Humanities & Social Sciences Communications

COMMENT

https://doi.org/10.1057/s41599-024-02958-x OPEN

Using stakeholder network analysis to enhance the impact of participation in water governance

Isidro Maya Jariego [1]✉

Citizen participation in water governance can improve the relevance, implementation, and effectiveness of public policies. However, participation can be expressed in a great diversity of forms, on a gradient ranging from mere public consultation to shared governance of natural resources. Positive outcomes ultimately depend on the conditions under which participation takes place, with key factors such as leadership, the degree of trust among stakeholders, and the interaction of public authorities with citizens. Social network analysis has been used to operationalize participatory processes, contributing to the identification of leaders, intersectoral integration, strategic planning, and conflict resolution. In this commentary, we analyze the potential and limitations of participation in water governance and illustrate it with the case of the Campina de Faro aquifer in southern Portugal. We propose that stakeholder network analysis is particularly useful for promoting decentralized decision-making and consensual water resources management. The delegation of power to different interest groups is a key process in the effectiveness of governance, which can be operationalized with network analysis techniques.

[1] Faculty of Psychology, Universidad de Sevilla, Sevilla, Spain. ✉email: isidromj@us.es

Participation has become a basic principle in public water management and governance policies. The European Union Water Framework Directive encourages member states to develop river basin management plans through participatory processes that inform, consult, and actively involve all stakeholders (Demetropoulou et al., 2010; Jager et al., 2016). Similarly, "integrated urban water resources management" strategies aim to involve citizens in service delivery and decision-making in cities, covering the entire water cycle (Mukhtarov et al., 2018). In development cooperation policies, it is also assumed that the involvement of local communities could contribute to sustainable and equitable access to safe drinking water (Jones, 2011). In all cases, the assumption is that participation contributes to more effective natural resource management. It involves considering the interests of different stakeholders.

However, the principle of participation has very different meanings in practice. In the field of international cooperation, it is initially associated with the idea that the provision of (water) infrastructure is not sufficient to contribute to local development, but that it is necessary at the same time to pay attention to the forms of organization and the decision-making process (Tropp, 2007). Thus, speaking of governance implies moving from an almost exclusive focus on infrastructure to the consideration of social factors. Nevertheless, this opens up a wide variety of potential forms of citizen involvement, on a gradient from informing or consulting local community representatives, to joint deliberation in public forums or more demanding modes of co-governance, among others (Margerum, 2008; Mukhtarov et al., 2018). It is to be expected that each form of participation will have its dynamics and generate different results.

A key distinction is to differentiate between formal government-driven participation and participation that emerges, bottom-up, in community contexts (Van Buuren et al., 2019). On the one hand, public administration frequently resorts to the involvement of civil society to improve policy acceptance and to prevent conflict between different stakeholders (Newig and Fritsch, 2009). Participatory water basin councils are a clear example of this type of initiative, where multiple stakeholders are usually invited to collaborate in decision-making and the allocation of scarce water resources (Mancilla-García and Bodin, 2019). On the other hand, there are occasions when participatory spaces are the result of community self-organization, either in reaction to government initiatives or to respond to local needs (Romano, 2019). A paradigmatic case is water user associations, which usually resort to self-regulation, understood as "the decentralized collective management of groundwater resources" (Van Steenbergen and Shah, 2003, p. 242). As we can see, there is a wide and diverse typology of institutional arrangements through which participation can be channeled.

Likewise, assuming a participatory approach does not necessarily imply obtaining the intended results. It is a political process, which ultimately depends on the ability to influence or form alliances. Even when the composition of public forums is designed inclusively, stakeholders do not always have the technical knowledge that allows them to participate effectively (Mancilla-García and Bodin, 2019). Water management often involves mastering complex issues that unbalance the influence capacity of the different members of the decision-making committees. At other times, it is the centralized structure of the state itself that becomes an impediment to an adequate level of community involvement (Demetropoulou et al., 2010). Consequently, not every time participation is deemed necessary is sufficient to trigger the desired changes[1].

This makes it necessary to pay attention to the conditions under which participation takes place. In this regard, three types of factors to take into account have been identified, which refer respectively to (1) the capacities of participating actors, (2) the interaction of public authorities with participants, and (3) the adaptability of public institutions to community initiatives and, in general, to participatory processes (Van Buuren et al., 2019). This means that the achievement of positive results may depend, among other factors, on leadership, the internal social capital of the participating organizations, transparency, capacity for dialog, or the degree of trust among stakeholders. Effective participation is based on the motivation and skills of participants, deployed persistently in an organizational context (often community-based associations and initiatives) that allows the development of strong personal relationships (Maya-Jariego et al., 2023). Each participatory process has a unique history. When it comes to effective water governance, this necessarily leads us to complement the generic references to participation with the operationalization and traceability of the conditions under which it occurs.

Therefore, there are different forms of participation and one way to characterize them is to evaluate the structure of the collaboration patterns between the different actors involved. That is why network analysis can be useful, as we explain in the next section.

The analysis of water governance networks

Social network analysis is one of the empirical approaches that enables us to "translate" the principle of participation in an operational way. The most common use has been to describe the patterns of collaboration among a set of relevant stakeholders in water governance. It is a structural approach. Mapping the inter-organizational networks of collaboration serves to identify the most central stakeholders, describe the relationships between existing subgroups, and assess the degree of transversal integration between the different sectors of the public administration. In Table 1 we have summarized some of the most productive applications of network analysis in participatory water governance. We review them below.

The emphasis on the structural properties of a social system is particularly appropriate when we seek to describe multi-stakeholder governance arrangements. Participatory governance can be formulated as a collaborative network between government agencies, environmental groups, water user associations, and non-governmental organizations, among other relevant community stakeholders. Organizations are nodes that may be connected by information relationships, resource exchange, or shared projects. This way of reducing stakeholder collaboration allows the role of individual stakeholders to be examined and, at the same time, represents the performance of the water sector as a whole.

Individual centrality indicators indirectly reveal the distribution of power in water governance. It is common to find the dominant role of government agencies so that most of the power lies with the public sector (Fliervoet et al., 2016; Kharanagh et al., 2020). These are hierarchical structures where decision-making control is preferentially concentrated in the management units (Nabiafjadi et al., 2021). As a counterpart, there are other stakeholders, such as agricultural organizations, which sometimes play a marginal role despite the water demand they usually entail (Gatt, 2016). Something similar occurs in remote rural areas, which are often disconnected from the institutional spheres where decisions are made (Delgado et al., 2021). Although many users of network analysis resort to this tool to justify or induce patterns of collaborative governance, the results they obtain often paradoxically confront them with the limits of actual participatory processes[2].

On the other hand, if we focus on the structural properties *as a whole*, we obtain a comprehensive representation of how the relationships between the different stakeholders are articulated.

Table 1 Uses of network analysis in participatory water governance.

Strategy	Network applications	Practical implications for participation
• Describing collaboration patterns	Participatory governance is represented as a social structure of multi-stakeholder interaction.	The understanding of the system depends on the chosen relationship, which can refer to the mere exchange of information or shared decision-making.
• Identifying leaders and key players	It allows the distribution of power among the different stakeholders involved to be examined.	This information can be useful in regulating representativeness and balance of power in decision-making.
• Assessing intra- and intersectoral integration	It consists of examining the coordination between the different subgroups that make up the network, sometimes through the identification of intermediaries.	Coordination among diverse stakeholder groups allows for integrated management of the socio-ecosystem.
• Contributing to strategic planning	The identification of key stakeholders and their relationships generates a shared vision and can be used to generate collective action.	In this case, network analysis is a catalyst for stakeholder involvement and relationship formation.
• Facilitating conflict resolution	The diagnosis of power dynamics facilitates negotiations.	The relationship map provides a comprehensive representation of the stakeholder groups and their relationships with each other, thus guiding the negotiation process.

Note. Five applications of network analysis in water governance are described in the table. From left to right, each column, respectively, (1) indicates what network analysis is used for, (2) describes what this application consists of, and (3) explains the implications that the use of network analysis techniques may have in participatory processes and governance. The second column presents the type of application of social network analysis in water governance and the third column presents the implications that, consequently, can be observed in the participation processes.

The systemic vision provided by network analysis makes it a useful tool in the integration of different government agencies. For example, it can be used to coordinate (both vertically and horizontally) agencies responsible for water, energy, and food management (Kurian et al., 2018). It also allows organizations involved in the governance of rivers, lakes, and aquifers to be connected with those focused on soil moisture used by plants[3] (Stein et al., 2011); or entities that coordinate flood protection with those focused on natural resource management (Fliervoet et al., 2016).

In this area, individuals or organizations that act as intermediaries and connect different areas of the network are usually identified, facilitating coordination between stakeholders. Intermediaries condition the flow of information and resources, facilitating the development of interactions and contributing to the construction of social capital and trust in the social system of reference (Maya-Jariego and Holgado, 2021). In lake co-management, it has been observed that intermediaries connect management with non-governmental stakeholders and sometimes link to external sources of information as well (Lakshmisha and Thiel, 2022). In water basins subject to heavy soil erosion, intermediaries connect local entities with others at the national level, generating credibility and trust among both farmers and hydropower producers (Vignola et al., 2013). In rural contexts, water user associations have been found to bring together stakeholders that are sometimes on the margins of institutionalized forums and that would be disconnected were it not for the key role of village leaders (Stein et al., 2011). In all these cases the role of intermediaries is critical to facilitate understanding and coordination between heterogeneous groups of stakeholders (Horning et al., 2016).

Other applications consist of integrating network analysis into action research or strategic planning processes. For this purpose, it can be combined with qualitative methodologies that facilitate the generation of a shared vision among participants (Ahmadi et al., 2019). The representation of relationships makes it possible to make visible all the stakeholders that are relevant in a given area (Jatel, 2013; Maya-Jariego, 2016; Ogada et al., 2017) and to monitor institutional transformation toward adaptive water governance models (Chaffin et al., 2016). The assessment of power relations between stakeholders can also support the undertaking of negotiations and conflict resolution processes (Reyhani and Grundmann, 2021), even in circumstances of high polarization (Rojas et al., 2020).

Therefore, network analysis provides a structural view of governance patterns, allows the distribution of power to be described, and serves to assess how the heterogeneity of stakeholders is integrated into the management of the socio-ecosystem (Fig. 1). In Box 1 we illustrate with a case from the Algarve, in southern Portugal, how the interaction with ecosystem services shapes the conflict and cooperation relationships of stakeholders sharing the same territory. In this case, a relevant and effective governance strategy would require promoting consensus in a context of potentially conflictive intergroup relations.

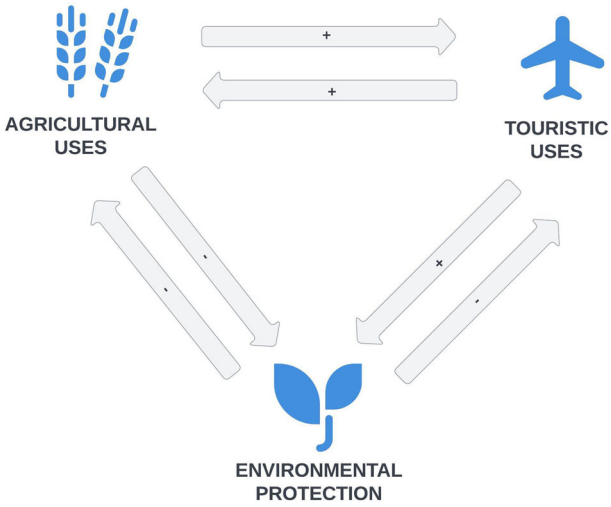

Fig. 1 Agricultural products are a tourist attraction, so there is a natural synergy between the influx of tourists and the primary sector. Environmental protection organizations consider that farms are the main consumers of water from aquifers and one of the main threats to the sustainability of the region. The relationship is more ambivalent with the tourism sector. Although tourism actors increase population pressure on water consumption, they are also an incentive to preserve the environmental and cultural heritage of the region. This makes tourism a sector with greater potential for intermediation between the different stakeholders.

The case we present below illustrates how the identification of the relevant subgroups in the territory, as well as the relationships they maintain among themselves, allows the interests of different stakeholders to be integrated into a common policy. It is an example of the fifth and last strategy mentioned in Table 1.

Box 1 | Stakeholders and intermediaries in Campina de Faro (southern Portugal)

The Campina de Faro aquifer is a hydrogeological formation covering an area of 86.4 km² in the Algarve, southern Portugal. It is composed of two differentiated subsystems (one of a superficial nature and the other a lower reservoir), which drain directly into the Atlantic. It covers the counties of Faro, Loulé, and Olhão. The region has protected areas of high ecological value that are part of the Ria Formosa Natural Park. The aquifer is under heavy pressure from intensive water extraction, especially for agricultural and livestock uses. High nitrate concentration has been detected in some areas, possibly associated with fertilizer use (Costa et al., 2015). In addition, through fluid exchange, contamination is transferred directly between shallow and deep aquifers (Almeida and Silva 1987; Stigter et al., 2006).

Coastal tourism development has also been reflected in increased water consumption. Thus, in areas such as Vale do Lobo it has led to situations of overexploitation, with a significant reduction in water levels (Almeida et al., 2000). One of the activities that has had the greatest impact in this regard is golf tourism (Videira et al., 2006). Consequently, episodes of seawater intrusion occur with resulting saline contamination (Da Silva et al., 2010; Fernandes et al., 2020; Stigter et al., 2009). Some strategies based on infrastructure provision have been tried to cope with this situation, such as the implementation of aquifer recharge systems (San-Sebastián-Sauto et al., 2018) or desalination (Serra et al., 2021). Strategies of collective management for the reduction of extractions have also been implemented to guarantee the sustainability of aquifers (Molle and Closas, 2020).

Tourism and agricultural uses in the area both exert pressure related to intensive water consumption and have potential pollution effects. Agriculture fertilizers can affect water quality, while excessive consumption associated with tourism can reduce water levels and increase salinity through seawater intrusion. Furthermore, the tourism and agriculture sectors influence each other at the local level.

Since July 2020 the administration, the municipalities together with key stakeholders from agriculture and tourism are collaborating to overcome the water crisis of the region and have devised the Regional Water Efficiency Plan of the Algarve Region. In addition, the funds from the Recovery and Resilience Plan are targeting large sums to tackle the main infrastructural problems linked to water scarcity. In this administrative body, the regulatory entities for water use (at the national and regional level) come together with social entities grouped in a "sustainable water platform."

Tourism and agricultural uses vary in their relationship with environmental protection actions and, in general, with sustainability initiatives. Farmers have traditionally maintained a conflictive relationship with the environmental movement. The tourism sector is also seen as a threat, especially in areas like Vale de Lobo where the consumption of golf areas is even higher than that of agriculture. However, environmental attractions have sometimes been used as a factor in tourism development. This has made tourism an element with some potential to coordinate local economic development.

As has also been observed in other geographical contexts, decision-making is highly centralized in public administration. Partly as a reaction to this scenario, civil society is organizing itself into environmental heritage defense networks. However, other stakeholders are direct users of the water basin for agricultural and tourism uses. We have summarized the confluence of interests in Fig. 1. Systematic examination of stakeholder networks in this case could serve both to facilitate decentralized decision-making and to facilitate consensual water resources management.

Discussion

Citizen participation in water governance is expressed in different modalities and intensities. The same term of "participation" is used when information is provided to citizens, when certain proposals of the administration are submitted to public consultation when committees are created with a representation of different stakeholders, when models of co-management between government and civil society are developed, or when the structure of decision-making is transformed to empower marginalized groups (O'Faircheallaigh, 2010). Each modality (or degree) of participation may be more or less relevant depending on the problem to be addressed. In any case, it is important to specify what we mean when we talk about participation. In practice, sounding out the population's opinion, promoting heterogeneous representation in decision-making forums, and empowering certain groups involve setting differentiated political processes in motion.

Being explicit and specific in the use of the concept has at least two implications: Not only does it call into question the assumption that "the more participation the better," but it even pushes us to question whether participation is always the best option by default. A study with wide international coverage found that participation in water exchange, either as donors or recipients, was associated with an increased likelihood of perceived distress and conflict (Wutich et al., 2022). Although much academic research has focused on collaborative processes, there are many cases in which the existence of conflicting interests over the use of natural resources comes to the fore (Bodin et al., 2020). Thus, despite the observed benefits of cooperation in environmental governance, it seems justified to adopt a pragmatic perspective that assesses when participation is appropriate (and when it is not), what type of participation is relevant in each case, and what participation is expected to contribute to the policy process. Referring to participation in a generic way, as a panacea for all kinds of problems, is insensitive to the diversity of situations that water governance normally faces.

However, when we descend to an operational level, we have found that participation facilitates community inclusion in decision-making, can offset power imbalances, and contributes to taking a holistic view of the ecosystem. First, the mere inclusion of the community in water policies contributes to democratizing decision-making and improves the relevance of actions, especially concerning the most disadvantaged groups (Hossen, and Wagner, 2016). Community monitoring has been experimentally proven to improve common pool resource management in all types of socio-geographic contexts (Slough et al., 2021). Secondly, participation is a way to represent the diversity of interests that converge in the same socio-ecological scenario. It is paradoxical to repeatedly encounter the concentration of power in governmental stakeholders, even though collaborative governance is proposed as a horizontal alternative in decision-making. Part of the potential of network analysis lies precisely in serving as a tool to improve the representativeness of participating stakeholders and indirectly contribute to the distribution of power (Lienert et al., 2013). Thirdly, the consideration of different stakeholders facilitates the adoption of a systemic or bio-regional approach, which assumes an integrated view of all the resources of a river basin and promotes integrated water resources management (Huitema et al., 2009). As Megdal et al. (2017) point out, "water management and governance issues comprise many dynamically related components, which can only be adequately addressed by understanding their interconnections" (p. 6).

Citizen participation can improve the quality and legitimacy of political decisions (Ianniello et al., 2019; Newig et al., 2023). For this to happen, a series of conditions must be in place to facilitate the long-term interaction of a diverse set of stakeholders with an adequate level of institutional recognition[4]. Social network analysis provides us with insights into the characteristics of a network of actors that are relevant to the design of participation processes. As we have shown, adopting a structural perspective can be an effective means of improving

the representativeness and integrated functioning of stakeholders in water governance.

Data availability

Data sharing is not applicable to this research as no data were generated or analyzed.

Received: 27 August 2023; Accepted: 14 March 2024;
Published online: 29 March 2024

Notes

1 In fact, it has even been suggested that under certain circumstances participation can have negative consequences (Cooper and Elliott, 2000; Lawrence, 2003).
2 In Kenya, it has been documented how integrated governance strategies failed to improve coordination among local stakeholders, reducing the effectiveness of water conservation measures (Ngaruiya, Scheffran & Lang, 2015).
3 That is, the governance of what has come to be called, respectively, "blue water" and "green water".
4 Participatory strategies can help create the political climate for working towards long-term community development objectives (Paneque-Salgado et al., 2009).

References

Ahmadi A, Kerachian R, Rahimi R, Skardi MJE (2019) Comparing and combining social network analysis and stakeholder analysis for natural resource governance. Environ Dev 32:100451
Almeida C, Mendonça JJL, Jesus MR, Gomes AJ (2000) Sistemas aquíferos de Portugal continental. Centro de Geologia da Facultade de Ciências Universidade de Lisboa, Instituto da Água, 3
Almeida C, Silva ML (1987) Incidence of agriculture on water quality at Campina de Faro (south Portugal). In: IV Simposio de Hidrogeología de la Asociación Española de Hidrología Subterránea, Palma de Mallorca. AEHS, Granada
Bodin Ö, Mancilla García M, Robins G (2020) Reconciling conflict and cooperation in environmental governance: a social network perspective. Annu Rev Environ Resour 45:471–495
Van Buuren A, Van Meerkerk I, Tortajada C (2019) Understanding emergent participation practices in water governance. Int J Water Resour Dev 35(3):367–382. https://doi.org/10.1080/07900627.2019.1585764
Chaffin BC, Garmestani AS, Gosnell H, Craig RK (2016) Institutional networks and adaptive water governance in the Klamath River Basin, USA. Environ Sci Policy 57:112–121. https://doi.org/10.1016/j.envsci.2015.11.008
Cooper LM, Elliott JA (2000) Public participation and social acceptability in the Philippine EIA process. J Environ Assess Policy Manag 2(03):339–367
Costa L, Monteiro JP, Leitão T, Lobo-Ferreira JP, Oliveira M, Martins de Carvalho J … & Agostinho R (2015) Estimating harvested rainwater at greenhouses in south Portugal aquifer Campina de Faro for potential infiltration in Managed Aquifer Recharge. In: EGU General Assembly Conference Abstracts. p. 10415. Coimbra Editora & IHAR
Delgado LE, De Ríos R, Perevochtchikova M, Marín IA, Fuster R, Marín VH (2021) Water governance in rural communities of Chiloé Island, southern Chile: a multi-level analysis. J Rural Stud 83:236–245. https://doi.org/10.1016/j.jrurstud.2020.11.008
Demetropoulou L, Nikolaidis N, Papadoulakis V, Tsakiris K, Koussouris T, Kalogerakis N, Theodoropoulos K (2010) Water framework directive implementation in Greece: introducing participation in water governance–the case of the Evrotas River Basin management plan. Environ Policy Gov 20(5):336–349. https://doi.org/10.1002/eet.553
Fernandes J, Midões C, Ferreira A, Castanheira A, Monteiro F, Pereira A, Sampaio J, Reis E, Hugman R, Costa L, Standen K, Monteiro JP (2020) Tactic, Deliverable 5.3. Pilot description and assessment. Campina de Faro Aquifer System, Portugal
Fliervoet JM, Geerling GW, Mostert E, Smits AJM (2016) Analyzing collaborative governance through social network analysis: a case study of river management along the Waal River in The Netherlands. Environ Manag 57:355–367. https://doi.org/10.1007/s00267-015-0606-x
Gatt K (2016) Social network analysis as a tool for improved water governance in Malta. Int J Soc Syst Sci 8(2):131–154. https://doi.org/10.1504/IJSSS.2016.077013
Horning D, Bauer BO, Cohen SJ (2016) Missing bridges: Social network (dis) connectivity in water governance. Util Policy 43:59–70. https://doi.org/10.1016/j.jup.2016.06.006
Hossen MA, Wagner JR (2016) The need for community inclusion in water basin governance in Bangladesh. Bandung 3(1):1–17. https://doi.org/10.1186/s40728-015-0029-3
Huitema D, Mostert E, Egas W, Moellenkamp S, Pahl-Wostl C, Yalcin R (2009) Adaptive water governance: assessing the institutional prescriptions of adaptive (co-)management from a governance perspective and defining a research agenda. Ecol Soc 14(1). http://www.jstor.org/stable/26268026
Ianniello M, Iacuzzi S, Fedele P, Brusati L (2019) Obstacles and solutions on the ladder of citizen participation: a systematic review. Public Manag Rev 21(1):21–46. https://doi.org/10.1080/14719037.2018.1438499
Jager NW, Challies E, Kochskämper E, Newig J, Benson D, Blackstock K, Von Korff Y (2016) Transforming European water governance? Participation and river basin management under the EU Water Framework Directive in 13 member states. Water 8(4):156. https://doi.org/10.3390/w8040156
Jatel N (2013) Using social network analysis to make invisible human actor water governance networks visible-the case of the Okanagan valley. Doctoral dissertation. University of British Columbia
Jones S (2011) Participation as citizenship or payment? A case study of rural drinking water governance in Mali. Water Altern 4(1):54–71
Kharanagh SG, Banihabib ME, Javadi S (2020) An MCDM-based social network analysis of water governance to determine actors' power in water-food-energy nexus. J Hydrol 581:124382. https://doi.org/10.1016/j.jhydrol.2019.124382
Kurian M, Portney KE, Rappold G, Hannibal B, Gebrechorkos SH (2018) Governance of Water-Energy-Food Nexus: A Social Network Analysis Approach to Understanding Agency Behaviour. In: Hülsmann S, Ardakanian R (eds) Managing water, soil and waste resources to achieve sustainable development goals. Springer, Cham, https://doi.org/10.1007/978-3-319-75163-4_6
Lakshmisha A, Thiel A (2022) Bridging actors and their role in co-managing lakes: cases from greater bengaluru metropolitan region (GBMR). Sustainability 14(10):5865. https://doi.org/10.3390/su14105865
Lawrence DP (2003) Environmental impact assessment: practical solutions to recurrent problems. John Wiley & Sons
Lienert J, Schnetzer F, Ingold K (2013) Stakeholder analysis combined with social network analysis provides fine-grained insights into water infrastructure planning processes. J Environ Manag 125:134–148. https://doi.org/10.1016/j.jenvman.2013.03.052
Mancilla-García M, Bodin Ö (2019) Participatory water basin councils in Peru and Brazil: expert discourses as means and barriers to inclusion. Glob Environ Change 55:139–148. https://doi.org/10.1016/j.gloenvcha.2019.02.005
Margerum RD (2008) A typology of collaboration efforts in environmental management. Environ Manag 41:487–500. https://doi.org/10.1007/s00267-008-9067-9
Maya-Jariego I (2016) 7 usos del análisis de redes en la intervención comunitaria. Redes Rev Hisp Para el álisis de Redes Soc 27(2):1–10. https://doi.org/10.5565/rev/redes.628
Maya-Jariego I, Holgado D (2021) Influencers and connectors in community prevention of drug abuse: balance between multi-site consistency and local community fit in program implementation. Psychosoc Interv 30(1):13–26. https://doi.org/10.5093/pi2020a9
Maya-Jariego I, Holgado D, Santolaya FJ (2023) What Works to Promote Community Engagement: Strategic Plan for Volunteering and Participation in Andalusia (Spain). Anal Soc Issue Public Policy 23(2):259–281. https://doi.org/10.1111/asap.12344
Megdal SB, Eden S, Shamir E (2017) Water governance, stakeholder engagement, and sustainable water resources management. Water 9(3):190. https://doi.org/10.3390/w9030190
Molle F, Closas A (2020) Comanagement of groundwater: a review. Wiley Interdiscip Rev: Water 7(1):e1394
Mukhtarov F, Dieperink C, Driessen P (2018) The influence of information and communication technologies on public participation in urban water governance: a review of place-based research. Environ Sci Policy 89:430–438. https://doi.org/10.1016/j.envsci.2018.08.015
Nabiafjadi S, Sharifzadeh M, Ahmadvand M (2021) Social network analysis for identifying actors engaged in water governance: an endorheic basin case in the Middle East. J Environ Manag 288:112376. https://doi.org/10.1016/j.jenvman.2021.112376
Newig J, Fritsch O (2009) Environmental governance: participatory, multi-level—and effective? Environ Policy Gov 19(3):197–214. https://doi.org/10.1002/eet.509
Newig J, Jager NW, Challies E, Kochskämper E (2023) Does stakeholder participation improve environmental governance? Evidence from a meta-analysis of 305 case studies. Glob Environ Change 82:102705
Ngaruiya GW, Scheffran J, Lang L (2015) Social networks in water governance and climate adaptation in Kenya. In: Leal Filho W, Sümer V (eds) Sustainable water use and management. green energy and technology. Springer, Cham, https://doi.org/10.1007/978-3-319-12394-3_8

O'Faircheallaigh C (2010) Public participation and environmental impact assessment: Purposes, implications, and lessons for public policy making. Environ Impact Assess Rev 30(1):19–27. https://doi.org/10.1016/j.eiar.2009.05.001

Ogada JO, Krhoda GO, Van Der Veen A, Marani M, van Oel PR (2017) Managing resources through stakeholder networks: collaborative water governance for Lake Naivasha basin, Kenya. Water Int 42(3):271–290. https://doi.org/10.1080/02508060.2017.1292076

Paneque-Salgado PP, Corral S, Guimaraes Â, del Moral Ituarte L, Pedregal B (2009) Participative multi-criteria analysis for the evaluation of water governance alternatives. A case in the Costa del Sol (Málaga). Ecol Econ 68(4):990–1005

Reyhani MN, Grundmann P (2021) Who influences whom and how in river-basin governance? A participatory stakeholder and social network analysis in Zayandeh-Rud basin, Iran. Environ Dev 40:100677. https://doi.org/10.1016/j.envdev.2021.100677

Rojas R, Bennison G, Gálvez V, Claro E, Castelblanco G (2020) Advancing collaborative water governance: unravelling stakeholders' relationships and influences in contentious river basins. Water 12(12):3316. https://doi.org/10.3390/w12123316

Romano ST (2019) Transforming participation in water governance: the multisectoral alliances of rural water committees and NGOs in Nicaragua. Int J Water Resour Dev 35(3):430–445. https://doi.org/10.1080/07900627.2017.1363722

San-Sebastián-Sauto J, Fernández-Escalante E, Calero-Gil R, Carvalho T, Rodríguez-Escales P (2018) Characterization and benchmarking of seven managed aquifer recharge systems in south-western Europe. Sustain Water Resour Manag 4(2):193–215

Serra J, do Rosário Cameira M, Cordovil CM, Hutchings NJ (2021) Development of a groundwater contamination index based on the agricultural hazard and aquifer vulnerability: application to Portugal. Sci Total Environ 772:145032

Da Silva GC, Bocanegra E, Custodio E, Manzano M, Montenegro S (2010) State of knowledge and management of Iberoamerican coastal aquifers with different geo-hydrological settings. Episodes 33(2):91–101

Slough T, Rubenson D, Levy RE, Alpizar Rodriguez F, Bernedo del Carpio M, Buntaine MT, Zhang B (2021) Adoption of community monitoring improves common pool resource management across contexts. Proc Natl Acad Sci USA 118(29):e2015367118. https://doi.org/10.1073/pnas.2015367118

Van Steenbergen F, Shah T (2003) Rules rather than rights: Self-regulation in intensively used groundwater systems. In: Llamas MR, Custodio E (Eds.) Intensive use of groundwater: challenges and opportunities. Balkema, The Netherlands, pp. 241–256

Stein C, Ernstson H, Barron J (2011) A social network approach to analyzing water governance: the case of the Mkindo catchment, Tanzania. Phys Chem Earth Parts A/B/C 36(14-15):1085–1092. https://doi.org/10.1016/j.pce.2011.07.083

Stigter TY, Monteiro JP, Nunes LM, Vieira J, Cunha MDC, Ribeiro L, Lucas H (2009) Screening of sustainable groundwater sources for integration into a regional drought-prone water supply system. Hydrol Earth Syst Sci 13(7):1185–1199

Stigter TY, Ribeiro L, Dill AC (2006) Application of a groundwater quality index as an assessment and communication tool in agro-environmental policies–two Portuguese case studies. J Hydrol 327(3-4):578–591

Tropp H (2007) Water governance: trends and needs for new capacity development. Water Policy 9(S2):19–30. https://doi.org/10.2166/wp.2007.137

Videira N, Correia A, Alves I, Ramires C, Subtil R, Martins V (2006) Environmental and economic tools to support sustainable golf tourism: The Algarve experience. Port Tour Hospit Res 6(3):204–217

Vignola R, McDaniels TL, Scholz RW (2013) Governance structures for ecosystem-based adaptation: using policy-network analysis to identify key organizations for bridging information across scales and policy areas. Environ Sci Policy 31:71–84. https://doi.org/10.1016/j.envsci.2013.03.004

Wutich A, Rosinger A, Brewis A, Beresford M, Young S, Household Water Insecurity Experiences Research Coordination Network (2022) Water sharing is a distressing form of reciprocity: shame, upset, anger, and conflict over water in twenty cross-cultural sites. Am Anthropol 124(2):279–290. https://doi.org/10.1111/aman.13682

Acknowledgements

The preparation of the manuscript was carried out during a research stay at the Lisbon School of Economics and Management (ISEG), with an International Mobility Grant from the Internal Research Plan of the University of Seville (I.3A VIPPITUS). Marta P. Varanda provided comments on a previous version of the manuscript and shared her experience on the Campina de Faro case, developed within the framework of a European project to facilitate the sustainable management of groundwater in the region (eGROUNDWATER). Sergio Granados-Chahín collaborated in the design of Fig. 1.

Author contributions

IM: writing—original draft, writing—review & editing.

Competing interests

The author declares no competing interests.

Ethical approval

Ethical approval was not required as the study did not involve human participants.

Informed consent

Informed consent was not required as the study did not involve human participants.

Additional information

Correspondence and requests for materials should be addressed to Isidro Maya Jariego.

Reprints and permission information is available at http://www.nature.com/reprints

Publisher's note Springer Nature remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.