Supplementary Materials for Water Depletion: An improved metric for incorporating seasonal and dry-year water scarcity into water risk assessments

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# Text S1: WaterGAP modeland methods to compute water availability and consumption in sub-watersheds

The global integrated water model WaterGAP (Water – A Global Assessment and Prognosis) consists of two main components: First, a water balance model to simulate the characteristic macro-scale behaviour of the terrestrial water cycle in order to estimate water availability (Alcamo et al., 2003; Döll et al., 2012; Döll et al., 2003); and second, a water use model to estimate water withdrawals and consumptive water uses for agriculture, industry and domestic purposes (aus der Beek et al., 2010; Flörke et al., 2012). The current version, WaterGAP3, operates on a 5 arc-minute spatial grid (Schneider et al., 2011; Verzano et al., 2012).

Based on daily time series of climate data (precipitation, air temperature, and radiation from the WATCH-forcing data (Weedon et al., 2011)), the hydrologic model calculates the daily water balance for each grid cell for the time period 1971-2000, taking into account physiographic characteristics like soil type, vegetation, slope, and aquifer type. Runoff generated on the grid cells is routed to the catchment outlet on the basis of a global drainage direction map (Lehner et al., 2008), taking into account the extent and hydrological influence of lakes, reservoirs, dams, and wetlands (Döll et al., 2009).

Because of the current lack of documentation at the global level, WaterGAP3 does not yet account for inter-basin transfers or unsustainable depletion of groundwater storage (i.e., when extraction exceeds recharge) as sources of water. Because consumption is not constrained by this limitation, water consumption can exceed modeled availability.

Spatially distributed total water consumption and withdrawals were simulated for the five most important water use sectors: irrigation, livestock based agriculture, manufacturing, thermal electricity production, and households and small businesses. Countrywide estimates of water use in the manufacturing and domestic sectors are calculated based on data from national statistics and reports and are then allocated to grid cells within the country based on geo-referenced population density and urban population maps (Flörke et al., 2013).

The amount of cooling water withdrawn for thermal electricity production is determined by multiplying the annual thermal electricity production with the water use intensity of each power station, respectively. Input data on location, type and size of power stations were based on the World Electric Power Plants Data Set (Bergesen, 2010). The water use intensity is impacted by the cooling system and the source of fuel of the power station. Four types of fuels (biomass and waste, nuclear, natural gas, and oil, coal and petroleum) with three types of cooling systems (tower cooling, once-through cooling, ponds) are distinguished (Flörke et al., 2012).

Net and gross irrigation requirements, which reflect an optimum supply of water to irrigated plants, are computed based on a digital global map of irrigated areas (Siebert et al., 2005; Siebert et al., 2006) as a starting point for simulations. The model simulates cropping patterns, growing seasons, and net and gross irrigation requirements, distinguishing 18 crop types (aus der Beek et al., 2010). Water withdrawals for livestock were computed by multiplying the number of animals per grid cell by the livestock-specific water use intensity (Alcamo et al., 2003).

In the WaterGAP3 hydrologic model, available water accumulates as it is routed through sub-watersheds. To complement this, consumption is reported for each sub-watershed as the sum of all consumption in that sub-watershed and in all sub-watersheds upstream from it. In order to evaluate depletion in each sub-watershed independently, we consider “net” available water, subtracting all consumption that occurs upstream. We calculate depletion by comparing net water availability in a sub-watershed only to consumption that occurs within that sub-watershed.

Considering sub-watersheds independently instead of evaluating accumulated water availability and consumption reduces both availability and consumption in each downstream watershed. However, considering water depletion of net instead of aggregated sub-watersheds also reduces the number and area of highly depleted watersheds, illustrated in **Fig. S4** and **Fig. S5** and in **Table S3**.

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