Part IV: Debunking Ethiopia's Plentiful Water Resources vis-à-vis Egypt: A Closer Look at Basins' Water Budget

by

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Abstract

Following the construction of Grand Ethiopia Renaissance Dam, the hydro-electric dam meant to generate electricity, Ethiopia and Egypt are having a fierce battle over the Nile water resource. Egypt alleges that Nile water is the "only" freshwater source, and hence considers Ethiopia's dam as existential threat. Whereas for Ethiopia, the dam is the energy source that would electrify and light one of the darkest countries in Africa and the world. Therefore, this article applied the concept of hydrologic water budget to investigate annual net and reserve water of the two countries so as to verify if indeed Ethiopia has plentiful alternative freshwater resources, Nile water is the Egypt's sole freshwater source and the dam is an existential threat. Accordingly, Ethiopia's Nile river sub-basin receives 456.6 BCM of water as rainfall while losing 443.3 BCM of water as Nile river outflow and evapotranspiration. The resultant net water storage is, therefore, 14 BCM per year, which is only 4% of the rainfall it receives. On the other hand, Egypt receives 202 BCM of water as Nile river input, rainfall, groundwater extraction, and desalinization; while losing only 51 BCM of water as evapotranspiration. The net annual water storage for Egypt is, therefore, 151 BCM, indicating a clear water resource advantage over Ethiopia's 14 BCM. Secondly, owing to the reservoir of Aswan Dam, Egypt also has advantageous surface water reserves. There is 108 BCM more surface water reserve in Egypt's sub-basin compared to Ethiopia's 30 BCM. Thirdly, Egypt's is 63,200 BCM groundwater reserve is approximately, 400% higher than Ethiopia's 12,730 BCM groundwater reserve. Lastly, Egypt has an infinite access to coastal water, which up on desalination can provide unlimited domestic water supply, the resource that Ethiopia has no access to, as a landlocked country. Consequently, it is verified that Egypt has an overwhelming water resource advantage, and that Nile water is not the only freshwater source, and so the dam is not remotely Egypt's existential threat. Therefore, the perception pushed by Egypt that Ethiopia has a plentiful water to share Nile and/or Egypt would cease to exist with Ethiopia's dam, is mendacious. Unfortunately, the international communities echoing this dishonest sentiment are violating, the ideals of transboundary water resource sharing and nation's territorial sovereignty; which are enshrined in the UN convention. The fact that Ethiopia is a victim of this malicious doctrine, being a landlocked sub-Saharan African country, with multi-faceted socio-economic problems, makes it an exhibition of an appalling cruelty that must stop.

Keywords: Water budget, Hydrologic input, Hydrologic output, Water balance, Grand Ethiopian Renaissance Dam (GERD), Egypt, Ethiopia

1. Introduction

The growing population of Ethiopia and Egypt is exerting a fierce competition over shared limited water resources. Over the last decades, the population in these two countries are growing at an average 2.3%; which is 120% higher than the 1.05% global average. At this rate, studies are showing the population of Ethiopia and Egypt are doubling every 23 and 31 years, respectively; (Teisch, and Sherbinin, 1995), indicating gloomy future of further intense competition on this resource. Besides, there is an inevitable issue of equity that would be raised between these two countries. Ethiopia would want to catch-up with Egypt's per capital and yearly water use of 2,202 liters and 77.5 BCM; respectively; which are approximately 8 and 7 times higher than Ethiopia's per capital and yearly water use of 279 litters and 10.5 BCM water (WMI-Water; 2020). It also would like to catch up with Egypt's universal electrification. According to International Energy Agency, Egypt is one of the most electrified country in Africa, with an electrification rate of greater than 90%, while Ethiopia is only 42% (Kazeem, 2018). This is much lower rate even by African standard and only two African countries are less electrified than Ethiopia.

Hence, there is a need for an arbitration of this competing interest, based on hydrological science and other socio-economic factors. The fundamental concepts of this science apply the principles of hydrological (water) cycle, which studies the three regimes of water resources, (atmosphere, surface and the subsurface) and the movement between them. Although, atmospheric water regime is significant in water movement and redistribution, it is a small proportion of global freshwater, accounting only for a 0.04%. The majority of earth's freshwater is held on the surface as glacier (i.e., 68.7%) and surface water (i.e., 1.3%), while groundwater holds, the remaining 30%. One of the applications of hydrologic cycle is a water budget assessment for a watershed/country. The water budget is a hydrologic tool used for measuring water cycle, especially rate of movements and changes in all three water regimes. It also involves measurement of the quantities of water storages in each component, particularly, the surface and subsurface. Watershed managers use this tool for evaluating sustainable qualities and quantities of water supplies; watershed best practices, and watershed planning and management thereof.

The water budget concept applies the law of conservation of mass/matter. The law states that matter or mass can't be created or destroyed but can change from one form to another, such that the total mass of the matter on the reactant is equal to the total mass of the matter on the product side. Similarly, water coming to a land system through inputs, which will be the sum of the outputs and chance in storage. Hence, net change in water storage is expressed as a difference between hydrologic inputs and outputs. The hydrologic inputs can be precipitation, stream inflow, groundwater extraction, recycled water and desalinization; whereas the outputs are steam-water outflow, direct evaporation and basin's evapotranspiration (ET). Therefore, water budget assessment involves a comprehensive quantification of each hydrologic components to account dynamic water resources of a land system.

Additionally, the water budget also involves quantifying water reserves within compartments of a hydrologic cycle. These are mainly surface and subsurface water reserves. Surface water reserves includes waterbodies, such as but not limited to, lakes, reservoirs, wetlands, flooded plains, swamps, etc.… (Fig. 1). These waterbodies primarily gain water from the rainfall, streamflow, and groundwater discharge. On the other hand, sub-surface waters are water reserves beneath the surface of the earth, such as, soil water in unsaturated zone and groundwater in saturated zone. The source of water for these reserves are direct rainfall and surface water recharging through percolations, infiltrations and seepages (Fig. 1). Therefore, the overall objective of this article is to quantify the water resources of the sub-basins of the two country. It, first, investigates the net change in water storages of sub-basin as consequences of dynamic water movement in the hydrologic cycle. Secondly, it enumerates water held in the components of hydrologic regimes. The ultimate goal is again to debunk the perception that Ethiopia has plentiful water resources, to share Nile water with Egypt.

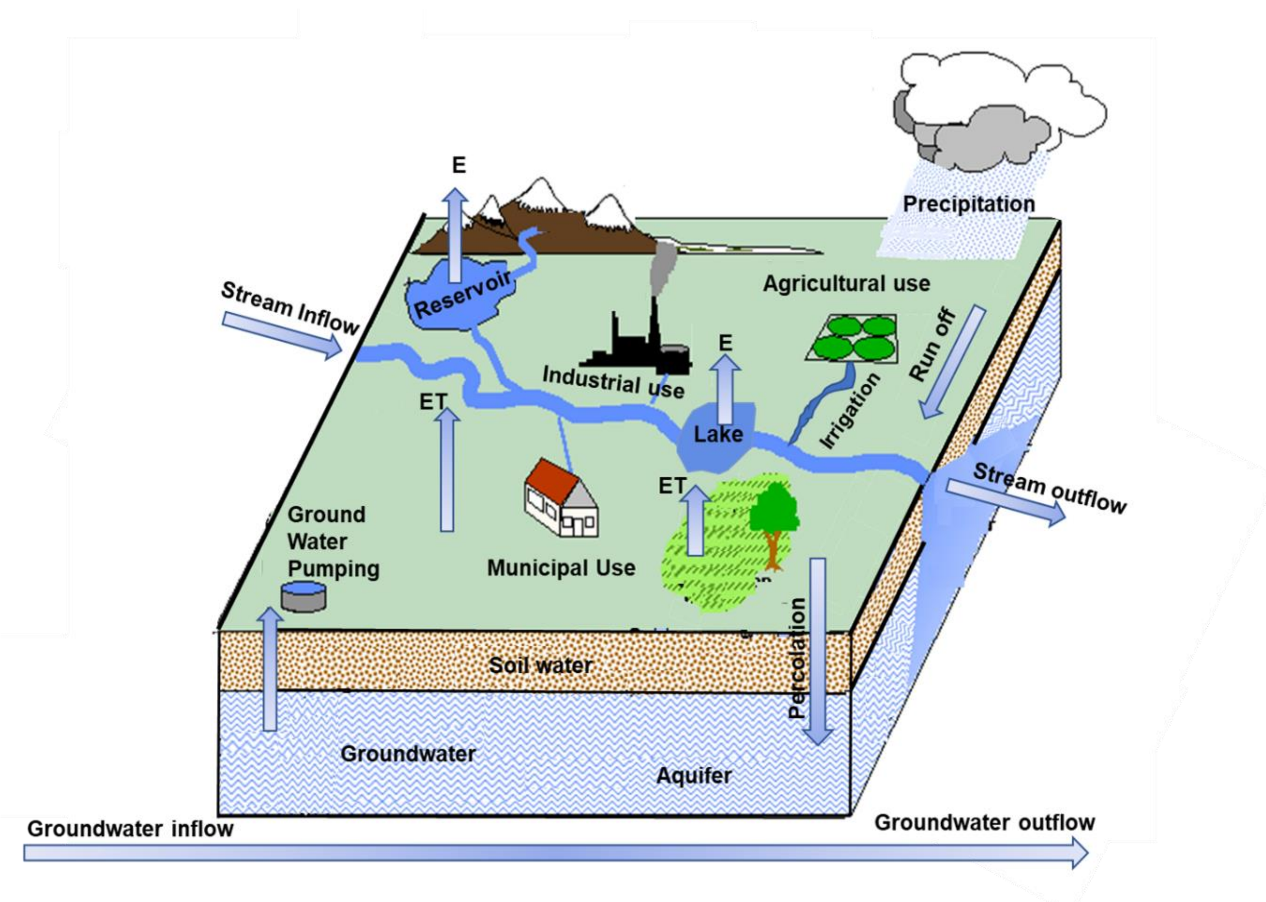

Fig 1. Conceptual model of water budget for a basin

2. Net Change in storage

2.1. Water Inputs

Hydrologic inputs to the Nile basin in two countries is discussed (Gala, 2020a) and is summarized in the following Table 1. Accordingly, Egypt's river sub-basin gets 12.0 BCM from precipitation, 84.0 BCM from Nile river inflow, 9.0 BCM from extraction of shallow and deep groundwater system and 1 BCM from desalinization of coastal water; a total of 202 BCM of water per year as the hydrologic input. On the other hand, Ethiopia's Nile river sub-basin receives 456.6 BCM of water through precipitation. This means Ethiopia's hydrologic input is 254.0 BCM higher and more than twice the amount of Egypt. It also means that Nile water is approximately, 42% of Egypt source of freshwater, but not as the only source as often claimed.

Table 1 Ethiopian vs Egypt rivers of Nile Sub-basins and their Hydrologic inputs

Role No.	Country	Types of Hydrologic Inputs	Volume in BCM	Total in BCM
	Ethiopia			**456.6 BCM**
1		Precipitation	456.0	
		Groundwater extraction	0.6	
	Egypt			**202.0 BCM**
1		Precipitation	12.0	
2		Stream Inflow	84.0	
3		Groundwater extraction	9.0	
4		Desalinization	1.0	

2.2. Water outputs

The hydrologic outputs of Nile basin in two countries is discussed (Gala, 2020b; Gala, 2020c) and is summarized in the following Table 2. Accordingly, Ethiopia's Nile river sub-basin is approximately, losing 12.8 BCM of water through Tekeze-Atbara river, 54.4 BCM of water through Blue Nile river and 13.6 BCM of water through the Baro-Akobo-Sobat river. These a total of 81.0 BCM water loss, 18% of its hydrologic input. On the other hand, Egypt's sub-basin loss of water to Mediterranean Sea through Nile river outflow is 0.000013 BCM. This is insignificant, as it is 15 part per million loss of Ethiopia's Nile sub-basin.

Table 2 Ethiopian vs Egypt rivers of Nile Sub-basins and their outflows

Role No.	Country	River system	Major tributaries	Average Surface Water loss	Total
	Ethiopia				**81.0 BCM**
1		Atbara	Tekeze, Angereb, Ataba and Mereb	12.0 BCM	
2		Blue Nile	Abbay, Jamma, Muger, Guder, Didessa, Beles, and Dabus	54.4 BCM	
3		Sobat river	Boro, Bako and Akobo	13.6 BCM	
	Egypt				**0.00 BCM**
1		Nile river system	Nile River	0.000013 BCM	

Similarly, direct evaporation loss of Egypt's Nile sub-basin is from Lake Nassir. Egypt loses 12 BCM of water per annum from the Lake through direct evaporation and 39 BCM through the evapotranspiration (ET) (Table 3). Conversely, Ethiopia's sub-basin is losing water from Lake Tana, in the order of 5.3 BCM of water, as direct evaporation and 357 BCM as the ET. The cumulative evaporation and ET water loss for Ethiopia's sub-basin is 362 BCM, while Egypt's is 51 BCM. This is 311 BCM more than and almost 9-fold the amount of loss from Egypt's Nile river sub-basin. It is also a loss that amounts to 79% of the rainfall obtained by the sub-basin. The overall hydrologic outputs from Ethiopia's sub-basin 443.3 BCM compared to Egypt's 51 BCM; which is again 392.3 more and 769% higher than the loss from Egypt.

Table 3 Ethiopian vs Egypt Nile Sub-basins and their total ET loses

Role No.	Surface	Mechanism of loses	Amount of ET losses	Total Loss
Ethiopia				**362.3 BCM**
1	Crops/Vegetation	ET loses	357 BCM	
2	Lake Tana	Evaporation	5.3 BCM	
Egypt				**51 BCM**
1	Irrigated agriculture	ET loses	39 BCM	
2	Lake Nassir	Evaporation	12 BCM	

2.3. Water balance (net change in water storage)

The overall water budget, which depicts the net change in water storage in the sub-basins of the two countries is expressed by water budget equation modified as in Table 4. Accordingly, the net change in water storage of Egypt's Nile river sub-basin has superior net storage over the Ethiopia's counterpart. Egypt has an overall net water of 151 BCM compared to Ethiopia's 14 BCM. In other word, Egypt's sub-basin has 137 BCM and eleven-fold more than the net water stored in Ethiopia's sub-basin. This annual available water advantage can supply domestic water for current Addis Ababa residents for almost 137 years. This finding is consistent with the amounts of available water for use of Egypt (i.e., 77.5 BCM versus Ethiopia (i.e., 10.5 BCM) indicated by the global water use statistics on Worldmeter-water (WMI-Water; 2020).

Table 4: Change in water storage of Ethiopian vs Egypt Nile Sub-basins

Ethiopia's Nile sub-basin	**Egypt's sub-basin**
$\Delta S = (P) - (E + ET + OF)$ Where: ΔS = Net storage P = Precipitation (i.e., Rainfalls) E = Evaporation ET = Evapotranspiration OF = Outflow	$\Delta S = (P + IF + GWE + Dsal) - (E + ET)$ Where: ΔS = Net storage P = Precipitation (i.e., Rainfalls) IF = Inflow GWE = Groundwater extraction $Dsal$ = Desalinized water E = Evaporation ET = Evapotranspiration

$\Delta S = (456.0\,BCM) - (5.3\,BCM + 357.0\,BCM + 81.0\,BCM)$	$\Delta S = (12.0\,BCM + 84.0\,BCM + 9.0\,BCM + 1.0\,BCM) - (12.0\,BCM + 39.0\,BCM)$
$\Delta S = (456.0\,BCM) - (5.3\,BCM + 357.0\,BCM + 81.0\,BCM)$ $\Delta S = (456.0\,BCM) - (442.0\,BCM)$	$\Delta S = (12.0\,BCM + 84.0\,BCM + 9.0\,BCM + 1.0\,BCM) - (12.0\,BCM + 39.0\,BCM)$ $\Delta S = (202.0\,BCM) - (51.0\,BCM)$
$\boldsymbol{\Delta S = 14\,BCM}$	$\boldsymbol{\Delta S = 151\,BCM}$

3. Other water reserves

3.1. Surface Water Reserve

Ethiopia is endowed with various Lakes as the surface water reserve. There are 18 major lakes and reservoirs in the country, covering a total area of 7,300 km square and storing about 70 BCM of water (Berhanu, et al., 2014). However, while most lakes are found in Ethiopian Great Rift Valley, only two of these major lakes are found in Ethiopia's Nile sub-basin. These are Lake Tana and Lake Fincha (Chomen). Lake Tana is stretched over a surface area of 3,047 km^2 found in the northwest, near Bahir Dar city of Amhara regional state, situated at 1788 m above sea level and contains 28.8 BCM (Berhanu, et al., 2014). Whereas located in the central Oromia, Lake Fincha is an artificial lake created as a reservoir of Hydroelectric dam on Fincha river. The Lake is stretch over surface area of 293 km^2, sitting on 2,302 m above sea level and holding 0.7 BCM of water (Tefera and Sterk, 2008). Both lakes together store a surface water than amounts to ~ 30 BCM.

Table 4: Water stored on the surfaces of Egypt's and Ethiopia's Nile river basin

	Lakes	Elevation	Surface area (km^2)	Average depth (m)	Volume of water (BCM)	Total (BCM)
Egypt						~138
	Lake Nassir	183	5370	25	132	
	Lake Idku	5	63	79	5.5	
Ethiopia						~30
	Lake Tana	1788	3047	9	28.2	
	Lake Fincha	2,302	239	2	0.7	

Egypt, on the other hand, is also endowed with 12 lakes or lagoons and five of which are within the Nile basin (Zahran, 2008). Three of these lakes (i.e., Lake Manzala, Lake Maryut and Lake Burullus) are shallow lakes with constant interactions with Mediterranean Sea and hence difficult to separate them from the infinite coastal water. The two exclusively inland lakes of Egypt's Nile sub-basin are Lake Idku and Lake Nassir. Lake Idku is stretched over a surface area of 63 km^2 near the city of Edku, on an altitude 5 m above sea level. The lake known for its fish farming, approximately, holds 5.5 BCM of water. Lake Nassir is an artificial lake made as a reservoir of the Aswan dam. The Aswan dam was constructed in 1970 to control the annual flooding and supply energy demand of the country. The lake which is located in the southern most Egypt and northern Sudan is stretched over surface area of 5370 km^2, holding on 132 BCM of water, and on a ground 183 m above sea level. Lakes Edku and Nassir together has a reserve surface water than amounts to ~ 138 BCM of water. In general, Egypt's 138 BCM of reserve surface water is 108 BCM higher and 360% more than Ethiopia's surface water reserve.

3.2. Coastline water

Egypt also has infinite access to coastal water. In total, Egypt has a coastline of 2897 kms on Red Sea, Mediterranean Sea, and Gulf of Suez. The coastline with regard to Mediterranean Sea, which includes Egypt's Nile basin is stretched over 1050 km. The Delta itself, which is a direct interface between Egypt's Nile sub-basin and coastal water is about 300km. This is a gateway for access to coastal water reserve, from which infinite freshwater can be harvested, through desalinization.

3.3. Groundwater Reserve

Several studies have documented the groundwater reserves of Ethiopia and Egypt (MacDonald, et al.,2013; Berhanu, et al., 2014; Satoh, and Aboulroos, 2017). According to MacDonald, et al., (2013), Egypt is among the African countries' that has a huge groundwater reserve. It ranks 4th among the African countries; only Libya, Algeria, and Sudan have more groundwater reserve than Egypt. There are three major aquifers for storing the groundwater in Egypt, namely: the Nubians sandstone aquifer, the Moghara aquifer, and the Nile aquifer (Satoh, and Aboulroos, 2017). Firstly, the Nubian sandstone aquifer is located in the southwestern part of the country shared with Sudan, Chad and Libya. It is assessed to have reserved a groundwater close to 150,000 BCM; where Egyptian segment exclusively reserved a groundwater in the order of 55,200 BCM (MacDonald, et al.,2012; Negm, 2019). Secondly, the Moghra aquifer, located on the northwestern part of the country, is estimated to have a reserve of 7,500 BCM of groundwater. Thirdly, Nile aquifer, which is found underlying the Nile river and delta, is estimated to have reserved a groundwater that amounts to 500 BCM. While, the Nubians sandstone and the Moghara aquifers are relatively deep groundwater storages, the Nile is relatively shallower often recharged by seepage from the Nile river, and the percolations from the irrigation water. It is also the most productive groundwater reserve in Egypt.

On the other hand, Ethiopia's groundwater system is unevenly distributed, spatially variable, discontinuous and isolated, owing to geological and lithological variations (MacDonald et al., 2013). According to MacDonald et al., (2013), Ethiopia is consisted of 4 major geological structures relevant to the country's hydrogeology, namely: the Precambrian basement (18%); the Paleozoic and Mesozoic sedimentary rocks (25%), the tertiary sedimentary and volcanic rocks (40%) and the quaternary sedimentary and volcanic rocks (17%). Most common areas of a groundwater aquifer are located on the geological structure consisted of quaternary sedimentary and alluvial zones. Ethiopia's groundwater reserve is in the order of 12,700 BCM of water, ranking 14th, among the African countries, 9 ranks below Egypt. Seventy percent of country's groundwater is found in Nile basin, while the remaining 30% found in the other part of the country (Berhanu, et al., 2014).

In general, Egypt has an estimated total groundwater storage of 63,200 BCM compared to Ethiopia's 12,700 BCM. This is 50,500 BCM more and 400% higher than the groundwater reserve of Ethiopia. Together with the surface water storage, Egypt has 63,338 BCM reserve water to Ethiopia's 12,730 BCM, which is 50,608 more and 5-fold greater than Ethiopia's reserve. This is without considering 1800 miles coastal area through which Egypt will have for an infinite access to seawater, an access that Ethiopia doesn't has as landlocked nation. Egypt is harvesting saltwater for domestic use through desalination. It is already among 120 countries around the world for having desalination plants to recover and use seawater.

4. Conclusion

The water budget concept is deployed to assess the water resources in Nile basins of Ethiopia and Egypt. The concept is an extension of the law of conservation of matter, which assumes that a matter never destroys that it only changes from one form to another. Therefore, the sum of materials in the reactant is the same as the sum of all possible products. Likewise, the concept assumes that the sum of the hydrologic inputs for a given watershed is equal to the sum of all the possible hydrologic outputs from the watershed. This article has made a comprehensive analysis and assessment of the hydrologic regimes and water movements in the Nile river sub-basins in in these two countries. Accordingly, Egypt's Nile river sub-basin has four pathways of receiving a total of 202 BCM of water per year; whereas Ethiopia's hydrologic input is 456.6 BCM. The hydrologic input of Ethiopia's Nile river sub-basin is 126% higher than the amount Egypt's receives. On the other hand, Ethiopia's sub-basin is losing a total of 443.3 BCM of received water through a stream outflow and the ET, which is about 96% of hydrologic input. Egypt is losing only 51 BCM of the received water through the ET, which is 25% of the input. In total, Egypt has a net surplus storage water of 151 BCM of water to Ethiopia's only 14 BCM, clearly indicating Egypt's rather higher annual net water resource advantage over Ethiopia. Additionally, Egypt has more reserve of surface as well as subsurface water when compared with Ethiopia. Egypt's surface water reserve of 138 BCM of water is 360% greater than Ethiopia's 30 BCM surface water reserve. Moreover, the groundwater reserve of Egypt is 63,200 BCM, 5-times more than Ethiopia's 12,730 BCM. Furthermore, Egypt has an infinite access to seawater for harvesting of freshwater through desalination, the resource that Ethiopia has no access to as a landlocked nation. Therefore, according to the water budget assessment of the Nile basin in Egypt and Ethiopia, the quantities of water in Egypt's sub-basin is infinitely superior to that of Ethiopia. This expose, the emptiness of the ill- engrained perception of Ethiopia's plentiful water resources, maliciously pushed by Egypt and naively echoed by international communities and financial institutions. This is a violation of the ideals of fairness and equitable utilization of shared resources in accordance with convention of transboundary water. It is also an infringement to international law of a sovereign state to fully control over affairs within ones' territory. The fact all these are committed on Ethiopia, a landlocked, sub-Saharan African country, with multi-faceted socio-economic problem, is harsh.

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