The Moroccan Association of Agricultural Economics (AMAECO)

in partnership with

International Association of Agricultural Economics (IAAE)	&	United Nations University-World Institute for Development Economics Research (UNU WIDER)

Climatic constraints play a predominant role in the performance of national agricultures and their capacity to support economic growth and assure food security for the population. With the climate changes and projected inter and intra annual fluctuations, management of the agricultural sector takes a particular dimension including management of risks inherent in the sector and searching for sustainable growth for the sector. Agricultural policies must permit a continual adaption of the processes of agricultural production and a reduction of negative effects of climate change in order to assure food security for the population.

In the face of climate change, the adaptation strategies can generate important development opportunities. Also, governments have need for pertinent evaluations of the impacts of climate change.

Considering the importance of this problem; to permit an exchange of ideas among professional staff, researchers, and specialists in the domain of development; to contribute to a richer understanding of methods and analytical tools ; and to contribute to better preparation of decision making in this domain – the Moroccan Association of Agricultural Economics (AMAEco) in collaboration with the International Association of Agricultural Economics (IAAE) and the World Institute For Development Economics Research of the United Nations University (UNU-WIDER) are organizing an international conference 6-7 December in Rabat, Morocco under the theme:

« Impacts of climate change on agriculture »
Rabat, Morocco   December 6-7, 2011

The principal themes proposed are the following::

1.   Analysis of the impacts of climate change on agriculture: simulations and projections

2. **Climate change and sustainability of agricultural production systems**

3. **Adaption strategies for agriculture in the face of climate change: systems of production, risks in agriculture, and policies for food security**

4.   **Water management in the context of climate change**

http://www.wider.unu.edu/events/past-conferences/2011-conferences-/en_GB/06-12-2011/

Water Valuation in Agriculture under climate change
(Case of Souss-Massa Basin, Morocco)

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Summary:

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. In this context of scarcity, Morocco is confronted with the need to adapt its water management policy from a supply management to a demand management one. Implementing such a policy requires the adoption of new policy instruments and decision making support tools that take into account the complexity of the current and future situation, as well as allowing the assessment of the economic, social and environmental impacts of various water resources allocation alternatives at the overall river basin level. This paper compares several methods for calculating the water value and proposes an integrated economic water management model at the river basin scale. This model takes into account the economic, institutional, hydrological and agricultural aspects, as well as the behavior of various agents involved in water resources management and the competition among sectors. 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 non linear objective function, and using the positive mathematical programming method technique for its calibration. Given the conjunctive use of water at the river basin level, the model results show the tremendous impact of surface water management on the overexploitation of the ground water 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 river basin level.

Keywords: water resources, scarcity, surface water, water value, positive mathematical programming, river basin, integrated economic model, groundwater, depletion.

1. Introduction

In Morocco, agriculture is considered as a strategic sector for socio-economic development. However, this sector faces many challenges, water management among others. In fact, drought years combined with aquifers depletion trend, economic growth and increasing demands pressure make water resources very scarce. These limited water researches are not generally well allocated.

The various local agents involved in water policy and their interests, often conflicting, generates use conflicts and excessive water demand that cannot be controlled only by using an integrated, decentralized and concerted water resources management. Such management could be conceived only on a river basin scale where exhaustible are water resources, and through developing policies and tools that allow an efficient and an equitable management between different stakeholders. Indeed, the river basin assembles all physical features and human activities and where the main focus of interest conflicts around water management between various agents having a direct effect on the system.

Water valuation policy is becoming an imperative for decision makers especially in the Mediterranean region and this for many reasons:

- Water scarcity: economic development, urbanization…
- Climate change and its impact

From an economic standpoint, several methods have been suggested in order to guide this political assessment of Water use Efficiency: residual method, market chain analysis and more recently other optimization methods were introduced. However, there is a more confusion in interpreting the results of these methods

- Generally, there is confusion between the private interest and the collectivity one (Producers interest and community interest): the farmer tries to maximize its profit but the community is more interested in water valuation.
- Confusion between competitiveness and Water Efficiency.

The choice of Sous-Massa Basin is guided by the economic position that occupies that basin and the acute water scarcity which it faces. In addition, tourism development and the important place of this basin in the national agricultural exports (leader in export of off-season fruit and vegetables) combined with population growth pressure and urbanization make water resources increasingly scarce in that basin.

Sous-Massa basin is characterized with limited and irregular surface water resources. It includes two aquifers overused. In fact, imbalance between a limited water supply and an increasing water demand has led in recent years to a water shortage alarming situation and to an overuse of groundwater resources beyond 260 Mm3/year of deficit[3].

2. Methodological approach and Previous studies in applied economic modeling for irrigation

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[3] ABHSM, Stratégie de préservation des ressources en eau souterraine dans le bassin de Souss-Massa, novembre 2005

To support the effort of a better allocation of irrigation water use, several studies have been undertaken. These works contribution is undeniable since it informs policymakers about the need to support technical decisions and policies with economic and social evaluations. In addition to classical studies based on assessment methods of investment projects that have accompanied almost all irrigation investment projects, we can distinguish other tools for supporting decision making that were developed for Morocco and were devoted to optimal allocation of irrigation water use.

We can distinguish among these groups of tools, the Market chain approach (*l'approche filière*) (Bengueddour, 1998; Benabdellah and Doukkali, 2000; Doukkali and Tourkmani 2001; Elkazdar and Passoulé 2009. All these studies focused on measuring differences of water valuation by irrigated crops and comparing the competitiveness of these crops. However, this approach has some limitations knowing that it ignores institutional constraints, resource availability or access to technology in farms.

Another type of tools based on farm models method that has economically derived demand functions for irrigation water of different farm types in different situations and has calculated the shadow price to evaluate water pricing at a given irrigation area (Bathaoui 1991; Fegrouch, 1998; HFID, 1999, Diani, 2001; Tsur, Roe, Doukkali and Dinar, 2004; Petitguyot, Rieu, Chohin-Kupper and Doukkali, 2005).

Applied modeling to agricultural sector (Essaidi, 2002; He, Tyner, Doukali and Siam, 2006) demonstrated differences in water efficiency and economic prices between different agro-ecological zones. However, these models have led to limited results because they do not integrate other sectors of the economy.

In addition to the tools already mentioned, the general equilibrium models with different levels of disaggregation more or less advanced were applied to study various issues faced by irrigated agriculture. One of the important of these works have focused on studying the impact of adjustment implementation and liberalization (Doukkali, 1998), Evaluation of National Irrigation Program and 2010 Strategy set up for Rural Development (Doukkali, Löfgren, Serghini and Robinson, 1999), irrigation water pricing study (Tsur, Roe, Doukkali and Dinar 2004b) and the study of the potential profits from decentralized water allocation at national economy level in a context of a large spatial heterogeneity (Diao, Roe and Doukkali, 2005). This type of model has highlighted the links between policy instruments and allocation of water resources and was used to assess economic policy instruments impact.

To complement these efforts and overcome the limitations of economic models mentioned above. This study proposes an economic integrated river basin model which stemming from modeling studies at the international level, notably by IFPRI (International Food Policy Research

Institute)[4], (Cai, 1999; Resegrant, Ringler, Mckinney, Cai, Keller and Donoso, 2000; Cai, Rosegrant and Ringler, 2001; Ringler and Nguyen, 2004). The model is integrated in the sense that it takes into account hydrological, agronomic, economic and institutional components, while apprehending the behavior of various demand sectors (irrigation, municipal water demand…) and stakeholders involved in water resources management in the basin. In this model, the basin is represented by spatial and functional units or nodes of water resources management through an exchange of water flow between these units, between units, reservoirs and aquifers and finally between these units and water demand sites. The Links between the different elements and units simulate water flow between these different components along the River. For the agricultural sector, irrigation water is allocated according to crop water requirements and the profitability of each crop. Various spatial scales allow the generation of reasonable results compared to actual observed data, including water flows downstream, water losses, water supply, irrigated areas, yields, productions, etc.

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 value added in agriculture while taking into account a set of constraints which are divided into hydrological, agricultural and resource availability constraints. The model calibration is based on positive mathematical programming 'PMP' (Howitt, 1995).

3. Results and Discussion

The purpose of this part is to analyze the results and compare several methods of water value study. Indeed, we will discuss irrigation water valuation by calculating water residual value and analyze results of the financial and economic market chain analysis of some important fruits and vegetables in Sous-Massa area. Then we will assess the relationship between crops and water valuation then between production systems and water efficiency. Finally, we will present the results related to water value study by the modeling approach of integrated economic water management.

3.1 Irrigation water valorization by the residual value approach

*Figure1: Comparison of the value added per Hectare and per Cubic meter*

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[4] **Rosegrant M.W., et al**., 2000. Modelling Water Resources Management at the Basin Level., Methodology and Application to the Maipo River Basin. International food policy research institute washington, d.c. research report 149.
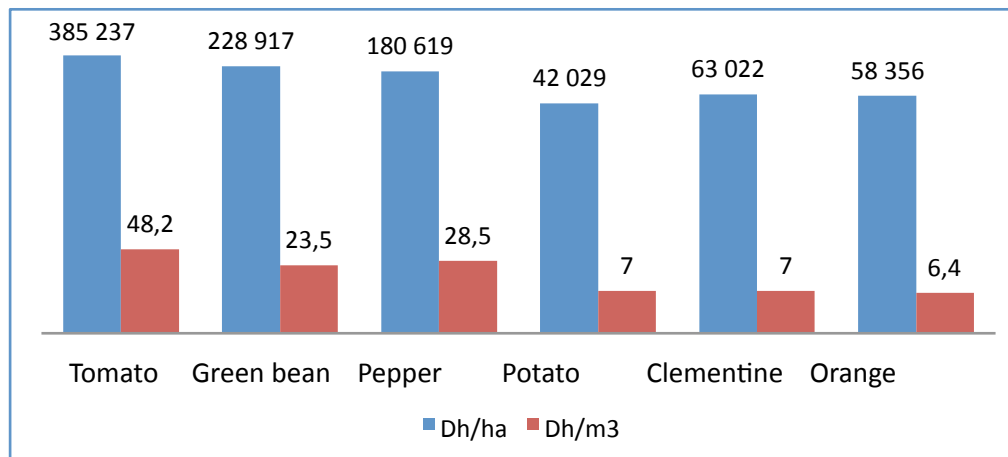
From this Chart, it appears that water valuation by pepper is more important than green beans while the value added per hectare of green beans is higher than that of pepper. The same finding for oranges compared to potato. This shows that water valuation must be calculated per cubic meter of water and not per hectare.

figure2: Perspective and point view of the producer and the community.
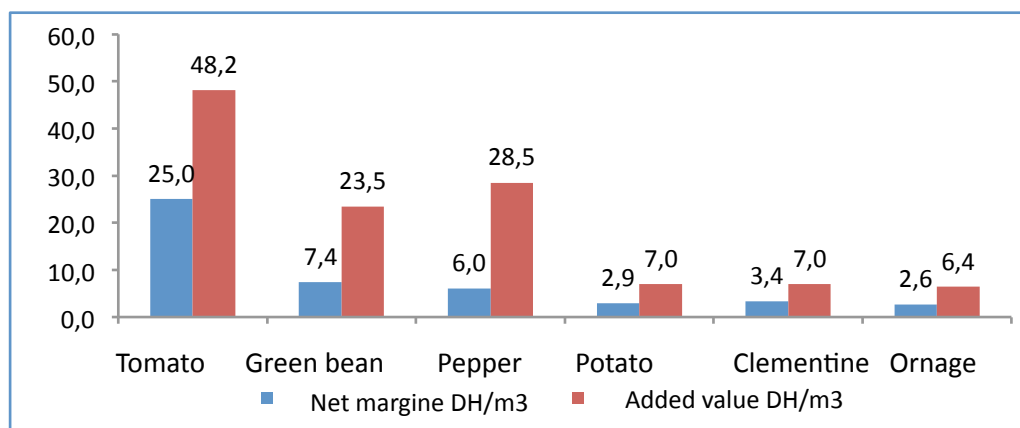
Community interest is to maximize water valuation and create a value added. However, the farmer sees things from another angle which sometimes may be different from the community view. The diagram above shows that the community would be indifferent between potato and Clementine choice, while the producer would prefer Clementine. In the case of green beans and peppers, views of the producer and the community would be opposed as the community will opt for pepper while the producer will choose beans from which the interest of a better information to help get a proper choice and judgment of public authorities .

*Figure3: Water valuation regarding financial and economic price (Dh/m3)*
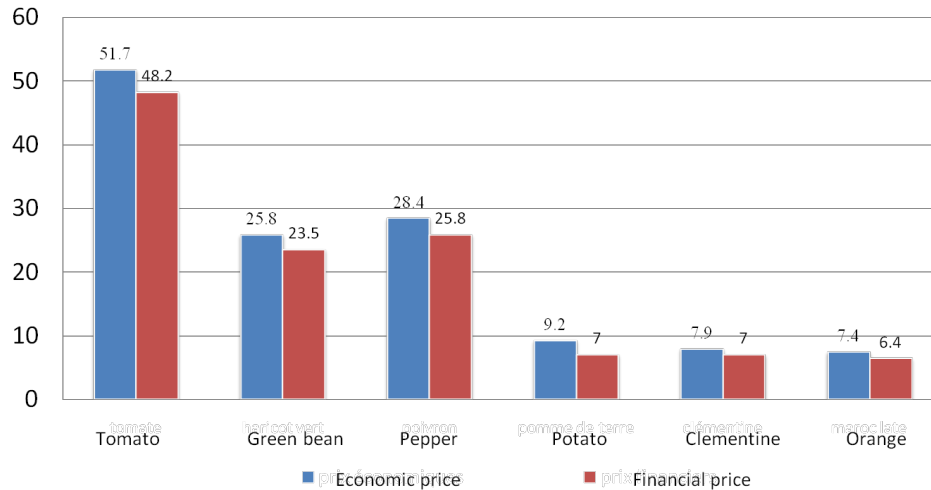
This graph shows that water valuation by the economic price, for all crops, is greater than water valuation by the financial price. If we take the case of Clementine for export and potatoes for the local market which have the same financial price, we note that from an economic perspective export crops are not those that valorize more water resources.

Table 1: Profitability and Water Efficiency

	tomato	Pepper	Green Bean	Potato	Clementine	Orange (maroc late)
Water valuation (Dh/m3)	48,2	28,5	23,5	7,0	7,0	6,4
Rate of profitability	57,0	14,0	24,0	10,0	41,0	33,0

Likewise, it is clear from this table that competitive exported crops are not necessarily those which more valorize water: case of citrus compared to Pepper and Potato

Figure4: Water valuation at the farm and the market chain scale
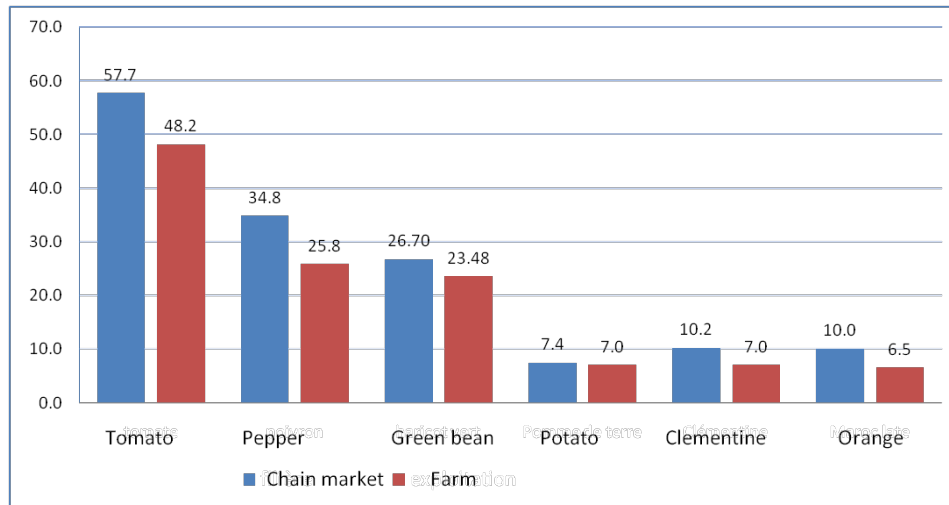
Water valuation at the Market chain level and the farm level is not the same as the graph above shows. A crop that appears to be less efficient at the farm level can be more efficient if we take into account the whole Market chain and vice versa: case of citrus compared to potato. Water value accounting must include the entire Market chain.
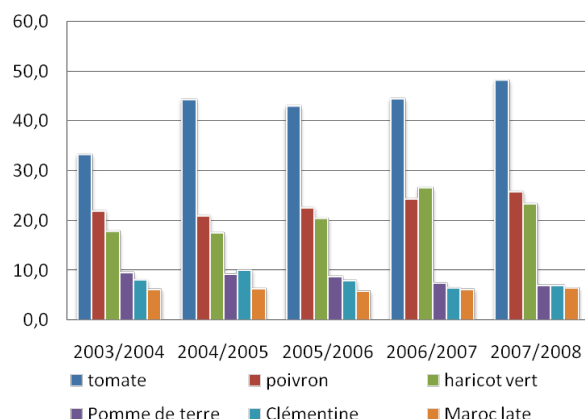
Analyzing these presented results, we find that the residual value method of water value accounting has some limitations. In fact, this method does not apprehend time changes for the value added or the Market chain competitiveness. In addition, water residual value does not take into account the interaction between crops and production systems (see part 3.3) and the real water scarcity represented by calculating water economic value (shadow price).

3.2 Water efficiency and competitiveness of Market chain over time

Water valuation should not be limited at the farm level since a given crop can have effects on the upstream and downstream of the Market chain. To better compare different crops, it is necessary to take into account, in addition to the farm, the wealth created by other agents in Market chains in particular seed plots and packing stations.

Figure5: water valuation in the farm and market chain level

Water valuation at the farm level	*Water valuation at the market chain level*
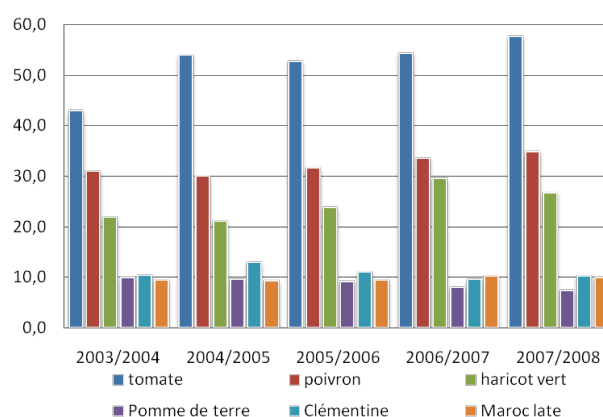
Comparing the two graphs, we see that water valuation changes over time at the farm level and Market chain level. In general, water valuation by Potato at the farm level is more important than Clementine. While at the Market chain level, water valuation by Clementine is better. An allocation decision of water resources which involves the future should not be based on an observation point and must take account of market dynamics.

Domestic resource cost coefficient (DRC[5]) compares the opportunity cost of domestic production to the value added calculated in equivalent foreign currency. The purpose of calculating the Domestic resource cost is to analyze the relative competitiveness of the Market chain and assess the relationship between water efficiency and competitiveness.

The two graphs below show that competitive crops are not necessarily those with high water valuation. Competitiveness trend may not be positively correlated with better water efficiency.

Clementine competitiveness in the first two seasons (2003/2004 and 2004/2005) and that of potato in 2003/2004 were higher than tomato competitiveness, although water valuation by tomato is much higher than Clementine and potato. Likewise, during the first three seasons, the competitiveness of potato was higher than that of green beans and pepper. However, green beans and pepper water valuation is much higher than that of potato.

Competitiveness does not reflect water valuation by crops. In other words, a high level of competitiveness does not mean better water efficiency.

[5] N.B.: low DRC means a competitive crop

Figure 6: market chain and water valuation

Competitivness per market chain   **Water valuation by the Market chain (Dh/m3)**
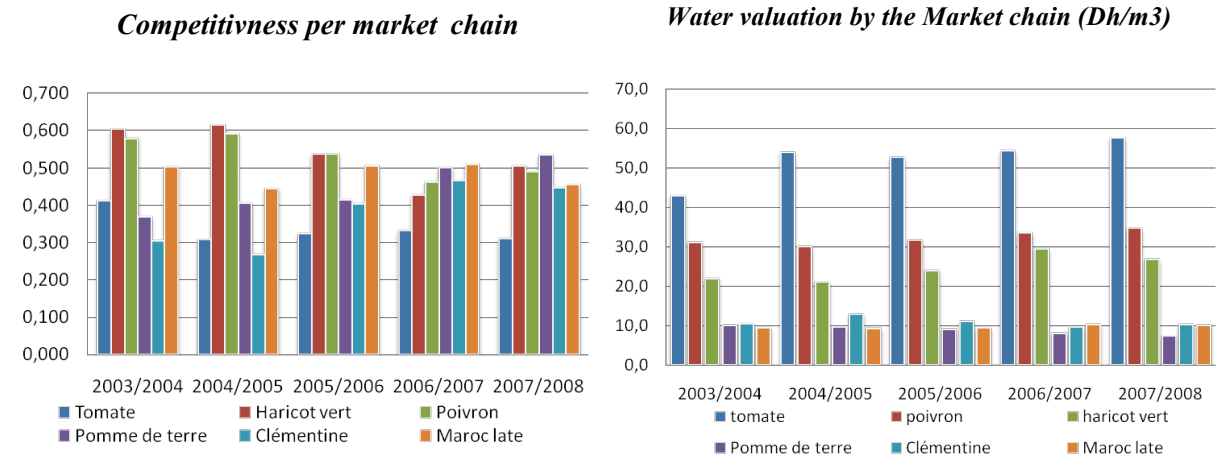
3.3 Production systems and water efficiency

This part presents some results of the integrated economic model of Sous-Massa basin which will be more detailed in the following paragraph. These results related to the source of water use (surface water, groundwater or conjunctive water) and to farm types in the basin.

Figure7: Water valuation per water use sources and farm size (Dh/m3)
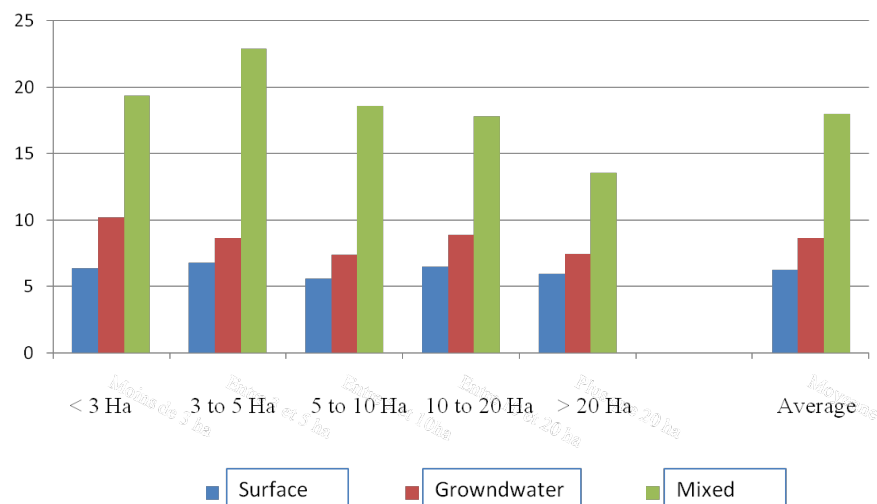
Farms having access to surface and groundwater (Mixed) valorize more irrigation water, followed by those exploiting groundwater. Farms using only surface water adopt production systems with less water use efficiency, which evoke the fact that there is a kind of adaptation of production systems to water supply.

Farms (less than 5 ha) tend to make better water use than medium and large farms and this for the three water sources.

Figure8: Water valuation per sub-basin and per farm size
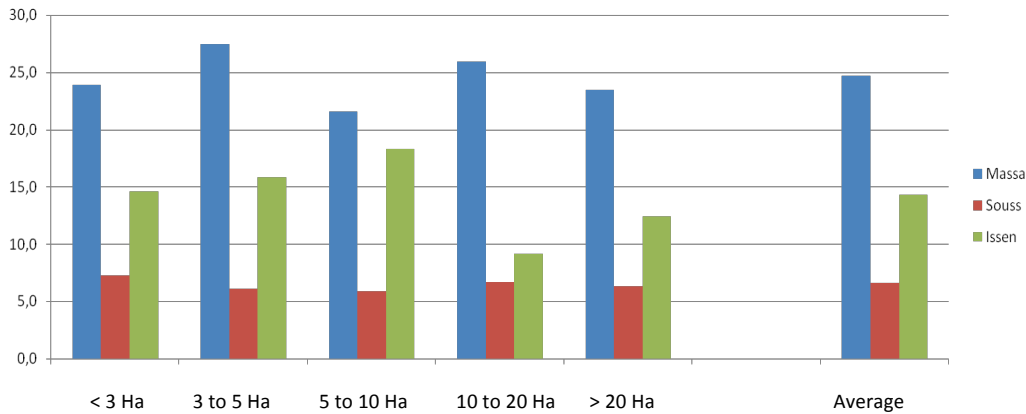
While averages show a superiority of small farms in the area, the calculations of the water value per area show that this result is not totally correct. Indeed, medium size farms In ISSEN area (5-10 ha) valorize better irrigation water. While in MASSA, medium to small farms followed by large to medium farms valorize more irrigation water.

We should notice that water use efficiency also depends on agricultural areas and farm size.

In addition to the limitations mentioned before, the residual method and the market chain method:

- assume fixed production coefficients (no inputs substitutability especially between water and other agricultural inputs). From which the need of a method that takes into account inputs substitutability

- do not take into account speculations substitutability within a production system

- assume unlimited water availability. Do not take into account water constraint and water resources competition

3.4 Economic Integrated Model of Water Management of Souss-Massa

Complexities of water allocation and water use across the basin require a holistic approach for water resources management and planning in order to get optimal and sustainable water and at the same time, an efficient and an equitable water use (McKinney et al., 1999).

The model developed in this study belongs to the integrated river basin models category. It is a more detailed model that includes hydrologic, economic and agronomic components of the basin. The advantage of this type of model is its ability to reflect the relationship and links between these various components listed above and to simulate the economic consequences due to policy choices. The model represents an efficient and useful tool for decision support on policy choices on water allocation and setting priorities for institutional and incentive reforms that guide water resources allocation.

The proposed integrated economic and hydrologic river basin model is based on real links between different spatial units of the hydrological network and connected by interconnections or nodes. Spatial units represent river flows, reservoirs, aquifers or water demand sites (agricultural demand area, drinking water, industrial water…). In the case of surface water, basic units are nodes distributed across the basin and represent water supplies, storage entities and water demand of different sectors. While for groundwater, nodes represent different aquifers used for agricultural, municipal and industrial purposes (see diagram below). The table below shows the various components of the model.

Table 2: Components of the model		
Water use	**3 Water flows**	**Agricultural Productions**
Irrigation water	-	**25**
Drinking water - Grand Agadir 1 (Surface water)	Souss	**21 Irrigated crops**
Grand Agadir 2 (Groundwater)	Massa	Soft wheat
Province Chtouka (Groundwater)	Issen	Hard wheat
Province Taroudant (Groundwater)	**12 periods : months of the year**	Barley
Province de Tiznit (Surface water)		Potat
11 agricultural zones grouped on 3 sub basin	**3 irrigation sources**	Tomato (Greenhouse) Tomato (open field)
Irrigated areas du *Souss bassin du Massa* Massa moderne public Massa traditionnel Massa moderne privé *Sous bassin de l'Issen* Issen moderne public Issen traditionnel *Sous bassin du Souss* Secteur G1- Souss-amont moderne public Souss privé Souss traditionnel Rainfed area Rainfed area (BOUR)	Ground Surface water Conjunctive water (GW+SW) **2 Aquifers** Sous Chtouk a **5 farm types** Less than 3 ha Between 3 to 5 ha Between 5 to 10 ha Between 10 to 20 ha More than 20 ha	Melon (Greenhouse) Carro Citru Maize Forage Maize pea Green beans (Greenhouse) Green beans Pepper Greenhouse Pepper Oliv Banana Lucern Bersi **4 rainfed crops** Soft wheat Hard wheat Barley Uncultivated land
3 principal reservoirs - Youssef ben Abderrahmen Tachfine Aoulouz		**2** **Livestock** Ovins Caprine Bovine

*Figure9: A schematic representation of the various components and interconnections of the Sous-Massa basin*
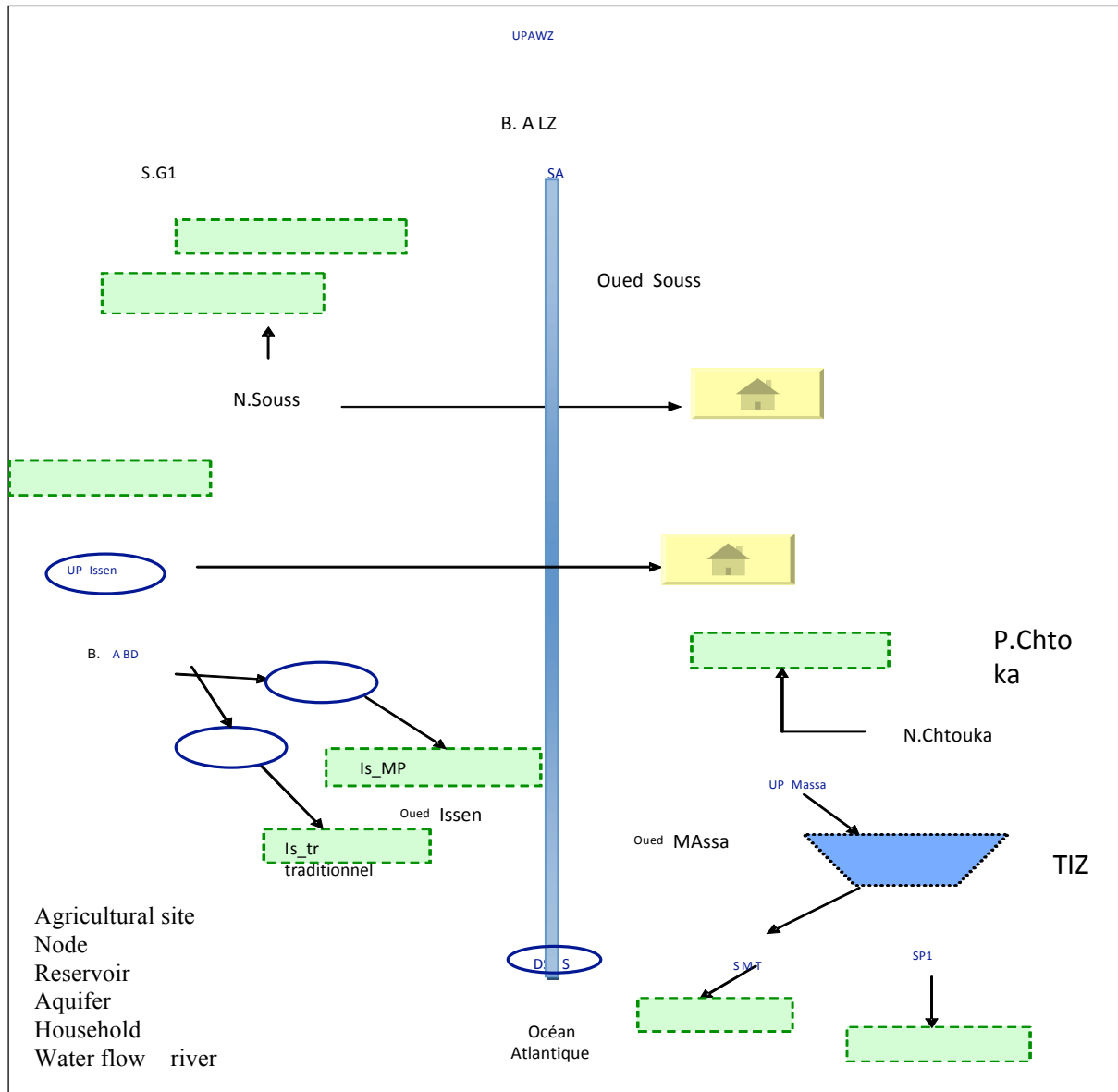
The model maximize the agricultural value added at the basin level taking into account a set of hydrological, agronomic and resources availability constraints (water, land, labor…).

These components described above are integrated into a consistent structure of water allocation, taking into account the functioning of hydrological systems, rules for allocating water at demand sites level and assessment of the environmental consequences and the economic viability of such allocation. Water demand is determined endogenously based on empirical yields and crops production functions. At each agricultural sector, water is allocated to crops according to their growth stages and crops requirements.

Water supply is obtained from the water supply-demand balance, result of maximizing the total value added in the Basin under physical, technical and political choices constraints.

Figure10: structure of the model
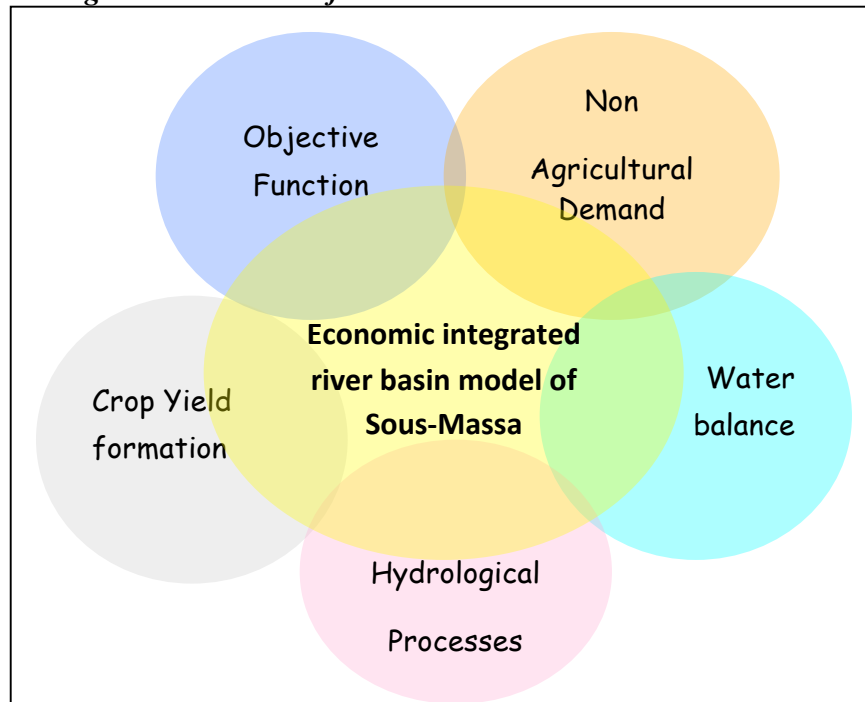
We use the positive mathematical programming method "PMP" for the calibration of this model. The PMP can perfectly calibrate the model using a restricted data set. This calibration process allows apprehending missing data and ensures that the model reproduces the allocation of land for the basic year (a normal year).

3.4.1 Results Analysis of the proposed model

Figure11: The average value added and the economic price

The average added value (Dh/m3)

The economic price(en Dh/m3)
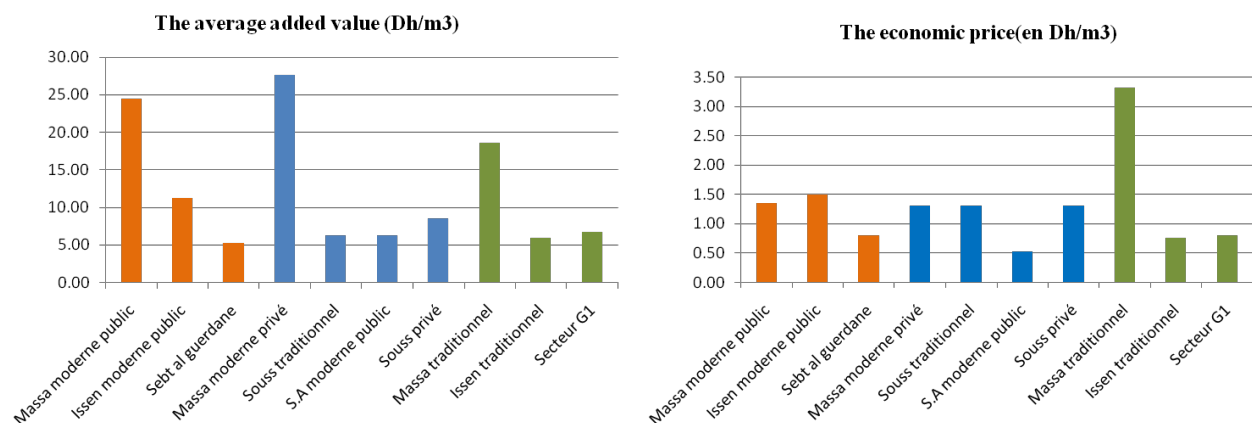
The two graphs show that water valuation changes depending on water access conditions. However, the value added does not reflect water resources scarcity. The approach used in calculating water value should reflect the actual scarcity of water resources.

Table 3: Water economic price by farm size and sub-basin

Water sources	Area	Less than 3 ha	between 3 and 5 ha	between 5 and 10ha	betwwen 10 and 20 ha	More than 20 ha
Conjunctive water	Massa moderne public	1.44	1.36	1.33	1.14	1.50
	Issen moderne public	1.60	1.46	1.24	1.37	1.65
	Sebt al guerdane	0.50	0.45	0.73	0.66	1.08
Groundwater	Massa moderne privé	1.31	1.31	1.31	1.31	1.31
	Souss traditionnel	1.31	1.31	1.31	1.31	1.31
	S.A moderne public	0.52	0.52	0.52	0.52	0.52
	Souss privé	1.31	1.31	1.31	1.31	1.31
Surface water	Massa traditionnel	2.39	3.31	6.06	1.64	3.15
	Issen traditionnel	0.41	0.48	0.29	0.41	2.95
	Secteur G1	1.11	0.72	0.98	0.31	0.54

If we analyze the following table according to farm types and water access mode, we find that:
- For farms that combine surface water and groundwater, large farms have the highest economic price;
- For farms that use surface water, farms with high economic prices depend on production systems and agricultural areas;
- farms that exploit only groundwater behave as if the resource is unlimited since there is no constraint limiting groundwater resources use, from where the need to take into account the actual scarcity of water resources.
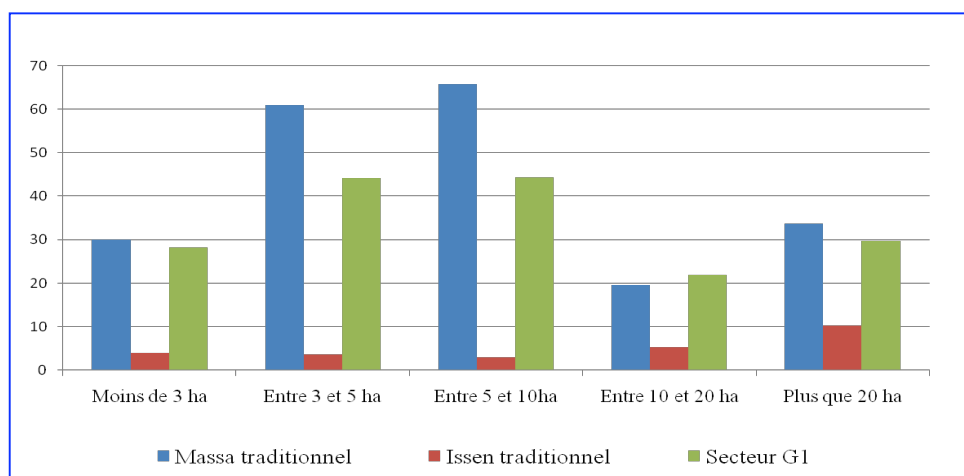
Figure12:   Impact of Drought: The economic price (Dh/m3)
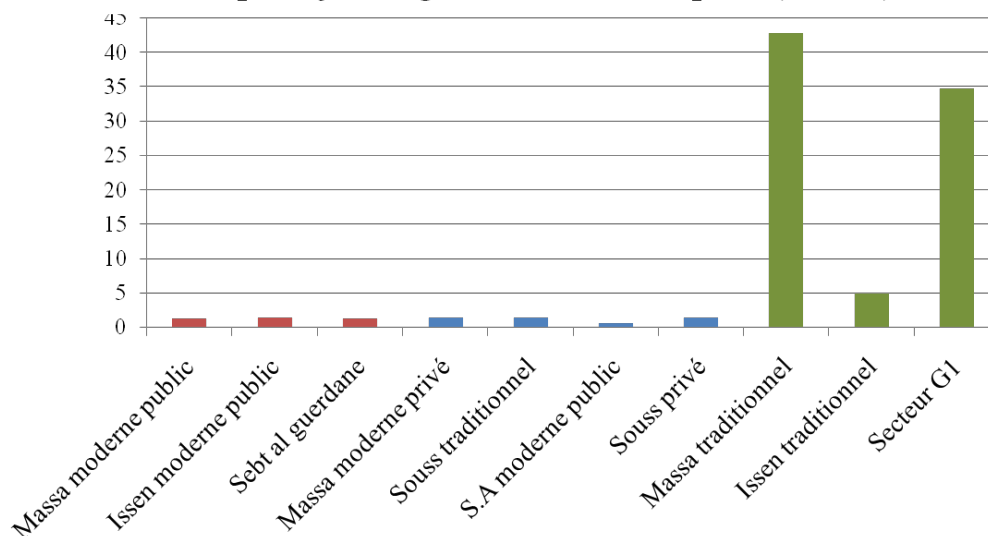
The graph above shows drought impact simulation on farmers' behavior; the effect of drought is felt differently depending on agricultural zones.

In case of drought, farms with access to groundwater continue to behave as if the resource is unlimited. They balance the lack of surface water by more water pumping from the aquifer. Farms using only surface water are more likely vulnerable to drought.

Figure13: Drought impact: Economic Price of Surface Water * (in Dh/m3)

In addition to differences between areas, the impact of drought is felt differently depending on farm types. Indeed, applying the same simulation of drought for areas using surface water, the economic price changes depending on farm types. In the case of 'Massa traditionel' area and 'sector G1' area, small to medium farms are more sensitive. While in the case of 'Issen traditionel' area, large to very large farms are more sensitive to drought conditions.

Figure14: The average value added (Dh/m3): *Comparison between a normal year (reference) and situations of gradual reductions of groundwater overexploitation by 20% to 100%*
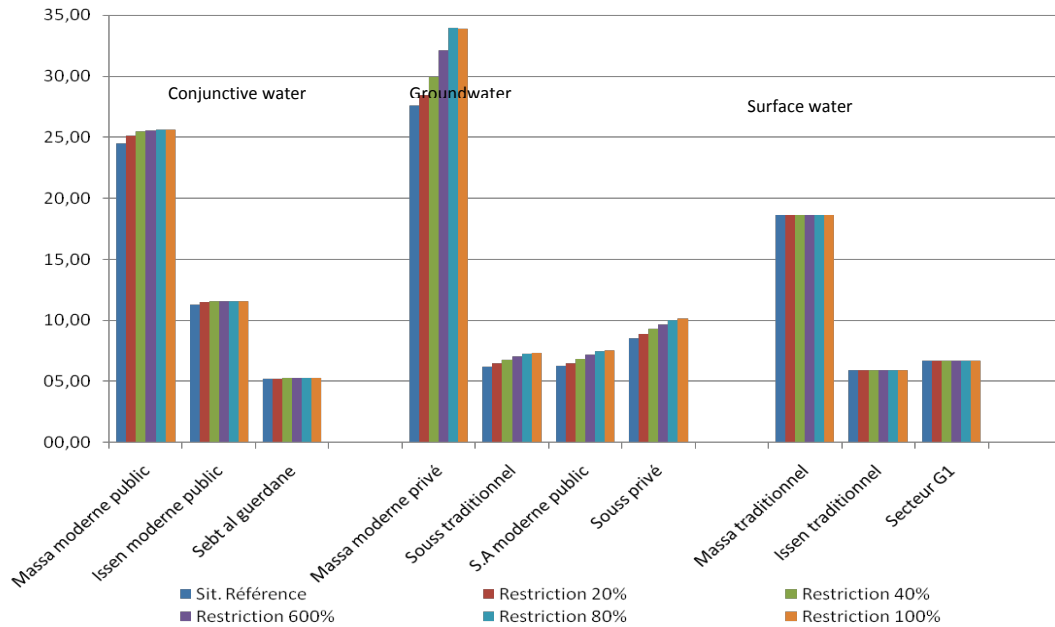
Applying restrictions on groundwater by progressive decreasing of the groundwater overexploitation, we notice that for areas that use surface water, restrictions on the groundwater overexploitation did not influence the average value added. While for areas that use groundwater, as restriction increases the average value becomes high, which means that the more limited is the resource the better is water valuation.

Figure15: Variation of the Economic Price (in Dh/m3): *Comparison between a normal year(reference) and situations of gradual reductions of s over-exploitation of groundwater by 20% to 100%*
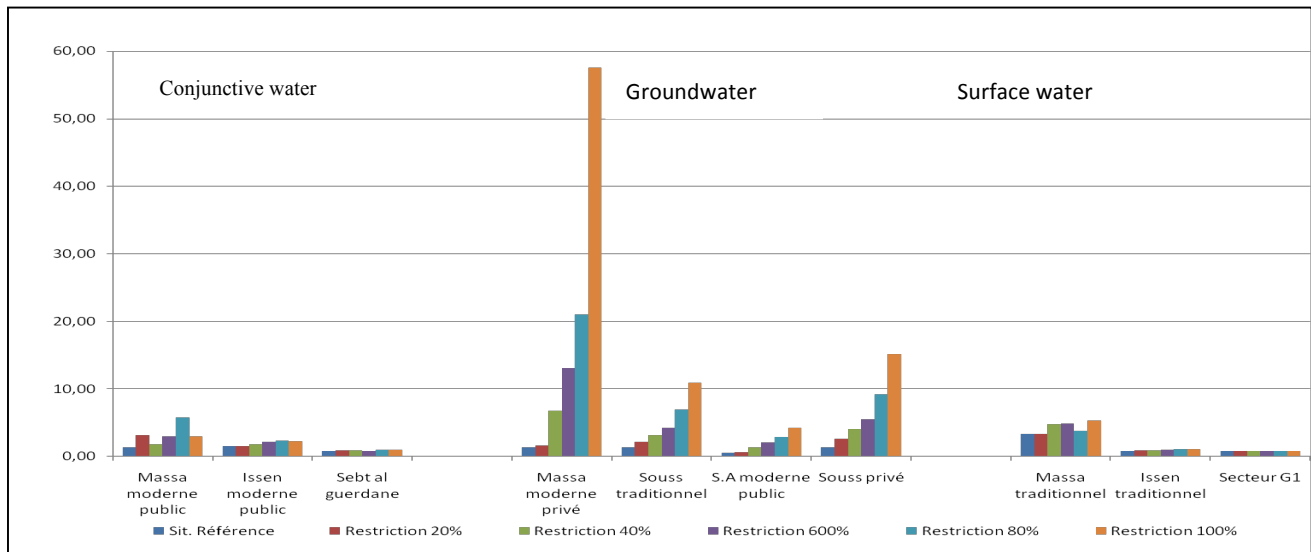
Applying restrictions on groundwater, we notice a significant increase of the economic price which better reflects the actual scarcity of the resource. A resource allocation policy must take into account the actual scarcity rather than the summary assessments of water value.

Figure16: Short-term gains of groundwater overexploitation

The added value (Milliard of Dh)   Total water quantity (Millions of m3)
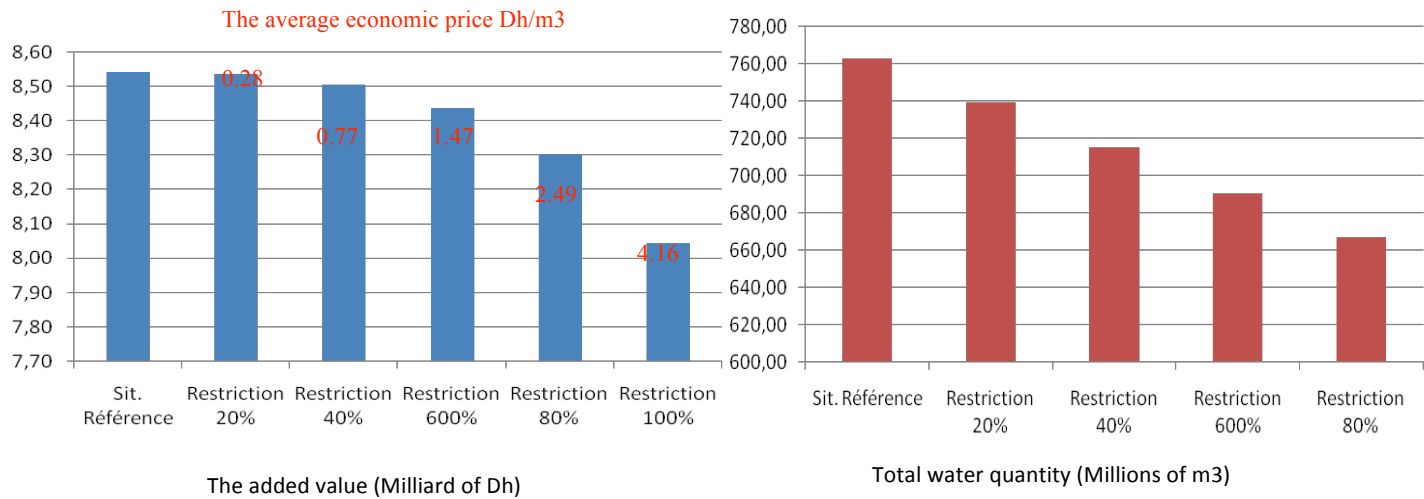
This simulation enables to calculate the effect of groundwater restrictions on the value added generated by agricultural sector.

A restriction of 'up to 40% of groundwater overexploitation' has basically no effect on the value added generated by agriculture. It begins to decrease significantly at 'over 40% of restriction'. An overuse of groundwater in an average year allows an annual gain in the short term of 500 Million Dirhams, in parallel the economic price jump at 4.16 Dh/m3. However, it is important to ask whether this gain justifies groundwater depletion risk with all the consequences that may have on the incomes and the environment.

Conclusion

In Morocco, groundwater resources remain overexploited. Most aquifers are suffering from an unprecedented decline especially in Souss Massa region where located most of exported crops. In this context of water scarcity, authorities show volition to increase exports and are therefore required to allocate water resources to crops with high water use efficiency.

This paper compares several methods for calculating water value and analyzes the results of different approaches. In addition, this study proposes a non linear programming model that takes into account water flows and relationships between the various components of the basin, which shed light on the reality of water resources use and exploitation in Souss-Massa basin.

The accounting method of water value has some limitations. In fact, this method does not apprehend time changes for the value added or the competitiveness of market chain. In addition, water residual value does not take into account the interaction between crops, production systems and real water scarcity represented by the Shadow Price. Likewise, water valuation should not be limited to the farm level since a given crop leads to effects on upstream and downstream of the market chain. This study shows as well that the competitiveness does not reflect crop water use efficiency.

Analysis of Souss-Massa basin integrated model results shows that water valuation differs depending on access conditions to water resources and adopted production systems.

Imposing and setting restrictions on groundwater use causes a significant decrease, but less than proportional, of irrigated areas and the net value added of agriculture as it induces an improvement of irrigation water use efficiency through a better allocation of this resource.

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