

Comment on 'An index-based framework for assessing patterns and trends in river fragmentation and flow regulation by global dams at multiple scales'

This content has been downloaded from IOPscience. Please scroll down to see the full text.

2017 Environ. Res. Lett. 12 038001

(<http://iopscience.iop.org/1748-9326/12/3/038001>)

View [the table of contents for this issue](#), or go to the [journal homepage](#) for more

Download details:

IP Address: 210.77.64.106

This content was downloaded on 30/03/2017 at 11:31

Please note that [terms and conditions apply](#).

You may also be interested in:

[Reply to Comment on 'An index-based framework for assessing patterns and trends in river fragmentation and flow regulation by global dams at multiple scales'](#)

Günther Grill, Bernhard Lehner, Alexander E Lumsdon et al.

[An index-based framework for assessing patterns and trends in river fragmentation and flow regulation by global dams at multiple scales](#)

Günther Grill, Bernhard Lehner, Alexander E Lumsdon et al.

[Influence of El Niño Southern Oscillation on global hydropower production](#)

Jia Yi Ng, Sean W D Turner and Stefano Galelli

[The role of storage capacity in coping with intra- and inter-annual water variability in large river basins](#)

Franziska Gaupp, Jim Hall and Simon Dadson

[Hydropower versus irrigation—an analysis of global patterns](#)

Ruijie Zeng, Ximing Cai, Claudia Ringler et al.

[Focus on water storage for managing climate extremes and change](#)

Bridget R Scanlon and Vladimir Smakhtin

[Partial costs of global climate change adaptation for the supply of raw industrial and municipal water: a methodology and application](#)

Philip J Ward, Kenneth M Strzepek, W Pieter Pauw et al.

[The costs of uncoordinated infrastructure management in multi-reservoir river basins](#)

Marc Jeuland, Justin Baker, Ryan Bartlett et al.

Environmental Research Letters



COMMENT

Comment on ‘An index-based framework for assessing patterns and trends in river fragmentation and flow regulation by global dams at multiple scales’

OPEN ACCESS

RECEIVED
3 November 2016

REVISED
19 January 2017

ACCEPTED FOR PUBLICATION
2 February 2017

PUBLISHED
8 March 2017

Thomas Hennig¹ and Darrin Magee^{2,3}

¹ Philipps-Universität Marburg, Germany

² Hobart and William Smith Colleges, Geneva, New York, United States of America

³ Author to whom any correspondence should be addressed.

E-mail: magee@hws.edu

Original content from this work may be used under the terms of the [Creative Commons Attribution 3.0 licence](https://creativecommons.org/licenses/by/3.0/).

Any further distribution of this work must maintain attribution to the author(s) and the title of the work, journal citation and DOI.



Keywords: China, hydropower, dams, Nu River, Irrawaddy River, Yunnan

Abstract

In their article ‘An index-based framework for assessing patterns and trends in river fragmentation and flow regulation by global dams at multiple scales’ (2015 *Environ. Res. Lett.* **10** 015001), Grill *et al* utilized a graph-based river routing model to simultaneously assess flow regulation and fragmentation by dams at multiple scales. Using global dam data they developed the river fragmentation index and the river regulation index, both based on river volume. Their results indicate that, on a global basis, 48% of river volume is moderately to severely impacted by either flow regulation, fragmentation, or both. Assuming completion of all dams planned and under construction in their future scenario, Grill *et al* find this number would rise to 93%, an effect they attribute largely to dam construction in the Amazon Basin. They also provide evidence for the importance of considering small- to medium-sized dams.

We find this approach interesting and the analysis straightforward, but in this response note some limitations to the Asia-specific data on which the analysis is based. China and India are not only the two most populous countries, but are home to the vast majority of the world’s largest dams and reservoirs, numbers which will rapidly increase in the future. Grill *et al* however, limit their modeling and subsequent basin assessment (flow regulation and river fragmentation) to less than ten percent of existing and forthcoming dams in those two countries. While we suspect this is due to data limitations, it results in what we feel are significant misinterpretations of the future of dams and rivers across much of Asia.

Introduction

Hydropower is enjoying a global renaissance. Between 2000 and 2015, global installed hydropower capacity (without pumped storage) increased by 55%, from 688 GW to 1,067 GW (IHA 2016). Such a sharp increase is unprecedented, and scholars have taken note (e.g. Hennig 2016b, Grill *et al* 2015, Zarfl *et al* 2014, Magee 2015, Ansar *et al* 2014). But this increase is very unequally distributed geographically. About 81% of that increase goes to Asia, and more than half the global increase (57.2%) has occurred in China (IHA 2016). Consequently, much current and future hydropower growth will occur in regions characterized by very limited data access (in terms of dam distribution and dam characteristics), a fact also noted by Grill *et al*.

In 2015, Grill and colleagues published an article in ERL about an index-based framework for assessing patterns and trends in river fragmentation and flow regulation by global dam construction on the basis of river basins. The authors argue that, based on global reservoirs and hydropower dams, discharge-based indicators rather than network indicators (e.g. length) prove to be a more reliable assessment tool. We appreciate this as an indubitable contribution to the field, especially as the authors emphasize the importance of considering small- to medium-sized dams to establish a baseline of natural fragmentation (Kibler and Tullos 2013). They conclude, however, that much of the increase in the number of dams globally stems from major dam construction in the Amazon Basin, the largest basin by volume worldwide. While we agree

the Amazon basin will almost certainly see a major increase in dam activities in the coming decades, we believe Grill *et al* overstate its contribution to world dam growth as a result of a fundamental lack of data for most parts of Asia. To correct this shortcoming we complement the approach taken by Grill and colleagues by discussing more specifically the present and future dam and reservoir situation in Asia, and join with Grill *et al* in a 'call to action' to scholars and practitioners to generate more comprehensive dam and reservoir data.

First critique: The data-challenge and database comparability

Grill and his colleagues use two different types of datasets, whose comparability is questionable and, in our view, limited. Both datasets were compiled by co-authors of the paper and are the basis of the paper's graph-based river routing model, which includes the river fragmentation index (RFI), the river regulation index (RRI), and dam impact matrix (DIM). It is our view that different dam databases result in different interpretations of global patterns and trends in river fragmentation and flow regulation.

The World Commission on Dams report (2000) indicated that only 12% of the estimated 50 000 large dams⁴ had been a primary use of hydropower. In consequence, 88% of the global large dams (in 2000) had other primary utilizations. Grill *et al* use data for 9751 global dams, of which 6374 are based on Lehner's GRanD database (Lehner *et al* 2011) and another 3377 dams are based on Zarfl *et al* (2014) future dam database. The criteria for inclusion in the latter are simple: all are hydropower projects with capacity greater than 1 Megawatt (MW) on rivers with discharge greater than $1 \text{ m}^3 \text{ s}^{-1}$; storage capacity plays no role and is often only estimated (due to limited data). Zarfl *et al* further differentiate between projects under construction (17% in the base year 2010) and planned projects (83% at that time). Further, most new hydropower dams are of diversion type (Hennig *et al* 2016). The dewatered river section (which is seasonally often totally dewatered) may be much longer than the average river-lengths of HydroROUT's 2.7 km. In our view, this fact is not sufficiently considered.

In contrast, the criterion for the other two-thirds of dams included in the GRanD database is neither hydropower nor installed capacity, but rather primary storage. Specifically, GRanD includes dams whose reservoirs have storage capacity greater than 0.1 km^3 (100 million m^3), as well as a seemingly random (yet large) sample of smaller reservoirs. A large number of those dams—as noted in the aforementioned WCD report—have other functions such as irrigation, flood prevention, or drinking water provision, with hydro-

power playing only a minor role (Lehner *et al* 2011). Based on those criteria, the same WCD report mentions some 1 700 large dams under construction, more than two-thirds of which are in India and China (WCD: 10), a fact not reflected in the future dams database.

Our point here is not to devalue or discredit the outstanding work of assembling and publishing the GRanD or future hydropower datasets, but rather to mark as problematic the combination of different underlying criteria for which dams are included in the databases, and consequently the conclusions drawn from those datasets. Grill and colleagues emphasize that it is not the sheer number of dams that is most relevant, but rather their locations within the river network (spatial distribution and length of disconnected network fragments). While we explicitly support this argument, we question its global assessment (and its implications) of river basins based on the two different existing datasets. In our view, a study based either exclusively on hydropower projects (above a certain minimum installed capacity) or exclusively on other criteria (like reservoir size and/or dam height, hence independent from the dam's utilization) would build on the important contributions Grill *et al* have made, and further our understanding of the magnitude, nature, and global geography of dam and reservoir impacts on rivers.

If reservoir size is included as a criterion, modelers should be aware of the special situation in semi-arid regions, where irrigation dams and barrages can lead to large-scale water diversion which can considerably reduce discharge, even to the point of total (seasonal) dewatering of river sections. Often large rivers hardly have water at their mouths, independent of whether they are inland-drained or drain into the ocean. It remains unclear how such considerably reduced water flows (seasonal and/or long-term average discharge $<0.1 \text{ m}^3 \text{ s}^{-1}$) are considered in the model developed by Grill *et al*. We also feel historic storage structures must be included in any study of dam/reservoir impacts on regional hydrology. For example (Hennig 2006), in southern India alone there are more than 130 000 centuries-old irrigation tanks (water storage ponds). The larger ones have storage volumes greater than 1 million m^3 each, far more than most of the world's new hydropower projects.

Second critique: Strong regional bias in both datasets

Both datasets (Lehner *et al* 2011, Zarfl *et al* 2014) have a strong regional bias which can be (generally) summarized by a significant underestimation of reservoirs in China and India in general and a few other nations and/or basins in particular. We illustrate our point with an example from China.

Zarfl *et al* list 238 future hydropower projects for China, a number far behind other countries/regions, especially Brazil, but also Turkey, Nepal and the Balkan countries. Yet from 2000 to 2015 China's *small*

⁴ We are aware of the problematic ICOLD definition of large dams based simply on dam height.

hydropower capacity alone (<50 MW) increased by 50 GW, with 18 GW of that increase occurring since 2010; this number is much larger than that of *all* other countries combined (World Small Hydropower Development Report 2013). Similarly, Grill *et al* refer to only about 770 dams in all of China (both databases), which is almost equal to the Mississippi basin (707). But, according to China's *Water Census* (2013), the country had 98 002 dams/reservoirs of different utilization, with combined storage capacity of 932.3 km³. Of those dams almost half (46 758) are hydropower dams, including multipurpose dams⁵. Again, of all hydropower dams almost half (22 190) have a capacity ≥0.5 MW and this immense figure does not include all the dams built after 2011. As our research has demonstrated (Hennig 2016a, Hennig *et al* 2016, Hennig *et al* 2013), in the western part of China's Yunnan Province alone (0.01% of China's territory) there are more hydropower projects than Grill *et al* mention for the entirety of China.

The China dataset on which Grill *et al* base their study is, we feel, also questionable in terms of reservoirs. As noted in the WCD report, at the end of the last millennium almost half the world's large dams were located in China (about 22 000 of 46 000). For 2011, China's *Water Census* (2013) lists 22 643 reservoirs having a storage capacity greater than 1 million m³, of which at least 4694 reservoirs have a storage capacity greater than 10 million m³. Some of these, we feel, should have been included in the GRanD database, especially since a number of dams of similar reservoir capacities were added for the US and Europe even if they were below the target reservoir capacity GRanD. The implications of *not* including these reservoirs in the study are reflected at the scale of river basins/sub-basins: for entire regions in China, few or no dams/reservoirs are identified, an error that results in dubious misinterpretations, e.g. in the (sub-) basins of China's arid and temperate Northwest which Grill *et al* refer to as not affected by large dams. In contrast, we identified about 50 existing larger hydropower projects, plus a much larger number of small hydropower dams and irrigation reservoirs (see also Deng *et al* 2010).

This significant data gap in Asia is also true for transnational basins and there, too, results in misinterpretations. Grill *et al* refer to only between 20 and 30 (existing and future) dams in the transnational Ayeyarwady and Nu basins and therefore classify those basins as weakly affected. In contrast, we identified (and georeferenced) in both basins more than 350 *existing* hydropower projects, plus a larger number of non-georeferenced reservoirs (cp. Hennig 2016a). Additionally, a large number of mainly large

hydropower projects are planned along the main rivers and/or large tributaries. Similar data gaps (even though less significant) can be described for other nearby transnational river basins, e.g. Yarlong Tsangpo/Brahmaputra, Mekong and Red River (cp. Hennig 2015, Hennig 2016b).

Finally, we also find the data for OECD countries is contradictory. For example, the EU-28 (plus Switzerland and Norway), currently have more than 5 000 hydropower plants with an installed capacity of ≥1 MW (ESHA 2016), but only a very small fraction of those are included in the database. Additionally, the future projects in the Zarfl database are almost exclusively limited to the Balkan region, which is in clear contradiction of European Small Hydropower Association (ESHA)'s hydropower development goals (Eurelectric 2015).

Conclusion

Our intervention here is not meant to disparage the work of Grill *et al* (2015), Lehner *et al* (2011), or Zarfl *et al* (2014), all of whom have made important contributions to scholarly understanding of dams, reservoirs, and their impacts. Yet we feel compelled to point out some shortcomings in the dam and reservoir data for a region we know well, having collectively conducted some two decades of research and fieldwork there (primarily in China and India). While the shortcomings in data are problematic per se, we are equally concerned about the implications drawn from those data, namely that the hotspots of future dam construction (and, by extension, river fragmentation) will be in Eastern Europe and Latin America. Such a regional bias risks overlooking, or at the very least downplaying, reservoir impacts in an area of the world already facing ground water and surface water stresses, some quite severe. Perhaps the most important lesson to be drawn here is that greater collaborative efforts are sorely needed from scholars and practitioners worldwide in order to fill the significant gaps in dam and reservoir data. The present authors look forward to furthering those efforts.

References

- Ansar A, Flyvbjerg B, Budzier A and Lunn D 2014 Should we build more large dams? The actual costs of hydropower megaproject development *Energy Policy* **89** 43–56
- China Census for Water 2013 *Bulletin of First National Census for Water* (www.waterpub.com.cn)
- Deng M, Yu H, Li X and Xu K 2010 Dam construction progress in Xinjiang *Water Resources and Hydropower Engineering* **41** 29–35 (in Chinese)
- Grill G, Lehner B, Lumsdon A E, MacDonald G K, Zarfl C and Liermann C R 2015 An index-based framework for assessing patterns and trends in river fragmentation and flow regulation by global dams at multiple scales *Environ. Res. Lett.* **10** 015001

⁵ We readily admit that official Chinese figures are often unreliable, but in this case, we feel the discrepancy of two orders of magnitude demands closer scrutiny of the Chinese case and greater caution in drawing broad-ranging conclusions based on such a small sample of actual Chinese dams.

- ESHA 2016 <http://streammap.asha.be/14.0.html>
- EURELECTRIC 2015 *The hydropower's sector contribution to a sustainable and prosperous Europe* (www.eurelectric.org/media/180750/macro-economic-study-press-release-final.pdf)
- Hennig T, Wang W L, Ou X K, Feng Y and He D M 2013 Review of Yunnan's hydropower development. Comparing small and large hydropower projects regarding their environmental implications and socio-economic consequences *Renew. Sustain. Energy Rev.* **27** 585–95
- Hennig T 2016a Damming the transnational Ayeyarwady Basin. Hydropower and the Water-Energy Nexus *Renew. Sustain. Energy Rev.* **65** 1232–46
- Hennig T 2016b Die globale Renaissance der Hydroenergie. Ursachen und Konsequenzen, Herausforderungen und Daten *Geogra. Rundsch.* **68** 32–40 (in German)
- Hennig T 2015 Energy, hydropower and geopolitics. Northeast India and its neighbours *Asien* **134** 121–42
- Hennig T, He D M, Wang W L and Magee D 2016 Yunnan's fast-paced large hydropower development: a powershed-based approach to critically assessing generation and consumption paradigms *Water* **8** 476
- Hennig T 2006 Changing tanks—irrigation and the evolution of cultural landscapes in South India *Geogra. Rundsch. Int. Edit.* **2** 22–8
- IHA; International Hydropower Association 2016 *Hydropower Status Report* (www.hydropower.org/2016-hydropower-status-report)
- Kibler K M and Tullos D D 2013 Cumulative biophysical impact of small and large hydropower development, Nu River, China *Water Resour. Res.* **49** 3104–18
- Lehner B *et al* 2011 High resolution mapping of the world's reservoirs and dams for sustainable river-flow management *Front. Ecol. Environ.* **9** 494–502
- Magee D 2015 Dams in East Asia: controlling water but creating problems *Routledge Handbook of Environment and Society in Asia* ed Harris P and Lang G (London: Routledge) pp 216–36
- World Commission on Dams (WCD) 2000 *Dams and Development. A New Framework for Decision-making* (London: World Commission on Dams, Earthscan)
- World Small Hydropower Development Report 2013 www.smallhydropower.org/
- Zarfl C, Lumsdon A E, Berlekamp J, Tydecks L and Tockner K 2014 A global boom in hydropower dam construction *Aquat. Sci.* **77** 161–70