Water Policy 14 (2012) 147–160

Unauthorized groundwater use: institutional, social and ethical considerations

Lucia De Stefano* and Elena Lopez-Gunn

Water Observatory, Botín Foundation, Departamento de Geodinámica, Facultad de Ciencias Geológicas, Ciudad Universitaria, Universidad Complutense de Madrid, 28040 Madrid, Spain
**Corresponding author. E-mail: luciads@geo.ucm.es*

Abstract

In many areas of the world, particularly in arid regions or in areas experiencing population growth, there is increased competition over scarce water resources. This is likely to increase in the future due to continued population growth, urban expansion and the challenge of the impact of climate change on water resource availability. In this context, groundwater is likely to play a pivotal role in facing water scarcity. When different users share a common-pool resource, basic rules are usually established to manage access to the resource and ensure balance between demand and supply. Water authorities worldwide are increasingly paying added attention towards regulating the use of groundwater because of its strategic value, e.g. in times of drought or as a natural reserve. In the case of groundwater, although regulatory measures exist, they are often difficult to enforce. This paper explores the situation with a discussion of two aspects: first (and in line with this special issue on water ethics), an examination of the fundamental individual values that underpin behavior in relation to water use, and second, an investigation of the typologies of unauthorized water use, its main potential impacts, potential root causes and reflections on imperfect institutions and social norms.

Keywords: Groundwater; Illegal use; Regulation; Spain

1. Introduction

In many areas of the world, and particularly in arid regions, there is increased competition over scarce water resources. This is likely to increase in the future due to continued population growth, an increase in living standards, urban expansion and the challenge of the impact of climate change on water resource availability. In this context, groundwater is likely to play a pivotal role in facing water scarcity due to its still partially unexploited potential and its intrinsic resilience to rainfall variability.

Over the last decades, groundwater use has experienced a spectacular increase over the entire world, enabling the development of formerly depressed areas. This ‘silent revolution’ was led by millions of

doi: 10.2166/wp.2012.101

individuals who drilled wells to access groundwater to feed different economic activities (Giordano & Villholth, 2007; Llamas & Garrido, 2007; Llamas *et al*., 2007; Llamas & Martinez-Cortina, 2009). When different users share a common-pool resource[1], basic rules are usually established to manage access to that resource and ensure balance between demand and supply. This becomes particularly key when, as in the case of groundwater, the resource has a strategic value and the viability of its exploitation is under threat. Increasingly, for this reason, water authorities worldwide are paying added attention to regulating or, at least, tracking the use of groundwater. Institutions devised to manage common-pool resources like groundwater, however, face at least two main problems: overuse or even destruction of the resource itself because one person's use subtracts from the benefits that other could get from it; and free-riding in water abstraction, due to the difficulty or cost of excluding some individuals from access to the resources (Dietz *et al*., 2002). Hence, it is no surprise that 'anarchy' or 'administrative chaos' are some of the words used in the literature to define past attempts to regulate groundwater abstraction, suggesting at least a partial failure in the control of groundwater development (Shah, 2008).

One of the key roles of water authorities worldwide is to regulate and plan water resource use to ensure its long-term viability and the compatibility of a series of co-existing uses, whilst maintaining the functionality and good status of water-dependent ecosystems. A strict legal compliance is no guarantee of success in ensuring a balance of demand and supply or maintenance of good water status. Indeed, legal instruments can be inadequate or insufficient to achieve their stated objectives of resource protection and long-term sustainability. Nonetheless, laws are one of the instruments available to an administration to manage common-pool resources such as water, and uncontrolled water abstraction can undermine the effectiveness of official regulatory and planning efforts. Indeed, such intense abstraction operates outside the formal regulatory framework and is thus difficult to internalize or account for in long-term resource planning. The existence of up-to-date inventories of groundwater users appears to be a basic prerequisite for a public administration to foster or support other non-regulatory measures that could enhance law compliance (Gouldson *et al*., 2008). Despite this, there is evidence of a significant volume of unauthorized or informal water abstraction. In Europe, a report by the European Academies Science Advisory Council (EASAC, 2010) concluded that, in Southern European Union Member States (SEUMS), 'a common concern is the rapid growth in the number of users of groundwater, which has, in many parts, led to a significant unregulated community of users. In some parts of the SEUMS, these unregulated users are in number equal to the regulated sector and make a similar level of demand' (EASAC, 2010: 1). In 2010, a conference of the European Commission on unauthorized water usage in agriculture provided an interesting picture of the challenges of regulating water use in Europe (Dworak *et al*., 2010). Estimates suggest that unauthorized water use can possibly be larger than authorized use in several regions of the EU, particularly in the more arid and semi-arid southern Member States. For example, on the island of Malta in 2007, official sources acknowledged an unlicensed groundwater abstraction of 18.5 million m^3/yr, while authorized pumping accounted for 15 million m^3/yr (Times of Malta, 2008). In 2005, the former Spanish Ministry for the Environment estimated that in Spain there were about 510,000 illegal wells (WWF, 2006a). This could mean an illegal water extraction

[1] 'A common-pool resource is a valued natural or human-made resource or facility that is available to more than one person and subject to degradation as a result of overuse. […]. When no property rights define who can use a common-pool resource and how its uses are regulated, a common-pool resource is under an open access regime' (Dietz *et al*., 2002; p. 18).

of about 3,600 million m^3/yr, representing 45% of the total amount of water pumped from aquifers per year (WWF, 2006a). Other sources (Llamas *et al*., 2001) estimate that in 2001 there were about 2 million wells in Spain, out of which 90% were illegal or in a legal 'limbo' (not registered even if they could have been registered).

Ultimately, unauthorized water abstraction can erode the security of access for users with existing formal water property rights, such as suppliers, farmers, industries and individuals abstracting water for domestic use. In addition, widespread unauthorized groundwater abstraction can have substantial negative environmental impacts such as degradation of groundwater-fed wetlands and alteration of river–aquifer dynamics. In many cases, the decrease in quantity goes hand in hand with a decrease in quality, due to saline intrusion or an increased concentration of pollutants (e.g. fertilizers and pesticides). Unauthorized water extraction can also be associated with other mirror practices, such as unauthorized transformation of protected areas or common lands into irrigated arable land.

This paper focuses on the reasons behind non-compliance of groundwater regulation of water use for agriculture in industrialized countries with well-developed and mature water economies. It draws particularly from the experience of Spain, where evidence suggests – as will be analyzed in this paper – that unauthorized groundwater use is a highly complex phenomenon, sometimes rooted in cultural and ethical constructs that influence the collective and individual behavior of groundwater users. In this sense, Spain exemplifies legal conundrums and cultural mindsets, as an example that might be relevant to other arid and semi-arid countries, or to other countries facing widespread unauthorized groundwater abstraction.

This limitation of our scope to agricultural water use in industrialized regions is justified by the need to circumscribe the discussion to a socio-economic context that is exempt from often sensitive considerations in emerging economies or developing countries, where the unauthorized access to water or customary use – for drinking, grazing or cultivating – is fundamental to livelihoods and to the subsistence of many water users. In contrast, in the case of industrialized agriculture, although it can represent an economic constraint, this lack of access to water does not have the same degree of life-threatening urgency that can be found in less developed economies.

In order to explore technical, cultural and ethical reasons for the potential failure or success of current regulatory efforts of groundwater in the above-mentioned context, this paper first briefly describes and analyses the most common typologies of unauthorized use and their potential societal and environmental impacts. Second, the paper analyzes the possible root causes of unauthorized groundwater abstraction by dwelling on ethical and value parameters for human behavior in natural resource use. Finally, the paper concludes by offering some practical paths to facilitate effective and equitable groundwater access and use.

2. Typologies of unauthorized groundwater use

The need for regulation of groundwater encompasses at least two aspects: first, user inventories, which can be backed up by licenses or by water rights, are necessary to keep track of groundwater abstraction; and, second, rules on how to use the resource are needed to pre-empt or tackle groundwater degradation, and to protect users (while ring-fencing environmental functions) from third-party effects and potential damages. The second of these (the planning and regulating of groundwater use) cannot occur without the first. Indeed, without a proper register and monitoring of water abstraction, water

use planning and actions to influence consumption patterns are very difficult to implement. Take for example the application of subsidies and how these impact on patterns of land and water use. The example of the Upper Guadiana Basin in central Spain described in Martínez-Santos *et al.* (2008) shows that unauthorized irrigated farms are administratively 'invisible' and therefore not included in any incentives programs, whilst these users may actually be at the root of the problem targeted.

In general, water use is regulated through the allocation of formal water rights. The nature of water rights varies greatly: in some cases they are owned by the state, in others they are private rights, referred to in different jurisdictions as licenses, concessions, permits, access entitlements, or allocations. In spite of this diversity, a number of basic attributes of water rights can be identified, and together these attributes circumscribe the extent of the access, use and control rights conferred on the holder of the water right (Table 1). These attributes can be grouped into those describing the resource (e.g. quantity and quality of the water, the source and location), the type of use (e.g. use and duration) and the management and administration of the right (ownership and transfer, security and enforcement) (Le Quesne *et al.* 2007).

The types of infraction associated with unauthorized water usage are strongly related to the specific water regulations in each country (Dworak *et al.*, 2010) and, even within the same country, the typology of unauthorized water use can be very broad. Taking into account the generic attributes of water rights described in Table 1 and using Spain as an example, it is possible to outline some general cases of non-compliance that are likely to put significant pressure on water resources.

2.1. Wells drilled and exploited in 'closed aquifers'

Sometimes wells are exploited without applying for authorization from the competent water authority. In the case of Spain, this situation is typical in areas where groundwater resources are declared legally overexploited. This means that an aquifer is closed by law, i.e. the competent water authority cannot grant new concessions because resources are already fully, if not over-allocated (Martínez-Santos

Table 1. Main attributes of water rights.

Attribute	Description
Quantity	The amount of water the holder of the right may abstract
Quality	The quality of the water to be abstracted or disposed of
Source	The specific resource and location from which the right is awarded
Timing	Restrictions on the time that the right applies, i.e. times that the volume may be abstracted
Assurance	Some rights are absolute (e.g. 100% of supply, guarantee of a certain quantity and quality), while other rights have variable assurance of supply and quality, depending on the available resource (which can be based, for example, on principles of priority or proportionality)
Use	The specific use for which the water is abstracted (e.g. irrigation, mining, etc.)
Duration and ownership	The duration for which the holder is entitled to the rights conferred. Some rights are permanent while other rights are authorized for a specified period of time
Transfer	Whether the right can be sold, transferred to another person or location, or inherited
Security and enforcement	Details of the administrative body that has the legal mandate to award the right, including the extent of that mandate
Price/fee	Details of the water price or fee according to its usage, possibly related to other attributes

Source: Le Quesne *et al.* (2007).

et al., 2008; Lopez-Gunn *et al*., 2011). In this context, entrepreneurs or water providers wishing to get or to increase their access to groundwater, can drill and exploit new wells without the corresponding permit. Often the opening of wells without a water right permit involves the transformation of dryland farming, or even of protected natural areas, into irrigated areas. Examples of this can be found in the surrounding of the Doñana National Park, in the southwest of Spain. In this area, a land use plan approved in 2003 established prohibition or limitations to transform rain-fed land into irrigated plots. In the period 2003–2009, however, 18.5% of the land was transformed into greenhouses (mainly as strawberry fields) intensively irrigated with unlicensed wells (Fuentelsaz *et al*., 2011). The transformed land included forest area (41% of the transformed land) and even highly protected public areas (11%).

2.2. Abstraction with on-going licensing processes

A lack of capacity in the competent authority in charge of granting water permits can mean that some users opt to open wells without permits. In Spain, the process of registering or being granted water rights is slow and cumbersome, and water authorities are often behind schedule with procedures to grant new concessions. The result is that many applicants start abstracting water before the authority replies to their formal application for a groundwater right.

2.3. Abstractions over the established limits

License holders can usually only abstract a volume specified in their water title or assigned by the water authority. In some cases however, water users end up abstracting greater volumes than that which they are entitled to. An example of this can be found in the Western La Mancha Aquifer (Upper Guadiana basin, central Spain), where audits carried out in 2005 on 70% of the irrigation farms in the area revealed that groundwater abstractions of 54 million m^3 above the amount authorized by the River Basin Authority (170 million m^3) were being made that year (WWF, 2006a).

2.4. Changes to the characteristics of the water right

In the case of Spain, changes in the characteristics of the water intake, e.g. through the deepening or widening of the registered well, have to be notified to the water authority. Therefore, by definition, these changes (if not reported) mean that the water right in many ways starts to operate out of the protection of the administrative system. This situation is very common in several aquifers in Spain, since any technical modification of a registered well implies a change in the legal status of the water right that is perceived by the holder to be less favorable, since it implies converting the private water right associated with the well into a public concession for water use. Moreover, some changes in the characteristics of the water intake may be needed as an emergency measure in the middle of an irrigation campaign, which is not compatible with the slow pace of the required administrative procedures.

Table 2 highlights that, although many of the references and examples used in this paper refer to Spain, irregularities in agricultural groundwater use are a widespread problem in a number of EU Member States, particularly where water resources are naturally scarcer due to their geographical location.

Table 2. Examples of unauthorized groundwater use in agriculture in several EU Member States.

EU Member State	Estimate/reference
Cyprus	50,000 unauthorized boreholes. The current level of abstraction is about 130 million m^3/yr, whilst the recommended level is 80 million m^3/yr
Greece	'Greece still faces serious water challenges, in particular in terms of its agricultural water use, which represents about 85% of overall abstraction. Excessive pumping of groundwater has caused water levels to fall dramatically in some rural areas, as well as salt water intrusion in some coastal aquifers. Illegal abstractions and discharges pose a hurdle to improving water management. Enforcement of regulations and water permit conditions has not sufficiently improved.' (OECD, 2010: 7)
Spain	An estimated 510,000 unauthorized wells abstract more than 7,000 m^3 each. Illegal water extraction could reach 3,600 million m^3/yr, representing 45% of the total amount of water pumped from aquifers per year (WWF, 2006a)
	In Aquifer 23 (Western La Mancha, Guadiana basin) in 2008, the water authorities estimated that 22,000 unauthorized boreholes existed, compared to 16,000 registered wells (CHG, 2008)
	'In the Guadalquivir River Basin, in 2006 the River Basin Authority reckoned that 10% of the existing 100,000 wells were illegal. A study of 68 farms in the neighbourhood of Doñana National Park showed that none of the exploitations which were audited was completely in compliance with the law' (WWF, 2006a: 4)
Italy	The estimates are of about 1.5 million unlicensed wells. In eight regions (Abruzzo, Molise, Puglia, Campania, Basilicata, Calabria, Sicily and Sardinia), about 830,000 ha are irrigated legally while the total irrigated area reaches about 1.6 million ha. In the Puglia region alone, it is estimated that there are 300,000 unauthorized wells, which provide for one third of the total irrigated area in that region (WWF, 2006b)
Malta	'Irrigated land amounts to just more than 9% of all agricultural land in the Maltese Islands. Most of it is found in the Upper Coralline Limestone regions in the north and west of Malta. Historically, the shallow depth of the perched aquifers and the occurrence of natural springs made water resources for agriculture more easily accessible. However, in the last decade, a large number of 'illegal' boreholes have been dug, particularly in the main Lower Coralline Limestone aquifers' (FAO, 2006: 37)
	In 2008, according to the Maltese Resources Ministry, the abstraction level of groundwater was around 30 million m^3/yr, 7 million m^3/yr more than the sustainable yield. According to the Water Services Corporation, water abstraction in 2007 was 15 million m^3, while illegal abstraction was 18.5 million m^3 (Times of Malta, 2008)

Source: adapted from Dworak *et al*. (2010).

3. Effects of unauthorized water use

Unauthorized water usage can have substantial impacts, both on water users and on the environment. As mentioned in the introduction, the existence of an authorization to undertake a certain action is no guarantee that it will have no negative impacts on third parties or the environment. In other words, if the law does not sufficiently or adequately regulate the use of the resource, it is possible that there will be negative consequences of water exploitation even if the law is strictly enforced. Nonetheless, in developed economies, it is usually unauthorized water use which is more often associated with the impacts described below.

First of all, the amount of resources available for licensed uses diminishes as unauthorized use increases. In this context, and particularly due to the nature of groundwater resources, it is difficult for water authorities to physically determine or even estimate the extent and particular characteristics

of unauthorized intakes. These can lead to aquifer over-exploitation, with substantial drops in groundwater levels leaving traditional water users without water in their wells. In Spain this occurs, for example, in the Segura basin or in the Upper Guadiana (WWF, 2006a). In other Spanish basins the plummeting of the water table has caused the disappearance of springs. An example of this can be found in Pegalajar (Andalusia, Guadalquivir basin) where between 1988 and 2008 the drilling of unlicensed boreholes dried out an historical spring (*Fuente de la Reja*), which had traditionally been used for irrigation and is strongly linked to the local socio-cultural identity (Castillo Martín, 2008).

Second, the intense exploitation of an aquifer can result in a wetland's water input diminishing or even disappearing, which in turn results in the deterioration of related ecosystems. One of the most well-known cases in Spain is that of the Las Tablas de Daimiel National Park (Guadiana basin), where the plummeting of the groundwater level of up to 40 m provoked the complete disconnection of the Ramsar site from the aquifer and almost caused its disappearance (de la Hera, 1998). In addition to impacts on wetlands, the decrease in groundwater levels leads to river–aquifer dynamics being altered, which causes degradation of riparian ecosystems.

Uncontrolled groundwater development can also have linkages to water quality issues such as nitrate contamination connected with intensive farming practices. In coastal areas, the intense (and often unauthorized) exploitation of groundwater can cause saline water to enter inland, resulting in freshwater and salt water mixing in wells and transitional surface water bodies. The lower quality of the available water in turn affects urban supply, authorized irrigators and aquatic ecosystems that are sensitive to changes in salinity. An example of changes in groundwater quality can be found in the Crevillente aquifer on the Mediterranean coast. Over the past decades, the water table has sometimes plummeted 30–40 m within a single year and in some sectors of the aquifer water is now 300 m deeper than it was originally. Intensive groundwater mining has not only depleted the aquifer but has also degraded groundwater quality, resulting in a 50% decrease in crop profitability over the last few years (Andreu *et al*., 2008).

Another unanticipated consequence of unauthorized use is the increased need for huge public investment. Due to economies of scale and large upfront investment, many water infrastructures (e.g. dams, canals, and inter-basin water transfers) are paid for with public money, and the driver for increased searches for additional water resources development is sometimes the attempt to reduce the effects of unauthorized groundwater use. For instance, in Spain the Júcar-Vinalopó transfer (Jucar river basin), estimated to cost €231.5 million in 2006, was partly designed to contribute to aquifer recharge after overexploitation due to intense, often unauthorized groundwater use. Equally, the Ebro transfer (the key infrastructure of the 2001 Spanish National Hydrological Plan, now repealed) was estimated to cost approximately €380 million. One of the rationales for the transfer scheme was that surface water would reduce the pressure on thousands of hectares of irrigated land (estimated to be about 100,000 ha in the Segura river basin) which were often irrigated without the relevant permits from aquifers used above their renewable or sustainable yield capacity (Albiac *et al*., 2006: 732).

4. Root causes of unauthorized groundwater uses

The examples of unauthorized water use in southern EU Member States presented in Table 2 suggest that, in the case of groundwater, the command-and-control approach to water usage often falls short of delivering its stated objectives (see also Shah *et al*., 2007). The key underlying factor of unauthorized

groundwater use is that, for individual users, the net benefits from unauthorized uses often outweigh its negative consequences. That is, the value of potential gains is perceived to be higher than the anticipated consequences in terms of drop in water levels, increased salinity or higher energy costs, potential sanctions and risks. In the case of Spain, the economic productivity (€/ha) in irrigated agriculture is about five times higher than that of rain-fed farming (Aldaya *et al*., 2010). This is due to a number of reasons: first, the type of crop that is cultivated through irrigation is usually more profitable and competitive in market terms (e.g. fruit and vegetables); second, traditionally rainfed crops (e.g. vines and olives), when irrigated, have higher productivity per hectare; third, the value of land increases notably is it has access to water: for example, land market prices in Spain show that access to water multiplies the value of land by a factor of 1.5 for vineyards and by 2 for olive groves (Garrido *et al*., 2005); fourth, until 2005, irrigated land received higher European subsidies because the subsidy calculations were based on production; fifth, the EU Common Agricultural Policy subsidized the stocking of overproduction for certain crops (grapes and olives), hence indirectly supporting production. In addition, farmers do not have to pay for water itself in resource terms (only the costs of abstraction), and do not internalize external environmental costs associated to irrigation such as diffuse water pollution and habitat degradation.

The actions of an individual, however, are surely not determined only by the weighing of benefits and losses, since they are also strongly influenced by social expectations, norms and actors' social identities (Stålgren, 2006). These, and the intrinsic nature of groundwater, influence the choice of individual water users. The next sections analyze these additional underlying factors that contribute to explaining the root causes of unauthorized groundwater use in Spain.

4.1. The intrinsic nature of groundwater

Groundwater exploitation does not need large upfront investments, as compared to access to surface water, for example. Hence, individual users like farmers, agri-businesses, or urban developers can access groundwater resources relatively easily, without the need for external public investment. Depending on the hydrological situation, investments can be relatively modest, and sometimes in a substantially smaller order of magnitude compared to surface water investments such as dams, water transfers or desalination plants.

In addition, groundwater offers the advantage that it is more reliable and readily available as a resource. While surface water users can be cut off from surface water, for instance during droughts, groundwater users have a built-in resilient system that acts as a kind of insurance against temporary water shortages.

Furthermore, groundwater is not as visible as surface water, which means that the attribution of externalities to specific groundwater users is harder to prove, especially when water authorities or river basin agencies have low capacity and/or expertise to deal with groundwater resources, since their experience and resources tend to be focused on surface water, rather than on groundwater.

The control and monitoring of groundwater is not necessarily an impossible task with the onset of new technologies such as remote sensing (Lopez-Gunn & Llamas, 2008) and with a proxy measure such as electricity connection and billing. However, control and monitoring is inherently more cumbersome and expensive compared to surface water use, which makes the 'risk of being caught' in the case of unauthorized groundwater use lower than in the case of surface water.

4.2. Imperfect institutions

A key issue of regulation compliance is related to social capital (Pretty & Ward, 2001), and in particular to distrust that water users might experience, for example in relation to water authorities, leading to a decreased legitimacy of official decisions and rules (Lopez-Gunn & Martinez-Cortina, 2006). The reasons for this lack of trust are diverse and might include a past history of inefficiency or ineffectiveness, or perceived unfairness or arbitrary decision-making on the part of the public administration. The reasons might also include a lack of ownership of identified solutions to water-related problems due to the limited involvement of water users in the design of these potential solutions.

In the case of Spain, the administrative complexity of water rights allocation and management may discourage water users from pursuing the required permits due to the long timeframe involved (Huertas, 2011 personal communication) and because of the convoluted steps needed to complete the process. Moreover, complex enforcement rules can overload the responsible authorities, thus decreasing their ability to respond to users' requests in a timely fashion.

Enforcement is sometimes hindered by a real lack of technical and human means to effectively detect and pursue law-breaching activities, especially taking into account the spatially scattered nature of groundwater intakes to be controlled. Added to this, there can be the complication of a lack of political will, for socio-political reasons, which translates ultimately into lax enforcement. Indeed, strict enforcement of water usage can be politically highly sensitive and difficult due to the economic, social and political importance of unauthorized water uses (Dumont *et al*., 2011).

In some cases groundwater allocation rules are too complex or rigid, giving little space to possible new needs or changes in water use. In mature water allocation systems, new users or users who wish to expand their economic activities are constrained by both a physical scarcity of water and a 'saturated' system where all available resources have already been allocated, or even over-allocated. In these cases, with a rigid water rights system that does not allow for a re-allocation of water amongst existing users, or allow the entrance of new users, this rigidity can itself sometimes trigger non-compliance.

4.3. Social norms

Sometimes social norms accept unauthorized groundwater abstraction and there is no strong social stigma attached to unlicensed groundwater use. This social tolerance makes it possible for users to openly associate in order to ask the administration for a negotiated solution, normally consisting of demands for the legalization of irregular uses and the provision of surface water from other areas, to decrease the pumping pressure on the aquifer. This occurs in the Loma de Úbeda aquifer (Guadalquivir, Andalusia) where, since the mid 1990s, olive tree irrigation has had a spectacular and uncontrolled development, leading to a situation where 90% of the wells used lack a corresponding abstraction license (Rubiales García del Valle, 2011). Triggered by the drop in water levels, farmers in the area are now creating farmers' associations to rationalize aquifer exploitation while asking for the legalization of their wells. Similarly, on the western borders of the Doñana wetlands (Guadalquivir, Andalusia), a number of strawberry farmers have developed their activities despite a ban on increasing irrigated land and groundwater abstraction in the area. This has led to the drilling of about 1,000 unauthorized wells (Junta de Andalucía, 2010) and a reduction in the water inflows into a protected wetland (Sánchez, 2009). Since 2006, the regional and central governments have been negotiating a solution with some of the stakeholders

which includes the partial legalization of the unlicensed irrigation farms and the provision of surface water from another river basin (Junta de Andalucía, 2010). In this context, social tolerance can sometimes create a reverse incentive, because in a system where non-compliance is generalized, breaching the law can seem the most rational thing to do.

Social acceptance of noncompliance can be partly explained and rooted in different perceptions and values of what needs to be preserved and how. For example, rural users in some cases perceive that they should use the resources that are locally available to achieve and maintain their socio-economic development, and that people or authorities who are not rooted in the area should not constrain that development. Others perceive the value of natural ecosystems differently from how they are established in formal norms, such as under law, and therefore do not share the preservation objectives pursued by the authorities.

Additionally, society as a whole often reacts only to blatant damage to common interests or goods. Groundwater resources, however, are largely invisible and unknown to most people. Hence, unauthorized appropriation of groundwater is not obvious, and its impacts are less evident when compared to other unauthorized activities such as the illegal development of pristine costal land. This is mirrored by a budding literature on the illegal use of natural resources (Gavin *et al*., 2009). When unauthorized use leads to severe groundwater over-abstraction, this rarely translates into the collapse of the economy. Indeed, other solutions (e.g. water transfers or desalination) are found to sustain the economic interests created by groundwater, whilst the environmental externalities are discounted or not internalized as a real cost.

Finally, in some regions, irrigated farming and associated activities (agricultural input services, food-canning industry, etc.) are major regional or local economic drivers and the main source of income for the local population. Therefore, strict enforcement of the law has associated real economic losses to the regional economy, which helps to explain the toleration for non-compliance by the local population and by the authorities who may turn a blind eye (Dumont *et al*., 2011). The end result is an overall perception that users do not have many alternatives except breaching the law if they want to access water, which is an important source of income.

5. Discussion

As we have seen above, relying solely on command-and-control measures for groundwater regulation is a simplistic approach to a complex problem, and is very likely to fail, especially if users disagree with the existing norms and regulations. The question, then, is what institutional, ethical and social considerations can contribute to solving the complex jigsaw of groundwater regulation?

A first consideration is related to the institutional incentives to achieve voluntary regulation compliance and, therefore, to influence the individuals' behavior beyond the (often weak) threat of punishment. Theesfeld (2008) observes that voluntary compliance requires that, first, formal legal systems and organizational forms and institutions have to respond to the demands of a society that asks the state to help in solving an impelling problem. Second, there must be an alignment of formal norms with underlying social norms and beliefs. Third, the laws and institutions in question must provide solutions for actual conflict scenarios which take the various interests behind such conflicts well into account. Fourth, voluntary compliance implicitly assumes a certain level of common understanding and

knowledge about the resources at stake. All these characteristics are interesting 'ingredients' that should be present when designing any regulatory effort.

A second consideration asks for a higher emphasis to be placed on the role of individuals' choice in groundwater use. Indeed, in the end, the final decision on how to use groundwater resources rests with the individual water user who chooses a behavior influenced by all the highly complex factors outlined above. These complex factors, however, should not completely cancel individual accountability and its associated 'moral' considerations. When discussing the issue of unauthorized groundwater use, non-compliance is rarely seen from the perspective of the choice of the individual. A possible reason for this is that, when there is a 'tragedy of the commons' and a problem that involves many individuals, society looks to the authorities and holds them accountable for not preventing the problem. Therefore, society asks for a 'solution of the commons' which ultimately does not fully hold individuals accountable for their actions.

In Section 3 above, we outlined several negative impacts of uncontrolled groundwater uses, which include the deterioration of aquatic ecosystems, occupation of protected public lands, deterioration of water quality for human uses, decrease of water availability for registered users and important public spending linked to the legalization of unregistered water uses. Additionally, in a democratic system, the act of breaking a law, even if justified by several complex circumstances, actually erodes the institutional credibility of the authority, leading to a loop effect: the administration loses credibility, being even less able to effectively manage the common good and to protect users and the environment in case of abuse. This leads other users to break the law because they perceive the administration as ineffective or unable to undertake its work. Moreover, the administration often reacts to its inability to stop illegal practices by issuing stricter rules that are perceived as even more unjust and difficult to abide. All this suggests that individual water users do contribute with their individual acts to the negative impacts of unlicensed over-abstraction and have a crucial role in determining the effectiveness of the whole regulatory system. Hence, in order for negotiated, collective solutions to be efficient and durable, these should also incorporate an acknowledgement of individual responsibility.

A third consideration of how to contribute to an effective groundwater regulation is related to the desirable increased role of water users in resource management. Increased water user involvement targets (from the collective perspective) the need to influence individual behaviors. This is implicit in efforts towards raising the awareness of water users and the public, empowering stakeholders through participation in decision-making processes and fostering collective action by groundwater users. These approaches have proved to create an environment favorable to negotiated solutions that contribute to reducing the pace of water table decline or stabilizing water levels. In Spain, examples of this can be found in the Upper Guadiana Basin (Zorrilla, 2009; Zorrilla *et al*., 2010), in the Western Mancha Aquifer, and in the Segura basin (AEVAL, 2010). These initiatives, however, rely on or are linked to significant public spending (e.g. for the construction of new water infrastructure or for the acquisition/lease of water rights by the water authorities). Sometimes these initiatives achieve their original objective but other times these do not achieve the recovery of aquatic ecosystems degraded by water over-abstraction, which seems to indicate that, in groundwater use as elsewhere, environmental conservation is the most challenging part of the sustainable development paradigm (Lopez-Gunn *et al*., 2012). This suggests that while water users' self-organization can contribute to making water abstraction more rational and efficient (relative to uncontrolled and unorganized action), it also needs to pass the litmus test of being economically self-sufficient while being compatible with strict environmental objectives established by law.

6. Conclusions

In developed economies, groundwater use requires some kind of regulation: top-down regulation, or users' self-regulation, or both. This is in order to avoid the strong deterioration of aquifers and the natural and human systems associated with them. Groundwater is difficult to regulate due to its intrinsic nature as a common-pool resource. While surface water in arid and semi-arid regions requires costly infrastructure built with important investments, and unauthorized abstraction is limited to areas close to waterways, the specific case of groundwater needs less upfront investment and offers endless possibilities for abstraction in multiple (and often widely spaced) water points. Different approaches have been designed and applied; none, however, has been fully satisfactory so far.

Several aquifers in Spain find themselves in deadlock because of a difficult balance between the economic benefits brought about by intensive groundwater use and the long-term viability of its use (from an environmental and/or social point of view). A number of issues determine the existence of 'enabling conditions' for having good groundwater governance, and to ultimately influencing an individual's decision to abide by the law (or not). In areas where non-compliance of groundwater regulation is generalized, it is common that society holds the relevant authorities responsible and accountable for the problem (and its solution), without questioning the actions of individuals in generating the problem. Collective action can contribute to achieve social peace and a more efficient use of groundwater resources. However, the next challenge is to prove its capability to substantially contribute to environmental conservation objectives. The combination of collective action with a stronger emphasis on individual accountability in the maintenance of ecosystems associated with groundwater could help to successfully link both material, utilitarian values with intangible ethical values, and to contribute to finding durable and viable solutions to groundwater exploitation.

Acknowledgements

The authors are thankful to the reviewers for their comments and Abel La Calle and Guido Schmidt for their inputs to the paper.

References

AEVAL (2010). *Evaluación de la gestión y funcionamiento de las Confederaciones Hidrográficas*. Agencia de Evaluación y Calidad. Ministerio de la Presidencia, Madrid, Spain, 241 pp.

Albiac, J., Hanemann, M., Calatrava, J., Uche, J. & Tapia, J. (2006). The rise and fall of the Ebro water transfer. *Natural Resources Journal 46*(3), 727–758.

Aldaya, M. M., Garrido, A., Llamas, M. R., Varela-Ortega, C., Novo, P. & Casado, R. R. (2010). Water footprint and virtual water trade in Spain. In: *Water Policy in Spain*. Garrido, A. & Llamas, M. R. (eds). CRC Press, Leiden, The Netherlands, pp. 49–59.

Andreu, J. M., Pulido-Bosch, A. M. R., Llamas, C., Bru, P., Martínez-Santos, E. & García-Sánchez, L. (2008). Over-exploitation and water quality in the Crevillenet aquifer (Alicante, SE Spain). In: *Water Pollution IX*. Prats Rico, D., Brebbia, C. A. & Villacampa Esteve, Y. (eds). WIT Press, Southampton, UK.

Castillo Martín, A. (2008). *Manantiales de Andalucía*. Agencia Andaluza del Agua, Consejería de Medio Ambiente, Junta de Andalucía, Sevilla, 416 pp.

Confederación Hidrográfica del Guadiana (2008). Real Decreto 13/2008. De 11 de enero, por el que se aprueba el Plan Especial del Alto Guadiana. Ministerio de Medio Ambiente. BOE No. 21, 24 de enero de 2008.

De la Hera, A. (1998). *Análisis hidrológico de los humedales de la 'Mancha Húmeda' y propuesta de restauración de un humedal ribereño: El Vadancho (Toledo)*. PhD Dissertation. Dept. Geodynamics, Geology faculty, Universidad Complutense de Madrid.

Dietz, T., Dolsak, N., Ostrom, E. & Stern, P. C. (2002). The drama of the commons. In: *The Drama of the Commons*. Ostrom, E., Dietz, T., Dolsak, N., Stern, P. C., Stornich, S. & Webers, E. U. (eds). Committee on the Human Dimensions of Global Change, National Academy Press, Washington, DC, 1–35.

Dumont, A., Willaarts, B. A., Novo, P. & López-Gunn, E. (2011). The extended water footprint and unauthorized groundwater use in the Upper Guadiana Basin (Spain): Can increased productivity explain non-compliance? In *Paper presented at: Groundwater 2011 – Gestion des resources en eau souterraine, 24th European Regional Conference of the ICID*, March 14–16, Orléans, France. Available at: http://www.groundwater-2011.net/program_and_proceedings (accessed 10 December 2011).

Dworak, T., Schmidt, G., De Stefano, L., Palacios, E. & Berglund, M. (2010). *Background Paper to the conference: Application of EU Water-related Policies at Farm Level*, 28–29 September 2010. Mercure Hotel, Louvain-la-Neuve (Belgium). Available at: http://ecologic-events.de/wfd2010/documents/LLN_backgroundpaper-final220910.pdf (accessed 10 December 2011).

European Academies Science Advisory Council (EASAC) (2010). *Groundwater in the Southern Member States of the European Union*. Policy Report 12 of the European Academies Science Advisory Group. German Academy of Sciences Leopoldina Halle (Saale), Germany. ISBN: 978-3-8047-2827-1.

Food and Agriculture Organization (FAO) (2006). *Malta Water Resources Review*. FAO of the United Nations, Rome, Italy. Available at: ftp://ftp.fao.org/docrep/fao/009/a0994e/a0994e00.pdf (accessed 10 December 2011).

Fuentelsaz, F., Hernández, E., Peiteado, C. & Geosys, S. L. (2011). El uso de la teledetección para analizar incrementos de regadíos y pérdida de zonas forestales. Estudio de WWF sobre cambios en el uso del suelo en el entorno de Doñana entre POTAD y 2009. In *Conference Proceedings: VII Congreso Ibérico sobre Gestión y Planificación del Agua 'Ríos Ibéricos +10. Mirando al futuro tras 10 años de DMA', 16–19 February 2011, Talavera de la Reina*. Fundación Nueva Cultura del Agua. Available at: http://www.fnca.eu/comunicaciones-a3-vii-congreso-iberico-sobre-gestion-y-planificacion-del-agua/ (accessed 28 January 2012).

Garrido, A., Martínez-Santos, P. & Llamas, M. R. (2005). Groundwater irrigation and its implications for water policy in semiarid countries: the Spanish experience. *Hydrogeology Journal 14*(3), 340–349.

Gavin, M., Solomon, J. & Blank, S. (2009). Measuring and monitoring illegal use of natural resources. *Conservation Biology 24*(1), 89–100.

Giordano, M. & Villholth, K. G. (2007). *The Agricultural Groundwater Revolution: Opportunities and Threat to Development*. CABI, Wallingford.

Gouldson, A., Lopez-Gunn, E., van-Alstine, J., Rees, Y., Davies, M. & Krishnarayan, V. (2008). New alternative and complementary environmental policy instruments and the implementation of the Water Framework Directive. *European Environment 18*(6), 359–370.

Huertas, R. (2011). Personal communication. Deputy Water Commissariat, Douro River Basin Authority, January 2011.

Junta de Andalucía (2010). Plan Especial de Ordenación de las zonas de regadío ubicadas al norte de la corona forestal de Doñana. December 2010. Available at: http://www.juntadeandalucia.es/obraspublicasyvivienda/obraspublicasyvivienda/portal-web/web/areas/ordenacion/texto/e7c03588-2497-11e0-8da3-6b048da97d96 (accessed 10 December 2011).

Le Quesne, T., Pegram, G. & Von Der Heyden, C. (2007). *Allocating Scarce Water: A Primer on Water Allocation, Water Rights and Water Markets*. Water Security Series. WWF, Goldalming, Surrey, UK.

Llamas, M. R. & Garrido, A. (2007). Lessons from intensive groundwater use in Spain: Economic and social benefits and conflicts. In: *The Agricultural Groundwater Revolution: Opportunities and Threat to Development*. Giordano, M. & Villholth, K. G. (eds). CABI, Wallingford, pp. 266–295.

Llamas, M. R. & Martınez-Cortina, L. (2009). Specific aspects of groundwater use in water ethics. In: *Water Ethics*. Llamas, M. R., Martınez-Cortina, L. & Mukherji, A. (eds). CRC Press/Balkema, Leiden. (ISBN 978-0-415-47303-3). pp. 187–204.

Llamas, M. R., Martınez-Santos, P. & de la Hera, A. (2007) Dimensions of sustainability in regard to groundwater resources development: an overview. In: *Global Importance of Groundwater in the 21st Century: The International Symposium in Groundwater Sustainability. Alicante, Spain, 24–27 January 2006*. Ragone, S., de la Hera, A., Hernandez-Mora, N., Bergkamp, G. & McKay, J. (eds). National Groundwater Association Press, Westerville, OH.

Llamas, M. R., Fornés, J. M., Hernández-Mora, N. & Martínez-Cortina, L. (2001). *Aguas subterráneas: retos y oportunidades*. Fundación Marcelino Botín, Ediciones Mundi-Prensa, Madrid.

Lopez-Gunn, E. & Llamas, M. R. (2008). Re-thinking water scarcity: Can science and technology solve the global water crisis? *Natural Resources Forum 32*, 228–238.

Lopez-Gunn, E. & Martinez-Cortina, L. (2006). Is self-regulation a myth? Case study on Spanish groundwater associations and the role of higher level authorities. *Hydrogeology Journal 14*(3), 361–375.

Lopez-Gunn, E., Zorrilla, P. & Llamas, M. R. (2011). The impossible dream? The Upper Guadiana system: Aligning changes in ecological systems with changes in social systems, in *On the Water Front*, vol. 2, Lundqvist, J. (ed.) SIWI, Stockholm, 115–126. Available at http://www.worldwaterweek.org/ on the water front 2010 (accessed 27 January 2012).

Lopez-Gunn, E., De Stefano, L. & Llamas, M. R. (2012). The role of ethics in balancing utilitarian and intangible values in water and food security. *Water Policy 14*(Supplement 1).

Martínez-Santos, P., De Stefano, L., Llamas, M. R. & Martínez-Alfaro, P. E. (2008). Wetland restoration in the Mancha Occidental Aquifer, Spain: A critical perspective on water, agricultural, and environmental policies. *Restoration Ecology 16*(3), 511–521.

OECD (2010). *Environmental Performance Reviews: Highlights*. OECD, Greece. ISBN: 9789264060838.

Pretty, J. & Ward, H. (2001). Social capital and the environment. *World Development 29*(2), 209–227.

Rubiales García del Valle, I. (2011). *Explotación y Ordenación de la Masa de Agua 05.23 de Úbeda*. SHAN Series, Vol. 3. Water Observatory, Boín Foundation, Madrid.

Sánchez Navarro, R. (2009). *Caudales ecológicos de la marisma del Parque Nacional de Doñana y su área de influencia*. WWF, Spain.

Shah, T. (2008) *Taming the Anarchy: Groundwater Governance in South Asia*. RFF Press, Washington, DC.

Shah, T., Burke, B., Villholth, K., Angelica, M., Custodio, E., Daibes, F., Hoogesteger, J., Giordano, M., Girman, J., van der Gun, J., Kendy, E., Kijne, J., Llamas, R., Masiyandama, M., Margat, J., Marin, L., Peck, J., Rozelle, S., Sharma, B., Vincent, L. & Wang, J. (2007) Groundwater: a global assessment of scale and significance. In: *Water for Food, Water for Life: Comprehensive Assessment of Water Management in Agriculture*. Molden, D. (ed.). Earthscan, London, pp. 395–423.

Stålgren, P. (2006). *Corruption in the Water Sector: Causes, Consequences and Potential Reform*. Policy Brief No. 4. SIWI, Swedish Water House, Stockholm. Available at: http://www.siwi.org/documents/Resources/Policy_Briefs/PB5_Corruption_in_the_water_sector_2006.pdf (accessed 10 December 2011).

Theesfeld, I. (2008). A review of national groundwater policy instruments: Grasping institutional aspects of transboundary groundwater governance. In *The 12th Biennal Conference of the International Association for the Study of Commons (IASC),* 14–18 July 2008. University of Gloucestershire, Gloucester.

Times of Malta (2008). Bid to crack down on borehole drilling. *Times of Malta*, *7* September 2008. Available at: http://www.timesofmalta.com/articles/view/20080907/local/bid-to-crack-down-on-borehole-drilling (accessed 10/12/2011).

WWF (2006a). *Illegal Use of Water in Spain. Causes, Effects and Solutions*. WWF Adena, Madrid.

WWF (2006b). *Drought in the Mediterranean: WWF Policy Proposals*. WWF/Adena, WWF Mediterranean Programme, WWF, Germany. Available at: assets.panda.org/downloads/wwf_drought_med_report_2006.pdf (accessed 12 December 2011).

Zorrilla, P. (2009). *Análisis de la gestión del agua en el acuífero de la Mancha Occidental: construcción de una red bayesiana mediante procesos de participación pública*. Tesis doctoral inédita, Departamento de Ecologia. Universidad Autonoma de Madrid, Madrid.

Zorrilla, P., Carmona, G., De la Hera, Á., Varela-Ortega, C., Martínez-Santos, P., Bromley, J. & Jorgen Henriksen, H. (2010). Evaluation of Bayesian networks in participatory water resources management, Upper Guadiana Basin, Spain. *Ecology and Society*, *15*(3), 12.