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Full Length Research Paper

A framework for defining equity and sustainability in the Nile River Basin

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The objectives of this research were to objectively define the two important terms, 'equity' and 'without appreciable harm', in the water utilization principles enshrined in the United Nation (UN) Convention in the context of visions of the Nile Basin Initiative (NBI). Need-based allocation of Nile waters and the new emerging concept of 'reserved' and 'shared' water were used as tools to quantify equity. Results of allocation based on per capita per year indicated that Ethiopia, Sudan, Egypt and Equatorial states, each, will get 15, 22, 49, and 14% of the annual flow of Nile waters, respectively. Evaluation of allocation scenarios of the Nile waters revealed that allocation based on the 1959 Water Agreement does not guarantee sustainable utilization and does not comply with the UN Convention. However, allocation based on the weighted area and per capita methods were found to guarantee sustainable utilization and to comply with the UN Convention. The results of this study can be used as a framework of negotiation platform to open up more fruitful discussions and dialogues among decision makers in the basin states.

Key words: Equity, benefit-sharing, reserved water, shared water, water allocation, sustainability and Nile River Basin.

INTRODUCTION

The Nile River Basin represents one of the critical and perhaps the most important shared water basins in Africa. Ten African countries presently share the Nile basin water which includes: Burundi, The Democratic Republic of Congo (DRC), Egypt, Eritrea, Ethiopia, Kenya, Rwanda, Sudan, Tanzania and Uganda (Figure 1). Although these 10 countries represent 10% of Africa's landmass, they house 40% of the continent's population of which 70% reside in the Nile Basin (FAO, 1997). Egypt, the extreme downstream country, has been the traditional user of the Nile water, exploring its water almost exclusively followed by Sudan.

The most comprehensive treaty that addresses allocation of the Nile water resource remains the 1959 Water Agreement which grants the full utilization of the Nile water for Egypt and Sudan. The treaty established the average annual Nile flow at about 84 Billion Cubic Meter (BCM), measured at Aswan high dam in Egypt, and estimated annual water loss due to evaporation and other factors as 10 BCM. After deducting the losses from the annual yield, the remaining flow was divided between Egypt and Sudan in the proportion of 75 and 25%, respectively (Tesfaye, 2001). The remaining member countries were not consulted over the final terms of the 1959 agreement and their water rights have not been explicitly mentioned. As a result, the countries have been objecting the agreement and requesting for renegotiation over its contents to make it more inclusive. Due to growing food insecurity coupled with the population explosion, the upstream countries have also begun to engage in unilateral water resources development in the basin in order to sustain their growing population (El-Fadel et al., 2003). Keeping the fact investment in agriculture, water management can contribute to poverty reduction through several pathways including: higher production, higher income and consumption, higher

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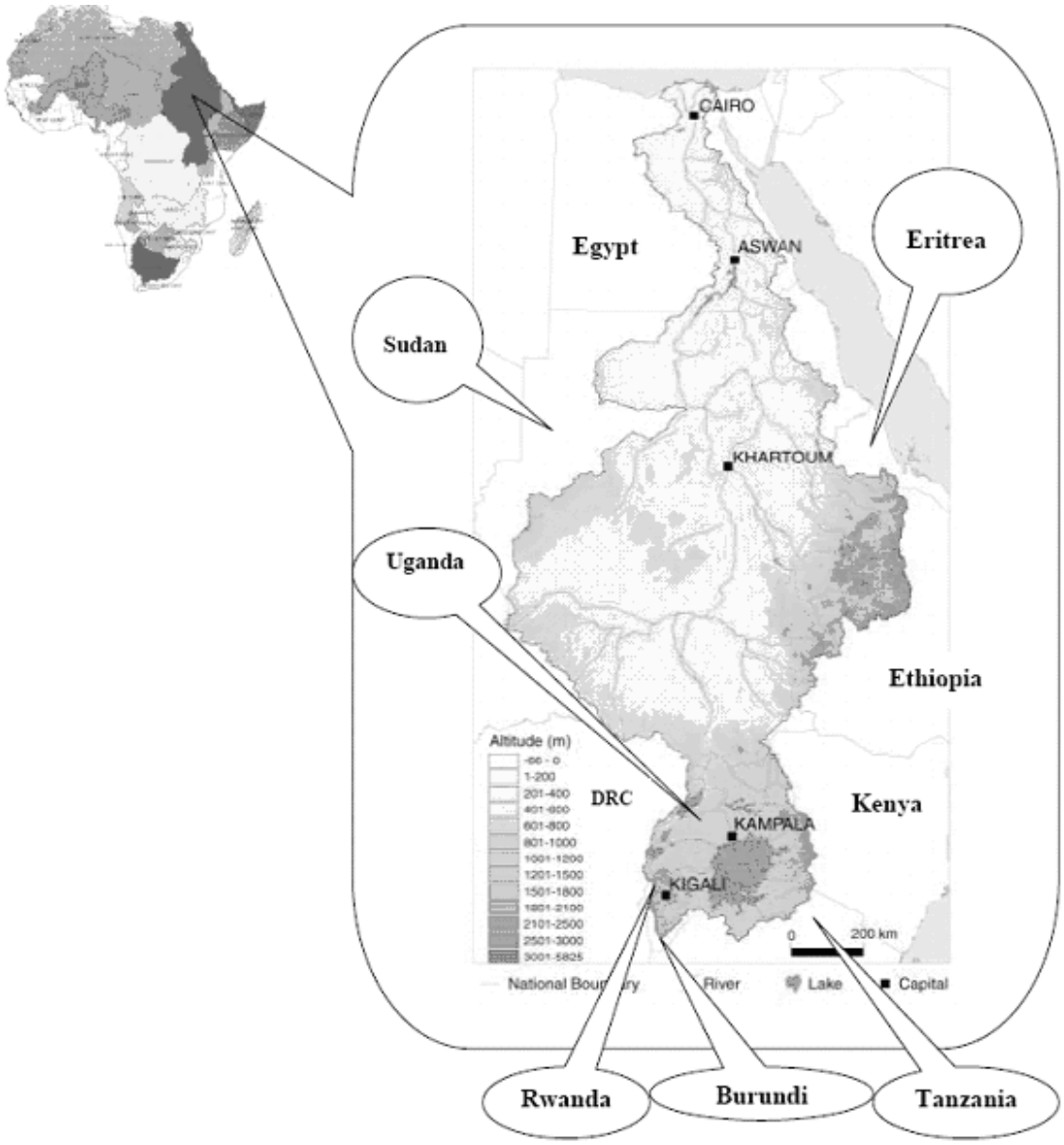

Figure 1. Map of the Nile Basin.
Source: FAO (1970).

employment and wage earnings, cheaper food, increases in agriculture and house hold assets, and favorable impacts on equity through better nutrition, education, and access to basic services (Hanjra et al., 2009). However, this uncoordinated planning and implementation of development programs will inevitably lead to unsustainable resource use practices and increased tensions among the riparian states. Hamouda (2009) reported that varying degrees of water resource vulnerability situations are already evident in the Nile riparian states.

The Nile riparian countries have signed a historic agreement in 1999 to establish cooperation through a transition mechanism known as Nile Basin Initiative (NBI). The shared-vision of the NBI is *"To achieve sustainable socio-economic development through equitable utilization of, and benefit from, the common Nile Basin water resources" (*NBI, 1999). All optimistic views suggest that this cooperation will pave way to the permanent framework arrangement in a win-win situation for regional development in the long run. One of the NBI objectives is attempting to look into the cooperation and the establishment of alternative development scenarios for the basin in the context of tangible benefit-sharing of the Nile Resources (NBI, 2001). The agreed upon alternative development paths and the derived benefits thereof have to be worked out and well defined. This implies that the concept of *benefit* shall be primarily defined in quantitative and tangible terms, which will be followed

Table 1. Nile Basin repartition (FAO, 1997).

Country	Land area (km^2)	Land proportion in the Nile Basin (%)
Burundi	27,835	47.6
DRC	2,345,410	0.9
Egypt	1,001,450	32.6
Eritrea	121,320	20.4
Ethiopia	1,127,127	33.2
Kenya	582,650	8.0
Rwanda	26,340	75.5
Sudan	2,505,810	79.0
Tanzania	945,090	8.9
Uganda	236,040	98.1
Total	**8,919,072**	**34.9**

followed by the development of acceptable set of criteria or parameters that will assist or direct definition of sharing of the benefits derived thereof. Although an internationally accepted need-based per capita assessment which is the most important factor in the basin was not considered, considerable efforts were made by Van der Zaag et al. (2002) to establish a framework for partitioning the Nile water into reserved and shared water. And there is almost no analysis of such amount, in particular the concept of equity and appreciable harm has not been empirically examined. Besides, emphasis has never been given to quantification of water utilization and sharing principles enshrined in Articles 5, 6 and 7 of the Law of the non-navigational uses of International Watercourses. To resolve their conflicts, riparian states have instead relied upon treaties that incorporate basin-specific needs and conditions and defined equity at the most local level (Giordano and Wolf, 2001). However, Mimi and Sawalhi (2003) developed a decision tool for allocating the waters of the Jordan River between all riparian states based on the existing international water laws.

Sufficient and reliable freshwater supply is essential for protecting human health, supporting food production, preserving ecosystems, sustaining economic development, and providing vital goods and services such as hydroelectric power. Water resources are essential to human development processes and to achieve the millennium development goals that seek, inter alia, to eradicate extreme poverty and hunger, achieve universal literacy, and ensure environmental sustainability (Hanjra et al., 2009). However, as population and development pressures have grown within many of the world's river basin, water has become a significant source of political conflict, particularly in the international rivers (Giordano, 2002). Perhaps continued population growth represents the most serious threat to water adequacy, whereby a large population leads to a higher water demand for food production and for domestic, municipal, and industrial uses. Not only does the amount of available freshwater per capita decreases as a country's population increases, but also does the amount received by other states sharing that resource. The latter situation is the result of dam construction or altering a water course for additional irrigation systems in a particular country (El-Fadel et al., 2003). Shared fresh water resources have been the source of international friction and tensions for many years, in many places. Worldwide, approximately 50% of all land area is contained within international drainage basins, and more than 200 rivers are shared by two or more nations. These geographical facts have led to the geopolitical reality of disputes over shared international rivers, including the Nile, Jordan and Euphrates (Mimi and Sawalhi, 2003).

The objective of this paper is to quantify the two important terms in water utilization principles, equity and without appreciable harm, in the context of the NBI vision. The paper also attempted to link the NBI shared-vision with the UN Conventions for sharing transboundary water resources. Special emphasis was given to operationalization of the water utilization and sharing principles enshrined in Articles 5, 6 and 7 of the UN Convention on the Law of the Non-Navigational uses of International Watercourses (Salman, 2007).

In spite of recent opportunities and enabling environment created by the NBI program vision, there is neither clearly articulated terms of agreement acceptable by all riparian countries nor consensus of any kind that may dictate sustainable development and sharing of the common resources of the Nile River system. Therefore, the paper also attempted to evaluate the *sustainable utilization* of the Nile water resource in the context of the NBI vision.

MATERIALS AND METHODS

Description of the study area

Nile is one of the longest transboundary rivers in the world flowing from south to north over a distance of 6,850 km and 35° of latitude

The Nile Basin covers a total area of 3×10^6 km^2, approximately 10% of the African total landmass, and spreads over 10 countries (Table 1).

Sources of data

The first step in this research was collecting basin countries information on nutritional status (calorie intake per capita) for each basin countries, water required for production of 1 kg cereal, water required for production of one tropical livestock unit (TLU), current number of population living in each riparian country and livestock population. This information was retrieved from the document of FAO (FAO, 2005, 2006), and Stockholm International Water Institute and International Water management Institute, (SIWI - IWMI, 2004).

Average annual flow volumes from 1961 to 2000 at different key stations in the basin (Malaka, Mogren, Khartoum, Dongola, Roseries, Kashim El Girba) and at border crossings were used to undertake sustainability analysis and generate time series data. These data were obtained from Eastern Nile Technical Regional Office (ENTRO), Sutcliffe and Parks (1999) and Khore Guang Loa (2006).

Approaches used in the analysis

The principle of *reasonable and equitable use* of the international water resources stated in the United Nations International Law Commission (UN/ILC) and International Law Association (ILA) of the United Nations or 1966 Helsinki Rules (Salman, 2007) are subjective in nature and needs clear objective definition in order to have consensuses and fruitful dialogues and negotiations among the Nile basin riparian states. For quantification of these basic principles of UN/ILC, need-based allocation of water among the respective riparian states was employed based on a new concept of apportioning the available water resource into *reserved* and *shared* water. Mechanisms of setting reasonable allocation algorithm were considered for computing equity.

Quantification of reserved water

The concept of reserved water is intended to initially take care of the basic needs of the society and environment before applying the principles of equity. The reserved amount of water is part of the available water reserved for each country which may be used for primary water requirements (basic water needs) of the basin population like food security, domestic water supply, livestock watering, basic needs for industry and for water requirements of riverine ecosystems; it remains outside the reach of negotiations. This quantity of water for each riparian country was estimated using a method which was originally developed by Van der Zaag et al. (2002). After estimating the population and the number of livestock in each riparian country, their respective water needs were estimated as follows:

1) Water for food security was estimated based on the minimum acceptable level of calorie per day per capita. Based on FAO/WHO guidelines, an average of 2700 calories of food should be available each day for every human on the planet to be healthy (SIWI-IWMI, 2004), and water required for producing common cereals cultivated in the basin that satisfies the required calorie; water production functions of common cereal crops were used in this exercise.
2) Water for domestic purposes (comprising drinking, cooking and bathing) was estimated based on the world's average urban and rural water consumption per capita standards (Rangwala et al., 2000).
3) Water for livestock was estimated based on the livestock water productivity concept, which is 450 m^3 of water, required to produce feed to maintain one TLU (Tropical Livestock Unit) (Don Peden, 2006).
4) Water for basic industrial demand was estimated on the basis of basic industrial products needed for basin population's daily consumption and ingredients for cooking foodstuffs (Rangwala et al., 2000).

The sum of all these needs was considered as the basic water requirements for the primary/basic needs of the basin population.

Equity-based allocation of the shared water

The water generated beyond the reserved amount can be considered as water available for the economic needs of the riparian countries and known as *shared-water* which is negotiable for sharing based on the existing international laws. In this study, the criteria recommended by Van der Zaag et al. (2002) were employed for the equitable allocation of shared-water resource using the following set of formulae. The number of riparian countries sharing the water, area of each country within the basin and the riparian population were considered as criteria for allocating the shared-water.

Criterion 1: Sharing the shared-water among the riparian countries equally:

$$Q_{r,i} = \left(Q_{t,i-1} + (1-R_b)\sum_{i}^{n} Q_{b,i} \right) \frac{1}{n-i+1} \quad (1)$$

$$Q_{t,i} = Q_{t,i-1} + (1-R_b)Q_{b,i} - Q_{r,i} \quad (2)$$

Criterion 2: Sharing the shared-water based on the weighted land area:

$$Q_{r,i} = \left(Q_{t,i-1} + (1-R_b)\sum_{i}^{n} Q_{b,i} \right) \frac{A_i}{\sum_i^n A} \quad (3)$$

Criterion 3: Sharing the shared-water based on per capita:

$$Q_{r,i} = \left(Q_{t,i-1} + (1-R_b)\sum_{i}^{n} Q_{b,i} \right) \frac{N_i}{\sum_i^n N} \quad (4)$$

Where:
A_i = basin area occupied by country i (km^2); A = total area of the basin (km^2); i = index of the riparian countries; n = total number of basin countries; N_i = number of people living in that part of the basin occupied by country I; N = total number of the population in the basin; $Q_{b,i}$ = surface water generated in country i

(m^3/yr); $Q_{t,i}$ = surplus water transferred to downstream countries (m^3/yr); $Q_{t,i-1}$ = surplus water coming from the upstream countries (m^3/yr); $Q_{r,i}$ = right to shared water for country *i* in excess of the reserved water (m^3/yr); R_b = fraction of blue water reserved for each riparian country

To operationalize these criteria, it was assumed that no water is pumped from the downstream to upstream countries (Van der Zaag et al., 2002). The procedure moves from upstream to downstream whereby at each border-crossing the remaining water is shared among the downstream countries on equitable basis. These three criteria were coded into a FORTRAN program to operationalize allocation of the shared-water resource for each riparian country based on these three criteria.

Sustainability of the Nile water resource

In this area, sustainability of the Nile water resource was evaluated in terms of defining the criterion which focuses on the obligation of a country *not to cause appreciable harm* to the downstream countries. Although this criterion plays a pivotal role in building trust and confidence among the riparian countries for eventual cooperation and benefit-sharing, its quantification appears to be ambivalent and little attempt has been made in this regard. In this study, the following scenarios were evaluated for their impacts on the sustainability of Nile water resource in terms of whether they cause appreciable harms to the downstream countries or not:

Business-as-usual scenario: This allocates the Nile water resource among Sudan and Egypt based on the 1959 Water Agreement signed between the two states ignoring the basic needs of the other riparian countries.

Equitable-sharing scenarios: This scenario is based on the three allocation algorithms proposed in this study for equitable-sharing of the Nile water resource among the riparian countries based on the three criteria discussed above.

The method proposed by Loucks (1997) which depends on reliability, resilience and vulnerability (RRV) of water resource systems (WRS) was adopted to evaluate the relative sustainability of the Nile water resource. Accordingly, flow data (x_t) were considered as sustainability criteria with the flow required to meet the aforementioned four criteria as threshold levels (x_o). Stochastic stream flow models (Thomas-Fiering) were used to generate time series of stream flow data (supply) into the future.

Considering 2015 as a planning year, the population was projected for each Nile Basin country using the software package SPECTRUM policy modeling system Version 2.42*. Then the basic water requirements of the projected population (water demand) were estimated using the method discussed earlier. The time-series data (both supply and demand) were then summarized using the statistical measures of sustainability (reliability, resilience and vulnerability) for each of the water allocation scenarios discussed earlier.

Detection of one or more failure periods ($x_t < x_o$) during the planning horizon at key gauging stations was considered as a criterion for evaluating sustainability of the four water allocation scenarios vis-à-vis the demands of the respective downstream basin populations. The basin was divided into four major users: Ethiopia, Egypt, Sudan and the Equatorial Nile countries (comprising Burundi, Rwanda, DRC, Kenya, Tanzania and Uganda). Subsequently, the key stations used in the analysis included Blue Nile discharge at Khartoum (to evaluate sustainability based on allocations made to Ethiopia), White Nile flow at Mongalla station (to evaluate sustainability based on allocations made to Equatorial countries) and main Nile discharge at Dongola station (to evaluate sustainability based on allocations made to Sudan and Egypt). Finally, sustainability indices were computed as follows:

Reliability: Is the probability that the supply time series of Nile water resource will satisfy the basic needs of the basin population during the planning period.

$$\mathrm{Re}\,l = 1 - \left(\frac{n}{N}\right) \quad (5)$$

Resilience: is an indicator of the speed of recovery from an unsatisfactory condition. It is linked to the duration of failure periods.

$$\mathrm{Re}\,s = \left(\left(\frac{1}{M}\right)\sum_{j=1}^{M} d_j\right)^{-1} \quad (6)$$

Vulnerability: A statistical measure of the extent of failure. The extent of a failure is the amount a value of the water supply falls short of the basic needs of the basin population. It is linked to the deficit volumes resulting from failure periods.

$$Vul = \left(\frac{1}{M}\right)\sum_{j=1}^{M} s_j \quad (7)$$

For $M = 0$, $Res = 1$ and $Vul = 0$.

Where:
n = total number of time steps where $x_t < x_o$; N = total time series; x_o = threshold level (demand time series); d_j = failure periods where the supply is less than the demand; s_j = corresponding deficit volume of the failure period; M = total number of failure events; x_t = supply time series; *Rel* = reliability; *Res* = resilience; *Vul* = vulnerability

Sustainability index: For each water user, the RRV (sustainability index) is estimated as follows.

The value ranges from 0 to 1, with 1 being the most desirable value which is very much sustainable.

$$S = \mathrm{Re}\,l * \mathrm{Re}\,s * \left[1 - rVul\right] \quad (8)$$

Where:
rVul = relative vulnerability = Vul of user/Maximum vulnerability among the three criteria

Non-sustainability index: The criterion with the largest vulnerability is not necessarily the worst, and hence, the method has been refined to estimate non-sustainability, *NS*, for each criterion.

$$NS = \left[1 - \mathrm{Re}\,l\right] * \left[1 - \mathrm{Re}\,s\right] * \left[Vul / mean\ vul\right] \quad (9)$$

Therefore, *NS* has a lower bound of zero and no upper bound. A zero value means a sustainable scenario (water allocation criteria).

* http://www.healthpolicyinitiative.com/index.cfm?id=software&get=Spectrum

RESULTS AND DISCUSSION

Reserved water and equity-based allocation of the shared-water

Reserved water for each riparian state was quantified in terms of the amount of water required to meet the basic needs of the state and the results are presented in Table 2. The amount of water required to meet the major components of the basic needs of each state is shown in Figure 2. In applying criteria number three, projection of the basin population indicated a 26% growth during the planning period (from an estimated 378 million in 2006 to 475 million in 2015). Accordingly, the equity share of each country based on international laws and conventions of Articles 5, 6, and 7 are estimated and presented in Tables 2 and 3.

These results revealed that the total reserved water to satisfy the basic needs of the basin population takes the largest share (about 96%) of the total Nile flow. When the total reserved water is distributed among the basin countries, the share of Ethiopia, Egypt, Sudan and Equatorial countries, respectively, become 11.51, 37.56, 17.44 and 11.50 in BCM. The remaining surface water (5.97 MCB) is shared among the riparian countries based on the criteria described previously. These results proved that the 1959 Water Agreement between Egypt and Sudan has been unfair and did not take into account the fair-share of the other riparian states. On the basis of these results and the agreement referred to, one can realize that Egypt has been utilizing the basin water resource beyond its fair-share (by an amount of 17.94 BCM) at the expense of the other upstream riparian states.

Results of allocating the unreserved (shared) water resource among the riparian countries based on Criterion I (Table 2) indicate that Ethiopia, Egypt and Sudan each receives 1.90 BCM whereas the remaining 0.26 BCM goes to the Equatorial countries. When weighted land area is considered (Criterion II), the allocation becomes 0.78, 4.33, and 0.69 in BCM for Ethiopia, Sudan and Egypt, respectively. If access to water is considered as the basic right of human being (Brooks, 2007; Biswas, 2007), surface water should be shared on per capita basis (Criterion III). Based on this criterion, 1.46 BCM, 1.32 BCM, and 2.93 BCM is allocated to Ethiopia, Sudan and Egypt, respectively. In general, results of equity-based water allocation among the basin states (sum of reserved and shared water) are presented in Table 3.

Sustainability

In this study, the net flows to Egypt after satisfying all upstream demands were found to satisfy the criterion 'detection of one or more failure periods' under all scenarios and thus considered for sustainability analysis as presented in the following sections.

Business-as-usual scenario

Under this scenario, water resources sustainability was analyzed only for Sudan and Egypt under the 1959 Water Agreement – fixed allocation of 18.5 BCM and 55.5 BCM to Sudan and Egypt, respectively. The simulated net flows to Sudan (without considering the basic needs of the upstream population) and Egypt (after meeting the evaporation and other losses and water rights of Sudan) were considered as supply time series.

Plot of time series of water demand and supply (Figure 3) shows that some failure periods are expected to be experienced by Egypt as a result of the 18.5 BCM water allocated to Sudan. In contrary, no failure period is expected to be experienced by Sudan. Accordingly, results of sustainability analysis (Table 4) revealed that the current utilization of the Nile water resource by Sudan based on the existing water agreement between the two countries will not guarantee sustainability in Egypt. From the value of the non-sustainability index, it can be inferred that this water allocation scenario may cause appreciable harm on Egypt in the near future which can be substantiated by the sustained shortfall of supply below the demand beyond the year 2009 in Figure 3. Moreover, it is quite obvious that the current Nile water resource allocation agreement between Sudan and Egypt is not based on the utilization of the common water resource on the basis of equity and benefit sharing principles and as a result does not comply with Articles 5 to 7 of the UN Convention.

Sustainability based on the three equitable-sharing scenarios

Taken as a whole, the three newly proposed water allocation scenarios are found to comply with the principles enshrined in Articles 5 to 7 of the UN Convention since they all take into account the basic needs and rights of all the riparian countries in the Nile River Basin. Indeed equity is shifting negotiations from "rights-based" towards "need-based" values (Giordano and Wolf, 2002). However, whether allocating the available Nile water resource to a particular riparian state based on these proposed allocation algorithms will cause harm to its downstream countries or not should be evaluated based on the sustainability indices.

Under these scenarios, it was found that if the proposed water allocations based on the three criteria are implemented in the Nile River Basin, no failure periods are expected to be experienced by all the riparian countries in the upstream of Egypt during the planning horizon confirming sustainable utilization. However, some failure

Table 2. Quantification of reserved and shared water among the Nile riparian countries.

Country	Irrigation Potential (ha)	Reserved water (BCM/yr)	Shared water (BCM/yr) based on:			Surface water contribution (BCM/yr)	Basin population (Million)	Land area in the Basin (km^2)
			Equal sharing	Basin area	Per Capita			
Ethiopia	2,220,000	11.51	1.90	0.78	1.46	72.24	35.66	365,177
Sudan	2,750,000	17.45	1.90	4.23	1.32	0	32.37	1,978,506
Egypt	4,420,000	37.57	1.90	0.70	2.93	0	71.70	326,751
Eq. countries	652,000	11.50				11.76	67.15	441,995
Total		78.03	5.71	5.71	5.71	84	206.86	3,112,429

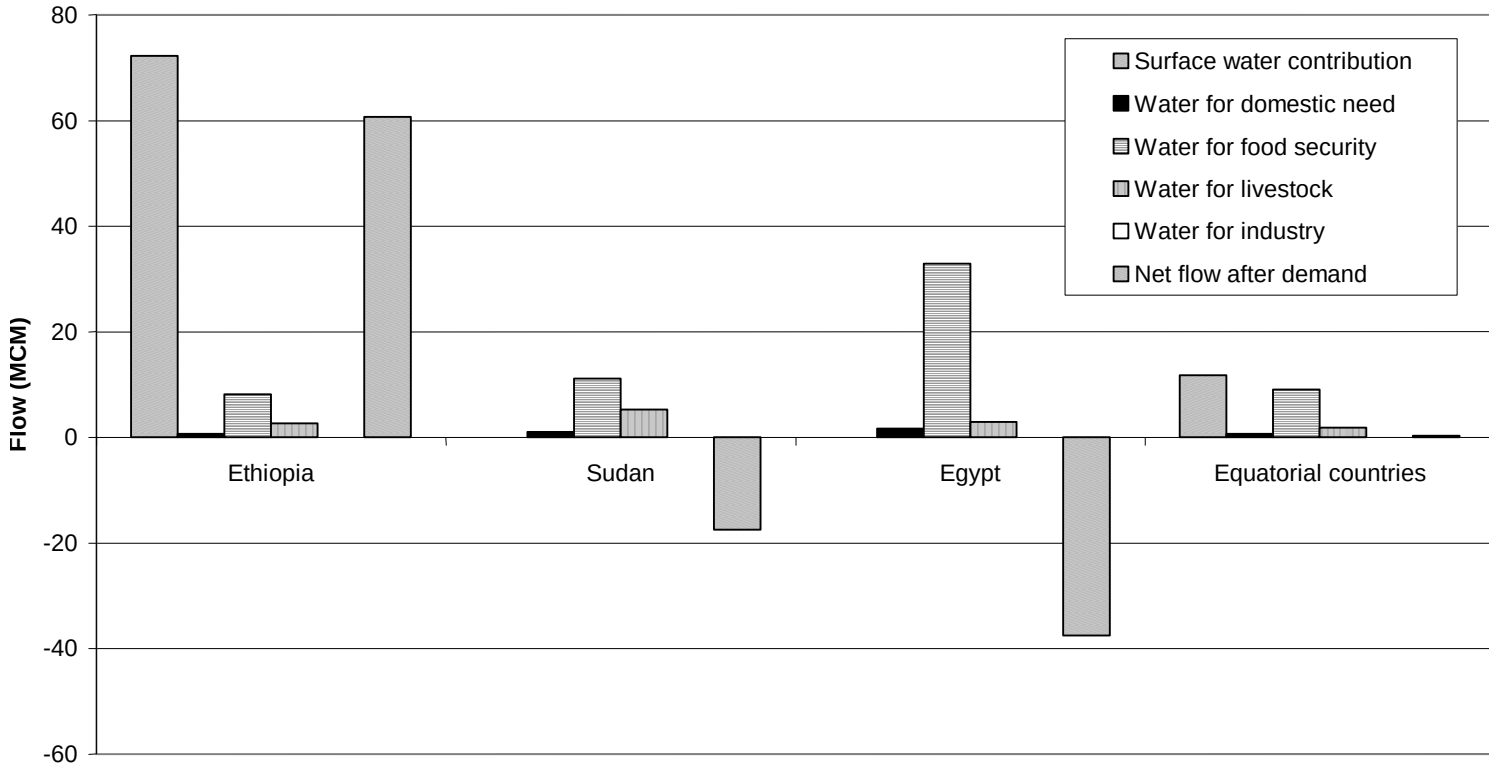

Figure 2. Reserved water for Nile riparian states to meet their basic needs in 2015.

Table 3. Equity-based allocation of the Nile water resource (BCM/year) among the basin countries.

Country	Criterion I	Criterion II	Criterion III
Ethiopia	13.41	12.29	12.97
Sudan	19.35	21.68	18.77
Egypt	39.47	38.27	40.50
Equatorials	11.76	11.76	11.76
Total	84	84	84

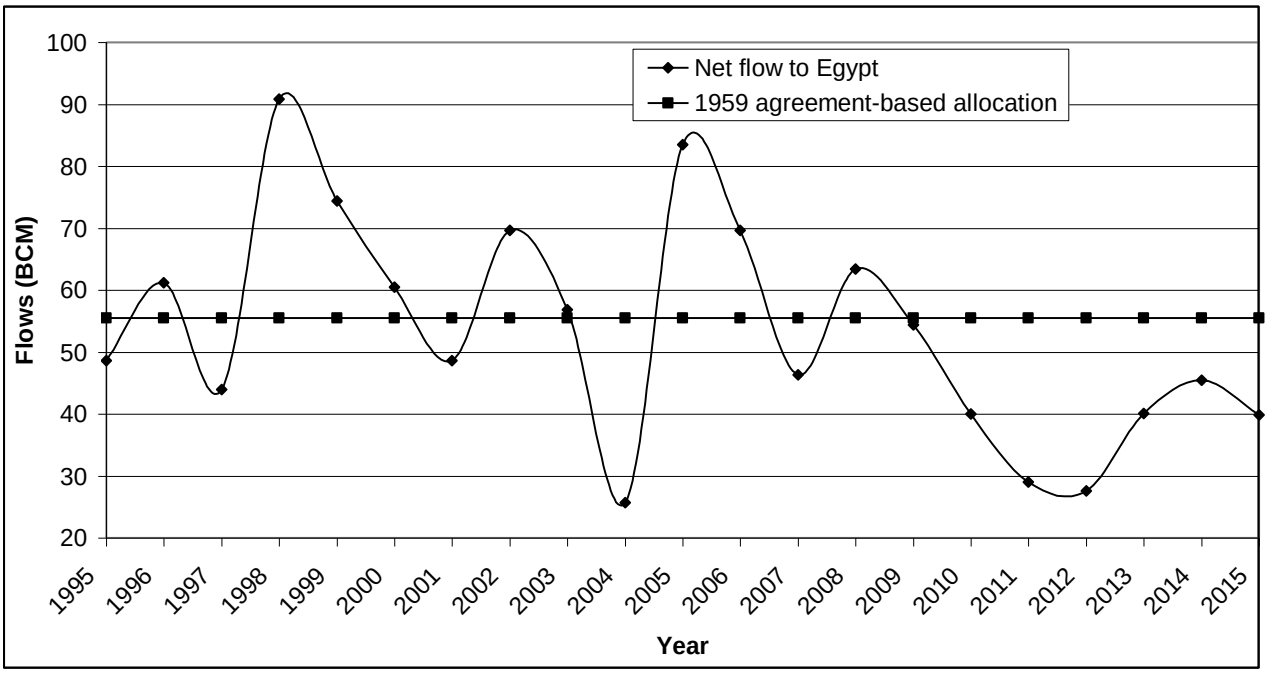

Figure 3. Plots of simulated flows to Egypt and the country's water right based on the 1959 Water Agreement.

Table 4. Summary of sustainability indices in Egypt under the 1959 Water Agreement.

County	Reliability	Resilience	Vulnerability	Sustainability index	Non-sustainability	Remark
Equatorials	-	-	-	-	-	-
Ethiopia	-	-	-	-	-	-
Sudan	1.0	1.0	0	1.0	0	Sustainable
Egypt	0.29	0.40	33.29	0.0	0.43	Not sustainable

failure events are expected to be experienced by Egypt under all the three scenarios as shown in Figure 4. However, the number of events is not constant in all the scenarios. Accordingly, results of sustainability analysis revealed that Nile water resource utilization will not be sustainable under equal-sharing scenario (criterion I) vis-à-vis the demands of Egypt whereas it is sustainable under the remaining allocation scenarios (criteria II and III). Nevertheless, allocation based on criteria I will not cause appreciable harm to Egypt as evidenced by its non-sustainability index. Sustainability and non-sustainability indices computed under these scenarios are presented in Table 5.

Comparing between scenarios II and III, it can be argued that scenario III is more realistic as it considers water as one of the basic rights of human being. The foundation of this allocation criterion is built on the basic principles that the people living in the basin have the right to get access to their basic needs (water) and indeed the governments have the responsibilities to feed their people.

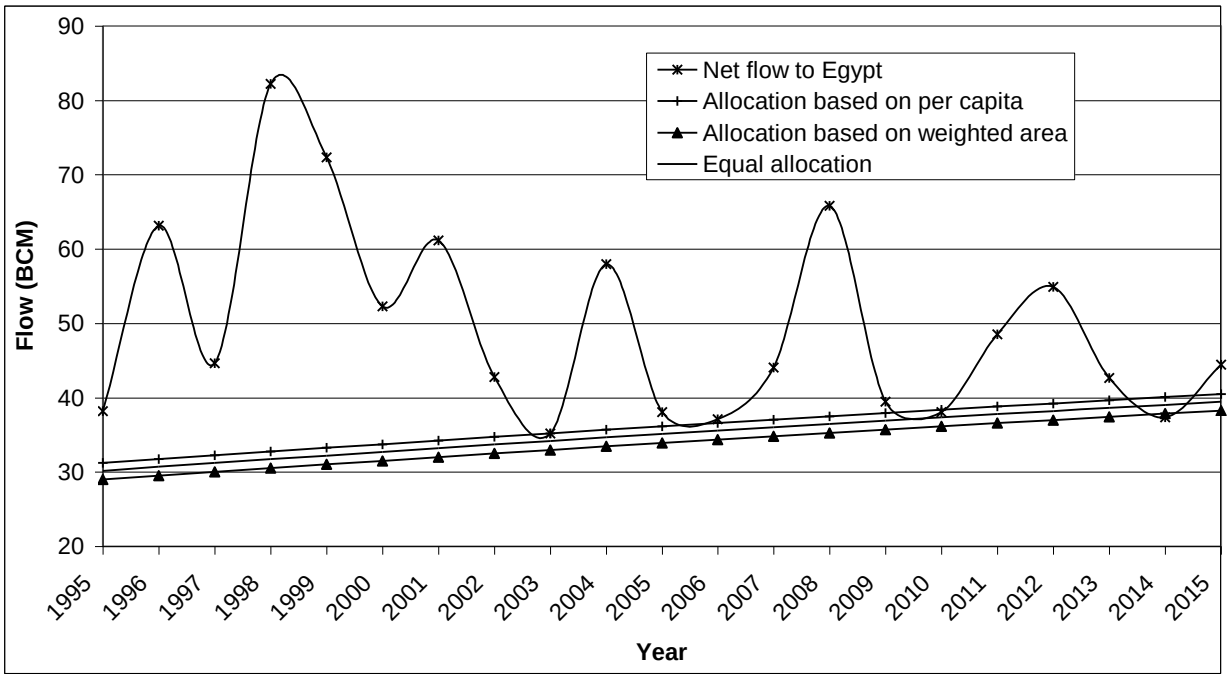

Figure 4. Plots of simulated flows to Egypt and the country's water rights based on the three allocation criteria.

Table 5. Summary of sustainability indices in Egypt under the three newly proposed allocation criteria.

County	Reliability	Resilience	Vulnerability	Sustainability index	Non- sustainability	Remark
Equatorials	1.0	1.0	0	1.0	0	Sustainable
Ethiopia	1.0	1.0	0	1.0	0	Sustainable
Sudan	1.0	1.0	0	1.0	0	Sustainable
Egypt						
Criterion I	0.95	1.0	1.68	0	0	Not sustainable
Criterion II	0.95	1.0	0.47	0.68	0	Sustainable
Criterion III	0.85	1.0	1.03	0.33	0	Sustainable

As a result, during negotiations of water allocation among the riparian state in the basin, it is sensible to shift in positions from the "right-based" to "need-based" values for a win-win situation in the basin.

This study revealed that allocation of the available water resource in the Nile River Basin among the riparian countries based on the weighted area and per capita is sustainable in spite of some failure events in Egypt. In general, if there is cooperation, coordination and commitment among the riparian countries based on equitable and benefit sharing principles, there is a possibility of conserving more water lost due to evaporation and spill over the banks in the upstream river sections (Baro-Akobo, Sobat, and Suud) through joint water management actions. This is part of the joint actions that can be taken to augment the flow deficits in Egypt. Another alternative action in the joint water management of the Nile River Basin recommended by Waterbury and Whittington (1998) is building dams in the cooler regions of Blue Nile (Ethiopian highlands) to reduce the current annual evaporation loss of 10 BCM from the Aswan high dam.

Conclusions

This study revealed that there is the possibility of defining subjective nature of the international laws into objective criteria for allocating common water resources of the Nile River Basin using the new concepts of 'reserved' and 'shared' water. It was found that business-as-usual (allocating the Nile water resource based on the 1959 Water

Agreement) does not guarantee the sustainable utilization of the basin water resources and does not comply with the principles enshrined in Articles 5 to 7 of the UN convention. Allocation of the Nile water resource among the riparian states based on the newly proposed allocation criteria (scenarios II and III) will guarantee equitable use of the available water resource by the states with no appreciable harms on any of the down-stream states. Attempts were also made to quantify the two important terms enshrined in the articles, *equity* and *no appreciable harm*, using the newly proposed allocation criteria. However, the aim of this study is not to provide a definitive solution to the question of all riparian states' entitlements. Rather, it is to demonstrate a methodology by which such entitlements can be estimated.

The member states should think of the benefits derived from the implementation of a need-based water allocation mechanism that is agreed upon by all the riparian states beyond sharing the available water resource. The benefits derived thereof include lessening tensions, promoting regional integration, enhancing cross border trade and ensuring food security in the riparian states.

RECOMMENDATIONS

The following recommendations are drawn based on results of this study:

1) The riparian states should develop joint water development and management measures to ensure longer term sustainability in the utilization of the Nile water resources;
2) Competitive advantage of producing food where the consumption of water per unit of output is lowest (with an agreed upon principle governing its marketing) should be considered as a key for the management of the basin water resource. This division of labor and/or production based on comparative advantage could then be extended to other economic sectors;
3) Once the need-based water allocation mechanism is in place in the basin, efforts need to be made to come up with the Nile Basin Benefit/Cost-sharing treaty. To this effect, further investigations are required to identify potential benefits/costs to be shared, to develop mechanisms for valuation of the benefits, to develop mechanisms for distribution of the benefits/costs and etc;
4) The analysis, although preliminary, can provide a way forward for detailed study by the extending and refining the framework proposed in this study which may ultimately serve as a basis for policy dialogue among the Nile Basin states.
5) Regarding the contribution of other economic activities for satisfying food security in Egypt was not considered in this study, for the reason that it is beyond the scope of the study, thus this preliminary study can be used for detailed study including other economic activities that has impact on satisfying food security in the basin area.

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