Remote Sensing in Service of Concerted Management of a Major Transboundary Water Basin

The North West Sahara Aquifer System

AWF[1]/SSO[2]

ABSTRACT

This paper presents the main outcomes of the GEOAQUIFER project. Implemented with funding from the African Water Facility (AWF) and executed by the Sahara and Sahel Observatory (SSO) in cooperation with Algeria, Tunisia and Libya, GEOAQUIFER shows the contribution of satellite images in the concerted management of a major trans-boundary water basin: the North West Sahara Aquifer System (NWSAS).Periodically, studies have been conducted to assess the quantities of useable water in the NWSAS. The accuracy of these estimates hinges on several factors, including the estimation of the quantities actually drawn, for which sound knowledge and mutual information underpin the objective, equitable and sustainable operation of the consultation mechanism established by countries around the NWSAS. Such knowledge can be obtained by analyzing earth observation satellite imagery, which allows for a precise digital and updated mapping of the land occupancy and irrigated areas, and for estimating the amount of water used for irrigation, by comparing them to the volumes detected underground by the national water management agencies. Between the teams and stakeholders from the three countries, the activities collectively undertaken throughout the three years of the project provided exceptional opportunities for sharing experiences, learning practically how to take collective decisions and thereby strengthening the spirit of cooperation.

Key words: Aquifer –Sahara –Remote sensing –Consultation - Soil

1. INTRODUCTION

The GEOAQUIFER project covers the North Western Sahara Aquifer System (NWSAS) and the Tunisian and Libyan Djeffara coastal aquifer. NWSAS extends over one million km^2 in Algeria, Tunisia and Libya. The system extension and layer thickness have facilitated the accumulation of considerable water reserves, which are hardly renewable and only partly exploitable. Over the past 40 years, NWSAS's annual exploitation has grown fivefold, up to 3 times the average level of its natural recharge, exposing the aquifer to several major risks: heavy trans-boundary water salinity, end of artesian outflow, natural discharge depletion, increased excessive drawdown, etc. Therefore, the three countries concerned by the system's future naturally had to jointly search for some form of common management of the basin. Thus was born the "NWSAS Consultative Mechanism", a formal institutional framework for the joint management of shared groundwater resources.

The region's water authorities conduct regular resource assessment studies. These studies have faced the ever-increasing needs for more knowledge of groundwater systems. Such needs include estimating the amounts abstracted, the knowledge of which underpins the objective, equitable and sustainable operation of the consultative mechanism. In fact, National water agencies need to better locate areas where water is drawn for agricultural use and identify unlisted water consumption areas. This facilitates decisions within the consultative mechanism framework, based on objective, transparent, neutral and comparable data. These objectives can be achieved through analyzing earth observation satellite imagery, which allows for the preparation of a precise digital map and update of the land occupancy status.

2. OBJECTIVES

The GEOAQUIFER project aims to: (i) optimize the use of satellite data for understanding and managing the NWSAS shared aquifer; (ii) provide national water management agencies with tools to help enhance and improve the consultative mechanism for effective and sustainable management of the shared water resource; (iii) build the capacity of national agencies in the use of satellite data, and ownership of new technologies; and (iv) ensure replication of the project to other basins in Africa.

[1] African Water Facility (African Development Bank)
[2] Sahara and Sahel Observatory (SSO)

As main long-term results, the GEOAQUIFER project will help promote:

1 - Sustainable development of the region through enhanced consultation; and
2 - Better understanding of the exploitation and rational management of resources:

3. OUTCOMES

1 – Production of land cover maps: the study focuses on a number of model zones considered of major importance to be mapped at a scale of 1:50000. The study of land cover in model zones was also carried out earlier on two occasions (shot in 1990 and 2000) to monitor the evolution of the corresponding irrigated areas. The photo-interpretation was confirmed by field visits to the model zones. In total, 22 previous and current land cover maps of the model zones at 1:50000 were produced. GeoCover LC coverage acrSSO the Djeffara NWSAS was obtained, which is part of the global land cover map derived from the EarthSat Moderate Resolution cover. The adjusted data were used to produce the current general land cover map on the NWSAS-Djeffara at 1:200000.

2 - Production of Digital Terrain Models (DTM) and derivatives on the basin: knowledge of the terrain at an excellent definition has allowed for accurately determining the altitudes of water points and more reliable measurement of piezometric levels. It has also contributed to better understanding of land use planning in the Sahara regions.

3 - ***Creating a hydro-geographic repository, a regional virtual globe and a data dissemination tool:*** national agencies do not have a homogeneous national geographic repository to reference or organize all data. Topographic and geological maps at 1:250000 and 1:1000000 covering the region were scanned, geo-referenced and entered into the map server. This allowed for: (i) integration of hydrographic and water points data; (ii) creation of hydro-geographic repository and superimposition on a virtual regional globe; and (iii) online posting of metadata and a demonstration dataset: http://prog.SSO.org.tn/geoaquifer/index.php.

4-Capacity building: training in geospatial data management: the objective is to develop the skills of water, environment and agriculture service officials in the area of GIS, remote sensing, GPS and data base management. Eight training sessions of two weeks each were conducted, covering: ArcGIS, 3D Analyst, GEOAQUIFER products, remote sensing bases, GPS initiation, geographic and hydrologic modeling.

4. DISCUSSIONS (INTERPRETATION)

4.1. Land Cover Maps in Model Zones

Given the scale and dispersal of farmlands in the Saharan regions, the study focuses on eleven model zones to be mapped at 1:50000: four in Libya, three in Tunisia and four in Algeria. The study of land cover in model zones was conducted on two dates the shots taken (circa1990 and circa2000) to monitor groundwater exploitation.

In addition to the SPOT data used at 20 m resolution, it was pSSOible to back up the photo-interpretation of current images with data at very high resolution (75 cm) taken from Google Earth. The photo-interpretation was subsequently confirmed by fact-finding missions to eleven model zones. Twenty-two (22) former and current land cover maps of the model zones at 1:50000 were produced. Figure 1 provides an example: current land cover map in Jufrah, Libya. From the joint analysis of satellite earth observation images and field verification campaigns, fourteen categories were selected to represent different types of land cover identified (Figure 1).

To obtain the land cover picture from the photo interpretation of remote sensing images for each pilot area, a vector layer has been created to cover the model zone studied and accommodate polygons whose borders are the boundaries of plots with some land cover significance vis-à-vis the legend. All this work is done manually. Following the delineation of the detailed survey plan, the tributary area table of the land cover layer thus created is filled in accordance with the legend adopted (Figure 1).

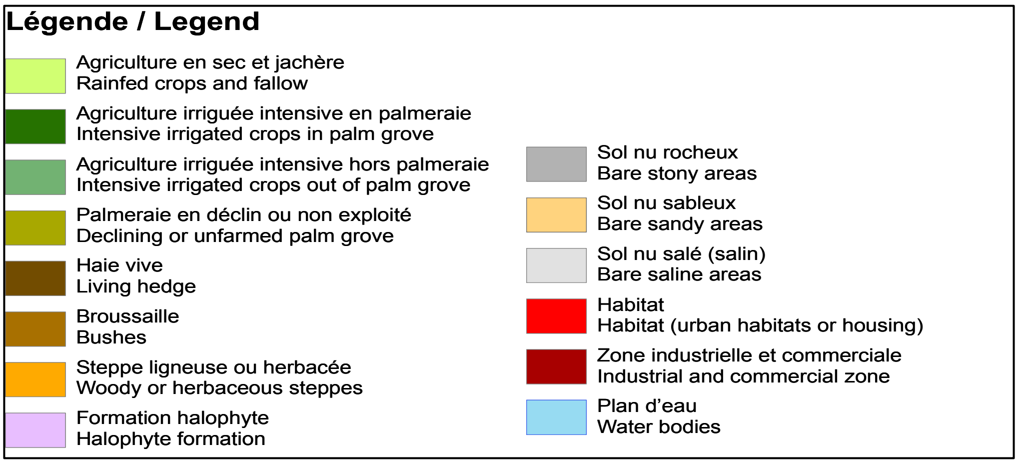

Fig.1: Classification and Legend adopted for the different categories represented on the land cover maps.

4.2. Land Cover Trend from the 80s to the 2000s:

Analysis of satellite images at two different times and verification missions on the ground have served to highlight the changes undergone by the land cover maps in the intervening time. The most significant and most demonstrative change was registered on the El Oued Souf pilot area, with an upsurge in the number of small-scaled and traditional irrigation pivots over the last fifteen years.

The pivot technique is recent: a comparison of images taken in 1987 and 2007 (Figures 2 and 3) shows a significant proliferation of this type of operation in the period in-between. Figure 2 shows clearly that the cultivation method in 1987 (SPOT image) was limited almost exclusively to Ghouta (traditional process where the palm tree abstracts the quantities it requires by directly tapping into the groundwater), while in 2007 circular pivots had become more extensive (Figure 2).

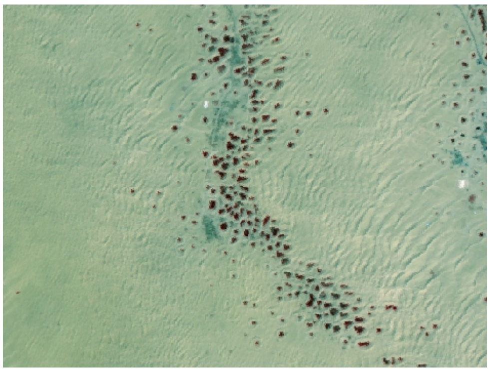

Fig.2: Series of Ghouta at El Oued in 1987

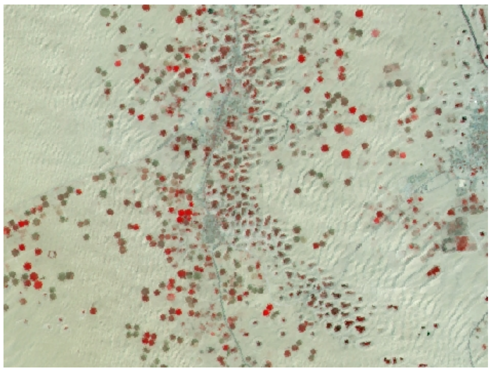

Fig.3: Image of the same sector taken in 2007

4.3. Land Cover map of the NWSAS-Djeffara Zone

GeoCover LC[3] Coverage acrSSO the NWSAS-Djeffara zone was obtained. This is part of the global land cover map derived from EarthSat at Moderate Resolution. This map is produced and marketed by MDA Federal[4] in the form of 1-degree square tiles. Our area is covered by one hundred and fourteen (114) homogeneous tiles according to the legend, which have been assembled into a vector raster layer. Adapted to the region, the legend[5] comprises 9 classes: (i) rainfed agriculture; (ii) irrigated agriculture; (iii) bush and thicket; (iv) woody or herbaceous steppes; (v) halophyte formations; (vi) bare stony or sandy areas; (vii) bare saline areas; (viii) habitat and industries; and (ix)

[3] ***http://www.mdafederal.com/geocover/geocoverlc/gclcoverview/***
[4] ***http://www.mdafederal.com/home***
[5] ***http://www.mdafederal.com/geocover/geocoverlc/geocover_legend/***

water bodies. The adjusted data were used to obtain the current general land cover map over the NWSAS-Djeffara area at 1:200000.

From the hydrologic point of view, this map has a huge theoretical pSSOibility: it allows for quick, accurate, transparent and scalable information for all the irrigated areas in the NWSAS-Djeffara region and, thereby, for an immediate estimate of the amounts abstracted at any point in the aquifer. The comparison with maps obtained at 1:50000 for the model zones shows that the map obtained at 1:200000, established from the GeoCover LC coverage, would be very useful for initial estimates of irrigated area in the NWSAS area. On Djeffara, the mapped areas have been systematically over-estimated because of the automatic classification method adopted by GeoCover.

4.4 DTM and Derivatives on the Basin

A Digital Terrain Model of the NWSAS-Djeffara with its derivatives was prepared from an SRTM source at 90 m resolution: 100 m equidistant contours, drainage system, watersheds.

In the model zones, eleven DTMs at 1:50000 with their derivatives were obtained through: (i) digital terrain modeling at 30 m resolution in two model zones (Ouargla, Zab) from ASTER images; (ii) acquisition of Spot Dem digital terrain models at 30 m resolution on the 9 remaining model zones. Derivatives relate to contours at 10 m equidistance, watersheds and river systems.

4.5 Hydro-geographic Repository, Virtual Regional Globe

A hydro-geographic repository comprising: (i) 87 topographic maps at 1:250000 and 1:1 000000 covering the NWSAS and Djeffara; (ii) a geological map; these maps were scanned, geo-referenced and entered into the map server; and (iii) the integration of Africa Data Sampler vector geographic databases; remediation of inadequacies; updating of the road network, administrative divisions and demographic and environmental data.

A meta database comprising: (i) integration of hydrographic, hydrogeologic and environmental data, and creation of a hydro-geographic repository; (ii) data description using the 9115 norm; and (iii) the online posting of metadata and data sets on the GeoAquifer portal. (http://prog.SSO.org.tn/geoaquifer)

This portal has typical GeoPortal features: access to data catalogue, ability to view metadata, data and metadata download, map navigation. Its originality lies in the use of the WorldWind virtual globe in the browser. There are still few applications that use a virtual globe that do not require installation. For the most part, the technologies used are innovative: OpenLayers/MapFish, AJAX, WorldWind JAVA Virtual Globe.

5. CONCLUSIONS

1. The GEOAQUIFER Project recorded significant progress in terms of mastery and processing of geo-scientific data. The project's two flagship products: (i) the land cover maps of the eleven pilot zones at 1:50000; and (ii) the website for dissemination of project data, are technological success stories evidencing remarkable technological expertise.

2. Despite the project's complexity, the diversity of stakeholders, the dispersion of activities over a very vast area and the transnational nature of the project, the Sahara and Sahel Observatory (the Executing Agency) was able to coordinate activities and guide various stakeholder institutions to adequately accomplish the tasks assigned them in implementing an operation fraught with difficulties.

3. The innovative nature of the project was highly integrated at the level of top water management officials in each country and water sector engineers, technicians and officials. This is reflected in the high number (fifty national officials) that participated in and took ownership of arguably the most popular activity of the project: the "capacity building and training in geo-scientific data management" component.

4. Upon completion of the project, a number of challenges remain: better knowledge of irrigated areas throughout the Libyan Djeffara, better knowledge of water removal on the NWSAS and the Djeffara, improved access by all interested parties to the opportunities offered by the remarkable GeoAquifer website, improved use of geo-scientific data and satellite images for water resource management and the ordinary operation of the NWSAS consultation mechanism. All these challenges, which are natural offshoots of the GeoAquifer project, should be part of future cooperation programmes between the Sahara and Sahel Observatory and the African Water Facility.

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