Modeling the Impacts of Climate Change projections on Groundwater Flow and Socio-Economic vulnerability in the Beni-Amir Aquifer (Tadla Complex, Morocco)

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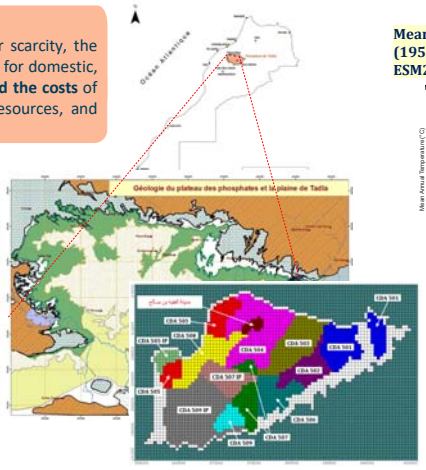
1. Introduction

The Moroccan region currently faces major water challenges related to water scarcity, the sustainable management of water resources and the delivery of water services for domestic, agricultural and industrial uses. **Climate Change (CC) can increase the risks and the costs** of water resources management, impact the **quantity and quality** of water resources, and generate secondary effects that influence the climate resilience.

2. Area of interest & Database

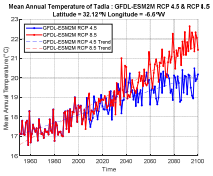
2.1 Complex aquifer system of Tadla (Morocco)

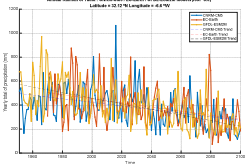
- Located in the Oum Er Rbia basin, between the High Central Atlas in the South and the phosphate highlands in the North.
- Covers an important agricultural area of 10,000 km² that produces beet cultures to supply 3 important sugar industrial units in Morocco.
- Described as a multilayer system made up of 3 main hydrogeological units closely dependent (with age ranging from Turonian to Plio-Quaternary).
- The main supplier of water resources for drinking water of several urban centres of the area and the industrial water supply of the OCP installations and the processes of phosphate washing, besides the water requirements of the agriculture of large irrigated perimeters of Tadla.



Distribution of the Agricultural Development Centers (CDAs) in the area.

Mean temperature (°C) over time (1951-2100) in the study area (GFDL-ESM2M for RCP 4.5 and RCP 8.5)

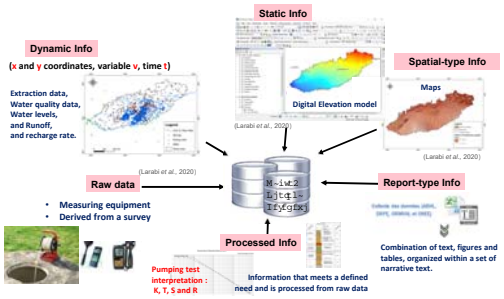




Precipitation (mm/year) over time (1951-2100) in the study area of RCP8.5

- Temperatures are mainly increasing, while precipitations are mainly decreasing for both scenarios.
- Groundwater resources will be affected by climate change due to a reduction in natural recharge from reduced precipitation (the mean will be 20% less at the end of the century for RCP 4.5; and 50% less for RCP 8.5) ;
- Assessment of climate change impacts on groundwater resource availability and use in Morocco, specifically on groundwater abstraction from the Tadla aquifer complex system that supplies domestic water as well as large irrigation schemes in the Beni Amir agricultural area.

2.2 Data collection and storage:

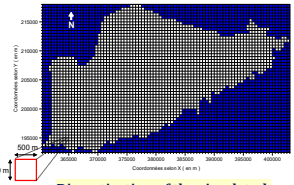


Various steps of the information management process covering data collection, storage, organization, and analysis

3. Conceptual model

3.1 Boundaries and Discretization

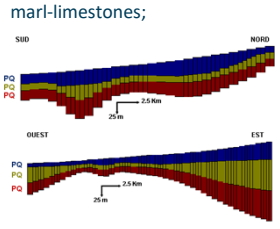
- This area covers **592 Km²**.
- The discretization scheme used is the **finite difference method (MODFLOW)**.
- Design of grid of square cells of **500 m**.
- The 3D model contains **7104 active cells**, **85 columns**, **51 lines** and **3 layers (i, j, k)**.



Discretization of the simulated domain by the finite difference method; the cells in blue colour represent the inactive cells

3.2 Hydrogeological description of the model domain

- ❖ the **upper sequence** (or **PQ3**) consisting of polygenic conglomerates, calcareous crust sometimes conglomerates, silts, marls and clays. It corresponds to the summit part of the plio-quaternary complex of Beni-Amir.
- ❖ the **intermediate sequence** (or **PQ2**) represented by alternations of marl and limestone that can laterally evolve into marls, clays or marl-limestones;
- ❖ and the **lower sequence** (or **PQ1**) represented, mainly, by the sandy marls and the clay marl which constitute the first plio-quaternary fills of the Tadla depression;



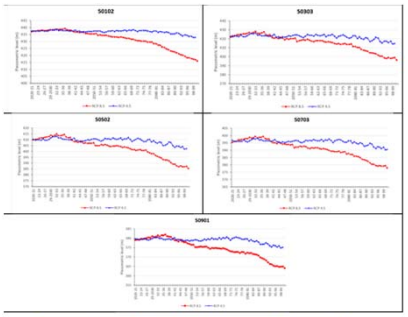
Vertical profiles a) N-S and b) E-W of the aquifer system in a three-dimensional mesh

4. Numerical Modeling on the Beni-Amir Aquifer

4.1 Average of the 3 RCM Models

Overall, simulated piezometric records show declining drawdowns as a general trend over the entire period 2020-2100.

Analysis of the water balance shows that the minimum balance that would be recorded over the entire period is **120 Mm³** (i.e., less than **15%** of the balance obtained by the RCP 4.5 scenario) and would be reached in 2085. The same analysis indicates also that the balance sheet of the simulated aquifer over the whole period 2020-2100 varies between **200 Mm³** and **120 Mm³**.

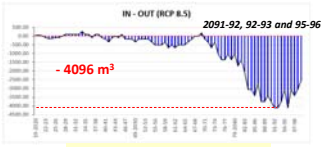


Comparison of simulated piezometric records in the study area (RCP 4.5 and RCP 8.5)

DWA = 119 911 067 m³ ≅ 120 Mm³ (2084-2085)

Time (Year)	2021/22	2030/31	2047/48	2075/76	2093/94	2097/98	2099/2100
STORAGE IN (m³)	13 882 443	85	21 439 701	30 485 205	37 121 320	124 43 437	51 375 443
RECHARGE IN (m³)	91 821 317	99 657 727	72 594 433	80 233 473	56 422 400	70 176 257	57 085 610
LAT FLOW IN (m³)	59 127 336	59 127 339	56 822 483	53 351 850	48 507 053	48 347 733	47 786 153
TOTAL IN (m³)	164 831 093	158 785 157	150 856 360	164 070 397	142 051 000	130 966 533	156 247 067
STORAGE OUT (m³)	13 437 434	19 634 981	5 703 669	5 866 283	269 717	13 169 941	216 107
WELLS OUT (m³)	151 393 691	139 150 163	145 152 917	158 204 417	141 781 000	117 797 200	156 030 967
TOTAL OUT (m³)	16 4831 125	158 785 153	150 856 363	164 070 743	142 050 667	130 967 167	156 246 700

Water balance evolution in the study area (RCP 8.5)



Storage and destocking of the aquifer reservoir (2020-2100)

❖ 2nd layer

(Dry cells over 16.5 Km²)	(Dry cells over 68.5 Km²)
RCP 4.5	RCP 8.5

❖ 3rd layer

(Dry cells over 1 Km²)	(Dry cells over 4.5 Km²)

Groundwater level in 2099-2100 for the second and third layers

Whereas for the RCP 4.5 scenario :

- **the dried areas** are relatively reduced to **16.5 km²** on the 2nd layer and
- **1 km²** on the 3rd layer located at the north of the study area.

Analysis of the aquifer piezometry at the end of the century shows that several sectors of the aquifer **will be partially or completely** dried up :

❖ for **RCP 8.5 scenario :**

- all the pumping wells crossing the first layer **will be dried**,
- as well as over an area of **68.5 km²** of the 2nd and **4.5 km²** of the last layer.

5. Conclusion

- The **increase in evapotranspiration** caused in part by **higher temperatures** (the mean is about 2°C increase for RCP 4.5 and more than 4°C increase for RCP 8.5 at the end of the century).
- in terms of **water balance** of the aquifer system, the RCP 8.5 scenario gave **weak balances** compared to those obtained for the RCP 4.5 scenario.
- the **reduction of the water balance** will be accompanied by a **groundwater table decrease** for both scenarios varying from 10m (RCP 4.5) to more than 25m (RCP 8.5) which makes some aquifer areas completely dry.
- These results are of great importance as key information for **decision-makers** regarding the future of the sustainable exploitation of groundwater resources in the aquifer.

Acknowledgements: This study is a part of the collaboration between the OCP and the regional water center of Maghreb at EMI. We also thank ORMVAT and ABHOR (Oum-Er-Rbia) for the remarkable cooperation that has occurred between both the university and the administrations and for providing data that have been used in this study. Financial support was provided by the FOCP of Casablanca.