The challenge of collaborative groundwater governance: four case studies from Spain and Australia.

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Abstract

Ostrom and others have proposed a number of conditions for resilient internally managed common property resources. These conditions are used to assess the implementation of groundwater management regimes in the Namoi and Murray NSW catchments in the Murray Darling Basin in Australia and the Mancha Occidental and Campo Montiel aquifers in the Upper Guadiana Basin in Spain. These examples share some favourable features for internal self management including well defined resource boundaries and long term resource tenure. Other aspects are more problematic including agreement on sustainable resource yields, users' involvement in setting resource management rules, and users' capacity to establish their own resource management arrangements including effective monitoring and sanctions. Further efforts are needed to establish effective collaboration between water authorities and water users and to improve the link between benefits that users receive from using groundwater and costs that they incur in managing the resource.

1. Introduction

Irrigation is responsible for about 70% of the world's freshwater withdrawal, a proportion that increases up to 80-90% in semiarid countries. These have experienced a large increase in groundwater development for irrigation during the last half-century. This has been brought about mainly by the personal initiatives of millions of farmers, while government water agencies have been mainly concerned with building and operating surface water supply systems (Llamas and Martinez Santos 2005).

Groundwater has a number of beneficial features as a source of supply. Groundwater is not a subject to the same evaporative processes as surface water. It moves comparatively slowly, and can be tapped close to its place of use. It also remains available year-round and even during droughts. Many irrigators have long since turned to groundwater as an alternative source or a buffer to cover peak, seasonal and drought water demands. Groundwater infrastructure is relatively cheap, enabling individuals to arrange for their own supply, and offering considerable potential for adaptive management in the face of supply uncertainties.

However, groundwater is a more difficult resource to govern than surface water. The movements of groundwater are not visible, and more difficult to map. Hydrogeological boundaries are often diffuse, as is the connection of individual aquifers with other aquifers and surface waters. Therefore, there is a lot of uncertainty

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involved in determining the individual effect of groundwater users on one another, on the aquifer or on surface stream flows.

Historically landowners have been allowed to pump water from underneath the land with minimal control. Because of the uncertain impacts of groundwater use, and their individual investments in pumping equipment farmers are reluctant to reduce or cease pumping when called to do so (Schlager 2006). As groundwater irrigation mounts farmers form increasingly strong lobbies to protect their own interests, to the point that social conflicts may arise if water table depletion or groundwater quality degradation becomes an issue (Garrido et al 2006). Other unwanted effects of intensive groundwater use can include land subsidence and adverse ecological impacts on aquatic ecosystems. Though often coupled with significant social and economic benefits, these issues have become particularly widespread in arid and semiarid regions (Llamas and Custodio 2003). Yet, adequate groundwater monitoring, management and governance remains an important to challenge to ensure long-term sustainability (Shah 2005, Llamas and Martinez Santos 2005, Kretsinger and Narasimhan 2006).

This paper examines the robustness and relevance of the design principles proposed by Ostrom and others for sustainable groundwater management and governance. This is carried out within the context of a comparison of groundwater irrigation management in Australia and Spain. Australia and Spain are chosen because they both have substantial water supply challenges (which may increase owing to climate change) large and varied irrigated agriculture, areas with significant reliance on groundwater, and substantial experience with decentralised catchment-based management. Both countries present a substantial decentralisation of land and water management. At the same time they have significantly different institutions and policy preferences, and significant internal variation. This enables resource management design principles to be examined in a wide variety of circumstances.

The next section contains a brief analysis of the principles for adaptive and sustainable water resource governance, largely based on work by Elinor Ostrom and others. The following section outlines water facts and policy in Australia and Spain to provide a context for the more detailed analysis of groundwater management and governance in two catchments in each of the two countries. Specific resources at the sub basin level have been chosen because many of the important details and relationships affecting the success or otherwise of water management and governance arrangements are masked when larger and more aggregated comparisons are made.

The final section summarises the outcomes of this analysis, discusses the robustness of Ostrom's design principles and suggest areas for further research, policy and institutional development.

2. Principles and framework for adaptive management and governance of water resources

Following comparative analysis of governance for common-pool resources in many settings Ostrom and others have proposed nine design principles for robust

institutions for effective governance[3]. The first seven principles are intended to apply to fairly simple localised biophysical and social systems, and local governing bodies, but are also relevant to more complex systems and higher governing bodies. The other two principles are intended to apply to complex systems (Ostrom 1990, Ostrom 2005).

1. ***Clearly defined boundaries***: The boundaries of the resource system, and the individuals or households with rights to harvest resource units are clearly defined.
2. ***Proportional equivalence between benefits and costs***: Rules specifying the amount of resource product that a user is allocated are related to local conditions and to rules requiring labour, materials and/or money input[4] (most participants receive sufficiently large payoffs that they are willing to learn about better options. Participants with larger stakes have interests broadly congruent with increased productivity for the system.
3. ***Collective choice arrangements***: Many of the individuals affected by harvesting and protection rules are included in the group who can modify these rules[5].
4. ***Monitoring***: Monitors who actively audit biophysical conditions and user behaviour, are at least partially accountable to the users and/or the users themselves.
5. ***Graduated sanctions***: Users who violate rules in use are likely to receive graduated sanctions (depending on the seriousness and context of the events) from other users, from officials accountable to these users, or from both.
6. ***Conflict resolution mechanisms***: Users and their officials have rapid access to low-cost, local arenas to resolve conflict among users or between users and officials.
7. ***Minimal recognition of rights***[6]
   a. Resource users have long-term tenure rights to the resource[7].
   b. The rights of users to devise their own institutions are not challenged by external government authorities. (The political environment encourages autonomy but also provides oversight regarding corruption and accountability as well as conflict resolution).
8. ***Nested enterprises***: Appropriation, provision, monitoring, enforcement, conflict resolution and governance activities are organised in multiple layers of nested enterprises.

Sustainable community governance of small (and large) scale resource systems can be threatened by rapid exogenous changes in the physical environment, population and technology; intergenerational failures in the transmission of resource management principles, roles and responsibilities; excessive reliance on blueprints derived from specific successes; and corruption and rent seeking. Ostrom recognizes that while small-scale community government resource institutions may be more effective than centralised government in achieving many aspects of sustainable development,

[3] Ostrom proposes that it is not possible to analyse all the potential rules that might be used to examine most common property resources, therefore rule changes should be viewed as experiments. As systems prove themselves they are likely to be adopted further. No one set of rules is optimal for every situation - there is no universal blueprint. But there are some broad structural similarities.

[4] In other words costs met by users are in proportion with benefits that users gain from the resource

[5] Local control can lead to domination by interest groups such as landowners, but it also increases the chance of local ownership and compliance with the management regime.

[6] This principle is split into two parts in this study for the purpose of analysis.

[7] The environment is counted as a resource user – this adds to the complexity of managing complex water systems.

supportive large-scale institutional arrangements are needed for some purposes. These include the provision of reliable information, education and extension facilities and low-cost conflict-resolution mechanisms, the protection of citizens rights and assistance in the case of natural disasters (Ostrom 2005). In addition higher level arrangements are needed to coordinate complex systems that include multiple actors, statutory frameworks, organizations and policies (Connell et al 2007).

The following section provides a brief overview of water use and policy in Australia and Spain to provide a contextual background for the following analysis of groundwater management experience in specific catchments.

3. Scope for the comparative study: recent developments in water policy in Spain and Australia

Spain and Australia are both relatively large users of water. In 2002 Australia consumed 1,300m^3 per person (fourth in the OECD) and Spain consumed 950m^3 per person (sixth the OECD) (OECD 2006). The relatively large water use in both countries this can be explained by the large share of water consumed by agriculture. Irrigation is the largest user of water in both countries, 68% in Spain (MMA 1998) and 65% in Australia in 2004-05 (ABS 2005)[8]. In Spain 50% percent of the value of agricultural production comes from irrigated land (OECD 2004: 26) in Australia 23% (ABS 2005). Since 1980 irrigation as a proportion of cultivated land has increased by 51% in Australia and 43% in Spain (OECD 2006). In Australia the volume of groundwater use increased by 58% in Australia and by over 200% in New South Wales, Victoria and Western Australia between 1983-84 and 1996-97 (NLWRA 2001), while in Spain it nearly doubled between 1970 and 2000 (MMA 2000).

In the last two decades both Spain[9] and Australia[10] have followed international trends towards integrated water resource management (IWRM). This has been carried out through national initiatives that aim to ensure the continued sustainability of surface and groundwater systems, taking account of economic, environmental and social impacts in an integrated manner.

In Spain the 1985 Water Law represented a major reform of water policy. Key principles of the 1985 law were integrated management of water resources, a strong emphasis on the river basin as the main management unit[11], increased use of participation in decision-making and reliance on water planning to balance social economic and environmental considerations (Del Moral et al 2003). Key innovations included declaration of groundwater as part of the public domain and giving river basin agencies broad powers for the management of aquifers. These included granting compulsory permits for users who started pumping after 1985 and a registry for public

[8] In 2004-05 both use of water in irrigation and proportion of agricultural production produced in the irrigated sector were unusually low owing to drought conditions and reduced supplies of water.
[9] Water Act 1985.
[10] Intergovernmental Agreement on a National Water Initiative, between the Commonwealth of Australia and the Governments of New South Wales, Victoria, Queensland, South Australia, the ACT, and the Northern Territory signed on 25 June 2004.
[11] Though the law enforced their position, basin agencies were commonplace several decades before the enactment of the 1985 reform.

and private groundwater use[12] (Embid Irujo 2003). This coexistence of private and publicly registered water rights has led to ongoing difficulties in the property rights regime (Fornes et al 2005). The new legislation also included the possibility to declare aquifers 'overexploited'[13].

During the last two decades, several amendments have been introduced in an attempt to strengthen the 1985 water law. The main changes include new provisions to comply with the EU Water Framework directive, particularly in regards to tightening water quality requirements and recognizing ecological values. In addition, there have been new guidelines for water pricing and requirements for water metering, and holders of water licences have been given new options for water transfers (Blomqvist et al 2005).

In Australia, until the late 1980s most of the emphasis was on building infrastructure and water supply capacity. In 1994 the Council of Australian Governments (COAG) agreed to a package of reforms of the Australian water industry including the development of water pricing, allocation, and institutional mechanisms but implementation was slow (Ingle Smith 2001)[14]. In 2004 COAG established an Intergovernmental Agreement on a National Water Initiative (NWI), The NWI provides for: comprehensive planning for surface and groundwater, substantial progress towards returning overallocated systems to sustainable levels of extraction[15] (by 2010), secure water access entitlements, an expansion of water trading (with legal/institutional arrangements in place by 2007), and best practice water pricing. The NWI emphasises, public consultation and monitoring, and stregthens reporting and accounting of water use[16].

These Spanish and Australian initiatives have many features in common: a river basin approach to water planning and management, environmentally sustainable levels of water extraction, improved water pricing, better monitoring and measurement of water use, and encouragement of community and stakeholder participation in decision-making. These features are consistent with IWRM and the monitoring requirements of adaptive water management[17]. There are however some significant differences. For instance Spain has shown a greater preference for public ownership, while also being slower to encourage private ownership and market-based solutions than Australia.

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[12] Water users that were using groundwater before 1985 had the option to register their rights as private water rights, or to register them in the public register, those starting to use water after 1985 are obliged to register them in the public register.

[13] The practical implications of this legal consideration are explained further on.

[14] The COAG initiative was followed by the development of several frameworks and guidelines relating to specific aspects of water policy. These included national frameworks for Improved Groundwater Management in Australia (1996), and Managing Overallocated Groundwater Systems (2002).

[15] The National Groundwater Committee (a group of federal and state officials) have defined sustainable groundwater yield as "the groundwater extraction regime measured over a specified planning timeframe, that allows acceptable levels of stress and protect dependent economic, social and environmental values. This definition has been designed to allow for groundwater mining on a temporary basis, but also includes a precautionary and adaptive approach (NGC (2004)).

[16] Most jurisdictions have separated water access entitlements from land titles, and the functions of water delivery from regulation, and made explicit provision for environmental water.

[17] However, neither initiative explicitly recognises the need for policy experimentation in response to uncertainty

The remainder of this study analyses and compares groundwater management in three catchments; the Namoi and the Murray in the MDB, and two examples in the Upper Guadiana basin. These aquifer systems have been chosen because they illustrate both similarities and differences in responses to intensive groundwater overexploitation.

3.1 The Upper and Lower Namoi groundwater source (New South Wales, Australia)

The COAG 1994 reforms required the establishment of separate and tradeable water entitlements. The NSW Water Act 2000 provides for the establishment of Water Sharing Plans that set the rules for the sharing of water between domestic users, livestock, the environment, irrigators, and industrial users[18].

The Namoi catchment in northern NSW covers approximately 42000 km². Rain is highly variable from as high as 1100mm/year over the Great Dividing Range in the east to 470mm/year in the west. Total groundwater storage is estimated to be 285 billion m³, mostly in the Great Artesian Basin. The Namoi groundwater resource accounts for about 40% of NSW's total groundwater use, and is one of the most intensively developed groundwater resources in NSW. Groundwater has been extensively monitored since the 1970s, which has allowed the development of a groundwater model (Turral and Fullager, 2007). In the period between 1991-92 and 2003-04 average irrigation use was only slightly less than annual average aquifer recharge. In the drought years of 1992-93 to 1994-95 annual aquifer extraction increased to almost double the annual recharge[19]. A similar pattern has been repeated in the prolonged drought since 2000 (Figure 1).

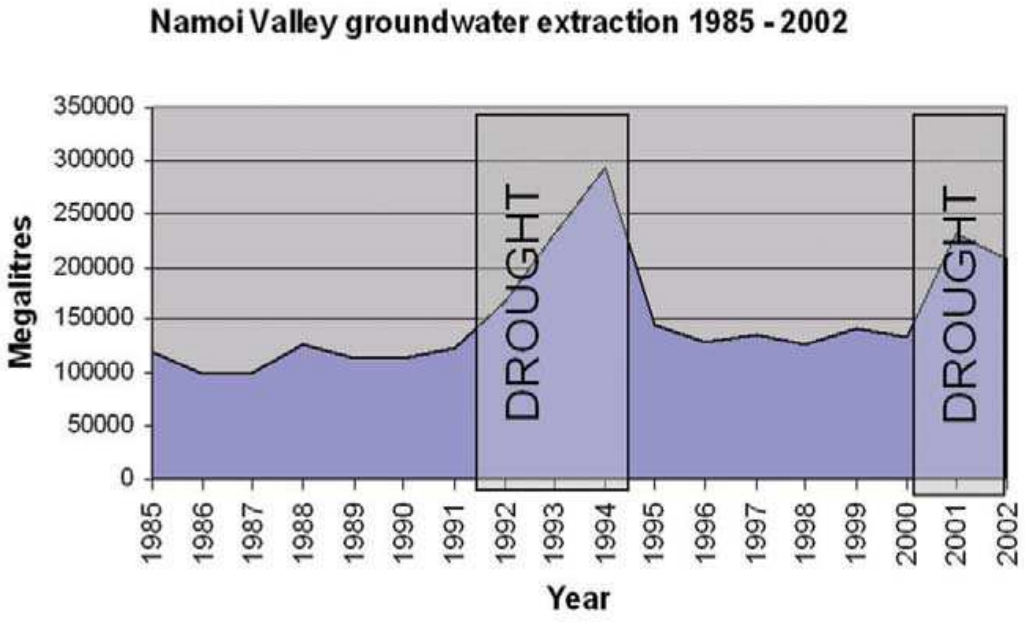

Figure 1. Graph adapted from Namoi Groundwater Taskforce Final report with additional data provide by Department of Natural Resources (Kuehne and Bjornlund 2006).

[18] http://www.dnr.nsw.gov.au/water/plans.shtml, accessed 9 August 2007.

[19] The average annual use was 184Mm^3 and the highest annual use was 329Mm^3 in the period 1991-92 to 2003-04 http://naturalresources.nsw.gov.au/water/pdf/key_amendments_namoi_info_sheet-18-8-06.pdf accessed 11 August 2007

Although aquifer extraction has rarely exceeded recharge, water use entitlements substantially exceed both actual use and recharge. In 2003 groundwater use licences (463Mm^3) were over double the estimated sustainable yield, based on recharge (191Mm^3) (Department of Natural Resources, 2003)[20]. This over-allocation has occurred because the NSW government encouraged water use and issued entitlements well in excess of annual recharge, coupled with a lack of information on recharge and the low value of water. While groundwater use has generally been below recharge, in drought years groundwater use has exceeded recharge because farmers have activated inactive licences to counter drought (Kuehne and Bjornlund 2004).

The Namoi Groundwater Sharing Plan was developed from 2001-2003, earlier than most other water sharing plans. The main sources of contention were the definition of sustainable extraction, the allowance for environmental purposes[21], and whether entitlement reductions should be "across the board", or adjusted in favour of heavy water users. The 2003 plan was based on a 100% annual average recharge less an allowance for environmental health (approximately 30%). The plan defined 13 separate groundwater management zones, and determined separate and varying reductions in access licenses for each zone. Overall aquifer access licences were reduced by 51% in the Lower Namoi and by 61% in the Upper Namoi. Nearly 300 irrigation licence holders received aquifer access licences with a reduced share component[22].

There were concerns about the economic impact of this approach on those irrigators who had developed their enterprise and were regularly using more than their reduced entitlement (active users) compared to those who used little or none of their entitlement (inactive users)[23]. Following representations from individual irrigators and the New South Wales Irrigators Council, the Minister for Natural Resources deferred the commencement of the Plan. There was a further delay owing to legislative and policy development following the National Water Initiative. In 2004 the Department of Natural Resources announced that the formula for entitlement reductions could be tailored to each water system. In May 2006, following consultations with the community, the Namoi Catchment Management Authority recommended that entitlement reductions should take account of historical use, with a

[20] There has been substantial debate in NSW about the definition of sustainable yield. It has been generally defined as 100% of the long-term average recharge, with further reductions to reserve water for groundwater-dependent ecosystems. It has been argued that recharge undersestimates sustainable use because aquifers in unconsolidated sediments such as alluvium of Namoi Valley could be expected to respond positively to a lowering of water levels by being more receptive to recharge water. It also ignores possibility of enhanced induced or artificial recharge (Pigram 2007: 146-147).

[21] The Nature Conservation Council of NSW argued strongly for precautionary implementation of 70% annual average recharge and as an environmentally sustainable yield in underused zones, with a 10 year transition for over exploited zones.

[22] Groundwater licences comprise a share (still considered the same as volume in many areas) and an allocation. The introduction of groundwater management plans in overallocated areas alters the previously assumed 1:1 relationship between share and volume.

[23] Although an economic study of the impact of the licence reduction plan showed little difference between the economic impact of reductions across the board and lower reductions for high users (Wolfenden and Van der Lee 2002: vi)

75%-25% weighting between active and inactive users (Department of Natural Resources, 2005)[24].

In order to assist high water users to adjust to lower water entitlements they received supplementary water access licences that are being progressively reduced until year 10 of the plan when supplementary water will no longer be available (Pigram 2006). An Achieving Sustainable Groundwater Entitlements Program (ASGEP)[25] jointly funded by federal and state governments and water users will provide financial assistance to help compensate irrigators for the loss of water entitlements and restrictions on extractions[26]. Namoi entitlement holders are expected to receive $60 million under the scheme. Irrigators are being issued with a new licence to use groundwater. This licence provides entitlement to a share in the groundwater resource, rather than a fixed amount of water, thus allowing use entitlements to be varied in accordance with changes in water supply e.g. owing to climatic factors. The licence provides a perpetual right to access groundwater and is fully tradeable.

Water licence holders, particularly irrigators with a history of high water use have been strongly critical of the process for developing the Namoi water sharing plan. There have been questions about the concept of sustainable yields based on estimated annual average recharge. Despite ongoing monitoring of groundwater levels, the data record is relatively short-term and there are data deficiencies. Recent investigations in the Namoi Valley suggest that recharge figures may have been underestimated (Crawford et al 2004). Moreover there may be some circumstances in which mining groundwater is justified at least in the short term to meet social and economic goals (Pigram 2006, Llamas and Custodio 2003). In any case sustainable yields are subject to review as the climate and scientific knowledge change.

Stakeholders have also had problems with the water planning process. Firstly, they have felt that their ideas have not been listened to and adopted. There has been criticism of the procedural fairness of the process. The perception of unfairness has increased as the timetable for completing the Water Sharing Plan was repeatedly extended, even though the eventual outcome reflected the concerns of active users. The criticism of procedural fairness has not been formally addressed during recent development of the plan. Indeed the Water Management Act was amended in 2004 to remove requirements for specific parties to be consulted and to allow the Minister to carry out consultation at his discretion (Kuenhe and Bjornlund 2004).

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[24] http://naturalresources.nsw.gov.au/water/pdf/key_amendments_namoi_info_sheet-18-8-06.pdf. accessed 8 August 2007

[25] The Achieving Sustainable Groundwater Entitlements Program (ASGE) was introduced in 2005. The Australian and NSW governments jointly invested $110 million in the programme, AGSE applied to six catchments including the Upper and Lower Namoi and the Lower Murray. http://dnr.nsw.gov.au/water/pdf/sgep_brochure_draft2c.pdf accessed 8 August 2007

[26] Financial assistance may be paid in relation to the "active" (water actually used) and " inactive" (water not used) components of the licence. Firstly if the value of tradeable water in the new licence is less than the value of " inactive" water in the old entitlement, and secondly if the volume of their historical extraction ("active" water) was greater than their new entitlement. Namoi irrigators who had already had their usage kept below their old entitlement levels receive an additional one-off payment. http://dnr.nsw.gov.au/water/pdf/financial_draft_131205b.pdf accessed 8 August 2007 CLARITY?

3.2 The Lower Murray Groundwater Source (New South Wales, Australia)

The annual sustainable yield for the Lower Murray Groundwater Source is estimated at 83,7Mm^3 [27]. Groundwater use in the period 2001-02 to 2004-05 averaged 71Mm^3 except for 2002-03 when it jumped to 130Mm^3. Groundwater entitlements then totalled 263Mm^3.

The Groundwater Sharing Plan for the Lower Murray was initiated in 2005 in the second round of groundwater sharing plans in New South Wales under the ASGEP Programme. The Murray Catchment Management Authority (MCMA) had responsibility for developing details of the planning consultation with stakeholders. In February 2006 the MCMA issued a discussion paper on options for entitlement reduction and held consultation meetings with water licence holders. Following consultations it was agreed to reduce licence entitlements to the sustainable yield giving a weight of 78% to active entitlements and 22% to inactive entitlements. Under this formula it has been estimated that licence holders previously using 75% of their entitlements will retain 44%. In addition 48.5Mm^3 were granted as supplementary entitlements to be phased out over 10 years. Like the Namoi licences, water entitlements are expressed as a share of the available resource, are granted in perpetuity and are tradeable.

The Murray groundwater planning process has been less divisive than the Namoi process for a number of reasons. Firstly, the process was not delayed by debates over the basic formula for water sharing entitlements (historical entitlements versus across-the-board) or by legislative and policy development following the National Water Initiative. Secondly groundwater planning processes in the second round had the advantage of learning from experience in the first round. The MCMA made sure that stakeholders were well informed about options for reducing entitlements, and also about the parts of the package which were non-negotiable such as the assessment of sustainable yield, the timing of entitlement reductions and financial assistance payments. While some concerns remained about formula for calculating sustainable yields, the establishment of resource boundaries, the legality of the entitlement reductions and the adequacy of compensation for the loss of water[28], the package achieved general acceptance by the community. The availability of supplementary entitlements and financial assistance as part of the package from the outset were important factors in gaining support for the process. Despite legal action against the plan by some irrigators, authorities and some stakeholders consider that the planning process was a success.

3.3 The Mancha Occidental Aquifer (Castilla-La Mancha, Spain)

The Mancha Occidental aquifer is located in the Castilla-La Mancha region, central Spain. The aquifer covers approximately 5,500km^2 and is home to 300,000 people. The climate in the region is typically semiarid, with long dry periods alternating with short wet ones. Average annual rainfall is about 415 mm. Rivers run dry most of the

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[27] Sustainable yield was estimated by a consultant developed model calibrated my observations of levels and yields in conservation and production bores, recharge from rainfall and shallow groundwater.

[28] http://www.parliament.nsw.gov.au/prod/PARLMENT/hansArt.nsf/V3Key/LA20060330037 30 March 2006, accessed 6 August 2007

time, and surface water resources are limited. Groundwater traditionally supplies over 90% of the catchment water demands (Guadiana Water Authority 2005).

Over the last thirty years, the generalization of intensive groundwater use has virtually offset the effects of the region's endemic drought problems, thus supporting irrigation-based social and economic welfare and acting as the main driver for the region's prosperity. Consequently the total irrigated area increased from 30,000 to 150,000 hectares between 1960 and 2003 (Guadiana Water Authority 2005). During that time, groundwater extraction consistently surpassed 500Mm^3/yr, well in excess of the area's nominal[29] renewable resources (320Mm^3/yr).

Most of this development was uncontrolled. As a result, there is no accurate estimate of yearly water abstractions from the aquifer, the total irrigated surface or the distribution of irrigated crops (Guadiana Water Authority 2006). Intensive pumping has led to unexpected and adverse environmental effects. Before intensive aquifer exploitation began there were strong surface water-groundwater interactions. These gave rise to valuable wetland ecosystems that include UNESCO's *Mancha Humeda* Biosphere Reserve and Ramsar-listed *Las Tablas de Daimiel* National Park (Martinez Cortina 2003). Intensive pumping caused the water table to drop by as much as 1m/yr between the 1970s and the 1990s, thus drying a significant proportion of the area's wetlands (De la Hera 2003).

Since the late 1980s basin authorities have attempted to establish legal controls on water use. This includes a legal "declaration of overexploitation", which essentially entailed yearly pumping restrictions (also named "pumping plans"), an obligation to constitute water user associations and a ban from drilling new wells. But the establishment of uniform property rights has been constrained because pre 1985 well owners have been allowed to maintain private wells. The lack of a clear inventory of groundwater rights has also played its part, since owners drilling their wells after 1986 have been able to claim that they did so before the new law came into place.

More recently measures co-funded by the European Union have provided compensatory payments to encourage Mancha Occidental farmers to voluntarily cut down on water use (Fornes et al 2001). While the latter have been somewhat more effective, neither of these measures have met their main objectives (Martinez-Santos 2007). Over 20,000 unauthorised boreholes still exist within the aquifer (Guadiana Water Authority 2005), and downward water table trends have not been reversed (IGME 2004).

Following the enactment of the EU Water Framework Directive, which demands that a good quantitative and qualitative status of the water bodies should be achieved by 2015, the key issue is how to achieve this goal while not having a negative impact on the social and economic importance of irrigation in the area. All stakeholders perceive this as a difficult task, particularly in view of the area's groundwater management difficulties (Guadiana Water Authority 2006).

[29] This estimate is obsolete, as it refers to natural conditions. A dropping water table has led to a dramatic decrease in evapotranspiration, to the point that the aquifer's renewable resources could have probably increased to approximately 500Mm^3/yr (Martinez-Cortina 2003).

The problems associated with groundwater management in the Mancha Occidental aquifer are significantly due to the conflictual relationship between the Water Authority and the water users (Lopez-Gunn 2003, Lopez-Gunn and Martinez-Cortina 2006). Rather than facilitating the role of water managers, irrigation communities have openly contested the provisions made by the Guadiana Water Authority, and even encouraged their members to challenge these in court. Many farmers perceive high-level interventions either as an attack on their rights or other means to attain financial profits, without changing water use practices. Besides, water users have often felt that they have not been allowed to have a sufficient say in water management. Inadequate monitoring and knowledge of real water use, and lack of coordination between the implementation of agricultural and water policy have also significantly constrained effective decision-making.

3.4 The Campo de Montiel Aquifer (Castilla-La Mancha, Spain)

The Campo de Montiel aquifer is located immediately south of the Mancha Occidental, and spans approximately half the surface. It is a limestone aquifer system that provides part of the Mancha Occidental's natural recharge, and also presents some valuable aquatic ecosystems that largely stem from the interaction between surface and groundwater (the *Lagunas de Ruidera*, or "Ruidera Lakes").

Unlike the Mancha area the topography in Montiel is quite hilly and is therefore less favourable for agriculture. That, together with a population that does not exceed 20,000 people, is perhaps the main reason why the growth of irrigated agriculture in the area has not been so pronounced (from 200ha in the early 1980s to 8,000ha at the end of the 1980s expansion period - this figure has remained roughly steady to the present date). Irrigation is however the main water consumer in the area, and accounts for approximately 90% of the total water demands (AEUAS 2004).

Since the late 1980s the Campo de Montiel aquifer has also been under a "declaration of overexploitation". This has been the object of many a controversy in view of the aquifer's hydrological balance (Llamas 1994). While the maximum volume that has been pumped within a single year is approximately 35Mm^3, the estimated renewable resources of the system are in the order of 130Mm^3/yr (MMA 2000). The argument in this case is not about use in excess of sustainable yield, but how irrigation can affect particular sectors of the aquifer and have localized negative impacts on the Lagunas de Ruidera and on natural springs that supply water to villages (Viladomiu and Rosell 1997, Lopez-Gunn 2003).

Even if frictions have always existed between Campo de Montiel users and the Water Authority, these remain relatively small in comparison with the ones in the Mancha Occidental. This, and the fact that the Campo de Montiel aquifer is in relatively good hydrological shape, means that management issues in this aquifer generally plays a secondary role in the Upper Guadiana's water policy arena.

3.5 Summary of the case studies

The above examples illustrate the relevance of Ostrom's framework for assessing the robustness of groundwater management regimes, while also highlighting some of the difficulties involved. The key attributes of a groundwater management systems in the Namoi, Lower Murray and Mancha Occidental aquifers are summarised in Table 1.

The assessments in Table 1 are based on subjective judgements. The term “arguable” indicates that there is a reasonable case for either a positive of negative assessment.

Table 1. Groundwater management regimes in New South Wales and Castilla-La Mancha

Item	*Namoi*	*Murray*	*Mancha Occidental*	*Campo de Montiel*
Is the resource boundary and the sustainable yield well-defined taking account of any connection with other resources?	Arguably	Arguably	Arguably	Arguably
Are rights to harvest the resource well-defined?	Yes	Yes	Yes	Yes
Do resource users have long-term tenure rights to the resource?	Yes	Yes	Yes	Yes
Are users given official sanction to devise their own institutions to manage the resource?	No	No	No	No
Are most users affected by harvesting and protection roles included in the group who can modify the rules?	No	No	No	Arguably
The benefits that users receive from using a resource are proportional to the costs that they incur in the resource management regime	Arguably	Arguably	No	Arguably
Are roles and responsibilities for a.monitoring and b. sanctioning clearly identified and agreed by users?	Arguably	Arguably	No	Arguably
Do users and their officials have rapid access to low-cost local arenas to resolve conflicts among users or between users and officials?	Arguably	Arguably	No	No

In the New South Wales examples the resource boundaries and hydrological sustainable yields are well defined but the socio-political sustainable yields are contentious[30]. Groundwater users have long term entitlements to harvest the resource, but NSW authorities define institutional rules and arrangements to manage the resource, issue harvesting rights and determine the share of the resource that is available to water users in specific periods (seasons, years). This share is based on data and models developed by the authorities, without participation by groundwater users. Groundwater users are consulted in this process but authorities make the final decisions. Water is distributed by private water supply companies who work closely with irrigators. Monitoring is carried out by both the supply companies and government authorities, enforcement rests with the authorities. Users benefits are proportional to their contributions in the sense that users who have invested more in water using activities and used more water over time receive larger shares of the

[30] Hydrological sustainable yields are what is required to ensure that an aquifer is not depleted, socio-political sustainable yields reflect the outcome of negotiations between parties. The outcome of these negotiations may involve some depletion of the resource, at least in the short term.

available resource, and in the sense that operational costs of water supply are largely met by irrigators through the price mechanism. But enforcement costs, in so far as enforcement takes place, are met by taxpayers. Regional catchment management authorities have provided fora where some disputes have been resolved, but some conflicts persist with irrigators taking court action in relation to statutory water sharing plans.

Similarly in the Spanish examples the resource boundaries and hydrological yields are well defined but the sociopolitical sustainable yields are contentious. Resource users have long term rights to use the resource. River basin authorities are empowered to define the sustainable yield and the amount of water that may be used in a specific period but, especially in the Mancha Occidental, many users have ignored directions from authorities. Both Spanish cases are similar to the Australian ones in the sense that water authorities make water user plans in consultation with water user associations. In the Mancha area water user associations have not been able to achieve cooperation either with each other or with water authorities, leading to widespread disregard of pumping restrictions. In the Montiel case, however, strong leadership in the water user association led to an arrangement where some degree of cooperation has been attained between the water authority and the users. This includes monitoring users and denouncing abuses, but the association is not actually empowered to sanction illegal pumpers. In the Spanish cases proportionality of user costs and benefits only exists in as much as water user associations who become parties to water use plans have acquired responsibility for managing agricultural subsidies. In principle Water Juries embodied within Spanish Water User Associations provide a mechanism to resolve conflicts, but in practice these have been effective in resolving legal issues involved in groundwater disputes.

4. Discussion

It has been difficult to establish robust and adaptive water regimes based on well defined sustainable yields and rights to harvest in both the Murray- Darling Basin and the Guadiana. The following discussion outlines differences between the cases and then discusses common difficulties in establishing adaptive and effective management regimes.

4.1 Differences between the cases

Property rights reflecting calculated average sustainable yields have been put in place in the New South Wales aquifers after a long process of negotiation between responsible government agencies and water users. The development of groundwater management plans in overallocated resources, and collaboration between the government, irrigators and environmental groups has been difficult, but the difficulties have been reduced by the relatively small number of irrigators involved. Key factors explaining the eventual achievement of collaborative solutions in both the Namoi and the Murray catchments have been a shared perception by all stakeholders that the long-term resource availability and farm viability depend on controlling water resource use. This has lead to the eventual acceptance of official sustainable yield calculations. The availability of a transitional period for reducing entitlements and financial compensation have been important factors in reaching agreements.

The perception of the importance of controlling water use is shared by most stakeholders in the Mancha Occidental and Montiel aquifers. However, collaboration between the Basin Authority and water users has been established in the Campo Montiel but not in the Mancha Occidental. Lopez-Gunn (2003) argues that there are three main reasons why this is the case[31]. Firstly, water user communities have been unwilling to denounce illegal pumpers. This reflects *localismo*, a social trait whereby neighbours are unwilling to denounce each other (Pitt-Rivers 1971. Montiel users have traditionally been able to denounce illegal users quickly, thus preventing the situation from getting out of hand. Secondly, lack of trust between water users and the Basin Authority has led long-standing confrontational attitudes on both sides. In the Mancha case, water user associations have largely adopted a defensive attitude, shielding farmers from water policy initiatives rather than to facilitating dialogue between managers and users. In the Campo Montiel strong leadership in the water users association has enabled cooperation between users and authorities.

Thirdly, and most importantly the number of farmers using the La Mancha aquifer (15000) is much larger than the numbers involved in the Namoi (550), the Murray (200) or the Campo Montiel (100)[32]. In the Murray case, it was possible for the water authority to discuss the issue on a one-to-one basis with a large share of the area's two hundred farmers.. In contrast, it is beyond the capacity of the Basin Authority staff to hold discussions with 15000 farmers. Moreover, farmers in the La Mancha region are also more diverse than farmers in the other catchments in terms of both farm scale and products. As a result, their interests are diverse, they tend to associate into different lobbies[34]

Fourthly the Mancha region received substantial investment of public funds on agriculture during the late 1980s and early 1990s, financed by the Common Agricultural Policy. In Spain agricultural subsidies are managed regionally, whereas water policy is managed nationally, and these administrations have lacked coordination over the years. For example, in the early 1990s strict pumping restrictions were introduced in the Mancha aquifer but simultaneously, the Castilla-La Mancha government was paying subsidies that encouraged water-intensive crops. The

[31] This author provides a comprehensive application of Ostrom's principles to the Mancha Occidental in comparison with two neighbouring aquifers (Campo de Montiel and Mancha Oriental), establishing why the latter two have managed to establish a much more robust groundwater management regime.

[32] Also the Campo de Montiel aquifer is represented one single (and small) water association, whereas the Mancha Occidental is divided in approximately twenty different communities.

[34] Mancha farmers range from small land-owners (about one hectare) to agri-businesses (over 100ha), and grow a wide variety of crops, ranging from vineyards and olive trees to cereal and horticulture. Mancha Occidental water user associations are diverse in themselves, not only in terms of how active a role they play in fulfilling their roles but also as to the advice they provide to their associates. However, there are also different farmer unions, cooperatives and other farmer lobbies that bring further complexity into the situation. There are 20 water user associations of whom 13 fall under one umbrella association. This association represents larger irrigators whose main activity is agriculture. Another association represents "investment farmers". Small farmers are represented on a more ad hoc basis.

Basin Authority lacked the human and economic means to enforce its own restrictions, and many farmers chose to drill illegal wells in order to receive the subsidies. While coordination is being slowly improved, uncoordinated action between the central and state administrations accounts for a significant share of the current problems.

4.2 Common difficulties in establishing an effective regime

The Australian and Spanish experiences reveal some common difficulties in establishing a robust and sustainable resource management regime as defined by Ostrom. Firstly, surface water management has received much more attention than groundwater management at a national level, because in most locations surface water is the primary source of supply. Much more effort has gone into developing surface water management regimes and the underpinning science. A determined push is needed to develop adequate groundwater management systems, especially given the gaps in knowledge about the connectivities between surface and groundwater and the impact of groundwater use on groundwater-dependent ecosystems. Estimates of sustainable yield are also often disputed for a variety of reasons, not only by scientists (Sophocleous 1997 and 2000, Custodio 2002), but also by users (Turral and Fullagar 2007, Guadiana Water Authority 2007). The management of groundwater and connected surface and groundwater resources requires scientific input, including models. Experiences in both the Australian and Spanish cases indicate that great effort is needed to explain model outputs, and to get affected parties to accept scientific uncertainty and iterative solutions (Martinez-Santos et al, in press). Gaining feedback through public seminars and discussions is insufficient and ongoing engagement between scientists and practioners is required (Letcher and Jakeman 2002).

Moreover, the development of groundwater resources has outpaced the establishment of robust systems of groundwater ownership and use entitlement. In Australia and Spain central intervention has been needed to determine the sustainable yield and to establish the legal underpinning of the groundwater management regime. However, centrally organised processes have not been readily accepted by water users. When overexploitation has occurred and water authorities have attempted to limit pumping rights there has been strong resistance from users who have made considerable investments in the expectation of a reliable, continuing source of supply. Sustainable management is also constrained by lack of measurement of groundwater use.

Since some central intervention is needed to manage complex social and ecological systems such as groundwater systems with complex user groups (including the environment). At the same time effective implementation depends on support from water users. Robust regimes have only been achieved where authorities and water users have been able to collaborate (Lopez-Gunn and Martinez-Cortina 2006). The establishment of effective collaborative processes remains a major challenge. Participative processes have been introduced in all the aquifer's studied, but these have been complicated by a lack of shared perceptions and trust between participants. One problem is that public consultation often appears more symbolic than real, because it does not take sufficient account of stakeholder views and/or takes place major policy changes have been made. Transparent and inclusive consultation processes are particularly important in order to achieve collaborative solutions. This

requires strong leadership and effective institutions for implementing policy on the ground.

A further challenge is to establish incentives for collaboration that link user benefits with their contribution to the water management regime. In the cases studied water users Government organisations have primary responsibility for water planning and allocation, and enforcement. Users have an incentive to collaborate with authorities in order to receive legal water allocations, but in Spain this incentive is limited by lack of effective enforcement of water use limits. In these cases governments have relied on "positive" incentives - in Australia allocation of saleable water rights and compensation for reduced entitlements, in Spain access to substantial agricultural subsidies.

5. Conclusions

The above case studies suggest several priorities for further research, policy and institutional development. On the research side there is an urgent need to map groundwater resources and understand their connectivity with surface water and ecosystems, and to develop robust methodologies for establishing what is meant by sustainable groundwater yields. These are long-term research tasks that will require sustained commitment over many years. Australian experience emphasises that surface and ground water reform should occur together to avoid lags in policy development and implementation. Sustainable yields need to take into account the temporal and geographical distribution of water use and environmental assets (Turral and Fullager, 2007)

Demands for groundwater use will continue to increase, and further problems are likely to become evident because of land uses changes and climate change. This will involve ongoing evaluation of groundwater sustainable yields and management regimes including use entitlements in the light of changing knowledge about climate, hydrogeology and other factors influencing water scarcity, and continuing policy adjustment in the light of improve knowledge and increased experience. General social acceptance of the need for limitations on groundwater use involves a change in values that takes a substantial amount of time and effort to achieve. Therefore it is very important to prepare the ground for strategies of adaptive management and gain political acceptance for them. This is not an easy task because adaptive experimental approaches are difficult to implement within short-term political cycles where a premium is placed on quick and certain results (Allan and Curtis 2005).

More efforts are needed to develop ongoing understanding and collaboration between governments, water users and other stakeholders in order to achieve adaptive groundwater management. Government agencies and stakeholders need to work together to further develop mechanisms and processes that span the boundaries between sectoral policies and different levels of government, to share information across jurisdictional and sectoral boundaries and to build the capacity and skills for regional and local implementation. Legal limits are unlikely to be enforced successfully by governments without the active cooperation of water users. Further incentives for cooperation (positive and negative) could be explored, along with fair processes in relation to stakeholders who are being disadvantaged by change. Leadership in all spheres will continue to play a crucial role in encouraging long-term

approaches, precautionary and adaptive approaches and adjudicating and resolving conflicts.

Finally the transition to adaptive surface and groundwater management could be accelerated and the transaction costs of implementing new groundwater governance models could be reduced by improving the exchange of lessons learned. Further comparative research on experience in adaptive groundwater management could make a useful contribution to the transition towards sustainable groundwater management regimes as water scarcities and demand pressures increase.

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