ENVIRONMENTAL RESEARCH
LETTERS

COMMENT

Comment on 'Egypt's water budget deficit and suggested mitigation policies for the Grand Ethiopian Renaissance Dam filling scenarios'

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Abstract

The Grand Ethiopian Renaissance Dam (GERD) filling and operation is a highly sensitive issue for Egypt and Sudan. A recently accepted manuscript by Heggy *et al* (2021 *Environ. Res. Lett.* **16** 074022) assessed the water deficit for Egypt based on different scenarios for the first filling of GERD lake and estimated 31 billion cubic meters per year under a 3 year filling scenario. We would like to present grossly mischaracterized assumptions, inaccurate data, and controversial conclusions found in this accepted manuscript through this rebuttal. Although the accepted manuscript does not include any new analysis of the River Nile Hydrology, the results of previous substantive studies were misinterpreted or ignored. Moreover, we have serious concerns about the basic hydrological assumptions that are the basis for the economic impacts and the potential loss of the Egyptian agricultural lands. The main methodological flaws of concerns are (a) how the deficit is calculated, losses from GERD, especially the evaporation losses that contradicts several previous studies (e.g. Wheeler *et al* 2016 *Water Int.* **41** 611–34; Eldardiry and Hossain 2020 *J. Hydrol.* 125708; Wheeler *et al* 2020 *Nat. Commun.* **11** 1–9); (b) neglecting the normal role of High Aswan Dam (HAD) reservoir and directly linking the deficit of the water budget to an immediate loss of agricultural lands with all other associated exaggerated economic impacts estimates; (c) including highly exaggerated seepage losses from the GERD lake; (d) neglecting the updated situation of Aswan High Dam reservoir levels and the GERD's infrastructure itself, and (e) quantifying the impacts of potential changes of water level on HAD reservoir on the Nubian aquifer. We herein present a direct fact-checking approach including the studies cited in the accepted manuscript. We believe that this critical comment paper can serve as a basis for defending scientific integrity and contributes to cooperation and peace in the region.

1. Introduction

The Grand Ethiopian Renaissance Dam (GERD) being constructed on the Blue Nile and at 80% completion is considered the biggest hydropower project in Africa with more than 15 000 GW h in a year (Mulat and Moges 2014). Once completed, it will have a maximum storage of 74 billion cubic metre (BCM) behind an operational range of 49–74 BCM (Wheeler *et al* 2016). Since the collapse of the last

round of negotiating regarding the filling and operation rules of the US$ 5 billion GERD on the Blue Nile in April 2021, the diplomatic tensions between downstream countries of Egypt, Sudan, and the upstream country Ethiopia have escalated (Ambassador Taye Atske-Selassie 2020, BBC 2021, Egyptian Ministry of Foreign Affairs 2021). In a recently accepted manuscript in the Environmental Research Letters, Heggy *et al* (2021) investigated the annual water budget deficit for Egypt and developed a feasibility index for different mitigation measures. They claimed, without new mitigation measures, the 3 years filling scenario could wipe out 72% of Egyptian agricultural land with an estimated gross domestic product (GDP) reduction of $51 billion resulting in potential instability and significant migration (Heggy *et al* 2021).

The authors of the current comment paper have great concerns related to the hydrological data used by Heggy *et al* (2021), associated estimated socio-economic impacts on Egypt due to the different filling periods, and several assumptions that are not scientifically justified in our opinion. For example, the GDP and unemployment projections were calculated based on the water budget deficit that is questionable. Finally, the current comment paper is not considered a holistic assessment/view of the GERD filling/operation policies impacts on the Egyptian/Sudanese users, rather it discussed only what was investigated by the accepted manuscript. The negotiations were not only discussing the first filling policies but also more crucial dam operation rules, and long-term impacts on Egypt and Sudan especially on the potentially revenging impacts of droughts (consecutive years with low precipitation/river discharge) (Egyptian Ministry of Foreign Affairs 2021). We will present our concerns related to the hydrological data acquisition for the filling scenarios, contradicting positions with several prior scientific studies, and more importantly water budget deficit assessment.

2. Filling scenarios of the GERD

Heggy *et al* (2021) presented some previous studies of the impacts of the GERD filling scenarios such as King and Block (2014), Zhang *et al* (2015, 2016), Wheeler *et al* (2016), Liersch *et al* (2017), Donia and Negm (2018), and Omran and Negm (2018) but ignored other findings of more recent studies such as Eldardiry and Hossain (2020), and results of Wheeler *et al* (2020) (The Nature Communications study is only cited in the introduction) for the risk of water shortage in Egypt during the GERD filling. Heggy *et al* (2021) used a 3 year filling scenario to highlight their work. Even with the study's questionable assumptions, currently, none of the three countries are looking at a 3 year filing period. The most optimistic scenario that has been in discussion in the last several years looks at five to seven years. Given GERD construction is at 80% completion today and it is in the second year of filling (including this summer), there is no conceivable way to have GERD filled in 3 years. We believe the use of such an unrealistic scenario and putting it as the main result of the study simply increases tension among the countries and potentially creates what scientists warn as 'water panic' (Wheeler *et al* 2020).

Heggy *et al* (2021) also miscalculated how much water is needed to fill the GERD that has a design capacity of 74 BCM. Without any justification or clear explanation, it claimed in the earlier version of the accepted manuscript that: 'the actual volume that will be needed to fill up the basin may even be 110 BCM if we account for losses due to seepage and evaporation'. The first author recently justified how they got to 110 BCM and the answer was 'we clearly explained in the paper that the 110 BCM is the sum of fill + seepage + evaporation and the references we used in our estimate'. Yet there is no explanation how seepage and evaporation were estimated to total 36 BCM (Heggy 2021), with an estimated evaporation loss of 17.5 BCM/3 years in the cool Ethiopia highland. There is no study to date that can show even remotely close to this estimate. After this, we have noticed that the final published version of Heggy *et al* (2021) has removed the '110 BCM' and changed it to 'maybe even higher as shown in the studies summarized in table 2'.

3. Inaccurate water budget deficit assessment

Heggy *et al* (2021) stated that the seepage losses have been largely underestimated in the previous studies without citing any evidence why they think so or giving a strong justification why they decide to use a much higher seepage rate. Heggy *et al* (2021) cited only a study by Liersch *et al* (2017) and stated that the seepage-related losses can reach annually up to 15 BCM. We looked at the referenced study and others within Liersch *et al* (2017), we found nothing to support it. Liersch *et al* (2017) have three seepage scenarios as 'low' 'medium' and 'high', where a user could specify a seepage ratio and conduct 'what-ifs' scenarios. The study (Liersch *et al* 2017) justified the high seepage rate to be explored as a scenario to be included because of another reference, which we traced back to Noureddin (2013). Unfortunately, Noureddin (2013) is in an opinion piece published in El Ahram Newspaper, majority-owned by the Egyptian government (The European Union to Egypt 2011) and there was no scientific justification for the above claim. 'Noureddin (2013) assumes that, due to rock formations, seepage losses may amount to 25% of the actual storage volume' along with 10 BCM evaporation as he stated that the dam is being built in the hottest part of Africa. This 'statement' was only published in a link entitled 'Ethiopia's Catastrophic

Dam' and the piece includes some conspiracy theory statements, for example, the author asked, 'Could the Muslim Brotherhood, the rulers of Egypt at the time, have been part of a conspiracy against the country?'. The website link has expired but can be accessed through a web archive tool (Noureddin 2013). In addition to the study (Liersch *et al* 2017) cited by Heggy *et al* (2021), we reviewed scientific studies published by Professor Nader Nor Eldin and we did not find a single study that scientifically calculates or even mentioned the exact seepage rates (Noureddin 2013, Mohamed 2018). Surprisingly, Prof. Nader Noor Eldin (Professor of lands and water resources at Cairo University) was interviewed after Heggy *et al* (2021) accepted manuscript was published and strongly opposed the study results (Noureddin 2021) joining many other Egyptian water resources professors (Sharaky 2021) along with Professor Alaa Elzawahry (Member of the official Egyptian Negotiation Team) (Aljazeera 2021). It is shocking to us that a significant assumption of the water budget deficit assessment is originally based on an opinion article published by newspapers. This summary was also highlighted in the abstract and was picked up by many news outlets.

Heggy *et al* (2021) stated that the evaporation loss reported by Liersch *et al* (2017) is 3.8 BCM which we confirmed in the study that stated 'The ensemble range indicates that uncertainties related to climate model input can be rather large in the historical period. Mean annual inflows are in the range between 38 BCM and 54 BCM, mean outflows between 36 BCM and 52 BCM, mean reservoir evapotranspiration between 3.7 BCM and 4.0 BCM'. However, a recent Nature communication study (Wheeler *et al* 2020) reported that at the full operation of the Dam 'Net evaporation losses from the GERD Reservoir will average ∼1.7 bcm per year and will not fluctuate much from year to year'. This is aligned with the assessment of another study (Digna *et al* 2018; figure 5(a); scenarios S10 and S11) which implies that the net evaporation in the order of 1.7 BCM yr^{-1} will only occur when the reservoir behind GERD is fully filled, and while it is not yet fully filled, the reservoir area will be smaller and thus the net evaporation losses will be proportionally less. The study goes on to say: 'Our analysis illustrates how during filling the HAD reservoir could fall to levels not seen in recent decades, although the risk of water shortage in Egypt is relatively low. The new normal will benefit Ethiopia and Sudan without significantly affecting water users in Egypt'.

In addition, a recent High Aswan Dam (HAD) simulation study conducted by (Eldardiry and Hossain 2020) under 3 and 7 year GERD filling scenarios at different initial HAD levels found 'The filling scenarios of the GERD dam indicated a smaller impact on downstream outflow when following a slower filling scenario or by keeping HAD storage at high level prior to GERD filling'. Results of this study under the 3 years filling scenarios with the 180 m initial head indicate that the HAD will sustain its levels above 170 m. Currently, HAD is at ∼180 m and May 2021 was the highest it has been in 30 years for the month (on 09-06-2021 it was 179.8 m, http://hydroweb.theia-land.fr/hydroweb/view/L_nasser?lang=en). In Wheeler *et al* (2020) study, the HAD reservoir levels should reach a certain level for a drought management plan activation (5%, 10%, and 15% reductions at 159.4, 157.6, and 155.7 m) as clearly explained in the supplemental material of Wheeler *et al* (2020). Both studies highly contradict the results of Heggy *et al* (2021) that estimated a deficiency of ∼31 BCM yr^{-1} under a 3 year scenario. It is important to note that none of the draft documents under consideration by Egypt, Ethiopia, and Sudan that are already in the agreement are looking at a 3 year filling period as mentioned earlier. The most optimistic scenario has a filling period of 5–7 year.

Another study (Wheeler *et al* 2016) investigated the filling approaches of the GERD. Figure 5 of the study Wheeler *et al* 2016, presents 'Average annual shortages for Egyptian water users without the HAD drought management policy or GERD-HAD safeguard policy'. The figure has many initial HAD levels (knowing that the levels for the HAD Reservoir lake are 179.8 on 09-06-2021), results that show even with a 25 BCM annual release of the GERD (the average flow is 48.5 BCM), Egypt's shortage is below 5 BCM even with an initial HAD of 165 m. These results again contradict Heggy *et al* (2021) result of 31 BCM deficiency that was further processed to agriculture land losses and all other associated impacts. For example, using this miscalculated deficit, it reports a staggering 72% loss in Egypt's cultivated land and US$ 51 Billion associated loss on GDP.

4. Issues with socio-economic assessment

Looking at the Heggy *et al* (2021) socio-economic assessment, we found the study is based on reductionism and linear causal understanding of the system that is much more complex than that. In fact, the paper underestimates the complexity of farmers' livelihood strategies and the actual dynamics in agrarian societies in Egypt. The accepted manuscript estimated that the degradation of 2.8 million hectares of land would result in 4.75 million jobs (P21). The field observations and socioeconomic studies show the complexity and non-linear relationship between farming and revenue. In a context where multi-activity is widespread, with almost 50% of farm households involved in multiple activities, the linear assumption regarding the unemployment rate may be difficult (Marzin *et al* 2017). To measure the unemployment in this context, one needs to integrate farmers' household income-generating activities to know

the percentage of the income generated from agriculture, from remittances, from off-farm jobs (Marzin *et al* 2017, Ayeb and Bush 2019).

Heggy *et al* (2021) study did not suggest new mitigation strategies for the exaggerated water shortages but just reviewed already published studies. Many of these propositions are already in the National Water Resources Plan 2017 (MWRI 2005) and the Government of Egypt's Strategy for Sustainable Agricultural Development 2030 (ARDC 2009). However, these mitigation strategies have been criticized by social science researchers and plot-level research regarding the efficiency and the socioecological impacts of such strategies. The farm systems in Egypt are thus a complex object that embodies various social, economic, cultural, ecological, and technical realities. Consequently, defining water deficits and mitigating policies cannot be reduced to reducing rice cultivation or any one-dimensional practices. For example, the limitation of rice cultivation in the delta from 1.9 million feddan to 1 million feddan cannot be discussed without a corresponding analysis of the soil salinization/ salt balance and small farmers' livelihoods. Rice cultivation is central in north delta farmers' salinity control and maintaining an acceptable level of salinity in the soil of their plot (Molle *et al* 2013, 2018). In the same direction, Heggy *et al* (2021) did not discuss the difference between water-use efficiency on the plot and at a system level. The improvements in plot-level efficiency do not necessarily translate into gains at the holistic system level. Finally, the crop-based water requirements data is used without discussing largely inconsistent and variation of theoretical crop water requirements between the MALR and the MWRI (Molle *et al* 2018). IWMI, WMRI (2013) argue that these theoretical crop irrigation water requirements are not as accurate as Heggy *et al* (2021) assume.

5. General comments on the paper

There are some minor and major comments on the text itself. Aside from using the term 'Colonial' to describe the 1959 agreement, signed by Egypt and an independent Sudan, that increased Egypt's share to 55.5 BCM. Moreover, by the time the 1929 agreement was signed (Crabitès 1929), Ethiopia was an independent country, unlike Sudan. We believe these controversial political issues should be discussed as a contested term and not used as accepted reality in a pure technical research paper. A more critical topic that is discussed in Heggy *et al* (2021) yet does not impact the final water deficit assessment is the groundwater dynamics around HAD reservoir. Heggy *et al* (2021) study stated that 'The Nubian aquifer receives an annual recharge of 6 BCM yr^{-1} compared to 0.7 BCM yr^{-1}, when the lake level drops to 170 masl.' A study by Sharaky *et al* (2018) contradicts this and stated that 'The mass flow balance indicates that the calculated total recharge from the High Dam Lake in 100 years is 9.41 billion m^3 (94.1 million m^3 $year^{-1}$)'.

6. Conclusions

Despite the awareness of the limitations of scenarios indicated by prior investigators, Heggy *et al* (2021) chose to misrepresent and at times mislead readers. We witnessed the negation of some central sources and omission of prior scientific study even when allowed to explain their controversial study. This includes: (a) the use of inaccurate and sometimes misleading data to arrive at headline-grabbing, the highly exaggerated deficit of 31 BCMs and associated economic impacts (wiping out 72% of Egypt's agricultural land), (b) the use of controversial concepts, (c) the linear interpretation of the agricultural and water systems, and socioeconomic relationships, and (d) failure to explain how evaporation and seepage loss at GERD would add up to 36 BCM. These comments in totality make it difficult to treat the paper as a purely scientific paper and this is what forced us to engage with it. We found that the most significant part of the water budget deficit assessment is based originally on an opinion article published in a newspaper.

Left unchecked, this kind of study sets a dangerous precedent. From the absolute defense of scientific ethics to not let pass these accumulated errors in a prestigious peer-reviewed journal and end up being used as an incontestable reference for future researchers and decision-makers as well as public opinion is what brought us together to challenge this paper. Particularly in such a sensitive project as the GERD and the tense current regional situation. We would like this paper to be given a second look at whether it should stand as is. In addition, several international media outlets have already picked this study up. Your website data show that until now (July 2021), 2525 tweeters shared this research output and 96% of them are not within the academic sphere https://iop.altmetric.com/details/107547418).

7. Recommendation

Given these significant issues with the paper, we recommend this article should be looked at carefully for a potential retraction, editorial expression of concern, or something similar.

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