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Global violations of environmentally critical groundwater discharge

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Groundwater serves as a vital resource to meet global water demands, particularly for irrigation services. Unsustainable abstractions threaten extant stores and risk irreparable depletion, potentially leading to disconnects between the surface and sub-surface systems. With a growing global need for freshwater, understanding the ongoing hydrological processes is increasingly important. This study, therefore, assesses the environmentally safe operating spaces for global groundwater abstractions.

Environmentally critical groundwater discharge was calculated at the gridcell level (5 arcmin) for monthly timesteps during the period 1965-2010 using PCR-GLOBWB-MODFLOW coupled model output from a *natural run*, which excludes human interference. Output from a *human-impacted* run was then compared with these critical flow thresholds to calculate violations of the environmental flow requirements (EFR) due to groundwater abstractions. Two methods of estimating groundwater EFR – the Q_{90}[1] and Presumptive Standard[2] – were used. The Q_{90} method considers the 10^{th} percentile (90% exceedance) of monthly flows from a 60-month moving window as the EFR threshold, while the Presumptive Standard stipulates that 90% of natural flows must be maintained to satisfy the EFR.

Results were aggregated to the river basin scale, and the frequency and severity of groundwater EFR violations were calculated. Intensively irrigation regions, such as the Upper Indus-Ganges basin, North-China Plains, and southeastern United States were among the basins with the worst groundwater EFR violations. Notably, when comparing the two groundwater violation methods, the Presumptive Standard violations tended to be more severe than the Q_{90} violations due to generally having a higher EFR threshold. The same river basin-scale analyses were conducted for the low-flow periods as well. These periods were isolated using the Q_{90} as the low-flow threshold. The biggest difference between the Q_{90} and Presumptive Standard violations during such periods was no longer the severity, but rather the frequency, with Presumptive Standard violations occurring more often than Q_{90} violations, but both being of similar magnitudes.

The findings of the groundwater EFR violation analysis will be validated with surface water EFR violations, applied using the Variable Monthly Flow[3] approach. Further research into this topic will then yield insights into current and future violations of environmentally critical groundwater discharge, as well as the associated environmental impacts of such violations due to groundwater abstractions.

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