EGU22-989
https://doi.org/10.5194/egusphere-egu22-989
EGU General Assembly 2022

Revisiting optimal groundwater withdrawal under irrigation: including groundwater-surface water interaction and global analyses

Marc Bierkens[1,2], Rens L.P.H. van Beek[1], and Niko Wanders[1]
[1]Utrecht University, Physical Geography, Utrecht, Netherlands (m.f.p.bierkens@uu.nl)
[2]Deltares, Unit Soil and Groundwater Systems, Utrecht, Netherlands

The increasing population numbers and demand for food has greatly increased the dependence of irrigated crops on groundwater resources. This has resulted in a steep rise of groundwater withdrawal for irrigation around the globe, with a decline of groundwater levels and the potential economic depletion of aquifers as a result. In this presentation we revisit the classic problem of determining economically optimal groundwater withdrawal rates for irrigation. The novelty compared to previous mathematical analyses is the inclusion of non-linear groundwater-surface water interaction that allows for including the impact of capture and the application of this framework at the global scale.

We base our analysis on a recently published analytical framework of groundwater-surface water interaction subject to groundwater pumping (Bierkens et al., 2021). This framework distinguishes between two regimes: 1. a physically stable withdrawal regime, for which groundwater withdrawal q is smaller than a critical withdrawal rate q_{crit}. Here, groundwater level decline reaches an equilibrium and all groundwater withdrawal eventually comes out of capture; 2. a physically non-stable regime ($q > q_{crit}$) where groundwater withdrawal is larger than maximum capture and leads to persistent groundwater level decline. Using a simple hydroeconomic model based on competition of resources, we derive an equation for the optimal withdrawal rate under the stable regime. Similarly, we use the hydroeconomic model to derive economically optimal withdrawal and depletion trajectories for the non-stable regime assuming either full competition or optimal control (intertemporal efficiency). The expressions derived for optimal depletion trajectories under the non-stable regime are a generalization of the work of Gisser and Sánchez (1980), by including (non-linear) groundwater-surface water interaction.

We apply the hydroeconomic framework at the global scale, limited to regions with significant groundwater use for irrigation. For the regions with stable groundwater withdrawal ($q<q_{crit}$) we determine the optimal withdrawal rate q_{opt} and check whether it is attainable in the stable regime ($q_{opt} < q_{crit}$). We also assess the economic gain that can be achieved when the current withdrawal is set equal to q_{opt}. For regions with non-stable groundwater withdrawal ($q>q_{crit}$) we estimate the final groundwater level decline and associated net present value (NPV) of accumulated profits over time, and compare these between competition and optimal control. This allows us to assess, at

first order, globally where the so-called Gisser-Sánchez effect olds, in that competition and optimal control lead to similar depletion rates and economic value. Finally, we use the hydroeconomic framework to assess for regions with non-stable groundwater withdrawal ($q > q_{crit}$) whether it is more profitable (in the long run) to pursue controlled depletion or reduce withdrawal rates to the stable regime.