Part III: Debunking Ethiopia’s Plentiful Water Resources vis-à-vis Egypt: A Closer Look at the Hydrologic Outputs - Evapotranspiration

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Abstract

Evapotranspiration is among critical ecosystem processes, which facilitates water movements in hydrologic cycle and its redistribution on the earth’s surface. However, evapotranspiration is also a mechanism by which available water on the surface and subsurface, is lost from the ecosystem into unavailable water form. Such loss of water is a critical fraction of hydrologic inputs (i.e., precipitation, stream inflow, groundwater extraction, etc..) of a basin. This article assessed the evapotranspiration of Egypt’s and Ethiopia’s sub-basins to resolve the quantities of sub-basins’ water losses and the resultant water resources of the two countries. Accordingly, the Ethiopia’s Nile river sub-basin and Lake Tana together lose a total of 353.3 BCM of water through the evaporation and evapotranspiration; while Egypt loses 51 BCM water from its arable lands of the sub-basin. This Ethiopia’s water loss is, approximately, 7-folds and 600% more than a loss from the Egypt’s sub-basin, an accounting that is ignored from the alleged Ethiopia's possession of plentiful water resources. Therefore, in the interest of rational and reasonable deliberation, it is imperative that this component of hydrologic outputs is appraised and made available for debates and inform the settlements on the Nile basin water resources sharing.

Keywords: Evaporation, Evapotranspiration, Water budget, Grand Ethiopian Renaissance Dam (GERD), Egypt, Ethiopia

1. Introduction

Evaptranspiration is a critical process in a hydrologic cycle of a watershed or landscape. When the input component of hydrologic cycle, a rainfall event land a landscape, it has one of the following three fates. These are run-off, evaporation, and infiltration into soils. Run-off, which discussed in Part II of this article, is a fraction a rainfall event, excess of infiltration, that flows down-slope a basin or landscape. This run-off water concentrates into channelized rivers or streams for eventual discharge of rainfall water into inland lakes or ocean. Conversely, infiltration is a fraction of a rainfall event that soaks the soil to constitute soil-water available for plant growth. Some infiltration water further percolates deep into subsurface saturated zone to recharge the groundwater. The third is evaporation, a fraction that evaporates to atmosphere in gaseous form.

Such change in phase of water from liquid to gas, has various hydro-ecological implications. For instances, Evapotranspiration consumes lots of energy to mediate the phasal change of water and thence, connect global hydrologic and energy cycle, to control regional weather and climate phenomenon. It is also a mechanism by which moisture redistribution is enhanced from regions of high moisture status (i.e., oceans and sea) to regions that are relatively dry. Evapotranspiration (ET) is a combined process of evaporation and transpiration. While evaporation denotes a process of converting rain waters intercepted by soils, held in lakes, wetlands and rivers, and wet vegetation, into water vapor; transpiration denotes the process by which soil-water absorbed by the plant roots are released into atmosphere, as vapor, through plants' leaves openings. Both Evaporation and transpiration are pathways of basin's water resources are loss. However, transpiration is rather considered a productive water losing process, unlike evaporation, because transpiration suction (i.e., pull) also facilitates plants' nutrient absorption and crop production. Additionally, an absorbed water, through this suction, helps maintaining plants' cellular pressure that offers the necessary structural support.

Several soil-plant-atmospheric factors are affecting the actual ET rate. These are solar radiations, air temperatures, humidity, wind-speeds, soil moisture contents and land cover characteristics. Firstly, solar radiation is an energy input from the sun, which in the process of heating the earth surface, aerosols and air molecules; affects the ambient air temperature. The air temperature provides the latent heat needed for vaporization. Secondly, humidity is a quantity of water vapor in the air, and is contingent on the ambient air temperature. Usually, warmer airs have lower relative humidity and therefore, have more rooms for holding vapor than the colder airs. Thirdly, wind-speed and aerodynamics affects ET by horizontally bringing evaporative heat through advection (i.e., horizontal transfer of heat via wind-flow). Additionally, they enhance the displacement of the humid air, from near the plants, by rather drier air with more evaporative demands. Lastly, soil moisture influences the types and densities of vegetation cover on the landscape. ET is generally higher on the landscape covered with taller, rough, and deep-rooted plants than the otherwise.

The measurement of actual ET of a basin or landscape would, therefore, requires parameterizing and quantifying the above-mentioned soil-plant-atmosphere factors and the interactions therein. This is difficult considering that it would demand extensive and comprehensive mechanistic modeling exercises, especially for approximations at the scale of watershed. A pragmatic solution for this has been the implementation of a simplest approach, which involved estimating the actual ET of an area from inference of its potential. Hence, the Potential ET is the amount of water evaporating from an area, when there is no barrier or an ample amount water is present. The assumption is that the potential ET is only constrained by the ability of the ambient air to evaporate.

Generally, evapotranspiration is potentially high for both in Egypt and Ethiopia, because of latitudinal location with regards to incident of solar radiation. However, the actual ET in these two countries are very different. For example, the higher incident solar radiation, coupled with soil moisture contents, and vegetation cover, which pumps subsurface water is essentially responsible for higher actual ET from Ethiopia's sub-basin (Fig. 1). On the other hand, although, the evaporative demands of Egypt's sub-basin's ambient air are high (because of direct incident radiation), soils are dry and are devoid of vegetative land cover. Besides, a relative dull topography and gentle air pressure gradient makes the wind-speed and aerodynamic low. As a consequence, the actual ET loss is from the Egypt's Nile river sub-basin is lower, despite high evaporative demands of the ambient air.

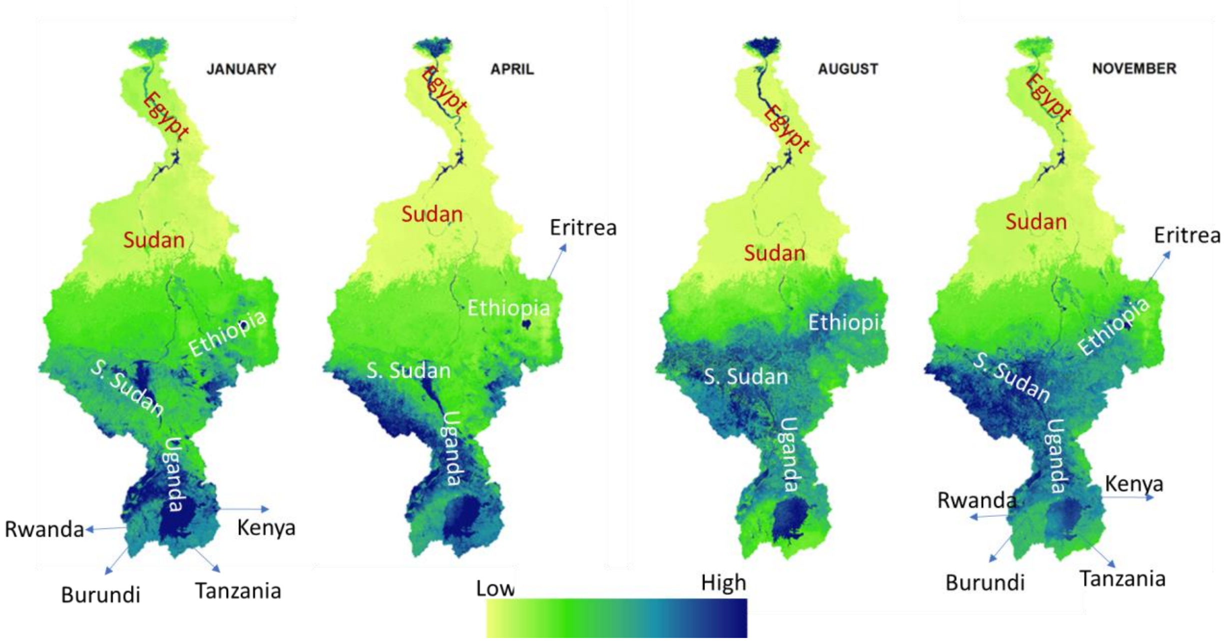

Fig 1: Direct evaporation and evapotranspiration (ET) of January, April, August, and November from the Nile river basin (Source; Nile basin water resource Atlas).

It is, therefore, most likely that the actual evaporation and evapotranspiration loss from Ethiopia's Nile sub-basin may erases any rainfall advantage it had over Egypt. Hence, the objective of this article is to conduct detailed inventory of the evaporation and transpiration of Egypt's and Ethiopia's sub-basins. This is to shed light on the magnitude of sub-basins' water losses through the actual ET, which is critical for objectively comparing resultant available water resources in these two countries. The ultimate goal is again to debunk the alleged Ethiopia's plentiful water resources possession vis-à-vis Egypt.

2. Evapotranspiration

2.1. Evaporation

Both Egypt's and Ethiopia's Nile sub-basins are experiencing loss of water through direct evaporation. Ethiopia's sub-basin is directly losing from the Lake Tana, whereas Egypt's is losing from the Lake Nassir (Table 1). Lake Tana, with surface area of 3047 km^2, is losing vapors at estimated evaporation rate of 1722 mm per annum, which is equivalent to 5.3 BCM of water per year (Table 1). On the other hand, evaporation loss from Egypt's sub-basin is restricted to expanded flood water created behind Aswan dam also known as Lake Nasser. Evaporation loss from the Lake Nasser, with the surface area over 5370 km^2, is estimated to be 2222 mm per annum, which amounts to 12 BCM of water per year.

Table 1: Direct Evaporation over Nile sub-basins (Source: Nile base initiative)

Lake names	Surface Area (km2)	Direct Evaporation	
		Rate (mm/year)	Volume (BCM/year)
Lake Tana	3047	1722	5.3
Lake Nasser	5370	2220	12

Generally, the direct evaporation loss from the Lake Nassir is more than 2-fold and 126% higher than the amount from the Lake Tana. This is partly because of the Lake Nassir's surface area of exposure, which is 76% higher than the Lake Tana. Additionally, it could also be due to higher evaporative demands of air above the Lake Nassir versus Tana. The evaporative demands of the air over Lake Nassir is 30% higher than the Lake Tana. Therefore, considering that the Lake Nassir is an artificial lake, this higher evaporative loss is a classic example of an inefficient Nile water use, on the part of Egypt.

2.2. Evapotranspiration

Table 2 shows the actual ET on Ethiopia's and Egypt's Nile basin. Rates of the actual ET losses are variable among areas of Ethiopia's Nile sub-basin. In general, the rate is highest on the Baro-Akobo-Sobat sub-basin (i.e., 1,070 mm/year), followed by the Blue Nile (i.e., 945 mm/year) and the Tekeze-Atbara sub-basin (i.e., 630 mm/year). The rate of the actual ET loss from the Baro-Akobo-Sobat sub-basin is 13% higher than the Blue Nile and 70% higher than the Tekeze-Atbara sub-basin. The Blue Nile sub-basin is in turn losing at the rate 50% higher than the Tekeze-Atbara. Such variation of the actual ET rates is, perhaps, attributed to varying moisture regimes, micro-climates and vegetation characteristics.

Table 2: Evapotranspiration loss over Nile sub-basins

Sub-basin names	Surface Area (km^2)	Evapotranspiration (ET)	
		Rate (mm/year)	Volume (BCM/year)
	Ethiopia Total		348
The Tekeze-Atbara	139115	630*	88
Blue Nile	200065	945**	189
The Baro-Akobo-Sobat	65930	1070*	71
	Egypt Total		39
Egypt's Nile valley & Delta	46200	848***	39

* Nile Basin Initiative, 2014
** Allam, et al., (2016)
*** Salama et al., (2015)

However, the Blue Nile sub-basin is leading in the overall actual ET loss. It loses 189 BCM of water, from 200065 km^2 catchment area, followed by the Tekeze-Atbara, which is losing 88 BCM of water from 139115 km^2, and the Baro-Akobo-Sobat that is losing 71 BCM of water per year from 65930 km^2. Accordingly, the Blue Nile sub-basin loses 115% more water than the Tekeze-Atbara and 166% more than Baro-Akobo-Sobat sub-basin. The Tekeze-Atbara sub-basin in turn loses 25% high water than the Baro-Akobo-Sobat, the difference is, in part, attributed to variations of the sub-basins' surface area. Generally, Ethiopia's Nile sub-basin is losing a total of 348 BCM of water per year via the actual ET losses.

On the other hand, the actual ET loss from the Egypt's sub-based is restricted to strips of arable lands on the flood plains of the Nile river and delta. This cover a geographic area of 46,200 km^2 (FAO-Aquastat, 2015). According to the FAO-Aquastat, (2015), Egypt's agriculture is 100% irrigated and it consumes, approximately, 85% of 55 BCM of water assigned to the country as per 1955 Nile water agreement. This amounts to an irrigation water use of 47 BCM water per year. However, only a portion of this irrigation water is lost as the actual ET, while the other portion is percolating to recharge the groundwater that often recycled for the municipal water use (FAO-Aquastat, 2015). Salama et al., (2015) reported the water use efficiency of irrigated Egypt's agriculture. According to Salama et al., (2015)'s report, Egypt's irrigated agriculture is 84% water efficient in crop production, which can also be translated as the actual ET loss at rate of 848 mm/year and a total loss of about 39 BCM per year. This Egypt's loss is 1/9 of and 309 BCM water less than the amount of the actual ET loss on Ethiopia's Nile sub-basin.

3. Conclusion

Evaporation and transpiration are important ecosystem processes that control the movement of water among the components of hydrologic cycle. They are also the processes by which landscapes or watersheds are losing a huge sum of water resources into atmosphere. The Ethiopia's Nile sub-basin loses 348 BCM of water through the actual ET and 5.3 BCM of water through direct evaporation. On the other hand, the Egypt's sub-basin losses 39 BCM of water through the actual ET, and 12 BCM through the evaporation. The Ethiopia's total evaporation and actual ET loss of 353.3 BCM of water is 7-folds and 600% more than the loss from the Egypt's sub-basin, which is totaling 51 BCM of water. The water resource loss, of this magnitude, would essentially erase any rainfall advantages that the Ethiopia's Nile sub-basin had over the Egypt. Therefore, again the perception that Ethiopia has plentiful water resources is dubious because it is without accounting these losses, which actually has shown a strong evidence of a relative water advantage of Egypt over Ethiopia.

4. References

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