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Groundwater use and irrigation can negatively affect the net atmospheric moisture and amplify water scarcity problems

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Groundwater pumping and irrigation can disrupt natural atmospheric processes, affect the whole water cycle, and potentially worsen water shortages during heatwaves, a new study suggests. The findings contribute to our understanding of how to manage water resources under future climate change conditions. The study shows how some of the most intensively water managed areas of Europe — such as the Iberian Peninsula — could be affected by extraction of groundwater during years when conditions are especially hot and dry, potentially amplifying water scarcity in already-stressed regions.

In the global water cycle, more water is typically absorbed by the land from the atmosphere than is lost through evaporation and transpiration from plants ('evapotranspiration') — the land is a 'continental sink'. This net absorption causes water to run off the land and into rivers. However, extracting groundwater for human use and crop irrigation can disrupt this natural cycle by increasing evapotranspiration. Water used for irrigation mostly evaporates instead of running off the land or returning to groundwater, and this, in turn, influences the atmosphere. Irrigation further affects the atmosphere by reducing the temperature of the land which changes how it reflects the Sun's rays back into the air.

Depending on local conditions, the ultimate impact of these complex feedback processes can either increase or reduce both rain and the extent of the continental sink. This has potentially far-reaching consequences for river flow beyond the local scale and in remote locations, with implications for water availability and governance. The effects are likely to be strongest during hot, dry periods when water demands increase greatly.

Recent advances in computer models for Earth systems allowed the researchers involved in a recent study to examine feedbacks between human water use and the atmosphere — which are otherwise challenging to observe — and model the effects of groundwater use and irrigation across Europe on the continental sink.

The study focused on the year 2003, when there was a major heatwave. Whilst the weather in 2003 was extremely unusual for the time, it could indicate some of the water-security implications of future heatwaves and drought under climate change. For the full year, they assumed realistic daily groundwater abstraction rates for industrial, domestic, and agricultural use (based on previous studies by the same researchers), as well as irrigation.

The results suggest that groundwater pumping and irrigation led to an increase in the release of water from the land to the atmosphere. This reduced the net sink of moisture by an average of between 0.7 and 3.2 millimetres per year (mm/yr) across Europe (compared with a scenario with no groundwater pumping and irrigation). This range of figures reflects high uncertainty in the exact amount, and levels of around 1 mm or less would represent only a small reduction. However, the data do consistently show that there was a reduction to some degree, and that this disruption may affect rivers and freshwater availability far from where the water extraction and irrigation took place. Moreover, long-term effects of groundwater pumping and irrigation remain uncertain, but potentially exacerbate the feedbacks and increase the risk of water shortages.

Continued on next page.

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Groundwater use and irrigation can negatively affect the net atmospheric moisture and amplify water scarcity problems *(continued)*

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The region that experienced the biggest decrease in its sink was the Iberian Peninsula (Portugal and Spain), one of the most intensively water-managed areas of Europe. This region suffered an additional reduction of 2.6–7.8 mm/yr; the overall natural sink in this area is 456 mm/year. At the watershed scale — a watershed being an area where multiple water sources drain into a single, larger, body — the Guadalquivir basin in southern Spain showed the biggest reduction of all: 13.2–19.2 mm/year.

In contrast, the continental sink increased over the rest of the Mediterranean (also managed intensively for water) by 0.7–12.3 mm/year on average — a result that is tied to the particular climate systems seen in the region. Results were less certain for some other regions of Europe, such as central and eastern Europe, which were less irrigated and where less groundwater pumping occurred.

The researchers suggest that the reduced continental sink, caused by feedbacks between human water use and the atmosphere, contributed to the drying of watersheds in southern Europe during 2003. This raises socio-economic concerns, as it indicates that the effects of a lower sink on the atmosphere could, in some areas, potentially amplify water scarcity in regions already stressed by high levels of groundwater abstraction and irrigation, as in the Iberian Peninsula.