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The shadow price of non-renewable groundwater

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The expansion of irrigated agriculture into areas with limited precipitation and surface water during the growing season has greatly increased the use of non-renewable groundwater. As a result, the depletion rate of groundwater resources has increased during the last decades. Although water pricing has been used extensively to stimulate efficient application of water, it does not preclude the use of non-renewable water resources. A possible reason for this is that, in most countries a fully functioning market for water does not exist, while not all costs are included in the price of water. As a consequence, the price that users pay for their water does not reflect its scarcity and value. An alternative way to assess the actual value of water is calculating its shadow price, which is defined here as the marginal value produced. When applied to irrigation, it is calculated as the value of the crops produced with the last m3 of irrigation water consumed. A low shadow price then signifies inefficient use of water.

Here we determine the shadow price of non-renewable groundwater for eleven of the most important groundwater depleting countries and for four staple crops and one cash crop: wheat, maize, rice, potato and citrus. To quantify the shadow price, the relation between the output and water input is represented using production functions. We use globally available panel data on country-specific crop yield and prices together with water consumption, calculated with the global hydrological model PCR-GLOBWB, in order to parameterize the production function by country and crop with econometric analyses. The novelty of our analysis is its focus on non-renewable groundwater and its global extent.

Our results show that the shadow price for citrus is highest in 6 out of the 11 countries and for maize in 3 countries. In 8 out of 11 countries rice has the lowest shadow price, while for the other 3 countries it is wheat. Shadow prices for certain crops are very low, indicating economically inefficient or even wasteful use of non-renewable groundwater resources. We also analyse the effects of changing the crop mix, showing that small changes could lead to large reductions in fossil groundwater use or alternatively, create additional financial means to invest in water saving technologies. Our study thus provides a hydro-economic basis to further the sustainable use of finite groundwater resources.