Groundwater Management in China: Current Situation and Challenge

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2017.09.22
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① Groundwater Management

② Experience in China

③ Challenges
Groundwater Management
Groundwater system

- Discharge to surface water, subsurface outflow, and groundwater evapotranspiration
- Discharge from groundwater abstraction
- Recharge from precipitation, surface water, and subsurface inflow
- Recharge due to water use
- Managed aquifer recharge

Predevelopment  Moderate Development  Overdevelopment  Back to Equilibrium

(Dillon et al., 2012)
Over-exploited aquifers

(Gleeson et al., 2012)
Tragedy of commons

Common-pool resource

- Rival, non-excludable
- Negative externality → overuse of resource
- Positive externality → a lack of maintaining resource
- E.g., pasture, groundwater

Carrying capacity: 6 sheep

Add one sheep: private benefit, shared cost

Reduce one sheep: private cost, shared benefit

Pasture degradation is a tragedy of commons.

(Hardin, 1968; Ostrom et al., 1999)
Negative externality

Price

Increase private cost by tax/charges

Marginal benefit

Marginal social cost

Marginal private cost

Social optimum

Limit quantity by quotas/water (use) rights

Market optimum

Quantity
Positive externality

Marginal social benefit

Increase private benefit (e.g., subsidize water-saving behaviours, groundwater bank)

Marginal private benefit

Marginal cost

Market optimum

Social optimum

Quantity

Price
Make water rights tradable

Water right trade can reallocate water rights to a more efficient use.

Total net benefit: 46

Total net benefit: 47

Price: 10
Beyond costs and benefits

Classical economics
- People are always rational.
- Focus on costs and benefits (monetary factors)

Behavioural economics
- People are not always rational.
- Non-monetary factors, such as information, can affect behaviours.

Case study: a randomized experiment on household water use in USA (Farraro and Price, 2013)
Toolkit of policy instruments

**Sticks - regulatory instruments**
- Regulations on drilling wells
- Water rights allocation

**Carrots - economic instruments**
- Trade of water rights
- Tax/charges
- Subsidy
- Groundwater bank

**Sermons - informational instruments**
- Campaign
- Education
- Demonstration project
- Billboard

(Vedung, 1998)
Regulations on drilling wells

• Register existing wells
• Drilling a new well needs an approval: the location, the depth, and the use of new well
• Drilling new wells is not allowed when groundwater is over-pumped.
Water rights

• Water rights define the right of water users to take and use a quantity of water.

• Water rights are usually allocated uniformly by water authority.

• Compared to fixed-amount water rights, fixed-share water rights are more flexible.
Uniform water rights

Uniform per well
Case: Jordan highlands
150,000 m³/well/year

Uniform per unit of land
Case: Guantao county, China
220 m³/mu/year

Uniform per unit of land (based on crop)
Case: Jordan valley
Vegetable: 2 mm/plot/day
Citrus: 4 mm/plot/day
Bananas: 8 mm/plot/day

Uniform per unit of land (based on farm size)
Case: La Mancha aquifer
0-30 ha: 2640 m³/ha/year
30-80 ha: 2000 m³/ha/year
>80 ha: 1200 m³/ha/year
Vineyard: 1000 m³/ha/year
Flexibility of water rights

Case: New south wales, Australia

- **Fixed-amount**
  - 4 ML
  - Climate change
  - Over-allocated 2 ML

- **Fixed-share**
  - 4 Units
  - Climate change
  - Flexible adjustment
  - 1 unit = 1 ML
  - 1 unit < 1 ML

Adjust over-allocated water rights

- **Groundwater access licence**
  - 2 ML
  - Supplementary licence

- **10-year adjustment**
  - 2 ML
  - 1.8 ML
  - 1.6 ML
  - 1.4 ML
  - 1.2 ML
  - 1.0 ML
  - 0.8 ML
  - 0.6 ML
  - 0.4 ML
  - 0.2 ML
Water right transfer

Temporary transfer
- Cases: China, Australia

Permanent transfer
- Cases: the UK, Australia, Mexico

Transfer mechanisms

Sellers and buyers negotiate
- Cases: Australia, the UK, Mexico

Brokers match sellers and buyers
- Cases: Australia, Mexico

Water authority matches sellers and buyers
- Case: Shiyang River Basin, China

Water authority buys water rights from sellers, and sells water rights to buyers
- Case: Manasi County, China
Charges on obtaining water rights

- Land area-based
  - Case: Gansu, China
  - Basic water fee
    - 4 CNY/mu

- Quantity-based
  - Case: Australia
  - Access charge
    - $ 6.95/unit of entitlement

Charges on using water

- Uniform volumetric fee
  - Case 1: Australia
  - Case 2: Algeria
  - Case 3: Thailand

- Block volumetric fee
  - Case 1: Jordan
  - Case 2: Israel
  - Case 3: China
### Uniform volumetric charges

<table>
<thead>
<tr>
<th>Country</th>
<th>Charges ($/m$^3$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Australia</td>
<td>$2.09/Unit</td>
</tr>
<tr>
<td>Algeria</td>
<td>$0.027/m$^3</td>
</tr>
<tr>
<td>Thailand</td>
<td>$0.42/m$^3</td>
</tr>
</tbody>
</table>

### Block volumetric charges

<table>
<thead>
<tr>
<th>Country</th>
<th>Quantity (% of quota)</th>
<th>Charges ($/m$^3$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Jordan</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>0-100%</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>100-133%</td>
<td>0.007</td>
</tr>
<tr>
<td></td>
<td>&gt; 133%</td>
<td>0.085</td>
</tr>
<tr>
<td>Israel</td>
<td>0-50%</td>
<td>0.36</td>
</tr>
<tr>
<td></td>
<td>50-80%</td>
<td>0.43</td>
</tr>
<tr>
<td></td>
<td>&gt; 80%</td>
<td>0.55</td>
</tr>
<tr>
<td>Gansu, China</td>
<td>0-100%</td>
<td>0.01</td>
</tr>
<tr>
<td></td>
<td>100-130%</td>
<td>0.02</td>
</tr>
<tr>
<td></td>
<td>130-150%</td>
<td>0.03</td>
</tr>
<tr>
<td></td>
<td>&gt; 150%</td>
<td>0.04</td>
</tr>
</tbody>
</table>
Water use reduction

Adopt water-saving irrigation
Cases: USA, Spain, China

Change planting structure
Case: Hebei, China

Close wells
Case: Gansu, China

Recharge enhancement

Flood free rice fields with river water
Cases: Janpa

Build sand dam
Case: Kenya
Groundwater bank

Case: California, USA

Save in wet years
- Replace groundwater with surface water
- Artificial recharge

Use in dry years

History of Water Banking Activity

- State of California
- Metropolitan Water District of So. Cal.
- Santa Clara Valley Water District
- Alameda County Water District
- Zone 7
- Vidler Water Company
- Newhall Land & Farming Co.
- San Diego Water Authority
- Irvine Ranch Water District
- Gastaic Lake Water Agency
- City of Tracy
- Post Creek Water Company LLC

Stored

Recovered
Informational instruments

Campaign

Billboard

Demonstration

Education
Experience in China
National policy

• Water Law of the People’s Republic of China (1988)
  • Water resources are owned by the state.
  • Water use plan is allocated top-down.
  • In over-exploitation areas, groundwater use is restricted.

• Regulations on Administration of Water Abstraction Licensing and Collection of Water Resource Fees (2006)
  • A water abstraction license is required to use water.
  • Water users need to pay water resource fees.
  • The water resource fee of agricultural water should be less than that for other sectors.
National policy

• Guidelines on Applying the Strictest Water Resources Control System (2012)
  • Three red lines for total consumption, use efficiency, and water pollution. Total water consumption should be less than 700 billion m$^3$ per year.

• Guidelines on Deepening the Water Reform (2014)
  • Establish a water right system and a water price mechanism so that markets can play a role in allocating water resources in a more efficient way.

• Guidelines on Agricultural Water Pricing Reform (2016)
  • Water price should reflect the full cost of water supply and reduce water use.
Project areas
<table>
<thead>
<tr>
<th></th>
<th>Guantao</th>
<th>Gaotai</th>
</tr>
</thead>
<tbody>
<tr>
<td>Annual precipitation</td>
<td>530 mm</td>
<td>130 mm</td>
</tr>
<tr>
<td>Decrease of groundwater level</td>
<td>5 m to 25 m</td>
<td>5 m to 30 m</td>
</tr>
<tr>
<td>(from 1980 to 2016)</td>
<td>(from 1986 to 2016)</td>
<td></td>
</tr>
<tr>
<td>Crop land area</td>
<td>30,000 ha</td>
<td>21,000 ha</td>
</tr>
<tr>
<td>Main crop</td>
<td>(winter) wheat and (summer) maize rotation</td>
<td>seed maize</td>
</tr>
<tr>
<td>Land area per household</td>
<td>4 mu</td>
<td>20 mu</td>
</tr>
<tr>
<td>Land area irrigated by single well</td>
<td>60 mu</td>
<td>200 mu</td>
</tr>
<tr>
<td>Main type of well</td>
<td>shallow well</td>
<td>deep well</td>
</tr>
</tbody>
</table>
Regulations on drilling wells

• Guantao
  • Forbid drilling new wells
  • Seal all deep wells by 2017 - provide surface water to replace groundwater

• Gaotai
  • Forbid drilling new wells
  • Sealing one or two old wells is required to drill a new well.
Agricultural water pricing reform

- Water right + water pricing system
- Reflect full cost of water supply
- 80 pilot counties – include Guantao and Gaotai

Billboard of water pricing reform in Luotuocheng
### Water rights and water pricing

<table>
<thead>
<tr>
<th></th>
<th>Guantao</th>
<th>Gaotai</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Water rights (m³/mu/year)</strong></td>
<td>220</td>
<td>814</td>
</tr>
<tr>
<td><strong>Water price (CNY/m³)</strong></td>
<td>Volumetric fee</td>
<td>Volumetric fee</td>
</tr>
<tr>
<td></td>
<td>&lt;water rights: free</td>
<td>0.1</td>
</tr>
<tr>
<td></td>
<td>&gt;water rights: 0.1</td>
<td></td>
</tr>
<tr>
<td><strong>Basic fee</strong></td>
<td></td>
<td>Basic fee</td>
</tr>
<tr>
<td></td>
<td></td>
<td>4 CNY/mu</td>
</tr>
<tr>
<td><strong>Water resource fee</strong></td>
<td></td>
<td>Water resource fee</td>
</tr>
<tr>
<td></td>
<td></td>
<td>&lt;110% of water rights : 0.01</td>
</tr>
<tr>
<td></td>
<td></td>
<td>110%-130% of water rights: 0.02</td>
</tr>
<tr>
<td></td>
<td></td>
<td>130%-150% of water rights: 0.03</td>
</tr>
<tr>
<td></td>
<td></td>
<td>&gt;150% of water rights: 0.04</td>
</tr>
</tbody>
</table>
Enforcement

- **Luotuocheng**: The new water pricing regulation worked from June 2015 when IC card meters were installed on all wells.

- **Guantao**: Not enforced due to a lack of monitoring system.
## Surface water vs. groundwater

<table>
<thead>
<tr>
<th>Item</th>
<th>Charges (CNY/m³)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Volumetric fee</td>
<td>0.152</td>
</tr>
<tr>
<td>2 Basic water fee</td>
<td>0.0025</td>
</tr>
<tr>
<td>3 Water resource fee</td>
<td>0.005</td>
</tr>
<tr>
<td>4 Canal maintenance fee</td>
<td>0.02</td>
</tr>
<tr>
<td>Total</td>
<td>0.1795</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Item</th>
<th>Charges (CNY/m³)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Volumetric fee</td>
<td>0.1</td>
</tr>
<tr>
<td>2 Basic water fee</td>
<td>0.0049</td>
</tr>
<tr>
<td>3 Water resource fee</td>
<td>0.01</td>
</tr>
<tr>
<td>Total ( + electricity fee)</td>
<td>0.2149</td>
</tr>
</tbody>
</table>

**Total**

**Surface water** 0.1795 < 0.2149 (Groundwater)
• Saved water rights can be traded.
• Farmer → farmer
• WUA → WUA
• No trade is reported yet.
• No cap is really set.
Subsidize water saving

• Guantao
  • Water-saving irrigation technology (sprinkler irrigation, underground pipe irrigation, drip irrigation): free irrigation devices
  • Double cropping (winter wheat/summer maize) → single crop: 500 CNY/mu

• Gaotai
  • Water-saving irrigation technology (drip irrigation): free irrigation devices
- Billboards, demonstration programs, flyers, television commercials...
Challenges
Monitoring pumping

- Monitoring is a key issue for enforcing water right and water pricing system.
- Installing water meters is costly or infeasible when the number of wells is large.
- Controlling pumping via monitoring electricity.

Water-energy nexus

- Water rights → Electricity rights
- Water charges → Electricity charges
Mexico

- 2002: Untitled wells pay regular electricity tariffs, titled wells pay subsidized tariffs → The number of illegal wells declined.
- 2004: Night-time subsidy for agricultural electricity

Electricity to pump agricultural groundwater (Scott, 2013)
Qingxu County, Shanxi Province

Quota and volumetric charges

- Each well is equipped with a smart water meter.
- Water fee is transferred to electricity fee and collected together with electricity fee.
- Pre-pay card is used to control water use.

Remarkable results

- Groundwater levels have been increasing with 1.6 to 4.8 meters a year.
- Decrease in consumed groundwater: 59 million m³ in 2004 → 35 million m³ in 2009.

(Fan et al., 2013)
Water-electricity system

[Diagram showing the structure of electricity supply and responsible bodies for fee collection.]

- Electricity grid
- Electricity transformers
  - Well No. 1
  - Well No. 2
  - Well No. 3
  - Well No. N
- Village electrician
- Electricity supplier
- Local Water Authority
- Well managers
- Farmers
Set water rights

**Gaotai**

- Water rights (Historical use): 814 m³/mu
- Actual use: 560 m³/mu
- Sustainable level: 150.5 m³/mu

**Guantao**

- Water rights (sustainable level): 220 m³/mu
- Revised water rights: 150.5 m³/mu
Water right trading

- There is no water right trading reported in Guantao and Gaotai.
- The cap is not set.
- Trading mechanism can be used: Shiyang river basin mode, Manasi mode.
Shiyang River Basin

- Water right trading platform in Shiyang river basin: www.syh-watertrading.com
- Trading platform started in 2013
- Match buyers and sellers
Manasi, Xinjiang

**Used volume**

Farmers’ quota allocated by water administrative department

**Saved volume**

Farmers’ quota

**Farmer**

WAD: water administrative department

Pay: 0.077 CNY/m³

**Sell**

Farmer → WAD

CNY 0.385/m³

Industry

Buy

CNY 1.5/m³

2%: WAD

20%: Water user association

78%: farmer
Thank You