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A Model for the Distribution of Waters of International Rivers among Sharing Countries [1]

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Abstract: The Scarcity of fresh water worldwide makes the issue of sharing water a highly sensitive one. In case of international rivers which are shared by millions of people all over the world, the problem of sharing water becomes even more contentious as life and development are highly centered around this important resource. The closing part of the 20th century has already witnessed the first sings of the conflicts over waters of international rivers. Many observers believe that conflicts and wars over water will become widespread during the 21st century. This is so because pressure on fresh water resources will be brought to bear by rapid population increase, over-utilization of the resource, and mismanagement. International rivers on which depend the lives of millions of people carry only a very small fraction of liquid fresh water. Competition among states over the limited volume of river water becomes acute, particularly in arid regions like the Middle East. In a politically unstable region such as the Middle East the question of water shortages, resulting from unfair sharing, will be highly politicized. States which are taking more than their share of water will create an explosive situation and increase the possibility of war among sharing countries. So as to avoid the terrible consequences of war over the water issue, the authors have been able to develop the proposed model for understanding that this model which is based primarily on the Helsinki rules of 1967 will be acceptable to all sharing states, since it includes wide-ranging physical and socio-economic factors. In a sense, the model is to be considered as a natural and fair method for the distribution of common waters among sharing countries.

Key words: *Scarcity of fresh water, pressure on water resources, International river basin, Co-riparian, conflict and wars over water, factors affecting the distribution of water.model for sharing common waters.*

المستخلص: ان النقص في كميات المياه العذبة على مستوى العالم يجعل تقسيم المياه بين الدول المتجاورة امرا في غاية من الحساسية , تقسيم مياه الانهار بين الدول المشاركة , قابل للنزاعات حيث ان الماء هو عصب الحياة , بدأت النزاعات حول مياه الانهار منذ بداية القرن العشرين . و ذكر كثيرين من المهتمين بموضوع المياه ان القرن الحادي و العشرين قد يشهد بداية الحروب حول المياه . و السبب في هذا القول ان الطلب على المياه العذبة يتزايد بزيادة السكان بوتيرة سريعة إضافة الى الضغط على الموارد المائية مع الضعف الظاهر في إدارة المياه . هذا مع العلم ان الأنهار الدولية لا تحمل إلا جزاء صغيرا من كمية المياه على الأرض. و في نفس الوقت يعتمد عليها ملايين من البشر .إن التنافس على اقتسام مياه الأنهار يبدو كبيرا خاصة في المناطق الجافة و شبه الجافة كما هو الحال في منطقة الشرق الأوسط التي تكثر فيها النزاعات تبدو مرشحة لزيادة حدة هذه الصراعات . إن إمكانية نشوب الحروب في منطقة الشرق الأوسط حول تقسيم المياه بين الدول تجعل من الحكمة تفادي الصراعات المسلحة لذا يقترح الباحثان استخدام نموذج رياضي لتقسيم مياه الأنهار إعتمادا على قواعد هلينكس (1967) و الذي يعتمد على عناصر طبيعية و اجتماعية و اقتصادية هذا النموذج يعتمد على عناصر محايدة مما يساعد في التوزيع العادل بين الدول لكميات المياه الخاصة بكل دولة مما يجعل من الممكن تفادي النزاعات و الحروب حول مياه الأنهار الدولية .

كلمات مفتاحية *: نقص المياه العذبة , الضغط على موارد المياه , أحواض الانهار الدولية , الصراع الحروب حول المياه ،العناصر المستخدمة في النموذج لتوزيع المياه بين الدول.*

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I. Introduction

In spite of the fact that water is found in abundance (1.4 billion Km3) on planet earth, covering about 70% if the earth's surface, fresh water constitutes about 2.5%, the rest is saline or sea water. Most of the fresh water (70%) is in the form of ice and frost and is, therefore, not readily available for human use. Fresh liquid water (30%) itself is mostly groundwater (98.7%), and most of the groundwater is too deep (800 meters) to be available for human consumption. River water, on which depends the life of the so many people on earth, is no more than 0.02% of the liquid fresh water (Oudshoorn 1997). There are over 200 international rivers in the world. An international river is a river shared by two or more states. An international river may run along or across a group of countries are called successive As such the water resource situation in arid regions like the Middle East becomes highly precarious. The Middle East suffers from severe shortages of water, as 90% of the land receives less than 250 mm of annual rainfall. The water resources of rivers such as the Nile, Tigris-Euphrates and the Jordan, are over-stretched because of the aridity, poor water management and a high rate of population increase, together with the launching of the ambitious development projects by the countries of the region. Altogether the lives of some 500 million people depend on the waters of these three Middle Eastern river basins resulting thereby in considerable pressure on the resource. Moreover, as the Middle Eastern rivers flow through arid and semi-arid terrain, their total discharge is considered small when compared with discharge of the major international rivers. So even through the Nile is the longest river on earth. (> 6700Km.), its discharge is about 3000M3/second, equaling 1/60 the discharge of the mighty Amazon (El-Bushara 1998) (Fig.1) The situation is being complicated rivers, and those like the Senegal that run between countries, such as the Nile, are called contiguous rivers (Kliot 1994).

Pressure on the world fresh water resources is brought to bear by rapid population increase. Total world population has been estimated by the UN in 1999 at 6 billion, and the figure is expected to grow by another 2 billion within the coming 25 years. As water is needed for every aspect of human life, the pressure on available resources becomes tremendous. The situation becomes even more pressing as people everywhere tend to think of water as unlimited resources. This is why water is being over-utilized domestically and in all the sectors of production. Careless handing and poor management of water resources are the main causes of the water shrtages worldwide.

still further in the Middle East due to the large number of countries sharing the river basins. The greater the number of the countries sharing the river basins, the greater will be the problem of how to share the waters of the river in equitable and just way. Ten countries share the waters of the Nile basin, while the waters of the Jordan-Yarmuk have to be split among five political entities including the lands under the Palestinian Authority. As more countries come to share the limited supplies of these international rivers conflict over water is almost inevitable, particularly if the attitude of some sharing countries is hostile toward the other co-riparians (El-Bushra 1998); Rowley 1999).

As the question of sharing river water is a sensitive one, because water is life, it would be unwise for any country sharing an international river to use force to increase her share at the expense of the others, or take action unilaterally by building water projects that will decrease the share of other co-riparians. Violations of the nature described above have already been committed by both the Zionist state in case of the Jordan-Yarmuk and Latin rivers, and Turkey in case of the Tigris-Euphrates. As such violations will certainly be conductive to conflict over the water issue, it would be advisable for sharing countries to use of the Helsinki rules (1967) as basis for water agreements among themselves. The equitable utilization of waters of the international rivers are detailed in chapter 2, article V, of the Helsinki rules (Kliot 1994). Using the rules as basis for the model proposed in this chapter, most important (Kliot 1994; El-Bushra 1998).

II.Factors to be taken into account when allocating the waters of the international rivers to sharing countries:

a) Physical factors:

1. Climate (arid, semi-arid, humid), total amount of the annual rainfall, and the extent to which the sharing country depends on the river for its water needs.
2. Share of each country of the river catchment area.
3. Contribution of sharing country to the total river discharge.
4. Length of river (rivers) in sharing countries.
5. Suitable sites for the construction of water projects within the territory for the sharing country.

b) Socio-economic and political factors:

6. Number of countries sharing the waters of the international river basin.
7. Population size of the sharing countries including rates of growth, migration, and density.
8. Population structure of sharing country (age, sex, education and occupational characteristics).
9. Urban and rural distribution of population of sharing country.
10. History of utilization of river water by sharing country during the past 100 years.
11. Per capita income and gross domestic product (GDP) of sharing country.
12. Contribution of agriculture to GDP of sharing country.
13. Area of land irrigated form the river in sharing country.
14. Additional land area that can be irrigated from the river in sharing country.
15. Degree of self sufficiency in food products (food importation) in the sharing country.
16. Type of crops grown in sharing country and their water requirements.
17. Irrigation system adopted in the sharing country (traditional, modern).
18. Other uses of river water by sharing county (domestic, industrial, transport, generation of hydropower, sewage system, recreation, etc.).
19. Contribution of industrial sector to GPD and type of industries in sharing country.
20. Development of national water networks in sharing country.
21. Availability of other natural resources contributing to GDP, such as petroleum and minerals.

2- Model for Distribution of the Total Quantity of the Available Water among Sharing Countries

1. The Model:

A. Description of the model:

The proposed model is based on assigning weights W_k k=1,…,n to each of the factors F_k k=1,…,n that were considered significant in deciding the distribution of available water among the m countries that share the river.

The factors F_k are estimated numerically in appropriate units. Denote the numerical value of the factor F_j for the country I in the some units, by F_{ij}.The "ratio" of country I for this factor F_j is then $R_{ij}$where

$$R_j = \frac{F_{ij}}{\sum_{k=1}^{m} F_{kj}} , \begin{matrix} i = 1, \dots m \\ j = 1, \dots n \end{matrix} \qquad (1)$$

The elements R_{ij} may be called the normalized components of F_j the share Q_i of country *i* of the total quantity *Q* of water is then.

Q=Q , i = 1…m .(2)

Where

$$Si = \sum_{j=1}^{n} R_{ij} W_j \quad , i=1,\dots,m. \quad (3)$$

Note that

$$\sum_{i=1}^{m} Si = \sum_{ij} \frac{Fij\, Wj}{\sum_k FKj} = \sum_{j=1}^{n} Wj \frac{\sum_i Fij}{\sum_k FKj} = \sum_j Wj = 1$$

So that $\sum_{i=1}^{m} Qi = Q$ (4)

B.Characteristics of the proposed model:

i.the model is linear in the normalized factor components R_{ij} , i.e. the calculated shares are linear sums over these components. The components R_{ij} are dimensionless and satisfy $0 \le R_{ie} \le 1$.

ii. With the relevant quantifiable factors F_k agreed upon, the only degree of freedom in the model is the assignment of the weight W_k. These reflect the significance accorded to the relevant factors and are, of course, negotiable.

iii. The model is readily extensible to include more countries or more factors. It is also flexible in the choice of weights.

iv It is assumed that all relevant factors F_k are " favorable", in the sense that a larger value of F_k implies a larger share .

Should negative factor be considered relevant, a corresponding positive factor can always be defined and used.

For example if rainfall is negative, then lack of rainfall is positive.

This is quantified by calculating the components R_{ie} for negative factor N_e and then defining the components R_{ie} for lack of N_e by

Note that R_{ie} = 1- R_{ie}

$0 \le R'ie \le 1 \to 0 \le R_{ie} \le 1$

v. the model indicates a natural time –scale for the revision of agreements based on it. It is the time span considered suitable for a measurable change in one or more of factors F_k or in the significant coefficients W_k.

2- Example of Calculation (also see Table 1):

Take m=2 (i.e two countries)

N=3 (i.e three relevant factors)

With :

	F1	F2	F3
Country 1;	1.2	1	6
Country 2;	0.4	5	4
Proposed weights	0.2	0.6	0.2

Quality of water =1000 units then

F_{11} =1.2 F_{12} =1 F_{13} =6

F_{21} =0.4 F_{22} =5 F_{23} =4

Quality of water =1000 units. Then

$R_{11} = \frac{F_{11}}{F_{12}+F_{21}} = 1.2 = \frac{3}{1.6}$; $R_{21} = \frac{F_{21}}{F_{11}+F_{21}} = \frac{0.4}{1.6} = \frac{1}{4}$;

$R_{12} = \frac{F_{12}}{F_{12}+F_{22}} = \frac{1}{6}$; $R_{22} = \frac{F_{22}}{F_{12}+F_{22}} = \frac{5}{6}$;

$R_{13} = \frac{F_{13}}{F_{13}+F_{23}} = \frac{6}{10} = \frac{3}{5}$; $R_{23} = \frac{F_{23}}{F_{13}+F_{23}} = \frac{4}{10} = \frac{2}{5}$;

$$\therefore S1 = R_{11} W_1 + R_{12} W_2 + R_{13} W_3 = \frac{3}{4} * (0.2) + \frac{1}{6} * (0.6) + \frac{3}{5} * (0.2)$$

$$= \frac{0.6}{4} + \frac{0.6}{6} + \frac{0.6}{5} = 0.6 \frac{15+10+12}{60} = 0.6 \frac{37}{60} = 0.37$$

$$S_2 == R_{21} W_1 + R_{22} W_2 + R_{23} W_3 = \frac{1}{4} * (0.2) + \frac{2}{5} * (0.2)$$

= 0.05 +0.05+0.08=0.63

$\therefore Q_1$ = S1Q=0.37 $* 1000 = 370$ *units*

$\therefore Q_2$ = S2Q=0.63 $* 1000 = 630$ *units*

Table (1): Calculation of the Distribution of Blue Nile Waters on the basis of the given data (see appendix 1)

	Factor					
Country	F1	F2	F3	F4	F5	F6
(1)	6	7.5	1.75	45	0	1.2
(2)	3.5	5	155	30	1.97	7.5
(3)	5	0.05	0.2	15	0.2	2
Weights	W1 0.25	W2 0.2	W3 0.15	W4 0.1	W5 0.15	W6 0.15

Quantity of Bule Nile Water : Q=50 billion m^3

Definition and units of factor :

$F_1 = Population\ in\ 10^7\ persons.$

$F_2 = Irrigated\ area\ \ in\ 10^6\ feddans.$

$F_3 = Irritable\ are\ in\ 10^6\ feddans.$

$F_4 = Degree\ of\ urbanization\ (percentage)$

$F_5 = Catchment\ area\ in\ 10^6 (km^2).$

$F_6 = Channel\ length\ in\ 10^3\ km.$

Index for countries :

From the data we obtain:

$R_{11} = \frac{6}{14.5}$, $R_{12} = \frac{7.5}{12.55}$, $R_{13} = \frac{1.75}{156.95}$, $R_{14} = \frac{45}{90}$, $R_{15} = 0$, $R_{16} = \frac{1.2}{10.7}$.

$R_{21} = \frac{3.5}{14.5}$, $R_{22} = \frac{5}{12.55}$, $R_{23} = \frac{155}{156.95}$, $R_{24} = \frac{30}{90}$, $R_{25} = \frac{1.97}{2.17}$, $R_{26} = \frac{7.5}{10.7}$.

$R_{31} = \frac{5}{14.5}$, $R_{32} = \frac{0.05}{12.55}$, $R_{33} = \frac{0.2}{156.95}$, $R_{34} = \frac{15}{90}$, $R_{35} = \frac{0.2}{2.17}$, $R_{36} = \frac{2}{10.7}$.

Thus :

$$S_1 = \left(\frac{6}{14.5} * 0.25\right) + \left(\frac{7.5}{12.55} * 0.2\right) + \left(\frac{1.75}{156.95} * 0.15\right) + \left(\frac{45}{90} * 0.1\right) + (0 * 0.15) + \left(\frac{1.2}{10.7} * 0.15\right).$$

$$S_2 = \left(\frac{3.5}{14.5} * 0.25\right) + \left(\frac{5}{12.55} * 0.2\right) + \left(\frac{155}{165.95} * 0.15\right) + \left(\frac{30}{90} * 0.1\right) + \left(\frac{1.97}{2.17} * 0.15\right) + \left(\frac{7.5}{10.7} * 0.15\right) =$$

0.0603+0.0797+0.1481+0.0333+0.1362+0.1051=0.563.

$$S_3 = \left(\frac{5}{14.5} * 0.25\right) + \left(\frac{0.05}{12.55} * 0.2\right) + \left(\frac{0.2}{156.95} * 0.15\right) + \left(\frac{15}{90} * 0.1\right) + \left(\frac{0.2}{2.17} * 0.15\right) + \left(\frac{2}{10.7} * 0.15\right) = 0.0862 + 0.0008 + 0.0002 + 0.0167 + 0.0138 + 0.0028 = 0.146 .$$

$$\therefore Q_1 = 14.55\ billion\ m^3;\ Q_2 = 28.15\ billion\ m^3;\ Q_3 = 7.3\ billion\ m^3;$$

3. Conclusion:

The authors believe that by using the factors stipulated above, the proposed model will be acceptable to all the countries sharing the waters of international rivers. This is so because if a sharing country rates low according to one factor, that same country may rank higher according to another. It is also important that all states sharing the waters of an international river basin should recognize the water rights of one another. In other words, accessibility of a country to its water___share should be guaranteed irrespective of its location upstream or downstream , and irrespective of its military power. No sharing country should be allowed to use force or to unilaterally take action to increase her share of water at the expense of other co-riparian. The general attitude of all sharing states positive sign of development while conflict leads to tension, mistrust, animosity, and war. The problems arising from sharing the waters of international river basins should be settled peacefully through dialogue rather than resorting to the use of force. In case of disagreement over water right all parties must show their willingness to take the matter to international arbitration.

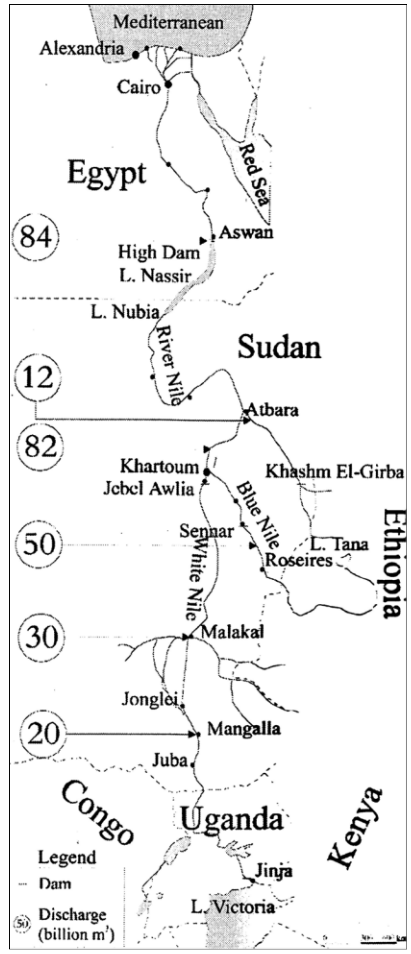
According to this model, countries sharing the waters of a river must not only agree on the factors to be included in distributing river water , but should also agree on the weights to be assigned to each factor depending on the importance of the factor in question. A model based on so many physical and socio-economic factors is bound to be fair to all concerned and will guarantee the distribution of river water in an equitable and just way . Finally, it is our firm belief that by using this model to allocate the waters of international rivers to co-riparians that tensions and conflicts over water sharing will be greatly reduced.

Appendix 1

Countries Sharing the Waters of the Bule Nile

Country	F1 Popuation	F2 Irrigated Area (fd)	F3 Irrigable Area(fd)	F4 Urbanization (%)	F5 Catchment Area (km2)	F6 Channel Length (km)
Egyept(m1)	60000000	7500000	1750000	45%	0	1200
Sudan (m2)	35000000	5000000	155000000	30%	1970000	7500
Ethiopia(m3)	50000000	50000	200000	15%	20000	2000
Weight: 1.00 100%	0.25 25%	0.20 20%	0.15 15%	0.10 10%	0.15 15%	0.15 15%

- Total Quantity of Blue Nile water : 50 billion M3
- Source : El-Bushra ,1998.



Source: adapted from Kliot (1994)

Notes:

1. El-Bushra. El-Sayed 1998, *The Problem of Water and its Impact on Arab National Security*, Naif Arab Academy for Security Sciences Press (Arabic).
2. Kliot, N. 1994, *Water Resources and Conflicts in the Middle East*, London, Routldge.
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