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Water Scarcity and Allocation in the Tarim Basin: Decision Structures and Adaptations on the Local Level

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Abstract: The Tarim River is the major water source for all kinds of human activities and for the natural ecosystems in the Tarim Basin, Xinjiang, China. The major water consumer is irrigation agriculture, mainly cotton. As the area under irrigation has been increasing ever since the 1950s, the lower and middle reaches of the Tarim are suffering from a water shortage. Within the framework of the Water Law and two World Bank projects, the Tarim River Basin Water Resource Commission was founded in 1997 in order to foster integrated water resource management along the Tarim River. Water quotas were fixed for the water utilization along the upstream and downstream river stretches. Furthermore, along each river stretch, quotas were set for water withdrawal by agriculture and industry and the amount of water to remain for the natural ecosystems (environmental flow). Furthermore, huge investments were undertaken in order to increase irrigation effectiveness and restore the lower reaches of the Tarim River. Still, a regular water supply for water consumers along the Tarim River cannot be ensured. This paper thus introduces the hydrology of the Tarim River and its impacts on land use and natural ecosystems along its banks. The water administration in the Tarim Basin and the water allocation plan are elaborated upon, and the current water supply situation is discussed. Finally, the adaptations made due to issues of water allocation and water scarcity on the farm level are investigated and discussed.

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Keywords: China, Xinjiang, water resources, land use

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Introduction and Objectives

The 1,321-kilometre-long Tarim River is China's longest inland river and the main water source for the Tarim Basin. The Tarim Basin, which comprises the entire southern part of the Xinjiang Uyghur Autonomous Region, covers an area of 1.02 million km² and is inhabited by 8.26 million people, not including the population of the state farms under the Xinjiang Production and Construction Corps (Song et al. 2000; Zhang 2006).

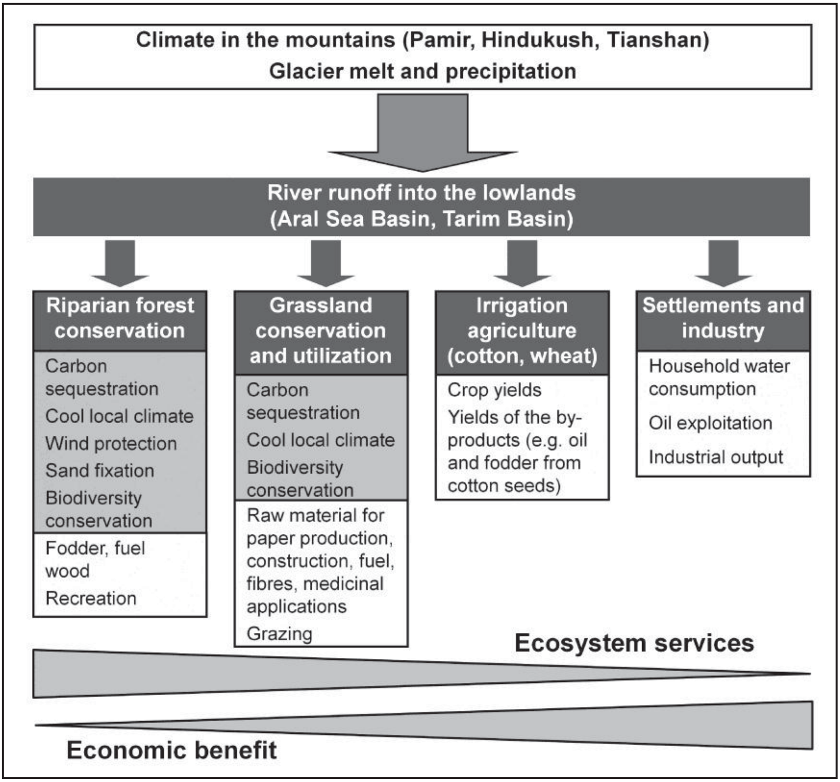
Due to the extremely arid climate in the Tarim Basin, all agriculture there depends on irrigation (Hoppe 1992). Settlements and industry extract water from surface water bodies as well as from the groundwater (Tang and Deng 2010): The natural vegetation relies on groundwater (Gries et al. 2003), which is recharged by the rivers of the Tarim Basin (Hou et al. 2007). In the Tarim Basin, the natural vegetation and agriculture as well as settlements and industry directly or indirectly depend on the river water as their major water source. This situation also applies to the arid lowlands in the Aral Sea Basin in Kazakhstan, Uzbekistan and Turkmenistan. Thus, agriculture, settlements and industry, along with the natural ecosystems, compete for river water (Figure 1).

From the 1950s until the 1970s, the area under irrigation was steadily enlarged, resulting in increasing demands for irrigation (Hoppe 1992; Giese, Bahro, and Betke 1998). Thus, during the 1970s, the 320-kilometre-long lower reaches of the Tarim River fell dry, and the terminal lakes Lopnor and Taitema vanished. This resulted in severe degradations of the natural riparian vegetation (Song et al. 2000; Giese, Mamatkanov, and Wang 2005). After 2002, within the framework of the Tarim River Regulation Scheme, flood pulses were diverted into the lower reaches of the Tarim River (Zhu et al. 2006). But, in five out of ten years from 2001 to 2010, the entire Tarim River middle reaches and the lower section of the upper reaches ceased to carry water during spring and early summer, i.e. during the planting and irrigation season. Consequently, water consumers, especially the farmers, faced water shortages.

Water shortages are a widespread problem for agriculture, industry and settlement all over northern and northwestern China, as thoroughly analysed by Cai (2008) for the Yellow, Huai and Hai River Basins. In contrast to those three rivers, the Tarim River (and the Heihe River in Gansu and Inner Mongolia) is a losing stream over its entire river length. So, the Tarim River does not receive any water except from its tributaries, and it drains into the groundwater over its complete river course.

Together with the arid climate, this enhances the crucial role played by the allocation of the Tarim River's water resources.

Figure 1: Scheme of the River Water Supply and Water Diversion into the Three Main Land Covers Competing for Water along the Rivers of Central Asia, Riparian Forests, Grasslands and Irrigation Agriculture, with their Economic and Ecological Benefits



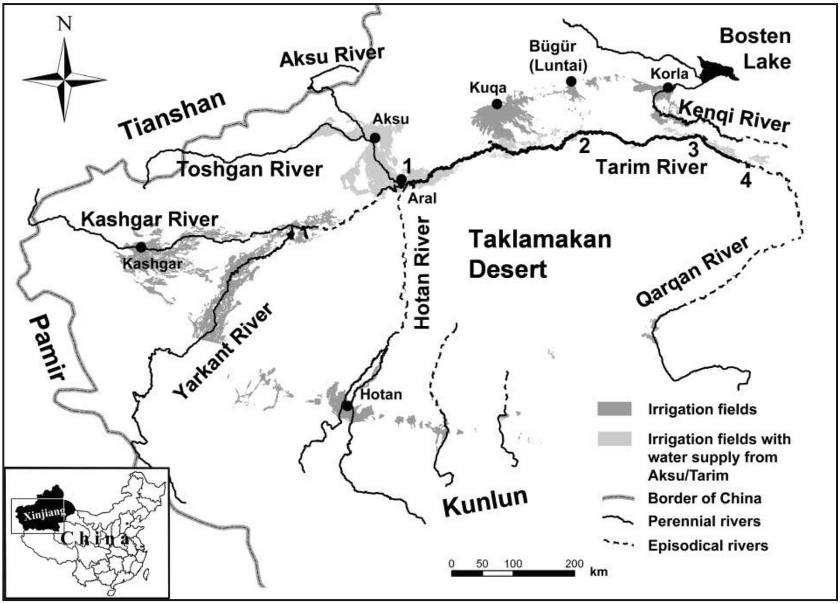
Source: Author's own compilation.

This paper first introduces the hydrology of the Tarim River with its impacts on land use and natural ecosystems along the Tarim River. Second, the water administration in the Tarim Basin and the water transfers under the Tarim River Regulation Scheme are described, and the current water supply situation is discussed. Third, the adaptation steps taken due to issues of water allocation and water scarcity on the farm level are investigated and discussed.

The Hydrology of the Tarim River

Up until the 1970s, the rivers Hotan, Yarkant and Aksu permanently discharged water into the Tarim River. The Kenqi River and the Tarim River were interconnected through an inland delta formed by numerous river branches (Report of the Comprehensive Expedition of Xinjiang 1978; Song et al. 2000). Today, only the Aksu River permanently delivers water into the Tarim River. The Hotan River and the Yarkant River only discharge into the Tarim during high floods (Giese, Mamatkanov, and Wang 2005).

Figure 2: Map of the Tarim Basin



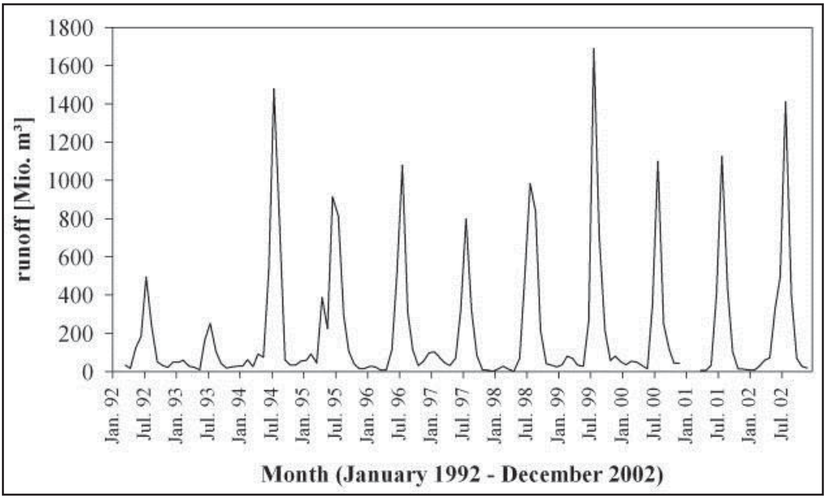
Note: Gauging stations: 1: Aral, 2: Yingbaza, 3: Qala Reservoir, 4: Daxihaizi Reservoir.
Source: Map based on Landsat ETM satellite images 2008.

The Tarim Basin is bordered by the Tianshan, Pamir and Kunlun mountain ranges (Figure 2). Consequently, all humid air currents from the

Indian and Atlantic Oceans are cut off, and the climate in the whole Tarim Basin is extremely arid with a mean annual precipitation of less than 50 millimetres (Yuan and Li 1998; Giese, Mamatkanov, and Wang 2005).

The headwaters of the rivers within the Tarim Basin are supplied by snow melt, glacier melt, and summer rainfall in the Kunlun, Pamir and Tianshan Mountains. The snow melt largely contributes to the springtime run-off of the Tarim River. Later, during summer, when the temperature in the high mountains has risen, the glacier melt water largely contributes to the Tarim River run-off. The rainfall reaches its maximum in July and August. Three-quarters of the annual river run-off are concentrated in the summer season, so the rivers cause summer floods, as shown in Figure 3. During these floods, the river banks and backswamps are flooded and the groundwater is recharged, both events serving to sustain the growth of the natural vegetation (Song et al. 2000). But, in contrast to most rivers fed by snow and glaciers, the peak flow of the Tarim occurs rather late, (July and August), so it does not support the vegetation during spring (Xu et al. 2006).

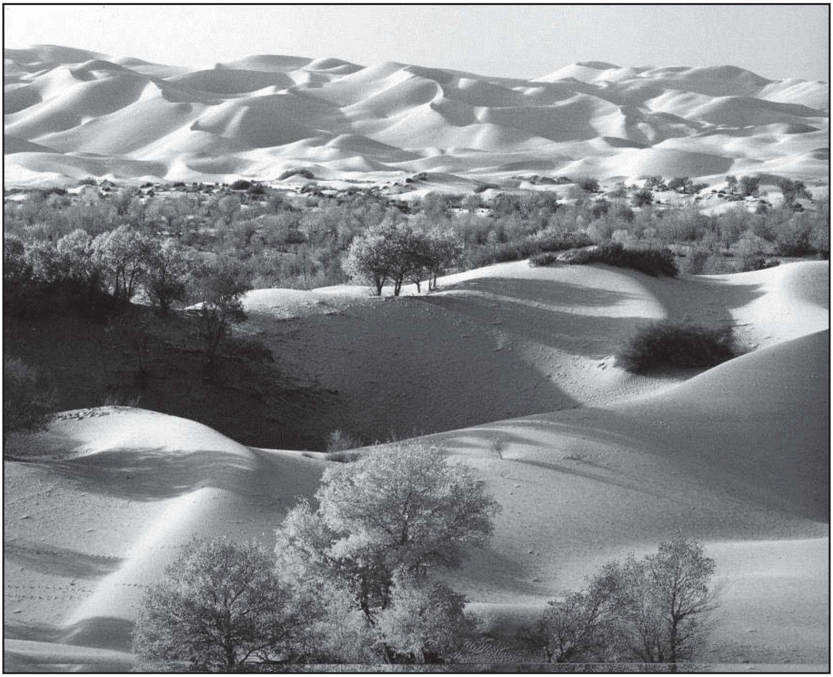
Figure 3: Monthly Run-off of the Tarim River's Middle Reaches (Hydrological Station Yingbaza)



Source: Thevs et al. 2008a.

The natural vegetation is adapted to the low river run-off during spring season by taking up water from the groundwater (Gries et al. 2003). The natural vegetation along the Tarim River, as well as the other rivers of the Tarim Basin, consists of riparian forests (Figure 4), grasslands, and shrub communities (Wang, Chen, and Li 1996; Thevs et al. 2008b). The riparian forests are built up by only two tree species, *Populus euphratica* (胡杨, *huyang*) and *P. pruinosa* (灰杨, *huiyang*). The grasslands are dominated by reed (*Phragmites australis*) as well as *Apoycnum* species (罗布麻, *luobuma*). The riparian forests and the grasslands are very productive ecosystems and provide a wide range of ecosystem services (Figure 1), like accumulating carbon, providing fodder and raw material to the local people, and combating desertification (Liang et al. 2006; Thevs et al. 2007).

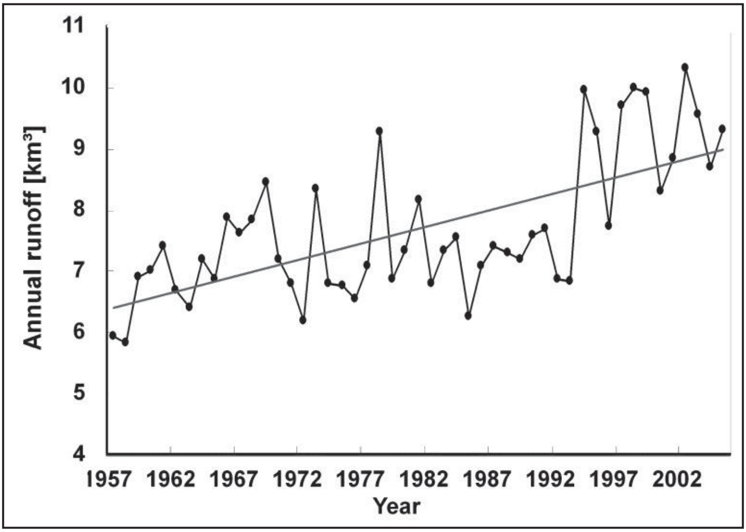
Figure 4: Riparian Forest along the Tarim River, Weili County, 80 Kilometres Southeast of Korla City



Source: © Photo N. Abdusalih 2007.

The water inflow into the Aksu River has increased over the past 50 years (Figure 5). This increase is remarkable after 1994 and is attributed to enhanced glacier melt due to global warming (Song et al. 2000; Tang and Deng 2010).

Figure 5: Annual Run-off at the Confluence of the Toshgan River and the Aksu River, 20 Kilometres North of Aksu City, 1957–2005



Source: Tang and Deng 2010.

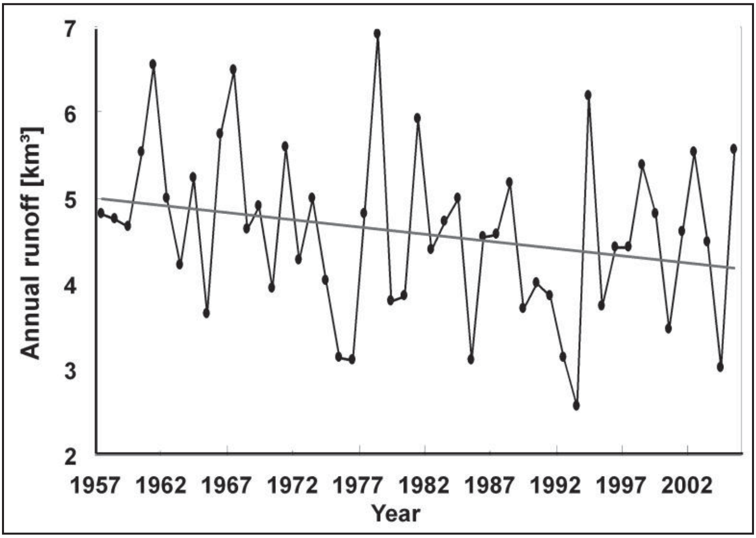
In contrast to the increasing run-off into the Aksu River (Figure 5), the annual run-off at the station Aral, the starting point of the Tarim River, shows a declining trend (Figure 6). The declining run-off into the Tarim River results from a higher number of areas being opened to agriculture.

Throughout history, irrigation agriculture has been concentrated in the oases along the foothills of the mountains that surround the Tarim Basin. Those oases have a history more than 2,000 years long; the Kuche, Kashgar and Hotan oases, for example, were part of the Silk Road (Hoppe 1992; Thevs 2007).

After 1949, the existing oases were enlarged, and large areas of virgin land were opened to agriculture. During the 1950s, 1960s and 1970s, virgin land along the upper and lower reaches of the Tarim River was converted into arable land, specifically in Aksu/ Aral and Weili Counties.

The Tarim's middle reaches apparently were too remote and dynamic at that time for land-opening campaigns (Hoppe 1992; Bohnet, Giese, and Zeng 1998). Therefore, in 1983 the Tarim Huyanglin Nature Reserve was established along the Tarim's middle reaches in order to preserve the last areas of natural vegetation (Yuan and Li 1998). After 1995, private investors opened land in the Tarim Huyanglin Nature Reserve (Hofmann 2006). Cotton gradually replaced wheat as the major crop in Xinjiang after 1978, and as of now, Xinjiang is China's largest cotton producer, accounting for 21.5 per cent of China's total cotton production (Hsu and Gale 2001; Chapagain et al. 2006).

Figure 6: Annual Run-off at the Station Aral, 1957–2005



Source: Tang and Deng 2010.

The conversion of virgin land into arable land resulted in steadily increasing demands for irrigation along the Tarim River and its tributaries, because all agriculture depends on irrigation. Therefore, after 1972 the lower reaches of the Tarim River – downstream of the Daxihaizi Reservoir – fell dry, and the terminal lakes Lopnor and Taitema vanished.

During spring and early summer 2007, 2008 and 2009 (cf. Figure 7), the Tarim River's run-off was interrupted all along its length. This very low run-off was mainly attributed to the low snowfall in the Tianshan

Mountains during the winters, which were rather warm, resulting in very low springtime run-off (Thevs, personal communication). Furthermore, the area under irrigation along the Aksu River increased sharply in size between 2000 and 2008 (cf. Table 1), resulting in an enhanced withdrawal of water from the Aksu River.

Figure 7: The Tarim River Bed at Yingbaza in July 2007

Source: © Photo Niels Thevs 2007.

Table 1: Agricultural Area along the Tarim River in 2000 and 2008

Region	Area (in 1,000 ha) year		Increase from 2000 to 2008	
	2000	2008	(1,000 ha)	(%)
Cropland along the Aksu and Tarim	760	955	195	26
Cropland of selected sub-regions				
Aksu and Aral	658.6	796.2	137.5	21
Weili region	42.7	67.7	25	58
Yingbaza	6.6	12.1	5.5	83
Tarim Huyanglin Nature Reserve	3.3	7.6	4.3	126

Note: Not all of the arable land is planted.
Source: Based on mapping from Landsat ETM satellite images.

The Water Resource Administration in the Tarim Basin and the Tarim River Regulation Scheme

Against the backdrop of increasing water scarcity along the Tarim River – and especially due to the dry and therefore degraded lower reaches of the Tarim River – the Tarim River Basin Water Resource Commission was founded, and the Tarim River Regulation Scheme, a bundle of measures for the restoration of the Tarim lower reaches, was carried out. Furthermore, a quota system was developed that serves as the basis for the water allocation between the upper, middle and lower reaches, as well as between the water consumers – that is, agriculture, oil exploitation and the natural vegetation.

The Water Resource Administration in the Tarim Basin

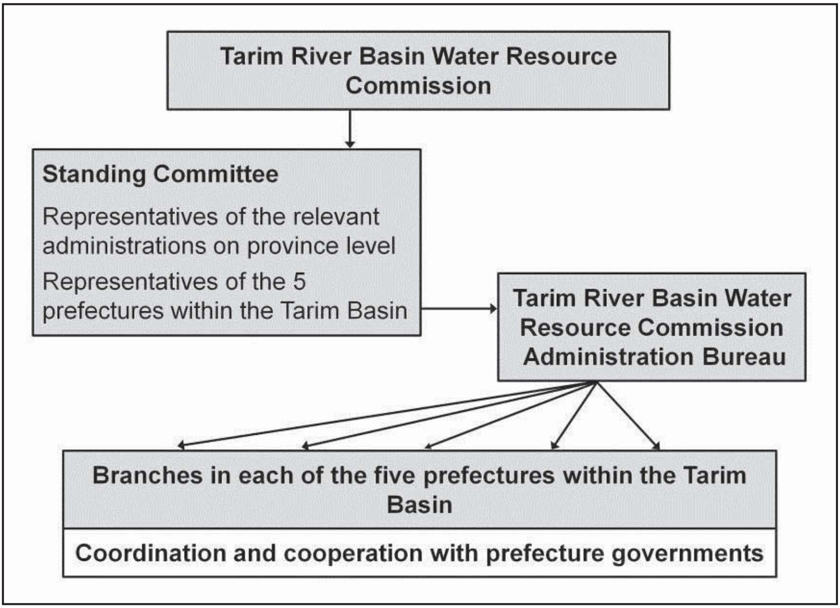
Within the framework of the Water Law of China of 1988, the Xinjiang government issued the Interim Provisions for Water Administration and Water Resource Management of the Tarim River Basin in 1994. Within these provisions, the Tarim River Regulation Scheme was drafted.

In 1997, the Xinjiang government adopted the Tarim Regulations (Zhang 2006; Zhu et al. 2006) and founded the Tarim River Basin Water

Resource Commission. Under this commission, there is a standing committee and the administration bureau (Figure 8).

The standing committee makes the decisions regarding water resource management, while the administration bureau executes the decisions. Members of the standing committee are representatives of the relevant administrations under the Xinjiang government (water, agriculture, environment, pasture and forestry) and representatives of the five prefectures within the Tarim Basin (Kizilsu, Kashgar, Hotan, Aksu and Bayingouleng). The administration bureau is responsible for the water allocation along the Tarim River as well as for planning and monitoring. But technically, the measures worked out by the administration bureau are implemented by the Water Administrations of the prefecture and county governments.

Figure 8: Structure of the Water Resource Administration of the Tarim Basin



Source: Author's own compilation.

The Tarim regulations with the administrative structure shown in Figure 8 were the first set of regulations in China that planned and allocated water resources based on the river basin level rather than for political reasons. In fact, all five prefectures within the Tarim Basin have access to the decision-making standing committee under the Tarim River Basin Water Resource Commission. But, the Xinjiang Production and Construction Corps, which runs eight large farms along the Tarim River, is an administrative entity that operates under the army rather than under the Xinjiang government. Therefore, the Xinjiang Production and Construction Corps does not partake in the decision-making processes of Tarim River Basin Water Resource Commission and cannot be controlled by the administration bureau, but of course consumes a significant share of the water of the Tarim River.

The whole process of establishing the Tarim River Basin Water Resource Commission was closely linked to the World Bank projects "Tarim Basin Project" (1991–1997) and "Tarim Basin II Project" (1998–2005). The Tarim Basin Project mainly focused on infrastructure investment like land reclamation, construction of irrigation and drainage channels, roads and administration buildings. The Tarim Basin II Project laid a stronger focus on the development of institutions and structures regarding sustainable water resource management (World Bank 2007).

The Tarim River Regulation Scheme

The Tarim River Regulation Scheme was drafted with the following main objectives (Zhang 2006; Zhu et al. 2006):

- to enhance irrigation efficiency, introduce water-saving irrigation techniques and thus save water in the agricultural sector and increase the yields from agriculture;
- to restrict agriculture to the field area from 1998, i.e. the end of the Tarim Basin Project;
- to construct water reservoirs in the mountains and give up water reservoirs in the lowlands along the main course of the Tarim River in order to prevent water losses through evaporation from lowland water reservoirs; and
- to provide water for the Tarim River's lower reaches in order to restore the riparian ecosystems there.

These objectives were in line with the objectives of the two World Bank projects. The Regulation Scheme of the Tarim River was listed as a key project of the tenth national Five-Year Plan. A total investment sum of 10.7 billion CNY was allocated for the Tarim River Regulation Scheme from 2002 to 2009 by the Chinese government.

Water-saving irrigation techniques (for example, drip irrigation), have been introduced into the farms within the scope of the Xinjiang Production and Construction Corps in the Aksu/ Aral region. Currently, the detailed plans for the construction of water reservoirs in the Tianshan Mountains along the headwaters of the Aksu River are being worked out. These reservoirs are located in China and Kyrgyzstan.

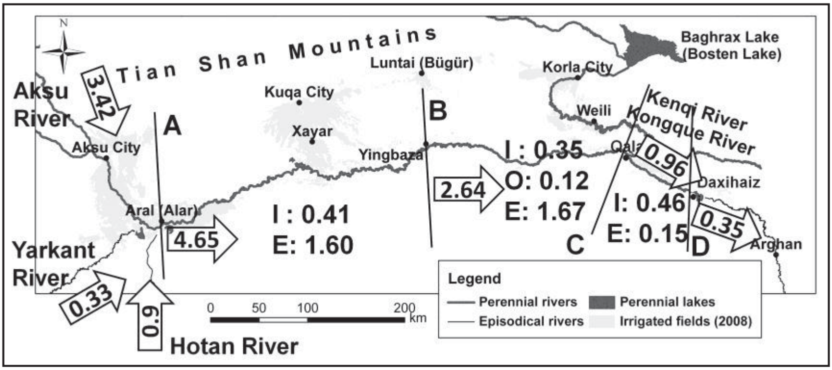
The largest construction projects within the Regulation Scheme of the Tarim River have been undertaken to provide water for the Tarim River's lower reaches. First, by 2002, two channels had been constructed between the Kenqi River and the Tarim lower reaches in order to transfer water from the Kenqi River System to the Tarim River's lower reaches. Second, by 2004, dykes had been constructed along the Tarim River's middle reaches, in order to control and reduce the water flow into the river branches of the inland delta. At the major river branches, sluice gates were constructed. Through this measure, the water coming from upstream is concentrated in the Tarim's main course and is channelled down to the lower reaches (Zhu et al. 2006; Thevs et al. 2008a, 2008b).

The Quota System for Water Allocation along the Tarim River

The Tarim River Basin Water Resource Commission has adopted a quota system to allocate water to Aksu Prefecture and the Xinjiang Production and Construction Corps along the Aksu River and between the upper, middle, and lower reaches of the Tarim River. Furthermore, within each river stretch, quotas are fixed for the amount of water diverted into irrigation, oil exploitation, and water left for the natural vegetation – that is, environmental flow (Tang and Deng 2010). The water allocation, planned using average run-off conditions, is illustrated in Figure 9.

The water allocation quotas between Aksu Prefecture and the Xinjiang Production and Construction Corps are displayed in Table 2.

Figure 9: Long-term Average Water Inflow from the Aksu, Yarkant and Hotan Rivers into the Tarim and Planned Water Allocation along the Tarim River (km³/a)



Note: I: irrigation and industry, E: environmental flow, O: oil exploitation. A–B: Tarim upper reaches, B–C: middle reaches, C–D: upper section of lower reaches, D and below: lower reaches. At Qala (C), on average 0.46 km³/a are transferred from the Kenqi River into the Tarim.

Source: modified after Tang and Deng 2010.

Table 2: Water Amounts For Utilization along the Aksu River and Water Release into the Tarim River under Different Inflow Amounts from the Headwaters (km³/a)

Inflow from headwaters into Aksu River	Water consumption along Aksu River			Water release into Tarim River
	Total	release into Tarim River	Bingtuan	
8.849	4.646	2.541	2.105	4.203
8.06	4.64	2.535	2.105	3.42
7.251	4.61	2.505	2.105	2.641
6.678	4.156	2.259	1.897	2.522

Note: The second line refers to average conditions.

Source: Tang and Deng 2010.

The inter-annual variations of the run-off (cf. Figures 3, 5, 6) have been taken into account within the quota system, as there are quotas between river stretches and water consumers not only for average conditions (cf. Figure 9), but also for a wide range of deviations (Tang and Deng 2010). In winter, a forecast for the run-off of the current hydrological year (1

November to 31 October) is calculated and taken as a basis for the quotas to be applied.

If an inflow of approximately 8.06 km^3 into the Aksu River is forecasted at the confluence of the Aksu River and the Toshgan River for a given hydrological year, then 4.64 km^3 can be diverted for irrigation and industrial use along the Aksu River, and 3.42 km^3 must be released into the Tarim River (Table 2). So, 57 per cent of the Aksu River's water – the only permanent water source of the Tarim – is allocated to Aksu Prefecture and the Xinjiang Production and Construction Corps. If lower inflows into the Aksu River are forecasted, the share of water allocated for the Aksu Prefecture and the Xinjiang Production and Construction Corps increases to 62 per cent (cf. last line of Table 2).

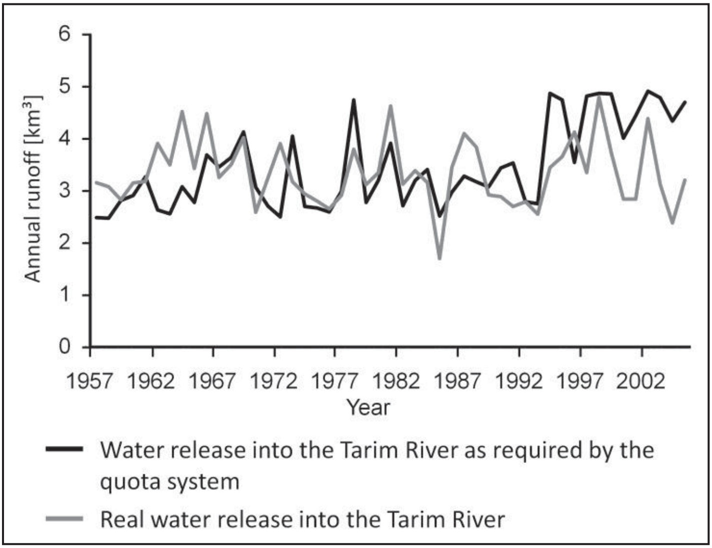
Under conditions of a forecast of 7.279 km^3 and 4.27 km^3 for the Yarkant and Hotan Rivers, respectively – the average water inflows from the mountains – only 0.33 and 0.929 km^3 have to be released into the Tarim River. If the forecast falls below the long-term average, no water from the Yarkant River and only 0.202 km^3 from the Hotan River will be released into the Tarim River.

The water allocation quotas for the Tarim River cover a forecasted run-off range of 2.5 km^3/a to 7 km^3/a at Aral. The water allocated for the oil exploitation along the Tarim middle reaches remains constant at 0.12 km^3/a, regardless of how much run-off is forecasted at Aral. The water quotas for irrigation along the upper, middle and lower reaches are constant at 0.41 km^3/a, 0.35 km^3/a, and 0.46 km^3/a, respectively (cf. Figure 9). Only if the forecast for the run-off at Aral falls below 4 km^3/a are the water quotas for irrigation reduced to 0.37 km^3/a, 0.30 km^3/a and 0.41 km^3/a, respectively. The run-off that exceeds the quotas for irrigation and oil exploitation shall be left to the natural vegetation as environmental flow.

The Water Supply Situation along the Tarim River

According to Tang and Deng (2010), the water amount released into the Tarim River at Aral has not met the proposed quota since 1989, as shown in Figure 10. This can be attributed to the sowing of cotton plantations in the Tarim Basin, especially in Aksu Prefecture and within the Xinjiang Production and Construction Corps.

Figure 10: Water Release into the Tarim River as Required by the Quota System versus Real Water Release



Source: Modified after Tang and Deng 2010.

In 2009, it was visible on satellite images (Landsat) that in May and June most of the water of the Aksu River was diverted from the river into reservoirs in Aksu Prefecture and the Xinjiang Production and Construction Corps. The Aksu River downstream and the Tarim River ceased to flow.

By end of the Tarim Basin II Project, the prefectures on average exceeded their quota as set by the Tarim River Basin Water Resource Commission by 20 per cent. The date as of which the prefectures shall follow this new quota was postponed from 2005 to a non-defined time between 2010 and 2020 (World Bank 2007).

This quota system faces the following difficulties: First, there is an inaccuracy related to the forecasts on which the water allocation for the following vegetation period is based. Second, the quotas permitted to the river stretches and water consumers refer to annual run-off values rather than monthly run-offs. As indicated in Figure 3, the run-off in the Aksu and Tarim Rivers is low during spring and early summer. If the farms along the Aksu River withdraw water with consideration only for their demand for irrigation, in water-scarce years, they may deplete the water in the Tarim without exceeding their permitted annual water quota. Third, there is a lack of control over the water withdrawal.

The Tarim River thus suffers from periods of water shortage during spring and early summer. The further downstream, the more prolonged the water shortage becomes. In some years, the middle and lower reaches of the Tarim River fall dry.

Investigation of the Adaptation toward Water Allocation and Water Scarcity on the Farm Level

Since agriculture completely depends on irrigation, water is the crucial input factor for agriculture along the Tarim River. Within the framework of the hydrological conditions explained in Section 2, the administrative settings as portrayed in Section 3, and the water allocation illustrated in Section 4, I will now discuss the adaptation of farmers to water scarcity in the region.

The cotton-farming systems along the Tarim River were investigated through semi-structured household interviews in 2002 outside the Xinjiang Production and Construction Corps (Hofmann 2006), 2007, and 2008. The interviews from 2002 described the basics of cotton-farming along the Tarim River (Hofmann 2006). In brief:

Aside from the Xinjiang Production and Construction Corps, there are two kinds of cotton farmers: The first group is local people in the villages, mostly Uyghur, who grow cotton on small, family-run farms, usually between 2 and 6 hectares. The second group of cotton farmers are private investors, who reclaim land outside the villages along the Tarim River and its branches. They grow cotton on a larger scale on plots between 20 and 200 hectares.

Cotton seeds are usually sown in March and April. The seeds are covered with a sort of cling film in order to reduce evapotranspiration in this early stage of plant establishment and in order to keep the seedlings warm at night. Fertilizer, pesticides and herbicides are applied (see Table 3). Plant hormones are applied in order to inhibit the stem growth of the cotton plants. Thus more biomass is allocated to the cotton fibres during the growth process of the plant. The harvest starts by September and lasts until November. The cotton is harvested by hand.

The family-run farms in the villages rely on public water infrastructure managed by the county, while the private investors install their own water pumps, which they run without any limits.

In September 2007, 11 private investors and 21 family-run farms were interviewed based on the questionnaire developed by Hofmann (2006). In July 2008, the farmers were interviewed again regarding changes in their water supply situation and their irrigation infrastructure. The interviews were located in Yingbaza (80 kilometres south of Bügür/ Luntai) and Tarim Xiang (Shaya County, 100 kilometres south of Kuqa). Both areas are located along the Tarim's middle reaches, thus along the river stretch that fell dry in 2007, 2008 and 2009; the farmers thus represent those affected by periodical water shortages of the Tarim River.

The average farm size, cotton yields, gross income from selling cotton, and the running costs are shown in Table 3. The running costs related to irrigation – costs for water pumps, groundwater wells and water fees – are significantly higher for the family-run farms.

The cotton farmers flood their fields after the harvest, in November or December, because most years the Tarim River carries water even to the downstream stretch during that time period. The soil remains moist until the spring of the following year, as the frost period starts by December and lasts until the beginning of March. If abundant water is available for irrigation in autumn, the salts can be leached from the fields in order to prevent soil salinization. The farmers start to irrigate again by the end of May/ beginning of June. So, June and July, until the onset of the summer flood, is the bottleneck period for irrigation.

Starting with the 2007 planting season, 9 of the 11 private investors in Yingbaza drilled their own groundwater wells, 3 to 5 wells per farm. Among the family-run farms, 12 had access to groundwater wells, either their own or ones shared with neighbours. The costs to drill a groundwater well were roughly estimated at 1,000 CNY per metre of depth. The private investors drilled 40 to 60 metres deep, while the family-run farms used wells with depths between 20 and 50 metres. The lifespan of the wells was estimated at 5 to 6 years. However, the groundwater is only exploited when the last available river water has been pumped (cf. Figure 5), as the running costs of the groundwater wells (mainly electricity costs) are much higher than they are for the water pumps.

By 2008, half of the private investors replied that the water level in their wells dropped, and two of them drilled new wells. Only four private investors started to use drip irrigation, while none of the family-run farms introduced this technology. A farmer must invest 9,000 CNY per hectare in order to install the main tubes. The main tubes have to be renewed every 15 years. The tubes, which supply the plants, have to be renewed every year, demanding about 1,500 CNY per hectare. Switching to more water-saving crops like wheat or native medicinal plants was not considered adaptation at all.

Table 3: Income and Running Costs for Growing Cotton per Area Unit

Farm type	Private investor	Family-run farm
Average farm size (ha)	135	8.7
Yield seed cotton (kg/ha)	3,510	3,465
Selling price of seed cotton (CNY/kg)	5.90	5.60
Gross income from selling seed cotton (CNY/ha)	20,709	19,404
Breakdown of running costs per area planted in 2007 (CNY/ha)		
Seeds	585.90	525.00
Cling film	790.50	735.75
Fertilizer	4,175.25	3,907.35
Pesticides	89.70	87.60
Herbicides	88.95	88.95
Hormones	145.20	58.35
Labour costs	2,300.70	3,791.85
Tractors and machinery	122.85	658.20
Water pumps	82.50	216.90
Groundwater wells	398.70	1,221.45
Water fees	251.70	588.75
Total running costs per area planted in 2007 (CNY/ha)	9,031.95	11,880.15

Source: Protze 2011.

Discussion of the Adaptations on the Farm Level

The decisions on the farm level are driven by the risk-minimizing strategies of individuals. Most farmers decide to combat the threat of water scarcity and crop failure on an individual basis. They drill groundwater wells on their own, even though this measure may help only for a short time – some wells fail to deliver water after one year. Only some of the farmers invest in a long-term adaptation to combat water scarcity, like drip irrigation. The reasons for this are a lack of capital and a general uncertainty regarding both the availability of water and the price fluctuations of cotton.

As of now, the administration bureau of the Tarim River Basin Water Resource Commission is powerless to allocate water all along the Tarim River in situations of water scarcity. The access to groundwater technically is uncontrolled, so there is no limit on the amount of groundwater a farmer can extract. This drives the farmers into an open access dilemma regarding the water utilization.

Cai (2008) concluded that there is a "deadlock" regarding agricultural water management in China due to the following conflicts: First, farmers waste water though they suffer from water shortages, resulting in water shortages for the municipal and industrial sectors. Second, farmers cannot afford investments in water-saving techniques and are not willing to pay a water price that reflects the value of water. Third, the national policy still puts forward the aim of food self-sufficiency, so irrigation is urgently needed in order to maintain high crop yields.

In this case, it is true that most farmers waste water since they do not introduce water-saving irrigation techniques like drip irrigation. But, this affects the farmers further downstream more than the industrial businesses in the area. The amount of water allocated to the oil exploitation is fixed over the whole range of run-off of the Tarim River. Furthermore, the oil-exploiting industry has sufficient equipment and capital at its disposal to exploit groundwater as needed. The oil industry even has the capability of pumping so much groundwater that the groundwater level drops too deep for the farmers to access.

The farmers investigated here who only invest in groundwater wells cannot afford further investments due to their current income and future income prospects. This finding is in accordance with Cai (2008) regarding water shortages in northern China.

Since the major crop here is cotton, the goal of attaining food self-sufficiency in China is not a driver for irrigation in Xinjiang. But the targets set for the prefectures in the Tarim Basin in the framework of the tenth Five-Year Plan – such as doubling farmers' incomes and contributing to the regional GDP (World Bank 2007) – drive the local decision-makers to propose cotton-farming. For many local decision-makers, the most uncomplicated way to attain economic growth is to farm cotton because all the infrastructure of cotton-processing and cotton-marketing is at their disposal. Considering these economic goals, the local decision-makers foster cotton irrigation within the area they are responsible for. These economic targets counteract the goals regarding water saving. Such contradictory goal-setting between economic development and resource protection is a common weak point regarding the implementation of environmental laws and regulations (Zhang and Wen 2008).

Conclusion

Periods of water shortage along the Tarim River occur during spring and early summer, during the growth of cotton. This period is the bottleneck for irrigators along the Tarim River. These periods of water shortage are a result of the natural hydrological conditions combined with excess water withdrawal along the tributaries of the Tarim and a weak water allocation administration.

Currently, the administration bureau of the Tarim River Basin Water Resource Commission is not able to ensure water flows all year round along the entire Tarim River, mainly because it is not able to control the water withdrawal by the water consumers along the Aksu River – the Xinjiang Production and Construction Corps and water users within Aksu Prefecture – during spring and early summer. As long as Xinjiang is regarded as an area set aside for cotton production, local decision-makers will promote cotton production. This most likely will result in an increasing area being irrigated along the Aksu River and the upstream of the Tarim, which will result in water shortages along the middle and lower reaches (Bazhou Prefecture).

In order to realize a run-off throughout the year, the water allocation quotas must be determined on a seasonal or even monthly basis, and the position of the administration bureau under the Tarim River Basin Water Resource Commission must be strengthened. Furthermore, a mechanism must be introduced through which the Xinjiang Production and Construction Corps, which is not under the administration of Xinjiang, but is administered directly from Beijing, must follow the water quotas set in Xinjiang.

Under pessimistic premises – that is, if the administration bureau of the Tarim River Basin Water Resource Commission is not strengthened – the Tarim River may shorten to the point that it will not flow permanently into Bazhou Prefecture anymore. If that happens, the Aksu and the Tarim will sustain only the irrigation agriculture within the Xinjiang Production and Construction Corps and Aksu Prefecture. The downstream Bazhou Prefecture thus has to make use of the "leftovers": the run-off during late summer and autumn and the irregular run-off during spring and early summer. As a consequence, Bazhou Prefecture would concentrate on the Kenqi River as its main water source, because the Kenqi River Basin lies entirely within the boundaries of Bazhou Prefecture.

If only flood pulses and no continuous run-off reach the middle and lower reaches of the Tarim River, the natural vegetation can be protected from further degradation because such flood pulses recharge the groundwater from which the natural vegetation supports its water demand. Even if the flood pulses occur late in autumn, the natural vegetation will survive. Although, the generative recruitment and thus the long-term conservation of the genetic diversity cannot be preserved under conditions of single flood pulses (Thevs et al. 2008a).

Irrigation agriculture under a hydrological regime of flood pulses in late summer and occasional run-off during spring and early summer will only be possible based on massive groundwater exploitation. Groundwater exploitation is costly and the amount of water extracted is very hard for the water administrators to control. Therefore, a more feasible option for farmers along the middle and lower reaches of the Tarim River would be to reduce the area used for cotton and increase the utilization of plants that are part of the natural vegetation. Two promising candidates might be *Apocynum venetum* and *Apocynum pictum*, because they cover their water supply from the groundwater and can be used as medicinal plants and fibre plants.

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