Critical Assessment of Groundwater Management Instruments in Tunisia: Current and potential instruments for better regulation of groundwater extraction

Aymen Frija[1], **Boubaker Dhehibi**[2], **Ali Chebil**[3], **Nicolas Faysse**[4]

(1) Corresponding Author. Higher Agricultural School of Mograne, Zaghouan, 1121. Tel. (+216) 72 660.043 / Fax. (+216) 72 660.563

(2) International Center for Agricultural Research in the Dry Areas (ICARDA); ICARDA, P.O. Box 950764, N° 11195, Amman, Jordan

(3) Institut National de Recherches en Génie Rural, Eaux et Forêts (INRGREF). P.O. Box 10, 2080 Ariana (Tunis), Tunisia

(4) Centre de Coopération Internationale en Recherche Agronomique pour le Développement (CIRAD), UMR G-EAU, Montpellier, France

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Abstract

Groundwater is very important in Tunisia, where 43% of water currently used for irrigation is pumped from deep and shallow aquifers. Groundwater resources have been intensively mobilized in many parts of the country since the 1980s, causing its overexploitation. As a result there are nowadays signs of aquifer depletion in many regions. The total number of aquifers in Tunisia is around 273, from them 71 are overexploited, with an average rate of 146%. In the literature, many authors attribute the overuse of the groundwater resources to the lack of appropriate governance framework, strictly enforced and monitored. Thus the objective of this paper is twofold: first, we aim to present and discuss the typology of different groundwater management instruments based on current available literature. Some seminal works are discussed and summarized in order to provide clear idea of what we consider as "types of groundwater management instruments". In the second step, a set of performance indicators, which was used to evaluate these instruments, is developed. Once this theoretical background is established, the second objective is to analyze and discuss different instruments currently used in Tunisia for managing the groundwater resource. In this case, a SWOT analysis is carried out in order to identify the strengths, weaknesses, opportunities and threats of the groundwater governance framework in Tunisia. Results of this study show that most of the economic and regulatory instruments in Tunisia, which are used to regulate the groundwater exploitation, are applied at the local levels through/by the Water User Association (WUAs). This means that the impact of these policies will highly depend on the WUAs performances. Moreover, at the national level, many decisions and policies targeting groundwater sector have been established since the 90's, however their implementation and enforcement is still very weak mainly due to non-favorable political, institutional, and social contexts. On the basis of our findings, we conclude that the remaining action for enhancing the sustainability of groundwater use in Tunisia has urgently to rely on two main axes: the first is related to the improvement of the institutional (especially administration) performances, related to the control and monitoring of the groundwater, and to the effective law enforcement. The second is related to the change of the currently established ethical values of various stakeholders, especially the farmers. Ethical values supporting institutional changes, such as salience, common understanding, trust and reciprocity and autonomy have to be incorporated together with technical and economic issues related to the national groundwater management strategy in Tunisia.

Keywords: groundwater, governance, regulation, participation, WUAs, Tunisia.

1. Introduction

In Africa there is little information on the present and potential role of groundwater (GW) in agriculture (Braune and Xu, 2009). However, it is widely recognized that this role is important, especially for the North African and Sub-Saharan countries. Groundwater is a key resource for socio-economic development and a strategic buffer resource during periods of drought in these arid and semi-arid countries (Custodio and Llamas, 2001; Giordano, 2009). It has the potential to play a strategic role in providing drinking and sanitation water, supporting agricultural production, industrial uses, and the touristic sector. Some of the socioeconomic benefits attributed to groundwater are the provision more equitable access to water for various classes of farmers, the insurance it provides against drought, and, most importantly, the stabilization of agricultural production and the generation of employment (Mukherji and Shah, 2005).

However, despite all of these benefits, groundwater is more difficult to govern than surface water (Ross and Martinez-Santos, 2010) because of its physical characteristics. Groundwater movement is in fact not visible and well understood, hydro geological boundaries are often diffuse as is the connection between individual aquifers and surface water. In addition to the diffuse nature of this resource, it is most of the time pumped by individuals on their properties, which makes it more difficult to control and monitor. In all parts of the world, these characteristics of the groundwater made it hard to develop easy and enforceable management strategies for its sustainable use.

This was also the case in North Africa (Siebert, 2010; Faysse *et al.,* 2011), and more specifically in Tunisia, where 43% of irrigation water used today consists of groundwater (Ministry of Agriculture and Hydraulic Resources: MAHR, 2007). Groundwater resources are being intensively mobilized in Tunisia since the 1980s, causing overexploitation. As a result there are many signs of aquifer depletion all over the country. According to the TICET (2009) the total number of aquifers in Tunisia is about 273, of which 71 are overexploited with an average rate of 146%. On the other hand groundwater use in Tunisia has given rise to several short and medium-term socioeconomic benefits, by providing a basis mainly for the extension of irrigated agricultural areas and drinking water supply in remote rural areas.

To date, the management of groundwater is hampered by a variety of uncertainties linked to climate change and socioeconomic growth, as well as by ineffective governance structures affecting resource use, regulation, protection and implementation of alternative strategies needed to achieve sustainable management (Knüppe, 2010). Most of the globally observed constraints for sustainable groundwater management can be linked to failure of governance structures (Bakker *et al.,* 2008; Rogers and Hall, 2007). Governance refers both to setting objectives, principles, and rules for managing the resource, and to processes for implementing the rules (Ross and Martinez-Santos, 2010). While the knowledge on hydrology and hydro-geology linked to groundwater management has advanced, still relatively little is known about the socioeconomic impacts and institutions that govern groundwater use (Mukherji and Shah, 2005). According to many authors findings, effective groundwater governance remains an important challenge to ensure long-term sustainability (Shah 2005; Llamas and Martınez-Santos 2005; Wang *et al.,* 2006; Kretsinger and Narasimhan 2006). Thus, besides the hydro-geological and economic attributes, institutional aspects must be considered when analyzing the reasons for inefficient use and

depletion of groundwater (Chermak*et al.,* 2005; Usunoff 2005; Puri and Aureli 2005; Solanes and Jouravlev 2006; Fischhendler, 2008).

Similarly to the international context, groundwater management in Tunisia is a hard task due to the specific physical, social and economic characteristics. It is however crucial because of the contribution of this resource to the total national agricultural production. Monitoring of groundwater extraction is qualified as insufficient in Tunisia (Jousma & Roelofsen, 2004). Private irrigated areas from wells and boreholes are slightly increasing and many aquifers are failing "everyday" (MARH, 2007; TICET, 2009). In this context, this paper provides a critical assessment of the groundwater management instruments in Tunisia, and draws conclusions and recommendations about the current performances and weaknesses of the Tunisian groundwater policy. Moreover, we identify challenges and constraints hampering the settlement of an effective groundwater management strategy in the country as well as the opportunities which can be exploited to enhance the sustainability of this resource use.

Theremaining sections of the paper are structured as follows. The second section presents different GW management instruments and the way they change when the GW development evolves. Moreover, in this second section we also provide a set of performance indicators for the evaluation of GW management instruments. The third section provides an overview of the GW resources in Tunisia as well as the Tunisian strategy for their management. Section 4 and 5 deals with the presentation and discussion of our results mainly the evaluation and recapitulation of these instruments in a SWOT matrix. Finally, section 6 presents the conclusion and policy implications drawn from this study.

2. Theoretical framework

This theoretical section frames main issues related to the evaluation of groundwater management instruments. First, we identify the main instruments currently used around the world to manage groundwater pumping. It is also important to investigate whether an instrument can be used at any stage of groundwater resources development or there are appropriate instruments for each specefic stage of exploitation. It is also important to evaluate the effectiveness and performances of different instruments, which is not an easy task. Some performances/effectiveness criterion will be identified in order to be able to make a comprehensive assessement of the different groundwater management instruments used in Tunisia.

2.1. Types of instruments for groundwater management

The legal, institutional and organizational management instruments for groundwater, that have been developed and applied all around the world, can be divided into three main types (Shah, 2005; Giordano, 2009; Kemper, 2007; Theesfeld, 2010; Forster *et al.,* 2010,): Regulatory or command-and-control policy instruments (such as groundwater access and use codes, groundwater use rights, etc.); Economic policy instruments; and Voluntary/advisory instruments. Each of these types contains a set of different sub-instruments that are usually combined differently in different countries contexts. Economic policy

instruments make use of financial sanctions and incentives such as groundwater pricing, transferability of water rights or pollution permits, subsidies and taxes (reducing pumping energy subsidies, tuning crop guarantee prices, etc.). Voluntary/advisory policy instruments are also called community participation instruments, and are those instruments that motivate voluntary actions or behavioral changes without use of direct financial instruments.

This typology and its assessment is a bit different from one author to another, the following table summarizes the different types, as well as the main instruments that each of these types contain, based on different seminal work of the previously mentioned authors.

TABLE 1 about here

These types of instruments are ideally combined and no policy option ever relies purely on one type of instrument (Stone, 2002). The aim of these instruments is to have an impact on the overall groundwater governance structure (Theesfeld, 2010). In addition to these instruments, to be successful, groundwater governance must take tradition and mental models into account, clearly define the administrative responsibilities, avoid bureaucratic inertia and provide effective conflict resolution mechanisms (Foster *et al.,* 2010). Moreover, these demand management instruments can also be complemented by some supply policies such as recharge enhancement, conjunctive use, provisioning of alternative sources, etc.

2.2. Relationship between the development of groundwater extraction and the conception of various management instruments

It is actually obvious that policies are always settled in order to deal with negative phenomenon which may have an impact of social welfare. This is also the case of groundwater policies around the world, which were progressing and changing in parallel with the aggravation of the overexploitation of groundwater use in different countries. A generic pattern linking the evolution of groundwater policies and instruments used with the aggravation of the observed overuse of the resources was provided by the World Bank in 2004 and is summarized in the following figure.

Figure 1 About here

Figure 1 explains that the baseline situation of groundwater exploitation is a situation where groundwater is available and accessible with adequate quality and exceeds a small dispersed demand. The needed management at this level is simply a registration of abstraction wells and captured springs. Consequently, a next step corresponds to a growth of aquifer pumping, with only few local conflicts arising. Simple management tools such as appropriate wells spacing are needed at this level. When significant stress

starts to appear, a regulatory framework will be needed. This framework need to be settled based on comprehensive resource assessment with critical appraisal of aquifer linkages. This regulatory framework needs to be complemented by a set of water demand management tools when the exploitation of groundwater passes to a stage of unstable development. At this phase, the aquifer is overused and the abstraction exceeds the sustainable level of resources development.

2.3. Criterions to evaluate the performances of groundwater management instruments

The available litterature about criterion used specifically to evaluate groundwater management instruments is very limited. The used criterions are, however, chosen based on a larger theoretical framework of policies analysis and evaluation, with some specifications to the groundwater case's. Lenouvel and Montginoul (2009) used five criterion to evaluate the performance and effectiveness of four water management instruments. The evaluated instruments are: quota on groundwater, binomial surface water pricing, fees on groundwater and volumetric groundwater pricing. The used criterions are: the abatment level of the aquifer, impact of the instrument on agregate income, acceptability, predictability, and durability of the instruments. Faysse *et al.,* (2011) used three criterions to evaluate the different types of groundwater instruments applied in North African region. These were: the impact of the tool on the increase of water resource availability, reduction of aquifer withdrawals and increase of water productivity.

The impact ofinstruments on agricultural Incomes: This criterionincludes the impact of the used instrument for groundwater management on farmers and public agency incomes. In practice, some instruments, such as the use of fees for groundwater use, may have an impact on farmers revenue. This impact is usually quantified through the estimation of water price elasticity in farmers water demand function. This criterion is only suitable to use for specefic instruments and in quantitative modeling assessements*(*Lenouvel andMontginoul, 2009, Chebil *et al.,* 2012). In our case, the impact of the instrument on water productivity (Faysse *et al.,* 2011) at the farm and local levels will be used as a first indicator. This lindicator is more expressive about the impact of the instrument on social welfare than the agregate income. Instruments qualification regarding their potential impact on water productivity will be based on literature review, policy makers interviews and farmers focus groups.

The acceptability/Sustainability of the instrument: These are key issues for the success of groundwater management instruments. The applied instruments have to be accepted by farmers in order to be enforceable and then sustainable. In our case, we approximate this acceptability/durability criterion by the enforcement level of the instruments. Some instruments are implemented and highly enforceable, others are implemented but very modestly enforceable. We assume that instruments that faces enforcement problems, and a phenemenon of breach of the law are modestly acceptable and sustainable. This criterion will only be considered from farmers perspectives.

Implementation/implementation cost:A management instrument have to be effectively implemented in order to have positive expected impacts on the field. Regarding this implementation criteria, there are two aspects that we consider, in the case of this study, as inherent to the implementation of instruments. First, the feasibility of the instrument have to be adressed. By feasibility, we mean the aptitude of a given

instrument to be applicable in the current institutional, cultural, social, and economic conditions. This firstimplementationaspect can be assessed at the national and regional levels depending on the type of instruments. the second aspect is the implementation costs. An instrument can be implementable, but its implementation cost can be very high. Thus, implementation cost is also very important determinant of the choice of one instruments. Implementation, operation, and maintenance costs of one instruments are usually compared to its expected discounted returns in order to decide about its adoption. In our case both aspects described above will be considered in the implementation criteria. We will draw conclusions about the implementation of different groundwater instruments based on our knowledge about the tunisian institutional context as well as on targeted literature.

Impact on the aquifer withdrawals: The used instrument have to be effective in terms ofecosystems restauration/sustainability. This is why the last criteria for the evaluation of groundwater management instruments have to be related to the impact of these instruments on quifers withdrawals.

3. Groundwater Resources and exploitation in Tunisia

3.1. Groundwater potential and use

Irrigated areas in Tunisia cover about 8% of total agricultural area. They provide however 35% of the agricultural output value, 20 % of total agricultural exports and 27 % of agricultural employment (Chebil et al., 2012). As mentioned in the introduction, around 44% of these irrigated areas are irrigated from groundwater sources, including both superficial and deep aquifers (Al Atiri, 2007).

Annual rainfall averages in Tunisia vary from 1000 mm in the top North to less 250 mm in the South. Overall water resources in the country are estimated to be around 4700 Mm^3 (Al Atiri, 2007) including 650 million m^3 of non-renewable resources (13.8 % of the total water resources). Surface water is estimated to account for 2700 Million m^3 (Table 2). This surface water is mobilized through large infrastructure: About 27 large dams, 182 hill dams and 698 artificial lakes. Groundwater resources account for around 43 % of the total water potential. In 2008, groundwater use in Tunisia is estimated to be around 2000 10^6m^3, confined within 212 shallow aquifers (containing 719 10^6m^3) and 267 deep aquifers (INS, 2010). It is estimated that 650 millionm^3 of this resource is located in the Southern part of Tunisia and is non-renewable. Table 2 traces the evolution of groundwater withdrawal in Tunisia between 1990 and 2015.

Moreover, like surface water, groundwater is characterized by unequal allocation and variable quality in terms of salinity. It is distributed among regions in Tunisia as follows (Ben AbdAllah, 2007):

- The north has 55 % of the shallow groundwater resources and only 18 % of the deep groundwater[1] resources.
- The centre provides 30 % of the shallow resources and 24 % of the deep resources.
- The south provides 15 % of the shallow resources and has 58 % of the deep resources.

[1] In Tunisia, groundwater resources located at a depth less than 50 meters are considered as shallow aquifers while deep aquifer resources are these deeper than 50 meters.

TABLE 2 about here

Good quality groundwater is only found in 8 % of shallow water and 20 % of deep aquifers. If it is assumed that salty water with a salt content up to 3 g/l can be used in the agricultural sector and for drinking water, then approximately 36 % of groundwater resources are unsuitable for these purposes (Ben AbdAllah, 2007). Another phenomenon, which has a significant effect on water quality, is drought. In periods of drought, the salinity of the water stored in shallow aquifers can reach 3.5 g/l, in some cases due to over-extraction.

Shallow aquifers in Tunisia were under an increasing pressure during the last two decades. This pressure was particularly high in the coastal (Cap Bon, Sahel, and Gabes) and central (Kairouan) regions (Al Atiri, 2007). The shallow aquifers have been the main irrigation source for the privately irrigated areas of Tunisia, which cover around 38% of the total irrigated area in the country. The privately irrigated areas are those areas which are irrigated from private individual wells and boreholes. The depth of these wells is usually less than 80 meters, as mentioned in the water code. Deep aquifers are also used for the irrigation of some public irrigated areas mainly in the Southern oases.

Because of the climatic variation and the growing food demand in the 80's, Tunisian agricultural strategy was based on the extension of the irrigated areas through investments in large water infrastructure and the use of groundwater. With the extension of old irrigated areas and the creation of new ones, the pressure on groundwater resources has increased rapidly. In fact, the number of wells in Tunisia passed from 60415 in 1980 to 128400 in 2000, representing an increase of 113% (5.6% per year). This dynamic was also observed for the equipped (pumping engines, solar energy, etc.) wells of which the number passed from 23,061 in 1980 to 86,965 in 2000 indicating a total increase of 380% (19% per year).

3.2. Administrations responsible for groundwater management in Tunisia

Among the main central administrations, within the Ministry of Agricultural and Hydraulic Resources, that are currently involved in the groundwater exploitation, control, and management in Tunisia we distinguish: (1) The General Direction of Water Resources, which elaborates legislations and collects data on water resources. It also provides assistance and framings for regional and local administrations for the management of data related to water resource use, exploitation and management; (2) The General Direction of Rural Engineering and Water Exploitation, which monitors the institutional aspects regarding the training of WUAs and the implementation of water management instruments in the agricultural sector (water saving technologies, etc.). It is also responsible for the implementation and design of new public irrigation perimeters as well as for the maintenance of the existing irrigation infrastructure; (3) The General Direction of Dams and Large Hydraulic Projects, which is mainly responsible for the mobilization of surface water, implementation of aquifer recharge, for projects and for conjunctive use of surface and groundwater.

At the regional levels, generally the*"Commissariat Régional Au Développement Agricole"* (CRDA) is mandated to assess and monitor surface and groundwater water resources use at the governorate level. They collect data on water exploitation, use, quality, availability, etc. They are also responsible, through their different entities, for the implementation of water management instruments at regional and local levels. Regional administrations are thus responsible for the implementation and enforcement of water policies at the local level through their special administrative entities, including the WUA. These latter are often still highly dependent on the trainings and financial support/subsidies of the regional administration, which indirectly makes them willing to implement the administration's decisions. According to their statute, among the main objectives of WUA's are the exploitation of public water resources (surface and/or groundwater) at the local level and the accomplishment of the tasks related to the public water resource management under their jurisdiction. This means, for instance, that they have to organize farmers in sub-districts, to ensure the delivery of irrigation water at farm level, to collect water fees from irrigators and to undertake investment in order to accomplish these tasks.

These objectives were adjusted by the law n°2004-24, March 15, 2004 which sets, among others, the following significant new objectives: Collective management and protection of natural resources (especially water) in their territories. This new objectives can be interpreted as a call for the increase of participation and collective involvement of WUA in water resource operation and management, as well as any other incentive and/or regulation policies which are targeting the sustainability of water resources.

3.3. Groundwater management strategies: an historical perspective

Based on the World Bank classification of the development stages of groundwater exploitation and appropriate management instruments to each stage, we present here by a historical trend of the groundwater use and policies in Tunisia. Different historical phases corresponding to the level of groundwater development in Tunisia are presented in table 3. Instruments (including regulation, laws, incentives, taxes and subsidies) used in each period will also be presented chronologically. The objective of this section is to investigate whether the trend of management instruments settlement in Tunisia corresponds to the level and intensity of groundwater development in the country.

TABLE 3 about here

Table 3 shows that in Tunisia, a wide range of regulatory and economic instruments exists (Faysse *et al.,* 2011) and are assured by the "water code". In fact, water development in Tunisia passed through different phases. Between 1961 and 1975, only incipient stress was observed. At that stage, the objective of policy makers was to increase the irrigated areas, through mobilization of surface water and encouragement of groundwater exploitation. The total water withdrawal per capita in this stage was around 179 m^3/inhb/year. For the period 1975-1985 groundwater use was peaking in the country and significant stress starts to be assessed in some irrigated areas from GW sources. At this stage, Tunisia

developed its 'first' water code and a number of aquifers become protected. Prior CRDA authorization becomes necessary for any new Drilling. Between 1985 and 1995, the same trend in GW development was observed. The stress was still significant, but further serious management instruments were considered at this stage. In fact, the government starts to enhance water supply in overexploited aquifers areas (creation of 30 artificial recharge site), and considered GW and SW officially together in management strategies instead of considering them separately as before. Decentralization of the agricultural and water administrations operations was established at this stage and more autonomy was given to the WUA.

From 1995 until now, the stress on GW remain high and many signs of unstable development start to appear. Many areas were used beyond the sustainable level of resource development. Aquifers water depletion became a common phenomenon in many regions, seawater intrusion in almost observed in all coastal irrigated areas, etc. Main decisions and instruments adopted during this period as follows: i) establishment of the national program of water saving, ii) in 2001, a first update of the water code was done, iii) another current reforms of the water code, starting in 2012, iv) current studies about the possibility to introduce electricity-based tariffs in groundwater irrigated areas, v) reform of WUA status in 2004, with the settlement of the following new objective: "collective management and protection of natural resources (especially water) in their territories.

It is thus obvious that water policies and instruments of GW management were continuously updated and following the level of GW development in Tunisia. However, when looking to the current GW overuse in Tunisia and to the overexploitation of aquifer tables (see section 3.1), we can conclude that these instruments have only little impact. .

4. Evaluation of Groundwater management instruments in Tunisia

The set of performance indicators of GW management instruments, developed in section 2.3 will be applied in this section to assess the performance of groundwater management in Tunisia. Table 4 provides an assessment of each of these instruments currently applied in Tunisia, based on the impact on water productivity, reduction of aquifer withdrawals, acceptability and sustainability of the instrument and its implementation criteria.

TABLE 4 about here

4.1. Regulatory instruments

In terms of regulatory instruments, the following official regulations and legal instruments were introduced as being a tool for good groundwater governance in Tunisia (Faysse *et al.,* 2011): (1) necessity of an authorization for the exploitation of groundwater resources deeper than 50 meters[2]. (2) The

[2] Water tables shallower than 50 meters are considered as free access resources except in the protected areas

classification of some overused aquifers as “preserved areas”. Within these areas, any exploitation of groundwater has to be strictly authorized by government administrations. These areas are specified through specific decrees, (3) The classification of other more critical aquifers as “prohibited areas”, again these are defined through specific decrees and here it concern areas where water resources are (or could be) insufficient with respect to actual and/or future planned needs. In these prohibited areas, all new aquifers exploitation, including deepening of existing wells, are strictly prohibited. A Replacement of a well by another (without increasing the water flow) needs an authorization from the administration. Any infraction to these laws may be punished.

However, it is observed that in many cases, local water administrations know the location of illegal boreholes within their jurisdiction, but intervention to enforce the law is rarely observed (Faysse *et al., 2011*). After the 2011 revolution, this phenomenon was deeply aggravated because of the political instability in the country, and the weakened authority of the government, especially in rural areas. According to Mukherji and Shah (2005), conditions for law enforcement are likely to happen in countries where the direct dependence on groundwater is low, farmers’ economic conditions are better and the political situation is stable. However, in Tunisia the new political context is not encouraging the enforcement of these laws. Before the revolution corruption was used to keep illegal exploitation, while after the revolution the administration capacity for law enforcement became weaker.

Other regulatory measures in Tunisia can be locally used, but do not officially belong to an overall implemented strategy. As an example, some regional/local administrations may encourage farmers to cultivate low water consuming crops. This decision is sometimes even imposed in areas where the situation of water table is very critical. A full conversion of the agricultural systems in such irrigated areas will however be a difficult task and will need a carefully studied strategy, in addition to governmental support and framing. When they were asked about their opinion, some farmers said that they were ready to shift their agricultural systems but did not have any knowledge of what could be a commercially and technically possible and suitable alternative.

As shown in table 4, regulatory instruments are the most widely applied in Tunisia. This could be explained by their low implementation cost. Moreover, these instruments could all have a positive impact on the reduction of aquifers depletion. In addition, regulatory instruments are also most of them not acceptable and sustainable in Tunisia. In fact, the main challenge to enhance the expected positive impact of these instruments is related to their enforcement. Farmers do not accept and apply the rules settled by the government concerning the prohibition or the exclusion of new access to GW aquifers in their regions. Phenomenon of breach of these laws is widely observed and sanctions were rarely applied.

4.2. Economic instruments

The main economic (incentive) instruments used in Tunisia to deal with the overexploitation of groundwater tables are related to the National Program for Water Savings. This program offers the farmers subsidies of 40 to 60% of their investment costs in irrigation saving technologies (Faysse et al., 2011). This program was established in 1995 and continues to be a main incitation instrument aiming to

reduce water use and enhance water productivity in irrigated areas in Tunisia. However, the observation of water use and extension of irrigated areas at the national level during the last decade shows that overall water consumption in the agricultural sector was not reduced during that period of time (Bachta & Elloumi, 2005; Frija, 2009). According to Al Atiri (2004), results of the program were rather mixed. In fact, water saving is not very substantial in volume (because irrigators have not yet fully mastered the modern technologies). However, water resources are currently better valorized both at farm and national levels. Al Atiri (2004) also indicates that water savings have been mainly used to intensify the existing irrigated systems.

Another economic instrument used to manage groundwater in Tunisia is water pricing. However, given the weak control on illegal boreholes, and the absence of electricity pricing for water pumps, government used a WUA-based pricing approach. In fact, publicly-managed small-schemes irrigated areas were created everywhere in Tunisia based on one main borehole managed by a WUA. They are known in Tunisia as "*Petite et Moyenne Hydraulique*" which means "Small and *Medium* public irrigated areas" and they are covering 24 % of the total public irrigated areas (MARH, 2008). Farmers in these areas were obliged to join the WUA in order to benefit from the irrigation water source. By this method, farmers will have to pay for water and water pumping and this can be easily controlled by the association. However, no information exists about how far this pricing method (through WUA) has an impact on limiting groundwater overuse, or it has been simply a method for cost recovery of various WUA expenses.

The main constraint for this approach was the weak technical capacities of the WUA, engendering low water supply reliability (Frija, 2009). Weak technical performances of WUA are mainly due to late maintenance interventions and subsidies provision from the side of public regional administration to the association (MARH, 2007). This means that these associations are still very dependent on the regional administrations. As the network of WUA extends in a given region, the management of their problems and the satisfaction of their needs will become a more difficult task for the CRDA. In many similar contexts of weak water reliability, farmers, who have the financial possibilities, leave the WUA and invest in private illegal boreholes (Faysse *et al.,* 2011).

Currently in Tunisia, there is also a debate on establishing an electricity-based pricing system for private boreholes. This idea is currently being negotiated between the Ministry of Agriculture and Hydraulic Resources, and the STEG (Tunisian Society of Electricity and Gas). Controlling groundwater use through electricity metering and pricing was proved to be successful policy in many countries around the world (Zekri, 2009; Mukherji, 2007). However, transaction costs related to this policy implementation are prohibitive (Zekri, 2009).

Based on the evaluation in table 4, it is clear that economic instruments for GW management are the most costly among all. However, they are widely applied in Tunisia and they are also accepted by farmers. It is rare to find farmers who are not paying for their groundwater acquisition for example. Their impact on increasing water productivity and on the reduction in aquifer withdrawal is mixed. For example, tariff application on groundwater in public irrigated areas is limited to maintenance and operation costs recovery. Environmental damage and investment costs are not included in the applied fees. Thus, when

water constitutes a minor charge in farmers cost structure, price elasticity of farmers will be very low and the pricing of GW will have only little impact.

4.3. Collective action instruments

The WUA organization, mode of creation, and functioning is set out by the decrees n° 87-1261, October 27, 1987 and n°87-1262, October 27, 1987, respectively (Al Atiri, 2007). Based on this set of laws, the governmental strategy for the development of a participative approach in groundwater management at the local level was mainly relying on the following guidelines (MARH, 2000): (1) the establishment of a specific juridical framework suitable for the development and constitution of WUA at the irrigated scheme levels, (2) the establishment and adoption of a national strategy for the creation, monitoring, and framing of WUA, (3) the creation of special entities at the level of regional administration for the training of WUA on participative management and other management-related issues, (4) the establishment of specific programs for technical training and assistance of WUA managers and trainers, (5) the adoption of the participative approach for the newly created irrigated schemes, (6) social advertising of participative management, based on open days, education, flyers, etc. (7) the elaboration of a national methodology to evaluate and monitor WUA performances.

As we can conclude from the previous guidelines, when we raised the participative management issue in Tunisia, discussions will quickly turn around WUA performances and related issues. This is due to (1) the absence of any other level of constellation, especially at regional level, where water sharing and allocations issues can be discussed among main agricultural and non-agricultural users. (2) The importance which water sector managers in Tunisia gives to the WUA as being the backbone of the whole irrigation management strategy. Therefore, the success of the constellation between farmers and other stakeholder at the level of irrigated areas is highly dependent on the performances of the WUA (Frija, 2009). This was widely observed during our various face to face discussions with regional administrators. WUAs, with strong technical and educational background of their staff, are more able to bring farmers together and to organize their efforts to face the water crisis in their areas.

Nowadays, government encourages the adoption of the participative approach at the first implementation step of any irrigation project, including rehabilitation projects related to the irrigation and drinking water. Special simplified methodological manuals were produced by the government in order to be used in all steps of irrigation development projects. Moreover, government is also encouraging the involvement of private consultancies in the training of farmers in participative management. Most of these interventions are being done at the level of WUA.

Based on our interviews, many regional and local irrigation managers recognize that the application of the participative approach in local irrigation problems is still not solid enough. It is not yet completely integrated in the irrigation management habits of farmers and local managers. The intervention of public administrations for initiation and framing of this approach is still necessary. Many factors such as the increase of intensification level at farm level, the successive increase of farmers' water demand, the supplementary demands of neighboring non-irrigator farmers to join the irrigated area (and benefit from

WUA water supply)and the depletion of water table made the constellation among farmers very difficult. WUA managers and regional responsible for groundwater management attribute the crisis of overexploitation and the lack of institutional arrangements to the farmers' mentality. According to them, farmers only think about short term benefits and are not willing to consider future benefits within a framework of sustainable aquifer management. This is in line with the statements of Shah (2009), who indicates that provincial governments are very often given responsibilities that are beyond their human and financial resources, while farmers and other stakeholders are asked to participate in aquifer management while their direct interests lie in non-participation. Moreover, Ross and Martinez-Santos, (2010) indicates that a main factor which makes groundwater management difficult is the coordination and collaboration among stakeholders. Although external (usually government) interventions are required to coordinate information and water users, and adjudicate disputes, top-down government intervention is unlikely to achieve sustainable resource management without the support of the main water users.

It should also be noted that WUA for the management of irrigation systems on itself are not enough to ensure stakeholders participation for groundwater resources (Foster *et al.,* 2010). According to Foster *et al,.* (2010), there is a definite need of a system for higher-level users and stakeholders participation, which may be called "aquifer management organization", to be formed at the initiative of the water resource regulatory agency, in which all WUAs and other main categories of stakeholders are represented. Such water management system" exists in some Mediterranean countries like Morocco and France. Based on this system, the monitoring and coordination of GW uses and allocations, among all stakeholders implicated in the aquifer management, become possible.

As analyzed in table 4, these instruments are not costly and are widely applied in Tunisia, at least at the formal level. However, we notice that only little efforts and resources are currently mobilized in Tunisia for collective action promotion. Regional administrators responsible of WUA promotion and framing are all complaining from the limited financial and human resources available for them. Moreover, the impact of these instruments can mainly be assessed in a medium/long term perspective.

4.4. Supply-side measures

In addition to the demand management tools to deal with groundwater depletion, Tunisian government also developed some supply alternatives aiming to enhance groundwater provision and water availability in groundwater-dependent irrigated schemes. Even if the impact of these alternatives, in terms of supplied volume, is still negligible, their implementation and the setting of a clear strategy concerning them, remains at this level a considerable success.

One of the main supply-side measures is the development of wastewater treatment and reuse in irrigation. At present, a total volume of about 57 million m^3 of treated effluent (approximately 30% of the total produced volume) is used for the irrigation of 12,000 ha of agricultural land; Irrigated crops include fodder crops and fruit orchards as well as grapes and olive trees (CITET, 2009). This water is mainly used in

spring and summer periods when groundwater in some irrigated areas becomes insufficient. Treated waste water is also used for aquifers recharge. In the north-east of Tunisia an effort was made to use treated wastewater from secondary treatment for this purpose.

Moreover, groundwater recharge is also widely practiced in Tunisia since 1992. According to the national environmental report (2007), 64 millionm^3 of water was used to recharge 21 aquifers in 2006. Water releases from large dams is also used in some cases to recharge aquifers in central Tunisia (Plain of Kairouan). In some other cases, such as the case of the Cap Bon coastal aquifer, treated waste water is used to recharge the aquifers.

5. Discussion: SWOT analysis for the groundwater management sector in Tunisia

As argued in previous sections, GW management strategies in Tunisia had only little impact on sustaining the development of GW. This situation was aggravated since the post revolution period where the force of law became weak especially in deep rural areas. Nowadays, there are serious debates at high policy levels in order to search for effective solutions to govern GW resources at national and regional scales. As there are many opportunities to benefit from, threats and weaknesses of GW sector remain and should be considered by policy makers when designing new reforms of the sector.

TABLE 5 about here

Table 5 summarizes the mains strengths, weaknesses, threats and opportunities of the GW sector in Tunisia. The SWOT matrix analysis indicates that main strength in our review is related to the relatively small size of groundwater aquifers in Tunisia, especially in the Northern and central parts of the country. This is a great natural advantage that can help making GW instruments easily applied and monitored. Moreover, the strong point in the National GW strategy in Tunisia is the combination of a wide range of instruments types, including regulatory, economic, supply-enhancement, and collective action instruments.

However, the weak enforcement level of the designed instruments (especially the regulatory ones) is a major weakness for the Tunisian GW sector. It is absolutely the starting point to improve in a new GW strategy in order to make the rest of instruments effective. Another additional weakness (which can actually also be considered as opportunity) is the relying on WUA network for the application of most of GW instruments. If WUA performances will not be enhanced, then, the impact of policies which the implementation is affected to these WUA's will also not be effective.

GW sector in Tunisia may also benefit from a wide range of opportunities. Groundwater is, in fact, still at a level where remediation is still possible. Moreover, the new political context in Tunisia can be driving

factor for the enhancement of farmers' participation in local GW decisions. In addition to this, the wide network of WUA in rural areas is an opportunity for social advertising and farmers' education about GW sustainability issues. The wide electrification network is, by the same, an opportunity for making water pricing possible in private irrigated areas (where the creation of WUA is impossible). Finally, possible threats to groundwater sector in Tunisia remain and will have to be seriously considered. The main threat in the short run is related to the political instability in the country, which may increase the phenomenon of illegal GW exploitation. Other possible threats are related to the low performances of WUA in some regions and to the short-run perspectives of farmers when dealing with GW.

6. Concluding remarks and policy implications

In this paper we critically assessed the groundwater governance in Tunisia based on literature review, interviews with national, regional and local stakeholders. Our main objective was to enlighten some critical factors which are negatively affecting the groundwater governance framework in Tunisia and causing the degradation of the resource. Results show that WUAs are the backbone of the Tunisian groundwater strategy. Most of the economic and regulatory instruments, used to regulate the groundwater use, are applied through/by the WUAs. This means that the impact of these policies will highly depend on the WUAs performances. However, these latter organizations are still facing many problems (Frija, 2009) and we found out that some of the illegal use of groundwater in Tunisia has being due to their low technical performance (such low supply reliability). A special care needs then to be given to improve the WUA performances and skills especially in the public irrigated areas installed on groundwater aquifers.

At the national level, many decisions and policies targeting groundwater sector were settled up during the last decade, but their implementation and enforcement is still problematic. An efficient executive agency, such as the "Water police" needs to be created in Tunisia in order to enforce the existing laws concerning prohibition and exclusion of groundwater use in critical areas.

Solving water and food problems is not only a technical challenge but also a problem of fundamental ethical values and political will (Lopez-Gunn *et al.,* 2012).From this perspective, we conclude that the remaining job for improving groundwater governance framework in Tunisia needs to rely on two main axes: The first is related to the improvement of the institutional (especially administration) performances related to the groundwater controlling, monitoring and law enforcement. The second is related to the change of the currently established ethical values of various stakeholders. Ethical values supporting institutional changes such as salience, common understanding, trust and reciprocity and autonomy will have to be incorporated together with technical and economic issues related to the groundwater management strategy.

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Table.1 Types of groundwater management instruments

Type of instruments	Instruments	Description
Economic instruments	Groundwater pricing (energy pricing, pricing water resources, etc.)	Setting fees on groundwater extractions. There are two options for pricing groundwater: pricing the resource itself or pricing the other inputs needed in order to pump groundwater (pumps, borehole, energy, etc.)
	Subsidies for technological improvements	Instrument which the objective is to improve groundwater management in agriculture by providing subsidies to improve farmers' irrigation efficiency. Either efficient pumping technologies or efficient irrigation systems can be subsidized.
Regulatory instruments[3] (also called administrative regulation by some authors)	(Tradable) groundwater use rights (permits, concession) / Groundwater markets	It is a way to overcome the common pool character of groundwater. Well-defined use rights set a maximum level of abstraction in a period of time. They are often ambiguous and difficult to define (Kemper, 2007). Prior information about farmers yield over time is needed to define water rights and to make water rights an efficient tool. Tradable rights make this instrument even more efficient. Property rights on groundwater need to be well defined and to give long term incentives to farmers. Use rights also need a set of enforcement, monitoring and sanction regulations mechanisms to be effective.
	Land surface zoning/mapping for aquifers and land planning	It is a land-use planning map for the decision-making process about water and land allocation. It is obtained by combining the aquifer and resource vulnerability maps. The aquifer map boundaries, in turn, are based on the bedrock map boundaries and the aquifer hydrological data collected about the system.
Community aquifer management/collective instruments	Encouraging local self-governance	Voluntary/advisory policy instruments, which are also called community participation instruments, are those instruments that motivate voluntary actions or behavioral changes without use of direct financial instruments.
Supply enhancement	Aquifer recharge	Recharge of groundwater aquifers through treated waste water or through flooding water.
	Surface water transfer / Conjunctive use of surface and groundwater	Transfer of water from one region to another. It is generally about transfer of surface water from neighboring dams/regions to irrigated areas where groundwater is overused. This is also called conjunctive use of surface and groundwater.
	Water harvesting	Harvesting rain water is the accumulation and deposition of rainwater for reuse before it reaches the aquifer, or before it will be flooded. Uses include irrigation, urban use (gardening), livestock, etc. In many places the water collected is just redirected to a storage reservoir that can be with different dimensions.

Source: own elaboration

[3] This set of instruments has absolutely to be supported by a set of enforcement, monitoring, and sanction mechanisms.

Table.2 Potential, mobilized water resources in Tunisia (values inMm^3)

	Potential resources (Mm^3)	mobilized resources (Mm^3)				
		1990	**2000**	**2005**	**2010**	**2015**
Surface water	2700	1179	1876	2200	2400	2500
large dams	(56%)	1170	1688	1927	2080	2170
Hill dams		5	125	160	190	195
Artificiallakes		4	63	113	130	135
Groundwater	2140	1576	1818	1860	1900	1940
Shallow aquifers	(44%)	740	740	740	740	740
deep aquifers		836	1078	1120	1160	1200
Total resources	4840	2755	3694	4060	4300	4440
mobilization ratio	-	59	80	88	93	96

Source: Al Atiri (2007).

Table.3 Characterization of the groundwater development stages and its corresponding management instrument in Tunisia based on the World Bank methodology (2004).

Stage of development	**Ratios/exploitation indicators**				**Management instruments (brief description)**
	Freshwater withdrawals as % of total renewable water resources	Agr water withdrawals as % of total water withdrawals	Agricultural value added to GDP	Total water withdrawals per capita	
(1961-1975) *Incipient Stress*	23.3 %	-	21.7% (average 1967-1972)	179 m^3/inhb/year (1975 value)	• Focus on surface water mobilization and supply enhancement.
(1975-1985) Groundwater use peak *Significant Stress*	45.7 % Average (1980-1985)	-	17.7 % (average 1977-1992)	289.2 m^3/inhb/year (average 1980-1985)	• Creation of the water code (1975) • A number of aquifers become protected and drilling becomes subject to prior approval
(1985-1995) *Significant Stress*	64.2 % Average (1990-1995)	87.2 % (Average 1990-1995)	17.7 % (average 1977-1992)	336.2 m^3/inhb/year (average 1990-1995)	• Enhancing water supply in overexploited aquifers areas: Creation of 30 artificial recharge site • Consider surface water and GW together in management strategies instead of considering them separately as before • Decentralization of agricultural administrations and more autonomy to WUA.
(1995-2001) *Significant Stress/unstable development*	61.6 % (2001 value)	75.9 % (2001 value)	12.6 % (1997 value)	295.8 m^3/inhb/year (2001 value)	• Adoption of the water management approach • Establishment of the national program for water saving
(2001-current) *Unstable development*	-	-	9.01 % (average 2002-2011)		• In 2001 update of the 1975-water code • Current reforms of the water codes which start in 2012 • Studying the alternative of introducing electricity-based tariff in groundwater irrigated areas • Reform of WUA status in 2004 with settlement of the following new objective: “Collective management and protection of natural resources (especially water) in their territories”

Source: own elaboration (from FAOSTAT),

Table 4: Various groundwater management strategies used in Tunisia

Type of policy	Instruments	Expected impacts				Challenges facing the effectiveness of the instruments
		Increased water productivity	*Reduction in aquifer withdrawals*	*Acceptability / sustainability*	*Implementation level / cost*	
Policies for increasing water resources supply	Aquifer recharge	Yes	No	Yes	Wide/relatively low	Monitoring the impact on water quality when using wastewater
	Transfer of surface water from other neighboring regions.	Yes/No	Yes	No	Wide/high	High implementation cost
Regulatory instruments	Obligation of getting authorization for exploiting groundwater deeper than 50 m	No	Yes	No	Wide/very low	Enforcement of the instrument
	Exclusion areas	No	Yes	No	Wide/very low	Enforcement of the instrument
	Prohibited areas	No	Yes	No	Wide/very low	Enforcement of the instrument
	Support conversion to lower water consuming crops	Strong impact	Yes/No	No	Rare/very low	Not instituted by law and farmers face no obligations
Economic (incentive) instruments	Support conversion to water saving technologies	Strong impact	Positive or negative impact	Yes	Wide/very high	High cost of implementation
	Tariffs for groundwater	No	Weak impact	Yes	Wide/relatively high	Setting the appropriate price of groundwater which can reduce the overuse of the resource
	Subsidy fuel	No	No	Yes	Wide/very high	Increases fuel price
	Electricity-based pricing	Yes	Yes	Positive or negative impact	Not yet implemented/very high	Prohibitive implementation cost
Collective action	Promoting establishment of WUA in groundwater irrigated areas	No	Expected positive impact	Yes/No	Wide/high	Difficult to implement in private irrigated areas
	Social advertising and farmers education	Yes/No	Expected positive impact	Yes/No	Wide/high	High cost of implementation/lack of administrative means of responsible agencies of these tasks

Source : own elaboration

Table 5. SWOT analysis of GW management instruments in Tunisia

Strengths	- Comprehensive/integrated approach of viewing groundwater governance - Combination of a wide range of instruments corresponding to the development level of the resource, - Small size (easy delimitation) of most of aquifers - Relatively small number of users per aquifer - Good monitoring network of the resource all around the country
Weaknesses	- Weak enforcement level of the settled instruments (especially regulations) for groundwater management - A preponderant role of WUA in the groundwater management strategy, - Weak updating ratio of farmers (no consciousness about the overdraft problems and cooperative solutions among farmers - Absence of a bottom up approach and for effective promotion of local participative management. - Lack of effective assessment: understanding the real problems/challenges before setting rules - Insufficient monitoring level,
Opportunities	- Groundwater development is still at a level where remediation's are yet possible - New political framework in the country may be positive driving factor for bottom-up approaches and to enhance farmers participation - Participation and involving local stakeholders – mobilizing the strong and wide WUA network for enhancement of farmers consciousness - Wide electrification network in rural areas, for the application of electricity pricing in GW use - New developed technologies that may interfere with other institutional instruments for better GW control and monitoring
Threats	- Low performances of WUA may deeply affect the effectiveness of some groundwater management instruments in Tunisia. - Political instability may increase the phenomenon of illegal exploitation.

Source: Own elaboration

Figure1. Stages of groundwater resource development in a major aquifer and their corresponding management needs (World Bank, 2004)