ALLOCATING THE GAPS OF SHARED WATER RESOURCES (THE SCARCITY INDEX) CASE STUDY PALESTINE ISRAEL

Mohamed Asheesh
Dr. of Technology, Senior Researcher and Responsible Lecturer
Institute of Technology, Kotkantie 1, 90100 Oulu, Finland,
email: mohamed.asheesh@oamk.fi

ABSTRACT

The paper aims at providing the parties involved in the conflict and the bodies responsible for successful implementation of the model proposed with a co-operation support model, that by using different tools, both technical as well as managerial ones, can eventually improve the water supply situation in whole Middle East area. The model suggests improvements in the patterns of information exchange (information collection and sharing the information on catchments, desalination, reuse techniques, etc.), institutional capacity building (qualified labour force, organisation) and management. Cooperation can be applied in many areas of water management: management of water resources (management of underground and ground water), management of the water supply network (operation, monitoring, maintenance), and wastewater management (water reuse).

To assist the management of shared water resources a mathematical model (The Scarcity Index) has been developed to evaluate water resources gaps on national and international level. The need is measured by the value of the scarcity index, which considers most of the elements that affect structural demands and ecosystem conditions of the water bodies.

KEYWORDS: Modeling, Sharing, Scarcity Index, Water Resources

INTRODUCTION

Sharing transboundary water resources and the process of portioning them are challenges for downstream countries around the world. Development and pollution are both increasing, while the supply of water is not. These days, there are more and more demands being put on our limited water supplies by people, agriculture and industry. In addition, we are dependent on our environmental partners. Before we all dry out or get flooded out, or in the worst case killed in struggles over water, we are encouraged by all interested parties whether private, governmental or non-governmental, to work together to manage our water better under leadership of the UN.

A water crisis is often a crisis of scarcity or misunderstanding between the parties sharing transboundary resources: a failure to integrate policies and practices related to the management of water resources. Good water governance exists where government bodies responsible for water establish an effective policy and legal framework to allocate and manage water in ways responsive to national, social and economic needs, and to the long-term sustainability of the resource base. There will be no transition to sustainable development without a transition to water sustainability (Swedish Environmental Institute (SEI) 2002), which requires a systemic perspective that links water resources to requirements for irrigation, industry, human needs and ecosystems. In recent years, the issue of the long-range adequacy of fresh water resources has moved to centre stage in international discussions of sustainable development. The call for the adoption of sustainable water strategies has become urgent as conflicts over the allocation of increasingly scarce water resources loom (GWP 2000).

WATER EQUALITY ACCOUNTING SYSTEM

The Water Equality Accounting System (WEAS) was created to monitor the inlet and outlet of available water in national and international basins. The model is based on Water Accounting For Integrated Water Resources (WAFIWR) developed by David Mulder at the International Water Management Institute (IWMI) in 2001 (IWMI 2001). The two models have in common the balancing of water resources supply and use by humans and environment. On the other hand, the WAFIWR model builds on factual data, while the WEAS is based on the availability, reliability and probability of sharing the data on the one hand and recognizing the equal rights of neighbours over transboundary water resources on the other. WEAS uses a water balance approach to quantify the amount of water entering an area (through precipitation, rivers, groundwater flows in addition to water re-use, other water resources obtained through transport or import, and desalination) and the amount leaving an area (through evaporation, plant transpiration, rivers and groundwater flows or other water losses) as illustrated in Figure **1**.

The amount of unused water flowing out of the system is classified according to whether it is committed for downstream use. Non-committed outflows are further subdivided into water that is currently utilisable and water that is not utilisable without additional infrastructure. The inlet and outlet parameters have to be defined and exchanged, and the following questions should be answered and analysed for each riparian state: (i) how water is being used, (ii) where water can be saved and, (iii) how efficiently the utilities are managing water resources.

In developing countries, strategies and planning should focus on reducing the flow of irrigation and drainage water into the sea (IWMI 2001). One of the biggest problems in developing countries is irrigation and use of water for food production. Planning of upstream and downstream irrigation systems for equal reasonable use should be ensured, water conservation at penetration areas improved, and well drilling controlled. Other alternatives can also be applied to conserve water. For instance, social and religious aspects in Saudi Arabia during the Hajj season can provide an opportunity to save water by reducing the water flow in the mosques and by recycling treated wastewater to the flushing system for almost three million Hajjis during their visit to the Mecca and Medina mosques (Asheesh 2001).

WATER BALANCING

Balance in general can be defined as the relation between the system input volume and the system output volume in all use directions. Balancing investigates the relation between the above-mentioned parameters as illustrated in Figure **1** during a certain time period under different conditions. The result of the balancing for a certain future time depends on reliability and availability of exchanged data, and when estimating missing data the probability theory should be applied. Water resources balancing parameters calculated for a state or riparian states can be divided into four major groups:

System Input Volume, System Output Used Volume, System Output Losses, System Output to Environment.

The grouping can help in determining the amount of annual water resources needed or available on the national or international scale.

System input volume

The System Input Volume group represents the annual input of water into the system on the national or international scale including the following inputs classified by the origin of the water resource:

Water re-used by natural or artificial means, Surface water, lakes, rivers, Underground water Desalinated water, Other resources: importing or transporting water or other options and alternatives for covering water gaps.

System output used volume

System Output Used Volume balance parameters that describe where the water has been used. Generally, the System Output Used Volume may comprise four key water categories:

Domestic use (domestic, urban and rural, including settlements and camps in some cases) , Industrial use, Irrigation in all forms, considering the type of crops and the methods of irrigation, Green services for public green areas.

System output losses

System Output Losses show where there are the opportunities to save water through monitoring and control:

Losses during distribution

The determination of the losses in the system and during distribution is an important aspect of water resources management. It is a significant factor in decision making related to portioning of shared water resources. In the case study, the amount of losses in the West Bank and Gaza Strip is estimated at 25-60 percent in some places (PECDAR 2000), while the leakage in Jordan is 60 percent (Alicante 2003). The water accounting system is one of the tools that can be applied to determine two parameters, the condition index for the network and Unaccounted For Water. These two parameters are important elements for completing the calculations of the Water Accounting System (Asheesh 1998).

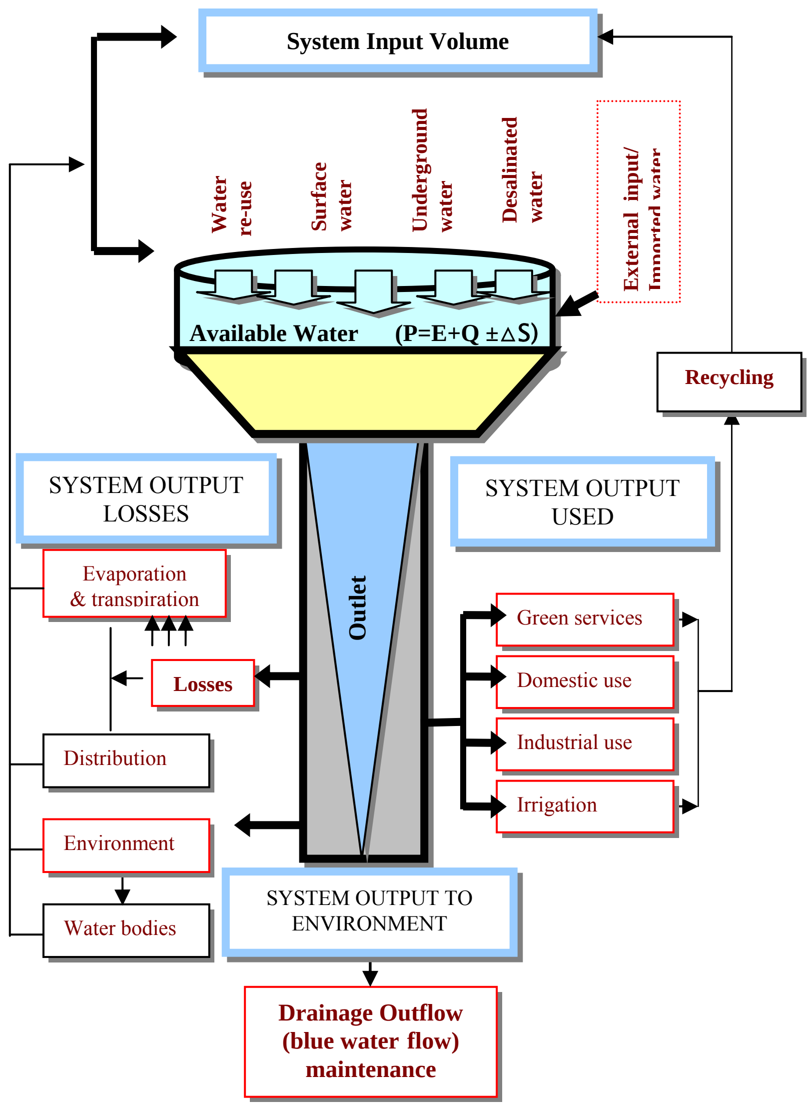

Figure 1 Water Equality Accounting System (WEAS) structure suggested by the author

Natural losses (evaporation & transpiration)

The evaporation process can have four different forms:

Evaporation from surface water, evaporation from snow, evaporation from soil surface, and evaporation from plants (transpiration). In general, it can be calculated as the difference between precipitation and runoff.

According to Algahriani (2002), the ratio of evaporation in arid and semiarid climates during irrigation and other agricultural activities can exceed 0.25 percent of the irrigation water. Changes in temperature should be considered in this case.

According to FAO (2002), plant roots suck or extract water from the soil to be able to live and grow. The main part of this water does not remain in the plant but escapes to the atmosphere as vapour through the plant's leaves and stem. This process is called transpiration, which happens mainly during the daytime. Evapotranspiration is a process of total evaporation from soil surface. Water from an open water surface that escapes as vapour to the atmosphere during the day is called evaporation. This volume is usually expressed in mm/day, mm/month or mm/season. The losses of water through transpiration can be controlled and prevented by humans by choosing appropriate crops.

System output to environment

System output to environment is a flow requirement defined as the minimum amount of water in stream flow required at a point on a river or diversion to meet water quality demands for fish, wildlife, navigation, recreation, downstream use or other requirements.

Water scarcity and the balance of water resources

There have been numerous attempts to develop indices related to scarcity. According to Turton (1999), water scarcity means water poverty. Priscoli (2000) defines with help of English dictionaries security as freedom from danger, from fear or anxiety, from want or deprivation. Indeed, this is what the history of humanity's management of water is all about: trying to be sure we have good water, in the right quantity, and at the proper time and place. Water crises are thus not driven only by absolute scarcity, but also by disruptions in distribution of water, knowledge and resources. Increasing our flexibility and capacity to respond to exigencies of nature and reduce our vulnerability to events such as droughts and floods will increase our security. That is: we are reducing uncertainty and building predictability and safety into what was often experienced as a harsh environment. As regards water, security can be seen as freedom related to water supply or society's dependency on water for numerous functions.

Water scarcity is usually evaluated with the help of a water scarcity index. Probably the most famous water scarcity index is the one developed by Prof. Malin Falkenmark, published in AMBIO (Falkenmark 1989 a). Basically, Falkenmark carried out a survey of a number of countries and calculated the water amount used per person in each economy. Falkenmark then determined the state of economic development of those countries. Based on that she calculated the index (Table 1) using the concept of the "water barrier" beyond which no industrialised country would be able to sustain itself.

Table 1 Water barrier demarcations according to Falkenmark & Widstrand (1992)

Index (m^3 per capita)	Category/Condition
>1,700	No stress
1,000-1,700	Stress
500-1,000	Scarcity
<500	Absolute scarcity

Ohlsson (1999) did some more sophisticated work on indices. By using the Human Development Index he worked out a fairly complex index which takes social aspects into consideration. According to Gleick (1993a), scarcity is the relationship between human needs and the reserve of water resources. Gleick claims that water availability should be 100 litres per person per day. Others define water scarcity as a situation where we cannot satisfy the minimum water requirements for drinking and planting for food. Different organizations' definitions of human needs also vary. For example, WHO defines the minimum daily water requirement as 150 litres per person (questionnaires Asheesh 2002). Gleick's interpretation of water scarcity is shown in Table 2.

Table 2 Water scarcity index according to Gleick (Gleick 1995; modified by the author)

Index (m^3 per capita)	Category/Condition
>1,667	Abundance
<1,667	Stress
<1,000	Scarcity

In Finland 'Water scarcity' has been defined by Kantola et al. (1999) as follows: "When the amount of fresh water is less than one thousand cubic meters per capita, we can say that there is scarcity of water" (Table 3).

Table 3 Some examples of the amount of available fresh water per capita in some countries around the world (Kantola et al. 1999).

Country	Amount of fresh water $m^3/cap.x10^3$	Country	Amount of fresh water $m^3/cap.\ x10^3$
Canada	94.4	England	1.2
USA	8.9	Kenya	0.7
China	2.2	Israel	0.3
India	1.9	Egypt	0.04
Finland	21.3		

The author suggests the following definition for water scarcity: "Water scarcity is a shortage in freshwater availability from renewable resources to meet the essential demand in various water consumption sectors. Essential demand includes domestic demand and agricultural demand needed to ensure food security for the nation, while industrial demand can be met, to a great extent, by recycled water."

Based on the above interpretations of scarcity and the relationship between the availability of water and human consumption needs, scarcity can also be understood as an increase in the use and need of water related to available water resources in a country or region.

The scarcity between the riparians can be most conveniently expressed as the relation between available water and the need of a human being (100 l/c/d) according to Gleick (1993b), or 100-150 l/c/d in arid and semiarid regions according to Falkenmark (the so-called barrier, i. e. use of available water resources fulfilling principles of equitable and reasonable use).

Another form of the scarcity index presented by Falkenmark and Gleick is the benchmark indicator; the 1,000-cubic-meter benchmark has been accepted as a general indicator of water scarcity by the World Bank (1992) and other analysts. Gleick (1993b), of the Pacific Institute, called it the "approximate minimum necessary for an adequate quality of life in a moderately developed country." In the Middle East, Israel, a relatively prosperous country, is commonly cited as surviving on much less than 461 cubic meters of fresh water per person (although Israel also depends on some non-renewable groundwater). But even countries with high water availability may experience problems because of regional disparities or very high water demand (Gleick 1992). Acknowledging such discrepancies, however, hydrologists and water use experts find that 1,000 cubic meters serves as a useful benchmark for water scarcity around the world. Falkenmark's higher benchmark of about 1,700 cubic meters per capita per year is a "warning light" to nations whose populations continue to grow. In time, in the absence of conditions that lead to population stabilization, most water-stressed nations will fall into the scarcity category (Falkenmark & Widstrand 1992).

Throughout our study we talked about water scarcity if the scarcity index defined by Equation 1 is negative. The water scarcity index is expressed by a balancing equation as follows:

$$W_{sci} = (W_{av} / W_{tad}) - 1 \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots 1$$

Equation 1 Scarcity index based on water balancing

Where :

W_{sci} Water scarcity index
W_{av}: Available water resources in shared basin (in the state)
W_{tad}: Total annual demands for all riparians/states

The scarcity index is an indicator that shows developments in the water situation of a riparian country. It points out the size of the gaps that should be covered or amounts to be returned into the system in order to secure the balance between available water and water demand.

Balancing of the system is accomplished by covering the gaps or preventing the depletion of water resources and monitoring the relation between the inputs and outputs of the system. In the case of depleted national or international river basin aquifers, covering of gaps or controlling and stopping the flow of the shared transboundary aquifer can be an alternative to balancing the situation inside and outside the system on the national and the international level. As an example, Figure 2 shows an international aquifer that can be protected for balancing purposes from both sides of the border. The process is assumed to be supported by riparian cooperation and establishment of an international commission by the riparians.

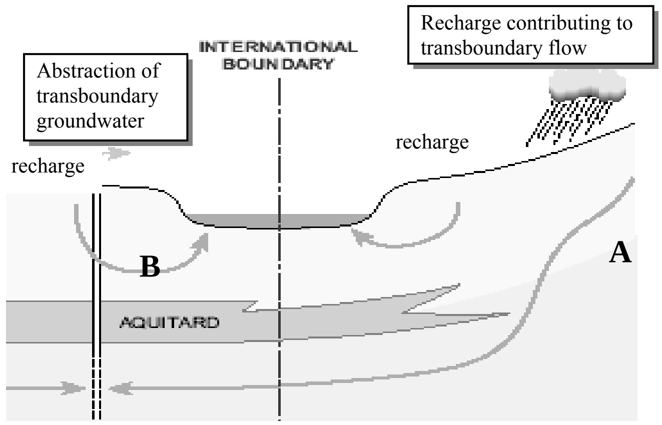

Figure 2 The boundary of an international aquifer river basin (ISARM 2001; modified by the author 2002)

In order to reduce water scarcity and support sharing of international water resources, water balancing needs to be done by applying mathematical calculations to assist the evaluation of the availability of water resources and projecting the demand for long-term and short-term development, as well as for system planning and plans implementation to meet future demand.

The calculations and evaluations will enable clearly depicting the ongoing situation in every sector inside the riparian states. The point of evaluation is to find the weak or strong sectors and to try to cover the gaps between the parameters inside the sector and inside the states. Recovering can be solved in expectable way by satisfying all the parties involved in sharing.

The developed equation is based on understanding the probability and availability of data, analysis of collected data and assumption of the risk for long-term and short-term development.
Balancing of inputs and outputs can be done through monitoring total available water resources and total use of water resources, monitoring

where the water is going, how the water is used, and how we can save water. These elements should be calculated in relation to changes in time (Δt).

Water demand and the scarcity index

The scarcity index developed in this study reflects the relationship between the water system inputs and outputs from the system based on population growth in a given time. The scarcity index is expressed as a shortage or gaps (expressed as percentages), as the relationship between the parameters of available water and demands as illustrated in Equation 2 The main element of the equation is population growth, which determines all water sector demand parameters. Population growth will increase the demand for green areas, irrigation, water distribution and development of industry of a certain type (water-intensive or just the opposite, like in the case of Nokia, there is no special need for water, but this depends on the country and its industrial base).

$$Wsci = \left(\frac{\alpha}{\left(\left[\frac{100}{100-p} \right] \beta \exp^{\lambda \Delta t} (\varepsilon + \gamma + \delta) \left(\frac{100}{100-\kappa} \right) + h + b \right)} \right) - 1 \text{...............}(2)$$

Equation 2 Scarcity index

Where:

W_{sci} Scarcity index

α: Input into system (A or B riparian)

ε: Annual domestic demand (m^3/c/y)

γ: Demand for green areas (m^3/c/y), it depends on population growth

δ: Demand for irrigation (m^3/c/y)

λ: = Ln (1+r), population growth rate

Δt: Length of time for which the estimation is made, the period can be calculated as the difference between the present and the future (t-k);

β: Population

t: Present time

h: Yearly evapotranspiration of water, depends on climate of country

b:	Water needed to maintain the environment, depends on the length and depth of the water body
k:	Estimated losses
p:	Industrial demand as a percentage, depends on country structure, its value can be determined as 15-25 percent of the domestic demand

Water balance and scarcity index calculation in the case of Palestine and Israel

Solving the exponential equation (Equation 2) for calculation of water scarcity can be carried out using software to assist the evaluation of the water resources situation in the area. The idea is to construct a node system inside the state or between riparians who share the river basin. Software can be used as a toolbox for the model suggested. By using this toolbox, the input and output of water at every node can be evaluated. After calculating the water inputs and outputs into and out of the node, the toolbox will allow transferring or locking the water from or to the node. In this way, the system can be controlled and every riparian will have the possibility to receive his portion of the shared water for at least the short term. The software can be written by Visual Basic, and the graphical part can be connected to a scanned form of a map digital system. In the example below, the calculation was performed using Excel spreadsheets; most of the parameters of Equation 2 were estimated, while some of them were collected from the field.

Table 4 The Palestinian water scarcity index

Palestine		
	Parameter	Water Demand mm^3/y
Input into water system	α	600*
Industrial demand	p	17
Population	β	2,600
Growth rate	λ	0.033
Time	Dt	20
Domestic demand	ε	54.75
Green area/c/y	γ	20
Irrigation demand	δ	35.58
Population at t	κ	20

Evapotranspiration	h	451,462
Maintenance water	b	140,000
Water scarcity index	**Wsci**	**-0.37**

*based on assumptions regarding the outcome of imminent bi-lateral negotiations in the region.

Table 5 The Israeli water scarcity index

Israel		
	Parameter	Water Demand mm^3/y
Input into to system	α	900*
Industrial demand	P	21
Population	β	6,000
Growth rate	λ	0.024
Time	Dt	20
Domestic demand	ε	54.75
Green area/c/y	γ	20
Irrigation demand	δ	38.325
Population at t	κ	20
Evapotranspiration	h	941,999
Maintenance water	b	180,000
Water scarcity index	**Wsci**	**-0.53**

* water available to Israel reduced by the Palestinian portion of the Aquifer in the West Bank

CONCLUSIONS AND RECOMMENDATIONS

Freshwater conflicts are common in arid and semi-arid regions, and they tend to remain particularly acute when international relations are otherwise tense. These two elements co-exist in the case of the West Bank-Gaza Strip and the Jordan River Basin.

Among the riparian countries, the situation is particularly difficult bilaterally between Israel, Palestine, Jordan, and Syria. Israel and Jordan, both suffering from extreme water scarcity, have not so far fully agreed on the sharing of the waters of the Jordan and Yarmuk Rivers, although major efforts for cooperation have been made recently. Syria has a contentious dispute/agreement with Israel regarding the future national control of the Golan Heights area. The Palestinians are not powerful enough to participate in any discussions involving the important headwaters of the Jordan River. Syria and Jordan have had some disagreements over the project to build a dam on the Yarmuk River, which Israel opposes anyway. Finally, the Palestinian State question is also closely linked to water issues, since the West Bank area aquifers constitute a major source of water for Israel.

In Israel and Palestine, the conflict over shared water is the result of distrust, sovereignty, ownership of the water resources in theory, and use of force in reality. On the other hand, international water rights and water sharing principles are ignored. It is a fact that the area will suffer from water shortages in the long term. Increasing the supply and decreasing the demands could be an alternative to covering the gaps. Water saving and water-use priorities could decrease the demands. This could be achieved by eliminating swimming pools in the settlement areas. Water demand for irrigation and other use also needs to be regulated and minimised. This can be achieved by growing the proper types of crops, or importing fruits and vegetables from neighbouring countries, if possible.

Allocation of the water resources in the area is important for long-term planning and strategy building. Any allocation or any portions should be based on the principles of international law.

Available tools and rules have to be applied to achieve the goal. The developed model is a tool applicable in allocation and evaluation of the water resources of the area. Yet, tools cannot be applied without faithful and real cooperation between the riparians. Exchange of information should be practiced to monitor the resources over the long term. Water authorities, consultancies, researchers and even decision makers can use this model.

Ironically, international cooperation is both necessary and difficult in the Jordan River Basin and the aquifer basin in the West Bank. The peace efforts of the 1990s could have eased the situation, but the only solution for the long run is to agree on basin-wide water allocations and management. It remains to be seen whether a general water agreement can be made before a lasting peace has been secured, or if these political questions must be resolved simultaneously.

REFERENCES

Algahriani, S. A. (2002): Future Perspective for Irrigation in the Southern Mediterranean Region, pp. 313-320, In: Policies and Management: Water Resources and Management.

Alicante (2003): Personal communication: discussion with Tahal engineering for consulting /Israel, and the Palestinian vice president of environment ministry/ Gaza. Alicante –Spain, 10-14 April, 2003.

Asheesh, M. (2001): Rules and Tools for Non-Navigational Use of International Watercourses, American Water Resources Association, University of Dundee International Specialty Conference on Globalisation and Water Management, The Changing Value of Water, August 6-8, 2001, Dundee, Scotland, Cd publication.

Asheesh, M.; Al-Otaibi, M. & Katko T. S. (2002): Model for Evaluation of the Scarcity Index of the National and International Water Resources, Conference Paper Presented at the First Regional Conference on Perspective of Arab Water Cooperation, Challenges constraints and Opportunities, Cairo, Egypt, 12-14.2002.

Asheesh, M (2003): Integrating Rules and Tools for Transboundary Water Resources Management, Case Israel and Palestine, Tampere University of Technology, Finland, 220p.

Asheesh, M. (1998): The mathematical model of the scheduling the rehabilitation of the water pipe network, Licentiate Thesis, TUT, IWEE, Finland, 96 p.

Falkenmark, M. (1989a): The massive water scarcity threatening Africa-why isn't it being addressed. Ambio, Vol. 18, No. 2, pp. 112-118.

Falkenmark, M. (1989b): Middle East Hydro politics: Water Scarcity and Conflicts in the Middle East, Ambio, Vol. 18, No. 6, pp. 350-352.

Falkenmark, M. & Widstrand, C. (1992): Population and Water Resources, A Delicate Balance, Population Bulletin, Population Reference Bureau.

FAO (2000): New Dimensions in Water Scarcity-Water, Scarcity and Ecosystem Services in the 21th Century, Land and Water development Division, Food and Agriculture Organization of the United Nation, Rome. FAO Report, AGL/MISC/25/2000. 82 p.

Gleick, P. H. (1995): Human Population and Water, to the Limits in the 21th Century, Symposium on Human Population and Water, Pacific Institute for Studies in Development, Environment and Security, Oakland, CA.

Gleick, P. H. (2000): Water Conflict Chronology September 2000 version, available online at http://www.worldwater.org/conflict.htm, (April 2003).

Kantola, A.; Auvinen, J.; Härkönen, R.; Lahti, V-M.; Pohjalainen, A-L. & Sipola, S. (1999): Maailman tila ja Suomi, Ministry of Foreign Affairs, Department of Development Cooperation, Helsinki, 2000, 351 p.

Ohlsson, L. (1999): Environmental Society and Conflict, A Study of Malthusian Concerns, Department of Peace and Development Research, University of Göteborg, Sweden.

PECDAR (2000): Palestinian Water Strategic Planning Study, Palestinian Economic Council for Development and Reconstruction (PECDAR), 142 p.

Priscoli, J.D. (2000): Water Security, Interdependency, Dependence and Vulnerability, SIWI Seminar, Water Security for Multinational Water System-Opportunity for Development, pp. 34-61.