12th International Conference on Hydroscience & Engineering
Hydro-Science & Engineering for Environmental Resilience
November 6-10, 2016, Tainan, Taiwan.

Integrated Model for management of irrigation water at the level of 'Ait ben yacoub' watershed in Morocco

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ABSTRACT

This work was designed to build a tool for analysis and decision support regarding policy on the allocation of the water resource, allowing a better reflection on the issue of water valorization by the agricultural sector. Thus, an integrated model disaggregated by type of farms was developed for a pilot area named "Ait ben yacoub»; located in the East of Morocco. This model integrates economic, agronomic and hydraulic data. It can simulate the behavior of farmers faced climate change.One Major contribution of this model is a detailed disaggregation by spatial units (hydrological units, cropping areas, and grazing land), by agricultural production systems (irrigated and rainfed crops), and by farm sizes. Basically it's an optimization model with a nonlinear objective function, and using the positive mathematical programming method technique for its calibration. The principal model results show the remarkable impact of surface water management on the overexploitation of the ground water and the risk of its depletion.

CONTEXT AND OBJECTIVES

Along the last decades, the production of knowledge on climate change has been highly fragmented. Recent research on climate change has approached the assessment of impacts, vulnerability and adaptation under biophysical or social perspectives (Downing, 2012; Füssel, 2007).

In the field of agriculture and water resources, most assessments have been based on biophysical modelling focusing on one specific dimension of climate change, such as the agronomic dimension (Moriondo et *al.*, 2010; Ventrella *et al.*, 2012), or the hydrological dimension (Joyce et *al.*, 2011; Rochdane et *al.*, 2012). However, the recognition of water management and climate change as multidimensional and multi-scalar concerns (Downing, 2012; Meinke et *al.*, 2009) evidence the need to integrate biophysical and social aspects looking at environmental and human contexts.

In line with this, varied types of integrated modelling frameworks have been developed to address the different scales (from the crop to the river basin) and the different dimensions of climate change, water and agriculture (hydrological, agronomic, and socio-economic). However, these frameworks have not always represented the socio-economic dimension of water use in sufficient detail and in some cases they have undervalued the role of human response to climate impacts.

Trying to better represent socio-economic issues, hydro economic modelling has been extensively used along the last decades as a prominent tool for guiding and implementing water policy decisions (El ouadi et al .,2014;Blanco-Gutiérrez et al., 2013; Brouwer and Hofkes, 2008; Heinz et al., 2007). These models are capable to consider the economic behavior of water users and the economic principles that govern water allocation.

Along this line, this paper presents a novel application of a hydro-economic modelling framework that is used to assess climate change impacts and adaptation in the Ait ben Yacoub Basin, taking into account the agricultural, socio-economic and hydrology systems.

The novelty of the approach presented here lies in the capability of this integrated framework to take into consideration agronomic, economic and hydrologic processes that take place at different scales. This research takes a step forward in hydro-economic modelling to advance in the analysis of climate change implications on irrigation agriculture systems from the crop to the farm and the water system levels.

Using this integrated approach, this paper evaluates the impacts of a severe climate change scenario (on the water system, on farms and on crops, looking at farmers' capacity to adapt.

WATER, AGRICULTURE AND CLIMATE CHANGE IN THE "AIT BEN YACOUB" AREA(MOROCCO)

In Morocco, water resources become increasingly scarce, scarcity that will become acute in the coming years due, Among Others, to a reduction in water supply, as a result of climate change, and the Increase in demand, Accentuated by the population Increase and the requirements of economic growth and development. Agriculture is regarded as a strategic sector for socioeconomic development .However, this sector faces challenges many, water management among other.

The study area named "Ait Ben Yacoub " is located in the east of Morocco and characterized by a semi-arid climate where water is a limiting factor, thus constituting an unfavorable conditions for a productive and competitive agriculture. Irrigation water resources Consist, on the one hand, Mainly by water from the source of "AinLaarais" share of the major most sources of region with a rate flow of up to 245 l / s and there Reviews the other hand, exploited by groundwater through wells and boreholes dug by farmers.

Currently, water is becoming a critical issue in the region. Water saving Represents now a major problem, since conflicts among uses and environmental pressures reached a critical level. In Climate change will add further Top pressure on the already Stressed water system and will pose additional challenges for the irrigation sector.

This area is characterized by traditional agriculture based on cereal mainly annual crops, with the presence of apple and some winter vegetables, especially potatoes. The land in the study area is sized as Follows:

Table 1. Representative farm types in "Ait ben yacout" area

Farm type	Size Average	Effective	Total size (ha)
S_farm	Less than 2 ha	95	164
M_farm	between 2 and 5 ha	50	228
L_farm	between 5 and 10 ha	59	519
XL_farm	More than 10 ha	58	1989
Total		262	2900

The study area is composed of two watersheds: lhardane basin and akhnig basin.

METHODS: A HYDRO-ECONOMIC MODELLING FRAMEWORK

To respond to the questions and challenges of climate change, we propose a hydro-economic

Modeling framework. The model developed integrates economic, agronomic and hydraulic data. It can simulate the behavior of farmers faced with climate change taking account competition for resources.

The proposed approach is based on nonlinear optimization techniques. It's a hydrological and economic model that uses water resources so as to maximize the profit at the level of the basin while taking into account a set of constraints which are divided into hydrological, agricultural and resource availability constraints. One Major contribution of this model is a detailed disaggregation by spatial units (hydrological units, cropping areas, and grazing land), by agricultural production systems (irrigated and rainfed crops), and by farm sizes.

The Positive Mathematical Programming Method (PMP) approach, as suggested by Howitt (1995), has been used to calibrate the models. The fundamental idea of PMP is to reconcile the new optimization of the mathematical programming model with the economic and social reality as evidenced in the base data set. Essentially, PMP adds calibration constraints so that the base solution is close to the base data set. For reasons of computational simplicity and lacking strong arguments for other type of functions, a quadratic cost function is often employed (exceptions: PARIS and HOWITT 1998 and 2000). The general version of this variable cost function to be specified is:

$$Cv = dx + \frac{1}{2} Q\ x^2 \qquad (1)$$

Cv = quadratic cost
d = (N×1) vector of parameters associated with the linear term
Q = (N×N) symmetric, positive (semi-) definite matrix of parameters associated with the quadratic term.
However, the objective function of non-linear programming problem is composed of a quadratic cost calibrated using observed area of crop.

$$\text{Max } Z = px - dx - \frac{1}{2} Q\ x^2 \qquad (2)$$

Subject to

$$Ax \leq b \quad [\lambda]$$
$$x \geq 0$$

Where
Z = objective function value
p = (N×1) vector of product prices
x = (N×1) vector of production activity levels
A = (M×N) matrix of coefficients in resource constraints
b = (M×1) vector of available resource quantities
λ = (M×1) vector of dual variables associated with the resource constraints.

RESULTS

The model simulates the assessment of climate change impact on irrigated agriculture. This scenario provides insight into the behavior of farmers in conditions of water scarcity. Simulate the impact of a reduction of 50% of water allocation, groundwater recharge and rainfall at the basin level

In this paper, the results of the assessment of climate change impacts and adaptation options in "ait ben yacoub " commune are presented for three selected variables: irrigation water use , shadow price of water and farm's income .These variables reflect the magnitude of climate change impacts and the potential for adaptation

Irrigation water use

Table 1 illustrates the effect of the climate change scenario on Irrigation water use. In the baseline scenario, without climate change, the irrigation water use is equal to 43.6 Mm^3. This value increases, in the climate change scenario, to 27.4 Mm^3. The results presented in Table 2 also demonstrate that climate change will produce increased use of groundwater for irrigation; this leads to overexploitation of groundwater subsequently a depletion of the round water resources.

Table 2. Climate change impact Surface water for irrigation (Mm3)

Volume of Irrigation water by Resource (Millions cubic meters)	Baseline scenario	Climate change scenario
Surface water for irrigation	39,35	21,5
Groundwater use for irrigation	4,31	5,92
Total irrigation water use	43,66	27,42

The model results show the remarkable impact of surface water management on the overexploitation of the groundwater and the risk of its depletion. A management policy of surface water based on administrative pricing, pumping cost, and water supply, marginal cost is proven inadequate for a sustainable resource management since it underestimates the overall water scarcity at the basin level (Fig. 1).

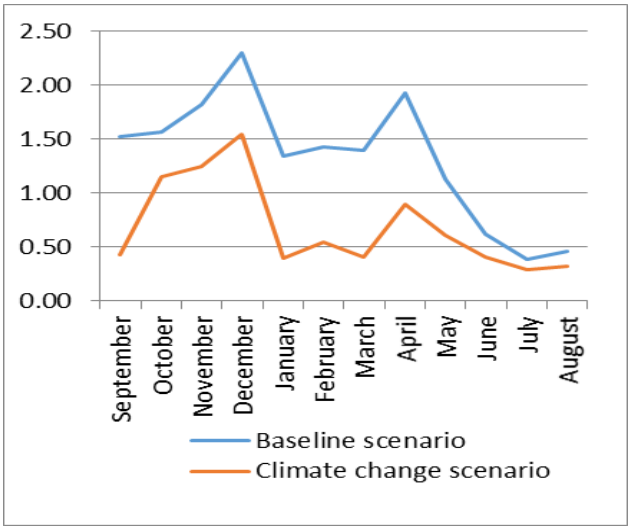

Fig. 1 Evolution of the volume of water stored in "itzer-injel" aquifers in million m3 (reference Year and climate change scenario)

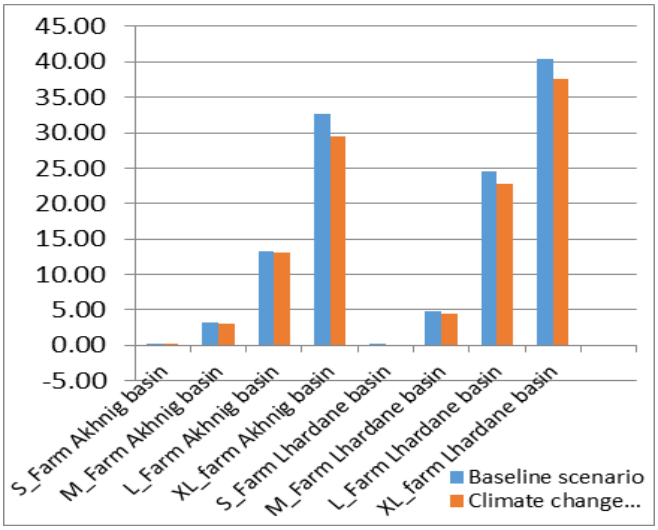

Fig. 2 Climate change impact on farm's income (millions MAD).

Shadow price of water

In terms of economic price, there is a significant increase in the marginal value of water relative to the reference situation. This value increased from 2. 2 Moroccan Dirham (MAD)/m³ observed in the reference year to 5.7 MAD/m³. In fact, water resource is becoming a constraint for production in the basin during a dry year.

Farm's income

The results presented in Fig. 2 demonstrate that climate change will produce significant reductions of farm's income from 118.7 to 110.6 millions MAD. Small farms will be most vulnerable to climate change. In this scenario, their income will become deficient.

A deficit in income will probably be compensated by livestock production. In fact, there is a need to develop the livestock component in the model in a future work to better understand the decisions of farmers.

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