

Interactive comment on “Evolving water science in the Anthropocene” by H. H. G. Savenije et al.

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First of all, we would like to apologise for reacting so late to this very thorough, inspiring and constructive review. It raised several important issues that required some thought and debate among the authors. Below we will make an attempt at answering them.

The first and probably main issue that the reviewer raised is on scale interdependencies, which he suggested to highlight particularly in sections 2.3 and 4.1.

Regarding the section "Nature talks back", the reviewer questioned if there are no early adjustments or adaptations that can be observed as a result of stress exercised by humans on the natural system. This is an interesting question. If we would study older civilizations, surely some interesting conclusions could be drawn (e.g. the effect of early agricultural development by the Sumerians in Mesopotamia, texts attributed to

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Plato on the effect of deforestation, large scale environmental change introduced by the Inca civilisation). The book by Clive Ponting "A Green history of the world" gives ample examples of such early examples of nature talking back. There appears to be proof that global biodiversity reduced substantially after humans arrived on the global scene. However, our paper does not pretend to provide a historical analysis, so we feel that an extensive treatment is beyond the scope of the paper. But in the revised paper we shall make mention of the main point, that interactions between human and the natural system have always been part of human history, probably starting at relatively small scales, but gradually increasing in scale as the range of command of the technology increased. Regarding the section "Emerging new concepts" the reviewer encourages us to highlight the scale-related challenges that these new concepts address, so as to avoid that they are presented as solutions looking for a problem. We shall rework this section as far as we can to put these new concepts into a scale perspective.

An important point raised by the reviewer is that there is not enough attention to the effect of humans on groundwater and on the way humans have tried to cope with this over time. Although groundwater issues often manifest themselves at local scale, there are definitely larger scale dimensions. At the catchment scale, the groundwater is the slow reacting system element that connects all activities within a catchment, be they water withdrawals, pollution, salinization or land use change. At global scales groundwater use has a direct physical impact on sea level rise, and indirectly on virtual water demands and trade (e.g. the rapidly expanding groundwater use in New Zealand to produce dairy products for the upcoming Asian markets). Also the coping mechanisms deserve attention, from the very effective and efficient Qanat systems introduced in early Iranian civilisations expanding over the entire semi-arid Arab world, until the rapidly spreading deep well fields as an example of a failing form of common pool resource use, causing global groundwater resources depletion observable from space by gravity satellites. We shall highlight some groundwater examples in the text to make the paper more balanced.

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The reviewer points out that there is a time line in the impact of humans on the water system (and vice versa). Small scale impacts start already with the earliest civilisations (even realising that biodiversity started to go reduce with the emergence of humans on the global scene), where humans had to cope with the impact of these disturbances. A good example of small scale effects may be the often devastating impacts humans have had on small island ecosystems, thereby eroding the very basis for their own survival. The large scale effects, whereby human induced developments have a substantial effect on global resources and processes, only started after the industrial revolution. We shall bring this out in the revised paper.

Although the reviewer appreciates the section on "Nature talks back", he considers it too much an impact-oriented approach, whereby he would prefer to see a more interactive analysis emphasising the mutual feed back between humans and nature. This is an interesting comment, which we shall address in the revised text. The question remains, however, if adaptive water management (AWM) may be considered a new concept or whether it should be considered "old wine in new bottles". There are arguments to consider AWM as a form of IWRM "avant la letter", and not one that comes after IWRM. In our interpretation, AWM is a "learning by doing" approach that characterises the entire water resources history that we tried to summarise in sections 2.2 (The hydraulic mission) and 2.3 (Nature talks back), but admittedly, proposes to incorporate (social) learning in a more systematic manner, and recognising uncertainty as a key feature in water management. We will include a comment to this effect in the section on IWRM (section 3.1), with an appropriate reference, e.g. to the work of Claudia Pahl-Wost et al. (2007)

The referee questions why in 3.1-3.3 we don't highlight global initiatives and Fora for consensus building such as WWF and WWC. These sections refer to novel concepts and conceptualisations of phenomena, thus to the knowledge realm. Following this suggestion, and that of the other reviewer, we will include an observation on global initiatives in the discussion section, focusing on global efforts to share data and come

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to shared understanding.

The referee next draws the attention to the fact that virtual water trade is not always positive (e.g. Scott et al. 2013). Even if it is positive at global scale, it may have negative impacts at local scales. We agree that virtual water flows can be either positive or negative from a water resources point of view. Positive is for example when water is used in a sustainable way in a region with sufficient water for making products exported to a region that is short of water. But even then, the reviewer is right that other factors like energy cost should be taken into account when evaluating trade from an environmental point of view. The spatial scale of analysis matters indeed. When studying virtual water flows between nations, differences within a nation will not come into the picture. See e.g. Ma et al. (2006) on virtual flows within China and Verma et al. (2009) on virtual water flows within India.

Next the referee points out that it is agricultural and energy development rather than production that has transformed the Earth system, the landscape and water management (e.g. Scott et al., 2011). This is an important and valid point and we agree with the reviewer. We shall pay attention to the water energy nexus in section 4.2.2 on external integration.

The referee observes that the Discussion on p7639 asks for the formulation of new research questions. We agree and we think this is an interesting and valuable suggestion consistent with a remark by the other reviewer. We will enrich our discussion section and formulate new, appropriate and critical research questions. We agree with the referee that the term 'human' is better than 'man'. Most of the time we do use 'human', but we will use it throughout the revised manuscript.

About the suggested rearrangement of paragraphs, we tend to disagree. New governance arrangements need to be informed by relevant data, and these particular sections make the point that new data sources have become available through new technologies and that this can feed new governance arrangements. We will clarify this

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point, that apparently we have not made clearly enough.

The referee suggests another title for "Global Instruments". This section is about the need for global stewardship/governance, requiring globally agreed instruments or arrangements. We suggest to use the term "global arrangements" instead of "global instruments".

Finally, the referee suggests to write "water knowledge and interventions" instead of only "water knowledge" to have played a key role in socio-economic development of societies. We prefer the following formulation: "We have shown that it is not only the water interventions per se, but also, and importantly, the water knowledge itself that has played a key role in the socio-economic development of societies"

We would again like to thank the referee for his very thoughtful, thorough and constructive comments, which will definitely help to improve our paper.

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