Managing water scarcity for sustainable irrigation in the Southern Mediterranean region

SAAD A. ALGHARIANI (*)

Abstract

Water scarcity is imposing severe constraints on sustainable development in the Southern Mediterranean region. The potentially available water supplies on renewable basis are insufficient to meet the continuously rising water demands of irrigated agriculture and other socioeconomic activities. The situation has been exacerbated by unchecked population growth and poor water management. The problems of water scarcity are discussed and understood in terms of the local water basins as a whole. Water movement and cyclicity within these basins are used to develop managerial strategies for maximizing water-use efficiency at the basin level. It is concluded that most water basins in the region have been developed to their full potential and are approaching a "closed system" state where no water of usable quality leaves these basins to salt sinks for disposal. The Jefara water basin in northwestern Libya is introduced as an illustrative example. Irrigated agriculture can be sustained at its present rate of expansion only through reopening the water basins to further water supplies from seawater desalting or interbasin water transfers. The Libyan experience with its Man-made River project provides a good example for water transfer economics in the region. Other possible measures may be implemented through macroeconomic manipulations and sociopolitical reorientations conducive to sustainable development.

Résumé

La pénurie de l'eau impose des contraintes sévères sur le développement durable dans la région au sud de la Méditerranée. Les fournitures hydriques potentiellement disponibles et renouvelables sont insuffisantes pour faire face aux demandes en eau croissantes de l'agriculture irriguée et d'autres activités socio-économiques. La situation a été exagérée par un accroissement démographique incontrôlé et une mauvaise gestion des eaux. Les problèmes de la pénurie de l'eau sont discutés et interprétés en termes de bassins hydriques locaux dans leur ensemble. Le mouvement de l'eau et le caractère cyclique à l'intérieur de ces bassins sont utilisés pour développer des stratégies d'entrepreneur pour maximiser l'efficacité d'utilisation au niveau du bassin. On clonclut que la plupart des bassins versants de la région ont été développé à plein et sont proches du seuil du «système clos» où aucune qualité d'eau sortant du bassin n'est utilisable pour saliniser les «exutoires». Le bassin versant de Jefara au nord-ouest de la Libye est donnée en tant qu'exemple. L'agriculture irriguée peut être soutenue à sont taux actuel d'expansione seulement à travers la ré-ouverture des bassins hydriques pour améliorer l'apport hydrique du dessalement des eaux de mer ou des transfers hydriques entre les bassins. L'expérience Libyenne avec son projet de la Rivière faite par l'homme représente un bon exemple de l'économie du transfer de l'eau dans la région. D'autres mesures possibles peuvent être mises en place à travers des manipulations macro-économiques et des réorientations socio-politiques qui aboutissent à un développement durable.

The Southern Mediterranean region of North Africa may be hydroclimatically considered as a transitional zone between the erimitic Sahara proper and the subhumid Southern European regions. Its population density and socioeconomic activities has been always in a delicate balance between the limited available natural resources and the basic human needs of a subsistence way of life. During the last few decades, however, the introduction of modern ways of resource utilization developed in the western humid zones has shifted the balance towards resource exploitation at levels far exceeding their rates of renewal.

The situation has been exacerbated by unchecked population growth demanding more food and a better standard of living under conditions of scarcity, poor resource management and low production efficiency. To meet these increasing demands agriculture has been dramatically changing from its traditional rainfed practices and limited irrigated areas into an extensively expanded large scale irrigation and intensively exploited resource base. The available renewable water resources are insufficient to meet the present rate of expansion on sustainable basis under the very low values of the dominant pluvio-evapotranspiratory ratios in the region.

The deficit between renewal and utilization has been presently satisfied by overdraft and mining of groundwater aquifers and increased dependence on poor quality water supplies.

The result is lower piezometric levels, seawater intrusions, soil salinization, more salt accumulation and pollution in production environments.

When the other rising water demands of urbanization and industrialization that compete with irrigated agriculture are considered the present situation is by all measures highly nonsustainable and calls for serious reconsideration of growth and development models based on better understanding of the water resources situation and its management under the minimum constraints conducive to development sustainability (Hamdy, Abu Zeid and Lacirignola, 1994). This article is intended to clarify some aspects of water resources management that may help along these lines.

Development of the water resources situation

The population of the region increased from 49.5 millions in 1955 to 118.1 millions in 1990 and it is expected to reach more than 188 millions by the year 2025

(*) Alfateh University, P.O. Box 91176, Dat Al Imad, Tripoli, Libya.

(UNPD, 1994). The total annual renewable fresh water supplies available in the region has been estimated at the fixed rate of 113.1 cubic kilometers per year (PAI, 1995). According to these figures, the regional annual average per capita water availability has been reduced from 2285 cubic meters in 1955 to 958 cubic meters in 1990 and is expected to reach 602 cubic meters by the year 2025. Thus the whole region is already experiencing water scarcity that is getting severer with time. As indicated in **tables 1** and **2**, however, these regional averages mask the spatial variability of the severity of water scarcity on a country by country basis. Even within the same country water availability varies widely from one location to another. This fact implies that any meaningful water resources management strategies should be based on the full understanding of the hydrological components and their interrelationships at the separate water basin levels in the region. These water basins vary in size and water resources volume from the huge Nile basin in Egypt to the smallest Wadi and valley plain in North Africa. Their hydrological properties, which are briefly discussed below, are similar and the principles of any well formulated integrated water resources management for sustainable irrigation and pollution control can be applied to them all.

WATER BASINS AS MANAGEMENT UNITS

A water basin, whether it is a huge river valley or a small desert oasis, is a hydrological unit surrounded by physical boundaries either geographically or hydrogeologically imposed or arbitrarily selected to facilitate management. The general hydrological equation of each water basin can be expressed as

$$I - O = \Delta S \quad (1)$$

Where I is the total annual inputs of water supplies; O is the total annual outputs of water leaving the basin and ΔS is the change in storage within the basin. The inputs are composed of annual precipitation, surface and subsurface water flows into the basin and any water diversion or seawater desalting. The outputs essentially include water losses by evapotranspiration, surface and subsurface flows outside the basin boundaries and surface and subsurface waters polluted by the accumulation of salts and toxic substances to concentration levels precluding their beneficial uses.

It must be realized that the annual rate of inputs on renewable basis within a given basin are fixed. Thus any attempt towards satisfying, even partially, the increasing food demands of an ever exploding population growth through expanding irrigated agriculture, which represents 80% of total water consumption at the present time, will eventually lead to imbalances in equation (1) and can be achieved only on the expense of storage in the local groundwater aquifers and More use of poor quality water, possibly through capturing and recycling drainage water flows and treated sewage effluent.

When all the renewable inputs are used up and no water leaves the basin or the water quality of the outflow, if there is any left, has been deteriorated to the extent where they become nonusable for any purpose, the water basin becomes permanently closed. Several water basins in the region have already reached this stage.

But since irrigated agriculture in the mostly arid and semi arid climates of the region, where the Pluvio-Evapotranspiratory ratio (P/PET) is very low and rarely exceeds 0.25, is essentially a high intensity evaporator, the accumulation rates of salts and other pollutants in the production environment are relatively high and must be contained within tolerable limits if sustainable irrigation in particular and the development process in general are to be maintained.

Assuming equilibrium salt precipitation and dissolution by chemical processes and negligible salt uptake and removal by biological activities within a water basin the general salt balance equation can be expressed in its simplest form as

$$(I)(Ci) - (O)(Co) = \Delta SS \quad (2)$$

where (Ci) is the average salt concentration of the total annual inputs entering the basin (I), (Co) is the average salt concentration of the annual outflows leaving the basin (O), and (ΔSS) is the change in salt storage within the basin boundaries.

Equation (2) is presented here to illustrate several points upon which management strategies may be based. First, salts and pollutants will continue to accumulate in the production environment of the whole

Table 1 ***Total renewable available water supplies and population distribution in the Southern Mediterranean region.***

Country	Water supply (km^3/year)	Population (millions) 1955	1990	2025
Egypt	58.9	24.7	56.3	87.1
Morocco	28.0	10.1	24.3	36.3
Algeria	17.2	9.7	24.9	40.4
Tunisia	4.4	3.9	8.1	11.8
Libya	4.6	1.1	4.5	12.4
Total	113.1	49.5	118.1	188.0

Source: UNPD (1994).

Table 2 ***Per capita renewable water availability in the Southern Mediterranean region.***

Country	Per capita water availability (m^3/year) 1955	1990	2025
Egypt	2,385	1,046	676
Morocco	2,764	1,151	770
Algeria	1,770	690	426
Tunisia	1,130	540	369
Libya	4,103	1,017	332
Regional Average	2,285	958	602

Source: PAI (1995).

basin or in irrigated lands as long as the outflow rates leaving these environments are insufficient to remove the added salts accumulating through the process of evapotranspiration. Secondly, as a water basin becomes closed or approaches closure the dissolved salts and pollutants contained in the water supplies used within the basin as a whole or consumed by irrigated agriculture will accumulate in the basin or in irrigated lands and eventually lead to an environmentally destructive non sustainable situation that is technically difficult and economically expensive to ameliorate. Thirdly, to achieve development sustainability within the basin at any level of acceptable salt content and pollution load in the environment equation (2) becomes

$$(I)\ (Ci) = (O)\ (Co) \quad (3)$$

implying that a certain percentage of the water inputs utilized within the basin must leave it with drainage outflows. This percentage is determined by the minimum salt concentration and pollution load that is acceptable within the production environments. It can be estimated from equation (3) as:

$$(O)\ /\ (I) = (Ci)\ /\ (Co) \quad (4)$$

This concept has been widely used in irrigation science to control salinity and is known as the leaching fraction.

THE JEFARA WATER BASIN AS A CASE STUDY

The northwestern part of Libya, known as the Jefara plain is the most advanced economic region in the country and contains more than half of the total population. The plain is physically isolated by the western mountain range from the south and east, the Tunisian border from the west and the Mediterranean sea from the north. It has been always considered and treated as a separate and independent water basin. It is introduced here as an illustrative example of the extreme cases of water scarcity development in the Southern Mediterranean region of North Africa. Its hydrological development reflects the basic ideas discussed in the previous sections in relation to sustainable irrigation and environmental pollution within water basins.

The total renewable available water supplies in the Jefara basin are limited to 250 million cubic meters per year. The historical development of water uses in the basin is presented in **table 3** which clearly indicates the widening gab between the rates of renewal and water use. The hydrological situation in the basin has been dramatically changed from a surplus of 160 million cubic meters per year during 1952 to a water deficit of more than 750 cubic meters per year during 1992. This is not surprising, however, where the renewable available water supplies per capita are limited to 125 cubic meters per year at the present population estimate in the basin.

The deficit has been met by pumping from groundwater storage with disastrous environmental impacts that has been reflected in declining piezometric levels, seawater intrusions along the coastal areas, deteriorating water quality, soil salinization, reduced agricultural productivity and diminishing biodiversity (Algthariani, 1988).

Table 3 ***Historical development of water use in the Jefara basin (million m³/year).***

Water use	Year 1952	1959	1972	1975	1992
Agricultural use	80	195	313	475	802
Municipal and industrial use	10	15	65	92	200
Total	90	210	378	567	1,002

Source: GWA (1994).

Ever since the basin became closed during 1965 drainage water outflows have been reversed into subsurface inflows of seawater leading to the contamination of the local aquifers and increased salinity. By the late seventies it was realized that to sustain irrigated agriculture and other socio-economic activities in the Jefara basin it should be immediately reopened by water importation from other water abundance regions in the country or through the introduction and development of an extensive seawater desalting technology. Comparative studies of the technical and economic feasibilities of both alternatives indicated clear advantages of water transfer from the southern extensive groundwater aquifers over seawater desalting. Hence the idea of the Great Man- made River project (GMR) was conceived and implemented. In addition to ameliorating the water shortage situation and correcting the negative environmental impacts in the Jefara basin the project will serve other water deficit basins along the Mediterranean coast, especially around the Gulf of Sirte and the Benghazi area. The Jefara basin will eventually receive a total flow of no less than 800 million cubic meters per year at a total cost of 0.34 US Dollars per cubic meter to the users gate. This flow rate is sufficient to face the present water deficit in the basin but inadequate to achieve long term sustainability at the present economic and demographic growth rates unless combined with other measures of water savings and alternative development models. These measures and their effective implementation are intensively studied at the present time.

FUTURE PROSPECTS

Sustainable water resources management in general and sustainable irrigation in particular imply the three basic principles of achieving equity, economic efficiency and environmental integrity. To realize these objectives in the face of increasing water scarcity and rising demand for water use the countries of the Southern Mediterranean region must establish water management strategies oriented towards doing more with less. But up to a limit. Several of these measures had been elab-

orated in the literature (Biswas, 1992; Hamdy, Abu Zeid and Lacirignola, 1994). Two of these strategies will be briefly discussed in the remaining section of this article.

INCREASING WATER USE EFFICIENCY (WUE)

The concept of WUE is highly controversial and can be clarified only according to ones perspective within the context of several interrelated factors. When generally defined as the total benefits (material goods, services, or financial returns, etc.) produced by each unit of water consumed, it can be directly linked to demand water management, opportunity cost of water uses, comparative production advantages and other macroeconomic manipulations. In irrigated agriculture, however, its use has been directly related to irrigation efficiency when water is the only factor limiting crop production. Under this condition any water management practice that increases irrigation efficiency tends to increase WUE. But any improvement of irrigation efficiency, as defined in terms of the water actually consumed by crop plants expressed as a percentage of the total amount of water diverted for irrigation, will depend on the hydrological conditions of the water basin. If the water losses due to low irrigation efficiency are wasted basin outflows of acceptable quality then any local improvement of irrigation efficiency within the basin will tend to increase WUE at the basin level. But if the wasted outflows are recaptured and reused within the basin, as it is most likely to happen in closed water basins, any local improvements in irrigation and WUE are only apparent gains while the overall basin efficiency remains the same. In this case local improvements can only be achieved on the expense of water shortages in other locations. This point was discussed more extensively by Seckler (1996).

WUE and irrigation efficiency should be optimized within the constraints of achieving the maximum potential yield of crop plants and maintaining the minimum basin outflows required by the environmentally acceptable salt balance as indicated by equation (4). Precautionary measures should be taken against deficit irrigation and the urgent calls recently made for the introduction and expansion of supplementary irrigation with its correlates of crop water deficiencies and soil salinization.

The highest priority has to be given to realizing the potential crop yields by removing any production constraints other than water. Present crop yields in the region are depressingly low. The WUE of cereal crops in Egypt, for example, is close to 0.5 kilograms per cubic meter of water (Higgins, 1988). Similar figures are expected throughout the region. In modern high-input systems of irrigated agriculture, it is hoped to obtain WUE values for cereal crops approaching 1.5 kilograms per cubic meter. Here lies the potential for getting more with less.

ECONOMIC AND SOCIOPOLITICAL MANIPULATIONS

In view of the present and expected future water scarcities in the region, irrigated agriculture cannot grow and expand in parallel lines with the demand for food by an increasing population. When the other projected rising

demands of urbanization and industrialization are considered irrigated agriculture cannot be sustained even at its present level of production if new water resources by importation or desalting are not developed.
The future concerns of water management will be most likely related to allocation problems of the limited available water supplies. The economic and sociopolitical challenges are enormous but not insurmountable. The opportunity cost of water in the competing sectors for water use should be one of the guiding criteria for water allocation. Subsidies must be limited to the minimum equity requirements for the poor and unpriviliged. Water pricing and water rights systems should change the conception of water supplies from water as a common pool resource to water as an economic commodity in the market place. Irrigated agriculture will certainly be a looser under these institutional arrangements, but irrigation does not have to be necessarily expanded or even maintained at its present level as long as the water supplies reallocated from the agricultural sector to the other sectors produce economic activities for the population and sufficient financial returns for food importation from the international markets. Agriculture may be restricted to crops of relatively high and competitive comparative production advantages at the global level.
The present trends of pursuing the mirages of food security and self sufficiency through the government sponsored irrigation projects of the green revolution and the lavish provision of subsidies to the private sector are major contributors to the present crisis. These trends must be reversed by reorienting the present socioeconomic systems towards privatization and the introduction and encouragement of other development models such as commerce, light industries and tourism that use less water with more economic returns. The geographic location and the favorable climate of the region are both conducive to these activities. Sustainable development is a holistic approach that can be realized through several options and alternatives. It should not be restricted, however, to a single economic activity on the expense of the socioeconomic system as a whole.

Concluding remarks

The Southern Mediterranean Region will be facing severe water crisis in the near future. The fast development of water scarcity during the last forty years has been enhanced by population explosion, unbalanced growth and poor resource management. Most of the water basins in the region have reached the closed hydrological system state with increasingly deteriorating water qualities, soil salinization and environmental pollution. Sustainable irrigated agriculture and other socioeconomic activities are apparently unattainable under these conditions. Sustainability can be achieved only through reopening of the closed water basins by fresh water importation or seawater desalting. Where these options are not technically and economically feasible the only other alternative is the implementation of water conservation measures and socioeconomic manipulations leading to more efficient uses of the limited available water resources. Hard decisions have to be immediately taken since the presently deteriorating situation cannot wait any longer. Reorientation of the present socioeconomic activities may be needed. Population growth must be checked.
Regional and global economic integration should be considered. The implementation of these measures requires extensive preparation in terms of financial resources, institutional arrangements and building the technical and administrative capacities through educational and training programs capable to deal with the expected challenges. ●

References

Algahriani S.A. (1988) - The environmental impacts of groundwater mining in the Jefara plain. Proceedings of the Fourth Congress of the Arab Committee for the Hydrological Program, Tunis, May 23-25, 1988. (in Arabic).
GWA (General Water Authority, 1994).Water resources of the Libyan Arab Jamahiriya. Tripoli, Libya.

Hamdy A., Abu Zeid M. and Lacirignola C. (1994) - Water resources management in the Mediterranean Basin. Proceedings of the VIII IWRA World Congress on Water Resources: Satisfying Future National and Global Water Demands. Cairo, Egypt, November 21-25, 1994.

Higgins G.M., Dieleman P.J. and Abernethy C.L. (1988) - Trends in irrigation development and implications for hydrologists and water resources engineers. J. Hyd. Sci. 33: 1,2/1988.

Pai (Population Action International) (1995) - Sustaining water: population and the future of renewable water supplies, Washington, D.C., USA.

Seckler D. (1996) - The new era of water resources management: from dry to wet water savings. Issues in Agriculture 8, The Consultative Group on International Agricultural Research (CGIAR), Washington, D.C., USA.

UNPD (United Nations Population Division, 1994). World Population prospects. The 1994 revision, UN, New York, USA.