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The disappearance of the Karez of Turfan

Report from the project 'Harvest from wasteland. Land, people and water management reforms in the drylands of Xinjiang.'

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Abstract

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This report has been prepared as part of the project 'Harvest from wasteland. People, land and water management in Xinjiang, China.' This project focuses on land and water management issues as well as ongoing water reforms in locations in the Tarim basin of Xinjiang Uyuar Autonomous Region, Northwest China. The report deals with karez irrigation in Turfan district. Karez irrigation is a type of irrigation based on underground canals and is well known in many dry areas of the Middle East and Central Asia under the name qanats. The report describes the situation today, the number of karez still in use, their importance as regards agriculture as well as to identify causes behind the decline in number of karez in use. The report is based on fieldwork in Turfan in October 2004. A major conclusion is that the karez as a unique form of irrigation is under substantial pressure and that if present development continues karez irrigation will more or less be abandoned in the region within a decade or two.

Keywords: Irrigation, Water, Reforms, Xinjiang, China

The disappearance of the *Karez* of Turfan

Haakon Lein & Shen Yuling

'*If you are born in Turfan you should know the importance of the karez*'

I. Introduction

This report has been prepared as part of the project 'Harvest from wasteland. People, land and water management in Xinjiang, China.' This project focuses on land and water management issues as well as ongoing water reforms in locations in the Tarim basin of Xinjiang Uyuar Autonomous Region, Northwest China.

More specifically the main objectives of the project are:

- Gain a better understanding of local water management institutions and how they are transformed during ongoing water reforms.
- Describe the situation as regards water pricing, to find out how water prices are set, how collection is organized from farm level and upward, and finally to try to assess the effects of the pricing system on farmers' use of water and whether the ongoing reforms are likely to bring about a functioning water market.
- Explore the concept of water rights, the multiple bases for claims to water, how these claims are negotiated and conflicts solved, and to what extent water reforms take into consideration the possibility that multiple forms of rights may exist.

Karez irrigation has been practised in Turfan as well as other parts of Xinjiang for centuries. The *karez* of Turfan are well known and have been briefly described by various travellers to the region (e.g. Huntington 1907, 1996 [1907]). However, literature focussing on *karez* in particular seems to be very limited and what exists tends to be very general or focussing on physical aspects and/or the historical origins (International Conference on Karez irrigation 1993).

The *karez* are extremely important for many farmers in this dry region. As will be described more in detail below, the construction of irrigation canals as well as installation of new wells have contributed to a lowering of the groundwater table causing many of the *karez* to run dry. If present development continues, there is a real danger that this form of irrigation may disappear from the region within the next 10–20 years.

This report sets out to:

- Describe the situation today, the number of *karez* still in use, as well as their importance as regards agriculture.
- To identify causes behind the decline in number of *karez* in use.
- To assess the links between *karez* and other forms of irrigation (canals and wells).
- To give a general outline on how the *karez* are managed.
- Explore the concept of water right as regards the *karez*.
- Has *karez* irrigation been influenced in any way by past and presentland and water policy reforms, and if so, in what sense?

The report is based on fieldwork in Turfan in October 2004. During this period local leaders, officials in various water management institutions and farmers were interviewed. A list of issues covered in the interviews is included in Appendix I. In addition to interviews in Turfan City, we visited three sites:

- 'Baza' village – located relatively close to the mountain and having good access to *karez* water.
- 'Dikaer' – a settlement located downstream on the desert fringe .
- 'Blak' village – a well-established settlement not far from Turfan City experiencing increasing water shortages.

In addition the study draws on literature and data provided by various government agencies during our stay.

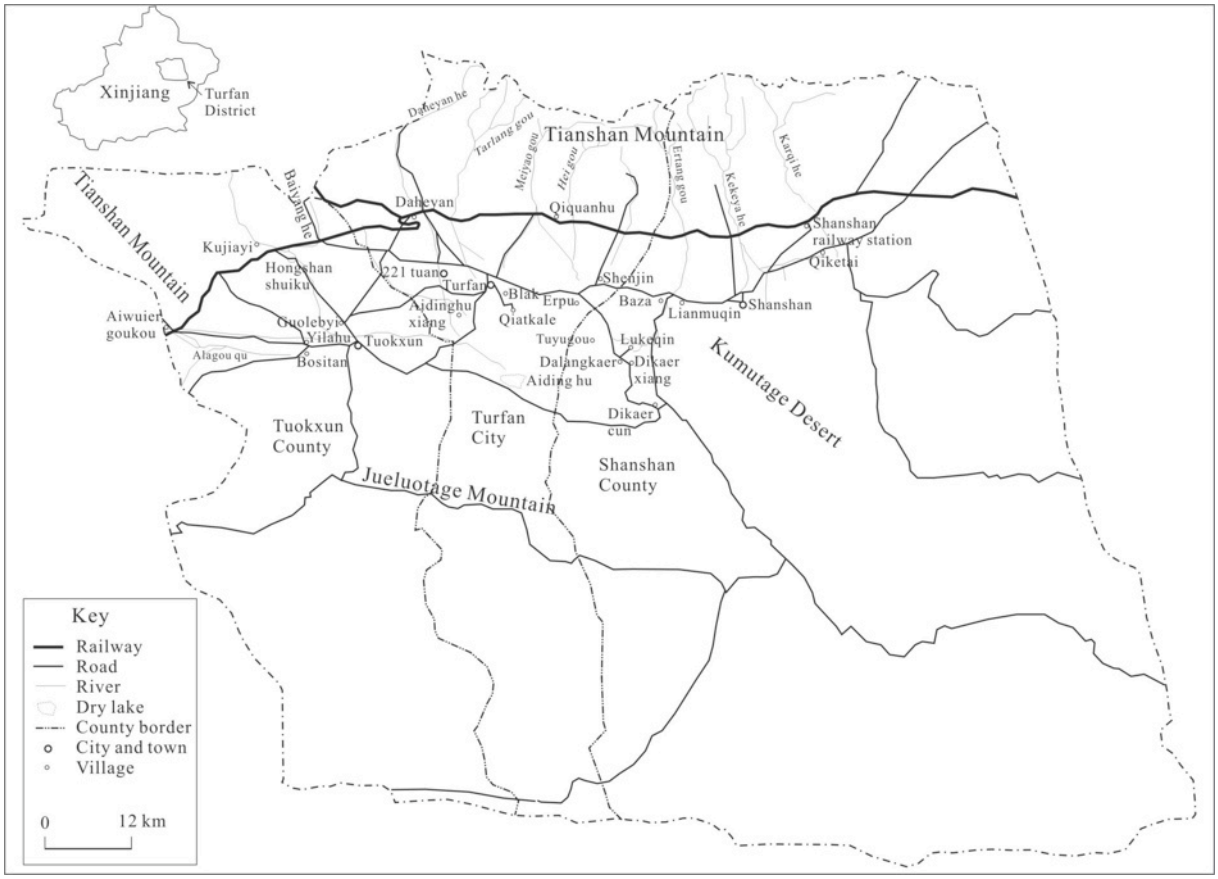

Figure 1 Map of Turfan district.

II. The study area

Turfan district is located in the east of Xinjiang Uyuar Autonomous Region. The district is located in a basin of east Tianshan Mountains and stretches *c.*300 km from east to west, and 240 km from north to south. The total area is *c.* 70,000 km^2, with mountain area and plain area accounting for 14% and 8% respectively. The main city is Turfan, an oasis settlement, over decades well known to traders and explorers and more recently to tourists coming to explore the many sights along the Silk Road. The Aiding Lake located to the south of Turfan City, 153 m below sea level, is the second lowest place on Earth.

From north to south the Turfan Basin can, according to Historical Records of Turfan City Editorial Board (2002), be divided into the following geomorphological units:

- Bogeda mountains (elevation 3500–4000 m)
- Gobi desert in piedmont (elevation 600–1200 m)
- Alluvial fan and plains (elevation *c.*600 m)
- Salt and Flaming mountains (elevation 300–500 m)
- Gobi desert and alluvial plain (elevation *c.* 100–500 m), where most settlements and cultivation are concentrated
- Aiding lake (elevation -153 m)
- Jueluotag mountains (elevation 600–1500 m).

The rivers of Turfan district originates in the northern and western Tianshan mountains, and are supplied by glacier and snow meltwater as well as rain. Annual average surface discharge is *c.*9.3x10^8 m^3, groundwater discharge is *c.* 2.4x10^8 m^3. Estimated total water resources available in the district are *c.*11.7x10^8 m^3 (Turfan District Water Conservancy Bureau, 2001).

As the rivers flow from the mountains much of the water seeps into the *gobi* desert which has deep sediments of gross texture materials. In summer, water flow in the rivers is high due to glacier and snow-melt in the mountains. If this is

combined with heavy rain flash floods can occur carrying large amount of mud and sand and causing damage to the railway, roads and irrigation canals.

At the northern gobi desert of the Flaming mountain, the depth of groundwater table declines from 100–150 m in the piedmont to 20–30 m near the Flaming mountain. The Flaming mountain obstructs both the surface flow and groundwater flow, which can only pass through certain gorges of the Flaming mountain. After the flows leave the Flaming mountain, part of the flow seeps into the ground again and becomes the water source for the *karez* in the southern area of the Flaming mountain.

The climate of the Turfan district varies from the mountains to the settled plains. On the settled areas below the mountains, annual average precipitation is 16.4 mm, whereas the annual average potential evaporation is above 3000 mm. It is very hot in the summer and cold in winter. The highest daytime temperature from June to August is above 35°C, average temperature in July is *c.*40°C, with the highest 49.6°C, making it is hottest place in summer in China. The average temperature in January is −9.5°C. The annual average period without frost is approximately 210 days (Historical Records of Turfan City Editorial Board 2002).

Population and cultivated lands

Turfan district is divided into three administrative units: Turfan City, Shanshan County and Tuokxun County. The population of the district was *c.*525, 000 in 1995, an increase from *c.*145,000 in 1949. At the beginning of the 20th century Huntington (1907) had estimated the total population in the Turfan to be *c.*50,000.

Along with the increase in population has there been a somewhat varying increase in land under cultivation from 31,200 ha in 1949 to 55,200 ha in 1965, followed by a decline to 43,300 ha in 1995 (Table 1).

The population of Turfan is made up of three main ethnic groups:

- Uygur
- Han Chinese
- Hui

As in Xinjiang in general, Turfan has witnessed high rates of Han immigration since 1949 (Table 2). In 1949 the population of Turfan City was *c.* 67,300, of which more than 60,000 (89%) were Uygur. In 1995 the population had grown to 196,000. Still the majority was Uygur but now 21% were Han Chinese

Table 1. Population and land under cultivation 1949–1995 in Turfan District.

Year	1949	1955	1965	1970	1975	1980	1985	1990	1995
Population (10,000)	14.48	15.85	23.60	29.41	35.39	40.15	43.23	47.42	52.48
Cultivated land (10,000 ha)	3.12	3.72	5.52	5.13	4.97	4.63	4.41	4.33	4.33

Source: Xinjiang Uyuar Autonomous Region Financial and Economic Leading Group, Xinjiang Uyuar Autonomous Region Statistic Bureau (1997)

Table 2. Changes in ethnic composition in Turfan City 1949–1995.

	Uygur		Hui		Han		Total
	Population	%	Population	%	Population	%	Population
1949	60,000	89	6466	10	640	1	67,300
1995	140,000	71	14,400	7	42,000	21	196,000

Source: Rudelson 1997, 101.

III. *Karez* irrigation

Karez irrigation is a type of irrigation well known in many dry areas of the Middle East, Central and South Asia but then under the name *qanats* (Beaumont 1993). One controversial issue relates to the origin of the *karez* in Xinjiang and whether these are indigenously developed or imported from neighbours in the west.[1] Some claim this is a technique adapted from somewhat similar type underground water canal found in other parts of China. Others claim that it most likely is a local innovation developed by people in Xinjiang as a response to the physical conditions of the region. A third explanation is that that this is an irrigation technique that has spread eastwards from Persia (Iran). Huntington (1907) refers to sources that support the latter view and actually date the introduction of *karez* in Turfan to approximately 1780. It is difficult to judge the basis for these varying claims, not least because the various explanations are linked to the more general and contested history on the role of Xinjiang in Chinese history.

A *karez* is basically an underground canal conveying water from an upstream aquifer to a lower lying area. The canal tap water from groundwater reservoirs in the alluvial fans located at the base of the mountain areas. The underground canal or tunnels can be divided into two main parts, a water collecting part and a water conveying part (Figure 2). Some *karez* may have several water collecting heads, joined together to form a single water conveyance tunnel.

Photo 1 Collapsed *karez* with two water supply tunnels

The conveyance canal channel the water downstream until it reaches the opening called *telemai* in Uygur. In order to construct the tunnel a number of vertical shafts have to be dug for taking out soil as well as to supply fresh air. The soil dumped around these shafts is a very characteristic sight in the very sterile, flat or gently sloping desert landscape.

Photo 2 Top of a vertical shaft of a karez

In the lower reaches, the distance between the shafts may be 10–20 m, and in the upper part it can be 30–70 m. The depth of the shafts varies with the depth of the tunnel, in the lower reaches the shafts may be only some metres deep, some of the deepest shafts may be more than 100 m deep. The size of the underground tunnel is between 0.5–0.8 m wide and 1.2–1.8 m high. In addition to the shafts and the conveyance tunnel it is common to have a storage pool not far away from the canal opening. This pool is used for storing water at night and may also be used as a means for measuring and dividing water among different users.

Most of the *karez* in the area are relatively old though some are of recent origin. Since many *karez* have become dry or are in the process of becoming dry, new and deeper *karez* are being built and old ones are extended upwards towards the mountains. The digging takes place during the winter. Digging of the *karez* used to be done by local people and in some places this is also the case today. However, it has become increasingly common to employ temporal labour migrants from other parts of China (Ganzou, Sichuan, Henan) to carry out this work.

[1] For various opinions on this, see papers in International Conference on Karez irrigation (1993).

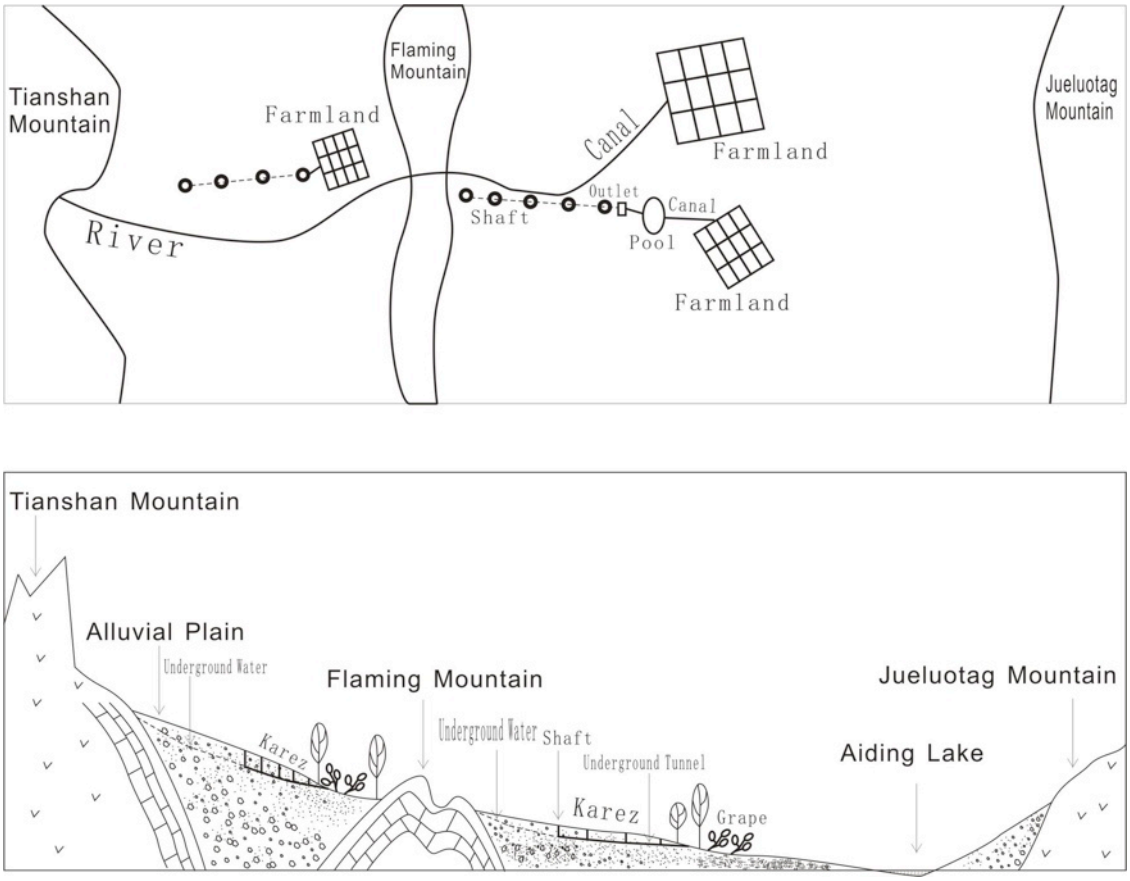

Figure 2: Schematic overview of *karez* in Turfan

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The group of *karez* diggers shown on photo 3 have come from Gansu to work on the extension of one of the *karez* in Baza village. The team consists of 8 men. They start work in October and return back to their home village in May in order to harvest wheat.

Photo 3 Karez diggers.

They work 8 hours a day: 4 hours underground and 4 hours outside. They can dig 1–2 m per day. The village provide the equipment needed and the tractor used for lifting the buckets of soil up from underground. The group has excavated a cave in the ground where they live throughout the winter. During the season each will earn *c.* 5000 yuan. The construction of the vertical shafts, which are more than 60 m deep, is considered most dangerous as there is a risk that the shafts may collapse. Below *c.*50 m conditions are very wet and the digging has to be done 'in the rain'. Also there is a problem with access to fresh air so the period of work underground has to be restricted.

The many archaeological sites of large settlements in the area indicate that the people must have been living in the area under quite different and wetter climatic conditions than at present. Huntington (1907) concluded that these ancient settlements must have been based on the use of wells and surface water. However, after *karez* irrigation was introduced in the area it was possible to support an increasing population and Huntington estimated that *c.*40% of the population during his visit was relying on *karez* water (Huntington 1907).

As shown in Table 3, there has been a rather dramatic decline in the number of *karez* in use since the 1960s.

Table 3. Number of *karez* with water flow in Turfan district 1949–2004.

Year	*Karez* (with water flow)			
	Turfan City	Shanshan County	Tuoksun County	District Total
1949	440	478	166	1084
1957	557	487	193	1237
1962	522	471	184	1177
1973	447	369	167	983
1979	364	n.a.	83	n.a.
1986	409	336	68	813
1992	375	264	59	698
2000	291	116	39	446
2004	192	70	n.a.	n.a.

Source: Turfan District Water Conservancy Bureau 2001.

This decline may have many causes. One may be that there has been a decline in precipitation in the mountains and/or a natural decline in water flow in the rivers affecting the recharge of groundwater. Unfortunately there are no meteorological stations in the part of the Tianshan Mountains where the rivers of the region originate. Although data on discharge exist for the major rivers originating in the mountains but the data are hard access to as this type of information is considered 'internal material'. However, available aggregate data from one of the main rivers Meiyaogou river, indicate no significant downward trend in water flow over the last decades. The data do, however, show that there are quite large variations in discharge from year to year. In the period 1956–1998 the smallest annual average discharge was 0.479×10^8 m^3 in 1985 and the biggest annual average discharge was 1.212×10^8 m^3 in 1990 (Table 4).

Although the climatic and hydrological data presented here are very scant, it is most likely that the decline in *karez* irrigation has been caused by human activities. During the interviews with water management officials and farmers, the decline in *karez* use was attributed to human-caused lowering of groundwater levels. The extent of decline in groundwater level is difficult to ascertain and will vary considerably from place to place. Officials from Shanshan County claimed that groundwater table had decreased 6.0 m in the southern part, and 3.9 m in the northern part of the Flaming mountain. A comprehensive study of the groundwater situation in the area is currently under way and hopefully this will provide better understanding of the present situation as regards groundwater resources in the region.

Table 4. Annual average discharge in ten-year period in Meiyaogou.

Year	1956-1959	1960-1969	1970-1979	1980-1989	1990-1998
Annual average discharge (10^8 m^3)	0.8515	0.7342	0.7338	0.7926	0.9360
Maximum discharge in the ten-year period (10^8 m^3)	0.959 (1958)	0.899 (1966)	0.874 (1977)	1.15 (1989)	1.212 (1990)
Minimum discharge in the ten-year period (10^8 m^3)	0.754 (1956)	0.646 (1962)	0.641 (1978)	0.479 (1985)	0.8 (1997)

Source: Data provided by Xinjiang Hydrology and Water Resources Bureau.

During discussion with staff in the local water bureaucracy as well as local leaders and farmers the decline in groundwater level tended to be attributed to two main causes:

1. The construction of water reservoirs and surface water canals reducing the recharge rates of the groundwater reservoirs.
2. The rapid expansion of groundwater pumping in recent decades.

Photo 4: Ertang gou River

Since the 1960 a number of reservoirs have been constructed at sites close to where the rivers leave the mountain river valleys. From these dams a number of lined canals have been built in order to carry as much as possible of the available water to the cultivated areas further down. Besides being used for storing water for the dry season, the reservoirs are important for controlling flash floods. Such floods due to snow-melt in the mountains and heavy rain may cause substantial flood damage to both roads and other types of infrastructure.

Table 5 shows there is a considerable variation in surface flow over the year. The discharge in the three months of June to August amounts to 57% of the estimated annual total discharge.

Although the construction of dams and river control measures may be important for controlling floods it is also assumed that the development may be harmful for the *karez* because such regulations will reduce the recharge of the aquifers. In practice only very little water is allowed to flow freely into the original riverbeds. In fact, it may be only during the winter – when water flow may lead to frost damage in the canals – that water is fed into the original riverbeds. The likely negative impact of these dams on the *karez* downstream was openly acknowledged during interviews. However, the importance of controlling damaging flash floods was seen as being of overriding importance. It was also argued by some water bureaucrats that surface water irrigation was a more 'modern' type of irrigation than the *karez* and that it thus was important to improve the water flow in the canal systems, even if this was done on the expense of the *karez* system.

Another and perhaps equally or more important reason for the decline in groundwater level is the spread of well irrigation. The installation of tube-wells started in the late 1960s. At that time there were somewhere between 1200 and 1300 *karez* with water in the district. In the period 1985 to 2000 the number of wells increased by 1500 (Table 6).

The tube-wells are used for pumping groundwater for irrigation as well as for other purposes. Especially since the introduction of the household responsibility system in 1982 there has been a growing interest in opening up new land as well developing grape production. In addition a number of oilfields (Tuha oilfields) have been developed and a considerable amount of water is pumped into these wells in order to enhance oil production.

Table 5. Discharge of surface flow variations in seasons in Turfan district.

Season	Spring (March-May)	Summer (June-Aug.)	Autumn (Sept.-Nov.)	Winter (Dec.-Feb.)	Total
Discharge (10^8 $m^{3)}$	1.17	5.20	1.53	1.30	9.2
Percentage	12.7	56.5	16.6	14.1	100

Source: Turfan District Water Conservancy Bureau, 2001.

Table 6. Tube-wells in Turfan district.

Year	Tube-wells
1985	3500
1995	4465
1997	4774
2000	5101

Source: Data provided by Turfan District Water Conservancy Bureau.

Table 7. Number of tube-wells in different parts of Turfan in 2000.

	No. of Tube-wells	%
Turfan district	5101	100
Turfan City	1908	37
Shanshan County	1729	34
Tuokxun County	1464	29

Source: Data provided by Turfan District Water Conservancy Bureau.

As Table 7 shows, the tube-wells are distributed fairly widely in all three counties.

IV. Changes in population, land use and water availability at the three sites

In order to gain an understanding of the use and importance of the *karez* at local level, three sites and a number of production teams were visited. The three sites proved to be quite different as regards access to and use of *karez* water.

Upstream: Baza village

Baza village was once a vital trading centre as it was located on the main road to Urmuqi. The road currently runs outside the centre and Lianmuqin xiang government, which used to be located here, was moved to a new place in 1966. During the period of Peoples Commune, Baza village was called Brigade No. 10. The brigade has 716 households and *c.*3700 people, with a land area of *c.*4500 mu (15 mu equals 1 hectare). Approximately 700 of those living in the village do not have own land.

The village used to have 7 *karez* but 10–15 years ago several began to dry up. These were shallower *karez* than the two used at present. After the oil company began to extract oil in the village the groundwater table declined from *c.*6 m below the surface to *c.*20 m. There are currently 20 oil wells in the village and much water is poured into the wells in order to sustain oil production. This water is supplied by a special tube-well installed in the village and 10 trucks carry water to the wells on a continuous basis. The oil company pays 20,000–30,000 yuan per annum to the production team owning the land on which the tube-well is installed.

Photo.5 Oilwells in Baza.

The village has two *karez* (Liqiza and Doulekunqi *karez*) which both lead to a large storage pool. Here water is stored at night (12 hours), and released in daytime (12 hours). In the daytime, water from the two *karez* is diverted directly to land without passing through the storage pool. In practice, the water stored in the pool provides four production teams with water during daytime, and at the same time water flowing directly from the *karez* provides the other four production teams with water.

The water rotation order between the different teams is arranged by the brigade, within the production team the rotation order is managed by the team's head. The brigade originally consisted of eight production teams but as part of the rural reforms the number was reduced to six in 2004. However, water is still managed by the former heads of production teams and is still distributed as originally.

In general, every production team receives water 10 times per year. As the number of households and the area under cultivation varies between production teams the length of irrigation period varies between the teams. The longest period for one biggest production team is eight days, while the shortest period for one production team is one day.

Different crops have different water requirements. Wheat needs no water before sowing as it has winter irrigation. Sowing is finished before 10th March and the first water in supplied on approximately 15th April, the second round of water supply is on 10th May, and so forth. In total there are four rounds of irrigation for wheat before harvest (approximately 20th June). When harvesting is finished, normally by the end of June, this land receives water and is planted with Chinese white sorghum, corn or cabbage. These crops need approximately five rounds of irrigation. All land has winter irrigation.

In 1982, there were almost no grapevines planted in the village. Today, 80% of the land area is planted with vines. During winter the grapevines are covered with soil. This cover is removed between 20th and 30th of March. Irrigation begins approximately on 1st of April, and then approximately every 20 days thereafter the land will receive water. Harvest starts approximately on 20th of June, and the peak season is in July and August. After harvest the grapes are dried as raisins in special houses (*liang fang*). This process takes about one month. After the harvest, land receives winter irrigation and the grapevines are again covered with soil before the first frosts occur.

The brigade has 10 tube-wells so that each production team has at least one tube-well used for supplementary irrigation. Also, in June the teams can buy additional water diverted from Ertanggou River.

The brigade started to collect water fees in 1982 after land had been distributed to farmers. Collection of fees was dependent on the cost of maintaining the *karez*; if there are no cash expenses, there are no fees. At that time farmers provided compulsory labour to clean the canals. Since 1995 this work has been contracted to farm labourers from inland China (Gansu, Sichuan and Henan). In 2000 the water fee was 1.2–1.5 yuan/mu and was used for covering the costs of cleaning the *karez*. From 2003 onwards the brigade started to collect water fees at the rate of 60 yuan/mu to cover the costs both for maintaining both *karez* and the tube-wells. In 2003, 200,000 yuan was collected. If, for example, the price of electricity is 0.42 yuan/kwh, water from the pump will cost farmers between 10 and 20 yuan/mu for one round of irrigation. The actual price varies because of variations in groundwater levels and conditions of the pump.

One mu can produce approximately 2 tons of fresh grape, and 5 kg of fresh grapes are needed to produce 1 kg of raisins. The price of raisins varies; in 2004 it was as low as 5.7–5.8 yuan per kilogram, giving farmers an income of approximately 2200 yuan/mu.

Blak village

Blak village is located south of Turfan City. It is a well-established settlement that has experienced increasing water shortages over the last decades. Blak means spring water and the village has acquired its name from the many natural springs once found in the area. The present Blak village used to be two ‘vanguard’ production brigades (Nos. 1 and 2), which were merged into one village in 2004 as part the central government’s policy to ‘reduce farmers’ burden’. In this process the number of production teams was reduced from 9 to 4 and the number of paid local leaders cut from 26 to 12. As part of this policy change, agricultural tax was also reduced from 150 yuan/mu in 2003 to 10 yuan/mu in 2004.

Table 8. Number of households, land and irrigation facilities in Blak village

.

	Old Blak village (2003)		New Blak village (2004)
Name in People's Commune period	Vanguard No. 1	Vanguard No. 2	
Name after People's Commune period	Blak	Daquio	
Number of production teams	4	5	4
Households	278	359	637
People	1280	1698	2978
Land (mu)	2300	1700	4000
Karez	4	6	10
- With water	4	1	5
- Dry	0	5	5
Tube-wells	4	5	9
Canal water	People's Canal No.1	People's Canal No.1	People's Canal No.1

Despite the reorganization water is still managed according to the former production teams and the brigade leaders have little influence on water management issues. The different production teams do to a varying degree depend on *karez* water, and only one is totally dependent on water from People's Canal No 1. Some have good access to *karez* water and only use tube-wells for supplementary irrigation. Others mainly depend on canal water but also use *karez* water and tube-wells. Since the village has land located on the southern desert fringe, i.e. at the end of the canal, the water supply is very unreliable and can be scarce in some parts. In 2004 much of the land experienced drought, as the canal water supply had been very erratic. The village wanted to install a new tube-well but had failed to be granted a licence for this. According to local regulations, no new tube-wells are to be installed closer than 500 m from existing *karez* and since instalment of a tube-well would infringe on this rule, the application to install a tube-well was turned down.

In addition to water from the *karez* and tube-well, farmers also depend on canal water from 'People's Canal No 1'. This canal conveys water from the Meiyaogou River and was constructed between 1956 and 1959 by farmers providing compulsory labour. Also up until recently people also had to provide free labour to maintain the canal. The water from this canal used to be reliable and cheap. However, due to opening up of new land in the upper stretches, water supply has become unstable and the length between each round of irrigation has increased. At the same time the price of water has risen substantially. The water is measured at a location far from the village and all water conveyance losses in the systems below have to be covered by the users, thereby adding to the water prices. In addition, the price of water varies from round to round. If water flow is low, it will take long time to complete one round of irrigation and water losses will be high, thus resulting in relative high prices. Currently, water also has to be paid before it is supplied, whereas previously farmers had to pay afterwards. The situation seemed to be confusing for farmers and local administrators, as the pricing system was difficult to understand.

The female brigade leader had on several occasions taken up the issue of the drying out of the *karez* with the leaders of the *xiang* who, according to her own view, probably regarded her as a problematic person. Also, some farmers had gone to Turfan City to protest directly to the city government over the problems of water scarcity and she, as a leader, had been reprimanded for not preventing this. The brigade leader's view was that '*If you are born in Turfan you should know the importance of the karez*'.

Her opinion was that the regulations for tube-wells should be stricter; the distance to the *karez* should be increased, there should be limits on the depth of the wells, and the electricity fee should be raised so as to make it more expensive to use. Access to *karez* was, in her opinion, important for the production teams and a production team should have access to at least one *karez*. Access to a *karez* meant that more vegetables for household consumption were grown; if water for pumps or canals were to be used for this it would be too expensive and farmers would stop growing vegetables.

On the desert fringe: Dikaer

Dikaer xiang

Dikaer xiang has six villages. As shown in Table 9, there was a rather moderate increase population from 1984 to 2004 whereas the land under cultivation increased by 6000 mu. Along with this development there was a rather dramatic decline in number of *karez* with water whereas number of tube-wells has increased from a few in 1984 to 257 in 2004. The most rapid increase in tube-wells was from 1994 to 2004.

Table 9. Changes in population, cultivated land and irrigation facilities in Dikaer xiang, 1984–2004.

	1984	2004
Population	6100	7000
Cultivated area (mu)	14,000	20,000
Karez with water	127	19
Tube-wells	4-5	257

Source: Interviews with local government officials, Dikaer xiang

This development came as a result of an active policy for opening up 'wasteland'. Currently, all wastelands that are developed to plant grapevines and melons are allowed to install a new tube-well. In 2003, Turfan district government began to advocate the development of greenhouse cultivation of vegetables (facility agriculture – *sheshi nongyie*). Since 2004, all who develop vegetable production in greenhouses can obtain approval to install a new tube-well.

Turfan district government has a favourable policy towards developing vineyards and every *xiang* is expected to develop viticulture. The natural conditions are considered suitable for this and vegetable production for the market in Urmuchi. At present, there are many professional land developers and commercial plantations establishing in the area, many of them run by people from inland China.

The leader of Dikaer xiang government argued that farmers like to use *karez* and have great confidence in this system. After land was contracted to individuals in 1982 the *karez* had, however, faced problems in terms of maintenance. The *xiang* government has not invested in maintenance of *karez* but in 2004 it applied and received 100,000 yuan for this purpose. All the *karez* have some water at the head of the system and some of the abandoned *karez* can be recovered. The rising costs of using water from the pumps have also made the *karez* more competitive and an attractive alternative. The price of electricity was 0.08 yuan/kwh in 1984, 0.22 yuan/kwh in 1995, and 0.35 yuan/kwh in 2004. On some land the cost of electricity for pumping can reach 200 yuan/mu per year. Dikaer xiang had three production teams that use water from the canals, but it was a common problem that when farmers wanted water most there was usually no water in the canal. The price of canal water is 0.043 yuan/m^3.

The changes depicted Dikaer is found also in other areas where the process evidently started earlier. In Dalangkaer xiang to the north of Dikaer the last *karez* went dry in July 2001. Here the number of tube-wells had increased from 200 in 1984 to 502 in 2004. At the same time the land under cultivation had doubled from 15,000 to 30,000 mu. Before 2002 all applications for opening up new land and a licence for installing a new tube-well (*dajing xukezheng*) was approved by the *xiang*. Due to the declining groundwater table new wells now have to be approved by the Vice Head of Shanshan County and since 2002 no new tube-wells have been approved.

'Hope' village

In 1996, altogether three settlements in Dikaer xiang were abandoned and people in these settlements were moved to a newly established village named Hope (near Dikaer xiang government site). The settlements were abandoned primarily because all *karez* carrying water to the villages had dried out. As these settlements were thinly populated, remote and

without public amenities such as electricity and schools, the *xiang* government decided to abandon the settlements rather than invest in new tube-wells. According to village elders these settlements had once been very good sites for grazing, with plenty of grass and bushes around but all this had disappeared after the *karez* ran dry. Some plots are still cultivated and there is still some grazing of sheep around the settlements.

Photo 6 Abandoned settlement, Dikaer xiang

In total, 130 households moved in the period 1996–1998. Each household received support to set up new houses in Hope and the total cost of moving was 26,000 yuan per household. This was partly financed by the *xiang* government, partly by Shanhshan Gold Mine Company. In addition, 35 have moved to Hope at their own expenses. In 2004 the village thus consisted of 165 households, all Uygur, with 709 people.

When settling in Hope each adult person was allocated 3 mu of land in three different plots. In 2004, a total of 1200 mu of land was under cultivation and of this 780 mu were vineyards. Other crops grown in the areas included melons, cotton and wheat. As this land was new previously uncultivated a total of 10 tube-wells were installed. The cost of installing a well is *c.* 90,000 yuan. The groundwater level had declined continuously in 1996 the groundwater table was *c.*20 m below the surface, in 2004 it was 33 m. More wasteland (600–700 mu) was still in the process of being opened up in the area. In addition, some private developers (*getihu*) have installed their own private tube-wells and opened up new land in the area in recent years. To convert the desert into cultivable land takes some time since the soil contains salts. These have to be washed out and this process normally takes two years, after which only Chinese white sorghum can be cultivated in the subsequent few years.

Dikaer village

Of the 19 *karez* in the *xiang* still providing water, 11 are found in Dikaer village. This is the most southern village, bordering the dry gobi desert to the south of Turfan district. The village has 2000 mu of land and 1100 people. No wasteland has been opened recently in Dikaer village but one settlement had been abandoned and the inhabitants moved to Hope village.

One of the production teams (No. 3) visited in 2004 consisted of 300 people holding *c.*600 mu of land. In 1982 land was contracted on the basis of 1.5 mu per person. There were five *karez* in the production team at the time. Land parcels were not distributed on the basis of the *karez* but land quality, which meant that a family could be drawing water from different *karez*.

Shayi *karez* is one of the *karez* in use. It is very old, 700 m long and irrigates *c.*65 mu lands. Twenty people use water from the *karez*, in addition to using water from other *karez*. Water from the *karez* is stored in a pool and released twice each day: first in the morning between 04.00 and 07.30, then water is stored again until 15.00, after which it is released until sunset. Every day, water is used to irrigate two farmers' land, regardless of where the plots are located. Some land cannot receive enough water from the *karez*, so farmers have to buy water from a tube-well. In July, August and September, crops need more water and farmers have to buy additional water from the tube-well. The fee for electrical pumping was 10 yuan/hour.

A fairly similar practice was followed in Gehep *karez* which belongs to production team No. 5. The water distribution rotation is organized so that each farmer gets water every 16 day. The farmers will have land in plots located at different places, but when he receives water all his plots will be watered regardless of location. The distribution is based on a 24 hour cycle. For 6 hours water is stored in dam, then water is released for 6 hours to three farmers, then 6 hours of storing, then 6 hours of release to three other farmers. If a farmer needs additional water he has to purchase from the pump.

V. Some general observations

Land and water rights

When land was distributed after 1982 as part of the introduction of the household responsibility system, it was distributed on a per person system. All adults, as well as children who were born at that time, were allocated land. As regards land allocated to children, the families operate this land until the children (male) marry and take over the land. Children born after 1982 inherit the land after the death of their parents. In some of the villages visited it was claimed that in general, the youngest son would inherit the land. Although girls may have right to land, they will normally not exercise that right as they will settle with their husband's family after marriage.

When land was distributed in 1982 it was done on basis of the production teams, the land held by the team was simply distributed to the people belonging to the team. As the production teams varied both as regards number of people and land this meant that the amount of land distributed to each person would have varied between different production teams. This is again reflected in present-day patterns, there may be considerable difference between even neighbouring production teams as to how much land a person holds today.

Since children born after 1982 have no right to land, a considerable group of young people have been affected. Their option will be either to find an alternative to agriculture, to rent land from absent owners, or to work as agricultural labourers in the village or on Bingtuan farms. In at least two of the villages (Dikaer and Baza) visited, shortage of land for this group was pointed out as a major problem. In one production team (No. 5) in Dikaer village, 60 out of 150 people, all born in the village, had no land.

In the distribution process the available land was classified according to land quality and people received pieces of land from each category. In most cases people will therefore have their land distributed between a numbers of separated plots, sometimes located far apart. This means that a farmer commonly will draw water from different sources, i.e. different *karez*, pumps or canals.

As regards the link between land and water rights, access to water from a *karez* is linked to access to land. Formerly, when a farmer was allocated land within the traditional command area of the *karez* he was also assigned a 'right' to water from that particular *karez*. Further, when land was rented out from an absentee landowner, as was practiced in Baza village, the land leaser would have the same access as the landowner to water from the *karez*.

As discussed, there has been considerable in-migration as well as opening up of new land in the region over the last few decades. This development has been based on the use of tube-wells and canals, not on *karez*. This is not only because the *karez* have been running dry but also because in practice existing *karez* are closed to newcomers. In none of the places visited was it possible for outsiders to link up to existing *karez* in order to obtain water for new land. This is very different from the situation as regards tube-wells and canals. Up until recently, the installation of tube-wells was not regulated and even today it is possible for newcomers to link up to existing surface canals and draw water against payment.

Water use and management

Although Turfan is well known for its grapes, raisins and melons, the traditional crops in this area have been wheat and Chinese white sorghum. Since liberation, cotton has also been an important crop. In the last few decades the importance of grape production seems to have grown substantially as a result of growing market demand.

Before 1949 the *karez* belonged to individual farmers or families and were also often named after the one who was responsible for the original construction, referring either to the person's name, their profession or other characteristic. For instance, Gehep *karez* is named after the person who organized the digging of the *karez*, thought to be more than 200 years ago, Carpenter *karez* is named after the carpenter who initially organized the construction of the *karez*, and in the case of Wujiamu *karez*, Wujiamu means a person that can be trusted.

After 1949 the running and maintenance of the *karez* has been based on local level farmers'

associations. After the introduction of the production brigades, the latter have played an important role in organizing all kinds of water issues, including *karez*, tube-wells and canal water.

In general, water is distributed according to a rotation system. Farmers are allocated a certain amount of time for water flow. In some areas water is directed towards certain parts of the village and an individual farmer may receive water for his plots on different day according to the location of his plots. In some of the smaller schemes visited, a farmer received water for all of his plots on a given day, irrespective of location. This practice might be less efficient as regards water use but more transparent and easy to manage.

Photo 7 Storage pond

If a farmer does not receive enough water he has to buy extra from a pump or canal, if available. In some areas it seemed that it was possible to 'borrow' water from another farmer. If neither of these options is available a farmer simply has to accept whatever water he receives and this often results in low yields.

In several cases, *karez* water is stored in a pond before being released to the fields. The use of storage ponds makes water distribution more transparent and measurable. The water stored for some time (e.g. overnight) prior to release at a given time and when the pond is empty the outlet will be closed. The system is easy to understand and be controlled by everyone. This practice also increases the water flow into the field canals. Some farmers also argued that the pond allowed the water to heat up before it was applied to the field and this was good for the crops. In some cases, water from tube-wells was also directed to these ponds in order to increase the temperature.

The water distribution issues are commonly discussed in local meetings. However, it seems that the order is fairly stable over time. As one informant explained, there would be much discussion at these meetings but in the end everything tended to be carried out as in previous seasons.

The advantages of *karez*

In most of the places visited *karez* were only one source of irrigation water as farmers also (to varying degrees) had access to tube-wells and/or canals. For some farmers this was the main source of irrigation, while for others it provided supplementary irrigation only. A comparison of the three sources of water for irrigation is presented in Table 10.

A well functioning *karez* can provide a year-round reliable supply of clean water. Many farmers emphasize the importance of the *karez* in the spring. In March–April the canals will be dry as the snow-melt has yet not started in the mountains and only a *karez* or a tube-well can provide the water needed to start growing grapes. In addition, the *karez* is used for other productive purposes which are otherwise often neglected. Firstly, it provides a steady flow of clean water for drinking as well as for other domestic use. Secondly, as strongly emphasized by a local party leader, the availability of a *karez* also tends to lead to the production of vegetables for family consumption. When water has to be bought at high price from a pump or a canal such subsistence production is difficult to uphold. Thirdly, due to the year-round inexpensive flow of water, farmers are more likely to use water for washing out salts after harvest in the autumn. Salinization of the soil is a problem in these areas and autumn and spring irrigation are essential to prevent these problems. However, it is known from other areas that farmers may try to avoid this when water becomes too expensive. Lastly, during winter the *karez* water is diverted outside the cultivated land and towards the trees and bushes surrounding the oasis. In some of the areas on the desert fringe vegetation forms a green buffer between the settlement and the desert. People claim that this winter irrigation is essential for maintaining this important vegetation.

Table 10. Comparison of different sources of irrigation water.

	Karez	Tube-well	Surface canal
Main advantage	Steady year-round flow of clean water	Flexible, can provide water when needed	Used to be inexpensive and reliable.
Main problem	Drying up	Expensive water, in some places running dry	Big variations in flow, increasing water shortages for some users, especially in the lower reaches
Season	All year. Important water source in spring	All year supply of water when needed Shortage in mid-summer.	Less water in spring, more in summer
Control	Controlled by farmers/local institutions	Controlled by farmers/local institutions	Controlled by water bureaucracy – farmers and local government little or no influence on decisions
Access	Closed systems, no new access to existing *karez*	Open, but recently regulated	Open
Costs/pricing system	Expensive to build but last for a long time. Maintenance costs often in the form of labour. Currently the cheapest water	Relatively cheap to install but needs technician to run and maintain. Becoming the most expensive water as electricity fees rise	Price of water varies between canals as well as between each round of irrigation. Difficult to understand pricing system.
Other uses	Domestic and drinking water. Maintenance of natural vegetation (Winter flow)	Domestic and drinking water.	Domestic use, in some places also drinking water.

Photo.8 *Karez* used for washing

Photo 9 *Karez* supplying water during winter to desert vegetation

VI.Conclusion

A major conclusion that can be drawn on basis of the visit to Turfan is that the *karez* as a unique form of irrigation is under substantial pressure and that if present development continues *karez* irrigation will more or less be abandoned in the region within a decade or two.

The problem of *karez* drying up is a remarkable result of the land expansion and agricultural development that has taken place in the region over the last half century. The rapid growth in grape production has provided farmers with new income opportunities and both local farmers and newcomers have taken advantage of this. However, water resources in the region are limited. The rather uncontrolled spread of tube-well irrigation has undoubtedly had a negative impact on the *karez* systems, as too has the development of canal irrigation supported by the government water bureaucracy.

The *karez* has its obvious strengths compared to canal water and tube-wells. It provides water early in the spring, the water flow is stable, the water is cleans and it provides water for domestic use as well as for non-crop vegetation. However, it is a closed system in the sense that water is only available for land being defined as belonging to the *karez* system. It is not open for newcomers or local children born after 1982.

The government water management institutions have entirely focused on developing canal water systems. This has contributed to the problems of declining groundwater tables, because it has meant channelling all river flow into the canals. Further, the control of tube-well installations has been neglected for a long period, and only recently does this seem to have been seriously regulated. It seems that the government water management institutions regard the *karez* as old fashioned and canal irrigation as more modern and efficient. The *karez* have probably also been seen as farmer-controlled systems, and difficult to manage by the official water bureaucracy.

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APPENDIX

List of issues addressed during interviews with farmers and officials.

THE STUDY AREA

Physical aspects

- General information about climate, soils and vegetation
- Is there any evidence of changing rainfall patterns over the last few decades?
- Do any measurements of water flow in the rivers upstream of human settlements exist? Is there any evidence of decline in water flow?
- Is it possible to find figures on water use/irrigation by various means in the region (tube-wells, canals and *karez*)?
- Other issues, e.g. problems of salinity and land degradation

Population and economy

- How many people are living in the area, including changes?
- The extent of in-migration from other areas
- The Bingtuan in the area: how many units, how many people?
- General information about the economy of the area : production of grapes, others (mining?)

THE *KAREZ*

Institutions

- Who controls the *karez* (village, family, sub-village)?
- Who can use water?
- What rights do water users have?
- What is a water right as local people perceive it?
- What obligations do water users have?
- How are decisions over water allocation made, and by whom?
- Is there a water committee?
- If so, who are the members, how often do they meet, and what kind of issues do they deal with?
- Do any written rules or agreements exist?
- What happens when someone dies, do sons automatically inherit water rights?
- Can women (widows, divorces, etc.) claim rights to water?
- What happens in cases of water scarcity?
- By whom and how are conflicts solved?

Why *karez*?

- What is the main advantage of *karez*?
- Is *karez* water cheaper?
- If so, in what sense: because it means less cash outlays?
- Do the *karez* have (more) stable flow throughout the years?
- Does *karez* water have other physical advantages (salt, temperature, etc.)
- What is water used for? Household use as well as water for animals?
- What are the main advantages and disadvantages of *karez* compared to tube-wells and canals?
- Problems
- What is the main disadvantage of the *karez*?
- Have there been/are there still problems of water availability. Are the *karez* drying out?
- If so, why, and what do people and officials see as the main cause?
- Problems of maintenance? Labour availability, skill, labour costs?
- What do people see as the main future threat to the *karez*?

Role of government

- What is the role of the government in running the *karez*?
- Are there any government investments for maintaining *karez*?
- What are the links between local institutions and government institutions?
- Have there been any attempts by the local government to introduce new institutions or rules?
- Do they have to pay any kind of water fee?
- If yes, how is this organized? Who collects?
- How is price set?
- What is the main argument for claiming water fees?

Policy changes

- How was the situation during the period of the People's Commune? Was the traditional way of operating the *karez* changed during that period?
- If 'yes', in what way?
- Have recent water policy changes had any impact on the *karez*?
- If 'yes', in what sense?
- Has *karez* irrigation become more popular recently (after the reform)?

Water distribution

- General physical layout of canals and fields.
- Sketch maps – possible to generalize or use for the purposes of case examples?
- How is water actually distributed to the fields, when, and for which crops?
- Who is responsible for overseeing this in the field?
- What is the rotation order? What is the main principle?
- Is water distributed according to volume, time or land area?
- How is water measured?
- How many times per season is land irrigated?
- For what crops?