Limits to large-scale groundwater withdrawal: on the role of surface water-groundwater interaction

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The issue

Global groundwater depletion represented by the groundwater footprint (Gleeson et al., 2012).
The big question: how much groundwater is there and how long does it last?

The framework

The nature of groundwater-surface water interaction in a phreatic aquifer under pumping:
Stage 1 withdrawal: groundwater connected with surface water; mostly affecting streamflow
Stage 2 withdrawal: groundwater disconnected from surface water; effect on streamflow limited; causing enhanced depletion

The model

Global hydrology and water resources model PCR-GLOBWB coupled with a global two-layer groundwater flow model based on MODFLOW (De Graaf et al., 2017)

Critical decline limit

Changes in groundwater-surface water interaction over North America between 1910 and 2010 (MSc-thesis de Cock)

Environmental flow limit

Time to reaching the environmental flow limit

Economic limit

Depth to economic depletion

Economic depletion: investments to go deeper exceed profit over next depreciation period

\[ C_d(t) = \frac{R(t) - C_d(t) - C_l(t)}{r} \]

- \( C_d(t) \): Depreciation period (years)
- \( r \): Interest rate (%)
- \( R(t) \): Revenues from crop yield
- \( C_d(t) \): Investment costs
- \( C_l(t) \): Energy costs
- \( C_l(t) \): Yearly interest payment

Time to reaching the environmental flow limit under groundwater pumping (De Graaf et al., in revision)