Desalination and Water Treatment
www.deswater.com

doi: 10.1080/19443994.2014.940659

55 (2015) 2364–2368
August

Scarcity and environmental quality in river hydrological basins

T. Mimides*, D. Koilakos, C. Mimidou, C. Riga

Department of Natural Resources Development and Agricultural Engineering, Agricultural University of Athens, Iera Odos 75, 11855 Athens, Greece, Tel./Fax: +30 210 5294072; email: teom@aua.gr (T. Mimides)

Received 31 March 2014; Accepted 17 June 2014

ABSTRACT

Fauna and flora depend on water of hydrological river basins to remain alive, where a conjunctive use of surface and ground water should take place. Also, water is a human right and must be treated as such to meeting other human rights such as civil and political. Except for drinking purposes, activities such as agriculture, industry, transportation, electricity and amenities make use of water. The last decade there is a growing concern that water is at scarcity and far exceeds the potential for its natural recharge. Degraded water quality deteriorates further the situation. Such worrisome concerns about water quality can be attributed to both natural processes and human activities. Significant environmental health issues and desalination processes at Greek hydrological river basins cannot be ignored. Over 20 countries worldwide are depending on water that is flowing from other nations, and more than 300 of the world hydrological river basins are considered transboundary. The tropics and mid-level northern hemisphere have the potential for freshwater than other parts of the world. According to the UK's Center for Ecology and Hydrology, rich developed nations are guilty of mismanaging and overusing water resources. In developing countries, water is extraordinarily inefficient because 68% of it is lost in evaporation or returned to rivers and aquifers. The long-term effects arising from irrigation comprise loss of biodiversity and the hydrological river basin waters the ability to natural self-cleaning mechanisms. Shortage of water deprives the fauna and flora of their ecosystems. Besides their contributions to water scarcity, irrigation, industry and domestic effluent are major sources of water pollution and contamination. According to the World Bank in Middle East and North Africa region, many countries fulfil their water demand partially or totally by desalinating seawater. River basins in the region have around 60% of the world's desalination capacity ($7.2 \times 10^9\,m^3$/year). According to the countries plans and their historic desalination capability, the total capacity is expected to increase and reach $19.1 \times 10^9\,m^3$/year by the year 2016 and possibly $31.4 \times 10^9\,m^3$/year by 2025. This will count for around 39% of the anticipated region's deficit. Preferably, the remaining deficit will be bridged through efficient demand and supply management. Comparing with Middle East and North Africa, Greece is still in an infantile stage.

*Corresponding author.

Presented at the Conference on Desalination for the Environment: Clean Water and Energy 11–15 May 2014, Limassol, Cyprus

Keywords: Water resources management; Hydrological river basins; Water scarcity; Desalinations

1. Introduction

Water scarcity is taking place after long-term water imbalances that combine low-water availability with a level of water demand exceeding the supply capacity of the natural system. There is no concrete definition of water scarcity but it can be referred as the lack of available water resources to meet the demands of water usage within a region. The water scarcity often occurs in areas with low rainfall, which are characterized by long drought periods, as well as in areas where the drought is combined with human activities such as tourist inflow, intensive agriculture and water demanding industries. It is very possible that the climate change in the future will deteriorate the problem, especially in the some parts of southern Europe and in Middle East and North Africa regions. There the combination of low precipitation and high temperatures can further reduce the available amount of water and increase the economic impacts and affect many sectors. The consequences can affect sectors such as agriculture, forestry, energy and drinking water providers. Moreover, a reduction in the amount of water aquatic ecosystems and groundwater may have huge environmental impacts that could range from too less water in rivers and lakes to the salination of the aquifers and the small reserve of water to dilute inputs of pollutants.

2. Water scarcity indices

The assessment of the vulnerability and the associated risk to water scarcity and drought is a complex problem caused by many factors. Despite the fact that the term "water scarcity" is regularly used by the media and scientists, there is no specific definition or method of measurement.

In order to reduce the confusion, methodologies were developed for measuring water scarcity over the past 20 years. The initial water scarcity threshold developed by Falkenmark in 1989 [1] was a very important foundation, on which water consumption demands were built [2]. Later, the water consumption led to the development of different water scarcity indices by different scientists, some of which are mentioned below.

2.1. Falkemark indicator

This index is one of the most commonly used measures of water scarcity. It was introduced by Falkenmark [3]. This method defines water scarcity in terms of the total water resources that are available to the population of a region. The measurement result determines if a region is water stressed or not:

(1) If the amount of renewable water in a country is below 1,700 m^3/person/year, this country is said to be experiencing water stress.
(2) If the measure is below 1,000 m^3 it is said to be experiencing water scarcity.
(3) If the measure is below 500 m^3 absolute water scarcity.

This method is easy to use and the data needed are readily available. On the other hand, this index has many disadvantages because:

- It ignores important regional differences in water available.
- It fails to account for whether or not those water resources are accessible.
- It does not include man-made sources of freshwater (desalination plants)
- It does not account for the fact that different countries and region within countries use different amounts of water.

2.2. Basic human water requirements

This index developed by Gleick [4] measures the ability of meeting all the human requirements for the basic human needs such as drinking water for survival, water for human hygiene and water for sanitation services and modest household needs for preparing food. The proposed minimum amount needed for each of them is as following:

(1) Minimum Drinking Water Requirement: 5 L/person/d.
(2) Basic Requirements for Sanitation: 20 L/person/d.
(3) Basic Water Requirements for Bathing: 15 L/person/d.
(4) Basic Requirement for Food Preparation: 10 L/person/d.

The proposed water requirements for the basic human needs give a total demand of 50 L/person/d.

Both Falkenmark and Gleick created the "benchmark indicator" of 1,000 m^3 per capita per year as a standard that has been accepted by the World Bank [2,5,6].

2.3. International Water Management Institute (IWMI)

Another index for water scarcity is the index that was developed by the IWMI and attempts to solve all the problems listed above by including:

(1) Each country's water infrastructure into the measure of water availability (desalination plants).
(2) Recycled water by limiting measurements of water demand to consumptive use rather than total withdrawals.
(3) Measuring the adaptive capacity of a country by assessing its potential for infrastructure development and efficiency improvements.

The disadvantages of this index are the following:

- Its requires significant amounts of time and resources to estimate
- It does not consider the ability of people within countries to adapt to reduced water availability by importing food growth in other countries, or by using water saving devices.

2.4. Water poverty index

A fourth index to measuring water scarcity is the Water poverty Index which take into account the role of income and wealth in determining water scarcity by measuring: (a) the level of access of water, (b) water quantity, quality and variability, (c) water used for domestic food and productive purposes, (d) capacity for water management and (e) environmental aspects.

This method is more suited for analysis at a local scale, where data are more readily available, than on a national level. Moreover, this approach is very complex to be applied due to the various factors that it measured.

3. Water scarcity and GIS

GIS can be defined as software that allows a user to view, store, manipulate and analyse spatial data. GIS is nowadays widely used in the development sector and for water management and there is now much greater awareness of the importance that the spatial dimension has to the majority of decision-making processes and in the role that GIS can play in providing spatial information [7].

The characteristics of GIS make it an invaluable tool. One of the most important is that it is able to present spatial information on maps in a quick and logical way. It provides assistance on data collection, data management and data analysis by spatial representation of these data. This is important because many aspects of water scarcity have an intrinsic spatial dimension, as demonstrated by fact that groundwater recharge rates and availability vary spatially over small distances [7].

A very common used GIS tool for the contribution of essential hydrological information to the decision-making process is the Soil and Water Assessment Tool (SWAT). SWAT is a physical semi-distributed model that runs on a daily time step and simulates the major hydrological processes and water balance components of a model catchment [7,8]. SWAT can simulate surface and subsurface flow, sediment generation and deposition and nutrient movement and fate [7,8]. SWAT copes relatively well with three of the major challenges faced by hydrological modelling: the complexity of the natural system; the spatial heterogeneity of catchment characteristics and lack of suitable data [7,9]. SWAT is also able to capture some of the spatial heterogeneity of catchments and utilize satellite data for many of the required model inputs. Therefore, SWAT has gained worldwide acceptance as a model that can be applied to a wide range of hydrological conditions at various scales, and as a result there are now over 1,000 published peer-reviewed articles on the model [10].

The SWAT model is a result of nearly 30 years of continuous research by the United States Department of Agriculture: Agricultural Research Service [7,11]. Its development has been driven by the need to assess the impact of climate change and land use on water resources and a need to assess which management strategies can help mitigate resulting problems [7,11]. It can therefore be used to quantify existing water uses and shortages and to predict how these will be altered by different impacts spatially across catchments; allowing interventions to be better targeted [7,10,12].

One major advantage of SWAT is that it can be applied to ungauged catchments and run without calibration, although in the majority of published studies, there is at least an attempt to calibrate the model because, without it, it is difficult to apply model results to any management decisions due to the uncertainty inherent in the outputs [7,10].

4. Water scarcity in river basins in Greece

Water scarcity occurs where there are insufficient water resources to satisfy long-term average requirements. It refers to long-term water imbalances, combining low water availability with a level of water demand exceeding the supply capacity of the natural system.

Moreover, water scarcity occurs when the amount of water pumped from lakes, rivers or groundwater is so great that water supplies are no longer adequate to satisfy all human or ecosystem requirements, resulting in increased competition between water users and other demands.

Several global studies have concluded that the Mediterranean will be significantly affected by climate change through decreases in precipitation and increases in temperature. These factors can lead to projections that the area will suffer from increasing water shortages in the future.

Water availability in Greece is limited because of its Mediterranean climate. Precipitation is spatially skewed with 1,500 mm/year in the west to less than 400 mm/year in the east. Water shortages are common, particularly in south-eastern areas where water use is highest while precipitation lowest.

Few rivers exist in peninsular Greece all of which are small, and many dry up during the summer. By contrast, rivers in the Balkan Peninsula, that flow through northern Greece, for example, the Vardar and Struma River, have significant summer discharge. The relatively small and seasonal nature of many rivers limits their capacity for irrigation. Agriculture uses 84% of available resources while domestic supply and industry account for 13 and 1.7%, respectively.

Overexploitation of groundwater resources has led to low groundwater levels and there is limited effective control on the amount of water extracted. In Greece, as in most Mediterranean Basin countries, financial institutions should pay close attention to the sustainability of water availability and water use, with a special focus on the groundwater exploitation by users in the vicinity of clients.

Groundwater salinity is a growing problem which is caused by both seawater intrusion into aquifers and return flows from irrigation water. Seawater encroachment is exacerbated by the long coastline of Greece, the karstic characteristics of the aquifer systems and the potential for sea level rises in the future. The bad water quality directly depletes overall resource availability, as irrigation water with a high level of salt content can damage crops.

Arsenic contamination in groundwater in the north of the country (Thessaloniki, Chalkidiki prefectures and others) is found in some agricultural places where groundwater is used for irrigation. Risks to food safety and yield are likely to increase with the build up of arsenic in the soil. The pollution of surface and groundwater from excessive use of agrochemicals further challenges farmers in Kopaida, Arta and Argolida.

The transposition of the European Water Framework Directive (WFD) into Greek legislation has resulted in a new institutional arrangement. The protection and management of river basins and the implementation of the WFD are the responsibility of the 13 Regional Water Directorates.

The transboundary rivers of Greece need special management of their waters, due to different water legislations prevailing it the countries through which they flow. In this case of shared river basins, the National Water Committee determines which regional authority is responsible. These rivers are the following:

- Strymonas River: It is shared between Greece and Bulgaria and its river basin is also extended to Serbia and FYROM. It has 400 km length and the river basin area is up to 18,078 km^2.
- Nestos River: It is a transboundary river between Bulgaria and Greece. The length of the river is 230 km, 126 km of which belong to Bulgaria and the rest to Greece. The basin area is calculated up to 2767 km^2.
- Evros River: It is shared between Greece and Bulgaria. It is also a natural border line between Greece–Bulgaria and Turkey. It has total length 530 km and its river basin area is about 53.000 km^2.
- Axios River: It springs from FYROM region and ends in Greece. It has 380 km length and its river basin's area is 24.338 km^2.
- Aoos River: It is the only transnational river in upstream position in Greece. It springs from Pindos Mountain and ends into the Adriatic Sea in Albania. Its total length is about 272 km of which the 80 km belong to Greece, and the remaining 192 km to Albania.

The majority of the rivers above face serious problems of water pollution and in some cases of water scarcity.

5. Conclusions

Water scarcity is a problem of big importance especially in regions where the drought is a very common phenomenon. In Greek, hydrological river basins the water scarcity can cause a lot of problems that are further connected to the pollution and the salination of the waters and the aquifers. Therefore, it is very important to take serious measures against the degradation of the water quality. In cases of transboundary waters, the National Water Committee should determine which regional authority is responsible. The water management in such cases is very complex and all the involved countries should cooperate for a better solution.

References

[1] M. Falkenmark, The massive water scarcity threatening Africa—Why isn't it being addressed, Ambio 18(2) (1989) 112–118.

[2] A. Brown, M.D. Matkock, A Review of Water Scarcity Indices and Methodologies, White Paper 106, University of Arkansas, The sustainability Consortium, 2011.

[3] M. Falkenmark, Coping with water scarcity under rapid population Growth, Conference of SADC Ministers, November 23–24, 1995, Pretoria, 1995.

[4] P. Gleick, Basic water requirements for human activities: Meeting basic needs, Water Int. (IWRA) 21 (1996) 83–92.

[5] P. Gleick, Human Population and Water: To the limits in the 21st Century, Human Population and Water, Fisheries, and Coastal Areas, American Association for the Advancement of Science Symposium, Washington, DC, 1995.

[6] M. Falkenmark, C. Widstrand, Population and Water Resources: A Delicate Balance, Population Bulletin, Population Reference Bureau, Washington, DC, 1992.

[7] Batchelor James, Using GIS and SWAT Analysis to Assess Water Scarcity and WASH Services Levels in Rural Andhra Pradesh, Working Paper l0, International Water and Sanitation Center, 2013.

[8] J.G. Arnold, R. Srinivasan, R.S. Muttiah, J.R. Williams, Large are hydrological modelling and assessment Part 1: Model development, J. Am. Water Resour. Assoc. 34 (1) (1998) 73–89.

[9] R. Srinivasan, X. Zhang, J. Arnold, SWAT ungauged: Hydrological budget and crop yield predictions in theupper Mississippi river basin, Trans. Am. Soc. Agric. Biol. Eng. 53(5) (2010) 1533–1546.

[10] K.R. Douglas-Mankin, R. Srinivasan, J.G. Arnold, soil and water assessment tool (SWAT) model: Current developments and applications, Am. Soc. Agric. Biol. Eng. 53(3) (2010) 1423–1431.

[11] P.W. Gassman, M.R. Reyes, C.H. Green, J.G. Arnold, The soil and water assessment tool: Historical development, applications, and future research directions, Trans. Am. Soc. Agric. Biol. Eng. 50(4) (2007) 1211–1250.

[12] A.K. Gosain, S. Rao, R. Srinivasan, N. Reddy, Returnflow assessment for irrigation command in the Palleru river basin using SWAT model, Hydrol. Process. 19(3) (2005) 673–682.