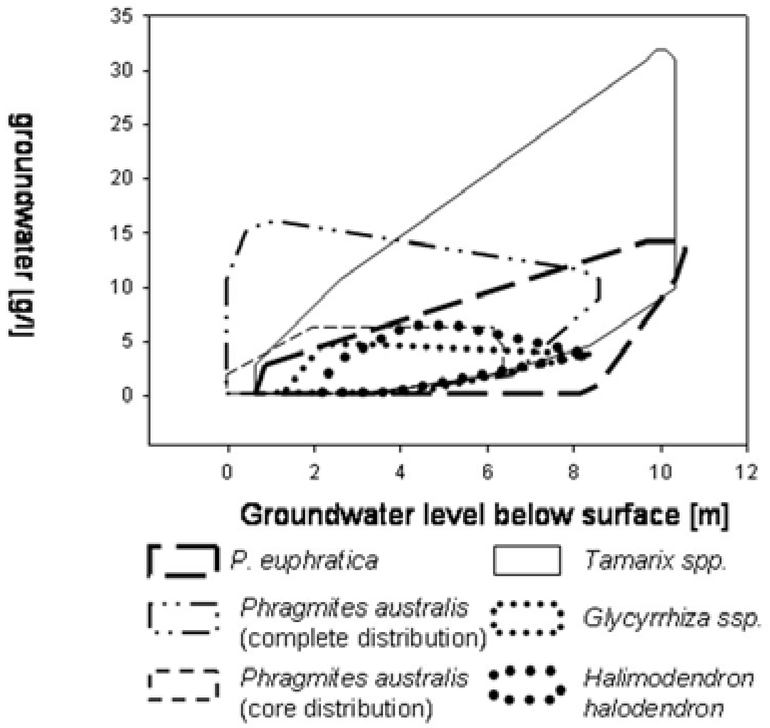

Fig. 9 Groundwater levels and groundwater salt concentrations under *Tamarix* spp. *P. euphratica*, *Phragmites australis*, *Glycyrrhiza spp.*, and *Halimodendron halodendron.*

Abb. 9 Grundwasserstände und Salzgehalte im Grundwasser unter *Tamarix* spp. *P. euphratica*, *Phragmites australis*, *Glycyrrhiza spp.* und *Halimodendron halodendron.*

Looking at the combination of groundwater and salt, the plants can be grouped clearer (fig. 9). *Tamarix* goes into the most extreme sites and has the widest amplitude, followed by *Populus euphratica* and *Phragmites australis*. *P. euphratica* can follow the groundwater deeper than reed. *Glycyrrhiza inflata*, *Apocynum venetum* (same amplitude), and *Halimodendron halodendron* require higher groundwater levels and soils with medium salt contents. Other species of this group of "intermediate plants" are *Alhagi sparsifolia* and *Karelinia caspica*. *Lycium ruthenicum* has a position which tends towards the halophytes (fig. 10). They can withstand salt as good as *Tamarix*. The group of plants, which require a very good water supply, includes *Calamagrostis pseudophragmites*, *Carex* spp. *Cyperus* spp., and *Myricaria pulcherrima* (fig. 11). Data presented in fig. 9, 10, and 11 were published in QU (1982), ZHANG et al. (1988), XINJIANG LINKEYUAN ZAOLIN ZHISHA YANJIUSUO (1989), WANG et al. (1995), MA et al. (2000), JI et al. (2001), LI (2003), and HUDABERDI (2003).

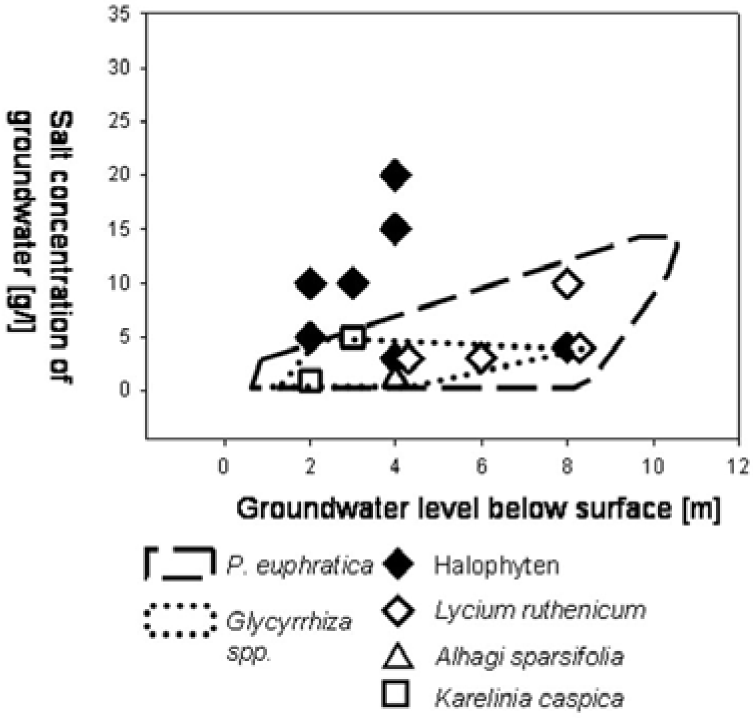

Fig. 10 Groundwater levels and groundwater salt concentrations under Halophytes.

Abb. 10 Grundwasserstände und Salzgehalte im Grundwasser unter Halophyten.

When looking at the groundwater data one has to take into account that deposition of aeolian sediments can result in soil surfaces of different heights above the level, where roots grow down from the plant, leading to different groundwater depths between sites with the same vegetation.

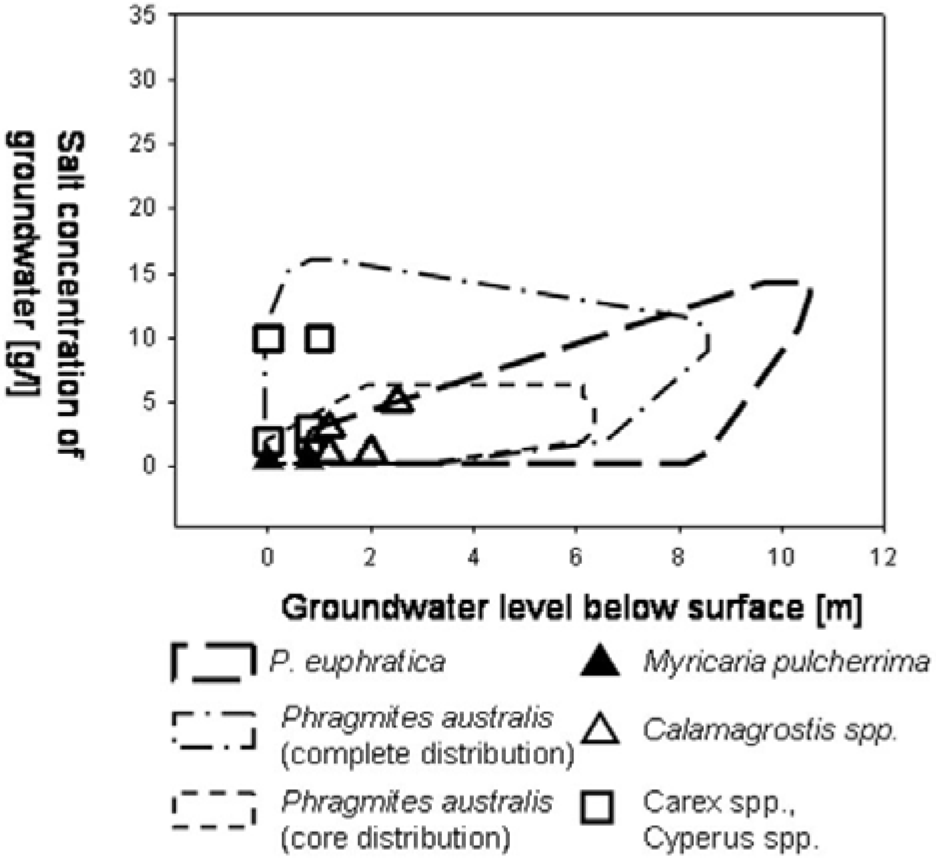

Fig. 11 Groundwater levels and groundwater salt concentrations under plants of moist sites.

Abb. 11 Grundwasserstände und Salzgehalte im Grundwasser unter Pflanzenarten feuchter Standorte.

6 Tugay vegetation types

Typologies of Tugay forests and Tugay vegetation (Tab. 3) have been worked out from the points of view of forestry (XINJIANG LINKEYUAN ZAOLIN ZHISHA YANJIUSUO, 1989), aminal husbandry (XINJIANG WEIWUER ZIZHIQU XUMU GONGCHENG KANCHA GUIHUA SHEJIYUAN; 2001), and vegetation science. ZHANG et al. (1988) presented a list of ecotopes.

Vegetation type	Site conditions	Authors
***Populus euphratica* Tugay forests**		
Young bush-like stands of *P. euphratica*	Along river courses Almost annual flooding Groundwater 1-2 m Low salt contents	Chinese Academy of Sciences (1980), Wang et al. (1995), Ma et al. (2000), Hudaberdi et al. (2002), Li (2003), Hudaberdi (2003)
Phragmites- and *Phragmites-Tamarix-P. euphratica* forest	Backswamps Almost annual flooding Groundwater 0-2 m	Qu (1982a), Liu et al. (1990), Wu (1992), Wang et al. (1995), Hudaberdi et al. (2002)
P. euphratica forests with rich undergrowth	Terraces close to river courses	
Glycyrrhiza inflata-P. euphratica forest	Groundwater 3 m	Wu (1992), Li (2003)
Glycyrrhiza inflata-Tamarix-P. euphratica-forest	Groundwater 3 m	Wang et al. (1995)
Glycyrrhiza inflata-Apocynum venetum-Halimodendron halodendron-P. euphratica-forest	Groundwater 4-8 m	Wang et al. (1995)
Species rich *Apocynum venetum-Halimodendron halodendron- P. euphratica*-forest	Groundwater 2-4 m	Qu (1982a), Liu et al. (1986)
Glycyrrhiza inflata-Apocynum venetum- P. euphratica-forest		Hudaberdi et al. (2002)
Lycium ruthenicum - P. euphratica forest		Wu (1992)
Halophyte-*P. euphratica* forest	Groundwater 1-3 m High salt contents	Chinese Academy of Sciences (1980), Qu (1982a), Liu et al. (1986), Liu et al. (1990), Wu (1992), Hudaberdi et al. (2002)
Tamarix-P. euphratica forests	River terraces, along dried up river courses Groundwater 5-10 m	Chinese Academy of Sciences (1980), Qu (1982a), Liu et al. (1986), Liu et al. (1990), Wu (1992), Wang et al. (1995), Ma et al. (2000), Hudaberdi et al. (2002), Li (2003), Hudaberdi (2003)
P euphratica forests in degeneration		
Pure *P. euphratica* forests in degeneration	Groundwater deeper than 8 m	Chinese Academy of Sciences (1980), Qu (1982a), Liu et al. (1986), Hudaberdi et al. (2002)
P. euphratica forests in degeneration with *Tamarix*	River terraces, along dried river courses Groundwater 5-10 m	Wang et al. (1995), Ma et al. (2000), Hudaberdi (2003)
Secondary *P. euphratica* forest from root suckers	Close to river courses Groundwater 1-3 m	Liu et al. (1986), Liu et al. (1990)

Further types of Tugay vegetation		
Phragmites australis-Calamagrosits pseudophragmites-Tamarix bush	Along river courses Almost annual flooding Groundwater 1-2 m Low salt contents	LIU (1995)
Halimodendron halodendron bush	Groundwater 2-4 m	HUDABERDI et al. (2002)
Tamarix bush (with or without undergrowth)	Groundwater 2-4 m	MA et al. (2000), HUDABERDI et al. (2002)
Halophyte-*Tamarix* bush	Groundwater 2-4 m	LIU (1995)
Halophyte bush	Groundwater 2-4 m	WU (1992), MA et al. (2000), HUDABERDI et al. (2002)
Phragmites australis grasslands		
Dense *Phragmites australis* grasslands	Groundwater 0,5-2 m	MA et al. (2000)
Sparse *Phragmites australis* grasslands	Groundwater 4-6 m	MA et al. (2000)
Pure *Phragmites australis* grasslands	Groundwater 1-4 m	HUDABERDI (2003)
Glycyrrhiza inflata-Apocynum venetum-Karelinia caspica-Phragmites australis grassland	Groundwater 1-3 m	HUDABERDI (2003)
Tamarix spp.- and *Lycium ruthenicum-Phragmites australis* grassland	Groundwater 4-8 m	HUDABERDI (2003)

Tab. 3 Types of Tugay vegetation at the middle reaches of the Tarim.

Tab. 3 Vegetationstypen der Tugay-Vegetation am Mittellauf des Tarim.

The succession of the Tugay vegetation is driven by river course movement and subsequent sinking groundwater levels and increasing salt contents (CHINA MINISTRY OF FORESTRY, 1990; LIU et al., 1990; WU, 1992).

7. Discussion

Young bush-like stands of *P. euphratica* are consistently defined by all authors through their water regime, location at river courses, and the presence of young *P. euphratica*. *Phragmites-P. euphratica* forests are similar in terms of groundwater levels, but are located in backswamps. Once flooded, the backswamps have limited water exchange with the river so that salts are not leached as much as in the young *P. euphratica* stands along the rivers.

Since *Phragmites australis* can withstand higher salt concentrations than *Calamagrostis pseudophragmites* it appears appropriate to distinguish two types of Young bush-like stands of *P. euphratica* and *Phragmites-P. euphratica* forest. As the ecological amplitude of *Tamarix* is wider than that of *Phragmites*, it is suggested to skip the *Tamarix-Phragmites-P. euphratica* forest for this first approach and only keep the *Phragmites australis-P. euphratica* forest. In the *P. euphratica* forests with rich undergrowth all accompanying species belong to the group of “intermediate” species. Therefore the vegetation types listed above are put into this group.

The Halophyte-*P. euphratica* forest is defined uniformly through the presence of Halophytes. The main Halophytes here are *Halstachys caspica* and *Tamarix* spp. The *Lycium ruthenicum-P*. *euphratica* forest holds an intermediate position between *P. euphratica* forests with rich undergrowth and Halophyte-*P. euphratica* forest. This forest does not have rich undergrowth, but Halophytes do not occur either.

The classification of Tugay forests based on *Tamarix* as accompanying species is difficult, as *Tamarix* shows a wider ecological amplitude than all other plants and than *P. euphratica* itself. Some authors describe *Tamarix-P. euphratica* forests as without any other plants except for *Tamarix* and *P. euphratica*. This then refers to sites with groundwater water levels so low and salt concentrations so high that the "intermediate" species and *Lycium ruthenicum* cannot survive. This approach is followed.

The *term P euphratica* forests in degeneration is used for *P. euphratica* stands which show growth constraints. As constrained growth of *P. euphratica* can occur with or without *Tamarix* or Halophytes as accompanying species, the word "in degeneration" can be added to the terms Halophyte-*P. euphratica* forest or *Tamarix-P. euphratica* forest, if necessary.

Secondary *P. euphratica* forests from root suckers do not differ floristically from *P. euphratica* forests with rich undergrowth. This type reflects land use history rather than soil and groundwater conditions.

The bush vegetation types all have a counterpart among the *P. euphratica* forests (s. Tab. 3):

- *Phragmites australis-Calamagrostis pseudophragmites-Tamarix* bush ↔ Young bush-like stands of *P. euphratica*
- *Tamarix* bush (with or without undergrowth) ↔ *P. euphratica* forests with rich undergrowth
- Halophyte-*Tamarix* bush ↔ Halophyte-*P. euphratica* forest

For *Tamarix* bush HUDABERDI et al. (2002) list the same accompanying species as in the *P. euphratica* forests with rich undergrowth. These three pairs reflect the same ecological conditions regarding groundwater and salt. The presence or absence of *P. euphratica* just reflects in former times conditions favoured the establishment of *P. euphratica* or not. One can imagine a situation as follows: Plants of the Tugay vegetation establish on sites with good water supply, i.e. close to rivers or backswamps. A succession due to movements of river courses can only work with the set of species, which are already established at the beginning of the succession. Succession then means that more and more species disappear with sinking groundwater levels and more or less increasing salt concentrations (fig. 12).

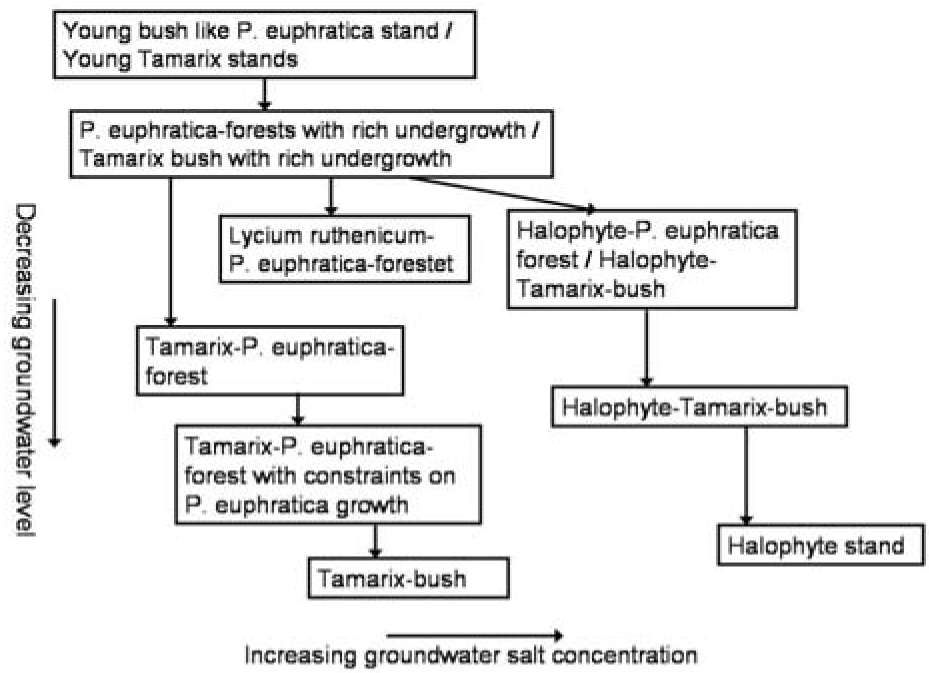

Fig. 12 Succession of *P. euphratica* forests and Tugay bush.

Abb. 12 Sukzession von *P. euphratica*-Wäldern und Tugay-Busch-Formationen.

For a first approach the following vegetation types for Tugay vegetation in the middle reaches of the Tarim are suggested:

Tugay vegetation with frequent flooding at river courses:

- *Myricaria pulcherrima* reeds
- *Calamagrostis pseudophragmites-Myricaria pulcherrima* reeds
- *Calamagrostis pseudophragmites* reeds
- Young bush-like *P. euphratica* stands
- Young *Tamarix* stands

Tugay vegetation with good water supply and low salt concentrations in the soil:

- *P. euphratica* forests with rich undergrowth
- *Tamarix* bush with rich undergrowth
- *Phragmites* reeds
- *Phragmites-P. euphratica* forests

Tugay vegetation with poor water supply

- *Lycium ruthenicum-P. euphratica* forest
- *Tamarix-P. euphratica* forests with normal growth of *P. euphratica*
- *Tamarix-P. euphratica* forests with constrained growth of *P. euphratica*
- *P. euphratica* forests with normal growth of *P. euphratica*

- *P. euphratica* forests with constrained on growth of *P. euphratica*
- Pure *Tamarix* bush

Tugay vegetation with halophytes

- Halophyte-*P. euphratica* forest
- Halophyte-*Tamarix* bush
- Halophyte yegetation

Field observations within this research work indicate that on sites with frequent flooding the vegetation types *Myricaria pulcherrima*-reeds, *Calamagrostis pseudophragmites-Myricaria pulcherrima*-reeds and *Calamagrostis pseudophragmites*-reeds are also present. Fig. 13 shows schematically the spatial distribution of the vegetation types perpendicular to the river bank. Within the young bush-like *P. euphratica* stands one finds rows of older *P. euphratica* trees. The reason for this structure might be that the trees of the rows have germinated from seeds in flood water lines of earlier years and then filled the space in between with root suckers. Here of course further research is needed to verify or falsify this explanation. On the dry end of the Tugay vegetation *Tamarix* bushes with undergrowth of "intermediate" species should be distinguished from those without any accompanying species. The latter reflects very deep groundwater levels and possibly high salt concentrations as only *Tamarix* can deal with. Tugay vegetation with halophytes indicates such salt concentrations that "intermediate" species have disappeared and halophytes had an opportunity to establish. Only the Halophyte-*Tamarix* bush and Halophyte vegetation indicate high salt concentrations that *P. euphratica* and *Tamarix* have disappeared respectively.

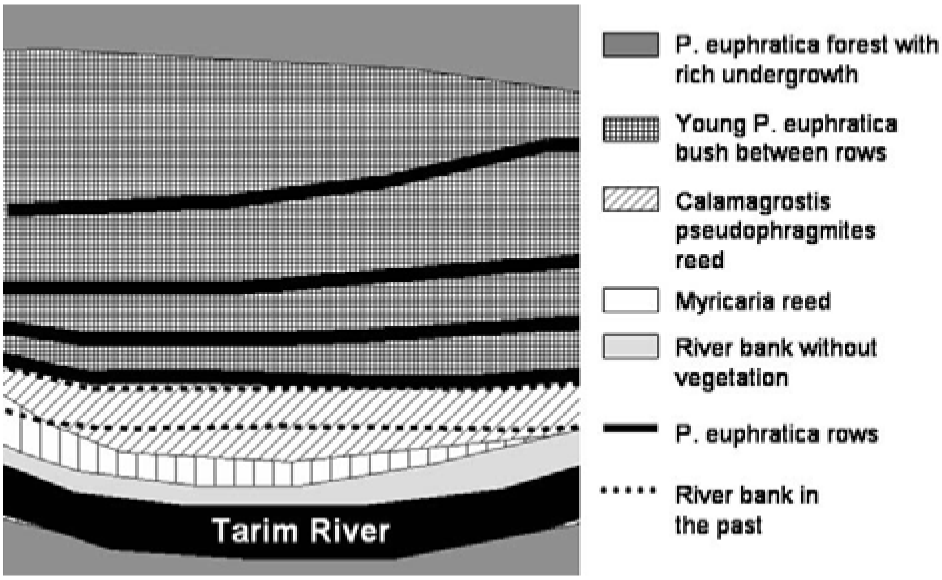

Fig. 13 Schematic spatial distribution of Tugay vegetation types and *P. euphratica* row structures at the Tarim River.

Abb. 13 Schematische Darstellung der räumlichen Verteilung von Tugay-Vegetationstypen und Reihen von *P. euphratica* am Tarim.

Acknowledgement:

I acknowledge the Heinrich-Böll-Foundation for providing my PhD-scholarship and the Volkswagen-Foundation for funding this research on Tugay vegetation in Xinjiang.

References

AGNEW, C. & ANDERSON, E. (1992): Water resources in the arid realm; London (Routledge).

CHEN, B.H., LI, H.Q.& LIU, J.G.: Research on biomass in natural *Populus euphratica* forests at the middle reaches of the Tarim (Xinjiang Talimu He zhongyou huyang tianranlin shengwuliang yanjiu); pers. comm. with Thevs, N. 2003. – Chinese

CHEN, G.T. & FENG, Q. (1997): Development and evolution of the eolian sand environment along the "Oil-Highway" through the desert of the Tarim Basin (Talimu Pendi shamo Shiyou Gonglu yan xian fengsha huanjing de xingcheng yu yanbian); Beijing.(China Environmental Science Press (Zhongguo Huanjing Kexue Chubanshe)). – Chinese

CHINA MINISTRY OF FORESTRY (1990): The forests of Xinjiang (Xinjiang senlin); Urumqi (Xinjiang Peoples Publishing House (Xinjiang Renmin Chubanshe)). – Chinese

CHINESE ACADEMY OF SCIENCES (1980): Vegetation of China (Zhongguo zhibei); Beijing (China Science Press (Zhongguo Kexue Chubanshe)). – Chinese

DRIESSEN, P.M. & DUDAL, R. (1991): The Major Soils of the World; Wageningen (Agricultural University Wageningen).

GENERALNYJ STAB. (1983) Kitaj; Moscow (Generalnyj Stab). – Map

HAMID, Y.,TASHPOLAT, T. & HIROKI, T. (2001): Groundwater Level Variation and its Environmental Effects in Southern Part of Tarim Basin. – In: TASHPOLAT, T. (ed.): The Study on Eco-Environmental Changes in the Southern Part of Tarim Basin; 247-255; Urumqi (Xinjiang University Press (Xinjiang Daxue Chubanshe)).

HEDIN, S.A. (1905): Scientific results of a journey in Central Asia 1899-1902; Leipzig (Brockhaus).

HUANG, P.Y. (1986): A Preliminary Study on the Decline of the Distribution Range and Regeneration of the Forest Land of *Populus euphratica* in the Tarimpendi Basin (Talimu Pendi huyang fenbu qu de xiaotui he lindi gengxin fuzhuang de chubu yanjiu). – Acta Phytoecologica et Geobotanica Sinica (Zhiwu Shengtaixue yu Dizhiwuxue Xuebao) **10**(4): 302-309. – Chinese

HUANG, P.Y., PAN, X.L. &. MA, Q.H. (1998): Restoration of the desert vegetation with *Populus diversifolia* as the main species for rehabilitating the ecological environment in Tarim River Basin (Zhong jian yi Huyang wei zhuti de huangmo zhibei zhengzhi Talimu He liuyu shengjing). – In: MAO, D.H. (ed.): The Water Ressources, Environment, and Management of Tarim River Watershed (Talimu He liuyu shui ziyuan, huanjing yu guanli); 218-223; Beijing (China Environmental Science Press (Zhongguo Huanjing Kexue Chubanshe)). – Chinese

HUANG, P.Y. (2004): Reasons for the Degeneration of Euphrates Poplar Forests and Strategies for its Restoration (Huyanglin de tuihua yuanyin yu lindi huifu celüe). – Environmental Protection of Xinjiang (Xinjiang Huanjing Baohu) **26**(zk):121-124.

HUDABERDI, M. & XU, J.G. (2000) Claves Plantarum Xinjiangensis (Xinjiang gao deng zhiwu jiansuobiao); Urumqi (Xinjiang University Press (Xinjiang Daxue Chubanshe)). – Chinese

HUDABERDI, M. & ABDUSALIH, N. (2002): The features of vegetation and eco-geography in Taklamaklan Desert. – In: ZERBE, S., KÜCHLER, J. & HAMANN, B. (eds.): Basic and applied aspects of nature and environmental protection in North China and South Korea with a focus on ecology and socio-economics; 52-61. – Seires Landschaftsentwicklung und Umweltforschung, No. 121; Berlin (Technische Universität Berlin).

HUDABERDI, M. (2003): (Discussion on the main vegetation types in the Tarim Basin and their relation to the groundwater (Talimu Pendi zhuyao zhibei leixing xianzhuang ji qi yu dixiashui guanxi de tantao); Manuscript for the conference "Schutz und Renaturierung bedrohter Flussökosysteme in den Trockengebieten Zentralasiens – Das Beispiel des Tarim in Süd-Xinjiang, China"; Korla (Sept. 1st-8th, 2003). – Chinese

JI, F., MA, Y.J. & FAN, Z.L. (2001): Soil water regime in *Populus euphratica* forest on the Tarim River alluvial plain (Talimu He chongji pingyuan Huyang de turang shuifen zhuangkuang yanjiu). – Acta Phytoecologica Sinica (Zhiwu Shangtai Xuebao) **25**(1):17-21.

LI, H.Q.: Distribution of *Populus euphratica* forests at the middle reaches of the Tarim and their administration (Talimu He zhongyou huyanglin fen tezheng jiqi jingying guanli); pers. comm. with Thevs, N. 2003. – Chinese

LI, H.Q., ZHOU, R.N. & LONG, B.Y.: Discussion on the issue of protecting, restoring, and developing the *Populus euphratica* forests in the Tarim watershed (Qian tan ruhe baohu, huifu he fazhan Talimu He liuyu de Huyanglin wenti); pers. comm. with Thevs, N. 2003. – Chinese

LIU, L.C. (1986): First researches on desertification processes in soils under *Populus euphratica* forests in the Tarim watershed (Talimu He liuyu Huyanglin xia turang huangmohua de chubu yanjiu). – Arid Zone Research (Ganhan Qu Yanjiu) **2**: 47-52. – Chinese

LIU, M.T. (1995): Comprehensive research results on the genus *Tamarix* including its propagation and utilization (Hongliu shu zhiwu zonghe yanjiu ji da mianji tuiguang yingyong); Lanzhou (Lanzhou University Press (Lanzhou Daxue Chubanshe)). – Chinese

LIU, P.J. ZHANG, L. & FAN, C.Q. (1986): Resources of *Populus euphratica* forests in the Tarim watershed (Talimu He liuyu de Huyanglin ziyuan); Urumqi (Zhongguo Kexueyuan Xinjiang Fenyuan Talimu He Yaogan Yanjiu Dui). – Chinese

LIU, P.J., ZHANG, L. & FAN, C.Q. (1990): Ressources of *Populus euphratica* forests at the Tarim River (Talimu liang an de Huyanglin ziyuan). – In: LIANG, K.Y. & LIU, P.J. (eds.): Remote sensing based analysis of the resources and the environment at the Tarim (Talimu He liang an, ziyuan yu huanjing yaogan yanjiu); 170-178; Beijing (Kexue Jishu Wenxian Chubanshe). – Chinese

LUO, B. & ZHOU, S.W. (1991): Study on the salt-resistance of *Populus euphratica* under water culture (Shui pei Huyang kang yan texing de yanjiu). – Forest Research (Linye Kexue Yanjiu) **4**(5): 486-491.

MA, J.Z., QIAN, J. & GAO, Q.Z. (2000): Groundwater evolution and its influence on the fragile ecology in the south edge of Tarim Basin. – Journal of Desert Research (Zhongguo Shamo) **20**: 145-149.

QU, Y.G. (1982): The water resources of the Tarim and their rational utilization (Talimu He shui ziyuan jiqi heli liyong). – Mem. of Desert Research Institute, Academica Sinica (Zhongguo Kexueyuan Lanzhou Shamo Yanjiusuo Jikan) **2**: 37-48. – Chinese

QU, Y.G. (1982a): Changes of environmental conditions after large scale land opening projects in the Tarim watershed and the rational utilization of the water, soilm and *Populus euphratica* forests resources (Talimu He liuyu da guimo nongken hou ziran tiaojian de yanbian ji shui, tu, Huyang ziyuan de heli liyong). – Mem. of Desert Research Institute, Academica Sinica (Zhongguo Kexueyuan Lanzhou Shamo Yanjiusuo Jikan) **2**: 15-35. – Chinese

SAITO, Y., SHIRAISHI, S., TANIMOTO, T., YIN, L., WATANABE, S. & IDE, Y. (2002): Genetic diversity of *Populus euphratica* population in Northwestern China determined by PAPD DNA analysis. – New Forest **23**: 97-103.

SCHULTZ, J. (1995): The ecozones of the world; New York, Heidelberg, Berlin (Springer Verlag).

SONG, Y.D., FAN, Z.L., LEI, Z.D. & ZHANG, F.W. (2000): Relationship between groundwater and the natural vegetation (Dixiashui yu tianran zhibei de guanxi). – In: SONG, Y.D., FAN, Z.L., LEI, Z.D. & ZHANG, F.W. (eds.): Research on water resources and ecology of Tarim River, China (Zhongguo Talimu He shui ziyuan yu shangtai wenti yanjiu); 215-240; Urumqi (Xinjiang Peoples Publishing House (Xinjiang Renmin Chubanshe)). – Chinese

TASHPOLAT, T. (2001): Study of Cele Oasis vegetation ecology programming (Cele Lüzhou zhibei shengtai guihua yanjiu) – In: TASHPOLAT, T. (ed.): The study on arid land environment change and application of remote sensing (Ganhan qu huanjing yanbian yu yaogan yong yanjiu); 45-62; Urumqi (Xinjiang University Press (Xinjiang Daxue Chubanshe)). – Chinese

TIAN, Y.Z. (1991): Tokai on the delta at the lower reach of the Keriya River - a natural vegetation complex reflecting ecological degradation. – In: JÄKEL, D. (ed.): Reports on the "1986 Sino-German Kunlun-shan Taklamaklan Expedition"; 99-112; Berlin (Gesellschaft für Erdkunde zu Berlin)

WANG, S.J., CHEN, B.H. & LI, H.Q. (1995): Euphrates Poplar Forest; Beijing (China Environmental Science Press).

WEILI XIAN DIFANGZHE BIANZUAN WEIYUANHUI (1993): Description of Weili County (Weili xian zhe); Urumqi (Xinjiang University Press). – Chinese

WU, S.Y. (1992): Tarim Basin heat and moisture transference research - Evaporation and its correlatives (Talimu Pendi shui re zhuangkuang yanjiu – zhengfa jiqi xiangguan wenti); Beijing (Ocean Press (Haiyang Chubanshe)). – Chinese

XINJIANG LINKEYUAN ZAOLIN ZHISHA YANJIUSUO (1989): Research on techniques to restore *Populus euphratica* forests (Huyanglin Gengxin Fuzhuang Jishu Yanjiu); Urumqi. – Chinese

XINJIANG TALIMU HUYANG ZIRANBAOHUQU GUANLIZHAN (2002): Integrated planning for the Tarim Huyanglin Nature Reserve in Xinjiang 2002-2011 (Xinjiang Talimu Huyang Ziranbaohuqu zongti guihua 2002-2011); Korla. – Chinese

XINJIANG WEIWUER ZIZHIQU XUMU GONGCHENG KANCHA GUIHUA SHEJIYUAN (2001): Research report on the feasibility of the construction of ecologica and environmentally sound pasture land in Weili County, Xijiang (Xinjiang Weili Xian caodi shengtai huanjing jianshe xiangmu kexingxing yanjiu baogao); Urumqi. – Chinese

XINJIANG ZIYUAN KAIFA ZONGHE KAOCHA DUI (1989): *Populus euphratica* forests (Huyanglin). – In: SHI, Y.L. (ed.): Evaluation and planning for the forestry production in Xinjiang (Xinjiang senlin ziyuan pingjia ji shengchan jianshe buju); 36-43; Beijing (China Science Press (Kexue Chubanshe)). – Chinese

XU, X.F. (2003): Discussion on the construction of a administration system for the restoration of the damaged ecosystems at the Tarim River (Talimu Shousun Shengtai Xitong Huifu Zhongjian Guanli Tixi Jianli de Tansuo); Urumqi (Zhongguo Kexueyuan Xinjiang Huanjing Kexue Yanjiusuo). – Chinese

YUAN, G.Y. & LI, W.H. (1998): Weili Poplar diversifolia Forest Nature Reserve (Weili Huyanglin Ziranbaohuqu). – In YUAN, G.Y. & LI, W.H. (eds.): Natural environmental protection and nature reserve in Xinjiang (Xinjiang ziran hunajing baohu yu baohuqu); 147-152; Urumqi (Science, Technology and Hygiene Publishing House of Xinjiang (Xinjiang Keji Wesheng Chubanshe)). – Chinese

ZHANG, L.D., CHENG, X.J., FAN, Z.L., LI, F. & LEI, J.Q. (1988): Soil types and soil resources in the valleys of the Tarim (Talimu hegu tudi leixing ji tudi ziyuan). – Arid Zone Research (Ganhan Qu Yanjiu) **5**(2): 10-18. – Chinese

ZHAO, H.,YAN, L. & JI, F. (2001): The dynamics of land utilization in the upper reaches of Tarim River. – Journal of Arid Land Ressources and Environment (Ganhan Qu Ziyuan yu Huanjing **15**(4): 40-43.

ZHU, Z.D. (1986): Deserts in China; Lanzhou (Institute of Desert Research, Academica Sinica).

ZHONGHUA RENMIN GONGHEGUO GUOJIA TUCIJU (1959): Map of Xinjiang; Beijing (Zhonghua Renmin Gongheguo Guojia Tuciju).

Archiv für Naturschutz und Landschaftsforschung

Archives of Nature Conservation and Landscape Research

Die Zeitschrift erscheint mit vier Heften pro Jahr (im Jahr 2003 waren es drei Hefte). Das Einzelheft ist zum Preis von 20 € (incl. Versand) zu beziehen. Ein Jahresabonnement kostet inclusive Versand 80 €. Bestellungen sind an die Schriftleitung bzw. direkt an den Verlag zu richten:

Verlag Dr. Kessel

Eifelweg 37, D-53424 Remagen-Oberwinter
nkessel@web.de, Tel.: 02228 - 493, Fax: 01212 - 512382426
www.ArchivNatur.de

ISSN 0003-9306

Hinweise für die Autoren

Das **Archiv für Naturschutz und Landschaftsforschung** publiziert Originalbeiträge sowie Reviews in deutscher oder englischer Spache, die das ganze Spektrum der landschaftsbezogenen Naturschutzforschung und Landschaftsökologie umfassen. Eingeschlossen sind dabei ausdrücklich Themen, die sich mit der zeitlichen Dimension, bis hin zu ausgesprochen palaeökologischen Fragen, auseinandersetzen. Beiträge aus dem Bereich der Einzelwissenschaften wie Bodenkunde, Vegetationskunde, Hydrologie, Klimatologie und Geomorphologie sollten einen konkreten Raumbezug aufweisen. Beiträge, die über den mitteleuropäischen Raum hinausgehen sind erwünscht.

Manuskripte können bei der Redaktionsleitung in zwei Exemplaren eingereicht werden. Der Text muss 1½-zeilig mit breiten Rand für vorzunehmende Korrekturen vorliegen. Jedes Manuskript wird von zwei Gutachtern beurteilt.

Nach positiver Begutachtung ist der Artikel in Form einer DOC-Datei mit einem Ausdruck einzureichen. Der Text ist außer Überschriften und Absätze als durchlaufender Fließtext (ohne Abb., Tab.; keine Silbentrennung) anzufertigen. Generelle Formatierungshinweise sind unter **www.ArchivNatur.de** zu erhalten.

Abbildungen, Tabellen und Fotos werden mit arabischen Zahlen nummeriert und mit deutschen sowie englischen Untertiteln versehen. Sie sind dem Manuskript gesondert beizufügen. Im Text ist ihre korrekte Position anzugeben. Abbildungen nur in Form von TIF-Dateien, andere Formate nach Rücksprache mit dem Verlag.

Die Autoren erhalten je ein Exemplar des Heftes, in dem ihr Beitrag publiziert ist, kostenlos. Zudem wird der Beitrag als pdf-file zur Verfügung gestellt.

Manuskriptgestaltung:

1. Überschrift (kurz und prägnant; ohne Großschreibung).
2. Ausgeschriebene Vor- und Nachnamen der Autoren/innen.
3. Institution, Anschrift der Autoren/innen.
4. Kurze Zusammenfassung in Deutsch und Englisch (Abstract einschließlich Titel), unter Angabe von 4-6 Schlüsselwörter/Keywords in alphabetischer Folge.
5. Zitate im Text mit Autor (KAPITÄLCHEN) und Jahreszahl [z.B. KOPP (2003) bzw. SUCCOW et al. (2001)].
6. Wissenschaftliche Artnamen *kursiv* geschrieben.
7. Grafiken und Schaubilder nur in zweidimensionaler Darstellungsweise.
8. Literaturverzeichnis (Autoren in alphabetischer Folge, Arbeiten zeitlich geordnet) in folgender Anordnung: Autorennamen (KAPITÄLCHEN), Vornamen (abgekürzt), Erscheinungsjahr in (), dann: Titel. – Zeitschrift (ausgeschrieben), Bandnummer (**Fettdruck**): Seiten; bei Einzelbänden Erscheinungsort und Verlag in ().

   Beispiele:

   MANTHEY, M. (1998): Bodenerosion auf Ackerflächen im Stechlinsee-Gebiet. – Archiv für Naturschutz und Landschaftsforschung **37**: 149-166.

   KOSKA, I., SUCCOW, M. & CLAUSNITZER, U. (2001): Vegetation als Komponente landschaftsökologischer Naturraumkennzeichnung. – In: SUCCOW, M. & JOOSTEN, H. (Hrsg.): Landschaftsökologische Moorkunde, 2. Auflage: 112-128; Stuttgart (Schweizerbart).