Resistance to the Regulation of Common Resources in Rural Tunisia

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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 sourced in the manner in which heterogeneity might determine the distributional impact of different management regimes.

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1 Introduction

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 group or sub-group 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 some 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, Johnson and Libecap [1982, p. 1006] have showed 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, 2003] have extensively analyzed this link between heterogeneity and the resistance to effective regulation of common resources. For example, Baland and Platteau [1998, p. 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 atransparent 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 and Platteau [1998]. In the case of farmlands overlying aquifers in isolated rural areas, the ownership of the associated farmland confers an

[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, p. 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.

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 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.[2] 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 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 Heterogenous 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 a 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 sub-group of users.

Here we set out the specifications required to achieve these results. Consider an economy where heterogeneous farmers $i = 1,...,n$ make water extraction decision 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; $f(.,.)$ represents the production function that

[2] 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.

transforms land inputs l_i (assumed constant over time but varies across farmers) and water extraction w_{it} into agricultural output. 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. $f_{w_i l_i} > 0$. Finally, following Bardhan et al. [2007], we assume that $f_{l_i w_i w_i} < 0$. This assumption is fairly innocuous since it is satisfied by the Cobb-Douglas function. 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. In addition extraction costs are convex in x, i.e. $C_{xx} > 0$ (and $c_{xx} > 0$).

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:

$$\begin{aligned} \Pi^*(x_t) &= \max_{w_{it}} \int_0^{\infty} \sum_{i=1}^{n} [pf(w_{it}, l_i) - c(x_t) w_{it}] e^{-\rho t} \\ \text{s.t. } \dot{x}_t &= R - \sum_{i=1}^{n} w_{it} \\ x_0 &= x(0) > 0 \\ w_{it} &\geq 0 \end{aligned} \tag{1}$$

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:

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

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

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

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, 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 in each plot of land i), any externality that would occur will be internalized. This will result in socially efficient water extractions.

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 used only for purposes of irrigating the overlying agricultural lands.

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

$$\begin{aligned} \Pi_i^{cp}(x_t) &= \max_{w_{it}} \int_0^{\infty} [pf(w_{it}, l_i) - c(x_t)w_{it}]e^{-\rho t} \\ \text{s.t. } \dot{x}_t &= R - \sum_{i=1}^{n} w_{it} \\ x_0 &= x(0) > 0 \\ w_{it} &\geq 0 \end{aligned} \tag{4}$$

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 Burt [1993]). As usual in this literature, this set-up produces the sort of behavior that leads to the inefficient outcome that characterizes the tragedy of the commons.

Lemma 2:

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

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

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

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

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, 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.[3] This heterogeneous capacity to make beneficial use determines the distribution of benefits from the common resource.

[3] This simple distributional outcome results from the assumption that water extraction and land holding are complementary inputs in agricultural production, and the only source of welfare from the use of the aquifer in this setup. 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 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.

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.[4]

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.

$$\begin{aligned} \Pi_i^{\tau}(x_t) &= \max_{w_{it}} \int_0^{\infty} [pf(w_{it}, l_i) - c(x_t)w_{it} - \tau_i w_{it}]e^{-\rho t} \qquad (7) \\ \text{s.t. } \dot{x}_t &= R - \sum_{i=1}^{n} w_{it} \\ x_0 &= x(0) > 0 \\ w_{it} &\geq 0 \end{aligned}$$

Lemma 3:

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

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

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

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

[4] The terms "first-best" and "second best" in this paper follow the environmental regulation literature. The former refers to a *feasible* (at least theoretically) regulatory instrument that ensures the maximization of joint profit across individuals (for instance the imposition of an individualized Pigouvian tax among heterogeneous agents), while the latter refers to an *achievable* regulatory instrument that falls short of maximizing the joint profit across individuals (for instance a uniform tax imposed on heterogeneous agents).

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 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 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 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)—so 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, since most of future water impacts are 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-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 reference to the introduction of a second-best uniform water-charging system in place of the heterogeneous charge outlined above (that is first-best).

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 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 ones. The effect is that some of the efficiency gain is achieved, through a second-best regime, but only with a significant redistributional impact.

Proposition:

Given farmers' heterogeneity in the size of individual landholdings l_i and common ownership of but differential optimal use of the water resource w_i, and further given that $f_{l_i w_i w_i} < 0$, then 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: $\partial w_i^\tau / \partial \bar{\tau} < 0$ and $\partial^2 w_i^\tau / \partial l_i \partial \bar{\tau} > 0$.

Proof:

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:

$$\frac{\partial w_i^\tau}{\partial \bar{\tau}} = \frac{n}{pf_{w_i w_i} + \dfrac{c'(x^\tau)}{\rho}} < 0 \tag{12}$$

Differentiating expression (12) with respect to landholding l_i gives:

$$\frac{\partial^2 w_i^\tau}{\partial l_i \partial \bar{\tau}} = -\frac{npf_{l_i w_i w_i}}{\left(pf_{w_i w_i} + \dfrac{c'(x^\tau)}{\rho}\right)^2} > 0 \tag{13}$$

□.

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 words, as uniform groundwater charge increases, water extraction declines disproportionately more for farmers with greater landholdings. 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 towards 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.[5] It has made 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.

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 becomes the major water resource in the Kairouan plain. This groundwater is then 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 from -42 meters in 1986 to -52 meters in 2006. The table is expected to fall to -60 meters by 2015.

3.1.2 Institutional Context

Collective management of irrigation water by local tribes 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 as 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.[6] 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 was governed by a centralized agency (*Office de Mise Valeur* or

[5] 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 land area to be irrigated.

[6] For instance, the *associations of oasis owners* created between 1912 and 1920, and the *associations of special interest in hydraulics* instituted in 1933 whose functions were similar to the modern Association of Collective Interest (AIC) and Group of Collective Interests (GIC) (Al Atiri [2007]).

OMV) in each *gouvernorat.*

Towards the end of the 1980s, the decentralization of the management of the irrigation schemes affirmed the State's willingness to disengage from direct management of the agricultural sector.[7] This shift resulted in the creation of local collective water management schemes, namely the Association of Collective Interest (AIC) which later in 1999 became known as Group of Collective Interests (GIC). 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.[8]

The alternative to GIC-based water management has been private initiative 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, transparent and substantial 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.

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

[7]In 1989, the OMVs were replaced by regional offices of the Department of Agriculture in charge of agricultural development in each (*Commissariats Régionaux de Développement Agricole,* CRDA). The *Office de Mise 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.

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

for monitoring and enforcement have proved 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' willingness to pay 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.[9] 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 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 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.*"

The choice experiment then 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 alternative credible system) physical restrictions on water use over designated land areas. The status quo is described as the current context, in which constraints prevent any of these characteristics from obtaining. It is expected that relaxing these constraints will aid in inducing acceptance of an institution by users (Ostrom [2000]). A credible regime would be expected to be one that has 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 the Agriculture, and the Regional Commission for Agricultural Development, CRDA of Kairouan), and considering the low literacy rate among farmers, we set out the four policy attributes of interest shown in Table 1.

[9]To prevent strategic voting, respondents are informed that "*the majority rule will be applied on the final voting outcome. 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.*"

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 fee would you pay (in Tunisian Dinars per year): 0, 10, 20, 30

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* indicates the character of the agency the farmers would prefer to be responsible for monitoring the meters and 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. The third attribute relates to the *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). 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. This attribute allows us to estimate welfare changes in monetary term. The indication 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 eight choice sets. Table 2 shows the example of a choice set.

Table 2: Choice Set Example

	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 don't vote for the new policy				☐

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.[10] In May and June 2007, the actual choice experiment was conducted with a sample 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. Within each group, farmers were randomly selected. 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 how to make choices.[11] The respondents were also provided with information on the current state of the water table and its likely future negative 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 towards the environment and the use of water in the region.[12] The information collected in these sections is required to control for heterogeneity among farmers and 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. A map of the sampled villages is attached in Figure (A1) in Appendix 2. The villages in the West and North West of El Haouareb Dam are located in the upstream part of the aquifer. These include villages in the town of Hafouz and some villages in the town of Chebika. The distance of each village to the dam is also collected.

[10]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.

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

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

3.3 Choice experiment: Model specification

We specify three different choice models: multinomial logit, conditional logit and mixed logit. While multinomial logit model is a standard limited dependent variable model, conditional logit model is used to control for individuals' fixed effects as each respondent completes eight choice sets. However, both multinomial logit and conditional logit are subject to the assumption of independence from irrelevant alternatives (IIA) which may be violated either due to nested choices or unobserved variables. The IIA assumption postulates that the odds between two alternatives is independent of the change in an third alternative. Put differently, this assumption predicts "that a change in the attributes of one alternative changes the probabilities of the other alternatives proportionately" (Train [1998]). Moreover, it is reasonable to believe that different individuals may have different preferences with regard to those attributes. Mixed logit is a flexible model that obviates these 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 coefficients vary randomly across individuals representing each individual's tastes. The utility under a mixed logit model is written as:

$$U_{nj} = \alpha Z_n + \beta_n' X_{nj} + \varepsilon_{nj} \tag{14}$$

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; 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 of 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 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 will estimate the mixed logit model assuming the variable coefficients have normal distribution.

We will first analyse how policy attributes alone affect farmers' choice. Then, we will control for farmers' individual characteristics, i.e. variables Z_n in equation (14). As the logit model identifies 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.

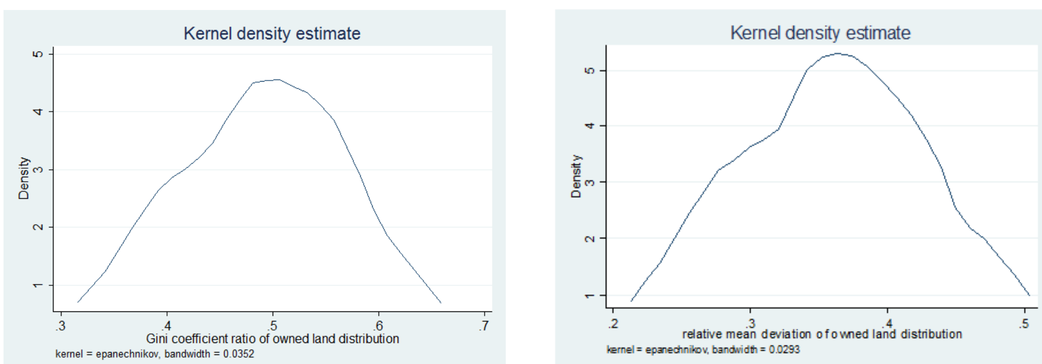
4 Empirical results

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, Kairouan and El Batan 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. 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 is listed in Table (A1) in Appendix 1.

The information collected on land distribution within each village allows us to measure inequality within village. We also measure a similar inequality indicator based on well depth. As the data on land distribution are grouped observations[13], we measure land distribution inequality based on the method proposed by Kakwani and Podder [1976].[14] To demonstrate the important role that heterogeneity plays in the management of the common resource, we also acquired information on the distribution of landholdings in the area. The inequality measurements are shown in Figure 1. 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 of landholding inequality level across villages.



(a) Gini coefficients

(b) Relative Mean Deviation

Figure 1: Inequality of land distribution within village

4.2 Choice experiment: Estimation results on the WTP for Uniform Water-Charging System

Table 3 presents the results of the various choice models controling 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

[13]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.

[14]A brief introduction of this method is included in Appendix 3. Please refer to Kakwani and Podder [1976] for details of this method.

takes value 1 for either of the policy options A and B, and equals 0 for the 'status quo' option. The first two columns report the results from the multinomial logit and conditional logit models while column (3)-(5) present the mixed logit results where some policy attributes coefficients are treated as random coefficients. Correlation between random coefficients is allowed in Column (6). Hereafter, we summarize the main results from Table 3.

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 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 to 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. Since 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.

Considering the possibility that different farmers may have differing preferences over transparency and accountability, we estimate various mixed logit models in Column (3)-(6), where the coefficients for these two variables are assumed random and normally distributed. In Column (3) and (4), we allow only one random parameter for either *transparency* or *meter reading* separately in each specification. The average coefficient for each variable keeps the same sign as in the multinomial or conditional logit model. In Column (3), the average coefficient for variable *transparency* is 0.307, slightly higher than the ones when parameter constancy was assumed. 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 (4) presents results of the mixed logit model assuming 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' preference regarding this policy attribute. A similar result obtains when both *meter reading* and *transparency* are treated as random but uncorrelated coefficients in Column (5). Nevertheless, if we allow both coefficients be correlated (Column (6)), the average coefficient on *meter reading* turns larger and significant at 10%, with 56% of respondents indicating 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

Table 3: Choice Experiment Results without individual characteristics

	(1) Multinomial logit	(2) Conditional logit	(3) Mixed logit	(4) Mixed logit	(5) Mixed logit	(6) Mixed logit
ASC	-0.350 ***	1.207 ***	1.328 ***	1.330 ***	1.545 ***	1.620 ***
	(0.123)	(0.112)	(0.124)	(0.119)	(0.133)	(0.134)
Meter reading by local authority	0.167 ***	0.149 **	0.265 ***	0.093	0.172	0.193 *
	(0.084)	(0.064)	(0.074)	(0.109)	(0.116)	(0.115)
Transparency	0.298 ***	0.246 ***	0.307 **	0.305 ***	0.316 **	0.354 **
	(0.100)	(0.062)	(0.149)	(0.067)	(0.154)	(0.160)
Irrigated land restriction 10%	0.032	-0.067	-0.002	-0.138	-0.071	-0.027
	(0.121)	(0.079)	(0.089)	(0.088)	(0.098)	(0.096)
Irrigated land restriction 20%	0.040	-0.063	-0.152	-0.113	-0.227 **	-0.225 **
	(0.135)	(0.094)	(0.106)	(0.098)	(0.110)	(0.110)
Irrigated land restriction 30%	-0.422 ***	-0.396 ***	-0.704 ***	-0.465 ***	-0.812 ***	-0.837 ***
	(0.173)	(0.086)	(0.107)	(0.092)	(0.116)	(0.115)
Fee	-0.005 **	-0.008 **	-0.006	-0.010 **	-0.009 *	-0.009 **
	(0.002)	(0.004)	(0.005)	(0.004)	(0.005)	(0.005)
Standard Deviation of Random Coefficient						
Meter reading by local authority				1.275 ***	1.274 ***	1.287 ***
				(0.118)	(0.125)	(0.128)
Transparency			1.930 ***		2.063 ***	1.486 ***
			(0.157)		(0.174)	(0.196)
Correlation between coefficients						
Corr(meterreading,transparency)						1.464 ***
						(0.215)
N	5736	5736	5736	5736	5736	5736
Prob > LR χ^2	0.000	0.000	0.000	0.000	0.000	0.000
log likelihood	-3910.119	-1881.360	-1732.209	-1819.071	-1686.891	-1667.561

corroborates our earlier discussion concerning the lack of credibility of the current GIC management.

Based on results in Column (6) in Table 3, 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 180 Tunisian Dinar (TD) to shift to the new management regime targeted at stabilizing the level of groundwater. In relative terms, this represents 2.6% of the median farmer's income.[15] On average farmers are willing to pay an additional TD 39 for a *transparent* regime.[16] And, farmers are also willing to pay an extra TD 21.4 for the local authority to guarantee *accountability*. Finally, farmers would reduce their contribution by more than half, i.e. TD 93, should irrigated land restrictions be introduced and exceed 30%.[17]

5 Discussion: The impact of heterogeneity - resistance to regulation

Our discussion in Section 4 has indicated that farmers support a move toward more efficient resource management institutions—they would prefer in 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 16, fully 40% of farmers in the survey refused to support the move toward a more transparent mechanism for monitoring resource usage. Since there is little prospect for the introduction of credibility in a regime 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 4, in which we include observed heterogeneity at 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), variables signaling the farmers' attitude 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 inequality 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-shape relationship). The regression models include a multinomial logit model (Column (1)) and various mixed logit model specifications (Column (2)-(4)). The model specifications differ in that in Column (2) we control for random

[15] 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.

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

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

Table 4: Choice Experiment Results with individual characteristics

	(1) Multinomial logit	(2) Mixed logit	(3) Mixed logit	(4) Mixed logit
Attributes and Interactions				
ASC	1.540***	25.05***	29.90***	30.62***
	(0.279)	(7.591)	(8.124)	(8.272)
Meter reading by local authority	0.194*	0.241**	0.146	0.117
	(0.0880)	(0.0768)	(0.118)	(0.118)
Transparency	0.308***	0.325**	2.884**	2.764**
	(0.105)	(0.149)	(1.317)	(1.211)
Transparency*log(land value)			-0.244*	-0.241**
			(0.127)	(0.118)
Irrigated land restriction 10%	-0.000345	-0.0678	-0.130	-0.0951
	(0.125)	(0.0932)	(0.102)	(0.100)
Irrigated land restriction 20%	-0.0365	-0.206*	-0.268**	-0.262**
	(0.140)	(0.110)	(0.115)	(0.114)
Irrigated land restriction 30%	-0.468***	-0.699***	-0.798***	-0.829***
	(0.181)	(0.112)	(0.121)	(0.121)
Fee	-0.00267	-0.00735	-0.00914*	-0.00848*
	(0.00228)	(0.00488)	(0.00517)	(0.00511)
Individual characteristics				
% Irrigated land	0.0312	-0.703	-0.805	-0.806
	(0.0477)	(0.508)	(0.553)	(0.581)
Land value (log)	-0.00321	-0.673***	-0.649***	-0.653***
	(0.00699)	(0.0890)	(0.0956)	(0.0974)
Factor 1: Awareness of water scarcity	-0.0295	-0.127	-0.189	-0.214
	(0.0917)	(0.157)	(0.166)	(0.174)
Factor 2: Awareness of externalities	-0.180*	-0.492***	-0.452***	-0.446***
	(0.0777)	(0.116)	(0.123)	(0.132)
Education-primary school	-0.0304	1.070***	1.206***	1.207***
	(0.0350)	(0.230)	(0.245)	(0.253)
Education-secondary school and above	-0.0257	0.254	0.396	0.365
	(0.0372)	(0.247)	(0.270)	(0.281)
Village Characteristics				
Number of farms in the village	-0.0000521	-0.000621	-0.000626	-0.000592
	(0.0000395)	(0.000392)	(0.000437)	(0.000457)
Land Gini Concentration ratio	-7.990***	-94.75***	-116.5***	-119.9***
	(1.040)	(33.97)	(36.47)	(37.31)
Land Gini Concentration ratio (square)	8.127***	103.2***	126.2***	130.3***
	(1.237)	(35.85)	(38.55)	(39.49)
Relative Mean Deviation of well depth distribution	-0.343***	-1.941	-2.352	-2.595
	(0.110)	(1.505)	(1.605)	(1.645)
Downstream	0.0513	2.411***	2.408***	2.462***
	(0.0548)	(0.475)	(0.510)	(0.521)
Downstream* distance to the dam	0.000996	-0.0175*	-0.0113	-0.0118
	(0.00116)	(0.0102)	(0.0111)	(0.0116)
Watertable fall 1990-2007 (m), log	0.0300	1.323***	1.356***	1.393***
	(0.0330)	(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				
Corr(Meterreading-local, Transparency)				1.172***
				(0.259)
N	5424	5424	5424	5424
LR χ^2		245.88	312.51	339.33
Log likelihood (pseudo in mlogit)	-3144.2	-1522.75	-1488.36	-1474.95

Standard errors in parentheses. $*$ p<0.05, $**$ p<0.01, $***$ p<0.001

coefficients for *transparency* alone whereas the parameters of both *transparency* and *meter reading* are allowed to vary in Column (3). In Column (4), we further allow for the correlation between *transparency* and *meter reading*. As both standard deviations and correlation between random coefficients are significant in addition to a larger likelihood value, we consider the specification presented in Column (4) as a better fit and we therefore only discuss its results here. Besides the finding that the policy attributes have qualitatively the same effects on farmers' choice as in Table 3, we make the following observations regarding the impact of heterogeneity on support for a move to an effective resource management regime.

First, at the village level, we find that landholding inequality does have an impact on the level of support for regulatory regime change. 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 (4), the marginal effect of the land Gini coefficient at the mean Gini coefficient on the willingness to pay for the policy change is 7.63.[18] This indicates that a 0.1 unit increase in the mean value of the land Gini coefficient from 0.49 to 0.59, enhances the probability that the average land holder supports the move to the new policy regime by 76.3%. This we find to be a somewhat subtle indicator of the distributive consequences of effective management. When landholding is more skewed, this means that 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. Since each farmer has one WTP included in the average (unweighted by landholdings), the increase in support can be seen as support by the average user for such a redistribution of benefits (as well as management).

This supposition is supported by the fact that farmers with larger landholdings in the irrigation district (i.e. with greater proportion of irrigated land)[19] tend to be more reluctant to support the move to the new regime, as suggested by the negative sign of the marginal coefficient on *log(land value)*. [20] 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 from the current water management scheme, and hence less supportive of the move to the new one.

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. Further education is not significant, indicating that it does not take much education to render apparent the benefits of effective regulation. Moreover, farmers' environmental awareness and concern has a positive impact: lower scores—which indicate a higher degree of environmental awareness—promote regime change.[21] 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

[18]The marginal effect of land Gini Concentration ratio in a logit model is calculated as:
$f(\beta X)\beta = \frac{exp(\beta X)}{1+exp(\beta X)}\beta = \frac{exp((-119.9+2*130.3*0.4900227)*0.4900227)}{1+exp((-119.9+2*130.3*0.4900227)*0.4900227)} * (-119.9 + 2*130.3*0.4900227) = +7.63.$

[19]Usually rich farmers grow more olive trees and other water demanding crops such as water melon, tomatoes, etc.

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

[21]In the farming household survey, we asked ten questions about farmers' general attitude towards water conservation using a Lickert scale. 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.

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.[22] 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 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.[23]

In summary, the result from our survey demonstrates 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 are most likely to lie in the heterogeneity that exists across current users. Although (as would be expected) there is support in 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) will be the group who experience the greatest incidence of the costs from 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, deriving 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. And, despite the existence of a 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 aggregate to support the adoption of such an effective regime. The majority of users is willing to pay for the adoption of an effective system, exhibiting 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

[22]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.

[23]This result seems puzzling. While it may not be 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 $downstream * distancetothedam$, we find both coefficients are significantly positive. This fact may be resulted from the local landscape and its unique geological environment. As land inequality has positive effect on villagers' preference on 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 preference on regime change.

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.[24] 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. We find in our study 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.

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 less-benefited by 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 (or support) to 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-in to the process of regulatory change.

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

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Appendix 1: Summary Statistics

Table A1: 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	
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 watertable from 1990 to 2007 (meters)	18.36	6.78
Mean of well depth (meters)	45.55	9.36

Appendix 2: Map of Merguellil

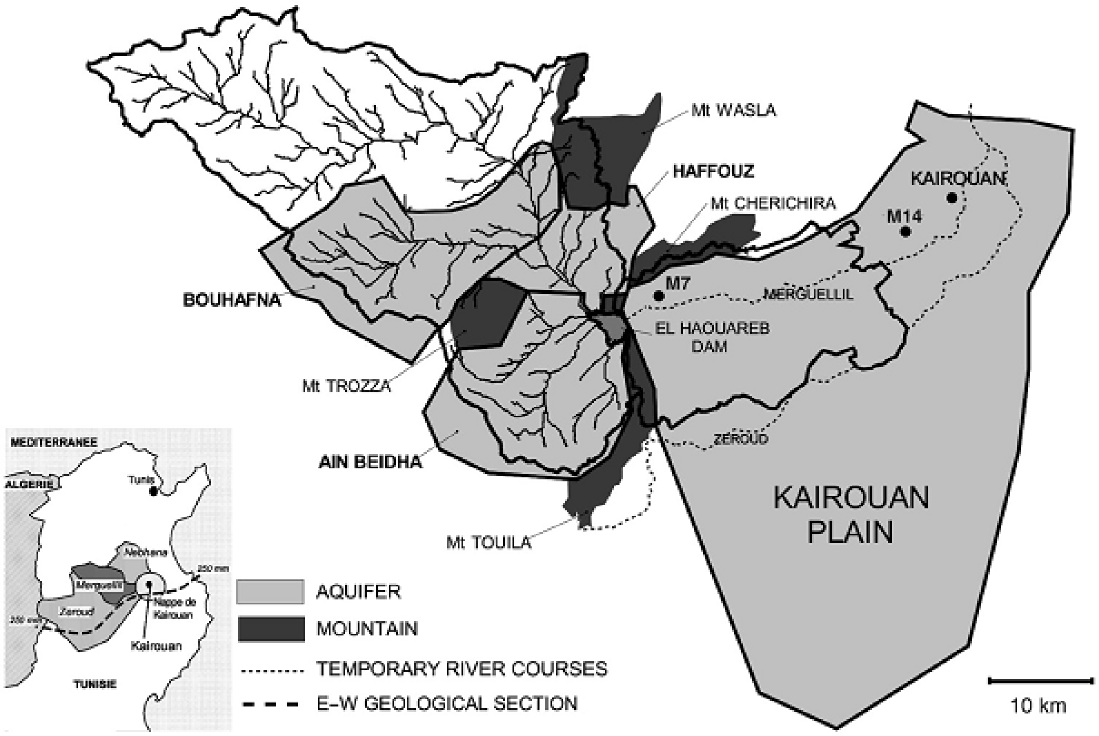

Figure A1: Location of Survey Area. Cited from Al Atiri[2006]

Appendix 3: Method to measure inequality from grouped observations

This appendix introduces briefly the method of using grouped observation to calculate inequality measurement first developed by Kakwani and Podder [1976].

Suppose a positive variable X of a family is a random variable with probability distribution function $F(x)$, density function $g(x)$, and mean μ. The first moment distribution function of X is given by

$$F_1(x) = \frac{1}{\mu}\int_0^x Xg(X)dX$$

The Lorenz curve is the relationship between $F(x)$ and $F_1(x)$. The curve is shown in Figure A2. The equation of the line $F_1 = F$ is called egalitarian line.

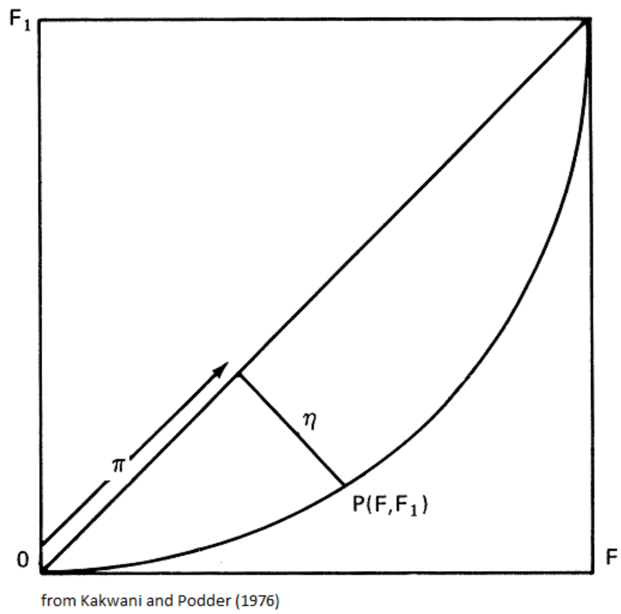

Figure A2: Lorenz curve

Let P be any point on the curve with co-ordinates (F, F_1), with $\pi = \frac{1}{\sqrt{2}}(F+F_1)$ and $\eta = \frac{1}{\sqrt{2}}(F-F_1)$. Then η will be the length of the ordinate from P on the egalitarian line and πwill be the distance of the ordinate from the origin along the egalitarian line. Since the Lorenz curves lie below the egalitarian line, $F_1 \leq F$ which implies $\eta \geq 0$. Further, if X is always positive, the above equation implies η to be less than or equal to π.

The equation of the Lorenz curve in terms of π and η can now be written as:

$$\eta = f(\pi),$$

where π varies from zero to $\sqrt{2}$.

We can write the Lorenz curve functional form as:

$$\eta = a\pi^{\alpha}(\sqrt{2}-\pi)^{\beta}, \qquad a > 0, \alpha > 0, \beta > 0 \tag{15}$$

when $\alpha = \beta$ the Lorenz curve has a symmetric shape, with the value of η at π and $(\sqrt{2} - \pi)$ be equal for all values of π.

In the empirical application, we estimate F and F_1 using the grouped observations of land distribution, calculate $\hat{\pi}$ and $\hat{\eta}$, and regress $log(\hat{\eta})$ on $log(\hat{\pi})$ and $log(\sqrt{2} - \hat{\pi})$ according to equation (15) to obtain the estimates $\hat{a}$, $\hat{\alpha}$ and $\hat{\beta}$, which can be substituted into equation (16) and (17) to determine the Gini Concentration Ratio (CR) and Relative Mean Deviation (T) of land distribution:

$$\begin{aligned} CR &= 2\int_0^{\sqrt{2}} f(\pi) d\pi \\ &= 2a(\sqrt{2})^{1+\alpha+\beta} B(1+\alpha, 1+\beta) \end{aligned} \tag{16}$$

$$\begin{aligned} T &= \frac{1}{2\mu}\frac{1}{N}\sum_{i=1}^{N}|x_i - \mu| \\ &= (\sqrt{2})^{1+\alpha+\beta}\frac{a\alpha^{\alpha}\beta^{\beta}}{(\alpha+\beta)^{\alpha+\beta}} \end{aligned} \tag{17}$$

where, $B(1+\alpha, 1+\beta)$ is the Beta function.