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Science for Environment Policy

Global groundwater pumping lowers the flow of water bodies and threatens freshwater and estuarine ecosystems

Groundwater is the earth's largest freshwater resource and is vital for irrigation and global food production. In dry periods farmers pump groundwater to water crops, this is already happening at an unsustainable level in many places — exceeding the rate at which rain and rivers can refill the groundwater stores. This study seeks to identify where groundwater pumping is affecting stream flows and estimates where and when environmentally critical stream flows — required to maintain healthy ecosystems — can no longer be sustained.

Groundwater resources are finite and are coming under increasing pressure in some parts of the world, due to a rising world population and the need to provide food. The increasing frequency of short- and long-term droughts under climate change is leading many farmers to exploit groundwater sources of freshwater even more. As groundwater levels fall, the costs of pumping increase, often leading to rising costs of food production. As a result, wells can run dry, threatening food security.

When water levels drop too much, the flow of groundwater to rivers, streams and other freshwater bodies declines, can stop completely or even reverse in direction. This can lead to low or no flow and devastate aquatic ecosystems.

The EU's Water Framework Directive[1] (WFD) and Groundwater Directive[2] provide measures to protect the quality and quantity of groundwater within EU Member States — including the establishment of groundwater monitoring networks and river basin management plans. This study simulates groundwater — surface water interactions at the global scale to analyse the effects of groundwater removal on streamflow.

The study focuses on estimating where and when environmentally critical streamflow will be reached as a result of groundwater pumping. The researchers used a global-scale surface water-groundwater model (GSGM). A simulation of groundwater movements from groundwater heads — high ground with high groundwater levels from which water flows downwards —at a high resolution of 10 km by 10 km.

The GSGM hydrological model simulations span the period 1960–2100, using published climate data and gridded human water demands, as input between 1960 and 2010. For the period 2011–2100 a 'business as usual' scenario is used, assuming domestic and industrial water demands remain as in 2010, as well as irrigated areas. Irrigation water demands change, among other factors, as a result of climate change. The researchers assume a representation concentration pathway 8.5 (RCP 8.5) (the greenhouse gas concentration trajectory adopted by the IPCC) and use the driest, wettest and average climate projections in terms of future global rainfall change uncertainty.

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Global groundwater pumping lowers the flow of water bodies and threatens freshwater and estuarine ecosystems *(continued)*

The model showed that, due to groundwater pumping worldwide, the environmental flow limits have already been reached for 15–20% of global watersheds with groundwater pumping and will be reached for more than 50% by the end of 2050. The researchers estimate that the first time at which environmental flow limits will be reached peak at around 2030. Regions that have already reached their environmental flow limit are mainly found in drier climates of the world, where discharge to streams is small and irrigation heavily depends on groundwater.

Hotspots of early limits which were reached prior to 2010 are found in groundwater depletion 'hotspots' such as the High Plains aquifer (central USA), parts of Mexico and the Upper Ganges and Indus Basins (India and Bangladesh). The researchers suggest that before 2050 other regions, such as southern and central Europe, will reach their environmental flow limit, due to projected drier climate conditions and increasing irrigation demand.

Environmental flow limits due to groundwater pumping are reached mostly before extensive losses in groundwater storage are experienced. The researchers suggest this study offers an opportunity to revisit the implications of groundwater pumping and its impact on European aquatic habitats. This study's results could, in turn, be useful for EU Member States in the development of the third river basin management plans under the WFD.

1. Water Framework Directive 2000/60/EC: https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:32000L0060

2. Groundwater Directive 2006/118/EC: https://www.eea.europa.eu/policy-documents/groundwater-directive-gwd-2006-118-ec