The Importance of the Groundwater Governance in the Global Change Context: A Proposal for a Mediterranean Aquifer (Llanos de la Puebla, Spain)

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1 Introduction

Groundwater (GW) governance has acquired relevant economic, social and political importance in the last decades, especially for developing countries where groundwater abstractions have become critical to sustain its growth (Siebert et al. 2010). Nevertheless, the majority of aquifers are still overdraft worldwide (Vaux 2011). GW is a classic common pool resource, defined by substractability and non-excludability (Ostrom 2005). Hardin's tragedy of the commons predicts that individualistic competitive exploitation of a common pool such as an aquifer with results in extracting too much groundwater too soon, leading to overabstraction rates as users ignore the social cost (or user cost) of their own abstractions. Further, climate change is introducing additional costs and risks hard to manage, including increased demand for groundwater and reduced recharge rates, with consequent heightened risk of conflict (Brouyere et al. 2004; Jyrkama and Sykes 2007). This fact is extremely important for countries such as Spain that suffer frequent severe droughts and where groundwater constitutes a strategic resource to maintain water supply during dry periods and to solve conflict among users (Custodio 2010).

Groundwater resources have enabled the development of an intense wealth-creating agricultural economy in many countries around the world. The economic development of many semi-arid areas of Spain has been due to or was started by intensive aquifer exploitation, in agriculture (most of the Mediterranean

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areas of southern and eastern Spain), industry (valleys of Catalonia and Valencia), and tourism (mainly in the south and the archipelagos). Llamas and Martínez-Santos (2005) estimate current aquifer storage depletion in the Iberian Peninsula at about 15 km^3, causing water table drop, water quality degradation, land subsidence and other negative ecological impacts.

2 Groundwater Governance (State of the Art)

Groundwater governance is included by many authors as being among the most important challenges for the future of water sustainability in the world (Grabert and Narasimhan 2006). Further, groundwater is inherently more complicated to govern than surface water because: (a) it is easily self-appropriated, with no need for cooperation and infrastructure management, (b) it is difficult to measure and control, (c) impacts of excessive pumping are usually detached in space and time from the actions that caused the problem. These unique characteristics explain that groundwater is weakly governed and underfunded within water policy frameworks. However, the role played by groundwater has increased as it serves as an essential resource to guarantee socio-economic development of some areas, especially those with arid or semi-arid climates. Groundwater governance requires therefore a drastic shift. Governance should be understood as the operation of rules, instruments and institutions that, built within a multi-actor context, can align stakeholders behaviour and actual outcomes with policy objectives in a multilevel framework with the use of multiple instruments. As a result of top-down and bottom-up processes, management decisions may benefit all parts (groundwater users included) and serve the implementation of longer-term integrated water resources management (IWRM) principles.

The governance framework proposed in this paper to illustrate the analysed case studies is based on Wiek and Larson (2012). This framework was developed within the "Water Partnership Program" led by the World Bank (Wijnen et al. 2012). It follows several phases (or levels) that should be accomplished in its practical implementation. Firstly, national and regional policies establish the objectives for groundwater governance within an integrated legal and management framework coordinated with other water, land and environmental related policies (i.e. agricultural, decentralization, etc.). The aim is to guarantee efficiency; equity and sustainability of groundwater uses (Fig. 1).

At a strategic level, an IWRM plan must be developed, including all necessary instruments to align stakeholder behaviour and outcomes with the previously established policy goals. Information constitutes here a critical issue, as it is crucial for the involvement of local actors (i.e. users); while obtaining reliable knowledge about the groundwater behaviour (recharge rates, transmissivity, etc.), withdrawals and uses is difficult since specialize research and modelling is required and accurate information is not guaranteed. Effective management of groundwater resources will therefore depend on the knowledge and attitudes of main actors, as stated by Allan

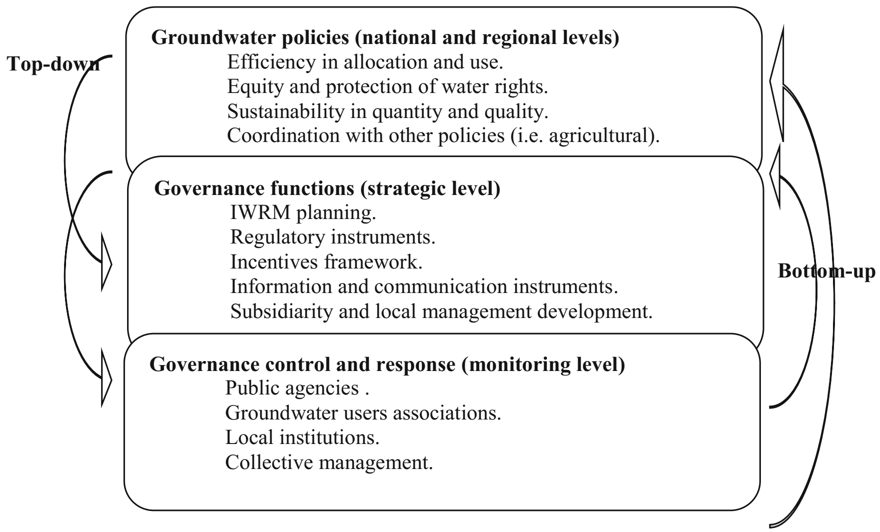

Fig. 1 Framework for assessing groundwater governance (adapted from Wijnen et al. 2012)

(2007), “more important than knowledge of the volumes and rates of use of renewable groundwater… is the knowledge constructed by political classes and by the major users of water in the region”. Finally, local level governance involves the institutions that control outcomes locally and respond to the instruments set at the strategic level. Monitoring (and control) in this phase are critical, as it guarantees the access to information about quantity and quality of the resource and permits adjustments backwards at higher levels, leading to bottom-up management initiatives. At this local level, advisory instruments developed through collective participation may be considered as supplementary tools for groundwater management. Thus, once the groundwater governance framework is in place, different management instruments can be implemented and tested.

There are several examples where delegation and collective management have proved to be effective, once top-down initiatives have been developed. Based on analysis of water governance systems in the Netherlands, Australia and South Africa, Huntjens et al. (2012) argue that groundwater water users associations (GWUAs) are able to establish and protect water rights. According to Ostrom (2005), most individuals affected by operational rules should be able to participate in modifying them and contribute to the “command and control measures”. In large-scale resource systems (i.e. river basin, major aquifer), it is important to enhance the participation of those involved in making key decisions about the system (Huntjens et al. 2012). Petit (2004) explained that in a situation of water stress, local stakeholders may recognize more easily the common characteristics of groundwater resources and try to find solutions to reduce/avoid over-exploitation.

3 Case Study

3.1 GW Management in Spain

GW in Spain accounts for 20% of the total water used for irrigation. Average aquifer recharge has been estimated to be about 30,000 Mm^3/year while the total amount of stored groundwater is probably two orders of magnitude higher that the yearly renewable resources. In the last decades, groundwater use in Spain has increased from 2000 Mm^3/year in 1960 to 6500 Mm^3/year nowadays and approximately 75% is used for irrigation of one million hectares, which is about 30% of the total irrigated area in the country (Molinero et al. 2011).

The implementation of the European Water Framework Directive (WFD) in 2000 implied the obligation for Member States to identify and classify groundwater bodies as part of the "Initial Characterisation Stage". In Spain, 699 groundwater bodies officially identified 259 (37%) were classified "at risk" of not attaining the environmental objectives set by the WFD for the horizon 2015. The aquifer Huéscar-Puebla analyzed in this work was within this group.

Historically, groundwater abstraction rights in Spain are tied to land ownership (Water Law of 1879). The Water Law of 1985 redefined abstraction rights and declared all aquifers as public domain, being the River Basin Authorities (RBAs) responsible for groundwater abstractions regulations. Further, a Register of Public Water and a Catalogue of Private Water was created as instruments for groundwater management. Registration was compulsory for all well owners. Control of wells and abstractions has not been easy due to limited resources at the RBAs but also to the unclear differentiation of water management competencies between RBAs and regional governments. Nevertheless, the new legal framework put in place in 1985 grants RBAs capacity to enforce pumping restrictions in both the public and private property regimes as well as the creation of groundwater uses associations.

3.2 "Llano de la Puebla" Hydrological System

The hydrological system of Huéscar-Puebla (MAS 05.04) is located under a plateau called "Llano de la Puebla" (or "El Llano"), surrounded by the Béticas mountain range in the north of the province of Granada (Region of Andalusia, southern Spain) (Fig. 2). The hydrogeologic system is composed by two sub-unities or sub-aquifers (Aljibe 2014): the carbonated aquifer of Parpacén (in the west) and the detrital carbonated aquifer of Fuencaliente (in the east). This system belongs to the Guadalquivir Basin. Puebla de Don Fabrique (to the north) and Huéscar (to the west) are the two urban concentrations that give the name to this aquifer system. There are two wellsprings, called Fuencaliente and Parpacén, both located in the surroundings of the town of Huéscar.

Fig. 2 Location map

The plateau "El Llano" has been devoted to rainfed agriculture since centuries, mainly to the cultivation of cereals and fodders. The development of horticulture in the Segura basin (60 km Eastwards) during the 80s and 90s, opened the market for cultivating high value crops such as broccoli, cauliflower, lettuces, etc. in the open air. By producing during the summer, this region covers the season when Murcia and Almeria greenhouse and intensive productions stop. Therefore, the abstraction of GW reserves affecting Fuencaliente spring was driven by the high profitability of cultivating high value vegetable crops. Figure 3 illustrates Fuencaliente's spring flows evolution. Farmers and citizens in Huéscar, who have used the spring since Roman time, made a claim to the Ministry of Agriculture and Environment for controlling the aquifer. This action led to an urgent intervention of the Guadalquivir RBA in order to re-establish the water balance in this groundwater system, as well as to manage the rising conflicts among the two towns (Huéscar and Puebla de Don Fabrique) and farmers. Consequently, the RBA made a complete hydrogeological study that conducted to an agreement between all affected parties in order to limit the abstractions and the cultivated area affecting the Fuencaliente aquifer. These measures did not affect the neighbour (East) Parpacén aquifer.

3.3 "Llano de la Puebla" Management Plan and Proposals

The terms of the agreement with the RBA were (a) abstractions decrease, from the estimated 8.7 hm^3/year (2003) to 5.6 hm^3/year in 2008 and 4.7 hm^3/year in 2013; (b) controlling annual withdrawals with individual well water meters; (c) annual water allocation to each farm (61 farmers have granted rights); (d) limitations of cultivated area from 2855 ha in 2003 to 1219 ha in 2013; (e) maximum of 20 ha

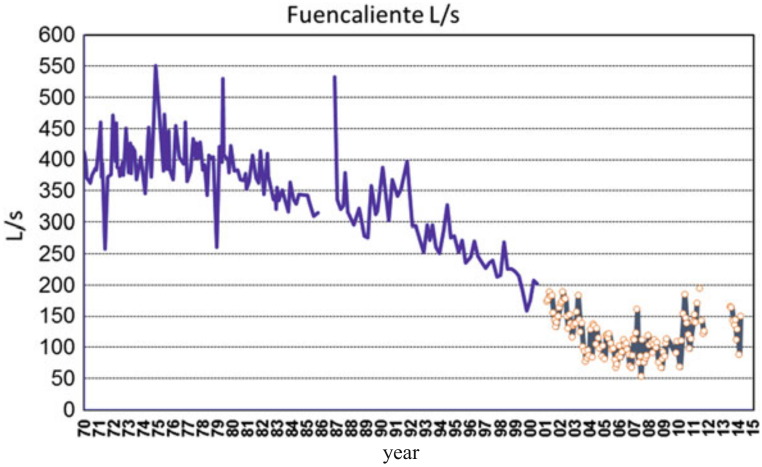

Fig. 3 Fuencaliente spring flow (*source* CHG)

per authorized well and no rotation or changes in the location of irrigated land; (f) creation of an unique interlocutor in the form of a GWUA and finally, (g) payment of a tariff to finance the water supply to former users of the "Fuencaliente" wellspring taken from the near San Clemente reservoir. The plan has allowed the recovery of piezometric level as illustrated in Fig. 4.

This specific payment of a groundwater tariff is exceptional in Spain. The Water Act does not foresee this possibility, thus, a reform of the Law would be required to introduce it. The financial resources for the RBAs come from the government budget and from the tariffs paid by users of regulated surface water. In the case of "Los Llanos" the payment of a water tariff is justified by the complementary use of surface water (from the San Clemente reservoir), but it is exceptional in Spain.

Fig. 4 Piezometic level 'Llanos de la Puebla' (*source* CHG)

4 Discussion and Concluding Remarks

The lack of an effective groundwater governance has usually resulted in the depletion of groundwater levels due to unsustainable agricultural development. The case described in this work serves as one example of effective governance and shed some light on the possible paths of sustainable governance of groundwater resources. The circumstances enforced sustainability in abstractions but further changes to improve flexibility and self-governance are required to guarantee an optimal management of the GW resources.

The aquifer "Llanos La Puebla" has reached a level of sustainability thanks to the governance model applied, including the use of innovative cost recovery instruments (tariff) that have not precedent in GW management in Spain. There are proposals to improve current management plan that should be attended (e.g. water rights trade, land rotation). Another avenue of research is the analysis of the different treatments given to this specific case and the nearby "Parpacén" (West) and "La Zarza" (East) aquifers. Important lessons about effective governance and the sustainability of groundwater resources use may be concluded from this research.

One easily implemented lesson in developed countries is the use of modern technology to monitor and map groundwater abstraction (e.g. meters, remote sensing), what needs to be implemented and placed on a cooperative ground between private and public agents. Thus, the implementation of governance frameworks with bottom-up initiatives, together with command and control measures (top-down direction) seems promising.

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