Title MSc project: Scaling the Planetary Boundary: the role of scale in translating global limits into actionable reduction targets for water use	
Assignment number: 18.22	**Internal project**
Head graduation committee Dr. Maarten Krol	**Daily supervision** Dr.ir. Rick Hogeboom, Han Su MSc.
Required courses Water Footprint Assessment; Hydrological Modelling and Forecasting (and / or Hydrology)	
Involved organisations UT-MWM	**Start of the project** flexible

Short description project aim and motive

Human activities have altered critical Earth systems to the point where we are now running the risk that these systems change into a state that we have not experienced before. The Planetary Boundaries framework was introduced to indicate critical thresholds for various Earth systems, including global water use (Rockstrom et al, 2009). While these boundaries are currently identified at the spatial scale of entire river basins, the various water-using activities take place at much lower spatial scales. From a management perspective, therefore, it makes sense to formulate water use boundaries, or water use reduction targets, at comparable scales. That is exactly the purpose of the Science Based Targets for Water initiative, from which this research topic is derived. This initiative by the World Wildlife Fund and other conservation organizations is seeking for the formulation of more actionable reduction targets, to which our group's research contributed.

In our research, we study water footprint caps, which were introduced by Hoekstra (2013) as a promising policy instrument to foster sustainable water use. Water footprint caps indicate an upper ceiling to water use in a particular geographical area. Such boundaries for sustainable freshwater use are limited not only by physical water availability, but also by the share of available water that should be reserved for environmental protection, quantified as environmental flow requirements (EFRs).

A wide range of approaches exists to determine EFRs, which can give very different results. For studies with a global scope in mind, methods that directly relate EFRs to the hydrological regime are often selected, such as Smakhtin et al. (2004), Richter et al. (2012), and Pastor et al. (2014). Such methods do not distinguish for river morphology or specific characteristics of environments or habitats protect, but they are generically applicable and appear reasonable compared to more specific methods (Pastor et al., 2014). Implications of differences between methods were illustrated by a study by Hogeboom et al. (2020), who showed variations in water footprint cap estimates due to the use of different EFR methods. However, their global study formulated caps only at the river basin scale.

A natural approach towards higher resolutions in river basin descriptions is to subdivide basins into subbasins, which can be done at different levels of scale (Linke et al., 2019). In such descriptions, river flow emerges as a combination of flow generated in a subbasin and inflows from upstream subbasins along the river network. Likewise, EFRs can be estimated at subbasin scale and accumulate over the river network.

It is currently unknown how basin scale EFR estimates would relate to estimates derived using subbasins at different spatial scales. Estimates may be expected to be scale-dependent, due to higher temporal variability in smaller subbasins, but exactly how scale affects basin scale EFR estimates and thus basin scale water footprint caps is unclear. Scale dependencies may be small (or even non-existent) for some methods or lead to biases in either direction for other methods; moreover, scale dependencies may get more pronounced when the level of subbasin disaggregation is more detailed.

The translation of subbasin EFRs to subbasin water footprint caps carries more complicating factors, and is an optional additional theme for this MSc project topic. Water availability accumulates through the flow network of a river basin (upstream to downstream dynamics), where upstream water use limits downstream availability. An additional component to consider, therefore, is to study and apply different allocation strategies and analyse how they influence water footprint caps at sub-basin level within a river basin.

Research objective

This MSc project aims to clarify i) what is the role of scale in determining river basin EFR and ii) what that implies for estimating sustainable water footprint caps and associated water use reduction targets.

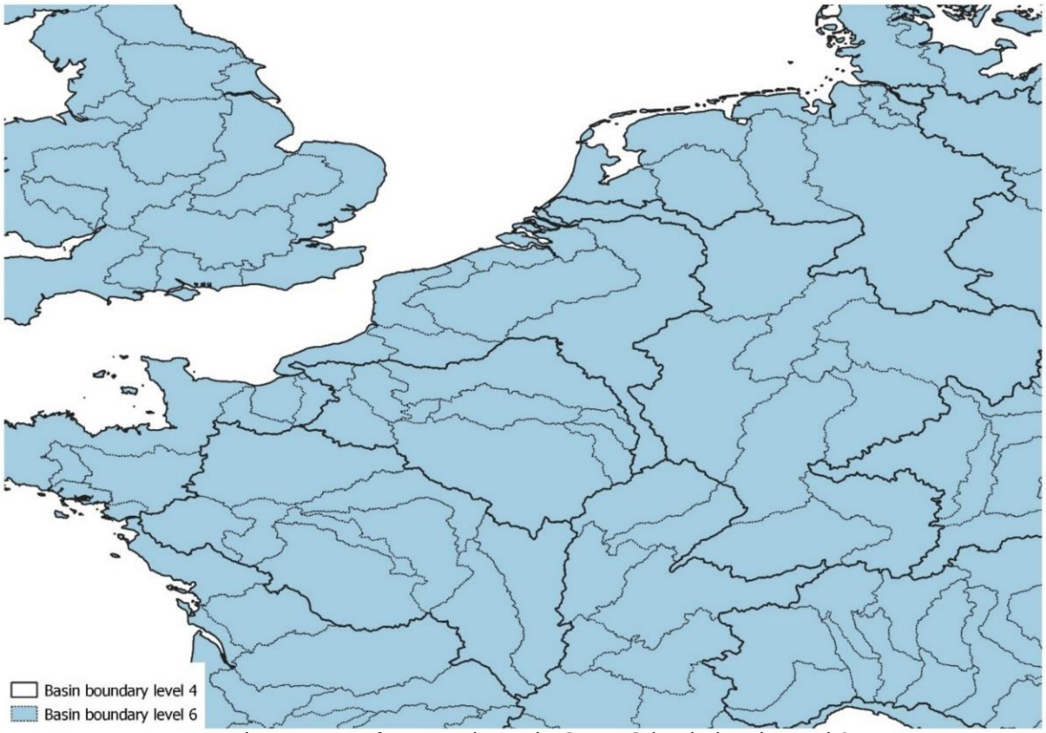

Figure: Part of Europe in HydroSHEDS basin level 4 and 6

Approach

The work will consist of the following steps:

- Worldwide estimates of (natural) runoff are available from various Global Hydrology Models; there is no need to run the GHMs yourself, but datasets that are consistent over a suite of GHMs and their modelling assumptions need to be retrieved, collated, and (quality) assessed.
- Make a selection of various EFR methods based on a thorough literature review, in which particular emphasis is given to assumptions and limitations pertaining to scale for each EFR method selected.
- Apply the selected EFR methods at a suite of spatial and temporal scales, drawing for the spatial scales from the HydroSHEDS basin delineations.
- Analyse how water footprint caps change with scale and EFR method applied.
- Analyse how variations in obtained water footprint caps translate to different water use reduction targets.

Optional part: extend the last step to subbasin water footprint caps. Note that this is really challenging, adding multiple conceptual dimensions and operational steps.

Outlook

This MSc topic connects to main research lines of the Multidisciplinary Water Management group and to recent or ongoing projects for World Wildlife Fund and World Bank. The research may actively contribute to such projects and/or the MSc thesis may be transformed into a journal publication.

Background material

Hoekstra, A. Y. (2013). The water footprint of modern consumer society. Oxon: Routledge.

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Linke, S., Lehner, B., Ouellet Dallaire, C., Ariwi, J., Grill, G., Anand, M., Beames, P., Burchard-Levine, V., Maxwell, S., Moidu, H., Tan, F., & Thieme, M. (2019). Global hydro-environmental sub-basin and river reach characteristics at high spatial resolution. Scientific data, 6(1), 283.

Pastor, A. V., Ludwig, F., Biemans, H., Hoff, H., & Kabat, P. (2014). Accounting for environmental flow requirements in global water assessments. Hydrology and Earth System Sciences, 18(12), 5041–5059.

Richter, B. D., Davis, M. M., Apse, C., & Konrad, C. (2012). A presumptive standard for environmental flow protection. River Research and Applications, 28(8), 1312–1321.

Rockstrom, J., et al., (2009). Planetary boundaries: exploring the safe operating space for humanity. Ecology and Society 14(2): 32.

Smakhtin, V., Revenga, C., & Doll, P. (2004). A pilot global assessment of environmental water requirements and scarcity. Water International, 29(3), 307–317.