



# OPTIONS

## méditerranéennes

**SERIES B : Studies and Research**  
Number 56 - Vol. II

### **Water Saving in Mediterranean Agriculture & Future Research Needs**

WASAMED Project  
(EU contract ICA3-CT-2002-10013)

Proceedings of the International Conference  
14-17 February 2007 - Valenzano, (Italy)

*Edited by:*  
**N. Lamaddalena, C. Bogliotti, M. Todorovic, A. Scardigno**

CIHEAM / IAMB - EU DG Research



# **A GIS-based Water Resources Information System: A Regional DSS for IWRM**

**Khaled Abu-Zeid<sup>\*</sup> and Omar Elbadawy<sup>\*\*</sup>**

<sup>\*</sup>Regional Water Resources Program Manager,  
Center for Environment & Development for the Arab Region & Europe (CEDARE)  
2 AElhegaz St. Heliopolis, Cairo, Egypt  
<sup>\*\*</sup>Senior Regional Water Resources Specialist, CEDARE

**SUMMARY** - In no other region of the world has water availability played such a dominating role in determining human activities, urban & rural settlement, socio-economic interactions and development, as it did in the Arab Region. More than 85% of the Arab Region is classified as arid and hyper-arid, receiving an average annual rainfall of less than 250 mm. Regional cooperation is a must to confront serious challenges to development of the region. CEDARE's Water Resources Information System (WRIS) was developed at the aim of facilitating accessibility to reliable water resources information on the Arab region.

CEDARE WRIS demonstrates the usefulness of integration of remote sensing, GIS and water resources information as a DSS tool for development in the Arab region. It represents an important tool for strategic planning. With an adequate database, GIS can serve as a powerful analytic and decision-making tool for tourism and agricultural development. This DSS tool could help the Arab countries to enhance their water strategies and define their long-term goals within the framework of Integrated Water Resources Management (IWRM).

**Key words:** GIS, DSS, IWRM, Water, Arab Region, CEDARE WRIS

## **INTRODUCTION**

It is believed that reliable information is of utmost importance for planning and decision making. Therefore, CEDARE's Water Resources Information System (WRIS) was developed at the aim of facilitating accessibility to reliable water resources information on CEDARE's region and its neighbors. WRIS was designed in a GIS based environment providing information and parameters that assist in addressing water availability, water balance, and water utilization per each nation of the region. The system could be utilized to perform a preliminary analysis of available information and comparative investigations of the status of fresh water in the region.

The assessment of water resources procedure is a dynamic process which has to be updated periodically to account for new data and enhanced measurements required for satisfying the various assessment components. Currently, the compiled information for the Arab Region is only limited to the data available in the international literature. This first draft is subject to review by all national authorities related to water resources management in order to verify and update the included estimates and to build a coherent water resources information system. The system will provide direct inputs to the Arab Region State of Water Report which is proposed to be issued on a biannual basis.

## **SYSTEM DESIGN**

CEDARE's Water Resources Information System is composed of a user-friendly interface built in a PC GIS environment using ArcView v3.1. Maps were obtained from ArcAtlas, cut and

processed. The landuse coverages were reclassified to fit within the classes of the study which are; irrigated crops, rainfed crops, natural pasture, forests, rocks and lava sheets, swamps & lakes and desert and semi-desert. Also, the areas of countries and each of its reclassified areas were computed.

A systematic methodology for water resources assessment is proposed and followed. Regional and national coverages for precipitation, land use, soil holding capacities, and solar radiation are compiled and processed. Data pertaining to rainfall, stream flows, groundwater recharge, shared rivers and aquifers, sectoral demands, water supply / sanitation coverage, and non conventional water resources are compiled from different sources and compared. The results are presented in tables for the region and each individual country, in addition to GIS coverage layers for the different parameters for each country. Data sources include FAO, WRI, DCW, UNESCO, CEDARE, and several country reports. Most of the data are, currently, relevant to year 2000.

### Information and Data Classification:

#### 1. Spatial data (maps)

The information incorporated in CEDARE WRIS includes the following maps and GIS layers:

- Lakes and swamps
- Rivers
- Dams
- Political boundaries
- Cities
- Surface Elevation (DEM)
- Landuse
- Vegetation coverage
- Temperature
- Precipitation
- Soil water holding capacity
- Solar radiation
- Groundwater age

#### 2. Water balance information

The water balance for each nation is calculated considering all different water components. The main components contributing to the water balance equation are: precipitation, surface runoff, groundwater, direct atmospheric supply and precipitation. The average annual national water balance equation can be written as:

$$(Incoming\ water\ resources) - (Outgoing\ water\ resources) = (Beneficial\ Abstractions) + (Evaporation) + (Un\ utilized\ water\ resources)$$

Where

- *Incoming water resources* include the summation of indigenous precipitation, trans-boundary incoming surface water resources, share from boarder rivers, and in-flowing groundwater,
- *Outgoing water resources* include the summation of trans-boundary outcoming surface water resources, and out-flowing groundwater,
- *Beneficial Abstractions* include the summation of abstractions from renewable water resources for: irrigation, industry, domestic uses, and atmospheric water directly consumed by rainfed agriculture, natural pasture, and forests,
- *Evaporation* includes the amount of water evaporated annually and is a direct function of the local aridity,
- *Un-utilized water resources* include the summation of water discharged to oceans, lost from reservoirs, a part of the nation's share of international water resources which is willingly bypassed to neighbouring riparian, ...etc.

## Main Menu:

The menus of CEDARE WRIS are pull down menus designed to facilitate data retrieval and analysis. The main menu incorporates four main components, which provide water resources information on the “Regional Level”, “National Level” and “Hot Spots” in addition to the “Programs” module for analysis. (Fig. 1)

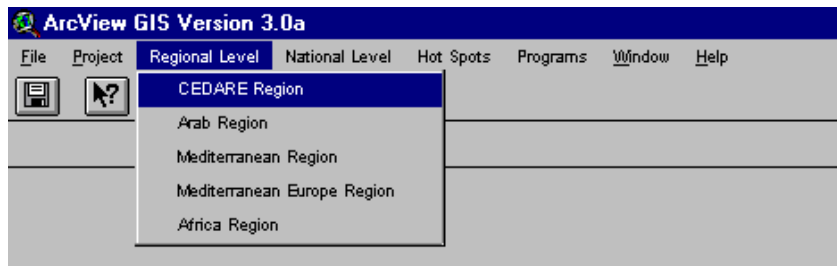


Fig. 1. Main Menu

## Regional level:

It was deemed necessary to group countries of common environmental features and water resources characteristics as an option in the WRIS. The regional level option enables the viewing of information by region. Regions available for data and maps retrieval in WRIS are CEDARE’s region, the Arab region, the Mediterranean region, the Mediterranean Europe region as well as Africa region. CEDARE region includes the entire region, i.e. the Arab countries and the Mediterranean Europe countries. (Fig. 2).

As per CEDARE’s concern with the environment and development of the Arab region, the latter was selected to be included in the system separately for its common hyper aridity nature and scarce water resources. This region includes Algeria, Bahrain, Djibouti, Egypt, Iraq, Jordan, Kuwait, Lebanon, Libya, Morocco, Oman, Palestine, Qatar, Saudi Arabia, Somalia, Sudan, Syria, Tunisia, United Arab Emirates and Yemen. (Fig. 3).

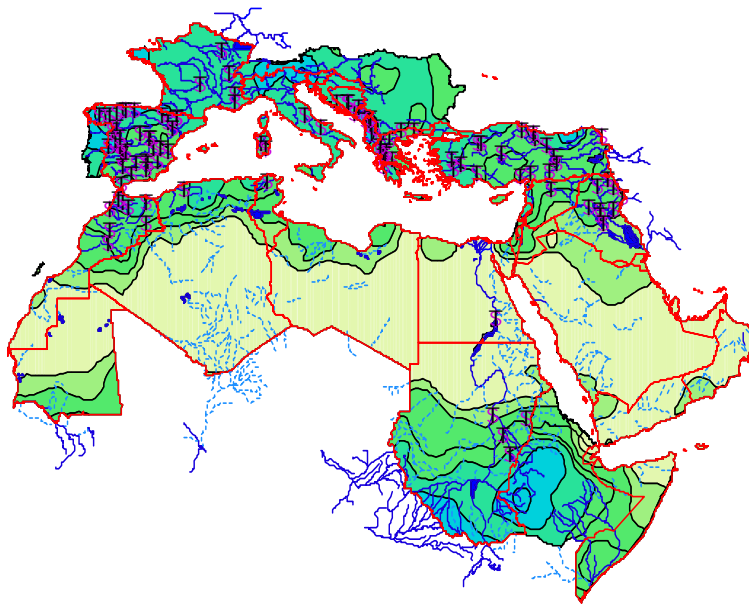


Fig. 2. Precipitation on CEDARE Region

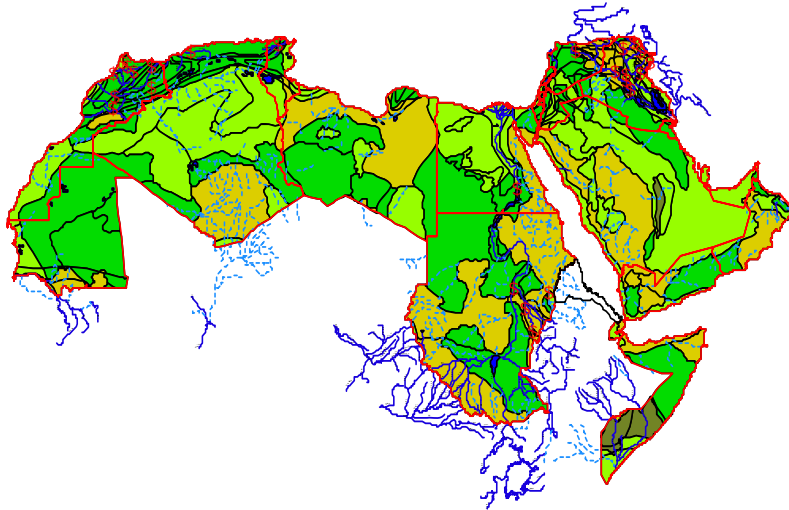


Fig. 3. Groundwater Age in the Arab Region

The Mediterranean region incorporates all the Mediterranean countries in Europe and the Arab Regions. These are Spain, France, Italy, Slovenia, Croatia, Bosnia and Herzegovina, Albania, Montenegro, Greece, Turkey, Cyprus, Jordan, Syria, Lebanon, Palestine, Egypt, Libya, Tunisia, Algeria and Morocco. The Mediterranean Europe Region encompasses Spain, France, Italy, Slovenia, Croatia, Bosnia and Herzegovina, Albania, Montenegro, Greece, Turkey and Cyprus.

Africa Region includes the entire continent as it contributes to the water resources of the Arab Region in North Africa. Most of CEDARE's region water resources are either originating or shared with countries outside the region. As this is a particular case in Africa in both surface and groundwater resources, the African Region was included in the system as a regional level option.

*National level:*

On the national level, water resources information for each country in CEDARE's region is available in WRIS (Fig. 4). Countries for which WRIS is providing information are: Algeria, Bahrain, Chad, Djibouti, Egypt, Iraq, Jordan, Kuwait, Lebanon, Libya, Morocco, Oman, Palestine, Qatar, Saudi Arabia, Somalia, Sudan, Syria, Tunisia, United Arab Emirates and Yemen.

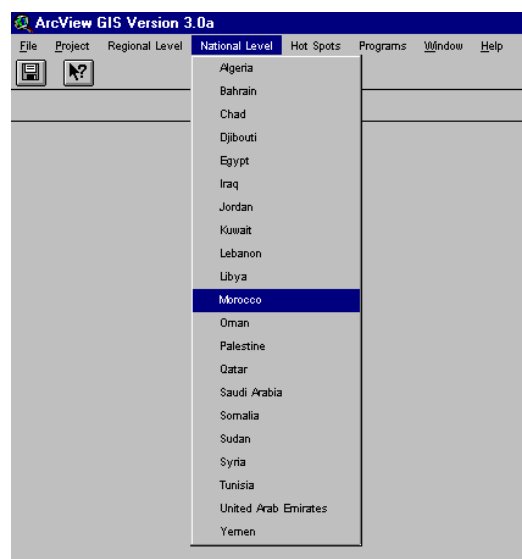


Fig. 4. National level menu



For each of the above listed countries, layers of water resources are available for retrieval and display. Also, transboundary water resources and rivers originating outside any country are included and indicated by extending projections to them. An example of the water resources on the national level is shown for Syria in (Fig. 5).

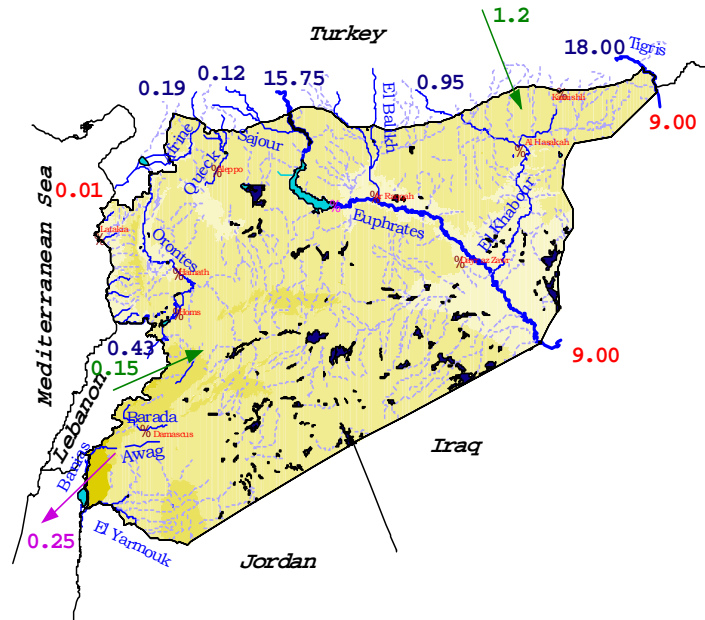


Fig. 5. Water Resources in Syria

#### Hot spots:

Of the hot spots in CEDARE's region are the Nubian Sandstone Aquifer, the Nile River Basin and the Euphrates River Basin. Information on each of these three hot spots is available in WRIS.

#### The Nubian Sandstone Aquifer:

The Nubian Sandstone Aquifer is a vast groundwater basin shared among four African countries, namely Egypt, Libya, Sudan and Chad. Three of these concerned countries are in CEDARE's region (Egypt, Libya and Sudan). (Fig. 6)

For the Nubian Sandstone Aquifer hotspot, the spatial information in the form of GIS maps and layers, in addition to the regular layers incorporated with WRIS components, are:

- The hydrogeological units
- Bedrock elevations
- Water level elevations
- Thickness of the aquifer
- Basement rocks outcropping
- Selected observation wells representing the behavior of the aquifer

## The Nubian Sandstone Aquifer

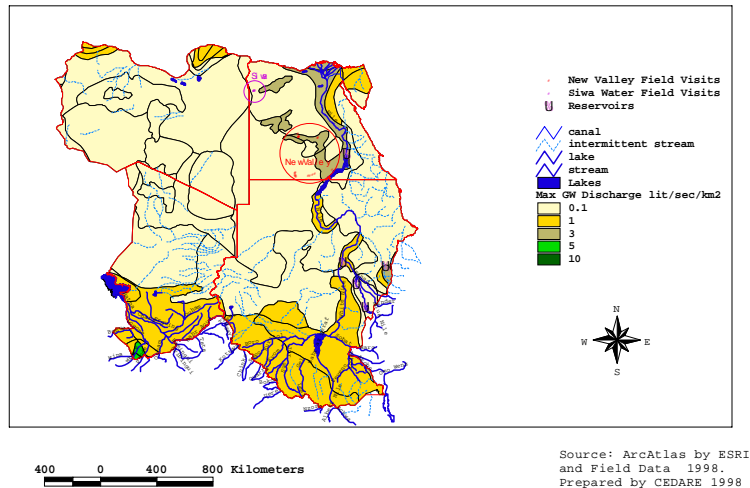


Fig. 6. The Nubian Sandstone Aquifer Layout

Attribute data associated with these enumerated layers could be identified by selection from ArcView toolbar buttons. Moreover, interactive hot links to images at some locations of particular significance are also included.

The Nile Basin:

The Nile basin is a particular case in which the water resources in two of CEDARE's countries originate outside CEDARE's region. The River Nile holds ten countries along its basin, which are Ethiopia, Rwanda, Burundi, Eritrea, Uganda, Kenya, Tanzania, Congo, Sudan and Egypt (Fig. 7). These ten countries are presented in a number of layers. In addition to the layers mentioned before, WRIS includes in the Nile Basin hot spot, the layers of:

- Main Nile branches
- Minor Nile branches
- White and Blue Nile rivers

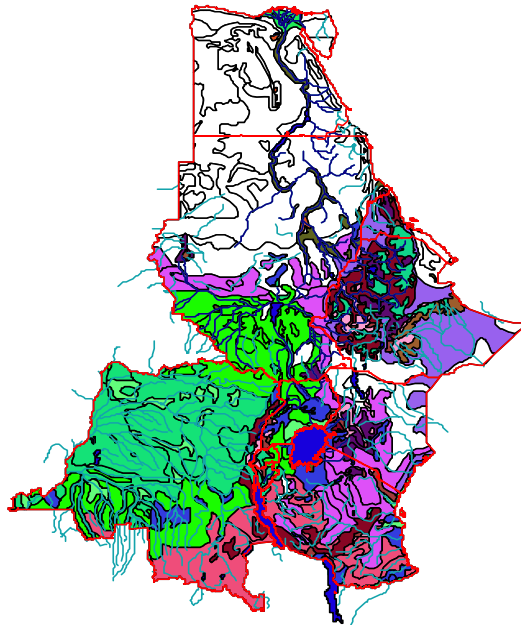


Fig. 7. Landuse of the Nile Basin

Moreover, a layer including the neighboring countries to those of the Nile basin and their streams is incorporated in the system. Also, hot links to images at different locations along the Nile are incorporated in the system.

The Euphrates River:

The Euphrates River, being one of the shared rivers of significant importance in the region is included as a hot spot in WRIS. The Euphrates runs through Turkey, Syria and Iraq.

### **Programs:**

Analysis could be carried out using the “programs” option of the main menu which enables the application of either a “soil water balance” or a “watershed analysis”.

#### *Soil Water Balance:*

The soil water balance module that was developed by David R. Maidment, at the University of Texas, was modified and incorporated in the WRIS. It was enhanced to be more user friendly. The input parameters for this module are climate data, precipitation, temperature, water holding capacity and net radiation. Based on the values of these input parameters the soil water budget could be calculated.

Scripts were developed and added to the system to make the processes of zone selection and input of files easier and more user-friendly.

#### *Watershed Analysis:*

The ArcView Spatial Analyst functions were utilized to perform watershed analysis by enabling the computation of delineation of watershed boundaries, flow directions as well as flow accumulations. In addition to these functions, other modules were deemed of valuable importance to be incorporated to compute slopes and aspects for watershed analysis purposes.

### **DATA PRESENTATION:**

In addition to the aforementioned views, there are two main layouts for each country and for the Arab region. One including geographic distribution of precipitation, landuse, soil water holding capacity and solar radiation. The other includes permanent streams, ephemeral streams, political boundaries and surface elevation distribution, in addition to figures regarding water resources inflowing to the country, water resources out flowing from the country, and beneficial abstractions of each country.

### **REFERENCES:**

“Water in the Arab World, Perspectives and Prognoses”, edited by Peter Rogers and Peter Lydon, Division of Applied Sciences and Center for Middle Eastern Studies, Harvard University, October 1-3, 1993.

“World Water Resources, A New Appraisal and Assessment for the 21<sup>st</sup> Century”, by Igor A. Shiklomanov, State Hydrological Institute, St Petersburg, Russia, International Hydrological Program, UNESCO, 1998.

“Lectures and Exercises for the CEDARE Regional training Course on Watershed Analysis Using GIS”, by David Maidment and Kwabena Asante, Cairo, Egypt, July 1-3, 1997.



"Water resources Assessment in the ESCWA Region Using Remote Sensing and GIS Techniques", Final Report, ESCWA, UNEP and IDB, 1996.

"Water Resources of African Countries: A Review", FAO, Rome, 1995.

"Water Issues between Turkey, Syria and Iraq", by the Turkish Ministry of Foreign Affairs, Department of transboundary and regional water, May 1997.

"CROPWAT, A Computer Program for Irrigation Planning and management", FAO Irrigation and Drainage paper # 46, 1992.

"Proper Water Resources Assessment: An Opportunity for Conflict Resolution in International River Basins", by Khaled Abu-Zeid, 9<sup>th</sup> IWRA Water Congress, Montreal, Canada, September 1 – 6, 1997.

"Water Benefits in the Nile Basin Countries", by Khaled Abu-Zeid, the Sixth Nile 2002 Conference, Kigali, Rwanda, February 1998.

"Water in the 21<sup>st</sup> Century", World Water Council, Paris, March 19-21, 1998.

"Using the ArcView Spatial Analyst", ArcView Spatial Analyst users manual, ESRI.

"Handbook of Hydrology", edited by David Maidment.

"Challenges for Studying Population-Environmental Interactions in the Arab Region", by Wolfgang Lutz, International Institute for Applied Systems Analysis, August 1996.

"Synthetic Generation of Missing Runoff Data of the White Nile, River Sobat and Bahr El Jebel", M.Sc. Thesis, Elwan, International Institute for Infrastructural Hydraulic and Environmental Engineering, April 1995.

"Water-Resource Assessment Activities", Handbook for National Evaluation, UNESCO and WMO, 1988.

GIS Hydro '97 CD-ROM, Integration of GIS and Hydrologic Modeling, Environmental Systems Research Institute, User Conference Preconference Seminar, 1997.

"Global and Continental Water Balance in a GCM", Climatic Change, by G. Thomas and A. Henderson-Sellers, 1992.

"The World Water Balance: Mean Annual Global, Continental and Maritime Precipitation, Evaporation and Runoff", by A. Baumgartner and E. Reichel, Elsevier, Amsterdam, 1975.

"Review of Australia's Water Resources 1975", Australian Water Resources Council (AWRC), 1976.

"World Water Balance and Water Resources of the Earth", Studies and Reports in Hydrology, no. 25, UNESCO, Paris and Gidrometeoizdat, Leningrad, USSR Committee for the International Hydrological Decade, 1978.

"World Water Resources and Their Future", by M.I.L'vovivh, Copyright by the American Geophysical Union, Washington, DC, 1979.

"Climatology of the Terrestrial Seasonal Water Cycle", by C.J. Willmott, C.M. Rowe and Y. Mintz, Journal of Climatology, 1985.

"The Evolution of the Earth's Biosphere", by M.I. Budyko, Reidel Dordrecht, 1986.

"Role de la Microclimatologie et la Bioclimatologie en Sylviculture", by Gilbert Aussenac, L'homme, la foret et Le bois, Revue du Palais de la Decouverte, 13, 130, 151-166, 1985.

"Forests, Climates, et Meteores", by Gilbert Aussenac and J. Parde, Rev. For. Fra., XXXVII.sp.issue, 83-104, 1985.

Digital Chart of the World (DCW), Environmental Systems Research Institute.

ArcAtlas, Environmental Systems Research Institute.