Towards a Xinjiang Environmental History: Evidence from Space, the Ground, and in Between

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Muhammad Haidar's sixteenth-century *Tarikh-i Rashidi* describes the inundation by sand of a town called Lob Katak, where the townsfolk had not heeded the warnings of their imam, Khoja Jamal ad-Din.[1] In Xuanzang's earlier Buddhist version of the tale, the people of a place called Helaoluojia are buried after ignoring a flying sandalwood Buddha and the town's one pious man.[2]

That Xinjiang's version of the flood myth involves inundation by desert sands is a powerful reminder of the prominent role of the environment in the region's history. The interaction of man and environment is of basic import to history anywhere. Nevertheless, fossil fuels and the ability they afford humans to transcend many environmental limitations, thereby easing human travel, settlement and distribution of goods around the planet, tend to make us forget that all human activity is dependent on or influenced by, and itself to some degree at least influences, the environment. In Xinjiang's stark climatic conditions, however, even a minor change of one environmental variable can have a major impact, and environmental factors do not so easily escape notice. Indeed, the apparently peripatetic nature of Lop Nor and the discovery of Kroraina and other ancient cities now lost in the sands were among the first things to excite travelers and archaeologists and formed one of the first topics of Xinjiang studies outside China.[3] Of particular interest to historians and archaeologists alike is the position of an arc of ruined cities, including the

[1] Khoja Jamal ad-Din would go on to meet Tughluq Timur, and Jamal's son, Arshad ad-Din, would convert Tughluq and the Mughals to Islam. These two sufis' descendents went on to form the rich and powerful Kataki order of Kucha. MIRZA Muhammad Haidar Dughlat 1541–47 [1972] *A History of the Moghuls of Central Asia, being the Tarikh-i-Rashidi of Mirza Muhammad Haidar, Dughlat.* ELIAS, N. eds., ROSS, E. Denison trs. New York: Barnes and Noble, I, p. 11; see also HAMADA Masami 1978 "Supplement: Islamic Saints and their Mausoleums," *Acta Asiatica: Bulletin of the Institute of Eastern Culture* 34, pp. 81–83.

[2] Xuanzang 玄奘 , *Datang xiyuji* 大唐西域記 . 12 (*Ershier guo* 二十二國), under *Qusadanna guo* 瞿薩旦那國 . JI Xianlin 季羡林 ed. 2000 *Da Tang Xiyuji jiaozhu*『大唐西域记校注』, 2 vols., Beijing: Zhonghua shuju, pp. 1026–27.

[3] A brief discussion of the various theories as to Lop Nor's history and apparent "movement," along with a summary of more recent geographers' theories may be found in ZHAO Songqiao and XING Jiaming 1984 "Evolution of the Lop Desert and the Lop Nur," *Geographical Journal* 150, no. 3, pp. 319–20.

ancient Kroraina (Loulan), in the southern Taklamakan. These sites lie considerably further from the mountains than do the oases today, in the middle of what is now waterless desert. The original location and subsequent abandonment of the cities suggests strikingly how changes in the environment have impacted human life in the Tarim basin.

Likewise, human activity has had a dramatic impact upon the Xinjiang environment, becoming apparent from the Qing period. The environmental changes worked by man in Xinjiang over the past half-century have been particularly extensive, involving urbanization, population growth, deforestation, diversion of water, reclamation of grasslands and desert in some areas and loss of arable land to desertification and salinification in others. The issue of environmental degradation in Xinjiang is now acute, and has spawned many studies of both past and present Xinjiang environments by geographers and other scientists. For example, the Association of Japanese Geographers and its research group, the Association for Arid Land Studies, organized a 1995 symposium on the subject in China.[4] Currently, scholars affiliated with the Japanese Research Institute for Humanity and Nature (總合地球環境研究所) are engaged in research on environmental history in northwest China.[5] Chinese geographers and ecologists, at Xinjiang University and especially those affiliated with the Xinjiang Institute of Ecology and Geography (中國科學院新疆生態與地理研究所) at the Xinjiang Academy of Sciences have of course also been working actively on this subject.[6] These scientists, while officially lending their expertise to the cause of continued development in Xinjiang, have voiced a strong note of caution regarding the environmental conditions and restraints in Xinjiang. The concept of "sustainable development" (*kechixu fazhan* 可持續發展) has now become a catch-phrase of the Great Opening of the West program. Environmental issues and research on present-day Xinjiang are thus firmly linked. Below, with a preliminary survey, I suggest ways in which environmental perspectives can also enrich our understanding of Xinjiang's history.

1. Concerning Textual Sources for Environmental History in Xinjiang

One of the features of environmental history is the deployment of technical studies

4 See TAKAMURA H., et al. 2002 "Environmental Changes and Human Activities in the Taklamakan Desert and Its Environs," *Geographical Review of Japan* 75, no. 2, pp. 750–61 (268–79) and the symposium entitled "Human Lifestyles and Environmental Changes in the Taklimakan Desert" in the Feb. 1996 issue of *Journal of Arid Land Studies* (Japan).

5 Information at www.chikyu.ac.jp. See especially Project 4-1, Historical Evolution of the Adaptability in an Oasis Region to Water Resource Changes [水資源変動負荷に対するオアシス地域の適応力評価とその歴史的変遷], at www.chikyu.ac.jp/oasis/.

6 The Institute's website may be found at www.egi.ac.cn/#.

from climatology, biology, botany, geography, glaciology, geology, physical anthropology and other scientific fields for the use of the historian. Another is the reexamination of textual sources in a new light to illuminate past environments and people's interaction with them.

The textual sources for Xinjiang's history from the Han and Tang periods, and especially the official documents, gazetteers, travel accounts and poetry from the Qing period, contain much geographic and climatic information on Xinjiang. Gazetteers (*difang zhi*) are an especially rich source of this sort of information, especially in their *dili* 地理, *shui* 水, *shan* 山, *wuchan* 物產, *shangwu* 商務, *hukou* 戶口, *tianwen* 天文, *yuliang* 雨量 and similar sections.

However, the environmental data in these sources are often scattered, difficult to interpret, inaccurate in key respects, and must be interpreted with care. Here, I will raise just one example to illustrate this problem: The *Xiyu shuidao ji* 西域水道記 by Xu Song 徐松.

This systematic survey of Xinjiang's waterways begins with Lop Nor, as the terminus of the Tarim River, and then describes each of the Tarim's tributaries and their respective tributaries in order. At the beginning of the work, Xu Song identifies Lop Nor as a "stopping point" for the headwaters of the Yellow River, citing a passage from the *Shanhai jing* 山海經 that asserts that the waters from Lop Nor disappear underground and flow towards *Zhongguo* 中國. The same claim appears in the *Huangyu Xiyu tuzhi* 皇輿西域圖志.[7]

This of course is wrong. But such inaccuracies can be revealing when read not for their factual content but as indicators of their authors' attitudes towards the natural world. Xu Song's geography drew on field work: while exiled in the region (1813–20) he spent two years traveling (1815–16), gathering data that informed not only his *Xiyu shuidao ji* but also the *Xinjiang zhilue* 新疆志略 (1821). Yet Xu Song was a Hanlin compiler, a classically trained man of letters for whom the landscape of the present could not be separated from the textual references of the past. Much of the *Shuidao ji* is given over to old placenames and references to Western Regions rivers in the classics and histories, as well as to listing corresponding names in Manchu, Mongolian and Turkic. To eighteenth- and nineteenth-century Chinese scholars, geographic description was inseparable from the historical and philological concerns of *kaozheng* 考證.

Can we speculate a bit further on the implications of claiming Lop Nor as the source of the Yellow River? Xu Song imposes a hierarchical, almost geomet-

[7] XU Song, 徐松 1823b *Xiyu shuidao ji*『西域水道記』, in *Xu Xingbo zhu shu sanzhong*『徐星伯著書三種』(Stringbound, 8 vols. in one case), 1: 1a, 1: 2a. The relevant passage from the *Shanhai jing* appears in full in FU Heng 傅恆, et al. comp. 1986 [1782] *Qinding huangyu Xiyu tuzhi*『欽定皇輿西域圖志』, WU Fengpei 吳豐培 ed., Tianjin: Zhongyang minzu xueyuan tushuguan, Repr. Guji zhenben congshu 古籍珍本叢書, 1986, 27, 9a–b (*shui* juan 4).

ric order on the waterways, starting with their end point—Lop Nor—and working backwards up the Kashgar, Yarkand, Khotan, Aqsu and other tributaries. Each flows into the Tarim River, and thus to Lop Nor. And by associating Lop Nor with the Yellow River, Xu Song links Xinjiang's rivers in turn to China proper, a connection with ideological significance. Moreover, this connection is rooted in classical texts. What is telling here is his insertion of Xinjiang within a moral-geographic order rooted in the Chinese classics, associating and locating the Kunlun Mountains, Lop Nor and the Tarim Basin within the Chinese oikumene.[8]

2. Technical Sources for Environmental History in Xinjiang

Historians, just like archaeologists, can avail themselves of a wide variety of scientific technical research. Famously, mitochondrial DNA analysis of the Tarim mummies has been used to establish the Indo-European origins of early inhabitants of the Xinjiang region.[9] As regards environmental history, remote sensing is another important tool. Satellite photography is of course useful in identifying potential archaeological sites, tracing the contours of such landscape features as defunct river and lake beds, and for all manner of mapping applications.[10] It has also been used to reconstruct changes in vegetative cover, and thus illuminate the agrarian histories of Tarim Basin oases. Though such data are restricted to the last three decades or so for which remote sensing images are available, the patterns they indicate are of use to historians of earlier periods.

One group of scientists have been working with images of the Cele (Chira) oasis from 1977, 1990 and 1998. By means of a process known as combined fuzzy clustering and supervised classification (COFCS), they have been able to categorize with a high degree of precision types of vegetative cover for a given location and

[8] I present a similar argument at greater length regarding Qing and Republican era Xinjiang cartography in MILLWARD, James 1999 "Coming onto the Map: "Western Regions" Geography and Cartographic Nomenclature in the Making of Chinese Empire in Xinjiang."

[9] CAVALLI-SFORZA, L. Luca 2000 *Genes, Peoples, and Languages*, New York: North Point Press; see also MAIR, Victor ed. 1998 *The Bronze Age and Early Iron Age Peoples of Eastern Central Asia*, 2 vols., The Institute for the Study of Man: The University of Pennsylvania Museum Publications and MAIR, Victor and J. P. MALLORY 2000 *The Tarim Mummies: Ancient China and the Mystery of the Earliest Peoples from the West*, New York: Thames & Hudson. Though the DNA studies do provide some support for the Indo-European origins of the Bronze Age inhabitants of the Tarim, there is also physical evidence suggesting a South Asian connection. See SCHURR, Theodore 2001 "Tracking Genes Across the Globe," Review of L. L. Cavalli-Sforza *Genes, Peoples and Languages*, in American Scientist Online (Jan–Feb.), http://www.americanscientist.org. Accessed Dec. 2, 2004.

[10] See Sohma Hidehiro's abstract on use of Corona satelite images to study the Miran ruins in Takamura et al. 2002: 275–76.

trace changes in land quality over time. From their study emerges a history of the environmental effects of several decades of agrarian and ecological policies in the Khotan region.

Earlier statistical data from land surveys indicate that the agrarian policies of the period from 1958 through the end of the Cultural Revolution had dire effects on the oasis environment of Cele. Over-ambitious land reclamation programs, excessive grazing, and aggressive cutting of trees and shrubs and extirpation of their roots for firewood resulted in much clearance of forested land, destruction of grassland, and destabilization of previously stable desert. Forest had covered 20.5% of Cele *xiang* before the co-operativization movement in the late 1950s; by 1980, forest coverage was only 9.5%. Deforestation and abandonment of land reclaimed without adequate water supplies caused the oasis to lose ground to the desert: in the 1980s, an enormous dune threatened to engulf Cele's county town. The Cele oasis had already relocated three times previously in its history, and looked to be doing so again.

Like other places in Xinjiang, Cele then embarked upon a large-scale tree planting campaign. The remote sensing studies confirm that these efforts in Cele were successful in one general sense: the stabilization efforts protected the oasis from inundation by desert sands, and overall oasis area even expanded. However, remote sensing also reveals other changes: between 1977 and 1990, the some 8–9% of good agrarian land along the outskirts of the oasis (the oasis-desert ecotone) was degraded to mixed bands of desert and arable, with a general loss of productivity; moreover, between 1990 and 1998, the area of bodies of water shrunk by over half.

What had happened was that increased use of water in the middle and upper reaches of the river feeding the oasis left insufficient water for places lower down the watershed. The groundwater level dropped in lower parts of the oasis, limiting the amount of water that could be used for irrigation, and precluding the practice of excessive irrigation, which had the effect of flushing out salts. Salinity levels in downstream irrigation water rose, and much former farmland was salinified. Abandonment of fields and desertification was the result, with windblown sand filling up what had been cropland.[11]

As we will see below, abandonment and retreat upstream has been a long-

[11] DING Jianli 丁建丽, Tashpolat TIYIP 塔西甫拉提 • 特依拜, and LIU Chuansheng 刘传胜 2001 "Ji yu yaogan de Cele lüzhou tudi fugai dongtai bianhua yanjiu"「基于遥感的策勒绿洲土地覆盖动态变化研究」, in XIONG Heigang 熊黑钢, et al.,『新疆资源环境与可持续发展』*Xinjiang ziyuan huanjing yu ke chixu fazhan*, Wulumuqi: Xinjiang daxue chubanshe, pp. 180–88. and YA-LI-KUN Ta-shi 亚力坤 • 塔石 and Tashpolat TIYIP 塔西甫拉提 • 特依拜 2001 "Liyong zhibei gaidu tuxiang dui lüzhou huanjing zhiliang bianhua de pingjia yanjiu"「利用植被盖度图像对绿州环境质量变化的评价研究」, in XIONG, et al. 2001, pp. 177–79. See also Takamura et al. 2002: 270, and pp. 277–78 for an abstract of a study by several of these same scientists analyzing the Cele oasis remote sensing data by means of fractal theory.

term pattern for the oases of the southern rim of the Taklamakan. Both the natural advance of aeolian (wind-borne) sand and human activity may have played a role in that process, and the recent history of the Cele oasis as documented by remote sensing data provides insight into its details.

Another scientific technique of interest to the Xinjiang historian is analysis of ancient sediments. Such deposits have been called "geoarchives" for the wealth of data they contain on climate and plant species diversity in the past. In areas sensitive to climatic change, like the highly arid Tarim Basin, slight changes in climate can result in wholesale shifts in the assemblage of vegetation in an area; these changes are in turn reflected in the strata of earth laid down by wind or water. Cores of such sediments may be extracted, their strata dated, and their pollens and ratios of geochemical elements analyzed.[12] Though application of these techniques to sediments from loess layers, dune sections, and lake sediments, scientists have identified multiple alternations between relatively warm-dry and cool-wet periods in Xinjiang over the past 13,000 years. Sediment cores analyzed include ones taken from Lakes Aibi, Barkol, and Bosteng; the Tianshan foothills; Damagou dunes and Niya.

When applied to more recent periods, the analysis of sediments can also corroborate textual materials. For example, a soil section from Niya shows that this area experienced relatively cool and wet periods in 2050–1500 BC, 550BC–AD 50, and AD 550–950; these alternated with relatively warm and dry periods in 1500BC–550BC, AD50–550, and from AD 1000 to the present. Moreover, the sedimentary record reflects human activity in the area: marked increases in the quantity of grass (i.e. grain) pollen appear within the samples for the 550 BC–AD 50 period (corresponding to the Jingjue kingdom 精絕王國, and again in the AD 550–950 period (possibly due to the nearby Tang outpost of Nirang cheng 尼壤城). The period during which states fell, Niya city was abandoned, trade routes were forced south and for which histories record successive droughts in eastern and southern Xinjiang is reflected in the sedimentary record by lower quantity of pollens overall, less diversity, and few agricultural grasses. The shallowest two centimeters of the Niya section are rich in tree pollens, a result of the late 20th century tree-planting campaigns in Xinjiang.[13]

[12] On paleopollen analysis, see GROVE, Jean 1989 *The Little Ice Age,* London: Routledge, p. 396.

[13] ISSAR, Arie S. ed. 2003 *Climate Changes during the Holocene and Their Impact on Hydrological Systems*, Cambridge and New York: Cambridge University Press, p. 68 cites work by Wen Qizhong and Qiao Yulo for the long series (since 13,000 aBP). ZHONG Wei 种巍 , SHU Qiang 舒强 and XIONG Heigang 熊黑钢 2001 "Ta-li-mu pendi nanyuan Niya peimian de baofen zuhe ji qi dui lishi shiqi huanjing yanhua de fanying"「塔里木盆地南缘尼雅培面的孢粉组和及其对历史时期环境演化的反映」, in XIONG, et al. 2001, pp. 3–5 covers the past 4000 years based on the Niya section.

Other techniques which yield climatological data in time series include dendrochronology (tree ring dating) and analysis of glacial ice cores. The glacial ice may be dated stratigraphically: dry season dust from the Gobi and other deserts create layers that can be accurately counted. Isotopic ratios in the ice are then used as proxy measures for temperature at each year of the sample: higher oxygen isotope values in precipitation indicate warmer temperatures. Moraines left by the advance and retreat of glaciers yield additional evidence of temperature at various periods; some moraines may additionally be dated by tree-rings, radiocarbon-dating or analysis of lichens growing on moraine rocks, thus indicating previous extent of glaciers and when recession began. Glaciers have been and remain critical to life in the Tarim basin, and I will discuss the evidence they yield at greater length below.

3. Mountains and Water: Key Characteristics of the Xinjiang Environment since the Upper Pleistocene

Xinjiang's modern landforms, climate and ecosystems are the result of on-going interplay between factors laid down in geologic time and more recent human activity. The point of departure and determining factor for much of what has happened throughout subsequent history of the region (and for much of Asia) was, of course, the uplift of the Tibetan-Qinghai plateau, a process which began some 100 million years ago with the breakaway of the Indian continent from Gondwanaland and its collision some 60 million years ago with Asia. This initiated uplift from the Hindu Kush and Karakorum to the Kunlun, forming the Tibetan plateau. Estimates vary as to when the mountains of the Tibetan Plateau reached threshold height (possibly 22–15 million years ago), but when they did, they created the Asian monsoon weather pattern. In this weather cycle, warm and moist air from the Indian Ocean and Pacific is drawn onto the Indian sub-continent and into East Asia by rising air masses over Tibet and Mongolia in the spring and summer, thereby bringing rains. In the fall and winter, cool high pressure zones centered on the high continental regions of Inner Asia exclude warmer, moister air from the sea, causing relatively dry winters.

The mountain ranges ringing Xinjiang, as well as lower ranges further east, effectively shield the Tarim Basin from the influence of southeasterly winds and the monsoons that determine China's climate. Over the longer term, China has followed what is known as a cold-dry/warm-wet regime of climatic change in which warmer epochs are characterized by increased moisture. Xinjiang, on the other hand, is most influenced by the westerly winds and follows the cold-wet/warm-dry pattern: warmer periods are drier and desertifying, while cooler eras result in increased precipitation and expanded glaciation at higher altitudes.[14]

Because of the barrier effect of the massive mountain chains, Xinjiang and the Tarim Basin in particular receive little precipitation; the average rainfall in the Taklamakan region as a whole is less than 50mm annually, but many of the oases enjoy only half as much rainfall. Evaporation rates, on the other hand, range from 1000–3000 mm per year. Open water in southern Xinjiang, in other words, quickly disappears. A modern scientist demonstrates this by pointing out that a lake 2 meters in depth would be dry in less than two years without an outside water source. To inhabitants of the Tarim oases, of course, the principle is second nature. As a line in a Uyghur poem from a century ago put it,

eriqdiki lay sudäk
ötüp ketidu yashliq

(Like muddy water in the canal, youth is gone before you know it).[15]
The mountains have other effects as well. They create a peculiar wind pattern, with predominantly northeasterly winds in the eastern part of the basin, and northwesterly winds in the south and west (Fig. 1).

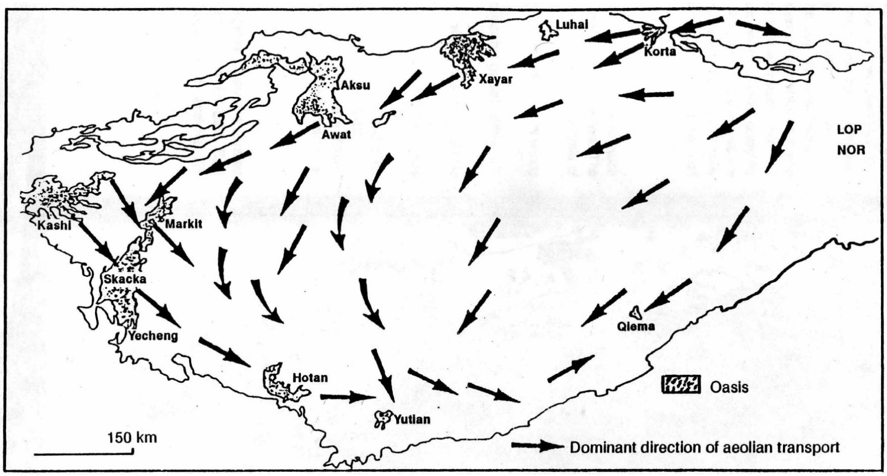

Fig. 1. Counterclockwise direction of winds in Tarim Basin
(Mainquet and Chemin 1988: 140)

[14] Zhao and Xia 1984: 311; Issar 2003: 63, 105.
[15] Zhao and Xia 1984: 311 for lake example; Poem excerpt retransliterated and translation slightly modified from JARRING, Gunnar 1951 [1947–1948] "Materials to the Knowledge of Eastern Turki," in *Lunds Universitets Årsskrift*, vol. 44, p. 110 #86.

They also make the Tarim Basin a sand trap—or, in technical terms, give it a "positive sand budget"—the highest positive sand budget of any desert in the world. Alluvial sediments washed from the Kunlun, Pamir and Tianshan ranges accumulate in the basin, and few ever leave again. Still, the enormous volume of these sediments has led geographers to conclude that more than incremental accumulation was involved. It is likely that during the final stage of the last ice age, rapid glacial melting flooded the basin and left sheets of sediments across its breadth. These were then shaped by the winds into massive transverse dunes called draa ridges, most over 100m in height, which make up the center of the Taklamakan. In places this Pleistocene sand layer is 400–500 meters thick. The draa ridges lie on a NE-SW axis in the eastern part of the desert, and a NW-SE axis in the west and south, and severely inhibit travel along an east-west axis in the desert—as Sven Hedin nearly fatally discovered. The draa ridges are old, permanent features of the Taklamakan which have not moved for at least the past eight millennia, nor have new draa ridges formed. But the winds do shift sands in the periphery of the desert, forming smaller ridges and superficial formations known as barchan dunes. It is these unstable dunes that endanger Cele and other oases, especially along the southern rim of the Basin.[16]

Finally, of course, orography has shaped patterns of settlement in the Xinjiang region, leading to the historical dynamics with which historians of the region are familiar. The land north of the Tianshan is generally suited for pastoral nomadism (including horse-breeding); it communicates fairly easily both with Mongolia to the east, and via passes with the oases of the Tarim and Turfan basins, which provide good farming. Northern nomads, therefore, with the military edge afforded by their horses, have generally dominated the oases of the south, be it from the bases in the Urumchi area or from as far away as Yetisu (Semirechiye). Moreover, powers based in north China have on occasion expanded into Xinjiang in the context of their rivalries with Mongolian-based powers, exercising a flanking maneuver to block the nomadic states' access to grain and tax revenue from the Tarim Basin.

The oasis dwellers settled primarily on the alluvial fans of the rivers emerging from the mountains or in piedmont zones where streams and springs provided water for farming or pasturing animals. With virtually no precipitation in the region, farms and settlements have always been dependent upon the meltwater from melting snow and glacial ice, which flows in several major rivers and many minor ones.

[16] MAINGUET, Monique and Marie Christine CHEMIN 1988 "Wind System and Sand Dunes in the Taklamakan Desert," *Chinese Journal of Arid Land Research* 1, no. 2, pp. 136–42; ENDO Kunihiko and KANEMAKI Motoko 2002 "Topography and Environmental Changes in the Taklamakan Desert," in TAKAMURA Hiroki, et al. 2002 "Environmental Changes and Human Activities in the Taklamakan Desert and its Environments," *Geographical Reiview of Japan* 75, no. 2, pp. 276–77.

In modern times, these have either disappeared into the desert or drained ultimately into the Tarim and thence to Lop Nor or other terminal lakes. Irrigation canals drew water from these river systems to farms; mountain run-off also filled the subsurface water-table of the oases which people then tapped via wells or springs. *Karez* or *qanat* wells are an improvement on nature: they channel water underground from the mountains to low-lying oases such as Turfan, thus limiting en route evaporation.

Oasis agriculture has thus been dependent upon the quantity of available melt-water, which in turn is largely a function of the height and shape of the mountain massifs, the size of the glaciers, the altitude of the snowline, the breadth of the snowfields above the oases, and of course temperature and precipitation, which affect accumulation, melting, and evaporation of snow and ice. The size and power of oasis kingdoms in historical times, as well as the possibility of agrarian expansion since Qing times, have been a function of oasis water supply and thus of these same factors. The general failure of the Tarim oases to unify except under an outside power is arguably related to limits on the strength of each oasis, again as ultimately determined by limits on water.[17]

Within this general pattern, there have been climatic fluctuations over time which likely affected the supply of water to various places in the Tarim Basin, and may have led to the human abandonment of Niya, Rawak, Karadong, Endere and other oases whose sites lie far north of the Kunlun piedmont zone in what is now desert. Working with Aurel Stein's dates for the final periods during which these sites were occupied, Hoyanagi Mutsumi pointed out that one group of southern Tarim Basin sites was abandoned around the end of the 3rd century, and another group by about the end of the 8th century. Moreover, "there were virtually no sites flourishing between, roughly, the 4th century and the early part of the 7th."[18] Hoyanagi speculated that diminution of rivers and springs likely caused the abandonment of these sites, and correlated these periods with cycles of global climate change derived from evidence from other parts of the world. Now, we have the benefit of local paleoclimate studies (such as the pollen analysis from Niya mentioned above). The Niya sediments show that the periods from 550 BC to AD 50 and from AD 550–950 were relatively cool and wet, which corresponds roughly with the dates available from archaeological evidence. It is interesting to note that the Han dynasty *tuntian* 屯田 operations in the southeastern Tarim flourished during

[17] WIENS, Harold 1966 "Cultivation Development and Expansion in China's Colonial Realm in Central Asia," *Journal of Asian Studies* 26, no. 1 (Nov.), pp. 69–71, 76–77; HOYANAGI Mutsumi 1975 "Natural Changes of the Region along the Old Silk Road in the Tarim Basin in Historical Times," *Memoirs of the Research Department of the Toyo Bunko* 33, p. 89.

[18] Hoyanagi 1975: 95–96.

the first cool-wet period demonstrated in the Niya sediments, but were not restored later after the Wang Mang interregnum, even by Ban Chao who exercised military dominance in the Tarim Basin in the late first century AD.[19] The era of active Tang involvement with the Western Regions likewise corresponds with what the Niya sediments tell us was a cool-wet period in Xinjiang.

Climatic change, therefore, probably played a role in the abandonment of the southern Tarim oases cities—although a broader correlation of recent archaeological and paleoclimatic findings would be necessary to definitively establish this. Some scholars have suggested, however, that human activity may also have contributed to the necessity for southward retreat of these oases.[20] Examples like that of Cele and many Xinjiang oases today show a possible mechanism: over-exploitation of upstream water leads to salinification and desertification of lands taking water from downstream, which in turn leads to their abandonment. Human use of water prevents its escape into the desert at the outskirts of oases, leading to the death of desert flora and the eventual retreat of the oasis boundary.

Oxygen isotopes measured in ice cores from glaciers in the Qilian and Kunlun mountains provide more finely graded temperature series for more recent centuries. Overall, the period from 1400 to 1900 was 1–2°C. cooler than today. More specifically, cores from the Dunde (Qilian shan) and Guliya (West Kunlun) glaciers both demonstrate that over the past six hundred years, there were three markedly cooler periods: from 1420 to 1520; from 1570 to 1690, corresponding to the global Little Ice Age; and from 1770 to 1890 (Fig. 2).

Interestingly, for the Guliya glacier, the cold period from the late eighteenth through the nineteenth century was colder even than the previous Little Ice Age minimum. Temperatures have been warming through the twentieth century, reaching annual and decadal average temperatures higher than any measured in the 1000 year Dunde core series. Warming since 1980 is dramatic, as measurements of glacial retreat corroborate.[21]

From the above survey, we may draw some general conclusions about the role of the environment in the region's history. There is an intriguing climatic coincidence here: cooling (not desiccation, as Huntington theorized) in North

[19] MA Yong and SUN Yutang 1994 "The Western Regions under the Hsiung-nu and the Han," in HARMATTA, János ed. *History of Civilizations of Central Asia*, Vol. II., Paris, UNESCO Publishing, p. 240.

[20] WANG Binghua 王炳华 and HU Wenkang 胡文康 2000 *Luobu bo: yige zhengzai jiekai de mi*『罗布泊：一个正在解开的谜』, Wulumuqi: Xinjiang renmin chubanshe, p. 155.

[21] YAO Tandong 姚檀栋, et al. 1997 "High Resolution Record of Paleoclimate since the Little Ice Age from the Tibetan ice Cores," *Quaternary International* 37, pp. 19–23; THOMPSON, L. G. 1992 "Ice Core Evidence from Peru and China," in BRADLEY, Raymond S. and Philip D. JONES eds. *Climate Since A.D. 1500*. Rev. ed. London and New York: Routledge, 1995; Grove 1989: 227–28.

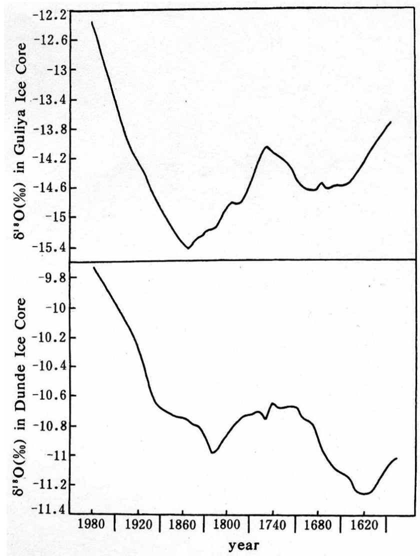

Fig. 2. Oxygen isotope record from Dunde and Guliya glaciers. Downturns of the curve indicated lower temperatures (Yao, Yafeng, and Thompson 1997: 21, fig. 6)

China and Mongolia may have contributed to crises in the steppe pastoral-nomadic economy and thus to state-formation and heightened conflict with states based in north China. A 1°C. dip in average annual temperature can effect grassland carrying capacity by up to 30%.[22] Gareth Jenkins first noted this connection by pointing out that the consolidation of Chinggis Khan's authority corresponds to a deep downturn in mean annual temperatures from 1100–1300.[23] (Though the scholars working on the Niya sediment series do not highlight this period as standing out from the general warm-dry trend of 1000-present, this period does show lower average temperatures in the Dunde ice core, in other physical records of world-wide climate change, and in Chinese written sources.) Following a similar logic, Fang Jinqi has correlated climatic changes with nomad invasions and Chinese

[22] Grove 1989: 396, based on a study in Iceland.

[23] JENKINS, Gareth 1974 "A Note on Climatic Cycles and the Rise of Chinggis Khan," *Central Asiatic Journal* 18, no. 4, pp. 217–24. See also BRADLEY, Raymond et al. 2003 "Climate in Medieval Times," *Science* 302, no. 5644, pp. 404–5. and D'ARRIGO, Rosanne et al. 2001 "Spatial Responses to Major Volcanic Events in or About AD 536, 934, 1258," *Climatic Change* 49, nos. 1-2, pp. 239–46, for more recent studies using Mongolian tree-ring data.

north-south migrations in historic times.[24]

If the expansion of Chinese powers into Xinjiang was primarily driven by the strategic desire to block access of northern nomadic states to agrarian products and trade revenue, then climate may have served as a complementary factor: cooler eras made life rougher on the Mongolian steppe, contributing to crisis and higher-level state-formation among tribal peoples.[25] In Xinjiang, however, the same decrease in average temperatures *increased* available water resources, thus making agriculture easier in southern Xinjiang oases, making the product of these oases more important to nomadic states, and increasing Chinese incentives to cut off nomad access to them. At the same time, cooler temperatures rendered more feasible the favored Chinese method of garrisoning distant frontiers with military farms. It would be an interesting project to gather and collate the recently available paleoclimatic evidence for both temperature and precipitation in Xinjiang as well as Mongolia and North China and examine these theses more closely (Jenkins' snowline and glaciometric data came from northern Europe, Russia and Alaska, not the Tianshan.)

Generally characterized in historical time by an arid climate, the Xinjiang region has nonetheless enjoyed periods when meltwater was more plentiful than it is today. And here lies second aspect of this coincidence: the periods when China projected power and established military farms in Xinjiang, during the Han, Tang and Qing, correspond to cool-wet periods. Climate change did not determine Chinese westward expansion: during the coolest period in recent centuries (1420–1520), the Ming did not colonize in Xinjiang. Nevertheless, the coincidence of Chinese colonization of Xinjiang with cool-wet eras draws our attention to the stark difference between arid Xinjiang and southern China. Expansion of the Chinese agrarian regime and political-economy from the temperate zone of north China into the transitional temperate-sub-tropical and sub-tropical zones of the south was well underway by about the year 1000.[26] By contrast, Chinese agrarian expansion and settlement in the far northwest, despite early outposts in Han and Tang times, is a really modern phenomenon dating only to the Qing. And this brings us to consideration of the Xinjiang environment during the Qing.

[24] FANG Jin-Qix (sic) 1990 "The impact of climatic change on the Chinese migrations in historical times," in LIU Chuang, et al. eds. *Regional Conference on Asian Pacific Countries of I. G. U.*: *Global Change and Environmental Evolution in China*, Section III., Hohot: Editorial Board of Arid Land Resources, pp. 96–103. cited in Issar 2003: 69.

[25] DI COSMO, Nicola 1990 "State Formation and Periodization in Inner Asian History," *Journal of World History* 10, no. 1, pp. 1–40.

[26] ELVIN, Mark 2004 *The Retreat of the Elephants: an Environmental History of China,* New Haven: Yale University Press, Chapter 4.

4. Towards an Environmental History of Qing Xinjiang

萬家煙火暖雲蒸
銷盡天山太古冰
臘雪淸晨題牘背
紅絲研水不曾凝

向來氣候極寒，數代以來，漸同內地，人氣盛也。

"Smoke from the fires of a myriad homes rises in a warm cloud, / melting the antique ice of the Tianshan. / Despite the snow, as I write on a tablet on clear mid-winter mornings /
The ink on my inkstone has never frozen. (In the past, the climate was extremely cold. Over the past several generations, it has gradually become like Neidi. People's spirits have risen.)"

-- Ji Yun, *Wulumuqi zashi*, Fengtu #3.[27]

In his poem and self-commentary above Ji Yun unintentionally highlighted the two central environmental issues in Xinjiang today: climatic warming and the melting of the glaciers. He attributed glacial melting to human activity—something that is true now, but was unlikely so in the eighteenth century.

In fact, as I'll discuss below, Ji Yun arrived in Urumchi at the end of a period of warmer temperatures, on the eve of a spell of climatic cooling that would last through the nineteenth century. It is unlikely that smoke from Urumchi in 1771 played any role in melting the Tianshan ice. However, there is a good deal of evidence in Qing materials to suggest that the Qing conquest and colonization of Xinjiang and exploitation of its agrarian and mineral resources did have substantial effects on the environment.

Consider for example the erection of the Hongshan Pagoda, today Urumchi's most famous extant historical monument. The hill on which it stands, facing Yamo shan across a small gap through which the Urumchi River flowed, is a sacred place: Oirat Mongols would dismount as they rode past Hongshan (or Tigerhead Mountain, as it was also known), to add a stone to an *obo* on the cliff. Qing authorities used the site for sacrifices, and erected several temples on it.

People believed that Hongshan was the abode of a dragon that had flown down from Tianchi (Heaven Lake), near Boghda Tagh. When the Urumchi river flooded several times in 1785–86 with great loss of life, many thought that the dragon spirits resident in Hongshan and Yamo shan were trying to approach each other. Should these mountains be allowed to meet, the river would be dammed and

[27] I am grateful to Yun Wenjie for identifying *hongsi* as a famous type of inkstone.

Urumchi inundated. In order to defend against such a calamity, Urumchi *dutong* Shang-an in 1788 erected a pagoda atop each hill to fix the spirits in place.[28] As any visitor to Hongshan in recent years can attest, dragons and river alike have been thoroughly quelled and banished from the vicinity of Hongshan. But we might well look for other reasons why the Urumchi river was flooding in the 1780s. The answer may lie in deforestation.

Already by 1762, the inhabitants of Urumchi were suffering from shortages of firewood and were having to travel further and further to get it. The local military government thus began to mine and sell coal to the soldiers for fuel, deducting the cost from their salaries. Ten years later, Ji Yun tells us, there was still "dense forest without limit" west of the city and in the second and third months people would bring wine for parties at a pavilion that a local official named Kun had built there. But people in the city heated and cooked with coal: the well-off burned high quality, smokeless coal, and the poor made do with a dirtier variety at 2/3 the price. Carts delivering the coal rolled through the city gates each morning. By 1782, the government began monopolizing sales of timber in its official stores—an effort to increase revenues, and a sure sign that wood had become a precious resource.[29]

I have not determined exactly when clear-cutting around Urumchi reduced the hills to their current barren state. One long-term resident of the city reports that the area beyond the city walls were forested in early 1933, when Jin Shuren had the trees burned to clear lines of fire against Ma Shiming's rebel forces.[30] However, for Ji Yun only a decade or so after the city's establishment, forest was already something you went to a colleague's weekend dacha to enjoy, and firewood had ceased to be an economical fuel, even for the poor who were hard-pressed to buy good coal. Thus we may assume that deforestation of the area around Urumchi was under way by the early 1760s, and continued through the Qing period, with deleterious effects on watershed stability.

The largest scale manmade environmental effects in the Qing period surely came from the efforts to expand the region's agricultural base through opening of new farms on steppe and desert lands. According to one estimate, farmland increased ten-fold from the conquest in the mid-eighteenth century to the end of the Qing, with over 11 million *mu* in cultivation by the late nineteenth century.[31]

28 ZAN Yulin 昝玉林 1983 *Wulumuqi shihua*『乌鲁木齐史话』, Wulumuqi: Xinjiang renmin chubanshe, pp. 11–13.

29 HE-ning 和寧 1804 *Huijiang tongzhi*『回疆通志』145–47; JI Yun 紀昀 1771 *Wulumuqi zashi*『烏魯木齊雜詩』, in WANG Yunwu 王雲五 ed. *Congshu jicheng chubian*『從書記程初便』, vol. 2307. Shanghai: Shangwu yinshuguan, 1937, stanza 139 (youlan 1), stanza 94 (wuchan 23).

30 Imin Tursun, lecture 16 October 2004, Bloomington, Indiana.

31 HUA Li 华立 1994 *Qingdai Xinjiang nongye kaifa shi*『清代新疆农业开发史』, Ha'erbin: Heilongjiang jiaoyu chubanshe, pp. 262–63; cf. FANG Yingkai 方英楷 1989 *Xinjiang tunken shi*『新疆屯垦史』, Wulumqi: Xinjiang qingshaonian chubanshe, vol. II, p. 757.

During his three years of exile in Xinjiang in the early 1840s, Lin Zexu alone charted out 800,000 *mu* of new irrigated land, overseeing the digging of everything from karez wells to major canals.[32]

Several historians have documented the success of eighteenth and early nineteenth century efforts to send Chinese peasants, exiled criminals, soldiers and even bannermen to farm lands in eastern and northern Xinjiang. Ji Yun hints at one reason for this success when he observes that "fields beyond the frontier are frequently left fallow (換種) to rest their strength. There is no talk of fertilizing the fields with manure."[33] By the eighteenth century, the land-population balance in most of China proper had reached a point where peasants had to apply labor-intensive methods to their small parcels of land in order to survive. This meant double- or triple-cropping, repeated weedings and applications of manure, and no luxury of letting lands lie fallow for a season. Though Chinese peasants are renowned for their industriousness, they did not invest labor like this as a cultural predilection. Where they had sufficient land and could afford to, Chinese farmers used less labor-intensive methods. This was evidently true in Xinjiang, as it was somewhat later in Manchuria.[34] There was plenty of land in Xinjiang, extremely fertile where it could be irrigated, and this attracted settlers and kept them in there.

Even in the relatively moist northeastern part of Xinjiang, however, water was not certain. Ji Yun versifies about dry fields suddenly overflowing with water after a waterfall is propitiated by a sacrifice, and of a *tuntian* field whose water source suddenly dried up, as if it had "run down the drain," leaving a field full of sand. He tells how everyone in Urumchi relied on household wells each year until the second or third month, when all the wells went dry and people had to fetch water from the river outside the city walls.[35] Ji Yun made special note of such hydrological vagaries in the Western Regions, since they were not what most Chinese were used to.

As measured by population growth, the Xinjiang reclamation efforts were highly successful. In the century between the Qing conquest in the mid-eighteenth century and the nineteenth century, Xinjiang population increased about six-fold, from some 300,000 to around 2 million ca. 1850.[36] China's population as a whole increased only about four and a half times during the entire length of the Qing dynasty (1644–1911). Much of Xinjiang's Qing period population growth derived

[32] YAN Xiaoda 严晓达 1989 "Lin Zexu he Xinjiang de shuili yu tunken shiye"「林则徐和新疆的水利与屯垦事业」, GU Bao 谷苞 ed. *Lin Zexu zai Xinjiang*『林则徐在新疆』, Wulumuqi: Xinjiang renmin chubanshe, p. 182.

[33] JI 1771: stanza 53 (minsu 20). It may seem that Ji Yun is discussing Uyghur peasants here, but this section on "popular customs" primarily concerns the ways of Chinese residents in the Urumchi area.

[34] See ISETT, Christopher 2007 *State, Peasant, and Merchant on the Manchurian Frontier, 1644–1862*, Stanford: Stanford University Press.

[35] Ji 1771: stanzas 10–11 and 21 (fengtu 10–11 and 21).

[36] Hua 1994: 262, 264.

from in-migration and subsequent natural increase of Chinese to the north and east. But it is instructive to compare figures for southern Xinjiang from the eighteenth and early twentieth century (Fig. 3).

Districts	**Ca. 1782**	**Ca. 1905**	**% increase**
Karashahr (Yanqi)	5390	22690	421
Kucha	4260	74776	1755
Aqsu (Wensu)	24607	101332	419
Bay	1735	40268	2321
Uch Turpan	3158	47267	1497
Kashgar (Shule + Jiashi)	66413	222318	335
Yarkand (Shache + Yecheng)	65495	255256	390
Khotan	44603	137841	309

Fig. 3. Population of southern Xinjiang cities in Qing period. 1782 figures from *Huangyu Xiyu tuzhi* (Fu 1782: *jiangyu* sections); 1905 figures from late Qing *Xiangtu zhi*, collected in Ma Dazheng et al., eds. 1990.

Even given all the difficulties with Qing census statistics, if we assume a roughly equivalent degree of undercount for both mid-Qing and late-Qing authorities, then the relative values of these figures are revealing. The high growth in Kucha, Bay and Uch Turpan may reflect Han in-migration, or simply low baseline counts in 1782. But all the other Tarim Basin towns, populated primarily by Uyghurs, show impressive population increases of three- to four-fold. Although there are certainly other contributing factors, including commercial expansion, we may safely conclude that agrarian expansion also contributed to the support of this increased population. Indeed, in the nineteenth century Qing officials directed their attention to reclamation efforts in southern Xinjiang.

Both land area under cultivation and the non-Turkic population (including Tunggan and Manchu as well as Han) was drastically reduced by the wars of the mid-nineteenth century in Xinjiang. Following recovery of Xinjiang from Yaqub Beq and Russia, Qing authorities attempted to restore the Chinese population and agrarian tax base through renewed homesteading efforts from the 1880s. This homesteading campaign was less successful than earlier efforts, however, and many of the Chinese farmers who started working on Xinjiang farms in the 1880s later abandoned them and returned east. Total cultivated land in Xinjiang peaked in 1887 at 11,480,190 *mu* (about 1,740,000 acres), and actually declined to 10,554,705 *mu* in 1910.[37]

[37] KATAOKA Kazutada 片岡一忠 1991 *Shinchō Shinkyō tōchi kenkyū*『清朝新疆統治研究』, Tokyo: Yūzankaku, pp. 189–94.

There were, no doubt, reasons of politics and personal safety behind this population shrinkage: many of the people who resettled in Xinjiang in the 1880s were refugees from disasters in Gansu and Shaanxi who returned home once those provinces had recovered. Likewise, after the ethnic blood-letting of the mid-century rebellions in Xinjiang, many Han and Tunggan may have feared staying on.

However, there may also be environmental reasons why the second round of reclamation in Xinjiang was less successful than that of the late eighteenth and early 19th century. Lands that have been farmed and then abandoned can degrade very quickly in a desert environment. Hardy desert grasses and scrub like *luotuoci* 駱駝刺 or tamarisk whose roots once stabilized the soil are no longer present, and in the absence of continuing irrigation, crops and other plants cannot survive. As a result, derelict fields fill with sand.[38] Many fields abandoned during the mid-nineteenth century wars, then, would have been harder to restore to workable condition than they were to reclaim in the first place.

Another factor behind the late nineteenth century loss of cultivated land acreage may have been climatic change leading to warmer temperatures and less meltwater. As I mentioned above, glacial ice cores from the Qilian and Kunlun ranges show that 1770–1890 was a cool period in Xinjiang. The surrounding mountains enjoyed more snowfall and a lower snowline, glaciers advanced, and there was less evaporation. These conditions generally translate into more run-off to feed oasis-based agriculture, and greater extension of the rivers.[39] This in turn made conditions more favorable to the land reclamation efforts of the *tuntian* during this colder spell, and could help explain the Qing success in expanding the agrarian economy in Xinjiang.[40]

A thorough survey of Qing materials regarding the hydrology of the Tarim Basin could yield more evidence to test whether the climatic minimum resulted in more meltwater during high Qing times. I have only a couple of examples here, but they do suggest rather robust meltwater flow. First, descriptions of Khotan, Yarkand, and Kashgar rivers which join the Tarim describe these rivers' confluence with the Aqsu as a permanent feature, implying that enough water flowed through them that they continuously contributed to the Tarim. Xu Song in his *Xinjiang fu*

[38] Ding, Tiyip, and Liu 2001: 185.

[39] Temperature, precipitation, and volume of meltwater into the Xinjang basins are related in a complex way. Warmer temperatures can provide the basin oases with *more* run-off, not less, because glaciers can melt faster in warm times, releasing stockpiled water. However, warmer temperatures also increase direct evaporation of the snow, precluding water from reaching the oases. To the geographer Hoyanagi, it is the lower altitude of the snowline which provides the greater volume of meltwater water in cooler times, and cooler temperatures also increase available water by reducing evaporation. (1975).

[40] Hoyanagi speculated that this might be the case. At that time, however, he did not have direct paleoclimatic evidence from the Xinjiang region (Hoyanagi 1975: 99–100).

and *Shuidao ji* describes the four tributaries converging in the northern rim of the Tarim Basin in the shape of a "railing around a well" (*jinglan* 井闌). The *Huangyu xiyu tuzhi* likewise makes no mention of the Khotan River's seasonality (in recent decades, the Khotan river has converged with the Tarim system to the north only when in full spate).[41] Qing maps, too, portray these rivers as reliable tributaries to the Tarim and filling Lop Nor (Fig. 4).

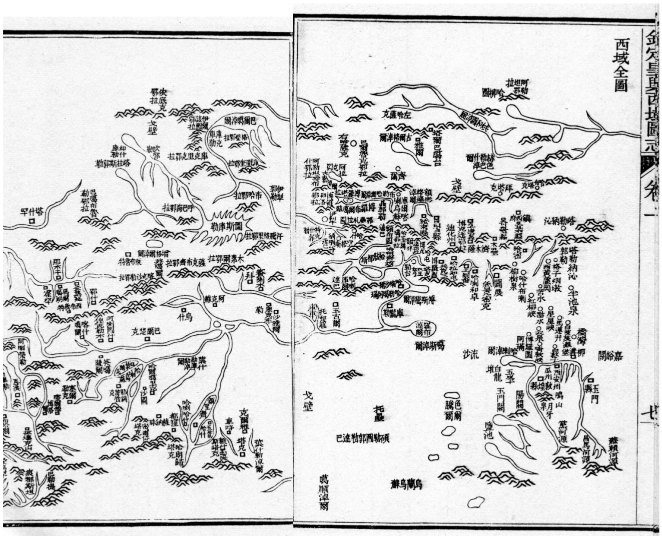

Fig. 4. "Xiyu quantu" (Map of the Western Regions) from *Huangyu Xiyu tuzhi* (Fu 1782: 1: 7b–8a)

The enormous Qing reclamation project involved major construction of irrigation canals and diversion of water, as well as clearance of forest and plowing of desert and grassland. Both Qing officials and subsequent Chinese historians have tended to write about these reclamation efforts in triumphal terms, much as American historians have written about opening and "taming" the US west, and indeed they do amount to an accomplishment of historic proportions. Nevertheless, the small sampling of Qing sources that I have looked at here suggest other dimensions to Qing colonization efforts in Xinjiang: first, environmental changes induced by human activity (deforestation, desertification and so on) that are so visible today began in Qing times; and second, the Qing agrarian expansion in Xinjiang may have benefited from a climatic minimum from 1770–1890, which in Xinjiang's warm-dry / cold-wet climatic regime translated into more available run-off water.

41 Xu 1823b 1:26; 1823a: 8a; Fu 1872: 2 (*tukao*):10a; 28 (*shui*):1a–b, 13a–b.

5. The Twentieth Century Perspective

A description from the early 20th century gives a vivid sense of the watery world created by the seasonal confluence of several rivers to form the Tarim system:

> One day's journey from Shah-yar to the South there is a big river. That river is flowing and joining with the Khotan-darya, Qarghaliq-darya, Yarkand-darya, Kashghar-darya, Maralbashi-darya and the Aqsu-darya. In the time when inundations are coming, at certain places the land is under water for one or two day's journey and at certain places the water stops (only) at the height of a poplar. A month later the water of the river decreases. When it is decreasing the water returns and flows down into the river. If there are deep places they become pools where the water remains. The places which the water has flooded become pastures and groves. They grow wheat in these places. They also grow melons and water-melons there. Melons are grown in the districts. They are also grown in places that have been flooded and in the jungles…[42]

The description sounds fantastic today, when neither Kashgar nor Yarkand rivers reliably flow into the Tarim system and the contribution from Khotan and even Aqsu rivers are greatly reduced due to upstream use for irrigation (Fig. 5).

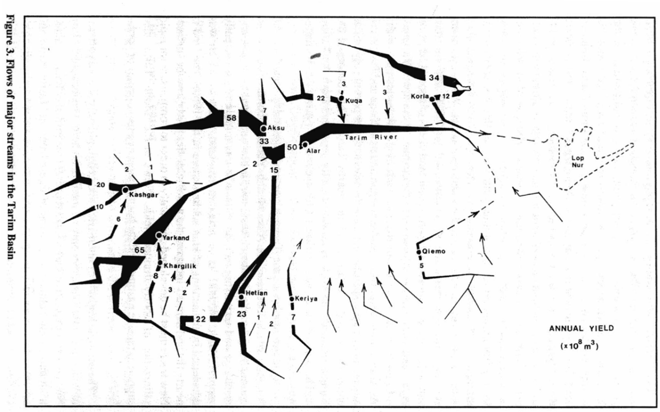

Fig. 5. Schematic map of showing volume of water in the Tarim River system in the 1980s (Reeves et al. 1990: 347, fig. 1)

The human contribution to environmental change in the twentieth-century, especially since the late 1950s, has been monumental. Xinjiang's population is now

[42] Jarring 1951: vol. 44: part 2, texts from Kucha, 179–80.

some 16 times what it was at the end of the nineteenth century. Forests have been radically depleted throughout Xinjiang, with area cut since the 1950s many times greater than area replanted. Grasslands, too, have been reduced; it is estimated that the current number of livestock exceeds carrying capacity of remaining pasture by one third. The air in Urumchi and other cities is severely polluted, with decades-old coal-mine fires adding to industrial and automotive emissions. Mountain meltwater no longer makes its way into the desert, but is almost entirely diverted into irrigation channels and either used to irrigate crops or lost to evaporation. This has produced results similar to those described above for Cele. In the Tarim system as a whole, because of increasingly intensive use of water in the upper and middle reaches, the lower 300 kilometers of the Tarim have been cut off from water flow for over 20 years. Lop Nor was completely desiccated after the Tarim-Kongque system was dammed in 1972; Tatema and Aibi lakes are greatly reduced in size. Water tables along the lower reaches of the Tarim river have plummeted, forests in this region have been reduced to a third and grasslands to a quarter their former area, while desertified lands have increased by over 30%. The vanguard of Xinjiang land reclamation in the PRC, the *bingtuan* or Construction Production Corps, is losing hundreds of millions of yuan due to desertification and salinification of farmland as the Taklamakan desert grows by 175 km^2 each year. Of over 33,000 km^2 of land reclaimed for farming in Xinjiang over the past 40 years, one fifth or almost 7,000 km^2 is no longer workable due to exhaustion, insufficient irrigation, and salinification and has become eroded and desertified.[43] And the rapid warming trend of the twentieth century, after an interruption in the 1960s, continues to accelerate today, threatening to melt the glaciers of the Tibetan plateau completely by 2100 severely reducing water supplies for Xinjiang and much of northern and western China.[44] In this sense, Xinjiang's water and the source of the Yellow River are, in fact, linked, as the old Chinese geographers assumed.

Although the man-made environmental changes of the twentieth century dwarf anything we can identify in earlier eras, when we view Xinjiang's environmental history from a long perspective we nonetheless see the continuities. Chinese presence in the Tarim Basin has always been linked to intensified agricultural development and increased exploitation of water resources. It may have benefited at some times, and suffered at others, from climatic fluctuations which influenced the availability of water. And today's sands, no less than those of Lob Katak or Helaoluojia, still inundate those who do not heed the warnings.

[43] Lü Xin, Zhu Ruijin, and Luo Yunqiang, "Xinjiang renkou, shui ziyuan, shengtai huanjing yu ke chixu fazhan."

[44] This is the conclusion of a 40 month study by a team of 20 US and PRC scientists, led by China's foremost glaciologist, Yao Tandong. Anonymous, "China warns of 'ecological catastrophe' from Tibet's melting glaciers."

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