1 Introduction

The Tarim Basin and the Tarim River are probably widely known through the Silk Road and the books of Sven Hedin (e.g. HEDIN, 1905). The Silk Road connected the West with the East as early as 2000 years ago. It ran along the foothills of the Tianshan and Kurum Mountains as well as along an ancient lower reach branch of the Tarim River that flowed through the Lopnor depression. Hedin traveled all along the Tarim River by boat with the objective to investigate the river course and the Lake of Lopnor. He described the Tarim River as flowing through hardly accessible areas of swamps, reeds, and forests. This riparian vegetation along the Tarim River and the various streams in the former Russian Empire is called "Tugai" vegetation.

During and after the land reclamation periods in the Soviet Union and China the Tugai vegetation was largely replaced by agriculture or destroyed by a growing shortage of water (HUANG, 1986; CHENG, 1993; WANG et al., 1996: 103; TRESHKIN, 2001). Therefore, only tiny patchy remnants of Tugai vegetation still exist today. Most of the remaining Tugai vegetation can be found in Xinjiang, concentrated along the middle reaches of the Tarim River. There, the Tarim Huyanglin Nature Reserve was established in 1983 to protect the Tugai vegetation consisting of riparian forests and other forms of riparian vegetation. The reserve extends 100 km along the middle reaches of the Tarim River (YUAN & LI, 1998: 147-152). The Tarim River measures 1321 km from the town of Aral, south of Aksu City, to its terminal lake Detama. The location of the study area is shown in Figure 1.

Figure 1: Location of the study area within Xinjiang and Central Asia.
图 1: 研究区域与新疆的地理位置。
تەتقىقات رايۇنى ۋە شىنجاڭنىڭ جۇغراپىيىلىك ئورنى

The Tarim Huyanglin Nature Reserve and the adjacent areas planned to be designated for nature conservation were selected for this study in order to investigate the ecology of a rather natural and intact area of Tugai vegetation. The aim was to gain insight into the specific ecological requirements for the conservation of Tugai vegetation. The distribution and the recent changes of the Tugai vegetation were also studied in order to locate the core areas of this vegetation which deserve highest conservation priority. The current land use practices and their impacts on the Tugai vegetation were examined in order to provide suggestions concerning practices to be avoided or favored in accordance with the Tugai conservation aims.

The fieldwork for this study was carried out from 2002 to 2005. During that time, from 2003 to 2004, lateral dykes were constructed by the Chinese government nearly all along the Tarim's middle reaches. Two weirs are still planned to be built within the nature reserve. In the light of the ongoing regulation of large segments of the Tarim River within the nature reserve, it has become all the more important to understand the ecological requirements of Tugai conservation.

This study first provides up-to-date knowledge of the Tugai vegetation and its key species (Chapter 2). Research hypotheses are derived and the research issues addressed in this study are introduced. Then the study area is described with regard to its geomorphology, geology, climate, hydrology, soils, and the human impacts on the hydrological conditions and the vegetation (Chapter 4). The methods employed are described in Chapter 5. The results and the discussion of the results are expounded in chapters 6 and 7. The results include a land cover map of the study area based on the classification of satellite images. The discussion closes with conclusions and suggestions for the conservation of the Tugai vegetation.

The place names will be presented in Uyghur wherever possible. In the text the Chinese names are provided in brackets whenever the Uyghur name is first introduced. The place names are also listed in both Uyghur and Chinese in Appendix III. The Hanyu Pinyin transcription is used for Chinese words, since it is by far the most commonly used transcription today. Uyghur words are also transcribed into Latin script which was used for Uyghur in China from the 1970ies until 1984. This transcription is similar to the Chinese Pinyin, but differs considerably from the transcription currently used in turkological studies. However, the transcription currently used in China was mainly adopted in this study because it happens to be the script commonly used by the Uyghur people today whenever they write their language in Latin script, for example, in e-mail communication.

The headings of Tables and legends of Figures are given also in Chinese and Uyghur. Each chapter is followed by a summary in Chinese and Uyghur. Only chapter 6, the results, is not supplemented by a Chinese and Uyghur summary, because a summary will not explain more than all Tables and Figures.

前言

塔里木盆地和塔里木河通过丝绸之路和瑞典来之 Sven Hedin 科学家的书籍 (例如 HEDIN, 1905)可能已是家喻户晓, 丝绸之路早在 2000 多年前就将东西方联系起来了。它沿天山和昆仑山脉以及古老的塔里木河流域下游的分支,经该罗布泊. Hedin 沿着塔里木河步行，其目的是研究塔里木河道和罗布泊湖泊。他描述塔里木河艰难的穿过沼泽,芦苇和森林地区。沿塔里木河岸分布的植被和前俄罗斯帝国内的各种溪流被称之为“土加依”。

在苏联和中国的土地开垦期间和之后的时期。土加依植被由于缺水在很大程度上被农业取代或摧毁(HUANG, 1986; CHENG, 1993;WANG et al., 1996：103; TRESHKIN, 2001)。 因此, 在今天只有小片的土加依植被残余依然存在。大部分的土加依植被残余在新疆被找到，它们主要集中在沿塔里木河中游的地方。为了保护由河岸森林和其他形式的河岸植被组成的土加依植被。于 1983 年在此建立了塔里木胡杨林自然保护区。保护区沿塔里木河中游延伸 100 公里（YUAN & LI, 1998：147-152)。塔里木河从阿克苏的阿拉尔至其终端的台特马湖长 1321 公里。研究区的位置如图一所示。

塔里木胡杨林自然保护区以及它附近的在计划中被指定为自然保护区的地方都将被选为本次研究的区域，以探讨土加依植被区域的生态学特征。目的是要深入了解其具体的生态要求, 以保护土加依植被。为了找出这种植被中得到最高优先保护的核心领域，对土加依植被的分布和近期变化也进行了研究。为了对土加依保护目标提供和谐一致的建议，对现行的土地利用方式及其对土加依植被的影响都做了调查。

为此研究将从 2002 年至 2005 年进行野外调查。从 2003 年至 2004 年的这段时间，中国政府几乎在沿塔里木河中游的所有地区建立了堤坝。在自然保护区仍计划将建立两个堰。在其不断对自然保护区内的大部份塔里木河流域进行调控，了解土加依保护的生态需求显得更加重要。

这项研究首次提供了有关土加依植被及其关键物种的最新知识(第 2 章)。在本文中研究假设被推导出来, 研究中需要解决的问题也被介绍。然后对研究领域的地貌、地质、气候、水文、土壤和人类活动对水文条件和植被的影响进行描述(第四章)。采用的方法在第 5 章有记叙，得出的结果以及对结果的讨论在第 6 章和第 7 有详细的阐述。结果包括研究领域的土地覆盖图都是以卫星图像的分类为基础的。讨论的结果和建议都是为了保护土加依植被。每章中都有中文和维文摘要。只有第 6 章没有汉语和维语总结, 因为它的结论都在数字和表格中表现出来了。图例中的数字和表格也都译成汉语和维文。

地名也将用维文介绍。在正文中维文名字写在前面，汉语名字写在后面并用括号括起来。附录三中的地名用维语和汉语列出。汉语拼音的抄本是为汉语词服务的, 因为它是迄今为止最常用的抄本。维文词也变成拉丁字母抄写，在中国从 1970 年直至 1984 年拉丁语就被用在维文中了，这种转录类似汉语拼音, 但与目前土耳其语系学研究的转录使用差别很大。然而, 目前在中国使用的转录在此次研究中被大量采用，因为它恰好是今天维吾尔人以拉丁字母为基础写自己语言的常用脚本, 例如, 电子邮件通信。

تۇنۇشتۇرۇش

تارىم ئويمانلىقى ۋە تارىم دەرياسى، يىپەك يولى ۋە سېۋىن ھىدىن (ھىدىن 1905) كىتابلىرى ئارقىلىق كەڭ تۇنۇلغان. ئىككى مىڭ يىللار ئىلگىرى يىپەك يولى شەرق بىلەن غەربنى تۇتاشتۇرغان ئىدى. ئۇ تەڭرىتاغ ۋە كوئىنلون تاغ باغلىرىدىن تارتىپ لوپنۇر ۋادىسىغا قۇيۇلىدىغان قەدىمكى تارىمنىڭ تۆۋەن ئېقىنلىرىغچە سۇزۇلغان. ھىدىن دەريا قېنى ۋە لوپنۇر كۆلىنى تەكشۈرۈش ئۈچۈن، قېيىق بىلەن تارىم دەرياسىنى كېزىپ چىققان. ئۇ تارىم دەريا سىنى يەتكىلى بولمايدىغان سازلىق، قۇمۇشلۇق ۋە ئورمانلارغا قۇيۇلىدىغان قىلىپ تەسۋىرلىگەن. تارىم دەريا سى ۋە كۆپلىگەن ئۆستەڭلەرگە تارقالغان،بۇ دەريا ساھىلى ئۆسۈملۈك يېپىنچىسى، چار روسىيە دەۋرىدە « توقاي » ئۆسۈملۈك يېپىنچىسى دەپ ئاتالغان.

سوۋېت ئېتنىپاقى ۋە جۇڭگودا يەر ئېچىشنىڭ ئالدى — كەينى دەۋرىدە ، توقاي ئۆسۈملۈك يېپىنچىسى دېھقانچىلىق تەرىپىدىن سقىپ چىقىرۋېتىلدى ياكى كۆچمىۋاتقان سۇ كەملىكى تەرىپىدىن نابۇت قىلىندى. شۇڭلاشقا ئىنتايىن كىچىك بىر پارچىسلا بۈگۈنگىچە ساقلىنىپ قالالىدى. ساقلىنىپ قالغان توقايلىقنىڭ كۆپىنچىسى شىنجاڭدا، بۇلۇپمۇ تارىمنىڭ ئوتتۇرا ئېقىنىغا مەركەزلەشكەن. تارىم توغراق تەبىئىي مۇھاپىزەت رايۇنى، دەريا ئورمانلىقى ۋە باشقا دەريا ساھىلى ئۆسۈملۈك يېپىنچىسىنى ئۆز ئىچىگە ئالغان توقايلىقنى قوغداش ئۈچۈن قۇرۇلدى. قوغداش رايۇنى تارىمنىڭ ئوتتۇرا ئېقىنىدىكى 100 كىلومىتر دائىرىگىچە سوزىلىدۇ. تارىم دەريا سى ئارال يېزىسىدىن ئاخىرقى كۆل تېتىماغچە 1321 كىلومىتر كىلىدۇ. تەتقىقات رايۇنى 1- رەسمىدە كۆرسىتىلگەنىدەك.

تارىم توغراق مۇھاپىزەت رايۇنى ۋە ئۇنىڭ ئەتراپىدىكى جايلار تەبىئىيلىكنى ساقلاپ قېلىش ئۈچۈن بېكىتىلگەن ۋە تەبىئىي ۋە پۈتۈن توقايلىقنىڭ ئىكولوگىيىسىنى تەكشۈرۈش ئۈچۈن، بۇ تەتقىقاتقا تاللانغان. مەقسەت توقايلىق ساقلاپ قېلىش ئۈچۈن بىرمەك بولغان ئېنىق ئېكولوگىيىلىك تەلىپى ھەققىدە چۈشەنچىگە ئېرىشىش. يۈكسەك دەرىجىدە قوغداشقا ئەرزىيدىغان مەركىزى توقايلىقنى بېكىتىش ئۈچۈن توقايلىقنىڭ تارقىلىشى ۋە يېقىندىن بۇيانقى ئۆزگىرىشى تەتقىق قىلىندى. ھازىرقى يەر ئىشلىتىش ئەھۋالى ۋە ئۇنىڭ توقايلىققا كۆرسەتكەن تەسىرى، توقايلىقنى ساقلاپ قېلىش بىلەن ماس قەدەمدە قوللىنىشقا بولىدىغان ۋە بولمايدىغان يەر ئىشلىتىش ئۇسۇلى ئارقىلىق تەكلىپ بىلەن تەمىنلىگەن.

بۇ تەتقىقات خىزمىتى 2002- يىلىدىن 2005- يىلىغىچە ئېلىپ بېرىلغان. 2003- يىلىدىن 2004- يىلىغىچە يان توسۇقلار جۇڭگو ھۆكۈمىتى تەرىپىدىن پۈتۈن تارىم ئوتتۇرا ئېقىنلىرىغا قۇرۇلغان. ئىككى توسۇقنى ھىلىھەم قوغداش رايۇنىغا قۇرۇش پىلانلىنىۋاتىدۇ. توختىماي ئېلىپ بېرىلىۋاتقان چوڭ كۆلەمدىكى تارىم دەريا تەبىئىي مۇھاپىزەت رايۇنىنى تۈزەشنىڭ نەتىجىسىدە، توقايلىقنى ساقلاپ قېلىش ئۈچۈن زۆرۈر بولىدىغان ئېكولوگىيىلىك تەلەپنى چۈشىنىش مۇھىم بۇلۇپ قالدى.

بۇ تەتقىقات تۈنجى بۆلۈپ توقايلىق ۋە ئۇنىڭدىكى تۈرلەر ھەققىدىكى ئەڭ يېڭى بىلىملەرنى تەمىنلەيدۇ. (2- باب) ئىلمىي پەرەزلەر، تەتقىقات جەريانىدا تۇنۇشتۇرۇلغان مەسىلىلەر ئارقىلىق ئېرىشىلگەن. ئاندىن تەتقىقات رايۇنى ئۆزىنىڭ گىئومورفولوگىيە، گىئولوگىيە، كىلىمات، ھىدرولوگىيە، تۇپراق ۋە ئىنسانلارنىڭ ھىدرولوگىيىلىك مۇھىتقا ۋە ئۆسۈملۈك يېپىنچىسىغا كۆرسەتكەن تەسىرى قاتارلىق ئالاھىدىلىكلىرى ئارقىلىق تەسۋىرلەنگەن (4- باب). قوللانغان ئۇسۇللار 5- بابتا تۇنۇشتۇرۇلغان. نەتىجە ۋە مۇلاھىزە 6 ۋە 7- باپلاردا ئىسپاتلانغان. نەتىجە تەتقىقات رايۇنىنىڭ تۈرگە ئايرىلغان سۈنئىي ھەمرا خەرىتىسىنى ئۆز ئىچىگە ئالىدۇ. مۇلاھىزە توقايلىقنى ساقلاپ قېلىش ئۈچۈن بولغان خۇلاسە ۋە پىكىر — تەكلىپ بىلەن ئاياقلاشتۇرۇلغان. ھەر بىر بابنىڭ خەنزۇچە ۋە ئۇيغۇرچە قىسقىچە مەزمۇنى بار. پەقەت 6- بابتىلا نەتىجە ۋە خەنزۇچە ۋە ئۇيغۇرچە ئىخچاملانمىغان. چۈنكى نەتىجىلەر رەسىم ۋە جەدۋەللەردە كۆرسىتىلگەن. رەسىملەر ۋە جەدۋەللەرمۇ خەنزۇچە ۋە ئۇيغۇرچىغا تەرجىمە قىلىنغان.

يەرنامىلىرى ئامال بار ئۇيغۇرچە كۆرسىتىلىشكە تىرىشىلدى. ماقالىدە ئۇيغۇرچە يەر نامىلىرىنى تۇنجى تۇنۇشتۇرۇلغان جايلاردا تىرناق ئىچىدە خەنزۇچە نامى تەمىنلەندى. يەر نامىلىرى ئۇيغۇرچە ۋە خەنزۇچە قوشۇمچە جەدۋەل 3 كە تىزىلدى. خەنزۇ تىلىنىڭ ئەڭ كۆپ قوللىنىدىغان يازما شەكلى، خەنزۇ تىلى پىنيىنى خەنزۇچە سۆزلەر ئۈچۈن ئىشلىتىلدى. ئۇيغۇرچە سۆزلەر، جۇڭگو ئۇيغۇرلىرى 1970- يىلىدىن تاكى 1984- يىلىغىچە ئىشلەتكەن لاتىن ھەرپلىرى ئارقىلىق تەسۋىرلەندى. بۇ خىل يازما شەكىل بۇ ماقالىدە قوبۇل قىلىندى. چۈنكى بۇ خىل يازما شەكىل ئۇيغۇرلار قاچانكى يېزىقىنى لاتىنچە يازماقچى بولغىنىدا، مەسلەن ئېلخەت ئالاقىسىدە ئورتاق قوللىنىلىدۇ.

2 State of the art

The Tugai vegetation consists of Tugai forests, Tugai shrub and reed communities, and harbors most of the biodiversity and important habitat for plant and animal species in the desert regions of Central Asia. However, most of the Tugai forests existing worldwide have been cleared to make room for agriculture. Especially in the 20th century, most of the Tugai forests have been destroyed in the Soviet Union and China. The remaining forests are suffering from the growing strain of water shortages since increasingly more water is being used for irrigation. This process has been discussed in detail by HOPPE (1992) in the case of the Tarim Basin and by GIESE et al. (1998) in the case of the Aral Sea and its tributaries.

2.1 Introduction to the term "Tugai vegetation"

The term "Tugai" was defined by OGAR (2003: 318) as "the floodplain forests and shrub or mixed arboreal-frutescent thickets in the extra-tropical desert areas". The term has only been used with regard to riparian vegetation in Central Asia. The floodplain forests within the North American deserts are called Cottonwoods, named after the poplar *Populus deltoides* (BRAATNE et al., 1996). TIAN (1991) defined the Tugai forests as riparian forests along the rivers in the deserts of Central Asia, formed by *Populus euphratica, Populus pruinosa*, and *Elaeagnus oxycarpa*. In this study the term "Tugai forest" is used according to this definition. Along the Tarim River most Tugai forests are constituted by *Populus euphratica,* while *P. pruinosa* is restricted to the upper reaches of the Tarim River and its tributaries (WANG et al., 1996: 17-22). The Tugai forests are distributed in patches alternating with shrub and reed communities. The shrub communities along the Tarim River are mainly composed of *Tamarix species* (HUDABERDI & ABDUSALIH, 2002) among which *Tamarix ramosissima* is the most common (LIU, 1995: 50-51). Most Chinese literature on the Tugai vegetation deals with the *Tamarix* genus rather than individual species (cf. Section 2.3). In this study, the shrub communities will be referred to as Tugai shrub. The reeds along the Tarim River consist of *Phragmites australis* (HUDABERDI & ABDUSALIH, 2002; THEVS et al., 2007). Tugai forests, Tugai shrubs, and reeds thus constitute the components of the riparian vegetation along the Tarim River referred to here as Tugai vegetation.

> The word Tugai: Tugai is derived from the Kazakh, Uyghur, or, Tatar word *toghay/tokhay/toghay* which designates bush vegetation or open grasslands. Today, it refers to riparian forests, shrubs, and reeds. Synonyms of Tugai in the scientific literature are Tokai, Togai, Tougai, or Turau. Chinese sources usually use the term *huyanglin* which means *Populus euphratica* forest, but usually subsumes associated species as well.

The two key species *P. euphratica* and *Tamarix ramosissima* are phreatophytes, i.e., species which can survive the arid climate by maintaining a continuous water supply from the groundwater (GRIES et al., 1996; WANG et al., 1996; FOETZKI, 2004). Rather than adapting to the arid climate by saving water, the Tugai plants are, on the contrary, designed to permanently remain in contact with the groundwater and thus to maintain a high level of transpiration. Most of the species of the Tugai vegetation are restricted to sites with groundwater levels not deeper than 10 m (cf. Section 2.3). Only *Tamarix ramosissima* is a facultative phreatophyte, i.e., it is able to survive for some time without groundwater contact (DI TOMASO, 1998; SMITH et al., 1998). The groundwater is replenished by the river course along which the Tugai vegetation is distributed. Thus, the Tugai vegetation is limited to the floodplains or river valleys (XINJIANG LINKEYUAN ZAOLIN ZHISHA YANJIUSUO, 1989; LIU et al., 1990). The rivers in Central Asia such as the Tarim, Syr Darya, or Amu Darya are fed by precipitation and glacier meltwater in the mountains during the summer, resulting in floods which recharge the groundwater (QU, 1982; XIA, 1993; TRESHKIN, 1997; TANG et al., 1998; ZHANG & HE, 1998;

XINJIANG WEIWUER ZIZHIQU SHUILI TING & XINJIANG SHUILI XUEHUI, 1999; TSYTSENKO & SUMAROKOVA, 1999; ZHOLDASOVA, 1999; SONG et al., 2000; TRESHKIN, 2001; NOVIKOVA, 2001; OGAR, 2003; GIESE et al., 2004; GIESE et al., 2005).

The Tugai forests of Central Asia have their equivalent counterparts in the Cottonwoods of North America's arid Southwest. There, the phreatophytic trees such as *Populus deltoides, P. fremontii, P. angustifolia, P. balsamifera*, and *P. trichocarpa* also form riparian forests under arid conditions (EVERITT, 1968; BRAATNE et al., 1996; SCOTT et al., 1996; AUBLE et al., 1997; SCOTT et al., 1997; STROMBERG, 1997; ROOD et al., 1998; SHAFROTH et al., 1998; MERRIT & COOPER, 2000; COOPER et al., 2003)

2.2 Distribution of the Tugai vegetation and Tugai forests

The natural distribution area of *Populus euphratica* is shown in Figure 2. Within this area Tugai forests and Tugai shrubs are distributed throughout the river floodplains. The largest stands of Tugai forests are to be found in the Tarim and the Aral Sea basins, especially in the Amu Darya Delta (HEDIN, 1905; LAVRENKO, 1956; WANG et al., 1996). However, Tugai forests also grow in the Transaltay Gobi of Mongolia (HILBIG, 1995: 81).

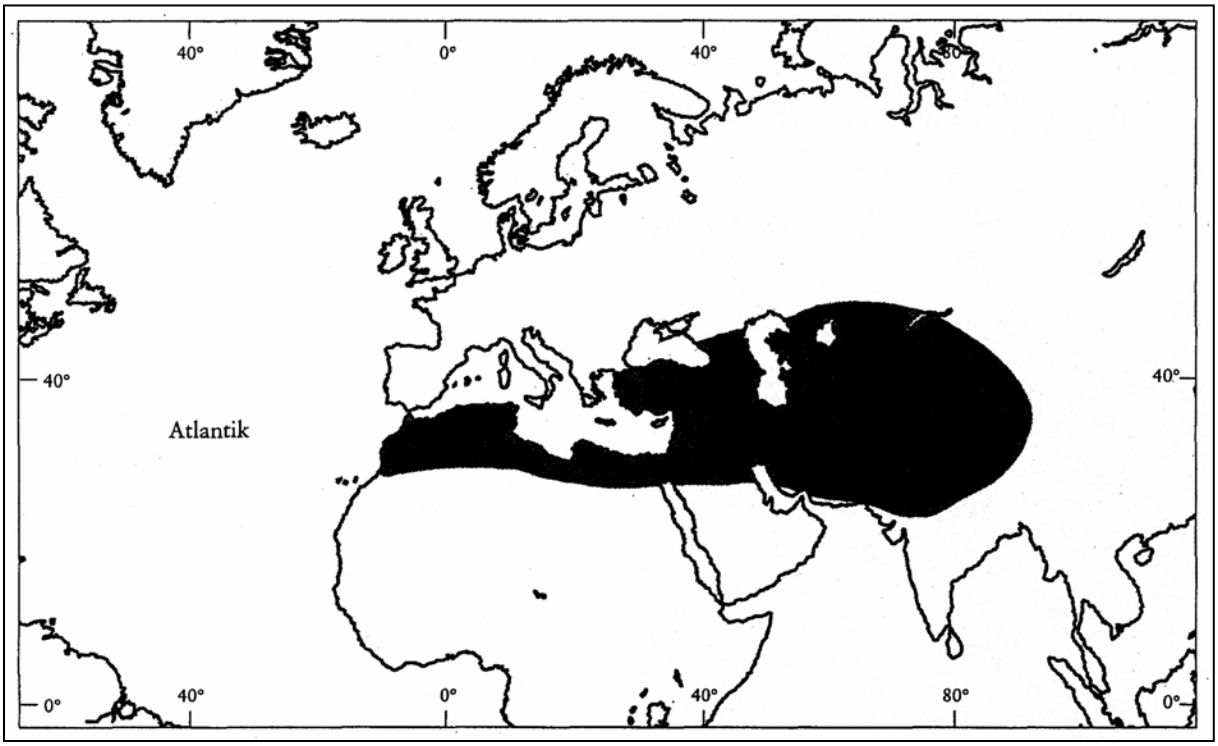

Figure 2: Natural distribution of *Populus euphratica* according to WANG et al. (1996: 18).
图 2: 胡杨的自然分布（WANG et al., 1996: 18）。
توغراقنىڭ تەبىئى تارقىلىشى

During the 50ies and 60ies of the 20th century large areas of land were opened up for agriculture in the Aral Sea and Tarim basins. Tugai forests and other Tugai vegetation were destroyed both directly and indirectly. Large stands of Tugai forests and Tugai shrubs were cleared for agricultural production and to provide timber and fuel wood. Increasingly more water was diverted into the expanding irrigation areas, leading to decreased river discharges and lowered groundwater levels along the rivers and lakes. The lower reaches of the Tarim River and Lake Lopnor both fell dry in 1972 (XIA, 1998a). Other branches of the Tarim River also dried out during the 50ies and 60ies (cf. Section 4.7). It was repeatedly reported that the Aral Sea water

level also declined, and the lower reaches of the Amu Darya and Syr Darya became desiccated (BELYAEV, 1990; GIESE et al., 1998; TSYTSENKO & SUMAROKOVA, 1999; KOSTIANOY et al., 1999; GIESE et al., 2004).

Most of the Tugai forests in the Amu Darya Delta and its lower reaches have been destroyed. The Tugai forest area there became reduced from 500,000 ha in 1950 to about 70,000 ha in 1998 (TRESHKIN, 2001). In the Tarim Basin the area of Tugai forests declined from about 500,000 ha in 1958 to about 150,000-200,000 ha in 1978 (HUANG, 1986; CHENG, 1993; WANG et al., 1996). Today most of the worldwide remaining Tugai forests are to be found in the Tarim Basin as shown in Table 1.

Table 1: Distribution of Tugai forests worldwide in 1993 (WANG et al., 1996: 26)
表 1: 全世界 1993 年吐加依林的分布 (WANG et al., 1996: 26)
پۇتۇن دۇنيادىكى توقايلىقلارنىڭ تارقىلىشى

Country	**Area [ha]**	**Proportion of world wide area [%]**
China	395,200	60.9
Tarim Basin, Xinjiang	352,200	
Inner Mongolia, Gansu, Qinghai, Ningxia	43,000	
Kazakhstan and other countries of Central Asia	200,000	30.8
Iraq	200,00	3.1
Iran	20,000	3.1
Syria	5,818	0.9
Turkey	4,900	0.8
Pakistan	2,800	0.4

The land reclamation campaigns along the Tarim River mainly focussed on the tributaries, the upper and lower reaches, but left the middle reaches untouched (HOPPE, 1992: 34, 41). Accordingly, the area of Tugai forests declined dramatically along the upper and lower reaches as shown in Table 2. Along the middle reaches the Tarim River formed, and in some parts still forms, an inland delta (cf. Section 4.1). The inland delta along the middle reaches was too difficult to access during the 1950ies and 1960ies. Therefore, the Tugai vegetation remained rather undisturbed throughout this area. Along the Tarim's upper reaches, the area of Tugai forests apparently increased from 1978 to 1983 due to reforestation (LIU et al., 1990).

Table 2: Distribution of Tugai forests along the upper, middle, and lower reaches of the Tarim River
表 2: 塔里木河上、中、下游吐加依林的分布
تارىمنىڭ باش، ئوتتۇرا، ئاياق ئېقىندىكى توقايلىقلارنىڭ تارقىلىشى

Year	**Area of Tugai forest [ha]**				**Source**
	Upper reaches of the Tarim River	**Middle**	**Lower**	**Total**	
1958	230,000	175,800	54,000	459,800	WANG et al., 1996: 180
1978	58,200	100,200	16,400	174,800	WANG et al., 1996: 180
1983	112,400	110,800	7,333	230,533	LIU et al., 1990

2.3 The Tugai plant communities along the Tarim's middle reaches and the biological features of their main species

Many authors have presented classification schemes of the Tugai vegetation or Tugai forests for the Tarim Basin as well as data on the site conditions associated with the various plant communities or individual plant species. These references were reviewed by THEVS (2005) and compiled in Table 3 on the following page. The studies available unfortunately do not clearly point out the research methods employed, and in most cases the study sites are only roughly indicated. Nevertheless, the studies reviewed provide valuable information for a basic understanding of the ecology of the Tugai vegetation and the biological functioning of the main species. The term "vegetation type" in this study is used as a neutral term to classify the Tugai vegetation into smaller units.

Since the Tarim River system is very dynamic by nature and its river courses often change their location, a web of Tugai forest belts has evolved along the current and former waters courses (LIU et al., 1990). River courses tend to relocate. Thereby they eventually move away from the stand sites, which in turn change from wet to frequently flooded, fresh, and eventually to dry conditions with groundwater levels 3-5 m below surface and some accumulation of salts, and finally to extremely dry conditions with groundwater levels of 8-10 m or deeper (CHOU, 1960; XINJIANG LINKEYUAN ZAOLIN ZHISHA YANJIUSUO, 1989: 70-71; LIU et al., 1990). The generative reproduction of most Tugai plants takes place on wet and frequently flooded sites. On the basis of generative reproduction, the succession in Tugai forests leads to sparse and degraded Tugai forests whenever the river course moves away from the stand site. On sites close to the rivers, grasses and herbs normally play a role as accompanying species in Tugai forests. However, on sites abandoned by river courses, the plant communities containing these species tend to disappear during the succession (QU et al., 1982: 15-35; LIU et al., 1986).