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Can Enhanced Information Systems and Citizen Science Improve Groundwater Governance? Lessons from Morocco, Portugal and Spain

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Abstract: New information and communication technologies have a significant potential to increase the transparency of aquifer management and improve groundwater governance. This research experiments the introduction of a mobile application that allows users to transfer and share information about their groundwater extractions and receive agroclimatic information and groundwater data. It takes place in three different aquifers in Morocco, Portugal, and Spain, each with varied institutional frameworks. This research tests and evaluates the potential of enhanced information systems and citizen science applied to groundwater management and aims to identify some factors that facilitate or hinder their adoption and implementation. To do this, the researchers developed a 4-year plan based on surveys, semi-structured interviews, meetings, participatory workshops, and public round tables with local actors. The main lesson learned from the comparative analysis of these three experiences is that the use of enhanced information systems is more positively perceived, accepted, and adopted when an appropriate social and institutional framework exists and that the more consolidated this framework is, the easier they will be to implement and develop enhanced information systems.

Keywords: groundwater governance; aquifers management; enhanced information systems; citizen science; transparency

1. Introduction

Groundwater governance [1–5] has been a major problem for many public administrations over the last decades [6–8]. After mobilising groundwater resources or relying on individual groundwater extraction for agricultural development policies, numerous countries have suffered the depletion of springs and wells and festered socio-political conflicts at the local or national levels [9–12]. Many of them have been unable to cope with the direct consequences of their expansive policies. Although various command and control formulas have been tried, the results on a global scale are rather disappointing [13–16]. The few successful strategies, generally based on co-management and collective action, are fraught with significant difficulties, such as a lack of knowledge of the resources system, lack of law enforcement and monitoring capacities, lack of institutional legitimacy, or lack of funding, among others [16–19].

However, there is some consensus that the future of groundwater governance must be based, among other factors, on the availability of accurate, accessible, and shared information [20,21]. This is not a new principle, as the classical formulation of the theory of the commons already insisted on this fact [22–24]. Moreover, compared to several other natural resources, obtaining information on groundwater resources (characteristics, dynamics, use by users, etc.) is particularly difficult. The lack of transparency and visibility hinders collective and external control and facilitates individualistic behaviours [25,26] that generate social injustices. This is no secret either; even the United Nations highlighted this need when it used "making the invisible visible" as the slogan for the World Groundwater Year in 2022 [27].

In recent years, new technologies have provided new ways to obtain groundwater information and facilitate its visibility, access, and sharing. The generalisation of information and communication technologies (ICTs) and the recent advances in citizen science show winds conducive to the generation of a new wave of governance [28,29]. This set of techniques and methods is often referred to by the term "enhanced information systems" (EIS). In relation to groundwater management, we use the term when (i) traditional means of data gathering (water meters and piezometers) are complemented by remote sensing techniques, water-soil-plant automatic sensors, or mobile applications; and (ii) citizens and/or stakeholders are engaged in data collection (citizen science) and use [20]. EIS have the potential to involve users in the production of information. This profoundly impacts stakeholder participation in managing a resource that has traditionally been managed (or attempted to be managed) by public administrations based on expert knowledge and traditional (and limited) information sources. For these reasons, EIS must be considered a key part of the paradigm shift from mere management to groundwater governance [28–31].

How can these technologies help the new wave of governance grow? What obstacles will we encounter in their implementation? How can we motivate users to overcome the resistance to provide and share very sensitive information? How and by whom will the information gathered be managed? What territorial and institutional scenarios are the most likely to adopt and use them? Numerous questions arise that open a stimulating novel field of research and are challenging for public and private groundwater management institutions. In this article, we aim to answer, albeit inevitably partially, some of these questions. To this end, we have designed an experiment based on the introduction, in three different territories with varied institutional frameworks, of a mobile app that permits users to transfer and share information on their groundwater abstractions and receive agro-climatic and groundwater data. This research aims to test and evaluate the potential of EIS for groundwater management and identify some factors that facilitate or hinder their implementation. In the following pages, we describe the methodology used and the characteristics of the three areas of study in Morocco, Spain, and Portugal; the results obtained in the three cases; and the conclusions to which this comparative experience led us.

2. Methods and Study Sites

The basis for this experiment was a mobile phone app co-developed by the multidisciplinary research team, a private company, and some users. The app (Figure 1) consisted of an interface allowing users to transfer well extraction and piezometric data and receive in return information on the evolution of the aquifer, agro-climatic forecasts, and irrigation recommendations based on models adapted and developed by the researchers [32]. The initial work plan involved showing the capabilities of this tool to users through a simplified mock-up version and allowing them to participate in its co-design or adaptation to their case studies. To do this and to analyse and improve groundwater governance in different socio-institutional contexts, researchers maintained close interaction with groundwater users and public authorities in the three study areas.

Figure 1. With the app developed (both for Android and iOS systems), users can provide boreholes and plot data to managers (above), and managers give them back hydrogeological data, irrigation recommendations, and weather forecasts (below, from left to right). All the functionalities are described at: https://www.youtube.com/watch?v=b4moFldmF4g (accessed on 26 September 2023).

This interaction took place in a variety of ways, including the development of surveys, semi-structured interviews, small group meetings, participatory workshops with various dynamization techniques, and some meetings and roundtables open to the public (Table 1). The number and distribution of these activities were programmed (and reprogrammed) according to the necessities and evolution of each study case. The participants in these activities represented the different water user sectors and the different levels of public administration involved in water management. The interviews were carried out to gather information on the management of each aquifer and the perspectives and visions of the different user groups on this management. On the other hand, the group activities organised with very diverse participatory dynamics were aimed at building a shared vision of the situation of the aquifers, reaching collective agreements, and co-designing shared future strategies for collective management [33]. This was a long process of dialogue between researchers and stakeholders that lasted four years. The researchers had to face the initial reluctance to participate of numerous agents, who gradually became involved in the project, probably stimulated by the participation of the most important agents and by gradually building trust between the researchers and the stakeholders.

Table 1. The number and type of activities developed during the study period were classified by stakeholders' type and study site. Others include webinars and events (round tables) open to the public.

	Sector	Ain Timguenay (Morocco)	Campina de Faro (Portugal)	Requena-Utiel (Spain)
Surveys		112		
Interviews	Agricultural	60	20	4
	Industrial			2
	Touristic		15	
	Municipal	4	4	
	Users' associations	4		2
	Water agencies	4	3	1
	Civil Society Organisations		6	1
	Regional authorities		2	
	Researchers		6	2
	Total	72	56	12
Meetings	Agricultural		5	5
	Industrial			
	Touristic		9	
	Municipal	6	4	2
	Users' associations	4		4
	Water agencies	10	6	1
	Regional authorities		9	
	Civil Society Organisations		1	
	Researchers		2	
	Total	20	36	12
Workshops		12	10	3
Others			6	1

The three study areas have different characteristics (Figure 2). The aquifer of Ain Timguenay-Ouled Mkoudou-Ighzrane (hereafter referred to as Ain Timguenay) is in the Middle Atlas region (Morocco). It is a relatively small (70 km^2) and shallow aquifer (maximum depth 100 m). Recent extension of the irrigated areas has resulted in an over-abstraction of water [23]. However, since there is currently almost no data, only very rough estimations of the aquifer status can be made, hindering the enabling of corrective actions. Farmers practise tree farming with highly diverse-sized farms (from less than 5 ha to a few large-scale farms owned by investors that farm over 300 ha each). They are highly concerned by groundwater depletion, and at the beginning of the project, in the absence of any serious state management action, they lack a collective institution for groundwater self-management. The River Basin Agency (RBA) has stopped delivering new pumping authorisations in the area but has limited power to enforce this decision. It aims to implement groundwater management contracts at the local scale, in line with national policies [34,35].

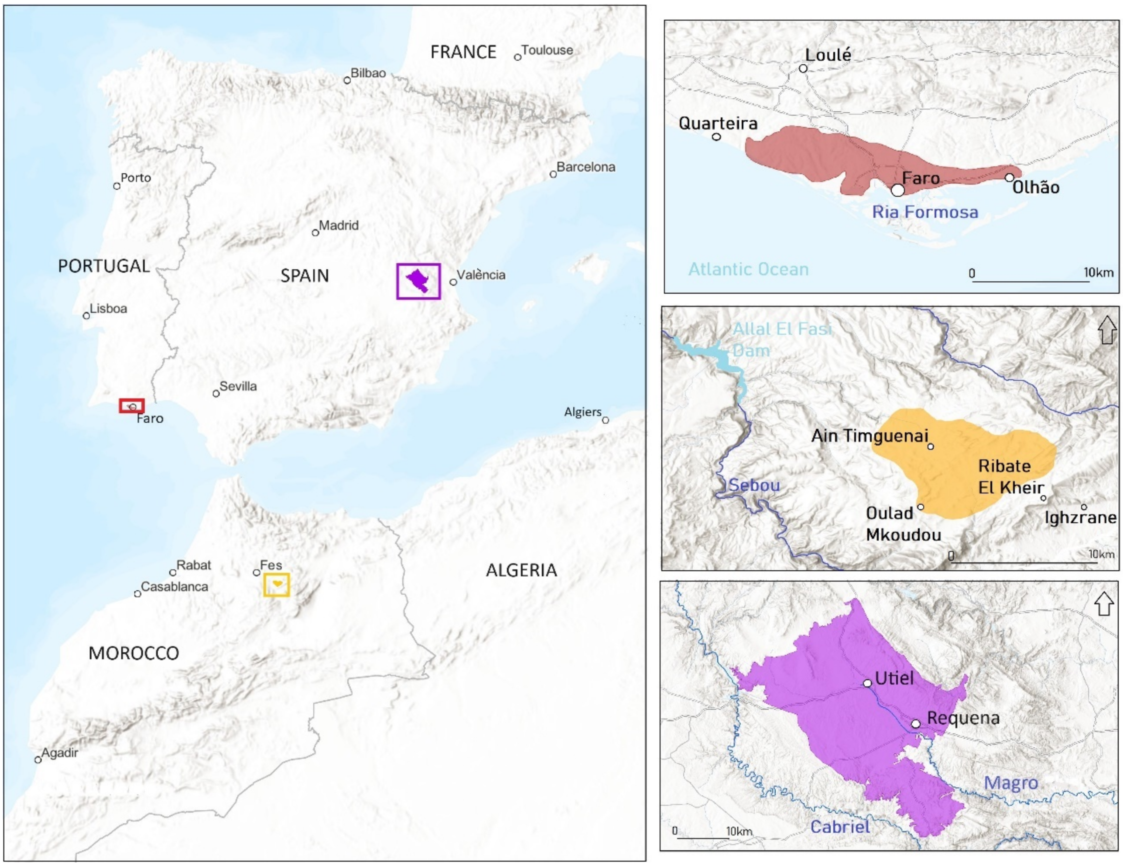

Figure 2. Location and delimitation of the three aquifers of the study sites.

The Requena-Utiel aquifer (Valencia Region, Spain) covers an area of 987.9 km^2 with an altitude ranging from 600 to 1200 masl. Between 1995 and 2019, the irrigated area increased from 1738 ha to 14,621 ha [33,36], based exclusively on groundwater resources, due to (i) the search for increased production, (ii) the promotion of irrigation modernisation through subsidies by the regional government, and (iii) the observed trend of decreasing rainfall. By 2015, the RBA detected a significant drop in the discharge from the aquifer into the river Magro. Numerous springs in the region, which had provided water for centuries, also dried up and were abandoned. Consequently, in 2016, the RBA declared the aquifer in poor quantitative status and, in compliance with Spanish legislation, obliged water users to create an institution, the Junta de Central de Usuarios de la Masa de Agua Requena-Utiel (JCRU), which was constituted in 2017. It represents all entities or persons who use water from the aquifer, whether for agricultural, industrial, or urban purposes. Subsequently, the RBA approved an exploitation plan to regulate water use and prevent overexploitation.

The Campina de Faro Aquifer, located in the Algarve (Portugal), has an area of around 86.4 km^2 and is currently separated into two sub-systems by the water authority (RBA) due to different water dynamics. The eastern system (sub-system Faro) is an area of significant agricultural development, which leads to a high input of nitrates but is currently in a good quantitative state. On the other hand, the western system (sub-system Vale do Lobo) is a highly touristic area that has shown seawater intrusion due to (i) increasing extractions near the coastline to supply two luxury tourist golf resorts, (ii) a smaller/slower north-south flow in this sub-system, relatively to the eastern sub-system, and (iii) little control and sanctioning of the RBA, which lacks human resources, know-how on complex social dilemmas, and legal back-up. In 2019, due to the deterioration of the situation, the RBA declared the Campina de Faro aquifer to be overexploited. The declaration reinforced the ban on new-use licences but did not stop the overexploitation and salinisation since many boreholes are unregulated and extracted volumes are communicated only by large users.

In 2020, the RBA started a project to install telemeters for all large users, but it has not acted very convincingly, and progress has been very slow.

3. Results

3.1. Ain Timguenay

In 2020, there was no associative fabric in the irrigated areas of Ain Timguenay. Nor did the users share a common vision of how the aquifer should be managed, and there were mutual misgivings between smallholders, large landowners, and those responsible for urban supply. However, despite the lack of hard data, they were all aware that if no action was taken within five years, the aquifer could reach a critical situation. With the intention of reversing this process, the researchers proposed two citizen science and EIS actions: the participatory use of probes to detect the water table and the use of a mobile phone app to report information on measured water levels, crop types, and existing boreholes.

The participatory use of probes was launched in early 2022, whereby farmers were trained in using low-cost, locally-made probes. The use of these devices allowed a dozen farmers to obtain information for themselves and share it with the research team. The introduction of the probes not only contributed to improving the characterisation of the aquifer but also made its problems visible to the users involved. This action was accompanied by mapping the irrigated areas and experiments to train users in more efficient water use (some farmers switched to lower flow drippers and tried other practices to consume less water). In this way, it was possible to build a shared diagnosis of the aquifer situation. In addition, the information obtained was useful for the RBA in determining how much irrigation cutback would be needed to restore the aquifer's balance. However, in March 2024, in the face of growing water shortages after six consecutive years of drought, farmers prioritised gaining access to new water resources from a nearby reservoir under construction rather than introducing demand reduction measures. They also focused on searching for new drilling authorizations because of the drying up of their boreholes (some have begun uprooting apple and plum trees to plant olive trees).

In parallel, other actions were developed to improve the internal cohesion of the user group. In autumn 2022, a trip to Spain was made to learn about experiences in collective water management and the use of new technologies, with the participation of local leaders who were also family farmers, a representative of a large-scale farm, members of the Ministry of Agriculture, and a member of the RBA. The trip allowed, first, to bridge the gap between small and large-scale farmers and between small and large-scale farmers and institutional actors. It also showed farmers how public institutions could collaborate with them to manage groundwater and that a 'participatory management' contract could be a framework for resolving a crisis. This stimulated the creation of four groundwater user associations representing farmers in the area and a federation with representatives from each association, which currently acts as interlocutors with the RBA.

The second measure was also launched in 2022. The app prototype was designed and demonstrated in test mode to farmers several times. However, they were unwilling to use it unless the new governance scenario that would rely on this new information was clear and the corresponding institutions were established. The prototype of the application was ready at the beginning of 2024, but the conditions for it to be used were not met. There was not enough trust about who would use the information, and, above all, there was a lack of an institutional framework in which this information would be produced, stored, shared, and used for decision-making. The use of the technical tool confronted actors with the complex realities of social and institutional issues (conflicts, social control, illegal drilling, positioning of water points in relation to water supply and neighbours, etc.).

Finally, in March 2024, the monitoring system that has proved to be very useful over three years almost completely collapsed due to a decrease in the collective involvement of the stakeholders and also because many boreholes dried. Many farmers are still using probes on their own, but they do not share data. The app irrelevant in the current situation, but in the future, two water user associations are very interested in having their own collective monitoring systems and have declared their willingness to organise them. In a few years, in an optimistic view, the app can play a key role in communication between farmers and associations. But before that, farmers and the government must sign a groundwater contract; farmers' associations must be involved in co-management; there must be an official irrigated area that cannot be further expanded, an official list of legalised boreholes, and so on. Governance must come first.

3.2. Requena-Utiel

As described above, the Requena-Utiel region has a recently developed institutional framework that is in the process of consolidation. The JCRU, together with the RBA, is the cornerstone of a co-management system.

During the first round of interviews and meetings between 2020 and 2021, the researchers presented to the members of the JCRU the idea of developing a mobile application to transfer water use data and receive information on the state of the aquifer and agro-climatic issues. The JCRU immediately seized on the idea and took steps to develop such a tool in addition to the one that was to be funded and developed under the research project. Their intention was to be able to completely control the design process of the tool and not be financially dependent on any company or project for its implementation. In this way, they could implement the tool without any external dependence beyond hiring a person to program the software, which would be their own.

In Requena-Utiel, despite ta well-established institutional framework that has proven successful in other territories, some discrepancies were in the perception of the aquifer's situation among users. This was mainly due to the lack of accessible and reliable information on the aquifer's behaviour and management, which caused grievances and mistrust among stakeholders and hindered the governance of the aquifer. To address this, in parallel to developing a mobile application, researchers and users held meetings and workshops to build a shared vision, jointly identifying grievances and co-designing measures to improve the co-management of the aquifer [33].

The JCRU launched its application during the 2022 summer irrigation season, with a version of functionality limited to reading and reporting users' abstractions. During this first year, participating users accounted for 65% of the estimated volume of abstractions, and during the 2023 season, this number rose to 75%. Participating users were divided into four groups, depending on the frequency of data reporting (every 1, 3, 6, or 12 months). According to the representatives of the Central Board and the users interviewed, the balance of this first experience was positive. They point out, on the one hand, that the main key to the app's success is its ease of use, and, on the other hand, they highlight the lack of collaboration of some users as the first obstacle. There are two reasons for this shirking attitude. Firstly, some farms still do not have water meters, although these will be installed soon—thanks to the contribution of state subsidies, strategic projects for economic recovery and transformation (PERT) for the digitalisation of irrigation. Secondly, some users are either distrustful of ICTs or are reluctant to be controlled (mainly small users), which, according to the interviewees, 'are few but rowdy.' Finally, in June 2024, farmers and JCRU agreed to incorporate piezometric information from their wells into the current app to boost transparency and resolve contrasting local perspectives on the evolution of the aquifer.

In addition, users state that communication with the RBA could be improved, as the RBA has hardly given them feedback on the information reported, although they think that, in this case, 'no news is good news.' They want to formalise this co-management by means of a collaboration agreement and strengthen the system with inspection visits and automated readings, which are already planned for all new meters. During this first phase, which will be closed when all meters are installed, tests have already been included to incorporate meteorological information into the app.

The second phase, to be implemented in the next few years, aims to integrate geolocated meteorological information in addition to incorporating data from lysimeters, piezometers, and other sensors. The cost of this phase is higher, so instead of resorting to the development of a network of new JCRU sensors, the irrigation communities' own sensors will be used. Most of their integration and installation will be co-financed with PERTE subsidies. Finally, the Board expects to be able to develop a third phase aimed at data analysis and the characterisation of evolution trends, for which a long observation period of at least a decade is necessary. The final purpose of the second and third phases is to provide users with better information about the aquifer's response to extractions because, as stated by Central Board representatives, "feedback is the key to success."

3.3. Campina de Faro

The social and institutional context in Campina de Faro was particularly challenging due to the atomisation of stakeholders and their different interests. The researchers' first contact with users highlighted varying degrees of awareness and engagement with the RBA and between users. The idea of the app was received with moderate interest by some users in the tourism sector affected by the salinisation of the aquifer, certain large agricultural companies, and the RBA (APA-ARH Algarve). These users shared the need to know more about the aquifer state as a whole (RBA data is public, but the information is difficult to access by the layperson), while the RBA wanted to improve consumption monitoring, especially of the residents of the golf resorts, which held unregulated boreholes or unknown consumptions.

On the opposite, small farmers and property owners were not interested in data and, most of the time, saw it as a threat, which could lead them to be more controlled by the authorities. The property owners were not interested in engaging in these discussions ("too busy having fun," as one told us). Farmers complained about both public authorities and researchers asking them for data, feeling an overload of demands while not being supported to solve other pressing problems (low prices of products and lack of commercialization channels). When explaining the app developed by the project, one of them said ironically: 'it's great, but you have to implement it,' criticising academics who come up with solutions but do not stay for their implementation. A hotel owner complained about the overload of institutional demands for data since the administrative sectors do not coordinate their demands.

The first sectorial workshops developed in 2022 facilitated reaching a consensus on the need to tackle governance problems instead of information gaps. The meetings with users highlighted that the information was not a key factor but rather its accessibility. The main problems identified were the communication and coordination between entities. On the other hand, all actors (users and public authorities) shared the need to improve governance issues such as the uncontrolled use of groundwater, the illegal boreholes, the lack of planning of economic activities consuming water, and the very bureaucratic administrative process to improve water use (e.g., reuse treated water). Users pointed to the need for a coordination committee that joins all interests in constructive conversations for solutions. Public authorities specified that a user's association needed an interlocutor and, in coordination, improved management to reverse the overexploitation.

The first general workshop (2023) managed to achieve a public consensus on advancing towards the establishment of an association of users (users, RBA, and the agricultural regional authority agreed). In the following workshop, they built a plan for creating this association and agreed that, after this step, the first collective task was precisely improving and sharing data of uses through an inventory. This inventory, the basis for the EIS, would come together with the support of the RBA to legitimate the process and guarantee that it will not be used for punishment but for improved and negotiated regulation of groundwater use. Only when users have guarantees on how and for what data is used, they feel that better users' data are needed (also as a requirement for fairness).

The gradual building of trust between the RBA and users has been key to any advancement towards the future implementation of an EIS. The participatory process is currently facilitating a formal agreement establishing the principles of collaboration between users and authorities to improve information on the aquifer and explore a new participatory management model. This involves developing an inventory of irrigated areas and boreholes as a basis for an EIS and a requirement for fair and sustainable resource management.

4. Discussion and Conclusions

Our initial hypothesis was that a new tool to collect and share information collaboratively would facilitate building a shared understanding of aquifer behaviour, strengthen the sense of community, and thus develop or consolidate groundwater institutions for sustainable governance. However, the main lesson learned from the comparative analysis of these three experiences is that the use of groundwater EIS is only positively perceived, accepted, and adopted when an appropriate social and institutional framework is in place and that the more consolidated this framework is, the easier EIS will be to implement and develop. Groundwater EIS have not proven, on their own, to have the capacity to catalyse a process of change or improvement in governance. Although they can be a notable element of support, they require a previous substratum of collaborative governance or a parallel work of accompaniment focused on the construction of this institutional and social framework.

4.1. The Key Role of the Institutional Framework in EIS Adoption

The need for co-management institutions capable of assuming and leading the development and management of EIS and having the capacity to enter into agreements and assume responsibilities has been highlighted as a determinant. Without these conditions, in a context of dispersion of actors and cross-interests, as we have seen in the case studies, it is extremely difficult to make progress in governance nor to adopt or advance in the management of EIS. The fundamental material for weaving this institutional framework is the trust of the groups of actors involved (both among themselves and among the members of each group). In addition, as other authors have pointed out [37], the institutional framework must be considered legitimate by users. In turn, these institutions must provide security to individual users regarding the handling of sensitive information; as in all three cases, this privacy concern is one of the main obstacles to the adoption of EIS.

In all case studies, it has been shown that large users or small users organised in collective management institutions are more likely to participate in the EIS implementation process than small users (e.g., farmers or residents). This is mainly because (i) large users either already have the necessary technologies or are already familiar with their use and information sharing, (ii) they have more experience in dealing with the administration or other actors, (iii) they have more interest in negotiating to assure their water rights, and (iv) it could also be that they are in a less vulnerable position than small farmers in case EIS is turned against them as restrictions and sanctions.

For Portugal and Morocco, the space for adopting EIS has been created simultaneously with formal agreements established among users and between users and water authorities, progressing towards co-management institutional frameworks. However, in all three cases, at some point in this long process, users have proposed avoiding working on a collective local solution and solving the aquifer problem by capturing resources from other territories or non-conventional resources. In other words, they proposed a way out of their situation by mobilising new water resources. As observed in the participatory activities, regardless of whether technically realistic, environmentally sustainable, and socio-economically viable solutions exist—which may be and can be combined satisfactorily—, the fact that state administrations support or politically nurture these options is evidently something that undermines self-management efforts. This can negatively impact when working on the construction of local groundwater governance by discouraging the participation of users in the search for local solutions based on self-control.

4.2. The Positive Feedback between EIS and the Social and Institutional Framework

The adoption of EIS marks the start of a process of positive feedback between social context and technology, which, in these cases, we have only been able to observe in its very early stages where a more favourable socio-institutional context existed. The use of probes in Morocco contributed decisively to building individual and collective awareness of the need to take further steps forward in aquifer governance. Similarly, the development of an incipient EIS in Spain, with the future incorporation of piezometric information, has been considered by users as a key aspect to advance governance and common understanding. In addition, the Spanish case shows us the capacity of irrigation communities to assimilate and completely appropriate technological innovations in order to make the most of them and ensure independent management and control, as has been demonstrated with other irrigation technologies [38]. In the case of Portugal, EIS is perceived to become useful when the new collective governance is in place, while before, it was refused or simply ignored/deemed unimportant.

For this feedback to work, the tools used (apps in this case) must meet five fundamental conditions as pointed out by users in these countries: (i) they must be easy to use and have simple interfaces or devices, (ii) they must ensure the return of information (hydrogeological or otherwise) to the users so that they can derive direct benefits from it, (iii) they must protect the personal data of users, (iv) they must be developed through co-design processes so that it is the users who define what information may be of interest to them and what is not, and thus facilitate its adoption, and (v) stakeholders should own or have control over the code to adapt it to their evolving needs. This research also shows that it is necessary to be realistic in the formulation of objectives and that, as in other aspects of collective resource management, it will not be possible to eliminate the presence of free-riders and outsiders. However, as the cases of Spain and Morocco show, it does seem feasible to reach a critical mass sufficient to obtain sufficient information to characterise the evolution of the aquifer and co-learn how to manage it sustainably. In Portugal, a group of committed stakeholders believes such a critical mass can be reached through incremental steps.

4.3. Building Frameworks for EIS

One of the clearest and most significant conclusions of this experience in three countries is that the processes of adoption of groundwater EIS are slow and require careful and lengthy work, which must go beyond the 4-year periods of most research projects. Especially because there should be a co-development of (i) a governance set-up, materialised by the creation of new, more participated institutions, (ii) the development of an improved shared knowledge of the resource and its uses (requiring several years of data collection when they do not previously exist), and (iii) the development of the information systems and the rules related to data availability and protection.

In all three cases, progress in the process of adopting EIS is linked to trust built through dialogue, meetings, and workshops with participatory dynamics and collaborative experiences. The mediation role developed by the researchers here is key; however, given the limitations of research projects, it could be assumed by other types of actors, either in partnership with researchers or not, if they can demonstrate their neutral character and mediation capacity. Understanding local issues and power asymmetries is also critical to ensuring a representative composition of different categories of stakeholders at meetings and a good distribution of the floor.

Finally, this experience has revealed that, despite the potential of EISs, the current literature often overlooks some critical issues that need to be considered before embarking on this path of socio-technological implementation. It is important to (i) assess the extent to which users value information about the resource, (ii) answer what are the incentives for users to participate, and mainly, (iii) work on the development of governance based on trust and long-term goals to activate the positive feedback loops between EIS and society that can propel the new wave of water governance.

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References

1. Wijnen, M.; Augeard, B.; Hiller, B.; Ward, C.; Huntjens, P. Managing the invisible: Understanding and improving groundwater governance. World Bank. 2012. Available online: https://hdl.handle.net/10986/17228 (accessed on 26 September 2024).
2. López-Gunn, E. Groundwater governance and social capital. *Geoforum* **2012**, *43*, 1140–1151. [CrossRef]
3. Shah, T. Groundwater Governance and Irrigated Agriculture (Tec Background Papers No. 19). Global Water Partnership (GWP). 2014. Available online: https://gwp.org/globalassets/global/toolbox/publications/background-papers/gwp_tec_19_web.pdf (accessed on 26 September 2024).
4. Villholth, K.G.; López-Gunn, E.; Conti, K.; Garrido, A.; Van Der Gun, J. (Eds.) *Advances in Groundwater Governance*; CRC Press: Boca Raton, FL, USA, 2017.
5. Closas, A.; Villholth, K.G. Groundwater governance: Addressing core concepts and challenges. *WIREs Water* **2020**, *7*, e1392. [CrossRef]
6. Megdal, S.B.; Gerlak, A.K.; Varady, R.G.; Huang, L. Groundwater Governance in the United States: Common Priorities and Challenges. *Groundwater* **2015**, *53*, 677–684. [CrossRef] [PubMed]
7. Shah, T. *Taming the Anarchy? Groundwater Governance in South Asia*; Resources for the Future Press: Washington, DC, USA, 2009.
8. Reddy, V.; Reddy, M.; Rout, S. Groundwater Governance: A tale of three participatory models in Andhra Pradesh, India. *Water Altern.* **2014**, *7*, 275–297.
9. De Stefano, L.; Lopez-Gunn, E. Unauthorized groundwater use: Institutional, social and ethical considerations. *Water Policy* **2012**, *14*, 147–160. [CrossRef]
10. Molle, F.; López-Gunn, E.; van Steenbergen, F. The local and national politics of groundwater overexploitation. *Water Altern.* **2018**, *11*, 445–457.
11. Kuper, M.; Faysse, N.; Hammani, A.; Hartani, T.; Marlet, S.; Hamamouche, M.F.; Ameur, F. Liberation or Anarchy? The Janus nature of groundwater use on North Africa's new irrigation frontiers. In *Integrated Groundwater Management: Concepts, Approaches and Challenges*; Jakeman, A.J., Barreteau, O., Hunt, R.J., Rinaudo, J.-D., Ross, A., Eds.; Springer: Berlin/Heidelberg, Germany, 2016; pp. 583–615.
12. Molle, F.; Sanchis-Ibor, C. Irrigation policies in the Mediterranean: Trends and challenges. In *Irrigation in the Mediterranean: Technologies, Institutions and Policies, Global Issues in Water Policy*; Molle, F., Sanchis-Ibor, C., Avellà-Reus, L., Eds.; Springer International Publishing: Cham, Switzerland, 2019; pp. 279–313.
13. Hoogesteger, J.; Wester, P. Regulating groundwater use: The challenges of policy implementation in Guanajuato, Central Mexico. *Environ. Sci. Policy* **2017**, *77*, 107–113. [CrossRef]
14. Rinaudo, J.-D.; Holley, C.; Barnett, S.; Montginoul, M. (Eds.) *Sustainable Groundwater Management. Global Issues in Water Policy*; Springer: Berlin/Heidelberg, Germany, 2019; Volume 24, pp. 47–65.
15. Molle, F.; Closas, A. Why is state-centered groundwater governance largely ineffective? A review. *WIREs Water* **2020**, *7*, e1395. [CrossRef]
16. Molle, F.; Closas, A. Comanagement of groundwater: A review. *WIREs Water* **2020**, *7*, e1394. [CrossRef]
17. Schlager, E. Community management of groundwater. In *The Agricultural Groundwater Revolution: Opportunities and Threats to Development*; CABI Publishing: Wallingford, UK, 2007; pp. 131–152.
18. Rouillard, J.; Babbitt, C.; Pulido-Velazquez, M.; Rinaudo, J. Transitioning out of Open Access: A closer look at Institutions for Management of Groundwater Rights in France, California, and Spain. *Water Resour. Res.* **2021**, *57*, e2020WR028951. [CrossRef]
19. Rouillard, J.; Rinaudo, J.-D. From State to user-based water allocations: An empirical analysis of institutions developed by agricultural user associations in France. *Agric. Water Manag.* **2020**, *239*, 106269. [CrossRef]
20. Reddy, V.R.; Syme, G.J. Social sciences and hydrology: An introduction. *J. Hydrol.* **2014**, *518*, 1–4. [CrossRef]
21. Villholth, K.; Conti, K. Groundwater governance: Rationale, definition, current state and heuristic framework. In *Advances in Groundwater Governance*; Villholth, K.G., Lopez-Gunn, E., Conti, K., Garrido, A., Van Der Gun, J., Eds.; CRC Press: Boca Raton, FL, USA, 2019.

22. Dubois, D.; Farolfi, S.; Nguyen-Van, P.; Rouchier, J. Contrasting effects of information sharing on common-pool resource extraction behavior: Experimental findings. *PLoS ONE* **2020**, *15*, e0240212. [CrossRef] [PubMed]
23. Janssen, M.A. The role of information in governing the commons: Experimental results. *Ecol. Soc.* **2013**, *18*, 4. [CrossRef] [PubMed]
24. Shalsi, S.; Ordens, C.M.; Curtis, A.; Simmons, C.T. Can collective action address the "tragedy of the commons" in groundwater management? Insights from an Australian case study. *Hydrogeol. J.* **2019**, *27*, 2471–2483. [CrossRef]
25. Trawick, P. Scarcity, Equity, and Transparency: General Principles for Successfully Governing the Water Commons. In *Mountains: Sources of Water, Sources of Knowledge*; Springer: Dordrecht, The Netherlands, 2008; pp. 43–61. [CrossRef]
26. Stone, A. Groundwater governance—Impact of awareness-raising and citizen pressure on groundwater management authority in the United States. In *Advances in Groundwater Governance*; Villholth, K.G., Lopez-Gunn, E., Conti, K., Garrido, A., Van Der Gun, J., Eds.; CRC Press: Boca Raton, FL, USA, 2019.
27. UNESCO. Groundwater: Making the Invisible Visible in 2022 and Beyond. 2023. Available online: https://www.unesco.org/en/articles/groundwater-making-invisible-visible-2022-and-beyond#:~:text=Summary&text=UNESCO,%20together%20with%20its%20centre,remain%20active%20throughout%20the%20year (accessed on 26 September 2024).
28. Sharples, J.; Carrara, E.; Preece, L.; Chery, L.; Lopez, B.; Rinaudo, J.D. Information systems for sustainable management of groundwater extraction in France and Australia. In *Sustainable Groundwater Management: A Comparative Analysis of French and Australian Policies and Implications to other Countries*; Springer: Berlin/Heidelberg, Germany, 2020; pp. 163–190. [CrossRef]
29. Manda, A.K.; Etheridge, J.R.; Grace-McCaskey, C.; Allen, T.R.; Howard, R. Are Groundwater Level Data Collected by Citizen Scientists Trustworthy? A Cautionary Tale. *Groundwater* **2020**, *59*, 123–130. [CrossRef] [PubMed]
30. López-Gunn, E.; Rica, M.; Zugasti, I.; Pulido-Velazquez, M.; Sanchis-Ibor, C. Use of the DELPHI method to assess the potential role of Enhanced Information Systems in Mediterranean groundwater management and governance. *Water Policy* **2024**, *under review*.
31. Varady, R.G.; van Weert, F.; Megdal, S.B.; Gerlak, A.; House-Peters, L.A. *Groundwater Governance: A Global Framework for Country Action*; FAO: Rome, Italy, 2013.
32. Garcia-Prats, A.; Carricondo-Anton, J.; Jiménez-Bello, M.; Juárez, J.M.; López-Pérez, E.; Pulido-Velazquez, M. Dynamic procedure for daily PM56 ETo mapping conducive to site-specific irrigation recommendations in areas covered by agricultural weather networks. *Agric. Water Manag.* **2023**, *287*, 1–18. [CrossRef]
33. Sanchis-Ibor, C.; López-Pérez, E.; García-Mollá, M.; López-Gunn, E.; Rubio-Martín, A.; Pulido-Velazquez, M.; Segura-Calero, S. Advancing Co-governance through Framing Processes: Insights from Action-Research in the Requena-Utiel Aquifer (Eastern Spain). *Int. J. Commons* **2023**, *17*, 347–362. [CrossRef]
34. Kchikech, Z.; Bouzidi, Z.; Faysse, N. More Collectives, Less Differences: Unveiling Unexpected Social Changes in a Groundwater Economy in the Middle Atlas, Morocco. *Water Altern.* **2024**, *17*, 73–93.
35. World Bank. *Morocco—Strengthen Capacity for an Inclusive Design of Groundwater Management Contract for Green Growth Project (English)*; World Bank Group: Washington, DC, USA, 2015. Available online: http://documents.worldbank.org/curated/en/247941468197630507/Morocco-Strengthen-Capacity-for-an-Inclusive-Design-of-Groundwater-Management-Contract-for-Green-Growth-Project (accessed on 26 September 2024)).
36. GVA. *Superficies Cultivadas por Municipios 2022*; Generalitat Valenciana, Conselleria d'Agricultura, Desenvolupament Rural, Emergència Climàtica i Transició Ecològica: València, Spain, 2023.
37. Houdret, A.; Heinz, R. Groundwater governance through institutional bricolage? Participation in Morocco's Chtou-ka aquifer contract. In *Groundwater*; Routledge: London, UK, 2023; pp. 59–76.
38. Poblador, N.; Sanchis-Ibor, C.; Kuper, M. The landing of parachuted technology: Appropriation of centralised drip irrigation systems by irrigation communities in the region of Valencia (Spain). *Water Altern.* **2021**, *14*, 228–247.