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How indices contribute to global water scarcity estimation uncertainty

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Abstract: With hundreds of papers spanning three decades, the concepts and tools used to estimate global water scarcity are well-established within academic sources and are increasingly used in the private sector through open-source data such as the Aqueduct tool (World Resources Institute 2025). Companies have used the Aqueduct Tool to determine which buildings and pieces of infrastructure are most susceptible to water scarcity, set water-related environmental goals and justify investments in water use reduction. However, different water scarcity indices generally yield vastly different spatial and temporal patterns of global water scarcity as evidenced by estimates of global water scarce populations that differ by 100s of millions of people. This uncertainty persists despite the growing sophistication and diversity of global hydrological models and water scarcity indices. Uncertainty in where and when water scarcity occurs means that companies may be misled about which of their assets are at risk, leading to the misallocation of resources.

To address this uncertainty, we must understand the causes of the disagreement between indices, which remain under-investigated and unclear. To address this gap, we investigated the differences between areas of high and low agreement. We used data from the global hydrological model, H08, using GSWP3-W5E5 meteorological forcing from ISIMIP round 3b (Frieler et al. 2024; Gosling et al. 2025). Using this data, we calculated four water scarcity indices, Falkenmark, Withdrawal to Availability, Cumulative Withdrawal to Demand and Consumption to Q90, assessed them by their respective thresholds and created a disagreement map. To probe the underlying differences between areas of disagreement and agreement, we created transects across major regions of disagreement. The values of the key index inputs were analysed, including supply variables like runoff and demand variables such as withdrawals.

Areas of disagreement are concentrated between the equator and 40 degrees north, particularly in densely populated areas such as regions of India and China, and tend to coincide with areas of high demand. In these areas of disagreement, regions could be classified as water-scarce or not-depending on demand representation. In contrast, areas of high agreement tended to be low-demand areas, such that regardless of how supply is measured, demand was always lower. This pattern indicates that disagreement is being driven by how demand is represented. Many global hydrological models employ highly simplified demand sub-models, yet devote considerable attention to the sophistication of runoff and routing methods, even though demand, as we demonstrate in our study, is the variable driving the disagreement. The implication is that there should be greater investment in improving and developing the demand sub-models of global hydrological models, not only for academic understanding but also so that companies can use them with greater confidence for risk assessment and resource allocation.

Keywords: *Global water scarcity, indices, thresholds, global hydrological models*

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