Metering groundwater wells

Some experience from China and transferability to solar wells

W. Kinzelbach and Team
IfU, ETH Zurich

Overpumping necessitates management

- Overpumping is a world-wide phenomenon: of about 1000 km^3/a pumped globally, about ¼ is not sustainable
- **Quota and water price** are instruments to limit groundwater use in water scarce areas
- Both quota and price require **metering** as a basis
- **Assessment** of resources for water balances also needs metering
- In principle, metering and fees are not necessary if **landuse management** guarantees an equlibrium between available water resources and irrigation requirements

Direct abstraction metering

Traditional water meter

Problems: Tampering, vandalism

Smart water meter

Operation via swipe card

Real-time data transmission in regular intervals to guarantee functioning

Problems: investment cost, operating and maintenance cost, opposition by farmers, vandalism

Antenna

Transmission unit

Power supply

Many brands available with different principles of measurement

Indirect abstraction metering using proxies

Monitoring via electricity consumption

Problem: Conversion factor required
Advantage: New smart electricity meters in China allow real-time reading from utility offices
Only feasible if wells are powered by electricity

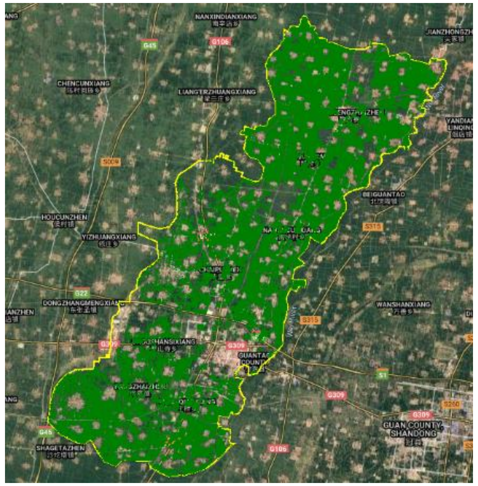
Monitoring via use-time

Oldest method, especially in surface water allocation

Monitoring via land use and irrigation norms

Facilitated through advances in remote sensing

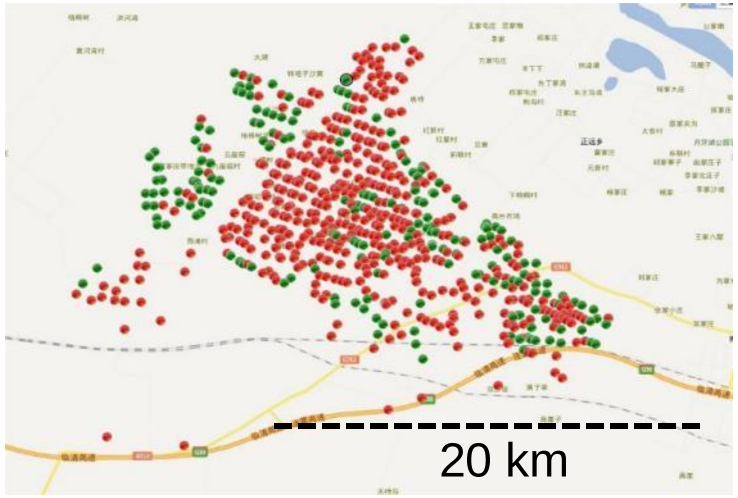
Only feasible in arid to semi-arid regions with little cloud cover in irrigation season. Radar RS for penetration of cloud cover. Surface water has to be abstracted

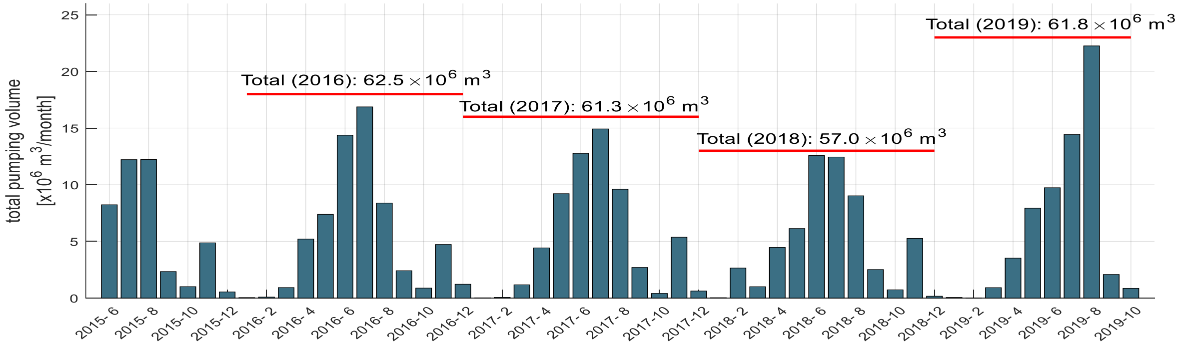


Winter wheat Guantao 2019
20 m resolution, combining optical and radar RS
(Ragettli, et al, 2019)

Application of smart metering in Luotuocheng irrigation district, Gansu, China

Luotuocheng irrigation district





Withdrawals of 667 monitored wells since June 2015

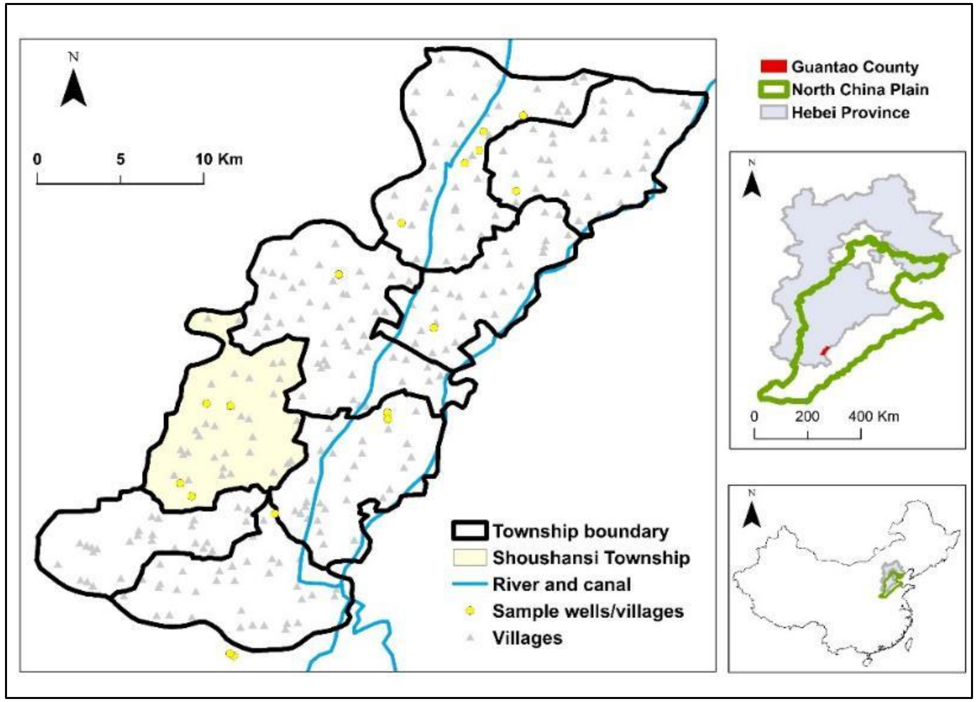
Huafeng meter

Smart meter and IC card for control of each single well

Successful application of smart metering with subsequent reduction in pumping: Doubling of price led to reduction by 30%

Transfer to Guantao County in North China Plain?

About 8000 wells, majority of which are small and primitive. Installation and maintenance of a smart water meter is often technically and economically infeasible.



Total area 456 km^2, arable land 300 km^2, 300 km south of Beijing

No matter how primitive a well, its electricity consumption is metered:
Clue to monitoring in NCP: Electricity consumption by pumps as proxy

Sources of irrigation water – different lift

- **Shallow unconfined aquifer**
  - Depth to groundwater table: 20m
  - > 7000 wells
  - Rated power of pumps: 7.5 kW
  - Irrigation area per well: 1- 6 ha
- **Deep confined aquifer**
  - Depth to groundwater table: 70m
  - ~ 200 wells
  - Rated power of pumps: 30 kW
  - Irrigation area per well: 15 ha
- **Surface water**
  - Imported through canals
  - Irrigation area：within 1 km along the canal
  - Increased availability since 2014

Conversion from electricity to groundwater pumping – Pumping tests

Pumping tests determine conversion factor c_f

$$V = c_f E \quad \Rightarrow \quad Q = c_f N$$

Flow rate Q： Ultrasonic flow meter or volumetric method

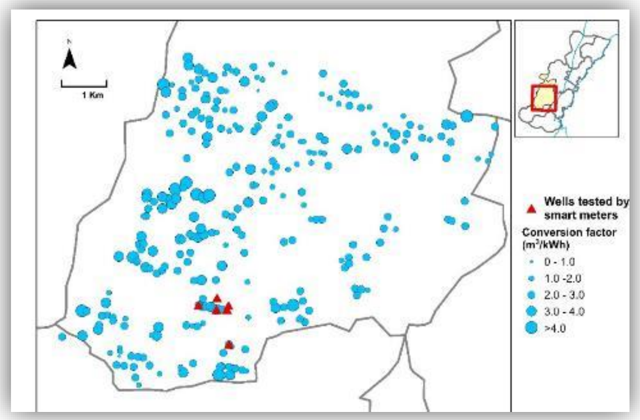
Power N： Reading electricity meter + Stop watch

Depth to GW table: Dipper (for deriving pump efficiency)

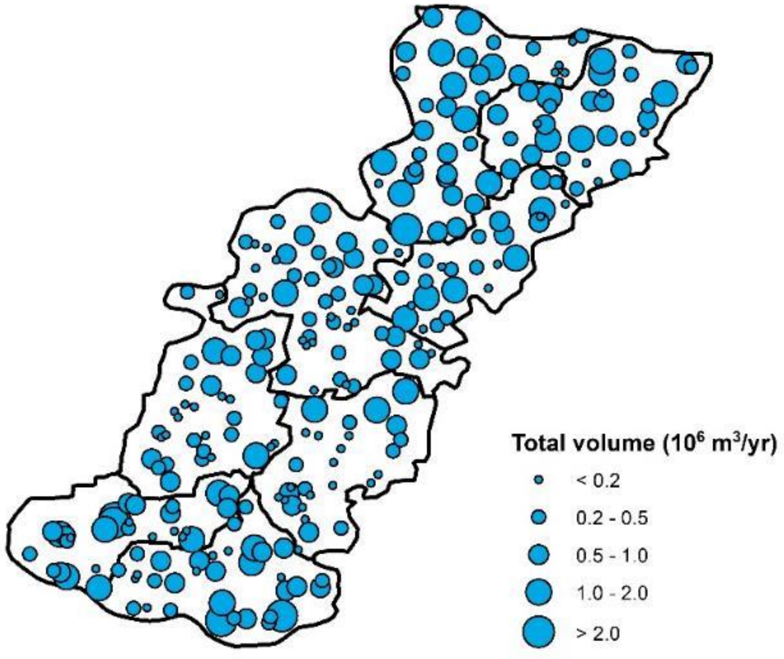
On average 2.62 m^3/kWh in shallow aquifer and 1.32 m^3/kWh in deep aquifer

Conversion from electricity to groundwater pumping – Accuracy

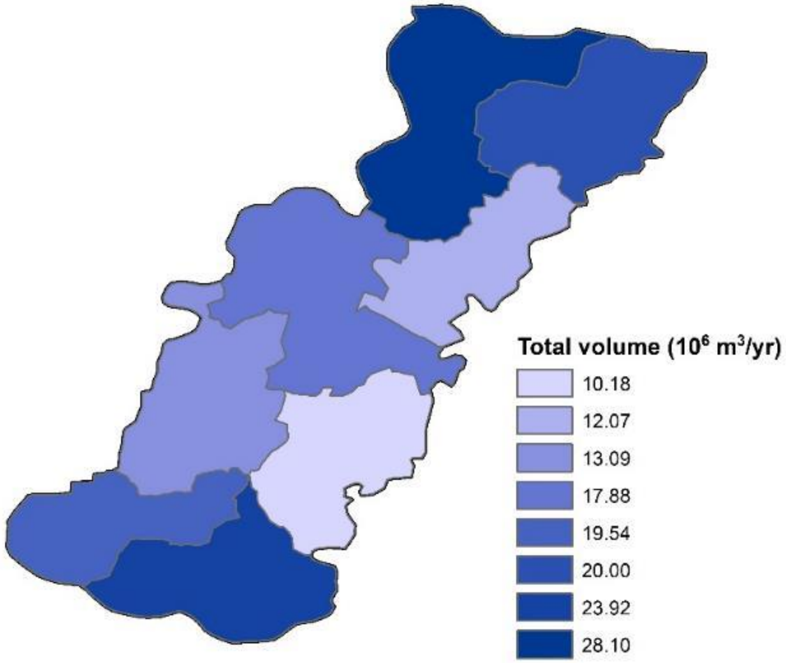
- Pumping tests are done for each type of water source, respectively
  - ➢ To account for difference in pump lift
- Seasonal change of conversion factor: ± 20%
- Additional tests are only necessary in extremely dry years
  - ➢ To cover long term decline: Repetition of tests once every 4-5 years
- Accuracy required for **fee collection**
  - ➢ Accuracy of 20% acceptable
  - ➢ Requires pumping at each well
  - ➢ If average c_f is used, error may be by ± 60%
- Accuracy required for **planning and water balances**
  - ➢ Average conversion factor from a few tests can be used
  - ➢ Error smaller than 20% if on the order of 20 wells are tested and averaged



Irrigation water use in Guantao obtained from electricity consumption – basis for taxing



Water use of villages



Water use of townships

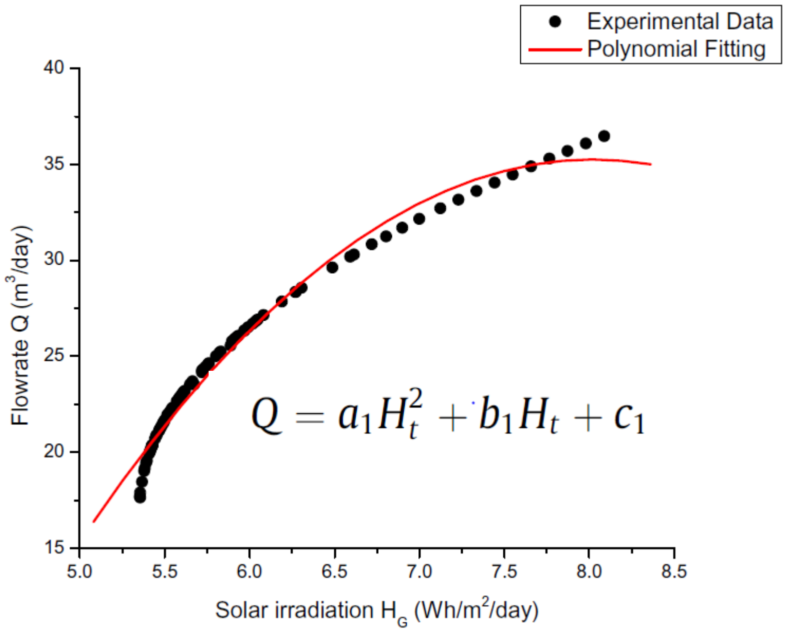
Results 2019

Total electricity consumption for pumping:	**38.2 $*10^6$ kWh/yr**
Groundwater abstraction:	**80.3 $*10^6$ m^3/yr**
Surface water lifting :	**29.6 $*10^6$ m^3/yr**

A typical village of solar farmers

How to monitor a solar powered well?

- Irrespective of electricity source: Volume is proportional to energy $V = c_f \cdot E$ or $Q = c_f \cdot N$
- In conventional case, power can be assumed constant (unless water level change is large compared to depth to water level)
- In solar case, power varies with solar radiation, but varying power can be recorded
- Empirical equation for conversion required, coefficients can be determined by pumping tests



M. Benghanem, K.O. Daffallah, A. Almohammedi, (2018)

Based on solar radiation measurement an empirical equation can be obtained

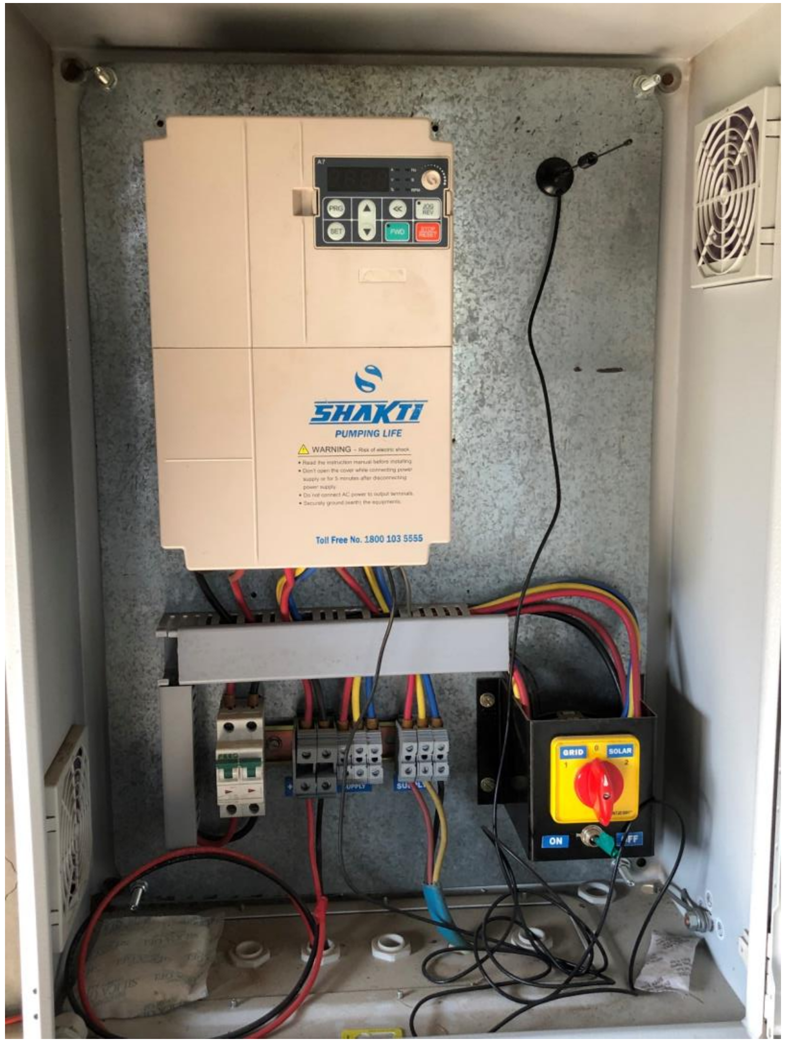
Simpler approach: Record power output and get average conversion factor $c_f(H)$ between power output and pumping rate for different lift classes H

$$V(T) = \int_0^T Q dt = \int_0^T c_f(H) N(t) dt$$

From pumping tests

From power record

The power switch and metering



Control Problem for Solar Pumps

- Metering is done automatically if solar system is connected to the grid
  - Subsidize connection to the grid to guarantee metering
- Subsidize kWh used by pump to guarantee metering
  - You subsidize every kWh from utility anyway
- Portable solar panels' owners could record kWh delivered for collection of their fees
  - Incentivize them by paying for data
- Maximum size limits pump size whith in turn limits the abstraction rate and the lift
  - Control maximum amount of pumping by regulating maximum size and number of panels

Conclusions

- Groundwater pumping monitoring using electricity as proxy
  - Objective data records
  - Simple electricity-to-water conversion with acceptable accuracy
  - Sustainable monitoring method
  - Reconstruction of pumping in history feasible
  - Real-time pumping monitoring feasible
- Challenges in China
  - Data and information sharing between electric utility and water authority
  - Fee collection
- Challenges in the case of solar power
  - Monitoring and control only possible if power output is recorded
  - Pumping tests are necessary

Thank you！

Reference: Wang, L.; Kinzelbach, W.; Yao, H.; Steiner, J.; Wang, H. How to Meter Agricultural Pumping at Numerous Small-Scale Wells?—An Indirect Monitoring Method Using Electric Energy as Proxy. Water 2020, 12, 2477. https://doi.org/10.3390/w12092477