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Resistance to the Regulation of Common Resources in Rural Tunisia

Xiaoying Liu, Mare Sarr, and Timothy Swanson

Abstract

We examine the effect of the introduction of uniform water-charging for aquifer management and provide evidence using a survey-based choice experiment of agricultural water users in rural Tunisia. Theoretically, we show that the implementation of the proposed second-best regulation would result both in efficiency gains and in distributional effects in favour of small landholders. Empirically, we find that resistance to the introduction of an effective water-charging regime is greatest amongst the largest landholders. Resistance to the regulation of common resources may be rooted in the manner in which heterogeneity might determine the distributional impact of different management regimes.

Key Words: commons, water, aquifer, heterogeneity, Tunisia

JEL Codes: O13, Q11, Q24, Q25.

Contents

Resistance to the Regulation of Common Resources in Rural Tunisia

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1. Introduction

“When the interests of appropriators differ, achieving a self-governing solution to common-pool resource problems is particularly challenging.” Ostrom (2002)

Cooperation regarding the use of common pool resources can be difficult to achieve. Sometimes the conditions for the generation of cooperation in the commons may exist but the adoption of an effective management regime may be resisted by some groups or sub-groups of users. Analysts have suggested that heterogeneity (e.g., spatial heterogeneity or wealth inequality) may be a fundamental factor in generating resistance to effective commons regulation (Johnson and Libecap (1982); Libecap and Wiggins (1985); Cardenas (2003)). The main reason that heterogeneity matters is that different users may have differing interests regarding regulation, with some benefiting more from existing regulation and others benefiting more under an alternative regime. In other words, different management regimes may channel a resource's benefits differently among users. This can be a problem, particularly when regulatory regimes are uniform in nature, i.e., when the regime fails to recognize extant heterogeneity. In this regard,

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Johnson and Libecap (1982: 1006) have shown that regulation via uniform quotas may be difficult to introduce into a fishery due to the resistance from the "more productive fishermen".

In short, there may be inbuilt resistance to the introduction of regulation. Baland and Platteau (1996, 1997, 1998 and 2003) have extensively analyzed this link between heterogeneity and resistance to effective regulation of common resources. For example, Baland and Platteau (1998: 8) examine how the move from a common property right regime with heterogeneous skill endowments to a uniform quota regime imposes greater individual costliness on those individuals with the higher skill endowments. In effect, the common property regime channels flows to users in proportion to their (skill) endowments, while uniform quotas do not. As a result, the move toward the more efficient regime is "paid for" primarily by the more highly-endowed part of the common property community. This sort of change of distribution engenders resistance to the regulatory regime that is proposed.

This paper examines a specific example of heterogeneity within a common property context, and the resistance to a proposed uniform regulation regime that it engenders. In particular, we analyze individual farmers' willingness to adopt an effective water-charging scheme as a regulatory instrument in the context of farmland irrigation ownership over a common aquifer. To explore this idea, we undertake a survey of Tunisian farmers in the Merguellil Valley regarding their individual willingness to adopt a regulatory regime aimed at stabilizing the water table. To date, groundwater management in the Merguellil Valley has been unsuccessful, as Tunisian authorities have been unable to enforce the existing regime, resulting in the decline of the water table on account of unauthorized boreholes.[1] An effective regime requires the introduction of a transparent and duly enforced system of mutual monitoring. In our survey, we attempt to ascertain the user-perceived characteristics of an effective regime, and the characteristics of users interested in adopting one.

We argue that the situation in Tunisia is an example of the problem of heterogeneous endowments resulting in resistance to regulation of the common resource, as described in Baland

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[1] In this region, farmers rely on groundwater for their agricultural production and continue to construct wells and boreholes without authorization. Under law, every new borehole must be authorized and its depth restricted to 50 meters. In practice, unlicensed sources of water have multiplied beyond control. For instance, the official number of wells in the Kairouan plain increased by at least 15%, from 4026 in 1995 to 4576 in 2000 (Albouchi (2006: 139)). As a result, the water table level continues to fall, from 42 meters in 1986 to 52 meters in 2006, and is expected to reach nearly 60 meters by 2015.

and Platteau (1998).[2] In the case of farmlands overlying aquifers in isolated rural areas, the ownership of the associated farmland confers an implicit or *de facto* use right in the underlying common resource (Bardhan (2000)). This is because the primary usefulness of the water lies in its proximity to the farmland, and so increased ownership rights in the overlying agricultural land increase the land owner's ability to make greater beneficial use of the associated water. Any attempt to introduce a regulatory regime that might possibly substitute for this skewed system of implicit use rights in the resource, toward a more uniform distribution of its use (such as the uniform quota system analyzed by Baland and Platteau (1998)) or benefits (as with the use-based tax analyzed here), will necessarily engender resistance from those disproportionately benefited by the resource under the common property regime. In this study, we find that resistance to the introduction of the regime is rooted in the heterogeneity of endowments amongst the user community. In particular, those who benefit most under the common property regime are the ones most resistant to the idea of introducing a more uniform regulatory environment.[3] In short, heterogeneity in common property resource ownership breeds resistance to the introduction of more uniform (but also more efficient) systems of resource management.

The paper is structured as follows. Section 2 introduces a very simple model of how the heterogeneous distribution of complementary inputs (such as land) might determine the distribution of benefits from a common property regime, as well as the nature of the change to this distribution with the introduction of an effective regulatory regime. In Section 3, we describe the Tunisian study area and institutional arrangements, and discuss the design and

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[2] As in many instances of commons analysis, Elinor Ostrom introduced many of the issues concerned with the heterogeneity of appropriators in commons problems (Ostrom (1990, 1992); Schlager and Ostrom, (1992); Ostrom, Gardner and Walker (1994)). She also analyzed many of these questions in the context of irrigation projects as well, focusing especially on the questions of heterogeneity (Ostrom and Gardner (1993)). Ostrom examined issues of heterogeneity as a question of coalition formation, examining those appropriators with common interests as natural coalitions of common interest. If a coalition was of sufficient size, it could aid in the development of commons management around its own interest. Under this reasoning heterogeneity in endowments need not necessarily militate against the development of commons management, as it would depend upon the capacity for one group to use similar endowments as the vehicle around which cooperation might form. In the following analysis, we find that such coalition formation around common attributes is indeed possible, but that such a coalition might operate against commons management as well.

[3] Our evidence is derived from a survey meant to identify whether agricultural users are willing to adopt a transparent and enforceable regulatory regime for water management. The results of our experiment demonstrate that, although there is substantial willingness to adopt such a regulatory regime, the willingness to support the regime depends upon the initial conditions facing the farmer surveyed. Those who are wealthier, larger landowners are less willing to support the move to the enforceable efficient regime than are the smaller, less wealthy farmers.

implementation of the survey. The findings of the empirical analysis are reported in Section 4 and Section 5. Finally, Section 6 concludes.

2. A Model of Water Regulation with Heterogeneous Users and Complementary Inputs

In this section, we provide a very simple model of the situation in which a complementary input (here, land) determines the primary beneficial use of the common resource (here, an aquifer). That is, in our context, users benefit from using the resource solely by reason of their respective landholdings (as larger land holdings provide a greater capacity for making beneficial use of the underlying aquifer). Then we analyze a proposed change in management regime toward more efficient water management implemented via uniform water charges, which generates two important outcomes: 1) a joint efficiency gain (by reason of the reduced future cost of water extraction), and 2) a new distribution of the individual benefits received from using the resource (by reason of the altered regulatory system). We argue that the redistribution of benefits might outweigh the achieved efficiency gain for some groups of users.

Here we set out the specifications required to achieve these results. Consider an economy where heterogeneous farmers $i = 1, \dots, n$ make water extraction decisions w_{it} given the groundwater stock level x_t in period t by maximizing the future stream of profits from water extraction. The instantaneous profit function is given by $\pi_{it} = pf(w_{it}, l_i) - c(x_t)w_{it}$, where p is the output price and $f(.,.)$ represents the production function that transforms land inputs l_i (assumed constant over time but varying across farmers) and water extraction w_{it} into agricultural output.[4] We assume that f is a well-behaved function that is strictly increasing in both arguments and strictly concave in w_i, i.e., $f_{l_i} > 0$, $f_{w_i} > 0$ and $f_{w_i w_i} < 0$. We further assume that water use and land are complementary inputs, i.e., $f_{w_i l_i} > 0$. In addition, the cost of water extraction $C(x_t, w_{it}) = c(x_t)w_{it}$ increases linearly with extractions w_{it} but decreases with the level of the groundwater, that is, $C_{w_i} > 0$ and $C_x < 0$ ($c_x < 0$). The latter feature of the cost function captures the idea of a pumping cost externality. Extraction costs are convex in x, i.e., $C_{xx} > 0$ (and $c_{xx} > 0$).

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[4] The model relies upon the simplifying assumption that the quality of landholding l_i is homogeneous across farmers. Arguably this simplifying assumption does not hold empirically. For this reason, the value of landholding is more likely to be the relevant variable of interest in the empirical model (See footnote 27).

The critical assumption that drives the results of this paper is that $f_{l_i w_i w_i} > 0$.[5] This assumption implies that diminishing returns from water extraction are greater for farmers with smaller landholdings. Our critical assumption also indicates that the degree of complementarity increases with water use. Consequently, larger landholders (who also extract more water) are able to exploit complementarity between land and water in a more productive manner. In Appendix 1, we use both a constant elasticity of substitution (CES) production function and a class of variable elasticity of substitution (VES) production function developed by Revankar (1971) (see also Sirmans and Redman (1979)) to demonstrate that an important condition for this assumption to hold is that the elasticity of substitution between land and water be less than unity. In other words, it holds whenever the substitution between land and water is sufficiently limited, or equivalently when there is sufficient complementarity between the two inputs.

2.1 Sole Owner or Social Planner: Efficiency Regime

Consider a single owner or social planner who makes water extraction decisions from an entire aquifer basin, which is located under n plots of land of different sizes. The planner is pumping water w_i from each plot i for use on that plot's crops alone (Pfeiffer and Lin (2012)). The problem is to allocate the water efficiently to each plot of land, relative to the other plots (static efficiency) and across time (dynamic efficiency).

Under an efficient management regime, the social planner maximizes the discounted lifetime profit over all land plots, subject to the evolution of the groundwater level:

$$\Pi^*(x_t) = \max_{w_{it}} \int_0^\infty \sum_{i=1}^{n} [pf(w_{it}, l_i) - c(x_t)w_{it}]e^{-\rho t} \tag{1}$$

$$s.t.\ \ \dot{x}_t = R - \sum_{i=1}^{n} w_{it}$$

$$x_0 = x(0) > 0$$

$$w_{it} \geq 0$$

where R represents the rate by which the stock of groundwater regenerates and ρ denotes the discount factor.

Lemma 1:

1) In the steady state, the social planner will extract groundwater for each plot of land i *so that:*

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[5] The authors are grateful to an anonymous referee for comments relating to the production relationships that drive the analytical results in this paper.

$$p\frac{\partial f(w_i^*, l_i)}{\partial w_i} - c(x^*) = -\frac{c'(x^*)\sum_{i=1}^{n} w_i^*}{\rho} = \mu_i^* = \mu^* \qquad (2)$$

2) Under the assumption that $f_{w_i l_i} > 0$, $f_{w_i w_i} < 0$, $c' < 0$ *and* $c'' > 0$, *we have:*

$$\frac{dw_i^*}{dl_i} = -\frac{pf_{w_i l_i}}{pf_{w_i w_i} + \frac{c'(x^*)}{\rho}} > 0 \qquad (3)$$

Proof: See Appendix 2.

The first point of Lemma 1 establishes the conditions for dynamic efficiency in the use of the aquifer. It says that, in the steady state, the social planner will withdraw water up to the point at which the value of the marginal unit of water in production equals the value of a marginal unit of water as stock. Equivalently, this is the point at which the marginal revenue from withdrawing water equals the marginal costs, composed of the marginal private cost of extracting water and the entire social cost resulting from the fact that the pumping cost increases as extraction takes place and groundwater stock decreases. This social cost actually represents the common shadow price that the social planner would have for each farmer to withdraw an additional unit of groundwater, i.e., $\mu^* = -\frac{c'(x^*)\sum_{i=1}^{n} w_i^*}{\rho}$. Because the shadow price factors in the effect of all farmers' water use (i.e., the sum of the extractions on each plot of land i), any externality that would occur will be internalized. This will result in socially efficient water extraction.

The second point of Lemma 1 indicates the basis for achieving static efficiency across land plots of differing sizes. It says that the size of a parcel of land determines the efficient allocation of the water resource; larger parcels of land are able to make beneficial use of larger amounts of water, and so the efficient allocation will distribute water in greater quantities toward these larger parcels. In short, the distribution of the groundwater—and hence the distribution of the benefits flowing from the aquifer—is determined by the heterogeneity of the plot sizes that overlie the resource.

2.2 Unregulated Common Pool Regime

We now assume that each plot of land i is associated with a specific individual farmer-owner. The underlying aquifer is shared by all farmers and is used only for purposes of irrigating the overlying agricultural lands.

Then each farmer i maximizes its discounted lifetime profit subject to the evolution of the groundwater level:

$$\Pi_i^{cp}(x_t) = \max_{w_{it}} \int_0^{\infty} [pf(w_{it}, l_i) - c(x_t)w_{it}]e^{-\rho t} \qquad (4)$$

$$s.t.\ \ \dot{x}_t = R - \sum_{i=1}^{n} w_{it}$$

$$x_0 = x(0) > 0$$
$$w_{it} \geq 0$$

Individual farmers only consider their own actions when determining the level of groundwater extraction, taking as given the extraction of all the others. The problem is a typical *open loop* dynamic game and its solution corresponds to a perfect foresight intertemporal Nash equilibrium (Provencher and Oscar (1993)).

Lemma 2:

1) In the steady state, each individual farmer i in the unregulated common pool regime will extract groundwater until:

$$p\frac{\partial f(w_i^{cp}, l_i)}{\partial w_i} - c(x^{cp}) = -\frac{c'(x^{cp})w_i^{cp}}{\rho} = \mu_i^{cp} \qquad (5)$$

2) Under the assumption that $f_{w_i l_i} > 0$, $f_{w_i w_i} < 0$, $c' < 0$ and $c'' > 0$, we have

$$\frac{dw_i^{cp}}{dl_i} = -\frac{pf_{w_i l_i}}{pf_{w_i w_i} + \frac{c'(x^{cp})}{\rho}} > 0 \qquad (6)$$

Proof: See Appendix 2.

The first point of Lemma 2 indicates the nature of the dynamic inefficiency resulting from this decentralized regime. Each farmer has the incentive to withdraw water from the aquifer up to the point at which the value of the marginal unit of water in production equals the value of a marginal unit of water as stock. Equivalently, this is the point at which the marginal revenue from withdrawing water equals the marginal costs, which are composed of the marginal private cost of extracting water and a social cost component that results from the fact that the groundwater stock decreases as extraction takes place. This social cost component actually represents the opportunity cost that farmer i internalizes when withdrawing an additional unit of groundwater, i.e., $\mu_i^{cp} = -\frac{c'(x^{cp})w_i^{cp}}{\rho}$. A stock externality results, in that each farmer only considers the component of the social cost impacting upon itself, ignoring its impact on the costs of all other farmers exploiting the aquifer. As a result, each individual farmer will engage in excessive water extraction. As always, the common property regime is inefficient on account of this stock externality and suffers from the tragedy of the commons (Hardin (1968)).

The second point of Lemma 2 is more interesting. It indicates the manner in which water will be distributed under the common property regime. This condition states that the greater the land holding by the individual farmer-owner, the greater the amount of groundwater extraction. This result derives from the fact that, assuming common production technologies on farms, the larger farms have a greater capacity to make beneficial use of larger quantities of water.[6] This heterogeneous capacity to make beneficial use determines the distribution of benefits from the common resource.

2.3 Regulated Common Pool Regime: Management System through Water Charges

Now we will consider a second-best system of regulation, similar to the Baland and Platteau (1998) argument regarding the introduction of uniform quotas. We will examine how first-best regulation might be introduced within the common property regime, and then consider how a second-best (uniform) system of regulation would determine both the efficiency and distributional outcome regarding the management of the common resource.

2.3.1 A First-best Regulatory Regime

Considering first the theoretical construct of first-best regulation of the groundwater resource, we provide for the possibility of a water-charging system under which each individual farmer is made to internalize the previously-described stock externalities, by means of the introduction of individualized water charges τ_i per unit of extraction.

$$\Pi_i^{\tau}(x_t) = \max_{w_{it}} \int_0^{\infty} [pf(w_{it}, l_i) - c(x_t)w_{it} - \tau_i w_{it}]e^{-\rho t} \tag{7}$$

$$s.t.\ \ \dot{x}_t = R - \sum_{i=1}^{n} w_{it}$$

$$x_0 = x(0) > 0$$

$$w_{it} \geq 0$$

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[6] This simple distributional outcome results from the assumption that water extraction and land holding are complementary inputs in agricultural production, and are the only source of welfare from the use of the aquifer in this set-up. It would more typically be the case that common resources may have more than one form of potential use, e.g., the aquifer may be linked to a village or an industry as well, but it is often the case that prior appropriation of water is possible and that these appropriators might be typified by a common use (such as agriculture). Then the downstream uses may be effective in altering the distribution of benefits amongst upstream users only if they are transferable upstream, e.g., via a water trading system; otherwise, they may remain irrelevant to the distribution of benefits under an existing regime.

Lemma 3:

1) Under an efficient (first-best) water charge regulation regime, in the steady state each farmer will extract groundwater until:

$$p\frac{\partial f(w_i^{\tau},l_i)}{\partial w_i} - c(x^{\tau}) - \tau_i = -\frac{c'(x^{\tau})w_i^{\tau}}{\rho} = \mu_i^{\tau} \tag{8}$$

2) Under the assumption that $f_{w_i l_i} > 0$, $f_{w_i w_i} < 0$, $c' < 0$ *and* $c'' > 0$, *we have:*

$$\frac{dw_i^{\tau}}{dl_i} = -\frac{pf_{w_i l_i}}{pf_{w_i w_i}+\frac{c'(x^{\tau})}{\rho}} > 0 \tag{9}$$

Proof: See Appendix 2.

Again, the steady state equilibrium requires that the value of the marginal unit of water in production (which includes the marginal water charge τ_i) equals the value of a marginal unit of water as stock. Under a first-best regime, the regulator would set the marginal charge so that the impacts of individual extraction are fully internalized. In such a case, regulation through water charges can mimic the first-best solution if the *individually assessed* optimal charges τ_i^* are calibrated such that:

$$\tau_i^* = -\frac{c'(x^*)\sum_{j\neq i}^{n} w_j^*}{\rho} \tag{10}$$

That is, each user would be assessed a total charge amounting to the total costs that its use of groundwater stock *imposes upon all other users*.

This first-best water charge would need to take into account the heterogeneity in users, and would do so in a somewhat counter-intuitive manner. The heterogeneity of landownership implies that water benefits are distributed in a skewed manner, with larger landowners receiving larger shares of water and benefits. For this reason, the smallest landowners are in fact imposing the largest share of the external costs on users, and should face differential water charges reflecting this disproportionate rate of impact. For example, if the user-owner received a relatively small distribution of water under the common property regime, then the vast majority of the water stock actually benefits other users (under the common property regime). Therefore, a small user should receive a relatively large individualized tax charge. Analogously, the large user of water would receive a relatively small individualized tax charge, because most future water impacts will be internalized to him. In this manner, a first-best system of efficient water-charging would recognize heterogeneity by means of imposing unit charges inversely in relation to relative landholdings.

2.3.2 A Second-best Regulatory Regime

Now we will follow Baland and Platteau (1998) in considering the effects of moving from a common property regime to second-best regulation. Second-best regulation usually derives from the fact that first-best regimes recognizing heterogeneity are difficult to implement in practice. More often, uniform regulatory regimes will be relied upon for the pursuit of joint efficiency gains, ignoring the heterogeneity that exists amongst users and hence redistributing the benefits from use. We will illustrate such an effect by introducing a second-best uniform water charging system in place of the first-best heterogeneous charge outlined above.

In order to do this, we assume that the regulator will pursue second-best regulation by imposing a uniform average water charge $\bar{\tau}$ based on the average water user's characteristics, and that this uniform charge in the steady state may then be defined as:

$$\bar{\tau} = \frac{1}{n}\sum_{i=1}^{n} \tau_i^* = -\frac{(n-1)c'(x^*)w_m^*}{\rho} \tag{11}$$

where $w_m^* = \frac{1}{n}\sum_{i=1}^{n} w_i^*$. The mean rate of water extraction under the commons regime is used to calibrate the uniform water charge, in pursuit of the internalization of "average stock externality" imposed by any given user-owner.

It is straightforward to see that this sort of average water charge (as with a uniform quota system) has the effect of skewing the distribution of benefits from the new regime toward the small landholders, and away from the larger ones. This is because the tax is relatively smaller than the optimal one for smaller users, and relatively larger than the optimal one for the larger users. The effect is that some of the efficiency gain is achieved through a second-best regime, but only with a significant redistributional impact.

Proposition:

Assume a production function satisfying $f_l > 0$, $f_w > 0$, $f_{ww} < 0$ *and* $f_{lww} > 0$, *and a cost function satisfying* $c' < 0$ *and* $c'' > 0$. *Assume further that farmers are heterogeneous in the size of individual landholdings* l_i *and have common ownership but differential optimal use of the water resource* w_i. *Then steady state, the introduction of uniform (second-best) water regulation (here, a uniform water charge* $\bar{\tau}$*) will alter the distribution of the benefits flowing from the common pool resources away from larger landowners and in favour of the small holders, i.e.,* $\frac{\partial w_i^\tau}{\partial \bar{\tau}} < 0$ *and* $\frac{\partial^2 w_i^\tau}{\partial l_i \partial \bar{\tau}} < 0$.

Proof: See Appendix 2.

The proposition says that the shift from the common resource regime to a second-best (uniform) regulatory regime based upon a uniform water charging system leads, first of all, to a reduction in each farmer's extraction. Secondly, the proposition also demonstrates that $\frac{\partial}{\partial l_i}\left(\frac{\partial w_i^{\tau}}{\partial \bar{\tau}}\right) = \partial^2 w_i^{\tau}/\partial l_i \partial \bar{\tau} < 0$. In other words, as the uniform groundwater charge increases, water extraction declines disproportionately more for farmers with greater landholdings. This result relies critically upon the assumption that $f_{l_i w_i w_i} > 0$. Under this assumption, the introduction of a uniform water charge $\bar{\tau}$ reduces the larger farmers' groundwater extraction disproportionately relative to the smaller farmers, due to the larger farmers' flatter marginal revenue schedule.

That is, we have shown in this specific context that the introduction of a second-best uniform regulatory system will move the combined agricultural/aquifer production system toward greater efficiency, but will at the same time redistribute the benefits from the common property resource within the user community.

The implication of this analysis is that, as demonstrated in other contexts by other authors, the shift between management regimes may have both efficiency and distributional implications. The net effect on any particular user group will be determined by the incidence of the two differing impacts on users. In effect, the public good of aquifer management is being supplied here through relatively more restrictive charges on the larger landowners, resulting in a redistribution of the shares of benefits that were being received under the commons regime. The language is not meant to connote any sort of normative implications regarding the second-best charging regime's incidence. We are simply stating that the charges are restrictive relative to those required under a first-best efficient regime, and that the distribution of shares is different from that resulting under the commons regime.

For the above reason, we would anticipate that resistance to a regulatory change of the type outlined above would come from the largest landowners within the system. These are the users who benefited most from the use of the common resource when unregulated, and these are also the group on whom the incidence of a change to a uniform system of regulation will disproportionately fall. We turn now to ascertaining the evidence regarding resistance to regulation in Tunisia, when a uniform water-charging system is proposed for implementation in precisely these sort of circumstances.

3. A Choice Experiment: Study Area and Empirical Design

In order to investigate our proposition regarding the impact of heterogeneity in the context of irrigation, we undertook a survey of farmers/water users in the Merguellil river basin in Tunisia. We used the survey to conduct a choice experiment investigating farmers' willingness to pay to shift to an effective uniform water-charging system. In the remainder of this section, we provide a description of the survey area, the choice experiment design, and the specification of the model to be tested.

3.1 Survey Area

3.1.1 Geographic Context

Situated in North Africa, Tunisia has a typical Mediterranean climate in the North and a Saharan climate in the South. Water availability varies widely across the country and over the seasons. Since the 1970s, successive Tunisian governments have engaged in large-scale investment programmes to equip the country with an extensive water infrastructure, with the aim of promoting rural development. Thus, no less than 29 large dams, 200 tanks, 766 major reservoirs, 3,000 boreholes and 150,000 wells have been built since the 1970s (Le Goulven et al. (2009)). The agricultural sector is by far the largest water user in Tunisia, with an 80% share of all water consumed.[7] It has made a significant contribution to rural development and economic growth in Tunisia over the past decades. As in many other developing countries, this development did not come without environmental cost since it has been accompanied by the ongoing decline in the water table level.

Our study area, the Merguellil river basin, is located in the central area of Tunisia. The population there is about 100,000, with 85% residing in the *Gouvernorat* of Kairouan. Approximately 85% of the total population live in remote rural areas, but this proportion is decreasing steadily given the trend of rural-to-urban migration. Due to its geographical location, this region has not been directly impacted by the growth of tourism, but it has undergone changes through its relationship with the coastal areas: labour migration, water transfers and emergence of new markets for agricultural produce, especially water-consuming products such as fresh fruits and vegetables.

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[7] In the 1990s, the government initiated a loan program for farmers to invest in intensive irrigation technology such as sprinkling and dripping. While this program was intended to improve water use efficiency, it led to a substantial increase in water consumption because farmers extended the land area to be irrigated.

The Merguellil basin is divided into two parts by the large El Haouareb dam: a hilly region upstream and the Kairouan plain downstream. The mean annual rainfall is approximately 300 mm in the plain and increases up to 510 mm in the upper part. Rainfall varies widely in time and space, and nearly 80% of annual rainfall falls within a period of about 12 days each year. The resulting sporadic and unpredictably violent surface runoff led to the construction of the El Haouareb dam in 1989. However, the dam does not serve much purpose for water storage, as nearly two-thirds of the water resources from the El Haouareb reservoir infiltrate into the karst aquifer while another quarter disappears through evaporation (Le Goulven et al. (2009)). Therefore, groundwater is the major water resource in the Kairouan plain. This groundwater is, however, subjected to heavy exploitation from the overlying agricultural sector. A proliferation of private wells has resulted in a dramatic increase, from about 100 boreholes in the 1960s to about 5,000 in 2008 (Le Goulven et al. (2009)). Resulting from this, there has been a relentless fall in the water table level, as discussed in footnote 1. The table is expected to fall below 60 meters by 2015.

3.1.2 Institutional Context

Collective management of irrigation water by local communities has a long history in Tunisia. It dates back to the 18th and 19th century in the Merguellil basin, and since the 13th century in the oases (Al Atiri (2007)). Water was considered a right by farmers and was shared equitably according to rules enforced initially by communities and later on enforced more formally by associations of stakeholders.[8] However, social transformation, accompanied by the introduction of new technology by French colonization, imposed pressure on resource use and weakened the traditional collective management system. After independence in 1956, the Tunisian state was eager to modernize the agricultural sector and promote rural development. In that pursuit, it centralized the management of water away from the tribes. From the 1970s, the development and management of public irrigation schemes were governed by a centralized agency (*Office de Mise en Valeur* or OMV) in each *gouvernorat.*

Toward the end of the 1980s, the decentralization of the management of irrigation schemes affirmed the state's willingness to disengage from direct management of the agricultural

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[8] For instance, the *Associations of Oasis Owners* was created between 1912 and 1920, and the *Associations of Special Interest in Hydraulics* was instituted in 1933, with functions similar to the modern Association of Collective Interest (AIC) and Group of Collective Interests (GIC) (Al Atiri (2007)).

sector.[9] This shift resulted in the creation of local collective water management schemes, namely the Association of Collective Interest (AIC), which became known as Group of Collective Interests (GIC) in 1999. Their number increased rapidly from 100 AICs in 1987 to over 2,700 GICs at the end of 2002. Among these, 1,100 GICs were involved in the management of irrigation water. By late 2001, nearly 60% of irrigated public land was transferred from the regional administrative authorities (CRDA) to the GICs (Albouchi (2006)).

The evolution of these institutional arrangements reflects the state's commitment to decentralization and empowerment of water user associations. However, these associations often lack the financial, technical and organizational capabilities to adequately fulfill their mission. Without adequate enforcement capabilities, the associations are unable to fulfill their management objectives, and farmers have little confidence in these institutions.[10]

The alternative to GIC-based water management has been private initiatives to address problems of water scarcity, and most farmers have simply resorted to the further construction of private wells. Larger numbers of wells are put in place on agricultural lands each year, and (as the water table drops) the existing wells are deepened using a local manual technique (*forage à bras*). Water management associations are seen to be powerless in the face of private expansion, while the local authorities prefer to turn a blind eye to these practices in order to encourage regional agricultural development. As Le Goulven et al. (2009) has stated: "*The Merguellil basin provides an ideal case study to analyze the effect of the progressive establishment of water infrastructure, ..., [it] also provides the opportunity to examine the modes of governance, as well as the economic and regulatory tools which might assist in the control of access to water resources*".

A common resource management problem exists in the Merguellil basin, and it will take a credible and transparent institution to move the users away from private appropriation and toward common management. In the next sections, we describe a choice experiment devised to assess the characteristics of a credible institution, and the willingness of users to support a move to such an institution.

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[9] In 1989, the OMVs were replaced by regional offices of the Department of Agriculture in charge of agricultural development in the *Commissariats Régionaux de Développement Agricole* (CRDA). The *Office de Mise en Valeur* (OMV) could be translated as the Irrigation Development Authority and the *Commissariats Régionaux de Développement Agricole* (CRDA) as the Regional Commissions for Agricultural Development.

[10] As will be investigated below, there are also often many internal conflicts and inconsistencies in the associations, on account of the heterogeneity of the membership.

3.2 Choice Experiment: Design and Implementation

3.2.1 Design of the Experiment - Enforceable Uniform Groundwater Charging Regime

The *status quo* described above indicates the nature of the failure of both government and user groups to move to a credible regime for managing the common resource. Two obvious inefficiencies result. First, groundwater levels continue to fall rapidly (and so pumping and drilling costs continue to increase) on account of unmanaged exploitation of groundwater. Second, due to lack of enforcement, existing mechanisms for monitoring and enforcement have proven ineffective in managing the aggregate impact of private exploitation, and so have lost all credibility.

The key objective of our experiment was to elicit farmers' preferences for the implementation of a credible management regime for achieving the stabilization of the water table. In particular, we sought to determine the farmers' willingness to pay to switch to a uniform water-charging regime that would move away from the status quo described above. The operational part of the experiment survey reads as follows:

> "In order to stabilize the groundwater table at the current level, the government is designing a policy to encourage people to reduce water use. In order to do this, the government plans to charge for groundwater use by metering. The Department of Agriculture will install water meters for all the wells in the gouvernorat of Kairouan (Merguellil Valley) and will charge for groundwater use based on the volume used. The volumetric price will be the same as in the public irrigation scheme. Water management units will be instituted throughout the Merguellil Valley.
>
> An annual installation and management fee will be required from the farmers. To ensure an adequate design of this policy, the farmers' opinions will be taken into account. You have the right to choose the fee level you are willing to pay. You also have the right to opt out of this policy and keep your current situation, with the water table deteriorating at the current pace. Whichever policy you choose, majority rule will be relied upon, i.e., if more than half of the people in the village vote for policy change, the new water management association will be formed and collective action will be taken."

The choice experiment incorporates the main characteristics that might determine the credibility of a proposed water-charging regime: *(i)* transparency regarding water exploitation (individual water use, water theft, meter destruction, etc.); *(ii)* user group confidence in the monitoring and enforcement system; and *(iii)* (as a possible complementary credible system) physical restrictions on water use over designated land areas. The status quo is described as the current context and is characterized by lack of transparency and credible monitoring. It is expected that addressing these shortcomings will aid in inducing acceptance of an institution by users (Ostrom (2000)). A credible regime would be expected to have these characteristics (if users accept them) and therefore presents the opportunity for the users to move to effective water resource management.

After consulting local researchers (*Institut National Agronomique de Tunisie*, INAT and *Institut de Recherche pour le Développement*, IRD in Tunis) and local stakeholders (the Ministry of Agriculture and the Regional Commission for Agricultural Development, CRDA, of Kairouan), water practitioners and managers (managers and staff of public irrigation schemes and GICs, and managers of the El Haouareb dam) and farmers of the Kairouan region, we set out the four policy attributes of interest shown in Table 1.[11] When describing the choices, we also considered the low literacy rate among farmers.

The first attribute pertains to *transparency*. This attribute aims to provide a mechanism for disclosing information about individual water use, fraud and sabotage so that the system can be trusted and be less prone to free riding. It is captured by a simple binary variable, indicating whether relevant information for every water user is published every month in a designated public place. The second attribute, *meter reading*, characterizes the kind of agency that should be responsible for monitoring the meters. It is a proxy variable for accountability. Because corruption may occur, it is important that the water users believe in the fairness of the monitoring system. This attribute is captured by a binary variable that denotes two different regimes: a new water management association, and the local authority.[12] The third attribute relates to the

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[11] This project was entirely stakeholder driven. We engaged in intense interaction with all stakeholders mentioned above, in order to 1) ensure a good understanding of the problem faced in managing water in that region; and 2) discuss alternative regimes that are of possible relevance to the Tunisian context in general and the Kairouan region in particular. It is worth noting that the idea of water metering to restrain the demand does not come from the researchers. Water metering and volumetric pricing have, in fact, been a key policy instrument used in Tunisia since the early 1980s. The price then was mostly fixed and heavily subsidized. In the early 1990s, the mood in policy circles was that water pricing should more closely reflect actual costs. The concept of water metering is therefore familiar to most farmers. For instance, the irrigation infrastructure in the public irrigated schemes, as well as in the GIC, is actually equipped with meters. (See Albouchi (2006: 135-146))

[12] The term *"Water Management Unit"* describes a user-based association, where users will be responsible for the management of the resources within the boundaries of the association. It would be independent from the State authorities, as the GICs are. However, we did not want to call them "GICs" because of the bad reputation that "GICs" have due to internal conflicts. On the other hand, the term *"Local Authority"* describes a local agency organization in charge of monitoring and policing the new system. It would resemble the current situation in some public irrigated schemes that continue to be run by a local government agency (CRDA). The basic idea here is to contrast a self-monitoring system with a third-party monitoring system. Given the similarities of these two monitoring structures with the existing organizations running the public irrigation schemes (CRDA vs. GIC), we believe that the farmers know the difference.

restriction on irrigated land area. Such restrictions constitute a straightforward and transparent regime for effecting some form of water management. This regime has the advantage of being easily monitored by the neighboring farmers, and hence affords straightforward transparency and enforceability. In the empirical analysis, we will treat this variable as an ordinal categorical variable, with four dummies to denote each of the four levels: 0, 10, 20 or 30% land restriction (in the estimation, only three dummies will appear to achieve a full-rank model matrix).[13] The fourth attribute included in the choice experiment, the *installation fee*, asks farmers how much they would be willing to pay to install a water meter on the well. The fee will be paid annually.[14] This attribute allows us to estimate welfare changes in monetary terms. The choosing of a preferred combination of the attributes provides a means for users to indicate the nature of the management regime they would find most credible, and the amount that they would be willing to pay for a credible regime.

In combining the levels of the attributes into choice sets, orthogonality design was used to avoid strict dominance of one alternative over the others. Careful arrangement ensured balanced distribution of attribute levels and balanced utility across alternatives. These combinations generated 64 possible choice sets, out of which 16 were selected and separated into two groups of choice sets. Table 2 shows the example of a choice set.

3.2.2 Implementation of the Experiment

A pilot study (survey and experiment) was carried out with a small sample of farmers in the Kairouan plain to assess the relevance of the questions and the reaction of the farmers in March 2007.[15] In May and June 2007, the actual choice experiment was conducted with a sample

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[13] These land restriction levels were chosen based on discussions with local stakeholders, experts and practitioners. In addition, a pilot study was undertaken prior to the actual survey to validate their pertinence. The rationale for including these levels is that, during our visits, the managers of large irrigation schemes contended that the usual and fairly straightforward (and flexible) way that they control water consumption in case of increased water scarcity was to restrict the amount of land that is irrigated by each farmer in a particular scheme. This restricts the percentage of land which could not be irrigated. They claimed that, given that they know farmers' crops and water requirements, such restrictions were fairly easy to monitor and therefore could reach the water saving target with the least enforcement effort. This was corroborated by the CRDA. We adopted this practice because farmers would be acquainted with it.

[14] This installation and management cost can also be regarded as a club membership that allows farmers to join a particular water management association. As in footnote 13, the fee levels were chosen based on our consultation with local stakeholders, experts and practitioners. The pilot survey enabled us to validate the pertinence of the fee levels.

[15] The pilot experiment contained a fifth attribute (the group size in a given water user association) which proved to be irrelevant to the local farmers and was therefore dropped.

of 246 farmers located both upstream and downstream of the dam. We purposely oversampled farmers living in the downstream catchment where much of the over-exploitation of the groundwater takes place.[16] Within each group, farmers were randomly selected and they were randomly assigned to a group of eight choice sets. Five enumerators were selected from INAT and trained by one of the authors and a research assistant who is a native Arabic speaker and is fluent in English. During the interview, the enumerators carefully explained the purpose of the study, the policy attributes and the procedure for making choices.[17] The respondents were also provided with information on the current state of the water table and its likely future evolution should the current rate of water extraction continue.

In addition to the choice experiment, a survey questionnaire including the following sections was administered: 1) socio-economic and demographic characteristics; 2) cultivation and irrigation information; and 3) information about the farmers' attitudes toward the environment and the use of water in the region.[18] The information collected in these sections is required to control for heterogeneity among farmers and to investigate the effect of such heterogeneity on preferences.

A supplementary village survey was conducted in all the sample villages in December 2010 and January 2011 in order to better capture the heterogeneous circumstances faced by farmers in the Merguellil. Village level data pertaining to the water table change since 1990 was collected. We also collected information on the distribution of farm land and the distribution of well depths for the year 2007. This information allows us to examine the effect of inequality across villages on the farmers' behaviour. The distance of each village to the dam was also collected.

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[16] The study area spreads over four administrative districts (called delegations): Chebika, Hafouz, South Kairouan and North Kairouan/El Baten (see Figure 1). The Chebika district is particularly of interest because it is located in the downstream catchment and accounts for the highest concentration of private wells and boreholes in the entire Merguellil Valley (see Figure 2 for the map of the wells). South Kairouan and North Kairouan are located downstream just outside the river basin. Farmers there also rely heavily on private wells. We sampled 24 villages and communes in the downstream region. The villages/communes in Hafouz district, on the other hand, are located in the upstream catchment. In total, farmers in 28 villages/communes were sampled. We focused primarily on farmers who operate outside the public irrigation perimeters located in the Chebika district (61% of the sample), Kairouan South (21% of the sample) and North Kairouan (9% of the sample) since they rely almost exclusively on private wells as their source of water supply. In each district, we selected the farmers randomly. The remaining 9% were located in the upstream catchment, randomly selected from three villages/communes of Hafouz district and Rouissat, where farmers also relied on private wells.

[17] This was done to avoid any misunderstanding, given the low literacy levels among farmers.

[18] The latter section helps us understand how personal beliefs shape farmers' attitudes toward the proposed policies.

3.3 Choice Experiment: Model Specification

Our empirical analysis focuses on the estimation of random parameter (or mixed logit) models. Mixed logit is a flexible model that obviates the limitations of standard logit models by allowing for unrestricted substitution patterns, correlation in unobserved factors and random taste variation (Train (2003)). Instead of constant coefficients in utility function, it assumes that coefficients vary randomly across individuals representing each individual's tastes. The utility under a mixed logit model is written as:

$$U_{nj} = \alpha Z_n + \beta_n' X_{nj} + \varepsilon_{nj} \tag{12}$$

where Z_n are observed individual n's characteristics, X_{nj} are choice j's attributes, β_n is a vector of unobserved coefficients assumed to vary across individuals according to some distribution, and ε_{nj} is an unobserved random term that is independently and identically distributed according to the extreme value distribution, independent of α, β, X, and Z.

In this model, the probability that individual n chooses choice j is:

$$P_{nj} = \int \left(\frac{e^{\beta_n' x_{nj}}}{\sum_k e^{\beta_n' x_{nk}}} \right) f(\beta) d\beta$$

In other words, the mixed logit probability is a weighted average of the logit formula evaluated at different values of β, with the weights given by the density $f(\beta)$ (Train (2003)). We estimate the mixed logit model assuming the variable coefficients have a normal distribution.

We first analyse how policy attributes alone affect farmers' choice. Then, we control for farmers' individual characteristics, i.e., variables Z_n in equation (12). Because identification in the logit model runs only through within-group (choice set) variation, it is necessary to interact Z_n with the alternative specific constant (ASC) in the model to account for preference heterogeneity that can be explained by observed factors.

4. Empirical Results

4.1 Data Description

Our data consists of a sample of 246 households living in 28 villages in the Merguellil Valley. We focus mostly on farmers outside the public irrigation perimeters located in Chebika, Hafouz, South Kairouan and North Kairouan/El Baten since they rely almost exclusively on private wells as their source of water supply. The mean age of the farmers in our sample is about 40 years of old. All respondents except one are men. Most respondents (around 72%) did not study beyond primary school.

Regarding farm characteristics, the average farmer cultivates seven hectares equipped with one private well or borehole. The average well is 45 meters deep (with a standard deviation of 9 meters), which is a little below the authorized depth of wells.[19] The water table level decreased by 18 meters on average between 1990 and 2007. Irrigation technologies are also fairly widely spread in the region: in our sample, 75% of farmers use dripping irrigation and 40% use sprinklers. The summary statistics of the survey data are listed in Table 3.

To account for the important role that heterogeneity plays in the management of the common resource as suggested in the literature (Baland and Platteau (1998, 2003); Johnson and Libecap (1982); Bardhan et al. (2007)), we also collected information on the distribution of landholdings within each village of our case study. Because the data on land distribution are grouped observations,[20] we measure land distribution inequality based on the method proposed by Kakwani and Podder (1976). The inequality measurements are shown in Figure 3a and Figure 3b. The left panel shows the distribution of the Gini concentration ratio while the right panel shows the distribution of the relative mean deviation. Both measurements show a large variation in the level of inequality of landholding across villages. We also measure a similar inequality indicator based on well depth.

Finally, we also collected data pertaining to farmers' environmental awareness. We asked five questions about farmers' general attitude towards water conservation using a Lickert scale, where the lower scores indicate a higher degree of environmental awareness. We integrated the results obtained into two factors using factor analysis. Factor 1 reflects the farmers' awareness of water scarcity in the local aquifer, and factor 2 indicates their awareness of the consequences of their water use on others.

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[19] The CRDA keeps a record of the depth of the wells when it grants licenses. However, given that many wells are either unlicensed or have become deeper over time, we relied on the village leader’s (the *"Omda"* in each *douar* (village/commune)) reporting, which arguably is likely to exhibit some measurement error. In addition, a number of studies were carried out in the study area by some of our partners (IRD, INAT together with the CRDA) to undertake in-depth assessments of the situation of the wells and private boreholes (GPS location, numbers, technology used, identity of owners, depth). See Jean-Paul Luc (2005). Luc's (2005) data also relies upon village leaders' information.

[20] More specifically, the data show the number of farms in a village with farm land in each of following categories: 0-2 hectares; 2-4 hectares; 4-6 hectares; 6-10 hectares; 10-20 hectares; 20-50 hectares and over 50 hectares.

4.2 Choice Experiment: Estimation Results on the WTP for a Uniform Water-charging System

Table 4 presents the results of the various choice models, controlling only for the choice sets' attributes. We estimate the probability of choosing a particular management policy as a function of the attributes of the policy and the alternative specific constant (ASC), ignoring the heterogeneity of respondents. The ASC takes value 1 for either of the policy options A and B, and equals 0 for the 'status quo' option. The model is estimated by mixed logit with different policy attributes' coefficients being treated as random coefficients. Correlation between random coefficients is allowed in Column (4). Hereafter, we summarize the main results from Table 4.

First, the positive ASC coefficients in nearly all columns indicate that, on average, farmers have positive willingness to pay for the introduction of an effective groundwater metering system, and hence are interested in pursuing a more efficient management regime for the common resource. They also express support for most components of such a regime. In the aggregate, they support a transparent regime that makes public information on individual water use. They further support *meter reading* by local government officials over the elected water management unit leader (indicating some dissatisfaction with the effectiveness of current arrangements of the same form). This seemingly paradoxical finding is consistent with the locally prevailing perception that the existing structures of the GICs are involved in private dealings with wealthy farmers to the detriment of the general interests.

The users do not respond positively to any proposed quantity restrictions. They are indifferent to restrictions on the use of water on lands that do not exceed 10% of individual landholdings. They are weakly against a 20% land restriction, but then they strongly oppose restrictions of 30% and above. The lack of opposition to the minor restriction is uncontroversial, as it is likely to be non-binding on most users. Because some marginal fallowing of fields is a common practice in the Merguellil Valley, an irrigated land restriction of less than 20% does not impact farmers' choices much. We will return to this result in our discussion regarding resistance below.

Columns (1)-(4) differ in the variables that are assumed to have random coefficients. In Columns (1) and (2), we allow only one random parameter for either *transparency* or *meter reading* separately in each specification. In Column (1), the average coefficient for variable *transparency* is 0.307, and the standard deviation of this coefficient is statistically significant, implying a large variation of this coefficient across the population. Using the normal distribution, we can show that 56.3% of farmers evince positive support regarding this variable. In other words, a weak majority of farmers prefer transparent management. Likewise, Column (2) assumes that the coefficient for *meter reading* is a random parameter. The average coefficient of this variable becomes statistically insignificant when heterogeneity is allowed. The standard deviation is large and significant, indicating a wide variation in water users' preferences regarding this policy attribute. A similar result obtains when both *meter reading* and *transparency* are treated as random but uncorrelated coefficients in Column (3). Nevertheless, if we allow both coefficients to be correlated (as in Column (4)), the average coefficient on *meter reading* turns larger and significant at 10%, with 56% of respondents indicating a preference for local authority. Moreover, the positive correlation between the two coefficients suggests that those who prefer transparency also prefer outsiders (in this case, local authority instead of the WUA leader) to monitor the new system. This result again corroborates our earlier discussion concerning the lack of credibility of the current GIC management.[21]

Based on the results in Column (4) in Table 4, we calculate farmers' willingness to pay for movement of all users into the new uniform water-charging system. On average, farmers are willing to pay 172.55 Tunisian Dinar (TD) to shift to the new management regime targeted at stabilizing the level of groundwater.[22] In relative terms, this represents 2.5% of the median farmer's income.[23] On average, farmers are willing to pay an additional TD 37.74 for a *transparent* regime.[24] Farmers are also willing to pay an extra TD 20.54 for the local authority to guarantee *accountability.* Finally, farmers would reduce their contribution by more than half, i.e., TD 89.2, should irrigated land restrictions be introduced and exceed 30%.[25]

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[21] Considering the low literacy level of the respondents and the number of choice sets (eight) that they have to complete, we test whether the estimation results are affected by a fatigue effect. Specifically, we tested the fatigue effect versus the learning effect by estimating the ratio of error standard deviations (i.e., variation in the unexplained component of utility) for the first four choice sets compared to the last four choice sets of the eight-question choice set. We estimated the model as specified in Column (1) using maximum likelihood, and found that the point estimate of the scale ratio is 1.028 (very close to 1). This finding suggests a weak learning process (Savage and Waldman (2008) and Carlsson et al. (2012)). The detailed results of this test are available upon request.

[22] The annual willingness to pay to shift to a new regime is given by $WTP = -\frac{\beta_{\mathrm{ASC}}}{\beta_{\mathrm{fee}}} = -\frac{1.619783}{-0.0093871} = 172.55$. See Table 6 for the computation of the WTP per attribute.

[23] We do not have the measure of individual households' income but rather households' income groups. The median income level is about TD 7000 (i.e., about USD 4500). The value of the "mean" income—obtained by using the medium level within each income group to proxy for the income levels for all respondents within that group—amounts to TD 7200.

[24] The fact that 40% of respondents oppose a move toward more transparency is indicative of the presence of very significant and meaningful heterogeneity in the survey group. See the following discussion in this regard.

[25] We discuss the importance of this attribute below.

5. Discussion: The Impact of Heterogeneity - Resistance to Regulation

Our discussion in Section 4 has indicated that farmers support a move toward more efficient institutions—they would prefer in the aggregate to move away from the status quo and toward effective resource management. However, the analysis thus far has glossed over the impact of heterogeneity on such support. For example, as mentioned in footnote 24, fully 40% of farmers in the survey refused to support the move toward a more transparent mechanism for monitoring resource usage. Because there is little prospect for credibility in the absence of transparency, the failure to support the introduction of this attribute in a regulatory regime could be equivalent to supporting the status quo, i.e., it could be indicative of inbuilt resistance to a move toward effective regulation.

This is indicative of the important role played by heterogeneity in supporting or resisting the introduction of a credible management regime. This concern is now addressed in the results reported in Table 5, in which we include observed heterogeneity at the village and individual level in the choice models. These include socio-economic variables (land value, education), geographical variables (location of the farm upstream or downstream, distance to the dam, fall in the water table), the factors of farmers' attitudes towards the environment, and village characteristics (number of farms, land inequality). As indicated in the introduction, the role of landholdings in the context of irrigation can be crucial. Land endowment is indicative of the manner in which benefits from the common resource are distributed in the unregulated regime, because larger landholders can make greater use of unpriced common water resources, and so uniform price-based management regimes (such as the one proposed in our choice experiment) are most likely to impact these users the most.

The extent of landholding enters the index equation in a non-linear fashion as we interact land value with transparency and incorporate a quadratic term for land distribution (to test a possible U-shaped relationship). The regression models are again estimated by random parameter mixed logit.[26] Our model's main prediction is supported by the fact that, conditional on within village land inequality, farmers with larger landholdings in the irrigation district (i.e., with a greater proportion of irrigated land)[27] tend to be more reluctant to support the move to the

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[26] Although the coefficient for *transparency* varies with land value in some specifications, there may exist other heterogeneity regarding the preference for policy attributes, which leads to random parameters.

[27] As indicated earlier, our theoretical model relies on the simplifying assumption that the quality of land is homogeneous across farmers. Arguably this simplifying assumption does not hold empirically. Indeed, there is a large variation in the quality of land in the region, from grazing land (which does not require irrigation) to olive tree

new regime, as suggested by the negative sign of the marginal coefficient on *log(land value)*.[28] In addition, the negative coefficient of the interaction term between *transparency* and *log(land value)* reveals that richer farmers dislike transparency, unlike the average farmer. These findings corroborate the belief that larger landholders are the greatest beneficiaries of the current water management scheme, and hence are less supportive of the move to the new one. We also calculate farmers' willingness to pay for all the attributes according to the results in Column (3), as shown in Table 6. After controlling for individual characteristics, the farmer with average land value is willing to pay slightly less than the level without controls, i.e., TD 35.88, for a *transparent* regime. In addition, farmers are also willing to pay an extra TD 13.83 for the local authority to guarantee *accountability*. Finally, farmers would reduce their contribution by TD 30.91 for 20% land restriction without irrigation, and a significant TD 97.72, should irrigated land restrictions be introduced and exceed 30%. These findings are quantitatively similar to those discussed in Section 4.2 where heterogeneity was ignored.

The way heterogeneity affects the level of support for regulatory regime change can also be seen through the coefficient of land inequality at village level. We find that farmers from villages with higher land inequality are more willing to pay for a water conservation regime. According to the results in Column (3), the marginal effect of the land Gini coefficient at the mean Gini coefficient on the willingness to pay for the policy change is 4.79.[29] This indicates that a 0.1 unit increase in the mean value of the land Gini coefficient, from 0.48 to 0.58, enhances the probability that the average land holder supports the move to the new policy regime by 47.9%. We find this to be a somewhat subtle indicator of the distributive consequences of effective management. When landholding is more skewed, the costs of effective management (when implemented by a uniform water charging system) will be borne more by the larger landholders. Greater landholding inequality is thus an indicator—for the majority of farmers—of the skewed manner in which costs of water management will be incident. Because each farmer's choice is equally weighted in the average WTP (unweighted by landholdings), the increase in

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farms to water-demanding vegetable and fruit tree farms. For the purpose of our empirical analysis, taking into account the heterogeneity of land quality (which has implications for the amount of water use) requires the use of land value rather than land size per se, since wealthier farmers typically grow the more water-demanding crops, such as olive trees, watermelon, tomatoes, etc.

[28] The marginal coefficient on *log (land value)* is -0.653, which has the same sign as the marginal effect.

[29] The marginal effect of land Gini Concentration ratio in a logit model is calculated as:
$f(\beta X)\beta = \frac{exp(\beta X)}{1+exp(\beta X)}\beta = \frac{exp((-119.9+2*130.3*0.4900227)*0.48)}{1+exp((-119.9+2*130.3*0.4900227)*0.48)} * (-119.9 + 2 * 130.3 * 0.48) = +4.79.$

support can be regarded as support by the average user for such a redistribution of benefits, as well as for more efficient management.

There are other facets of heterogeneity that have the expected effects on user group support for effective regulation based upon uniform water-charging. For example, basic education has a positive effect on farmers' willingness to pay for water conservation action, while further education is not significant. Moreover, farmers' environmental awareness and concern has a positive impact: lower scores—which indicate a higher degree of environmental awareness—promote regime change. However, concern for water scarcity in the aquifer alone is insufficient to motivate support for policy change, but must be combined with an awareness of the existence of external effects of groundwater exploitation. The number of farms within a village has little effect on individual farmers' decisions regarding support for the efficient regime.[30] Finally, farmers living in villages downstream are, as expected, more keen to stabilize the groundwater table, as they tend to be more vulnerable to groundwater scarcity. We also find that farmers who have experienced a greater fall in the water table fall since 1990 are more likely to vote for cooperative management of the resource. Surprisingly, those living greater distances downstream do not seem to exhibit greater support for groundwater conservation policy.[31]

In summary, the results from our survey demonstrate that the majority of farmers are willing to pay a non-trivial amount of money for a uniform water-charging system in the pursuit of greater efficiency in groundwater use. However, our findings also reveal that the main obstacles that impede cooperation most likely lie in the heterogeneity that exists across current users. Although (as would be expected) there is support in the aggregate for movement toward a more efficient water management system, those who benefit most under the current system would be least willing to support such a move. Large landholders who receive the largest benefits from the status quo (i.e., the existing inefficient common resource management system)

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[30] This finding seems inconsistent with the theory that group size matters for cooperation (see, e.g., Ostrom (2000)), but since group size is most relevant for monitoring purposes, it would seem to indicate, in this context, that the credibility of the enforcement mechanism (as specified in the experiment) is not in question.

[31] This result seems puzzling, but it may not be so if we realize that the degree of land inequality is positively correlated with the distance to the dam downstream. In a regression of land inequality level (not included in the current paper) on binary variable $Downstream$ and interaction term $Downstream * Distance\ to\ the\ dam$, we find both coefficients are significantly positive. This fact may result from the local landscape and its unique geological environment. As land inequality has a positive effect on villagers' preferences for water conservation, downstream distance may work through the same mechanism. Here, we treat land inequality as an exogenous variable which is formed by geology and in history. We do not assume it be correlated with other unobservables which also affect people's preferences for regime change.

will be the group that experiences the greatest costs of moving to the second-best uniform water charging management regime (Baland and Platteau (1998)). The support for an effective regulatory regime derives from flows of benefits, which originate from both efficiency gains and distributional change.

6. Conclusion

A major priority for Tunisian water users in the Merguellil Valley would be the implementation of specific regimes that would halt the ongoing decline of the water table. The main cause of the depletion of the groundwater, the unmanaged exploitation of the aquifer for agricultural uses, is well known. Despite the existence of legislation regulating drilling of boreholes and wells, existing enforcement regimes have little or no effect. The current regime results in a joint efficiency loss to all agricultural users of the aquifer, but also results in a specific distribution of the benefits from the use of that resource.

The introduction of a second-best uniform water charging regime was proposed to the water users of this region. The initial finding from our experiment is that water users are willing in the aggregate to support the adoption of such an effective regime. The majority of users are willing to pay for the adoption of an effective system that exhibits traits of transparency and independent monitoring.

More interestingly, in the presence of heterogeneity, we find that this aggregate support for regime change masks a substantial amount of underlying contradiction and conflict across individual users. Landholding heterogeneity among farmers is the key to explaining individual willingness to support the move to an effective regime or the preference to remain with the status quo. We argue that this is because the incidence of the introduction of a uniform water-charging system is dependent upon both the increased benefits from efficiency gains and also the changed benefit flows resulting from redistribution effects. For many of the smaller landholders, both of these effects cut in the same direction under the proposed second-best system.[32] For the largest landholders, these two effects move in opposite directions under uniform water-charging, and the net result is resistance to effective regulatory changes. In our study, we find that the largest landholders provide the least support for movement to the uniform water-charging management regime, and in fact withdraw their support in relation to increasing transparency/credibility.

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[32] For this reason, as land distribution becomes more unequal, farmers in the aggregate become more willing to accept water-charging regulation to achieve more sustainable management of the aquifer.

We believe that this is an observation that varies with the system being proposed, along with the distributional consequences implied. The uniform water-charging system examined here results in a very different distribution of benefits from the commons regime, and so is supported by those users who benefit less from the commons regime. A land-based quantitative restriction (if adopted in preference to water-charging) might preserve the existing distribution of benefits. For this reason, uniform water-charging, together with its distributive impacts, might be preferred by many users to many other regimes. Distributional consequences may be motivating many users to support particular regimes, and to resist others, depending upon their initial positions and the change proposed.

Our findings are both very general and very limited. They are general in that they demonstrate that efficiency is not its own reward in regard to regulatory change. Movements from inefficient to efficient regimes do not automatically generate Pareto improvements, even if all of the users are in a common relationship with one another and with the resource (as in the context of the irrigation-based use of aquifers). The inefficient regime will connote a particular distribution of benefits, and the movement to a more efficient regime may connote a very different distribution. It is this shift in distributional incidence that can generate resistance to (or support for) effective regulation, even in circumstances of commonality as apparently uniform as an agricultural aquifer. On the other hand, our results are also very limited because they occur in a context in which the only use of the common resource is agricultural, and so the complementarity of inputs implies a property rights distribution based on landholdings. It is this structural limitation that renders our context such a clear and straightforward case study on how regime change impacts both efficiency and distribution. In many cases, these same relationships will exist, but in a much more complex fashion. Resistance to regulation (of the commons) is built into the process of regulatory change.

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Appendix 1. Restrictions on production function satisfying $f_{lww} > 0$

Case 1: Constant Elasticity of Substitution (CES) production function

Define a CES production function:

$$f(l,w) = [\alpha l^{\eta} + (1-\alpha) w^{\eta}]^{1/\eta}$$

where the parameters satisfy: $-\infty < \eta < 1$, and $0 < \alpha < 1$. The third partial derivative of f is given by:

$$f_{lww}(l,w) = -\frac{(1-\alpha)\alpha(1-\eta) l^{\eta-1} w^{\eta-2} [(1-\eta)\alpha l^{\eta} + (1-\alpha)\eta w^{\eta}][\alpha l^{\eta} + (1-\alpha) w^{\eta}]^{1/\eta}}{[\alpha l^{\eta} + (1-\alpha) w^{\eta}]^{3}} < 0$$

$$f_{lww}(l,w) > 0 \Leftarrow \frac{w}{l} > \left[-\frac{1-\alpha}{\alpha}\frac{\eta}{1-\eta}\right]^{-1/\eta} \qquad and \quad \eta < 0$$

A negative substitution parameter $\eta < 0$ implies that the elasticity of substitution is less than unity ($0 < \sigma < 1$) since $\sigma = \frac{1}{1-\eta}$. It means that the assumption $f_{lww} > 0$ requires a restriction in the parameter space that ensures a limited elasticity of substitution. In other words, there should be enough complementarity between land and water.

Case 2: Variable Elasticity of Substitution (VES) production function

Define a production function that exhibits variable elasticity of substitutions (VES) following the seminal work by Revankar (1971):

$$f(l,w) = w^{\alpha(1-\delta\eta)} [l + (\eta - 1) w]^{\alpha\delta\eta}$$

where $\eta > 0,\ 0 < \delta < 1,\ 0 \leq \delta\eta \leq 1,\ \frac{w}{l} < \frac{1-\delta\eta}{1-\eta}$, and $\alpha > 0$. Note that we assume constant returns to scale by setting $\alpha = 1$. Revankar (1971) showed that the elasticity of substitution is variable and is given by:

$$\sigma = \sigma(l,w) = 1 + \frac{\eta-1}{1-\delta\eta}\frac{w}{l}$$

This class of VES production functions satisfies the requirements of a neoclassical production function and contains the Cobb-Douglas function as a special case ($\eta = 1$). But it does not contain the CES function (Revankar (1971) and Sirmans and Redman (1979)). The third partial derivative of f is given by:

$$f_{lww}(l,w) = \delta\eta l w^{-1-\delta\eta}[l + (\eta - 1)w]^{-3+\delta\eta}(\delta\eta - 1)[2w(\eta - 1) + \delta\eta l]$$

$$f_{lww}(l,w) > 0 \Leftarrow \frac{w}{l} > \frac{\delta\eta}{2(1-\eta)} \qquad and \quad 0 < \eta < 1$$

That is, if we impose $0 < \delta\eta < \frac{2}{3}$ and $0 < \eta < 1$, then our critical assumption $f_{lww} > 0$ will hold. Note that we have the Cobb-Douglas function when $\eta = 1$, while there is perfect substitution when $\eta = \frac{1}{\delta} (> 1)$. Thus, as ρ increases from zero to $\frac{1}{\delta}$, the elasticity of substitution increases steadily from zero to infinity. Our restrictions $0 < \eta\delta < \frac{2}{3}$ and $0 < \eta < 1$ imply an elasticity of substitution below unity ($\sigma < 1$) that decreases steadily with the water-land ratio. As a result, $f_{lww} > 0$ when the substitution between land and water is limited; in other words, when there is sufficient complementarity between the two inputs.

Appendix 2. Proofs of Lemmas 1 to 3 and Proposition

Proof Lemma 1

The sole owner maximizes the lifetime joint profit subject to the evolution of groundwater level:

$$\Pi^*(x_t) = \max_{w_{it}} \int_0^\infty \sum_{i=1}^n [pf(w_{it}, l_i) - c(x_t)w_{it}]e^{-\rho t} \tag{13}$$

$$s.t. \;\; \dot{x}_t = R - \sum_{i=1}^n w_{it}$$

$$x_0 = x(0) > 0$$

$$w_{it} \geq 0$$

$$\mathcal{H}_{it} = \sum_{i=1}^n [pf(w_{it}, l_i) - c(x_t)w_{it}] + \mu_{it}[R - \sum_{i=1}^n w_{it}] \tag{14}$$

$$\mu_{it} = p\frac{\partial f(w_{it}, l_i)}{\partial w_{it}} - c(x_t) \tag{15}$$

$$-c'(x_t)\sum_{i=1}^{n} w_{it} = \rho\mu_{it} - \dot{\mu}_{it} \tag{16}$$

$$\dot{x}_t = R - \sum_{i=1}^{n} w_{it} \tag{17}$$

The transversality condition is given by: $\lim_{t\to\infty}\mu_{it} = 0$.

In the steady state, i.e., when $\dot{\mu}_{it} = 0$ and $\dot{x}_t = 0$, the rent derived from groundwater extraction under the sole owner regime is:

$$\mu_i^{*} = \mu^{*} = -\frac{c'(x^*)\sum_{i=1}^{n} w_i^*}{\rho} = p\,\frac{\partial f(w_i^*, l_i)}{\partial w_i} - c(x^*) \tag{18}$$

By the implicit functions theorem, we obtain:

$$\frac{dw_i^*}{dl_i} = -\frac{p\frac{\partial^2 f}{\partial l_i \partial w_i}}{p\frac{\partial^2 f}{\partial w_i^2} + \frac{c'(x^*)}{\rho}} > 0 \tag{19}$$

Proof Lemma 2

The current value Hamiltonian for each farmer i under the unregulated common pool regime is given by:

$$\mathcal{H}_{it} = pf(w_{it}, l_i) - c(x_t)w_{it} + \mu_{it}\left[R - \sum_{i=1}^{n} w_{it}\right] \tag{20}$$

If we assume interior solution, then the first order conditions are given by:

$$\mu_{it} = p\,\frac{\partial f(w_{it}, l_i)}{\partial w_{it}} - c(x_t) \tag{21}$$

$$-c'(x_t)w_{it} = \rho\mu_{it} - \dot{\mu}_{it} \tag{22}$$

$$\dot{x}_t = R - \sum_{i=1}^{n} w_{it} \tag{23}$$

The transversality condition is given by: $\lim_{t\to\infty}\mu_{it} = 0$.

In the steady state, i.e., when $\dot{\mu}_{it} = 0$ and $\dot{x}_t = 0$, the rent derived from groundwater extraction under the unregulated common pool regime is:

$$\mu_i^{cp} = -\frac{c'(x^{cp})w_i^{cp}}{\rho} = p\frac{\partial f(w_i^{cp}, l_i)}{\partial w_i} - c(x^{cp}) \tag{24}$$

By the implicit functions theorem, we obtain:

$$\frac{dw_i^{cp}}{dl_i} = -\frac{p\frac{\partial^2 f}{\partial l_i \partial w_i}}{p\frac{\partial^2 f}{\partial w_i^2} + \frac{c'(x^{cp})}{\rho}} > 0 \tag{25}$$

Proof Lemma 3

The current value Hamiltonian for each farmer i under the regulated common pool regime is given by:

$$\mathcal{H}_{it} = pf(w_{it}, l_i) - c(x_t)w_{it} - \tau_i w_{it} + \mu_{it}[R - \sum_{i=1}^{n} w_{it}] \tag{26}$$

If we assume interior solution, then the first order conditions are given by:

$$\mu_{it} = p\frac{\partial f(w_{it}, l_i)}{\partial w_{it}} - c(x_t) - \tau_i \tag{27}$$

$$-c'(x_t)w_{it} = \rho\mu_{it} - \dot{\mu}_{it} \tag{28}$$

$$\dot{x}_t = R - \sum_{i=1}^{n} w_{it} \tag{29}$$

The transversality condition is given by: $\lim_{t\to\infty}\mu_{it} = 0$.

In the steady state, i.e., when $\dot{\mu}_{it} = 0$ and $\dot{x}_t = 0$, the rent derived from groundwater extraction under the regulated common pool regime is:

$$\mu_i^\tau = -\frac{c'(x^\tau)w_i^\tau}{\rho} = p\,\frac{\partial f(w_i^\tau, l_i)}{\partial w_i} - c(x^\tau) - \tau_i \qquad (30)$$

By the implicit functions theorem, we obtain:

$$\frac{dw_i^\tau}{dl_i} = -\frac{p\frac{\partial^2 f}{\partial l_i\,\partial w_i}}{p\frac{\partial^2 f}{\partial w_i^2} + \frac{c'(x^\tau)}{\rho}} > 0 \qquad (31)$$

Proof Proposition

Summing the first order condition (8) over i and dividing by the number of farmers n, we have:

$$\frac{1}{n}\sum_{i=1}^{n}\left[p\,\frac{\partial f(w_i^\tau, l_i)}{\partial w_i} - c(x^\tau) + \frac{c'(x^{\tau_i})w_i^\tau}{\rho}\right] - \bar{\tau} = 0$$

By the implicit function theorem, we obtain:

$$\frac{\partial w_i^\tau}{\partial \bar{\tau}} = \frac{n}{pf_{w_i w_i} + \frac{c'(x^\tau)}{\rho}} < 0$$

Differentiating $\frac{\partial w_i^\tau}{\partial \bar{\tau}}$ with respect to landholding l_i results in:

$$\frac{\partial^2 w_i^\tau}{\partial l_i\,\partial \bar{\tau}} = -\frac{npf_{l_i w_i w_i}}{\left(pf_{w_i w_i} + \frac{c'(x^\tau)}{\rho}\right)^2} < 0$$

Tables

Table 1. Choice Experiment Attributes

Attributes	Description
Transparency	Disclose and publicize water use, damage to meters: 1=Yes, 0=No
Meter reading	Institution responsible for reading the meters: 1. Water Management Unit 2. Local Authority
Restriction on irrigated land area	Extent of land restriction in irrigation: 0%, 10%, 20%, 30%
Installation fee	How much would you pay (in Tunisian Dinars per year): 0, 10, 20, 30

Table 2. Example of a Choice Set

	Restriction on land area to be irrigated	Meter reading	Transparency	Installation Fee (TD/year)	Tick the policy you prefer
Policy A	20% of land is not to be irrigated	Water Management Unit	Not Public	20	☐
Policy B	No restriction	Water Management Unit	Water use and damage of meter made public to all farmers every month	30	☐
Policy C	I would like to keep the *status quo* and would not vote for the new policy				☐

Table 3. Summary Statistics

	Mean	Standard deviation
Individual level (sample size=246)		
Gender (1=male)	0.996	
Age	40.615	14.77
Education		
Illiterate	0.18	0.39
Primary school	0.54	0.5
Secondary school	0.22	0.41
College	0.02	0.14
University	0.04	0.19
Cultivated land area(ha)	7.39	6.71
% of land irrigated	0.92	0.202
Land value (TD)	51667.37	62764.49
Currently in GIC	0.03	0.17
Number of private wells	1.05	0.24
Use dripping technology	0.75	0.44
Use sprinkling technology	0.39	0.49
Village level (sample size=28)		
Number of households	472.36	523.1
Number of farms	355.75	319.76
0-2 ha	50.04	44.07
2-4 ha	64.36	52.92
4-6 ha	70.14	90.42
6-10 ha	84.5	88.99
10-20 ha	49.43	50.03
20-50 ha	29.36	39.69
>50 ha	7.93	8.88
Downstream of the dam (1=downstream)	0.86	0.36
Fall of water table from 1990 to 2007 (meters)	18.36	6.78
Mean of well depth (meters)	45.55	9.36

Table 4. Choice Experiment Results without Individual Characteristics

	(1)	(2)	(3)	(4)
ASC	1.33***	1.33***	1.55***	1.62***
	(0.12)	(0.12)	(0.13)	(0.13)
Meter reading by local authority	0.27***	0.09	0.17	0.19*
	(0.07)	(0.11)	(0.12)	(0.12)
Transparency	0.31**	0.31***	0.32**	0.35**
	(0.15)	(0.07)	(0.15)	(0.16)
Irrigated land restriction 10%	0	-0.14	-0.07	-0.03
	(0.09)	(0.09)	(0.10)	(0.10)
Irrigated land restriction 20%	-0.15	-0.11	-0.23**	-0.23**
	(0.11)	(0.10)	(0.11)	(0.11)
Irrigated land restriction 30%	-0.7***	-0.47***	-0.81***	-0.84***
	(0.11)	(0.09)	(0.12)	(0.12)
Fee	-0.01	-0.01**	-0.01*	-0.01**
	(0.01)	0.00	(0.01)	(0.01)
Standard deviation of random coefficient				
Meter reading by local authority		1.28***	1.27***	1.29***
		(0.12)	(0.13)	(0.13)
Transparency	1.93***		2.06***	1.49***
	(0.16)		(0.17)	(0.20)
Correlation between coefficients				
Covariance (Meter reading, Transparency)				1.46***
				(0.22)
N	5736	5736	5736	5736
Prob > LR χ^2	0	0	0	0
Log likelihood	-1732.21	-1819.07	-1686.89	-1667.56

Standard errors in parentheses: * p<0.10, ** p<0.05, *** p<0.01

Table 5. Choice Experiment Results with Individual Characteristics

	(1)	(2)	(3)
Attributes and Interactions			
ASC	25.05***	29.90***	30.62***
	(7.591)	(8.124)	(8.272)
Irrigated land restriction 10%	-0.0678	-0.130	-0.0951
	(0.0932)	(0.102)	(0.100)
Irrigated land restriction 20%	-0.206*	-0.268**	-0.262**
	(0.110)	(0.115)	(0.114)
Irrigated land restriction 30%	-0.699***	-0.798***	-0.829***
	(0.112)	(0.121)	(0.121)
Meter reading by local authority	0.241**	0.146	0.117
	(0.0768)	(0.118)	(0.118)
Transparency	0.325**	2.884**	2.764**
	(0.149)	(1.317)	(1.211)
Transparency*log(land value)		-0.244*	-0.241**
		(0.127)	(0.118)
Fee	-0.00735	-0.00914*	-0.00848*
	(0.00488)	(0.00517)	(0.00511)
Individual characteristics			
% Irrigated land	-0.703	-0.805	-0.806
	(0.508)	(0.553)	(0.581)
Land value (log)	-0.673***	-0.649***	-0.653***
	(0.0890)	(0.0956)	(0.0974)
Factor 1: Awareness of water scarcity	-0.127	-0.189	-0.214
	(0.157)	(0.166)	(0.174)
Factor 2: Awareness of externalities	-0.492***	-0.452***	-0.446***
	(0.116)	(0.123)	(0.132)
Education-primary school	1.070***	1.206***	1.207***
	(0.230)	(0.245)	(0.253)
Education-secondary school and above	0.254	0.396	0.365
	(0.247)	(0.270)	(0.281)
Village Characteristics			
Number of farms in the village (x 1000)	-0.621	-0.626	-0.592
	(0.392)	(0.437)	(0.457)
Land Gini Concentration ratio	-94.75***	-116.5***	-119.9***
	(33.97)	(36.47)	(37.31)
Land Gini Concentration ratio (sq)	103.2***	126.2***	130.3***
	(35.85)	(38.55)	(39.49)
Relative Mean Deviation of well depth distribution	-1.941	-2.352	-2.595
	(1.505)	(1.605)	(1.645)
Downstream	2.411***	2.408***	2.462***
	(0.475)	(0.510)	(0.521)
Downstream* distance to the dam	-0.0175*	-0.0113	-0.0118
	(0.0102)	(0.0111)	(0.0116)
Water table fall during 1990-2007 in meters (log)	1.323***	1.356***	1.393***
	(0.367)	(0.399)	(0.413)
Standard deviation of random coefficient			
Transparency	1.868***	1.965***	1.605***

	(0.159)	(0.170)	(0.247)
Meter reading by local authority		1.246***	1.222***
		(0.138)	(0.135)
Correlation between coefficients			
Covariance (Meter reading, Transparency)			1.172***
			(0.259)
N	5424	5424	5424
LR χ^2	245.88	312.51	339.33
Log likelihood (pseudo in mlogit)	-1522.7458	-1488.3589	-1474.9488

Standard errors in parentheses. $*$ $p<0.10$, $**$ $p<0.05$, $***$ $p<0.01$

Table 6. Marginal Willingness to Pay (WTP) in Tunisia Dinar

	Without individual characteristics			With individual characteristics		
		Confidence Interval at 95% level			Confidence Interval at 95% level	
	Marginal WTP	Lower bound	Upper bound	Marginal WTP	Lower bound	Upper bound
Meter reading by local authority	20.54	-8.68	49.76	13.83	-15.78	43.45
Transparency	37.74	-11.15	86.64	35.88	-880.05	951.81
Irrigated land restriction 10%	-2.85	-22.65	16.94	-11.22	-36.05	13.61
Irrigated land restriction 20%	-23.97	-52.93	4.98	-30.91	-70.27	8.45
Irrigated land restriction 30%	-89.2	-180.61	2.22	-97.72	-216.24	20.79

The marginal willingness to pay is defined as the marginal rate of substitution between the annual fees and a given policy attribute, i.e., $WTP = -\frac{\partial U/\partial Attribute}{\partial U/\partial fee} = -\frac{\beta_{Attribute}}{\beta_{fee}}$. We calculated all the WTP and their significance using the Delta method. Practically, we used the Stata command *wtp*. Note that the policy attribute transparency is interacted with land value, as a result $WTP_{transparency} = -\frac{\partial U/\partial Transparency}{\partial U/\partial fee} = -\frac{\beta_{Transparency} - 0.241 \times log(landvalue)}{\beta_{fee}}$. Variable log(landvalue) is evaluated at the sample mean 10.22.

Figures

Figure 1. Location of Survey Area

Figure 2. Map of water sources in the study area. Source Bachta et al. (2005)

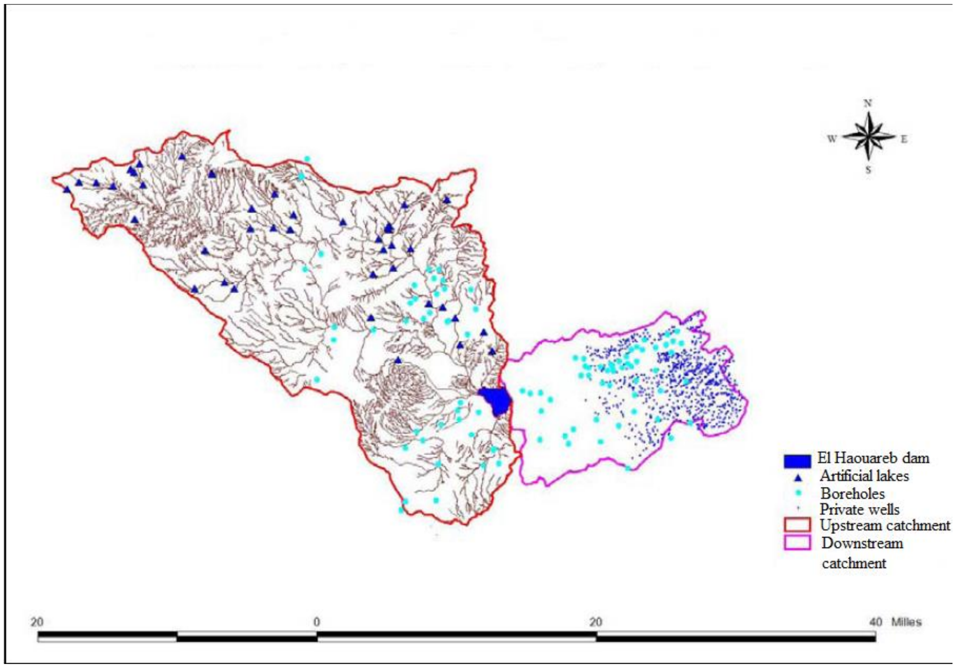

Figure 3. Inequality of land distribution within village

Gini coefficients

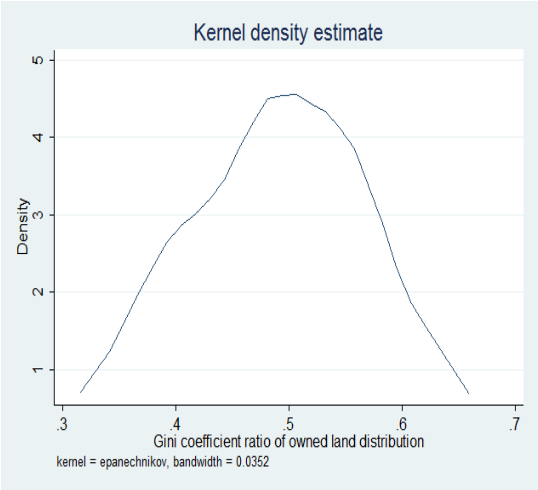

Figure 3a

Relative Mean Deviation

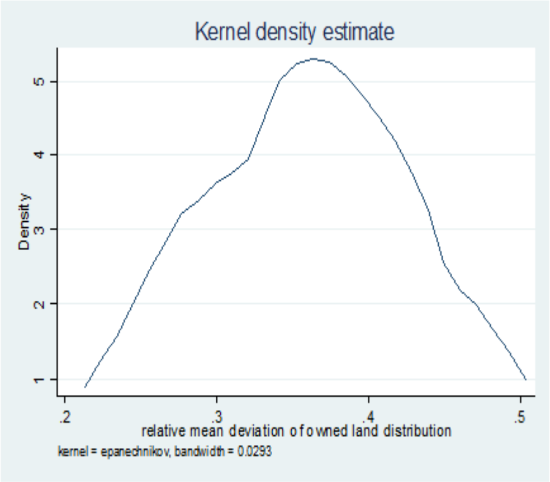

Figure 3b