

China Turpan Water Management Model

WATER SCARCITY SOLUTIONS FOR DEVELOPMENT IN ARID REGIONS

Innovations for Dryland Water Management

Turpan Prefecture in far western China is one of China's poorest and most arid regions. Struggling to balance limited water supplies with growing demands, the entire Turpan Basin faces significant water resources challenges:

- **Chronic and worsening groundwater overdraft, and dropping water tables**
- **Persistently low incomes for small farmers**
- **Current uses of scarce water resources leave insufficient supplies for important local ecosystems and priority future demands**
- **Previous large-scale efforts to save water had counter-intuitively led to an overall increase in basin water consumption**

The Xinjiang Turpan Water Conservation Project successfully used advanced remote-sensing (RS) technology, targeted improvements in irrigated agriculture, and reforms to water rights and water pricing for a 'whole-system' water resources management solution supported by the World Bank.

This new 'China Turpan Model' provides important lessons and sustainable solutions for combatting water scarcity and promoting development in arid regions with over-exploited water resources and degraded ecosystems.



Geographic location of Turpan in western China

| PROJECT PROFILE | | (P111163) |
|------------------------|-----------------|-------------|
| IBRD Loan Amount: | US\$100 million | |
| Implementation Period: | 2010 - 2017 | |
| World Bank Office: | Beijing, China | |



Turpan is a poor agricultural region in western China...



... in one of China's most arid zones...



... with ancient underground 'Karez' wells...



... and where lake ecosystems are drying up.

Project Area Context

Turpan Prefecture, located in Xinjiang Uygur Autonomous Region, is an ancient Silk Road outpost and one of the poorest, most remote, and most arid regions in western China. Turpan owes its existence to groundwater-fed springs and ancient water wells, called *Karez*, that for long provided water to caravans crossing the vast desert.

In modern times, rapid expansion of irrigated land has greatly increased the pressure on groundwater (GW) – threatening the viability of agriculture, which accounts for 70% of employment in the region. The Turpan government responded with investments in modern, water-saving irrigation technologies (e.g. drip-irrigation, sprinklers, canal-lining, low-pressure pipes, etc.). With optimistic estimates that they could save irrigated water through use of the new technologies, local planners reasoned they could both further expand irrigated farmland, and at the same time save water.

However, the expected water savings were not realized. Farmers expanded the total area of cultivated farmland, resulting in an increase in total water use for irrigation in the basin. Groundwater levels continued to decline by 1.5 – 2.0 meters per year, most karez systems fell into disrepair, sensitive oasis and lacustrine ecosystems were severely damaged, and little water was available for planned industry and urban development.

In 2008, the World Bank started to prepare the *Xinjiang Turpan Water Conservation Project* (loan: US\$100 million) to help investigate these issues and recommend innovative, workable solutions.

Timeline of Modern Water Stress in Turpan Prefecture

The 1980's and 1990's

China began economic reforms. In western China, agricultural production was promoted by expanding irrigated lands.

From 1992 to 1999

Turpan reclaimed desert lands by expanding basic irrigated farming from 60,000 to 80,000 hectares. However, this expansion was without significant consideration of local water carrying capacity.

From 2000 to 2008

By this time, surface and groundwater supplies were under great stress. The Turpan government invested in modern irrigation technologies to save water. But at the same time, irrigated farmland expanded from 80,000 to 107,000 hectares (+33%).

By 2008

Severe surface and groundwater problems had only worsened. GW over-exploitation exceeded 230 million m³ per year, water tables dropped 2m per year, and water management emerged as an unsustainable crisis.

China's Turpan Model: Identifying the Problem

The Xinjiang Turpan Water Conservation Project aimed to address water challenges in a comprehensive fashion from three important perspectives. These local challenges are only expected to intensify because of climate change.

Turpan Farmer's Perspective



Persistently low incomes

Small farmers in Turpan depend on groundwater for their livelihood. Access to water through shallow wells is threatened by rapidly dropping water tables and the need to install ever-larger and ever-more costly pumps.

With limited alternatives in the arid basin, small farmers never seem to have enough water when they need it. This leads to low yields and low incomes, which prevents investment in better water-saving practices. The result is a vicious cycle of persistent poverty and wasted water.



Farmers in Turpan rely on increasingly deep and costly wells.

credit: IBT, 2003

Water Managers' Perspective

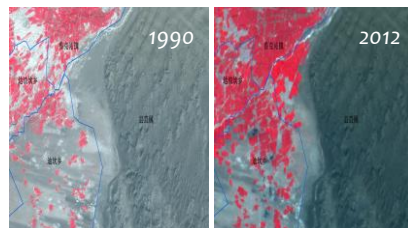


Insufficient data and management tools

Water managers in Turpan were aware of the challenges, but lacked the right data on water supplies and usage. Managers have been unable to monitor water consumption; nor could they control farmers digging new wells, expanding irrigated areas, and using more water.

Current water usage patterns leave insufficient supplies for the historic karez wells, local ecosystems, and new industry & domestic demands.

And, past efforts to save water with modern irrigation technology led to more overall water use (see below).



Irrigated farmland and total water use (red) expanded from 1990 to 2012.

Arid Ecosystems' Perspective



Chronic and worsening damage

Local ecosystems in Turpan were stuck facing severe and increasing stress. Water resources were not systematically managed to ensure sufficient environmental flows.

The result has been chronic and worsening groundwater overdraft (230 million m³/yr), dropping water tables (1-2 m/yr), and great stress on sensitive lakes and wetlands.

Turpan's Aiding Lake dried up, local trees and vegetation died, sensitive wildlife habitats shrunk, and erosive dust storms cause negative health impacts on local residents.



The surface area of Aiding Lake (blue) was completely dry by 2012.

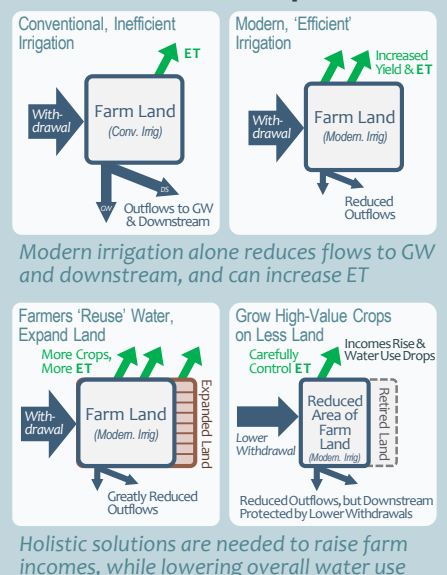
PARADOX : Modern Irrigation Efforts Do Not Always Reduce Overall Water Consumption

In Turpan, as in other arid regions around the world (North Africa, the Middle East, etc.), there is an observed paradox whereby modern, large-scale efforts to save water actually lead to an overall increase in total water consumption. The underlying problem is threefold:

- First, while modern irrigation beneficially increases crop health and yield, this can actually increase the water consumption of individual farmers (as measured by evapotranspiration, ET).
- Second, with conventional irrigation, excess water seeps into the ground or flows downstream and is relied upon by other farmers and ecosystems in the basin. Modern efficient irrigation systems reduce these flows and don't necessarily "save" water from the basin perspective.
- Third, current definitions of water rights entitle farmers to *withdraw a certain volume* of water from common conveyance channels. Any efficiency "savings" (i.e. reduced seepage) from modern irrigation technologies do not reduce farmers' withdrawal rights. Instead, it is in their economic interest to further "reuse" that water by expanding irrigated land area or increasing crop intensity.

The combined result is that more irrigated land is cultivated, more water is consumed, and less water seeps back into the ground or flows downstream (for other farmers, or ecosystems).

The solution to this paradox in highly water-scarce regions is to conduct water accounting and planning at the basin scale, define a sustainable limit on total water consumption, set targets for reduction, and then carefully monitor, control, and reduce the *actual water consumption* (ET) on each plot of land. As was found in Turpan, this may require a reduction in the overall area of cultivated land, the switch to high-value-low-water crops, and the use of water-smart agronomic practices, all in conjunction with modern irrigation technologies.



China's Turpan Model: Designing a 'Whole-System' Solution

Directly addressing the challenges in arid Turpan Prefecture required an understanding of water resources as a complex and inter-connected system. The World Bank approach combined five areas of targeted interventions and investments for a 'Whole-System' solution that benefits local farmers, water managers, and sensitive ecosystems.

Basin-wide Planning

A key element in the project was a comprehensive basin-wide plan for managing water resources as a system, based on effective mechanisms and tools for budgeting, allocating, and controlling overall water consumption (measured by evapotranspiration (ET)).

Set a Basin-Wide Sustainable Cap on Water Use
Determine and enforce a strict cap on overall water consumption (i.e. a scientifically-determined safe limit on water consumption).

Conduct Water Balance / Budget Analysis
Use multi-stakeholder decision-making to annually define a prioritized budget for water consumption in the basin. This basin-level balance accounts for all water supplies and all competing water demands (i.e. ecosystem, agricultural, industry, municipal demands, etc.).

Allocate Water-Use Targets to Farmers
Use the basin budget for agriculture to allocate "water-use permits" to each farmer (i.e. an expected farm-ET, converted to a withdrawal volume, & revised annually as irrigation efficiencies improve).

Water-Saving Agriculture & Irrigation Practices

Apply irrigation and agronomic interventions for **real** water savings that reduce actual ET, under the basin-wide water consumption cap, and which protect and improve farmer incomes.

Shift to higher-value, water-saving crops
Raise farmer incomes while consuming less water by growing grapes, melons, etc., instead of high-water-low-value crops like maize, cotton, etc.

Install water-saving irrigation technologies
Raise water-use productivity ($\$/m^3$) through modern drip irrigation, canal lining, low-pressure systems, etc.

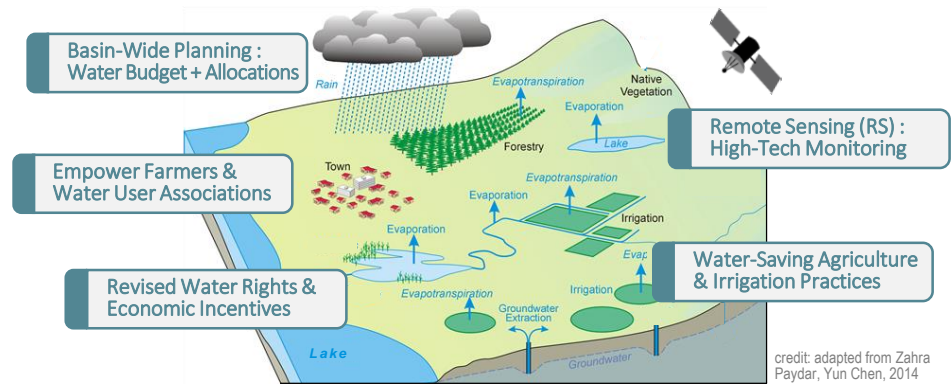
Optimize irrigation and agronomic practices
Raise water-use productivity ($\$/m^3$) with improved crop & irrigation practices (i.e. planting + irrigation schedules, greenhouses, etc.)

Reduce less-productive irrigated land
There was simply too much irrigated land under cultivation for the arid climate. With higher value crops and efficient irrigation, less productive lands could be retired; thereby protecting farmer livelihoods and saving water.

Revised Water Rights & Economic Incentives

Water rights and price reforms can be effective to reduce water consumption, especially when combined with other strong policies and enforcement.

Five Interlinking Elements of the 'Whole-System' Solution Adopted in Turpan



credit: adapted from Zahra Paydar, Yun Chen, 2014

ET-Consumption-Based Accounting and Management of Water

Evapotranspiration (ET) is the process by which water is transferred from the land to the atmosphere by evaporation from the soil and transpiration from plants. ET is in the water balance equation:

$$\Delta \text{Storage} = \text{Precipitation} + \text{Inflows} - \text{Outflows} - \text{ET}$$

The most important aspect of **real water savings** in agriculture is to control the total amount of consumption, or ET, to a sustainable level; and then maximize the productivity of "every drop" consumed by crops.

(..revised water rights, continued)

In Turpan, farmers' **water withdrawal permits were revised** to be based on the target water-consumption allocations under the basin-wide sustainable water cap.

To enforce the permits and discourage overuse, **water prices were revised** to a two-tier block tariff system. Actual water withdrawals are compared to the target/permit:

- If actual withdrawal is below the target, farmers pay low "water charges" only.
- If actual withdrawal exceeds the target, farmers pay a higher "water resources fee", plus the normal water charges.

Remote Sensing Monitoring: Cost Effective and High-Tech

In Turpan, the latest remote-sensing (RS) technologies were applied, along with land-use and weather data, to easily and accurately monitor water consumption – from the basin-scale to the farm level.

RS provides **high-resolution, basin-wide information at lower cost** than expensive metering and inspection systems – making RS well-suited to less wealthy dry regions like Turpan.

Advanced RS systems **continuously observe land-use & crop growth to measure actual farmer water consumption** against their allocated withdrawal permits.

An ET Management Center with expert trained staff and a user-friendly water monitoring platform was established to support basin-level decision-making.

RS accuracy is already on par with hydrology data, and the technology improves yearly.

Empower Farmers & WUA's

In Turpan, 43 Water User Associations (WUAs) were established and empowered to engage in on-the-ground water management, and to be responsible for ongoing operation and maintenance of the water systems.

Functioning WUAs not only have clear responsibilities for monitoring and enforcing water withdrawals, but are also given the technical and financial capacities needed to successfully implement their responsibilities.

Key Steps for Comprehensive Water Management

Setup of Institutions and Systems

- Revise and reform local Water Rights and Water Tariffs to be based on ET
- Invest in and setup RS Monitoring systems and an ET Monitoring Center
- Digitize land-use & water system maps

Regular Water Management Tasks

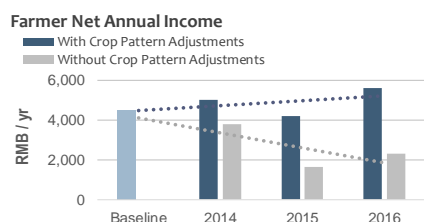
1. Define Basin-Level Consumption Cap
2. Specify Water-Use Budget and Allocate Withdrawal Targets to Water Users
3. Plan & Design Water-Saving Agriculture Practices for Farmers to Meet ET Target (crop selection, modern irrigation, retire lands, etc.)
4. Monitor the Actual ET vs. Target ET of Farmers/WUAs with Remote-Sensing
5. Continuous Improvement - (technical, legal, & economic incentives to raise water productivity)

China's Turpan Model: Achieving Results and Outcomes

The Xinjiang Turpan Water Conservation Project was rated 'Highly Satisfactory' by the World Bank Independent Evaluation Group (IEG) for its successful application of state-of-the-art technologies alongside farm-level agriculture and institutional reforms to create a 'whole-system' solution with multi-benefit outcomes that save water and improve farmer livelihoods.

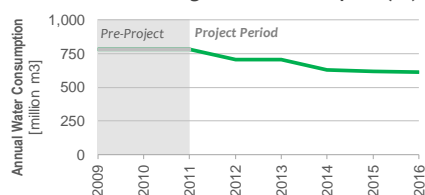
Farmer incomes increased and total agriculture water consumption declined, while inefficient irrigated lands were retired.

The project's training of farmers and careful application of modern technologies under strict water-use targets encouraged farmers to grow more valuable crops for higher incomes, while decreasing irrigated land area and water consumption.



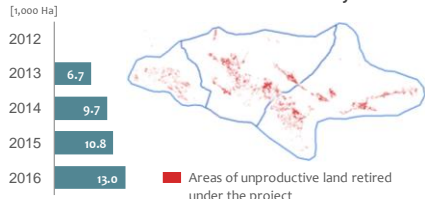
Farmer incomes rose by 24%, and water productivity rose from 1.8 to 11.58 RMB/m³

Basin Water Balance: Agricultural Consumption (ET)



Through efficiency and savings, total agricultural water consumption reduced by 22%

Land Retirement: Thousands of Hectares by Year



13,000 hectares of low-productivity irrigated land was retired from 2012-2016

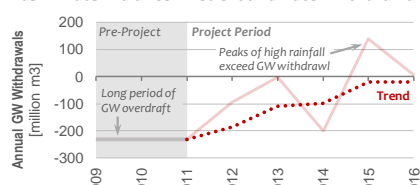


Farmers switched to growing melons (greenhouse), grapes, and other high-value crops

With total agricultural water consumption reduced, more water is available for GW and other ecological & human uses.

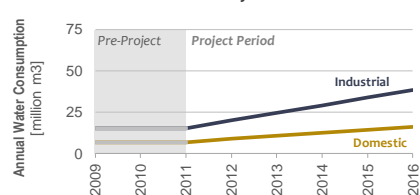
Turpan reallocated low-productivity water-use to better balance supplies for ecological protection and economic development – all while reducing the dependence on GW. Given its acute water scarcity, this is a key achievement for the arid region.

Basin Water Balance: Net Groundwater Withdrawals



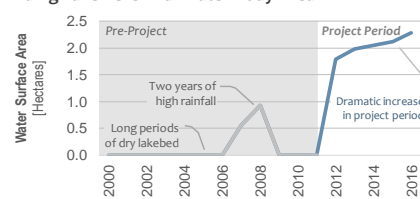
The project area reduced GW overdraft by 17 million cubic meters

Basin Water Balance: Industry & Domestic Water Use



Water savings reduce aquifer stress; and provide 5 million m³ for city & economic growth

Aiding Lake Perennial Water Body Area



Aiding Lake area steadily increased during the project, along with vegetation cover



Once nearly dry, the health of local habitats and ecosystem improved significantly

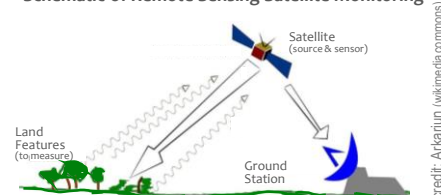
Institutional reforms and state-of-the-art tools have greatly strengthened local water management capacity.

Water User Associations (WUAs) were key to implementing and maintaining project investments and achieving outcomes from the ground-up; while the new ET Management Center provided top-to-bottom monitoring and control of basin water-use.



The project established 43 new water user associations (WUAs)

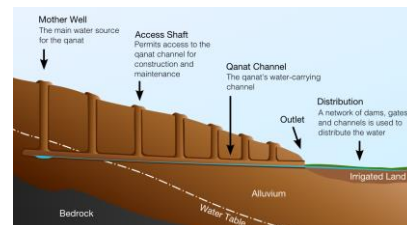
Schematic of Remote Sensing Satellite Monitoring



Remote-sensing satellites measure real water consumption for low-cost management



The ET Management Center allows high-resolution analysis for water planning



Groundwater recovery restored the functioning of ancient Karez well systems

For more information on this project and the innovative solutions, contact :

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