The shadow price of non-renewable groundwater Marc F.P. Bierkens, Stijn Reinhard, Jens de Bruijn, Yoshihide Wada

Background



Many of the major aquifers in the world experience groundwater overexploitation leading to the depletion of groundwater resources. The Figure shows the groundwater footprint: how much area is needed to sustain current groundwater withdrawal compared to the aquifer area (Wada et al., 2010; Gleeson et al., 2012).

Results: yields and shadow prices



Predicted yield (Eq. 1) versus reported yield (FAO) of wheat (left) and rice (right) for five countries





Introduction

Knowledge about the actual value of water as a resource is limited (Ziolkowska, 2015). The value of (ground)water for irrigation is represented as the costs of extracting water from aquifers and delivering it to the final consumer. This value does not reflect the value of water as a depletable (non-renewable) resource. Water for irrigating crops may be under-priced, which can lead to irreversible depletion. The actual value of water for irrigation can be represented by the shadow price of water. The higher the shadow price the smaller will be the gap with the unknown value of water as a non-renewable resource.

Methods

- Shadow price: defined as being equal to the benefits produced by the last m³ of non-renewable groundwater
- 12 countries with largest groundwater depletion; 5 crops
- For each crop, each country and each year:
 - 1. Yield, area irrigated and prize (FAO statistics)
 - 2. Actual evapotranspiration without irrigation (Green water) 3. Surface water and renewable groundwater consumption (Blue water)
- 4. Non-renewable groundwater use (NRG water) • 2,3 and 4: Global hydrological model PCR-GLOBWB (Wada et al., 2012)

Results: shadow price per crop/country

Estimated average shadow prices for the period 1990-2010 (\$/m³):

Country	Wheat	Potato	Maize	Rice	Citrus
China	0.058	0.073	0.179	0.105	0.160
Egypt	0.060	0.048	0.575	0.043	0.095
India	0.023	0.022	0.033	0.054	_1
Iran	0.066	0.048	0.194	0.027	0.090
Italy	0.065	0.075	0.138	0.017	0.368
Mexico	0.018	0.116	0.040	0.004	0.066
Pakistan	0.013	0.006	0.023	0.003 ²	0.043
South Africa	0.032	0.082	0.048	0.000	0.193
Spain	0.044	0.089	0.158	0.009	0.317
Turkey	0.049	0.039	0.089	0.002	0.732
United States	0.046	0.044	0.136	0.008	0.056
Average	0.043	0.058	0.147	0.025	0.212

 No estimate due to lack of yield and or price data Estimates based on 1991-2002 due to lack of yield or price data in later years

References

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Spain



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7.9X North China





Country	From crop 1	
China	Potato	
Egypt	Rice	
India	Maize	
Iran	Wheat	
Italy	Rice	
Mexico	Rice	
Pakistan	Rice	
South Africa	Rice	
Spain	Rice	
Turkey	Rice	
United States	Wheat	

Conclusions

We have shown that the shadow price for non-renewable or fossil groundwater can be determined from the econometric analysis of historical yield and price data supplemented with simulations of crop-water use from a global hydrological model. Our results show that shadow prices per crop and per country vary significantly. This provides opportunities for changing the crop mix within and between countries in order to limit groundwater depletion or to generate more revenue from nonrenewable groundwater use.



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