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Highlights: *The Gabes Jeffara aquifer system, located in the southeast of Tunisia is essentially recharged by rainfall infiltration and by groundwater inflow from the Continental Intercalaire aquifer in the north-west, but the increase of groundwater pumping for irrigation during the last decades has induced a serious decrease of groundwater levels and springs depletion. A multidisciplinary study was carried out in order to better understand the behaviour of oasien ecosystems and aquifer system and to provide tools and recommendations for the management of water resources.*

Keywords: *Gabes Jeffara aquifers, oasien ecosystems, hydrodynamic modeling, water resources management.*

1. Introduction

The socio-economic development of the Jeffara of Gabes, located in the southeast of Tunisia, has led to a strong exploitation of the coastal aquifers groundwater which has induced a drying up of the springs that supplied the oases (figure 1). The objective of the study is to improve the management of groundwater resources in the Gabes area, taking into account the needs of socio-economic activities and the sustainable preservation of coastal oasis ecosystems.

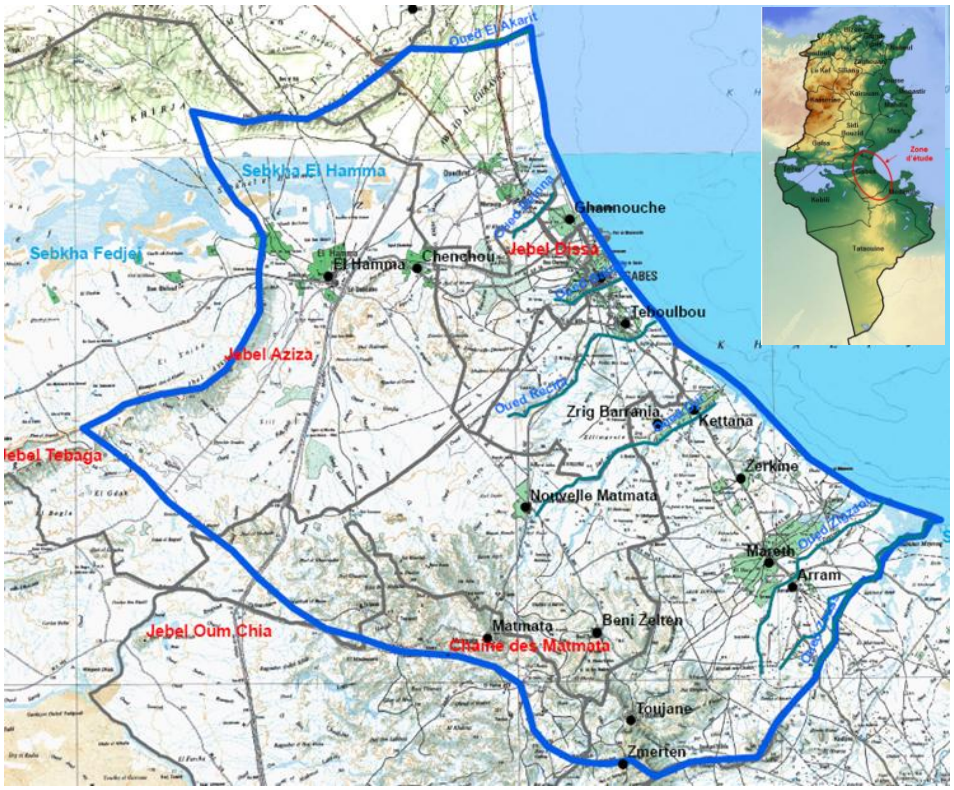

Figure 1- Map of the study area showing the boundaries of the aquifer and locations of the oases

2. Material and Methods

The study, of a multidisciplinary nature, integrates several components from knowledge of groundwater resources, with a 3D geological model and a hydrodynamic model, Integrated Water Resources Management, analysis of water consumption, irrigated agricultural production systems and oasis ecosystems.

An important part of the study was devoted to the development of a hydrodynamic flow model of the Djeffara aquifers which is used as a future groundwater management tool considering different recharging or exploitation scenarios. This model has been built with Processing Modflow, gathering data on geology, hydrogeology, hydrology, rainfall, piezometry, withdrawals and spring flowrates. All the data processed in the study were integrated in a GIS, including harmonized geological maps, satellite photos and irrigated perimeters.

3. Results and Discussion

The geological model has enabled to update the complex structural scheme to better understand the relations between the aquifer systems of the North-Western Sahara Aquifer System (NWSAS) and the Jeffara Plain. It also shows a correlation between the main faults and the distribution of hot springs in the region of El Hamma and in the Jeffara plain.

The conceptual model of the aquifer system of the Djeffara of Gabes has necessarily to be simplified in relation to the geological model ; it is composed of 3 layers (figure 2) :

- Aquifer 1 : The superficial aquifer contained in the quaternary formations and which is exploited by surface wells.
- Aquifer 2, 3 & 5 : The deep layers of Djeffara and Zeuss Koutine, which are exploited by deep wells.
- Aquifer 4 : The aquifer of the Continental Intercalary (CI) which is not exploited at the level of the study area. It will be used for the transfer of water from the CI to the Djeffara.

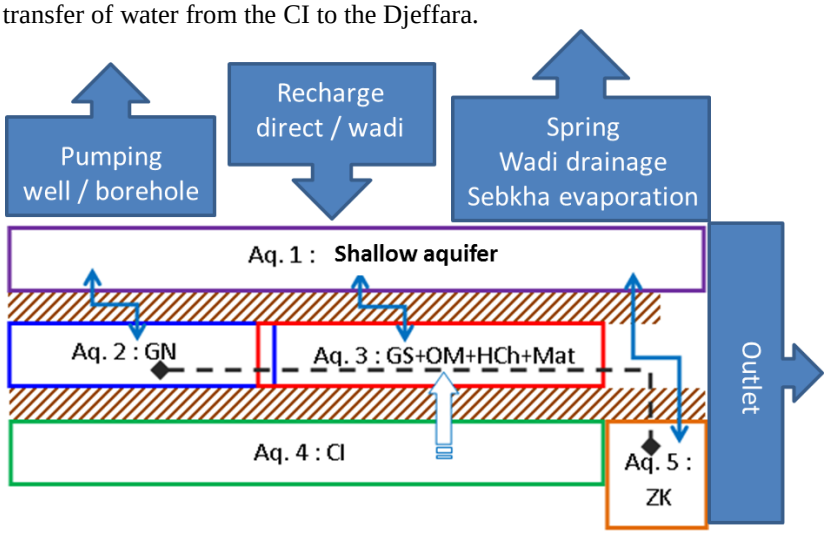

Figure 2 – Conceptual model of Gabes Jeffara aquifers

The model was calibrated in steady state with reference to the piezometric measurements measured in 1970. The piezometric maps plotted by the model confirm the hydrodynamic functioning of the groundwater and the drainage of the groundwater downstream of the wadis, at the level of the wetlands and the springs. The model was calibrated in transient state during the period 1972-2014, ie 44 phases of one year each, using chronicles of more than 200 wells and piezometers. Groundwater inflow from the CI, calculated in 1970 and 2000 are consistent with those calculated in previous studies (UNESCO, 1972 ; OSS, 2003 ; Besbes et al., 2005). According to the present model, the CI inflow is calculated at 0.3 m^3/s in 2014.

The analysis of current and future water consumption was carried out with existing data, processing of satellite images and surveys of farmers. Current water requirements are estimated at 125 Mm3 in 2014 (baseline year), of which 82% is for the irrigated perimeters for a total irrigated area of more than 14,000 ha. Non-agricultural water requirements are estimated at 22 Mm^3 in 2014, of which 13 Mm^3 are devoted to domestic use. Water requirements for the industrial and tourism sectors are low and represent only 7% of total requirements.Three scenarios were predefined for the future (A : trend, B : pessimistic, C : optimistic) (figure 3). By 2040, future irrigation water needs are estimated at best at 215 Mm^3/year (scenario C) and at worst at 517 Mm^3/year (scenario B). Considering the assumptions in the trend scenario, these needs would be 286 Mm^3/year in 2040.

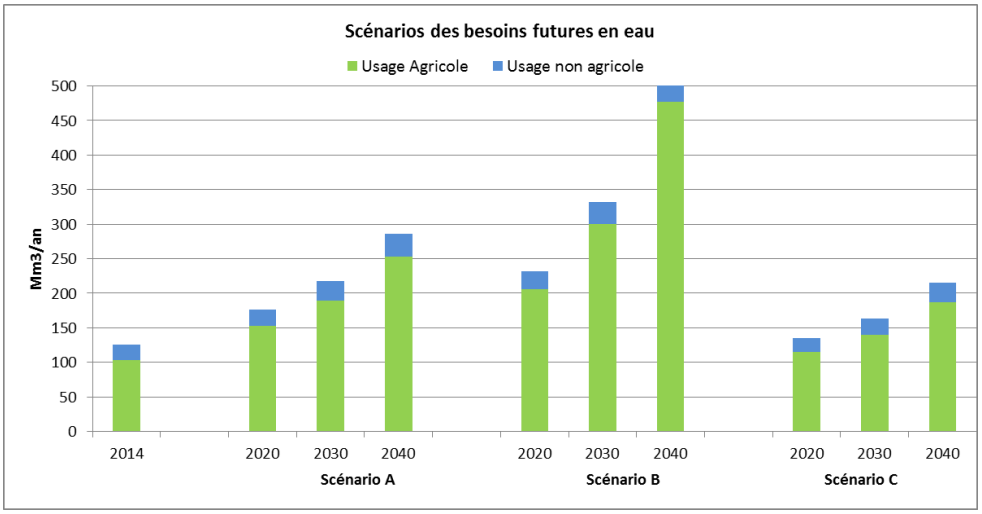

Figure 3 – Scenarios of future water demand (green : for agriculture ; blue : for drinking water)

The study of the functional levels of oasis ecosystems enabled to define the links between the ecosystems and the groundwater of the Tunisian Jeffara aquifers and to propose a protocol for monitoring the water-oasis ratio, through a number of indicators and predefined parameters.

Finaly, an Integrated Water Resources Management (IWRM) approach was carried out, with the main objective of defining scenarios of water demand combined with scenarios of groundwater withdrawal decrease, reinforcement of groundwater recharge and use of alternative water resources. These scenarios will be tested with the hydrodynamic model in order to see their impact on groundwater levels and spring flowrates.

Conclusion

The multidisciplinary approach implemented (geology, hydrogeology, modeling, socio-economics, oasis ecology, integrated water resources management) enabled us to understand the functioning of the oases and the aquifer system of the Jeffara of Gabes and to develop operational tools to improve the management of this aquifer system. These tools will be used to test different scenarios of changes in water consumption and water use, based on a reduction in groundwater withdrawals and the use of alternative resources.

Acknowledgements

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