Water bankruptcy in the mighty Nile river basin

Dagmawi Mulugeta Degefu¹ · Weijun He^{1,2}

Received: 23 September 2015 / Accepted: 9 November 2015 / Published online: 26 November 2015
© Springer International Publishing Switzerland 2015

Abstract Water is crucial for sustaining life and development. The Nile river basin is one of the river basins supporting human life since the earliest days of human civilization. Currently, with increasing water demand the river basin is experiencing pressures and the water conflict in the region is deepening. The riparian countries are building and planning various unilateral water use schemes along the river to meet their growing water demand. This paper considering the current and predicted water demands of the riparian countries introduces a new approach that should be taken into consideration in the management of the river basin, i.e., the scenario of water bankruptcy. After a careful analysis of the predicated water availability and demand in the river basin the authors believe that water bankruptcy is inevitable in the river basin. The water allocation and water right determination efforts in the river basin should take account this scenario into consideration. Doing this will assist in avoiding water conflicts in the future and ensure the fairness and sustainability of allocation rules.

Keywords Nile river basin · Bankruptcy · Water conflict · Water allocation · Water demand

Introduction

The Nile river basin is one of the most important basins since ancient human civilization and continues to be so until this day. It is the longest river in the world covering a distance of 6695 km. It drains an area of 3.1 million km² and its catchment basin covers approximately 10 % of the African continent, making it one of the largest and most important river basins in Africa (Nile Basin Initiative 2012a, b; FAO 2007).

The river basin is characterized by unevenly distributed water resources and uses. In addition, the basin's hydrology is highly variable through time and space (Nile Basin Initiative 2012a, b). The majority of the water originates from Ethiopia which is the source of the river's biggest tributary known as the Blue Nile; the remaining water is from the White Nile. Even though their contribution to the Nile water is almost negligible the majority of the water is utilized by the downstream counties, Egypt and Sudan.

The Nile river basin has always been a center of the attention in the region due to the existing water conflict and till this day there are no allocated water rights or benefits to the riparian countries which incorporates the principles of equitable and reasonable utilization of the basin's water resources which was stated by the united nations as a core principle for the management of transboundary water resources. The lack of agreed-upon rules for water and water right allocations makes the ongoing water conflict between the riparian countries more complicated.

The main reason for the lack of water allocation agreement between the riparian countries is because of the various asymmetries which exist between the basin countries. These asymmetries are the main reason for a common consensus not been reached between the riparian countries in terms of finding water allocation scheme that

✉ Dagmawi Mulugeta Degefu
dagmawimulugeta@outlook.com

¹ College of Hydraulic and Environmental Engineering, China Three Gorges University, Yichang, China

² College of Economics and Management, China Three Gorges University, Yichang, China

incorporates the principles of efficiency and equity. The asymmetries arise from differences in water contribution, political power, military, geographical position, water claims and historical uses that exist among the countries. These differences in turn bring differences among the riparian countries in terms of negotiation power (bargaining power).

The improved planning, management and extensive development of the Nile river basin first started in the downstream countries Sudan and Egypt and are mainly attributed to the British colonial era (Parkes 2013). Since then the basin's economic, environmental and social importance in the region has been increasing significantly. There are several reasons for the increasing significance of the river basin. The main ones are the increasing population and the emergence of new users and uses as a result of economic development in the basin. The Nile river basin is also sensitive to water stress and scarcity which could result due to climate change (Eckstein 2009). Considering the uncertain impacts climate change might have on the river basin in the future the riparian countries are competing for the river water (Table 1).

With the increasing extent of water use by the downstream countries and increasing number of number of new water users in the river's upstream, the hydro-political disputes between the riparian countries has been intensifying in recent years. Ethiopia, Sudan and Egypt are the three riparian countries which have huge roles in the existing water conflict. Cooperation and agreement between these countries could be the key for finding a sustainable solution for the water conflict in the basin.

Ethiopia

Ethiopia is the major contributor to the river waters since more than 85 % of the Nile water originates from the Blue Nile and also has positional advantage because it is an

upstream country (Elimam et al. 2008). The country's recent development policies put its water resources on the center of its development plans. The country only been able to utilize 5 % of its total surface water and only 0.6 % of the water resources of the Nile (Arsano and Tamrat 2004). The Blue Nile is among the main river basins in the country which are selected for fast track implementation of water development projects. The Ethiopian Grand Renaissance Dam, which will be the largest dam in Africa when completed, is a witness to the country's commitment to develop its water resources, especially the Blue Nile which is the main tributary of the mighty Nile.

Sudan

On the other hand Sudan also holds an important position and the country wants to maintain its good relationship with Egypt considering their previous bilateral agreements on the Nile River which are highly skewed in their favor (Selby and Clemens 2014). Egypt also supports the agricultural expansion in Sudan through its 'African farms' strategy. This also another bonding link between Sudan and Egypt which Sudan does not want to break.

The country also has the interest to benefit from the regulated water levels and cheap hydroelectric power which will be generated from the planned Ethiopian hydroelectric generating dams. Power transmission lines between the two countries which started to be built in 2010 with the support of the world bank's financial aid is a project which shows the country's intent to build energy market with Ethiopia. This initiative could be source of sustainable development and cooperation between the two Nile riparian countries (World Bank 2007). Besides it could be the bridging link that can assist in nurturing cooperation and agreement for the sustainable management of the Nile river between the two countries.

Table 1 The main Nile river basin Riparian countries

Country	Country area 1 (km ²)	Area within the Nile basin (km ²)	% of the total Nile basin area	% of the country in the Nile basin
Burundi	27,835	13,260	0.4	47.6
DR Congo	2,345,410	22,143	0.7	0.9
Egypt	1,001,450	326,751	10.5	32.6
Eritrea	121,320	24,921	0.8	20.5
Ethiopia	1,127,127	365,117	11.7	32.4
Kenya	82,6505	46,229	1.5	7.9
Rwanda	26,340	19,876	0.7	75.5
Sudan	2,505,810	1,978,506	63.6	79.0
Tanzania	945,090	84,200	2.7	8.9
Uganda	236,040	231,366	7.4	98.0

Source: CIA (2003) <http://www.fao.org/docrep/W4347E/w4347e0k.htm#theNilebasin>

Egypt

Egypt is the most superior country in terms of political power and economic development in the basin and has been historically using the river almost solely (Parkes 2013). Because of the country's superior political and military power compared to the other riparian countries, the country was able to maintain its hydro-hegemony on the Nile river basin in the past. Currently the country is demanding the right to the majority of the Nile water which corresponds to its historical water use (Cascão and Zeitoun 2010).

The other upstream riparian countries on the White Nile have not been given enough attention in the past because of their low demand and relatively smaller contribution to the total volume of the river water. But recently their importance in the water allocation of the river's water has been increasing because of their extended plans to develop the river basin within their territory to fulfill their increasing water demand.

Considering the need for the integrated management of the river basin to ensure equitable utilization, the Nile river riparian countries established the Nile basin initiatives to deal with the various issues in the river basin. In most of the transboundary river basin water sharing agreements the biggest problem is lack of higher independent authority which ensures compliance (Ansink and Arjan 2008). The Nile river basin is no different; the Nile basin initiative also suffers from this problem. It has limited enforcing capability since it is established by different sovereign riparian countries. While the initiative represents a critical first step forward for basin wide cooperation necessary to tackle the region's looming water crisis, critics suggest that progress of the NBI has been slow (Keith et al. 2013).

The Nile riparian countries except Egypt and Sudan have signed the Nile basin cooperative framework which aims to strength the cooperation between the riparian countries for the sustainable management of the Nile river basin. The fact that the two main important riparian countries have not signed the cooperative frame work is one evidence that shows the limited enforcing capacity of the initiative (Fig. 1).

Water uses in the Nile river basin

Nile river can support different multipurpose water management schemes. The upper eastern Nile basin in Ethiopia is very suitable for hydro power generation and building large reservoirs because of the suitable geological features and the low rate of evaporation (Nile Basin Initiative 2012a, b). Meanwhile, irrigation schemes are abundant in the downstream countries, Egypt and Sudan. However, several of the upstream countries now appear as stronger

parties in the competition for the Nile water and they have plans to increase their irrigation capacity too, to satisfy their growing demand for agricultural products (Cascão 2009). Hence this Basin is under rapidly growing pressure. The growing water scarcity and falling per capital water availability in the region indicate that most of the river basin countries are either water-scarce or water-stressed countries (WWAP 2015). Therefore, the competition for the river water is only expected to intensify as time goes by.

During the development and planning of water use and management projects on transboundary rivers the water consumption nature of the planned schemes are of due importance since the river is shared by the several riparian countries. If the schemes are highly water consumptive they could have huge impact on the availability of water in the other riparian countries.

Most of the riparian countries have hydropower and irrigation development plans on part of the basin with in their sovereign territory. There are several hydro power reservoirs planned to be built or are being built in the upstream of the river, especially in Ethiopia. The hydro power reservoirs built in the upstream of the basin are not water consumptive because the evaporation rate is very low. On the other hand, the evaporation rate in Sudan and Egypt which are the downstream riparian countries is very high compared to the Ethiopian highlands. In Aswan, 10–15 % of the Nile's water gets lost due to evaporation (Anja 2011). Besides in hydro power plants, less than 10 % of abstracted water is actually consumed during power generation and the vast majority of the abstracted water is redirected to the water cycle, ready to be used for other purposes by the downstream (Ansink and Arjan 2008). Hence hydropower development projects in upstream countries are not highly water consumptive. The only issue associated with hydropower schemes in the upstream is the time delay in the flow of water to the downstream riparian countries due to the time the water spends in the reservoir for the purpose of power generation. But this could also have its own advantage for downstream countries since it will feed constant water volume all year around for the downstream countries and makes more water available by reducing the losses as the result evaporation and seepage; in addition, the reservoirs can provide a buffer in water supply, decreasing the dependency on river water in low flow years (Halla 2008; Janmaat and Ruijs 2007).

Agriculture is the largest water-using sector in the world, accounting for 70 % of global water abstraction (Shiklomanov and Rodda 2003). Hence agricultural water needs in the basin are under huge treat from shortage of water that could happen due to the increasing demand or as a result of climate change. For instance Ethiopia plans to

Fig. 1 The Nile river basin.
Source: The World Bank (2000)
http://siteresources.worldbank.org/INTAFR/NILEBASINI/About%20Us/21082459/Nile_River_Basin.htm

expand agricultural production by an additional 3 million ha with the addition of many small and large-scale irrigation schemes in the basin. Meanwhile, Egypt has plans to develop the North Sinai Desert which is a huge land reclamation project estimated to cost nearly US\$2 billion (International Water Management Institute 2012).

The water availability to satisfy the increasing water demand for irrigation in the long term is uncertain considering the rising water demand and the fact that most of the basin's riparian countries are water scarce or stress

countries (WWAP 2015). It is inevitable the river basin will be under immense pressure in the near and far future. The main reasons for the increasing demand are population increase, economic development and the uncertain impacts of climate change.

Population increase

The population number in the riparian countries has dramatically increased in the recent years in the basin

Table 2 Total population by country, 2015, 2030, 2050 and 2100 (medium variant)

2005–2030 Nile basin population prospects: medium UNDESA variant

Country	2015 Nile basin ('000)	Nile basin 2030 ('000)	Nile basin 2050 ('000)	Nile basin 2100 ('000)
Burundi	11,179	17,357	28,668	9911
DR Congo	77,267	120,304	195,277	388,733
Egypt	91,508	117,102	151,111	200,802
Eritrea	5228	7311	10,421	15,616
Ethiopia	99,391	138,297	188,455	242,644
Kenya	46,050	65,412	95,505	156,856
Rwanda	11,610	15,785	21,187	25,692
Sudan	40,235	56,443	80,284	127,328
Tanzania		82,927	137,136	299,133
Uganda	39,032	61,929	101,873	202,868

countries. According to projections it seems that it will follow this trend into the future. According to United Nations Population Division, by 2030 the population number in riparian countries will be more than 654 million with more than half of the population living in the basin (UN 2012, 2015) (Table 2).

This trend of population growth in the basin countries is increasing the demand for the water in the already existing water abstraction sites and is forcing the riparian countries to start fast tract implementation of projects or to lay down unilateral development plans for the future in the sub-basins with in their sovereign border to support their current and predicted water demand. Thus projections of population number in the Nile river basin indicates that unless urgent measures are taken to address the rising population, the vulnerability of the countries to water shortage will keep increasing and water scarcity will most probably prevail deeply in the basin.

Economic development

Nile basin economies are heavily dependent on agriculture which accounts for more than half of the Gross Domestic Product and employs a majority of the workforce (Swain 2001; Anja 2011). These agriculture-based economies are highly vulnerable to water scarcity; hence these countries have strong desire to exploit the Nile river basin to the extent they can to mitigate this challenge. Most of the Nile river basin countries are among the poorest countries in the world, but recently the economies of these countries have been growing very fast (Table 3).

With the growing economy and GDP the water consumption behavior of the various economic sectors in the riparian countries are increasing. In the future the demand for the water will also increase more with the changing

Table 3 Year-over-year GDP growth rate in Nile Riparian countries

Country	2012 (%)	2013 (%)	2014 (%)
Burundi	4	4.5	4.7
DR Congo	7.2	8.5	8.6
Egypt	2.2	2.1	2.2
Eritrea	7	1.3	2
Ethiopia	8.8	9.7	8.2
Kenya	4.6	4.6	5.3
Rwanda	8.8	4.7	6
Sudan	−2.7	3.3	3
Tanzania	6.9	7	7.2
Uganda	2.8	5.8	5.9

Source: CIA (2003) World fact book <https://www.cia.gov/library/publications/the-world-factbook/fields/2003.html#et>

lifestyle of the people living in the river basin because of the rise in the standard of living.

Climatic change

In many river basins, water supply is negatively affected by climate change, in terms of average water availability and variability of runoff (Ansink and Harold 2015). Nile Basin is characterized by its high climatic diversity and variability, a low percentage of rainfall reaching the main river and an uneven distribution of water resources. (Mark and Jury 2011; Nile Basin Initiative 2012a, b). Potential evaporation rates in the Nile region are also very high, making the basin particularly vulnerable to drought (Nile Basin Initiative 2012a, b; Conway and Hulme 1993). It is estimated that the changes in precipitation and temperature in the future will have a huge impact on the water availability and variability of run off in the river basin.

Hence, different studies using different scenario models were done to simulate the future flows of the Nile River and found contrasting results (Voss et al. 2002; Strzepek et al. 1995; IPCC 2001; Conway 2005; Conway and Hulme 1996; Yates and Strzepek 1998); Tate et al. 2004; Yates et al. 2000; Kim and Kaluarachchi 2009; Arora and Boer 2001). Meanwhile Arnell 1999 argued that the precipitation level in the river basin would increase in the future but the increase will be equally met by the increased evapotranspiration indicating that the impact of the increased precipitation in the future is insignificant. This opinion was shared by (Vella 2012) who predicted that ultimately, climate change is expected to exacerbate the natural deficit of water resources in the Nile basin region.

Though the magnitude decrease in natural average runoff water in the river basin due to climate change is uncertain, the Nile river basin is known historically for its climatic diversity; hence the effect of the climate change will be variable through space and time causing high variability in water availability between different geographical regions. This could have very huge consequences for water resource management schemes in the basin and might be the probable cause of conflict.

The Nile river basin conflict

The Nile river basin has been supporting the livelihood of people in the basin for thousands of years by satisfying the increasing water demand. The river basin just like the most of the river basins in the world is currently feeling the pressures of increasing water demand and is becoming a source of conflict between the riparian countries. The demand for the Nile river waters has evolved through time with the social economic and environmental characteristic of the basin's riparian countries.

Until this day Egypt is claiming for the majority of the Nile waters by stating the historical rights of water use based on principle of prior utilization and bilateral agreements the country signed during the colonial era with the other downstream country, Sudan (Waterbury 2002). These agreements completely neglected the water contribution and the demand of the other riparian countries, completely ignoring the factors that should be taken into account for sharing transboundary river water resources stated in the united nation water course convention (UN 1997).

But currently, since most of the other riparian countries are asking for their share of water in the basin, the water conflict in the basin is at a more serious stage now than ever. Especially, Ethiopia following the political and economic stability that has prevailed in the country for a while now has started challenging Egyptian hydro hegemony through the unilateral development of hydraulic

infrastructures on the Blue Nile river (Cascão 2009; Cascão 2008; Laura 2013). Similar development intentions are also being expressed by the other upstream riparian countries of the White Nile (Cascão' 2009). The downstream countries are demanding that prior utilization entitles them the right to use the Nile water while those countries upstream argue that they have the right to use the water in their sovereign territory. Such conflicting extreme positions taken by the riparian countries in the river basin is having huge implication in deepening the water conflict in the river basin.

The timing of potential conflict as a result of water scarcity is expected to be most pronounced between 2020 and 2040 in anticipation of water resource constraints (Keith et al. 2013). Therefore, the effect of the rapidly increasing consumptive water demand for the river water will be a source of more serious conflict in the Nile basin in the near future even without uncertain impacts future climate change might have on the river basin's water availability.

Water bankruptcy in the Nile basin

The Nile river is shared by more than ten riparian countries. Its significance in the socio-economic development of the region is huge. Because of the overlapping water uses of the riparian countries it is well known that the basin has been the source of conflict but with increasing water demand in the river basin's riparian countries the hydro-political tension has intensified in recent years.

All the Nile river riparian countries are asking for their share of the river water. The determination of claims in the Nile river basin is a very challenging process. The main reason being the lack of worldwide accepted method for determining the credible and legitimate claims of the riparian countries in the shared river basins (Wolf 1999).

Water allocation mechanism for transboundary river basin should take into account the water availability and variability as the result of increasing demand and climatic

Table 4 The irrigation areas (Ha) in the Nile river basin for the current, medium- and long-term scenarios (Molden et al. 2010)

Country/sub-basin	Current	Medium-term	Long-term
Burundi	0	18,160	80,000
Egypt	3,324,300	3,764,733	4,205,166
Ethiopia	15,900	343,503	1,216,130
Kenya	5,600	70,000	200,000
Rwanda	5,000	50,000	155,000
Sudan	2,175,600	3,574,620	4,503,240
Tanzania	475	10,000	30,000
Uganda	9120	80,000	247,000
Total	5,535,995	7,911,016	10,636,536

Table 5 Total irrigation water demands (million m³) for the current, medium- and long-term scenarios (Awulachew et al. 2012)

Country/sub-basin	Current	Medium-term demand	Long-term Demand	Water that will be available in the future	
				Medi-um term	Long-term
Burundi	0	200	880	84.1 km ³	88.2 km ³
Egypt	43,216	48,942	54,668		
Ethiopia	152	4190	15,178		
Kenya	48	595	1700		
Rwanda	63	625	1937		
Sudan	22,425	39,239	50,992		
Tanzania	5	110	330		
Uganda	73	640	1976		
Total	65,982	94,541	127,661		

change, respectively (Drieschva et al. 2008). Considering this the best way to estimate the different water claims of the riparian countries is by assessing the current, short-term and long-term unilateral development plans. This way of determining the claims of countries facilitates the designing of the allocation schemes which are very flexible with the variable water availability and the increasingly changing demand of the riparian countries in the river basin.

According to a study done by Awulachew et al. (2010), the Nile river will be short of water in a few years. Taking into account the current unilateral water management and planning trends in the basin their study found that the total water requirement for the medium-term and long-term scenario would be 94.5 and 127 km³, respectively, higher than the 84.1 km³ short-term and the 88.2 km³ long-term predicted average water that is expected to be available in the basin. The results match the prediction made by (Molden et al. 2010; Brunnee and Stephen 2002) who stated that the water availability in the basin for the short-term and long-term future scenario will not be enough to satisfy the water demand in the basin.

Considering the extensive plans laid down by the riparian countries for unilateral execution, this prediction seems to be valid. It is only a matter of time before the Nile river basin become insufficient to meet the rapidly growing consumptive water demand and become water bankrupt, where the total water available is less than water demand (Table 4).

The above predictions were made considering the average flow of the river and the increasing demand for the river water; the uncertain impacts climate change might bring on the river basin were not incorporated. Regardless of the impacts of climate change, it is the matter of time before the river reaches its carrying capacity and become physically water bankrupt due to the rising water claims in the basin.

It is argued that the growing demand and variability in the supply of water will lead to a global shortage of water resources (Black and King 2009; Melinda and Faith 2014; Rogers and Leal 2010). Taking these conditions into account, possibility of physical bankruptcy of water in the future is inevitable in any river basin, but in a river basin like the Nile which has huge economic, environmental and social role under competing users the time frame for the demand to surpass the available water stock is more shorter.

Various scientific studies have emphasized that there is a cause and effect relationship between resource scarcity and conflicts, predicting that an increased demand for freshwater resources would likely lead to conflicts (Homer and Thomas 1994). Due to the lack of data only the demand of nine countries is considered (Table 5).

It is highly probable that water scarcity in the river basin will bring serious water conflicts in the region which could hinder the economic development of most of the riparian countries. Therefore, taking the bankruptcy scenario into consideration when designing a water allocation scheme for the Nile river is of great significance, since it will enable us to design a water allocation mechanism which is flexible, robust and sustainable.

Conclusion

The mighty Nile is a river which is highly tied with the social, economic and environmental conditions of the region. It has an immense importance in the region serving as niche for socio-economic development for the people living inside and outside the basin directly or indirectly. As we have discussed above, the river is becoming close to water bankruptcy as time goes by due to the rapidly rising water demands of the riparian countries. The authors propose that for the sustainable management of the river basin

it is crucial to take the water bankruptcy scenario where the amount of water available in the river basin is lower than the water demand to account to avoid conflicts which might rise in the future. Hence the water allocation and water right determination in the river basin should take this scenario into consideration to ensure flexible and equitable allocations which can be the base for sustainable cooperation between the riparian countries.

Compliance with ethical standards

Conflict of interest This paper has not been submitted elsewhere in identical or similar form. The authors declare that they have no conflict of interest.

References

- Anja KM (2011) Impacts of global change on the Nile basin options for hydro political reform in Egypt and Ethiopia. IFPRI discussion paper 01052, International Food Policy Research Institute Environment and Production Technology Division
- Ansink E, Arjan R (2008) Climate change and the stability of water allocation agreements. *Environ Resour Econ* 41(2):249–266
- Ansink E, Harold H (2015) The economics of transboundary river management. In: Dinar Ariel, Schwabe Kurt (eds) *Handbook of water economics*. Edward Elgar, Cheltenham
- Arnell NW (1999) Climate change and global water resources. *Glob Environ Change* 9:S31–S50
- Arora VK, Boer GJ (2001) Effects of simulated climate change on the hydrology of major river basins. *J Geophys Res Atmos* 106(D4):3335–3348
- Arsano Y, Tamrat I (2004) Ethiopia and the Eastern Nile basin. *Aquat Sci* 67(1):15–27
- Awulachew S, Rebelo LM, Molden D (2010) The Nile basin: tapping the unmet agricultural potential of Nile waters. *Water Int* 35(5):623–654
- Awulachew SB, Demissie SS, Hagos F, Erkossa T, Peden D (2012) The Nile river basin water, agriculture, governance and livelihoods. In: Awulachew SB, Smakhtin V, Molden D, Paden D (eds) *Routledge*, 1st edn. Taylor & Francis Group, UK
- Black M, King J (2009) *The atlas of water, mapping the world critical resource*, 2nd edn. University of California Press, California
- Brunnee J, Stephen JT (2002) The changing Nile basin regime: does law matter? *Harv Int Law J* 43(1):105–159
- Cascão A (2008) Ethiopia-Challenges to Egyptian hegemony in the Nile basin. *Water Policy* 10(2):13–28
- Cascão AE (2009) Changing power relations in the Nile river basin: unilateralism vs. cooperation. *Water Altern* 2(2):245–268
- Cascão AE, Zeitoun M (2010) Power, hegemony and critical hydro-politics. In: Earle A, Jagerskög A, Öjendal J (eds) *Transboundary water management: principles and practice*. Earth Scan, London, pp 27–42
- CIA (2003) *World fact book: year-over-year GDP growth rate in Nile Riparian countries*. <https://www.cia.gov/library/publications/the-world-factbook/fields/2003.html#et>. Accessed 9 July 2015
- Conway D (2005) From headwater tributaries to international river: observing and adapting to climate variability and change in the Nile basin. *Glob Environ Change* 15(2):99–114
- Conway D, Hulme M (1993) Recent fluctuations in precipitation and runoff over the Nile sub basins and their impact on main Nile discharge. *Clim Change* 25(2):127–151
- Conway D, Hulme M (1996) The impacts of climate variability and future climate change in the Nile basin on water resources in Egypt. *Water Resour Dev* 12(3):277–296
- Drieschva A, Giordano M, Fischhendler I (2008) Governance mechanism to address flow variability in water treaties. *Glob Environ Change* 18(2):285–295
- Eckstein G (2009) Water scarcity, conflict and security in a climate change world: challenges and opportunities for international law and policy. *Wis Int Law J* 27(3):409–461
- Elimam L, David R, Christina C, Kaveh M (2008) An ancient struggle: a game theory approach to resolving the Nile conflict. In: *Proceeding of the 2008 World Environmental and Water Resources Congress*, Honolulu 12–16 May 2008
- FAO-AQUASTAT (2007) <http://www.faoile.org/nbs/nilesystem.html>. Accessed 7 July 2015
- Halla Q (2008) Practical approaches to transboundary water benefit sharing. Working paper 292. Overseas Development Institute Road, London
- Homer D, Thomas F (1994) Environmental scarcities and violent conflict: evidence from cases. *Int Secur* 19(1):5–40
- International Water Management Institute (2012) *The Nile river basin water, agriculture, governance and livelihoods*. In: Awulachew SB, Smakhtin V, Molden D, Peden D (eds) 1st edn. Routledge 2 Park Square, Milton Park
- IPCC (2001) *Climate change 2001: the scientific basis*. In: Houghton JT, Ding Y, Griggs DJ, Noguer M, Van der Linden PJ, Dai X, Maskell K, Johnson CA (eds) *Third assessment report of the intergovernmental panel on climate change*. Cambridge University Press, Cambridge
- Janmaat J, Ruijs A (2007) Sharing the load? Floods, droughts, and managing international rivers. *Environ Dev Econ* 12(4):573–592
- Keith B, Enos J, Cadets Garlick B, Simmons G, Copeland D, Cortizo M (2013) Limits to population growth and water resource adequacy in the Nile river basin, 1994–2100. In: *Proceedings of the 31st international conference of the system dynamics society*, Cambridge, 21–25 July 2013
- Kim U, Kaluarachchi JJ (2009) Climate change impacts on water resources in the upper blue Nile river basin, Ethiopia. *J Am Water Resour Assoc* 45(6):1361–1378
- Laura P (2013) The politics of ‘Water Scarcity’ in the Nile basin: the case of Egypt. *J Politics Int Stud* 9:434–480
- Jury MR (2011) Climate variability and hydrologic response climatic factors modulating Nile river flow. In: Assefa MM (ed) *Nile river basin hydrology, climate and water use*. Springer, Netherlands, pp 267–280
- Melinda L, Faith S (2014) Water data systems: science, practice, and policy. *J Contemp Water Res Educ* 153(1):1–3
- Molden D, Awulachew SB, Conniff K, Rebelo LM, Mohamed Y, Peden D, Kinyangi J, Van Breugel P, Mukherji A, Cascão A, Notenbaert A, Demissie SS, Neguid MA, El Naggat G (2010) *Nile basin focal project: synthesis report*. CGIAR Challenge Program on Water and Food, Colombo
- Nile Basin Initiative (2012a) Summary: the state of the river Nile basin. Chapter 9 State of the river Nile basin. <http://sob.nilebasin.org>. Accessed 7 July 2015
- Nile Basin Initiative (2012b) Water resources of the Nile basin. Chapter 2 State of the river Nile basin. <http://sob.nilebasin.org>
- Parkes L (2013) The politics of ‘water scarcity’ in the Nile basin: the case of Egypt. *J Polit Int Stud* 9:434–480
- Rogers P, Leal S (2010) *Running out of water: the looming crisis and solutions to conserve our most precious resource*. St. Martin’s Press, New York
- Selby J, Clemens H (2014) Beyond scarcity: rethinking water, climate change and conflict in the Sudan. *Global* 29:360–370

- Shiklomanov IA, Rodda JC (2003) World water resources at the beginning of the 21st century. Cambridge University Press, Cambridge
- Strzepek K, Onyeji C, Saleh M, Yates D (1995) An assessment of integrated climate change impacts on Egypt. In: Strzepek K, Smith J (eds) *As climate changes: international impacts and implications*. Cambridge University Press, Cambridge, p 57–91
- Swain A (2001) Water wars: fact or fiction? *Futures* 33:769–781
- Tate E, Sutcliffe J, Declan C, Farquharson F (2004) Water balance of Lake Victoria: update to 2000 and climate change modeling to 2100. *Hydrol Earth Syst Sci* 49(4):563–574
- United Nations (1997) Convention on the law of the non-navigational uses of international watercourses. Adopted by the General Assembly of the United Nations. Entered into force on 17 Aug 2014
- United Nations, Department of Economic and Social Affairs, Population Division (2012) World population prospects: the 2012 revision, key findings and advance tables
- United Nations, Department of Economic and Social Affairs, Population Division (2015). World population prospects: the 2015 revision, key findings and advance tables. Working paper no. ESA/P/WP.241
- Vella J (2012) Future directions international-strategic analysis paper: the future of food and water security in New Egypt. Future Directions International Pty Ltd, Dalkeith
- Voss R, May W, Roeckner E (2002) Enhanced resolution modeling study on anthropogenic climate change: changes in extremes of the hydrological cycle. *Int J Climatol* 22(7):755–777
- Waterbury J (2002) The Nile basin: national determinants of collective action. Yale University Press, New Haven
- Wolf AT (1999) Criteria for equitable allocations: the heart of international water conflict. *Nat Resour Forum* 23(1):3–30
- World Bank (2000) The Nile river basin. http://siteresources.worldbank.org/INTAFR/NILEBASIN/About%20Us/21082459/Nile_River_Basin.htm. Accessed 10 July 2015
- World Bank (2007) Report no: 41425-ET Ethiopia/Nile basin imitative power export project: Ethiopia–Sudan inter connector project appraisal document
- WWAP (United Nations World Water Assessment Programme) (2015) The United Nation World Water Development Report (2015): water for a sustainable world. UNESCO, Paris
- Yates DN, Strzepek KM (1998) Assessment of integrated climate change impacts on the agricultural economy of Egypt. *Clim Change* 38(3):261–287
- Yates N, Strzepek K, David M (2000) Responses and thresholds of the Egyptian economy to climate change impacts on the water resources of the Nile river. *Clim Change* 46(3):339–356