Hydrol. Earth Syst. Sci. Discuss.,
https://doi.org/10.5194/hess-2019-399-AC1, 2019

Hydrology and Earth System Sciences
Discussions

Interactive comment on "HESS Opinions: The Myth of Groundwater Sustainability in Asia" *by* Franklin W. Schwartz et al.

Franklin W. Schwartz et al.

schwartz.11@osu.edu

Received and published: 20 October 2019

We are appreciative of the constructive comments on the paper from all three reviewers. Following here is our detailed response to comments of Reviewer #1.

We have considered Reviewer #1's comments carefully and made significant changes to the paper.

Reviewer #1:

The opinion paper by Frank Schwartz and coauthors discusses the lingering groundwater crisis in several Asian countries, some reasons how it could come so far, theoretically feasible technical solutions, and vague research directives. It is clear, that groundwater exploitation is not sustainable in many countries with (semi)-arid climate,

including actually large parts of the United States.

1. However, besides climate and land use there are also societal boundary conditions, and these differ tremendously between the countries discussed in the manuscript.

(response) The original paper draft was focused on mainly technical issues that we considered as hurdles that needed to be overcome for quantitative and verifiable management of large aquifers. Our view was that these issues for many countries in Asia constituted barriers that by themselves would preclude serious efforts towards sustainability. In this respect, the availability of data represents a critical information gap for many countries because you cannot manage something you don't understand. We also used experience from Orange County, California and California more generally to illustrate the true challenges of sustainable management of groundwater from a technical perspective.

However, Reviewer #1 quite rightly pointed out that sustainable management also requires a proper legal and socio-economic framework for action. Our paper hinted at the necessity for laws as basis for enforcing limits on withdrawals and synchronization of macroeconomic policies, but the coverage was minimal. Following the reviewer's suggestion have we expanded the paper significantly to explain frameworks for action and the various components that contribute to sustainability, and to provide a context for key countries that we considered.

We address points 1 and 3 together by adding a long section [lines 38 to 66] in the revised introduction that describes robust frameworks shown to work in areas of legislation, policy, regulatory/ macroeconomic tools. In section "3. What are the Hurdles to Groundwater Sustainability?" we have rewritten and generalized the 2nd "hurdle" concerning data to describe the status of India, Pakistan, and China [lines 194 to 224] with respect to the socio-economic framework discussed in the introduction. The treatment is economical (adding $\frac{1}{2}$ page new) and a significant rewrite of associated material.

2. The People's Republic of China definitely does lack democratic participation, but it

has a long standing tradition of a functional administration, and the economic growth of the last decades has led to the economic foundation for expensive technical solutions, if applicable. We see this in water treatment (both for freshwater and waste water) where tremendous progress has been made in recent years. Of all countries discussed in the manuscript, China is the one where the educational and administrative conditions are the best to implement water-management strategies comparable to those of Southern California - if the Communist Party decides sustainable groundwater management to be an important issue. In contrast, other countries lack the concept of groundwater rights.

(response) We have added a section explaining the present status of groundwater management in China as well as Pakistan and India. The China piece is part of the longer section described in 1 above (3rd paragraph). Assessments by various authors indicate much slower progress in groundwater management than with surface water. We added the sentiment expressed by Reviewer #1 that they would have the financial and technical capacities if the government wished to make progress.

3. If traditionally the owner of a piece of property is allowed to extract all resources thereof, including groundwater, implementing rules of sustainable groundwater management is doomed to fail. There must be an accepted legal framework stating that you don't own the water of the land that you own, that drilling and operating a new well requires a permit, that the permit can only be issued based on a management plan of the entire resource, that abiding by the rules must be monitored, and that a breach of regulations must be punished. If this basic societal understanding does not exist, sustainability cannot be enforced.

(response) We agree with this point. As mentioned, this is a specific example of the problems discussed in 1 and has been addressed in the revision. The specific case of China is now described in much greater detail.

4. I don't think that the authors should put Yemen into the mix of countries to con-

sider. Yemen has been in a Civil War for years, and one cannot expect that anything functions. Almost the same would hold for Afghanistan where the German Geological Survey had spent millions on developing groundwater management rules, including hydrogeological mapping and implementing groundwater monitoring. All of that disappeared when the security of western advisors was no more guaranteed. In such dysfunctional countries, sustainable groundwater management cannot be of high priority. Whereas it could in India.

(response) Rev#1 (and Rev#2) both recommended that we remove this piece and we have done so.

5. The authors present Orange County and Singapore as highly developed regions in which technical solutions for sustainable groundwater management have more or less successfully been implemented, monitored, and maintained. They could add Israel where advanced irrigation techniques and managed aquifer recharge has been developed on a world leading level. Like in Singapore, if even not much more so, Israel is in need of self-sufficiency, has a functional administration, and is home of some of the best engineers worldwide. Hence, when it comes to discussing why sustainable groundwater management appears achievable in Israel but not so much in some of its neighboring countries with similar climate and geology, the societal and governmental boundary conditions must be analyzed to a depth at which geologists and engineers feel uncomfortable. Being a hard-core scientist myself, I lack an in-depth discussion of societal differences among the different countries that can explain differences and give predictions on the chances of implementing sustainable groundwater management practices. Iran, India, China, and Pakistan are quite different countries.

(response) We agree with the reviewer's point here Israel is certainly worth noting as a country with success in managed aquifer recharge. We have added sentences to the discussion at this point in the paper discussing accomplishments in Israel. In our revision, we have pointed out our view as to why Orange County, Singapore, and Israel have been successful.

(revised wording in next draft). “Such sophisticated water management systems are uncommon in Asia. Yet there are several extraordinary examples. The island state of Singapore is home for an innovate collection of management activities creating near self-sufficiency from water imports from Malaysia (Irvine et al., 2014). Drinking and industrial waters come from capturing and treating rainwater captured with urban catchments, the advanced purification of urban wastewater to a product called NEWater, and the addition of desalination plants (Irvine et al., 2014). MAR projects in Israel also provide useful examples. The Dan Region Reclamation Project (also known as Shafdan) uses treated wastewaters from Tel-Aviv and environs for MAR (Cikurel et al., 2012). The system yields 140 Mm3/yr of high quality water that is pumped 100 km south for irrigation. As of 2012, this was the largest project of its kind in Europe and the Middle East (Cickurel et al., 2012). Israel also depends on the reverse osmosis of seawater with periodic storage of excess water in the Israeli Coastal Aquifer (Ganot et al., 2018).

The common characteristics of all three of these successful implementations include (i) extreme shortages of water to the point of exhausting local surface water and groundwater supplies, (ii) technologically advanced and prosperous societies, with modern and reliable infrastructures, and (iii) a manageable problem scope stemming from relatively small populations..”

We agree with the reviewers comments in the last few sentences of 5. As mentioned in 1 and 3 we have provided a much improved analysis of the legislative and operational “boundary conditions” to provide a better sense as to which countries are likely to succeed.

6. The authors rightfully point to water-quality issues related to groundwater management in arid climates and/or regions of intensive agriculture. However, you don’t need to go to Asia to realize that salt accumulation in over-exploited aquifers is an issue largely unrecognized by many groundwater managers. In large parts of the western United States, a continuous increase in salinity has been observed in conjunction with declining groundwater levels. At the end of the day, balancing the volume of water

is insufficient to obtain sustainability in systems undergoing strong evapotranspiration. We may come to the conclusion that managing the dissolved solids will require more aggressive treatments, such as membrane-based deionization before artificial groundwater enrichment. Luckily, the electricity needed for that can be gained by photovoltaic power in the arid regions that require such treatments the most. Likewise, arsenic (or fluorine) can be removed by technical treatment, but the premise of centralized water treatment is a centralized water supply. In as much, technical solutions for the supply of cities, where centralized treatment options are achievable, must differ from technical solutions for drinking water supply and irrigation agriculture in rural regions. And neither will work without a functional and responsible administration. The paper already makes clear there is more to sustainability than taking care of water balances. Indeed this is evident as we mention in both India and Pakistan.

(response) We thank the reviewer for mentioning possibilities with dealing more aggressively with the water quality problems. Although the points raised here concerning remediation membrane-based deionization, arsenic removal, are interesting they might come much further in the future once sustainability problems are recognized and have begun to be dealt with. These are topics that we feel are beyond the scope of the present paper and significantly outside of our areas expertise. What we have tried to emphasize is that character, distribution and concentration of contaminants remains an informational black hole for all these countries including China. So, we made no changes in response to this point.

7. With respect to research directives, I highly recommend prioritization. Western researchers are interested in exciting science, but that is not always the gateway to practical solutions. Understanding the release and fate of arsenic in deltaic aquifers in south-east Asia is an example of a scientifically challenging question. Alas, among the hundreds to thousands of publications on mechanistic questions related to arsenic in south-east Asia, only a few have been useful to help the people affected. There have been examples in which "cool" science actually contributed to developing sustainable

groundwater management strategies, but most of the science is done by the flock of academic sheep following a research bellwether. Most likely, raising the level of education in water-related sciences is the best that university scientists can do to contribute; we need to train people with a solid understanding of hydrogeology and environmental engineering, who hopefully reach positions where they can make decisions. But how a society has to change that responsible decision making by administrative authorities is implemented and accepted, I have no clue.

(response) We certainly agree with these comments. Obviously, the scope and scale of existing and future problems are too serious to be poking around answering basic-science questions. We have both reworded and added sentences in the conclusion to reflect this view from Rev#1 as follows.

(revised wording next draft) “It is worthwhile to consider international research to support those sustainability initiatives underway and likely to continue. For example, countries appear to invest in recharge projects, India with their tradition MAR (Davis et al., 2018) and China with their “sponge city” concepts. There are significant opportunities in adapting modern analytical approaches to these various strategies to identify strengths and weaknesses and to optimize the benefits for groundwater sustainability. To be most useful, such research should focus on best practices appropriate to the economic and technical capacities of the countries involved.”

A few minor comments.

1. line 33: Replace "by right" with "basically". Non-native speakers think you refer to a legal term. DONE

2. lines 43-44: Are there only one continuous shallow and one continuous deep aquifer in the entire North China Plain? Otherwise use the plural. OK as is

3. line 58: Do the percentages refer to India or are the worldwide numbers? The same question refers to the "two prototypical settings for groundwater". Word “India” added

twice in clarification

4. line 63: "recover to the levels pf previous years" or "recover from the withdrawals of previous years." Last is correct - text revised

5. line 77: The term "regionalized" appears odd here. This is a term used in geostatistics for interpolation of point data, but it seems you mean "restricted to certain regions". DONE

6. line 81: While the root cause of arsenic in the IGA system is in the Himalayan sediments, the mechanism are more complicated. I suggest dropping this explanation in order to avoid oversimplification. DONE

7. line 92: Nitrate is sometimes measured as concentration nitrate, and sometimes as concentration nitrate-N. Be specific! No change because not clear in the original report. We followed their usage rather than guess.

Interactive comment on Hydrol. Earth Syst. Sci. Discuss., https://doi.org/10.5194/hess-2019-399, 2019.