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Analysis of energy requirement in the irrigation sector and its application in groundwater over-pumping control at a local scale – A case study in the North China Plain

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1 Introduction

The North China Plain is one of China's most important **agricultural regions**. It relies heavily on **groundwater pumping** for irrigation powered by **electric energy**. This region is also facing a severe problem of groundwater over-pumping. The interaction of agricultural production, groundwater resources and energy requirement was analyzed in the case study of **Guantao County** (456 km^2). The results allow to provide recommendations for developing **practical strategies for groundwater over-pumping control**.

2 Guantao in North China Plain

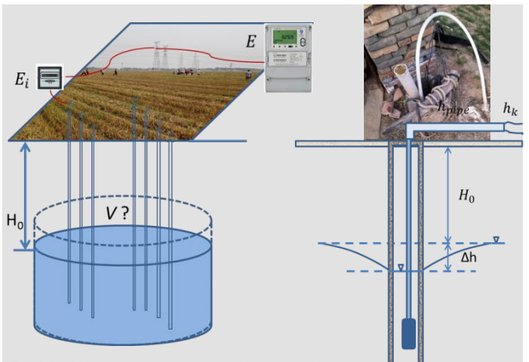


Fig. 1 Sketch of groundwater abstraction motored by electric energy in the irrigation sector

Fig. 2 A well in Guantao

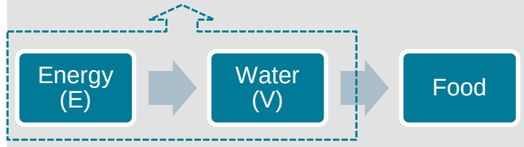


Fig. 3 Food-Energy-Water nexus in the irrigation sector

3 Method and results

1) **Reconstruct energy consumption for irrigation**

$$E_{irri} = E_{rural} - e \cdot GDP$$

   – e=0.037 kWh/RMB (from the records in 2007 [1])
   – Hypothesis: the inter-annual variability of E_{rural} [1,2] is caused by the randomness in annual precipitation.

2) **Test energy-water conversion factor α (kWh/m^3) at selected wells** (Fig. 4)

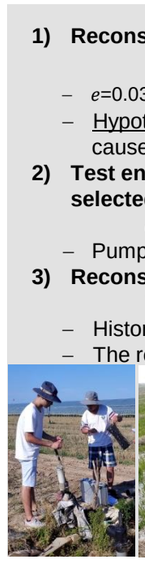
$$\alpha = E/V$$

   – Pump efficiency η can be then calculated (30%).

3) **Reconstruct historical groundwater abstraction**

$V = E/\alpha$; where $\alpha = H\rho g/(367\eta)$

   – Historical α was calculated using the historical lift H.
   – The result was verified by a water balance model(Fig.5).



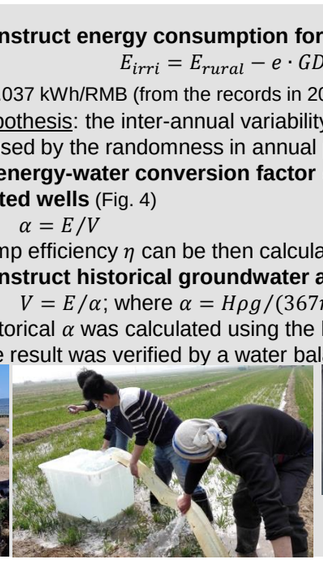


Fig. 4. Pumping test in Guantao

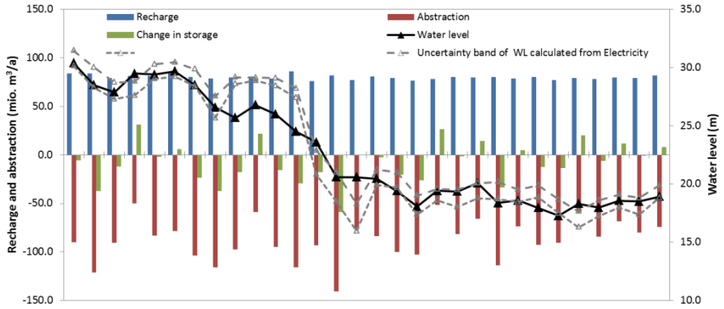


Fig. 5 Reconstructed groundwater abstraction verified in a water balance model

Table. 1 Comparison of water, energy and crop production in the past

Time	α (kWh/m^3)	V (10^6 m^3/a)	E (10^6 kWh/a)	Crop prod. (10^6 kg/a)	Water demand (m^3/kg)	Energy demand (kWh/kg)
1985-1999	**0.26**	86	23	144	**0.60**	**0.16**
2000-2016	**0.34** ↑	81	27	198	**0.41** ↓	**0.14** ↓

4 Application: Assessing strategies of groundwater pumping control

S0: Present situation. No water saving equipment, energy-water conversion factor α_0, groundwater consumption V_0, over-pumping rate k (10%). Energy consumption for pumping $E_0 = V_0 \cdot \alpha_0$, electricity price R_E (0.5 RMB/kWh).

To close the gap of over pumping, two strategies are compared:
S1: Subsidize water saving equipment. Sprinkler is installed; water consumption can be reduced by s (26%)[3]; more energy is consumed in water saving irrigation, α_1 (0.8 kWh/m^3).
S2: Reduce planting area. No water saving equipment; planting area is reduced by k (10%); crop production is also reduced by k due to the reduction of planting area. *(Table 2)*

S3: Increase water price to incentivize farmers to save water
Water price, R_W, should be high enough to make using water-saving equipment profitable.
=>$R_W > R_E \cdot [\alpha_1 \cdot (1-s) - \alpha_0]/s$
Water price should be at least 0.48 RMB/m^3, which is higher than the present water price of 0.1 RMB/m^3.

Table. 2. Description of water, energy and crop production for the strategies S1 and S2 (Data from 2013)

Strategy	α (kWh/m^3)	V (10^6 m^3/a)	E (10^6 kWh/a)	Crop Prod. (10^6 kg/a)	Water demand (m^3/kg)	Energy demand (kWh/kg)
S0: Present	0.34	89	30	233	0.38	0.13
S1: Subsidize water-saving	0.8	66	53	233	**0.28 (↓26%)**	**0.23 (↑77%)**
S2: Reduce planting area	0.34	80	27	**210 (↓10%)**	0.38	0.13

5 Conclusion

– The past groundwater abstraction was reconstructed by converting electric energy consumption using the E-W conversion factor. This method can be applied to regions where groundwater pumping is not monitored but is motored by metered electric energy.
– Water demand per crop yield decreased by 32% due to improvement of agricultural techniques and increase in rainfall after 2000. But energy demand for irrigation did not decrease as much as the water demand, which is mainly due to the decline of groundwater levels.
– The present water fee in Guantao is insufficient to incentivize farmers to use water saving equipment. The water fee should be at least 0.48 RMB/m^3 to make the use of sprinklers profitable.
– To close the gap of groundwater overdraft, using water saving equipment dramatically increases the energy consumption, while reducing planting area will cause decrease in crop production. Trade-offs have to be made among crop production, groundwater pumping and energy consumption.

6 References & Acknowledgement

1. **Guantao Statistical Bureau. Statistical Year Books Guantao. Guantao[M]. 1985-2016**
2. **Handan Statistical Bureau. New Handan 60 Years,1949-2009[M], Beijing: China Statistics Press, 2009**
3. **Assessment report on the effectiveness of Hebei groundwater overdraft control project in 2014, IWHR. 2016.**

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