A Multiscale Groundwater Flow Modelling for Assessment of the Effect of Managed Aquifer Recharge from an Infiltration Basin in the Mzab Valley – North Africa

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Summary

- The Touzouz Infiltration basin (TIB) for Managed Aquifer Recharge (MAR) allows the infiltration of **more than 99%** of the recovered floodwater.
- The mound is oriented to **the East and North** due to high Ks. It **cannot be widened** through an increase of the TIB capacity.
- The TIB raises the GW levels under **the agricultural zones** (good situation choice).
- The recharge should **enhance the groundwater quality**, however, the petrol station near the TIB presents a serious **contamination risk.**

Introduction

- In many developing countries, the groundwater constitutes the main resource for water supplies.
- For more than **five centuries**, the Mzab water management system is based on floodwater harvesting technique and it works on **capture, storage and distribution** of water coming from the rare floods of the Mzab stream and its tributaries.
- The Touzouz infiltration basin (TIB), as a part of the Mzab water management system, contributes on floodwater harvesting and aquifer recharge.
- The current study aims to understand the functioning of the TIB and **assesses its effect** on the groundwater flow dynamic for better management of surficial and underground water . Hence, a **conceptual groundwater model** of the shallow aquifer is built using the Modflow-2000 under GMS GUI software.

Materials and methods

- The Mzab stream forms the Mzab valley which is located in the Wilaya of Ghardaïa in the middle of the Algerian Sahara, the zone is characterized with **low rainfall amounts** (~ 70 mm/y) and important potential evaporation rates (~2100 mm/y).
- Geologically, the outcrop is basically formed by limestone of Turonian that forms the hills and alluvial deposits of Quaternary that cover the bottom of valleys. These two layers form the shallow aquifer of the Mzab valley. The shallow aquifer is basically recharged by runoff resulting from torrential rains.
- The pumping amount from the aquifer ranges from 13.184 Mm^3/ year to 20.759 Mm^3/ year.
- Built on the Touzouz watercourse, The **TIB capacity is estimated to 382776 m^3.**
- Since the 1990s, **the transgression of urbanization** on the sides of the basin has reduced the surface of the basin by **11.7%**. Recently, a **petrol station** was built near the basin area. Hence, It presents a serious risk of contamination to the aquifer.
- Using **a multiscale approach**, a numerical modelling of the groundwater flow is developed to assess the effect of the TIB recharge on the shallow aquifer.
- A **regional scale model** is used to define the aquifer parameters, then, the **local scale model** is constructed to simulate recharge from the TIB.
- The insertion of the MAR by the infiltration basins generates a piezometric mound below the zone of the application of the recharge leading to a significant **hydraulic gradient** when compared to the other zones of the aquifer. With **a smaller grid cells** size the local model should improve **the accuracy** of basin recharge simulation results.

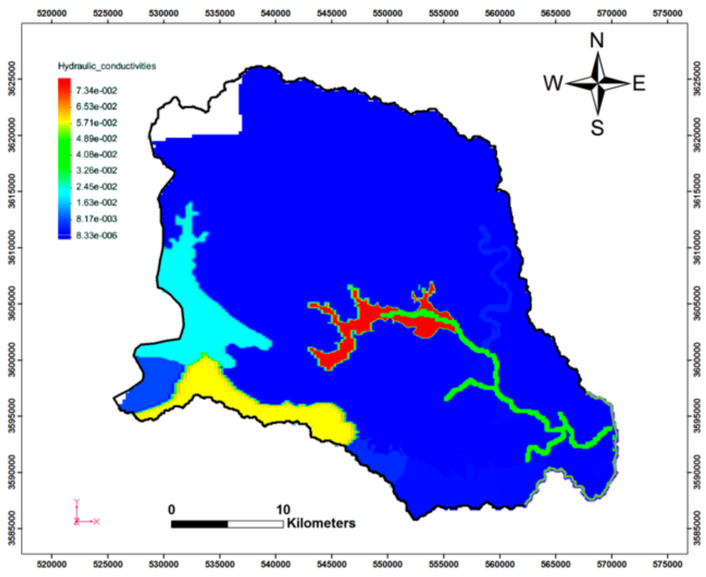

fig. 1: Hydraulic conductivities of the regional model

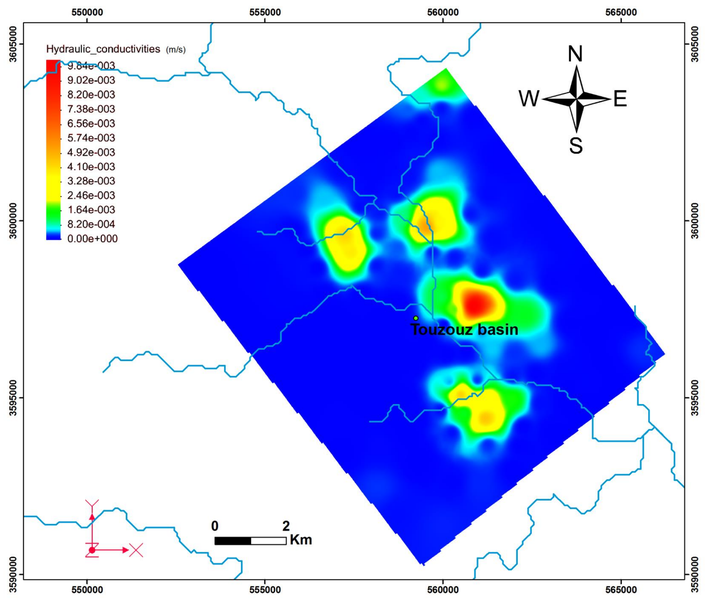

fig. 2: Calibrated hydraulic conductivities map in the local model

- The regional model **parameter optimisation** is accomplished with a mean square error (ME) and a root-mean-square error (RMSE) of 0.25 m and 3.00 m respectively for 81 observed wells (fig.1).
- The local model is calibrated in the steady state. The calibration mean error (ME) is -0.27 m, the root-mean-square error (RMSE) is 1.15 m and the discrepancy of the water budget equals to -0.021% (fig. 2).
- **Five scenarios of the TIB replenishment** rates (10, 25, 50, 75, 100 %) were simulated using the lake package. Leakance of the TIB is evaluated at $2.00x10^{-6}$ s^{-1}.

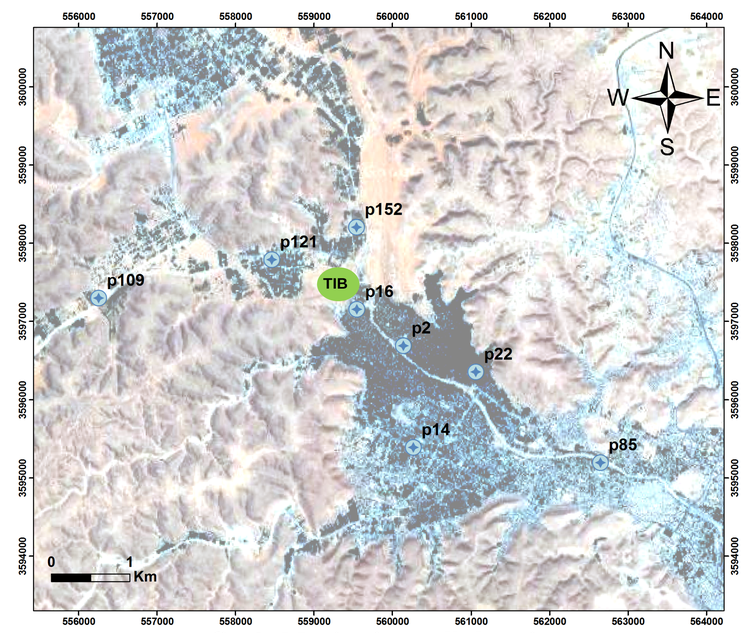

fig. 3: Monitoring wells locations.

Results

- Simulation results show that **more than 99%** of water is infiltrated into groundwater. The infiltration period varies between 25 and 35 days.
- The results analysis and comparison show that the groundwater mound extends mainly to **the east of the TIB** due to the relatively high hydraulic conductivities.
- The mound extent **increases rapidly** for low basin fillings to pass from 750 m for Scenario I to 3136 m for scenario II. However, it **widens moderately** for high TIB fillings, since it progresses from 4860 m to 5033 m (173 m of difference) for scenarios IV and V respectively (fig. 5). the mound extent tends to converge towards a certain limit whatever the quantities of water infiltrated through the TIB.
- The TIB recharge mound show that the water level raise occurs essentially in **agricultural zones** that are highly dependent on the shallow aquifer (fig.3 and fig. 4).

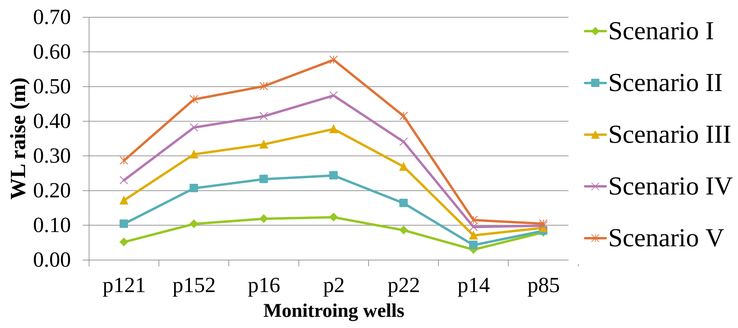

fig. 4: Water level (WL) raise after 90 days

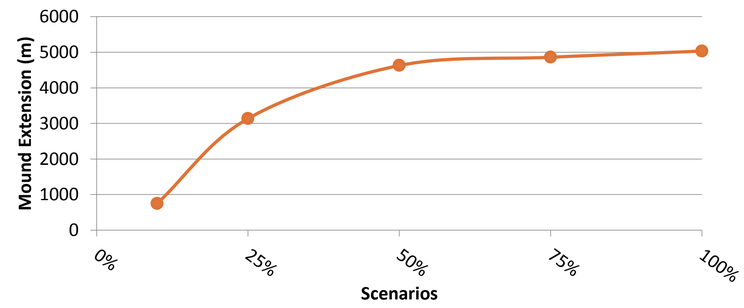

fig. 5: Mound maximal extent

Conclusions and recommendations

- The lack of studies on the TIB and on the Mzab water management system poses the primary challenge to valorise and improve the functioning of the system. Hence, our study focuses on **the assessment of the effect of recharge** from the TIB on the shallow aquifer flow dynamics using a numerical groundwater model.
- Results presents a support to the use of **infiltration basins technique** for aquifer recharge in this arid region, since it is effective way to recover floodwater. The fine sediments removal operation to prevent clogging could be **easily performed**, and theses sediments could be used for **regeneration of agricultural soils.**
- The study shows that the TIB is well placed to feed the aquifer under **the agricultural areas.**
- Recharge of the aquifer by floodwater from the TIB should **enhance the groundwater quality**. However, an eventual mismanagement of the near petrol station presents a high **contamination risk.**
- The **multiscale approach** for the groundwater modelling may be an interesting approach for modellers to overcome scale delineation problems in cases of managed aquifer recharge studies.
- Further researches should be led to enhance the system for more beneficial impacts on the aquifer quantitatively and qualitatively.

References

- ANRH-Direction régionale du sud (2003) Note relative à l'étude de la nappe phréatique de la vallée du M'zab (Report). Ministère des ressources en eau, 12 p
- Benmamar S, Poulard C, Berreksi A, Paquier A, Sioussiou R (2016) From the hydraulic system of ancestral M'zab to sustainable urban drainage systems for the management of floods, Proceedings of Novatech 2016, 06 p.
- Cao, Guoliang, Chunmiao Zheng, Bridget R. Scanlon, Jie Liu, and Wenpeng Li (2013) Use of Flow modeling to assess sustainability of groundwater resources in the north China Plain. Wat Res Reas 49 (1): 159–75.
- Gale I, Neumann I, Calow R, Moench M (2012) The effectiveness of artificial recharge of groundwater: a review: Groundwater Systems and Water Quality Programme. British geological survey, Commissioned Report,CR/02/108N, 59 p.
- Harbaugh, A W, Banta E R, Hill M C, McDonald M G (2000) MODFLOW-2000, The U. S. Geological Survey modular ground-water model-user guide to modularization concepts and the ground-water flow process, Open-File Rep. 00-92, U.S. Geol. Survey, Reston, Va.
- Imed, Projet DELTA (2002) Plan d'action, cas de Ghardaïa. 109 p
- Malley Z J U, Kayombo B, Willcocks T J, Mtakwa P W (2004) Ngoro: an indigenous, sustainable and profitable soil, water and nutrient conservation system in Tanzania for sloping land, Soil Till Res, 77: 47-58
- Oweis T, Hachum A, (2006) Water harvesting and supplemental irrigation for improved water productivity of dry farming systems in West Asia and North Africa. Agr. Water Manage., 80: 57-73.
- Oweis T, Prinz D, Hachum A (2001) Water harvesting: indigenous knowledge for the future of the drier environments, 2001, Ed. ICARDA, Aleppo, Syria, 40 p