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Integrated Approaches to the Assessment of the Impacts of Climate and Socio-Economic Change on Groundwater Resources in the Tensift Basin, Morocco

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Abstract: With barriers such as extremely fragile ecological conditions and severe water shortage, Tensift basin (Morocco) has been suffering from climate variations and will experience severe impacts of climate change on water resources, where effective water resource management is critical. Because of groundwater aspects have, up until now, not been an integral part of the development and management of the country's water resources. In this paper we first, follow BRIDGE's methods (Background cRiteria for the IDentification of Groundwater thresholds) to evaluate and assemble scientific outputs to set out criteria for the assessment of the chemical status of groundwater in the Tensift Basin. These criteria are data for characterization of natural and anthropogenic pollutants, parameters indicative for pollution, data for characterisation of groundwater bodies as hydrologic and hydro-geological parameters. Second, we review the integrated management of water resources using the Water Evaluation and Planning System (WEAP) computer modelling. The WEAP aims to incorporate values into a practical tool for water resources planning. WEAP places the demand side of the equation--water use patterns, equipment efficiencies, re-use, prices and allocation--on an equal footing with the supply side-stream flow, groundwater, reservoirs and water transfers. The results of the adaptation policy evaluation indicate that the feasibility of adopting technical and engineering adaptation practices is relatively low. These options include expanding sprinkle, trickle, pipeline irrigation, building reservoir upstream and increasing exploitation of groundwater. These options are hard to adopt due to difficulties in obtaining considerable capital support. Farmers and water resource managers are reluctant to invest in these engineering solutions that present high financial risks. On the contrary, water-saving practices such as cropping and cultivation structure adjustments are more feasible because of relatively small capital requirements.

Key words: Change • Vulnerability • Adaptation • Integrated management • Groundwater

INTRODUCTION

The Tensift El Haouz plain is located between two mountainous chains in the center of Morocco with an area of about 6000 km^2. The population is about 3102652 (2004 review). The area comprises two reservoirs, the first is the oldest dam in Morocco (Lalla Takerkoust), the second is one of the youngest dams [1]. The climate is continental arid and semi-arid. It's characterized by low precipitation about 170 mm, high evaporation and moderately elevated temperatures that can reach 39°C with important monthly and Daily variations.

Therefore, the hydrology of the Haouz plain is strongly influenced by climate, which acts directly on the balance sheet and at the same time on feed and losses.

Methods

BRIDGE: Background cRiteria for IDentification of Groundwater thresholds (BRIDGE) is an European specific research project, which aims to define a common methodology for establishing threshold values in groundwater (2005 - 2007). The overall aim of (BRIDGE) is to develop and test a method for the derivation of pollutant threshold values (TV) for groundwater bodies in support of the Status provisions of the Water Framework Directive (WFD) and the Groundwater Daughter Directive (GWDD). Threshold values for pollutants are quality standards for pollutants in groundwater which are set by individual Member States and represent a concentration of pollutant which must not be exceeded in order to protect human health and the environment [2].

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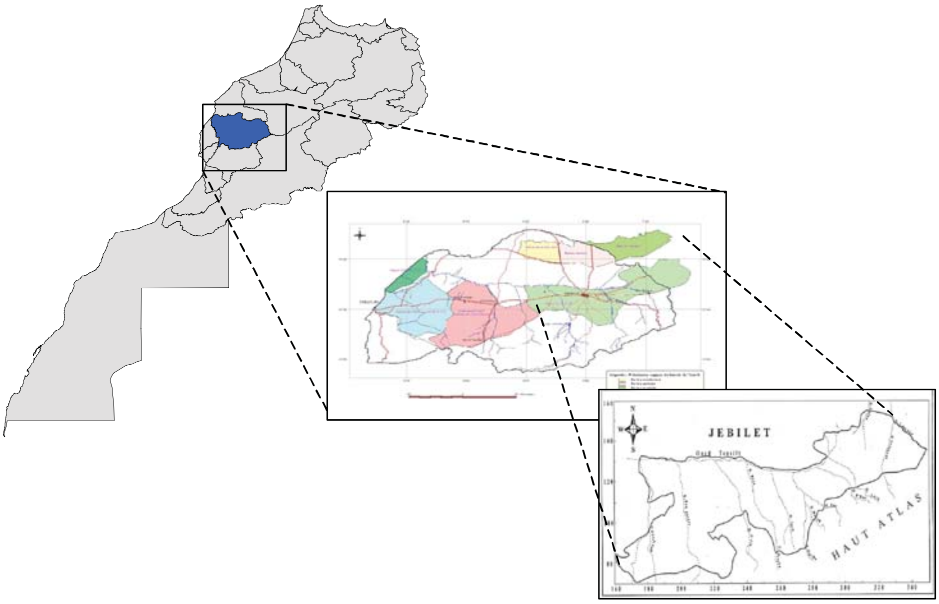

Fig. 1: WEAP Schematic of the Tensift El Haouz Plain

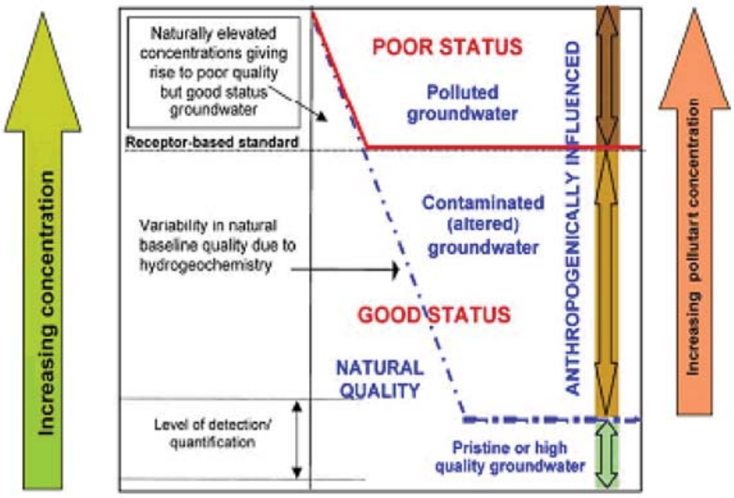

Fig. 2: General groundwater quality relationships under the WFD [3]

Such thresholds provide the basis for determination of good status in groundwater bodies established under the WFD and may also represent useful values in assessing pollutant trends in groundwater.

In the process of determining Status it is essential that a good conceptual model of the groundwater body is drawn up which includes data about pressures, processes, pathways and receptors involved. This will include issues such as the use of land and water, climate and water balances, geology, (bio) geochemistry and hydrogeology, characteristics of the aquifer and the unsaturated zone including soils.

In delineating groundwater bodies and the characterisation process Member States should already understand the nature of the pollutant risk to the receptors (e.g. type of pollution, transport pathways, wherever feasible, the natural groundwater quality, etc).

The first step of this method to establish threshold values is to define the final receptor at risk that receive the pollutant, then we must define the Natural Background, it 's an indicator of the natural quality for groundwater bodies, it must be taken out of any human activity.

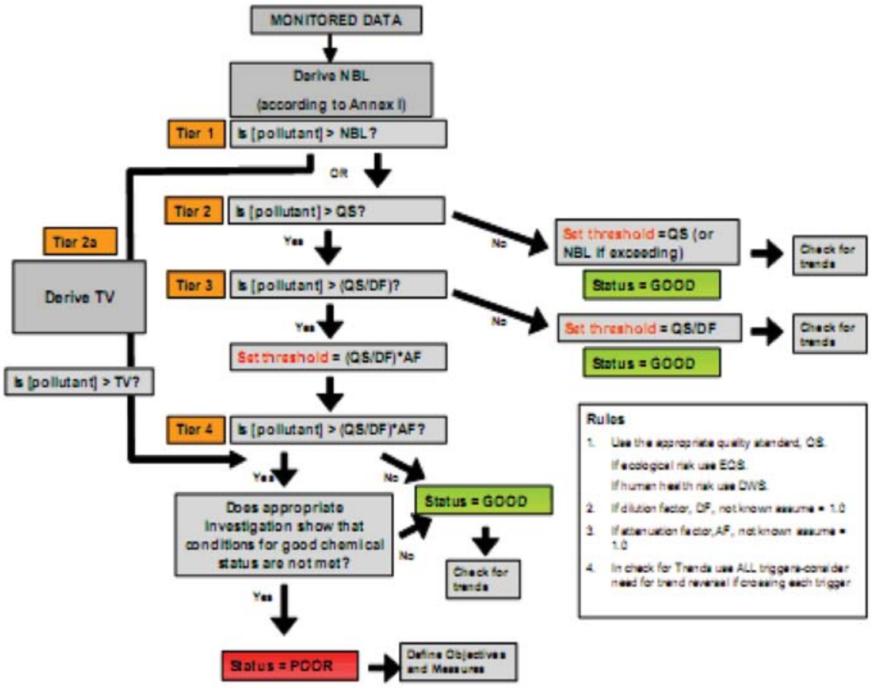

Fig. 3: Flow diagram illustrating the tiered approach proposed for derivation of groundwater threshold values for either dependent aquatic ecosystems (Tier 1-4) or for groundwater itself (Tier 1-2a) [3].

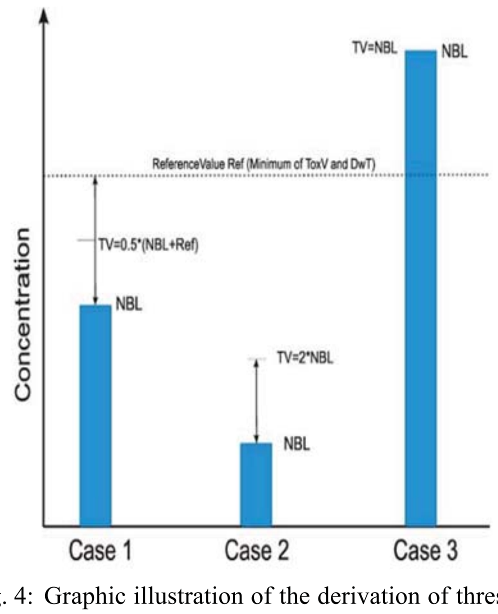

Fig. 4: Graphic illustration of the derivation of threshold values in the three defined cases [3].

The developed methodology has suggested 'groundwater itself' as a receptor in addition to the dependent ecosystems and outlined two basic options to derive threshold values; one for groundwater itself and one for dependent aquatic ecosystems [3]. In both cases the initial evaluation refers to the natural background level (NBL) of the investigated element or substance. Hence the first step towards the derivation of threshold values is to derive the NBL of the investigated substance. The flow diagram of Figure 3 illustrates the process of deriving threshold values, which may be derived for dependent ecosystems (Tier 1-4) depending on the system and the available data, or for "groundwater itself" (Tier 1-2a) based on natural background levels and relevant reference values, such as environmental quality standards (EQS) or drinking water standards (DWS).

It is proposed to derive groundwater threshold values based on groundwater itself (Tier 1-2a) as a receptor, where the groundwater body does not have a significant influence on a dependent ecosystem. The derivation of the threshold values are illustrated graphically in Figure 4.

WEAP: The Water Evaluation and Planning System (WEAP) is an integrated water management tool that allows basin evaluations including all water related activities in a specific area. WEAP calculates the demand, supply, runoff, infiltration, culture conditions,

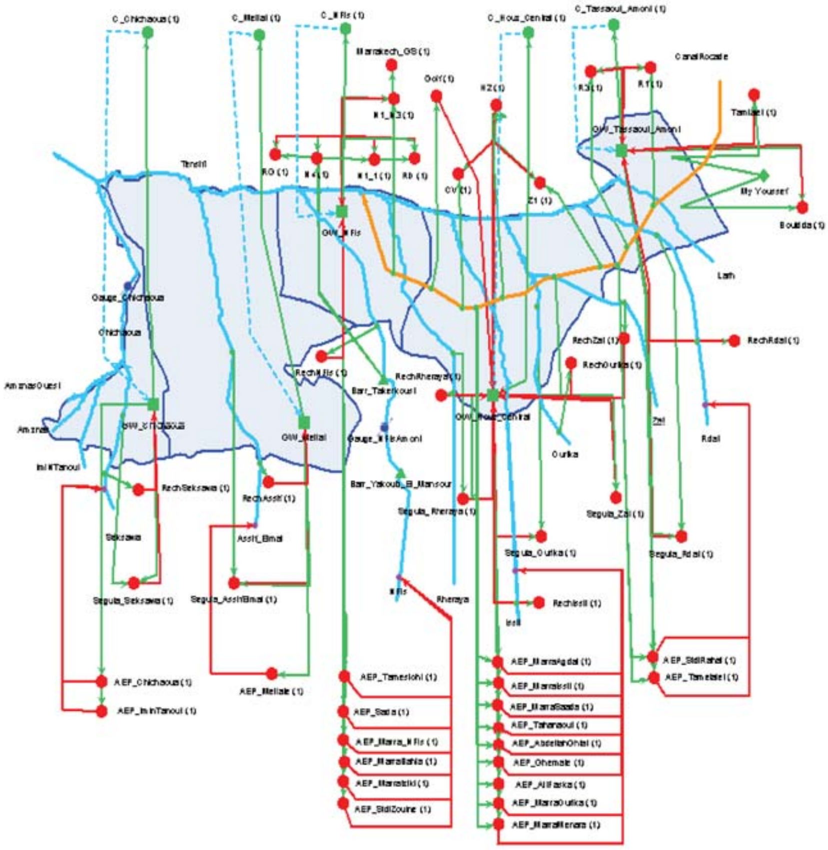

Fig. 5: WEAP Schematic of the Tensift El Haouz Plain

the flow and storage and production of pollution, treatment, discharge and quality of water flow under the effect of climate change scenarios by compiling hydrologic and political change.

The Tensift El haouz Basin was developed by the model WEAP (Water Evaluation Planning system) [4].

The Tensift-El Haouz Hydrology plain was developed by WEAP [4]. The model has been adapted, calibrated and validated for the Tensift-El Haouz Plain and permits the analysis of different hydrological parameters in different climate and policy scenarios. First, the hydrology and water supply were mapped into the WEAP layout of the selected representative different Agriculture Demand Sites and Urban Demand Sites in the geographical locations.

The Current Account "reference scenario" of the water system under study have created. Further, the WEAP model is still not completed and currently under development, it was possible to employ it in order to run simple policy scenarios with alternative assumptions about future developments regarding variety of hydrological, demographic, technological trends a "reference scenario" and climate variation and therefore representing the impact on supply and unmet demand and groundwater avaibility. Only the major water users were described for each major user, the activity level, the annual water demand (net values after accounting for losses), the monthly variation as well as a return flow.

The model is based on an extensive source of data base of ecological, meteorological, hydrological, hydrogeological, sedimentological, water management, GIS and remote sensing, vegetation, social, cultural and economic. [5-8].

RESULTS AND DISCUSSIONS

BRIDGE: Regarding the conditions proposed in BRIDGE method for determining the value of the NBL, defined areas without any human activity in our groundwater were determinated, which are selected to approximate a natural groundwater composition of a given aquifer typology.

Table 1: Example of calculated threshold for the groundwater in the studied area

	REF	NBL	TV
Cond (mS/cm)	1300	842,5	1685
NH_4^+ (mg/l)	0,5	0,01725	0,0345
NO_3^- (mg/l)	25	9,1475	18,295
NO_2^- (mg/l)	0,5	0,0072	1
Na^+ (mg/l)	200	151,075	175,5375
Cl^- (mg/l)	300	125,305	250,61

NBL : Natural Background Level.
TV : Threshold Value.
REF : Reference value of drinking water.

The studied groundwater are used for drinking water and irrigation supply, therefore understanding the receptor 'groundwater itself' as a resource for future uses drinking water standards would be an appropriate reference value.

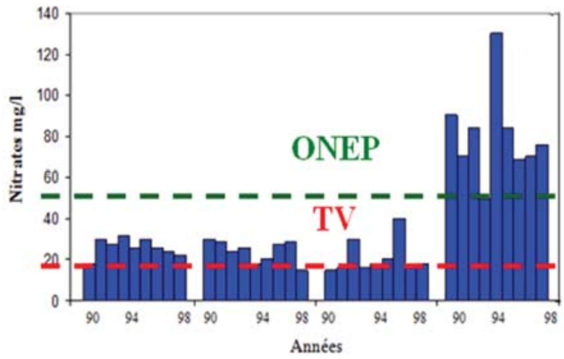

Fig. 6: Comparison between threshold values and calculated values proposed by ONEP
ONEP: Standard of the National Drinking Water, Morocco (Office National de l'Eau Potable)

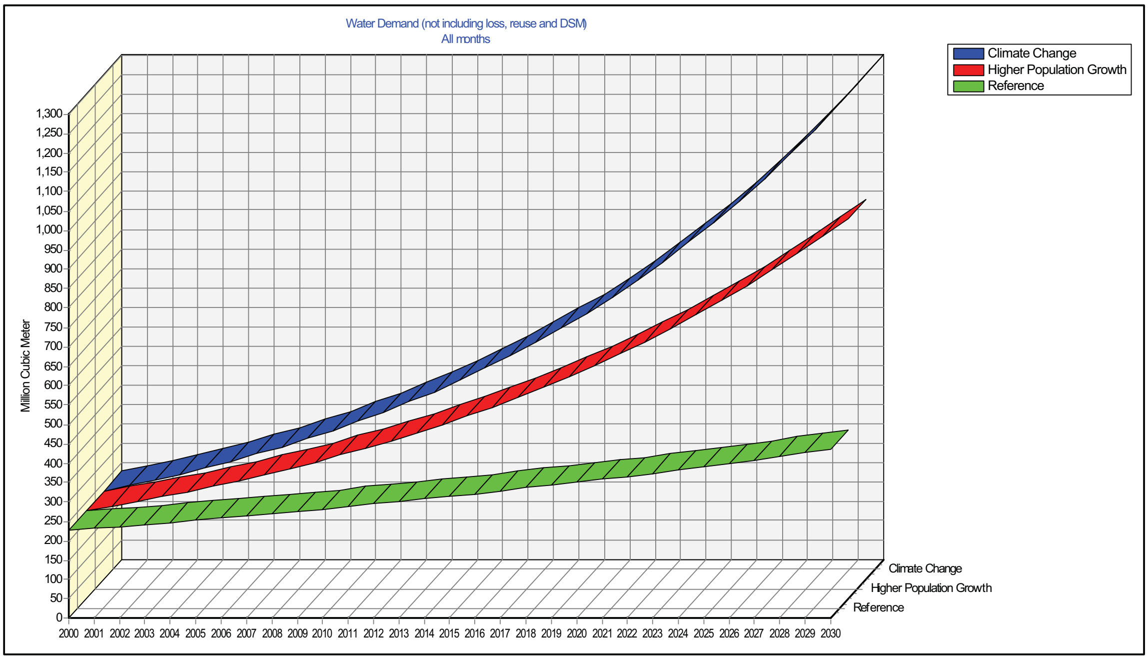

Fig. 7: Water demand scenario (2000 – 2050)

As for 'groundwater itself' as receptor most of threshold values were calculated according to case 1 and 2 (NBL<REF of Reference Value: (REF+NBL)/2; and NBL<1/3 of Reference Value; TV= 2 x NBL). The resulting TVs are consequently rather low and much lower than drinking water standards (i.e. nitrates).The practicability of establishing threshold values far below drinking water standards must be discussed. Measures triggered by such threshold values might be costly but environmentally inefficient.

The figure below shows the evolution of nitrates in some wells in the study area. We note that concentrations of nitrates have already exceeded the threshold values calculated and they have even exceeded the values recommended by the Moroccan organization (ONEP). Consequently these groundwaters suffer the impacts of human activities.

WEAP: The study of supply and demand or the study of water supply is an important objective in our research. Figures below show the comparison between three

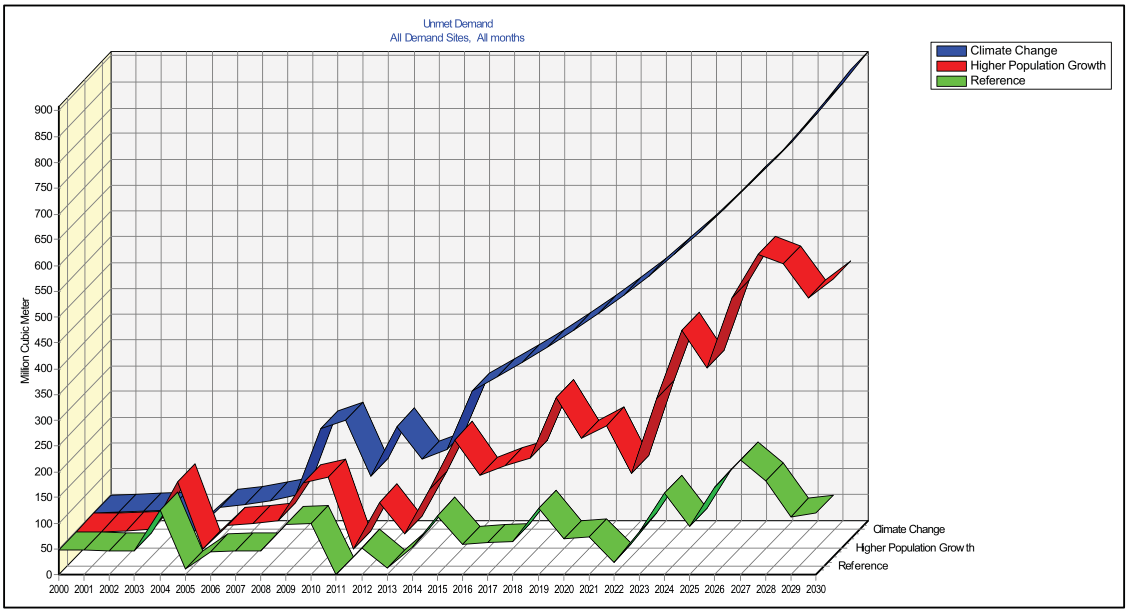

Fig. 8: Effect of population growth on annual water demand for 2000-2050.

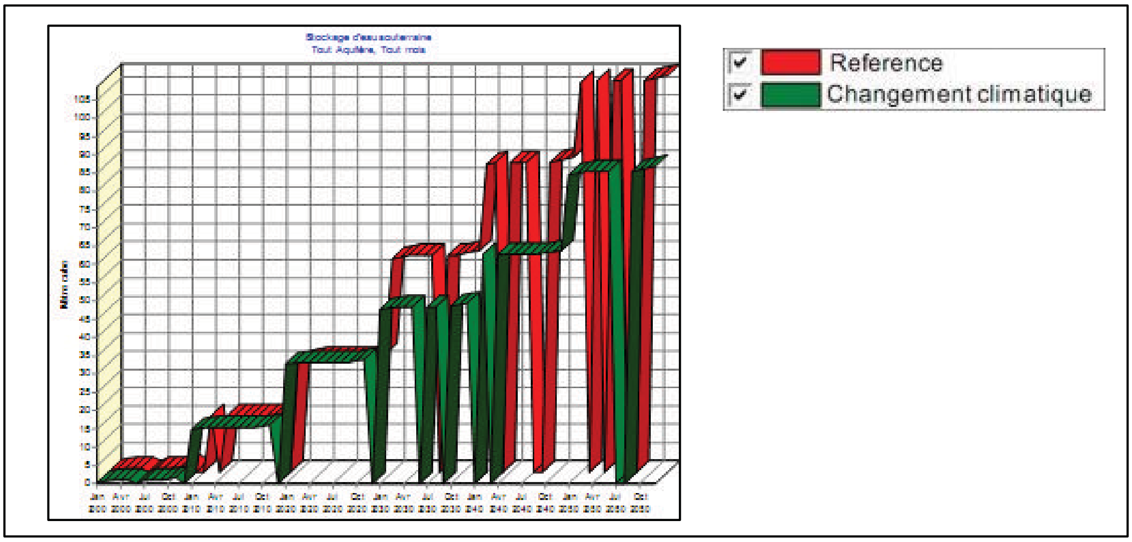

Fig. 9: Storage Groundwater evolution (2000-2050).

scenarios, a reference scenarios whith normal conditions, a scenario with a higher rate of population growth and the last one a scenario called "climate change" which implies a more sec, i.e., a dimunition of precipitation and increased temperature and evapotranspiration.

The figure shows that the unmet demand will be increased in scenarios where we will have an increase of the population that will require further works to supply water and the situation becomes more serious with the impact of climate change.

According to the IPCC (Fourth Report), projections indicate that by 2020, 75 to 250 million people in Africa will be exposed to increased water stress due to climate change. Coupled with rising demand, it will have adverse impacts on livelihoods and exacerbate problems related to water. For Morocco, it is expected that agricultural production and access to food is severely compromised by climate variability and climate change. Areas suitable for agriculture, the length of growing seasons will certainly decrease. And the drinking water will be affected by reducing of the availability of water resources.

Groundwater provides much of the drinking water supply and is also used for irrigation [9,10]. The graph below (Fig. 8) shows the evolution of the quantities of groundwater available or changes in water storage in the aquifer studied until 2050, with a baseline (or without climate change) and taking into account the effect of changes.

The recently released IPCC report [11] makes only scarce mention of on the impacts of climate variability and change on groundwater in Africa. The figure shows that climate change will have impact on the Storage of groundwater. The temperature increase, reduction and irregularity of the precipitation will reduce the natural recharge of the aquifer and since we will have over-exploitation of groundwater due to increaseing population, there for it will be a dimunition of the reserve in aquifers.

CONCLUSION

Chemical parametter concentrations have exceeded the calculated threshold values for some paramèttres which the groundwater is considered vulnerable to anthropogenic pollution.

In the other hand, Climate change clearly has serious implications for water management in the Tensift El Haouz Plain. This study shows that groundwater resources are affected by the phenomenon of climate change in the region Tensift-El Haouz. And we can consider the consequences of a population whose activities depend mainly on agriculture.

These usable water quantities require a strategy for integrated water resources management and adaptation to climate change sector, a resource assessment with the relevant requirements of users in order to make a choice about the type of operation.

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