Sustainability Science (2023) 18:79–96
https://doi.org/10.1007/s11625-022-01215-x

SPECIAL FEATURE: ORIGINAL ARTICLE

Networks of Action Situations in Social-Ecological Systems Research

Participatory interventions for collective action and sustainable resource management: linking actors, situations and contexts through the IAD, NAS and SES frameworks

Juan Felipe Ortiz-Riomalo[1] · Ann-Kathrin Koessler[1,2,5] · Yaddi Miranda-Montagut[3] · Juan Camilo Cardenas[4,6]

Received: 31 July 2021 / Accepted: 20 July 2022 / Published online: 20 September 2022

Abstract

Overcoming complex environmental challenges demands different forms of stakeholder participation and collective action. While informative and relevant for participatory interventions, the literatures on collective action and participatory governance have largely remained disconnected. We illustrate how the institutional analysis and development (IAD), network of (adjacent) action situation (NAS) and social–ecological system (SES) frameworks can be combined to provide a coherent approach that integrates these literatures, applies their insights and bridges this disconnect. We compare two similar participatory interventions, one in Colombia and one in Peru, whose design and implementation we supported. Transdisciplinary in nature, both sought to foster collective action for watershed management. The frameworks allow us to demarcate, characterise and reflect upon the action situations (ASs) for the collective choice, coordination and knowledge generation that constituted each participatory intervention (i.e. the constituent NAS) and other relevant operational and institutional ASs that lay outside the boundaries of the participatory interventions. These other ASs may not be linked to one another or to the intervention's constituent NAS, but they influence the outcomes of interest nevertheless, thereby shaping the potential of the participatory interventions for collective action and sustainable natural resource management. The framework then suggests, and our comparative analysis illustrates, that organisers and researchers of participatory interventions, such as multi-actor deliberative platforms and transdisciplinary research projects, should carefully consider, reflect upon and address the constellation of relevant actors, ASs and contexts co-determining the outcomes of interest. Our study demonstrates how the IAD, SES and NAS frameworks can support that endeavour.

Keywords Institutional analysis and development · Social–ecological systems · Networks of adjacent action situations · Collective action · Sustainable natural resource management · Participatory governance

Introduction

To stem ecological degradation, halt biodiversity loss and global warming, and attain sustainability, multiple actors and actions require coordination (Ravnborg and Guerrero

Handled by Christoph Oberlack, Centre for Development and Environment (CDE), University of Bern, Switzerland.

Miranda-Montagut: Independent researcher and consultant based in Bogotá, Colombia.

✉ Juan Felipe Ortiz-Riomalo
juanfelipe.ortizriomalo@uni-osnabrueck.de

[1] School of Business Administration and Economics and Institute of Environmental Systems Research (IUSF Research Centre), Osnabrück University, Osnabrück, Germany

[2] Present Address: Institute of Environmental Planning, Leibniz University Hannover, Hannover, Germany

[3] Bogotá, Colombia

[4] Department of Economics, University of Massachusetts Amherst, Amherst, USA

[5] Department of Geography and Environment, London School of Economics, London, UK

[6] School of Economics, Universidad de los Andes, Bogotá, Colombia

1999; Ostrom 2010a; Lubell and Balazs 2018; Dasgupta 2021). Thus, participatory interventions—that is, policy interventions that convene (some of) the relevant actors and stakeholders to attain specific social–ecological and/or institutional outcomes—seem promising for fostering collective action for sustainable resource management (e.g. Ostrom 1990; UNCED 1992; UN 2015; Baland and Platteau 1996; UNECE 1998; Dietz et al. 2003; Muradian and Cardenas 2015; ECLAC 2018). However, the bodies of research on collective action and on participatory governance have separately indicated that the outcomes of participatory processes in the context of natural resource management hinge on their design, scope and reach (Fung 2006; NRC 2008; Reed 2008; Ostrom 2006, 2010b; DeCaro et al. 2015; Newig et al. 2018; Reed et al. 2018). Despite their relevance for the sound design, implementation and analysis of participatory interventions such as multi-actor platforms and transdisciplinary research projects (e.g. Steins and Edwards 1999; Tribaldos et al. 2020), insights from these two streams of research have remained largely disconnected. In this paper, through a comparative analysis of two similar participatory interventions, we show how combining the institutional analysis and development (IAD) framework (Ostrom 2005, 2011), the network of (adjacent) action situation (NAS) framework (McGinnis 2011a; Kimmich et al. 2022) and the social–ecological system (SES) framework (Ostrom 2009; McGinnis and Ostrom 2014) with central concepts of participatory governance (e.g. Fung 2006; Newig et al. 2018; Reed et al. 2018) provides fruitful ways to integrate these insights and apply them to the design and analysis of participatory interventions.

Research on collective action suggests that allowing the relevant actors to communicate and participate in relevant decision-making processes fosters trust-building and the creation of suitable, legitimate and effective measures for sustainable resource management (Ostrom 1990, 1998, 2006; DeCaro et al. 2015; Dannenberg and Gallier 2020). Conversely, solutions that are externally devised and (weakly) enforced can have limited effects if the relevant actors see them unwarranted, unfair, illegitimate and/or ill-suited. External solutions may neglect relevant features of the context and waste local capacities and resources. They are likely to have a limited effect and may even backfire if they induce mistrust and resistance, undermine the capabilities of the relevant state and non-state actors or hamper their (intrinsic) motivations to act for the benefit of others and nature (Ostrom 2000, 2007a, 2010b; Ostrom et al. 1994; Baland and Platteau 1996; Cardenas et al. 2000; Frey et al. 2004; Muradian and Cardenas 2015; Bowles 2016; Heikkila and Andersson 2018; Ezzine-de-Blas et al. 2019).

Complementarily, research on participatory governance has explicitly stressed that, far from being guaranteed, the success of participatory processes hinges on their design, implementation and context (Beierle and Cayford 2002; Jager et al. 2020). At the appropriate stages of the policy process, well-designed participatory interventions can indeed facilitate meaningful and productive interactions among the relevant actors (NRC 2008; Reed 2008; Reed et al. 2018). However, relevant actors, decision-making processes and institutional arrangements outside the boundaries of the participatory intervention may limit its potential if these elements are not adequately considered and involved (NRC 2008; Reed 2008; Edelenbos et al. 2009; Gerlak et al. 2013; Bodin 2017; Lubell and Balazs 2018). In a similar vein, the literature on collective action pinpoints that the participation of a limited set of relevant actors in a limited set of relevant activities and decision-making processes leads to limited effects in terms of trust-building and actual cooperation (e.g. Ostrom 2006, 2010b; DeCaro et al. 2015). Thus, if collective action is to be promoted, it is essential to recognise and adequately involve the relevant state and non-state actors (or their legitimate representatives) in the relevant decision-making processes and activities concerning the design, monitoring, enforcement and assessment of the relevant institutional arrangements regulating their operations (Ostrom et al. 1994; Ostrom and Nagendra 2006; Poteete et al. 2010; Cox et al. 2010).

Despite being related, these insights have not been systematically integrated. In this paper, we show how researchers and practitioners can purposefully combine the IAD, SES and NAS frameworks (see also Cole et al. 2019; Epstein et al. 2020) and the concepts from participatory governance to integrate and apply these insights. We illustrate this application through a comparative analysis of two similar participatory interventions, transdisciplinary in nature, which we helped design and implement. Both aimed at fostering collective action for sustainable watershed management in the (Colombian and Peruvian) Andes.

The IAD framework provides a general template for organising the situational and contextual factors that influence the prospects for collective action in interdependent action situations (ASs) where particular and aggregate interests may be in conflict (i.e. collective action challenges or social–environmental challenges or dilemmas) (Ostrom 1990, 2011; Schlager and Cox 2018; Heikkila and Andersson 2018). Acknowledging that actors interact in several interlinked action spaces, the NAS framework helps to organise the analysis of all adjacent and distant ASs that jointly produce specific sustainability and equity outcomes in complex SES that are sometimes separate yet interconnected (e.g. McGinnis 2011a; Kimmich et al. 2022). It helps operationalise individual and collective decision-making processes as networks of simultaneously or sequentially interlinked ASs. Thus, it offers a template to organise, apply and further develop key concepts of participatory governance. The SES framework, in turn, expands upon the social–ecological and

governance-related contextual factors that shape the structure and thus the interactions and outcomes of the relevant NAS (Ostrom 2007b, 2009; Poteete et al. 2010; McGinnis and Ostrom 2014). Together, these frameworks help to map the complex constellations of actors, ASs and contextual conditions that any sound policy intervention aimed at fostering collective action should consider (Polski and Ostrom 1999; Heikkila and Andersson 2018; Cole et al. 2019; Epstein et al. 2020).

Previous research has successfully used elements of the IAD and NAS approaches to study policy design (e.g. Polski and Ostrom 1999; Carter et al. 2016) and various processes, such as policy-making (e.g. Pahl-Wostl et al. 2010; Pahl-Wostl 2015; Heikkila and Andersson 2018), multi-level learning (e.g. Pahl-Wostl et al. 2010; Pahl-Wostl 2015), decentralisation (e.g. Clement 2010; Epstein et al. 2020), co-management (e.g. Whaley and Weatherhead 2014) and telecoupling (e.g. Oberlack et al. 2018; Boillat et al. 2018). To the best of our knowledge, only a few studies have employed this combined framework approach to study participatory interventions.[1] Some have used the IAD framework to guide the design (e.g. Klok and Denters 2018) and analysis (e.g. Cárdenas and Ortiz-Riomalo 2018) of such interventions. Yet, they do not explicitly and systematically use the NAS framework to define, characterise and assess participatory interventions. Consequently, they do not systematically study the interactions between the broader context, the NAS that constitutes the participatory intervention, and the other relevant ASs that also influence the outcomes of interest. Ortiz-Riomalo et al. (2022) did use the IAD, SES and NAS frameworks in combination to conceptualise and characterise participatory interventions and their potential impacts by reviewing and integrating relevant empirical insights on collective action and participatory governance. However, they did not empirically assess the insights and conclusions derived from their review.

Our study builds upon these previous applications and provides, to the best of our knowledge, (one of) the first empirical application(s) of this combined approach to the analysis of participatory interventions. Therefore, the study's contributions are fourfold. First, it shows how this combined approach helps demarcate and characterise the distinct, yet interconnected ASs that constitute a given participatory intervention (i.e. the constituent NAS). Second, it shows how this approach helps to characterise and analyse the interconnections between the constituent NAS and the other relevant (linked and unlinked) ASs that may also influence the outcomes of interest. Third, it proposes that the absence of adequate linkages between the constituent NASs and other relevant ASs may limit the potential of participatory interventions to foster collective action in complex SESs. Finally, it lays out a conceptual and methodological basis for further assessing this proposition and, more generally, for systematically considering, addressing and incorporating the relevant contexts, actors and ASs in the research and practice of participatory interventions for collective action, such as multi-actor platforms and transdisciplinary research projects (e.g. Steins and Edwards 1999; Tribaldos et al. 2020).

After describing the main elements of the conceptual framework of this study in the next section, in the third section we briefly describe and discuss the data as well as the data analysis methods that form the basis of our conclusions. The fourth section presents and discusses the results of the comparative analysis, and the last section summarises the conclusions, contributions, limitations and implications of our study.

Framework

Collective action challenges

In a given complex SES such as a river watershed, ecological, institutional and social outcomes are the result of proximate, distant, multi-level and interdependent decision-making processes. These involve multiple, often heterogeneous actors in terms of their preferences, beliefs, endowments, location, affiliations and backgrounds (Edwards and Steins 1998; Ravnborg and Guerrero 1999; Ostrom 2005; Oberlack et al. 2018; Cole et al. 2019; Reed et al. 2020). Day-to-day operational land, resource, input and technology use decisions in one part of the system have socioeconomic and ecological implications locally and elsewhere. Institutional arrangements—crafted and enforced through formal and informal collective decision-making at different government levels—influence and are shaped by these operational decisions and outcomes. Furthermore, processes and outcomes in distant systems may interact with these through, for instance, complex value chains and seemingly distant ecological processes (Oberlack et al. 2018; Boillat et al. 2018; Villamayor-Thomas et al. 2019).

Hence, to attain socially desirable outcomes, such as just and sustainable food and water provision and nature protection in a given SES, the relevant actors need to coordinate their decisions and actions, often in multiple (types of) action spaces (Ostrom 1990, 2005; Kimmich 2013; Lubell and Balazs 2018; Kimmich and Villamayor-Tomas 2019; Reed et al. 2020). Actors need to address potential tensions between individual and collective interests and build shared understandings and collective agreements on desirable outcomes, actions, decision-making processes and allocation of

[1] For a systematic review on NAS research and different applications of the NAS approach, see Kimmich et al. (2022) in this special feature.

costs and benefits (e.g. a price, reward and/or punishment scheme to ensure sensible water consumption and equitable sustainable land use for stable and equitable water provision and distribution) (Ostrom 1990, 1999; Lubell and Balazs 2018). According to the IAD framework, expanded upon by the NAS and SES frameworks, the structure of the relevant decision and action situations, along with the attributes of the relevant actors and the broader context, jointly determine the prospects for collective action (Kiser and Ostrom 1982, 1987; Ostrom 2005, 2010b, 2011; Poteete et al. 2010; McGinnis 2011a, b; Schlager and Cox 2018; Cole et al. 2019). In the following, we expound on these aspects, marking the main concepts in italics.

Action situations (ASs) and network of action situations (NASs)

An action (or decision) situation (AS), the focal unit of analysis of the IAD framework, is the situation (i.e. the space, the setting) wherein action takes place and wherein actors make choices, interact and generate intended and unintended outcomes (Ostrom 1990, 2005). A particular type of AS can have several iterations and thus allow for repeated interactions (Ostrom 2005). In an AS, *actors* (i.e. the participants in that AS) make interdependent choices based upon the *positions* they occupy (i.e. the roles they play), their i*nformation* about potential *outcomes*, *costs* and *benefits* of their own and other actors' possible actions, and the *level of control* and influence they have over those actions and outcomes. These main elements—actors, positions, actions, outcomes, costs and benefits, information and control—are the seven *basic working components* that define the structure of an AS (McGinnis 2011a; Ostrom 2005, 2011). See Fig. 1 at the end of this section.

Decisions, actions and interactions may take place in distinct, yet sequentially or simultaneously interlinked (a) *operational* and (b) *institutional* ASs (Ostrom 1990, 2005; Ostrom et al. 1994). That is, actors may interact around (a) the actual use of natural resources and/or (b) the design, enforcement and assessment of possible institutional arrangements[2] and processes to govern resource use.[3] It is then possible to delineate the *boundaries of an AS* based on the types of activities taking place therein (e.g. provision, appropriation, learning, rule-making and social mobilisation) (see Ostrom 1990, 2005; Ostrom et al. 1994; McGinnis 2018). This is the approach we follow in this paper.[4]

The *focal AS* is the AS in which the critical decisions and interactions that produce the outcome(s) of interest take place (Kimmich 2013; McGinnis 2018; Cole et al. 2019). In water management, for instance, interactions around the provision and appropriation of water resources constitute the focal AS (Ostrom and Gardner 1993; Lubell et al. 2002; Cardenas et al. 2011; McGinnis 2018).[5] An *AS is said to be adjacent to another AS* whenever its outcomes influence at least one of the working components and thus shape the structure of the other AS. Two or more adjacent ASs constitute *a network of (adjacent) action situation (NAS)* (McGinnis 2011b; Kimmich 2013; Cole et al. 2019). The *relevant NAS* encompasses all the relevant ASs and actors that influence the focal AS (Kimmich 2013; McGinnis 2018) and thus (co-)determines the critical outcomes of interest, such as the amount and distribution of clean water and the socioeconomic status of water users in a watershed (Ostrom and Gardner 1993; Lubell et al. 2002; Cardenas et al. 2011). Lastly, *distant ASs* then correspond to those ASs that indirectly influence the focal AS through (a chain of) other distant or adjacent ASs (Oberlack et al. 2018; Boillat et al. 2018).

ASs *link* to one another through their common participants and their outcomes, which affects one another's working components. That is, ASs connect through (a) biophysical processes, such as changes in biodiversity, water quality and the state of physical infrastructure; (b) institutional arrangements and processes; (c) actors—including impacts on actors' attributes, such as their beliefs and preferences—; and (d) flows of information (McGinnis 2011b, 2018; Kimmich 2013; Cole et al. 2019). Actors may participate in one or several ASs to influence outcomes in desired directions. They may also coalesce with other individuals and organisations to advance joint strategies in one or several ASs within the relevant NAS. The study of the NAS, then, leads to consider the broad constellation of actors, as well as the broad constellation of ASs in which they participate and interact, to understand the underlying causes of specific

[2] Formal or informal rules and shared strategies to overcome collective action challenges (North 1994; Ostrom 2005; Cole 2017).

[3] The IAD and NAS frameworks generally recognise three main levels of choice and action: *operational*, *collective* and *constitutional*. The latter two, respectively, correspond to (*collective*) decisions on the design and enforcement of operational institutional arrangements (e.g. those that regulate resource use operations) and (*constitutional*) decisions on who can participate in the *collective* decision-making process and how. The *institutional-choice* level encapsulates these two (Ostrom 1990, Ch. 6). Hence, in this paper, we only distinguish between the *institutional* and *operational* levels for the sake of simplicity and because we do not delve into the constitutional choice level.

[4] For alternative ways to define the boundaries of ASs, see Pahl-Wostl et al. (2010) and McGinnis (2011a). For a review, see Oberlack et al. (2018) and Kimmich et al. (2022).

[5] A focal AS need not be associated with a specific geographical region or locality. Ostrom and Gardner (1993), Lubell et al. (2002) and Cardenas et al. (2011), for example, set the focal operational AS at the watershed level, where water provision and appropriation involving multiple actors and localities takes place. We follow this approach in this paper.

outcomes, to effectively influence them in desired directions (e.g. towards more sustainability, equity, empowerment and/or efficiency).

Context

Naturally occurring processes and previous outcomes of adjacent ASs then constitute the contextual conditions that influence the working components and thus shape the structure of the focal AS and associated relevant NAS (McGinnis 2011a, 2018; Kimmich 2013; Cole et al. 2019). The IAD framework and its extension, the SES framework, thus cluster these contextual elements in the *biophysical conditions of the resource system*, the features of the institutional arrangements and processes (i.e. the *governance system*) and the social, economic and cultural *attributes of the relevant actors* (Ostrom 2007b, 2009; Poteete et al. 2010; McGinnis and Ostrom 2014; Cole et al. 2019). (See Fig. 1.)

Participatory interventions

Under this framework, and based on previous contributions from institutional and behavioural economics (e.g. Bates 1988; Ostrom 1990, 2010b; Muradian and Cardenas 2015; Bowles 2016; Cárdenas 2018; Heinz and Koessler 2021; Velez and Moros 2021), it is thus possible to state that participatory policy interventions may seek to foster collective action in the focal AS. They do this by addressing and/or influencing the relevant attributes of (a) actors (e.g. their knowledge, beliefs, preferences or values) and/or (b) the governance system (e.g. specific rules or collective decision-making processes) (Ortiz-Riomalo et al. 2022). The intervention's ultimate impact will depend on whether and how it effectively influences the relevant NAS, its patterns of interactions and outcomes (Kimmich 2013; Carter et al. 2016).

A further distinction can be made between two types of ASs when defining, characterising and analysing participatory interventions. First, there is the NAS that the designers and organisers of a participatory intervention directly create, design, intervene in or shape (i.e. the intervention's *constituent NAS*) (see also Klok and Denters 2018). This constituent NAS thus set the *boundaries of a participatory intervention.* Commonly, these constituent ASs enable the participants to receive, provide or exchange information that allows them to adjust their strategies, norms and rules to attain better collective outcomes. The specific structure of these constituent ASs is set by the design features and participatory methods (e.g. participatory modelling, games, social cartography and deliberative exercises) that the organisers use to facilitate actors' interactions (e.g. Beierle and Cayford 2002; Cárdenas et al. 2003; Fung 2006; Kallis et al. 2006; Klok and Denters 2018; Ortiz-Riomalo et al. 2020; Reed 2008; Rowe and Frewer 2005; Von Korff et al. 2010; Voinov and Bousquet 2010; Medema et al. 2016). Jointly, and also influenced by the broader context, these methods and their specific arrangement determine the set of participants and the participants' roles in the process, possible actions and potential outcomes. They also determine the informational and knowledge bases for the actors' choices, as well as the degree of control actors have over the process and its outcomes.

The second type of relevant ASs encompasses those outside the boundaries of the participatory intervention. The designers and organisers of the intervention cannot directly shape these. In addition, these ASs may or may not link to one another and/or to the constituent NAS, but they (may) nonetheless influence (a) the constituent NAS in uts structure, interactions and outcomes and (b) the general outcome(s) of interest (see also NRC 2008; Edelenbos et al. 2009; Pahl-Wostl et al. 2010; Pahl-Wostl 2015; Klok and Denters 2018).

Based on the literatures on collective action and participatory governance, the potential of participatory interventions for collective action generally depends on the types of connections and interactions they facilitate between the actors, relevant ASs and the context. First, their potential hinges on the structure and internal linkages of the constituent NAS. These should facilitate communication, shared understandings and collective agreements among the participants, while properly considering the relevant features of the context (Ostrom 2006, 2007b; NRC 2008; Reed 2008; von Korff et al. 2010; Cardenas et al. 2011; Schill et al. 2016; Heikkila and Andersson 2018): the biophysical conditions (e.g. geographical distances, types of ecosystems and existing facilities), the governance system (e.g. regulations for resource use and stakeholder participation in resource management), and the specific actors' attributes (e.g. in terms of preferences, expectations and unequal endowments) (McGinnis and Ostrom 2014; Cole et al. 2019). Adequately addressing these interactions between elements of the biophysical conditions, governance system and actors' attributes requires, in turn, a transdisciplinary approach to incorporate and apply the different relevant sources of knowledge (e.g. Lang et al. 2012).

Second, their potential also depends on the way they connect with other relevant (adjacent and distant) ASs and actors outside the boundaries of the participatory intervention. If not properly considered, these relevant actors and ASs can limit, neglect and/or override the outcomes of participatory interventions (e.g. through lobbying, legislation, litigation, social mobilisation and bureaucratic hurdles in other formal and informal spaces) (Edelenbos et al. 2009; Quist et al. 2011; Gerlak et al. 2013; Bodin 2017; Klok and

Denters 2018; Newig et al. 2018; Boillat et al. 2018; Epstein et al. 2020).

Based on the above, we can then propose that successful participatory interventions are those that are adequately embedded in the relevant context. That is, (a) the design of the constituent NAS fit the context and (b) the constituent NAS have proper actor, knowledge and/or institutional linkages with other relevant ASs located outside the boundaries of the participatory intervention. An adequate link is established under one or two conditions. The first is that the outcomes of the constituent NAS effectively influence—in the desired direction—the interactions and outcomes of the other relevant ASs. Alternatively, the outcomes of these other ASs do not run counter to or over the outcomes of the constituent NAS. It is, therefore, critical to set the boundaries of the relevant NAS and the constituent NAS to identify those (adjacent and/or distant) relevant ASs which the organisers of the participatory intervention cannot directly influence but to which they should seek to establish adequate linkages. This process of setting limits and establishing adequate linkages would determine the degree of inclusivity, as well as the scope and potential, of the participatory intervention.[6]

Figure 1 depicts the main elements of this framework for the design and analysis of participatory interventions. The central element of the diagram illustrates the constituent NAS in interaction with those other relevant ASs. The conditions in the biophysical and social systems shape and are subsequently transformed by the outcomes of these ASs. The following section offers a comparative analysis to demonstrate and discuss the application of this combined approach.

Comparative analysis: data and methods

In the next section, we describe, compare and analyse two similar participatory interventions, transdisciplinary in nature, which took place in two Andean watersheds comparable in their general ecological and socioeconomic features. The first intervention took place in the Suratá River Watershed, Colombia, between January 2014 and January 2016, and the second in the Cañete River Watershed, Peru, between October 2018 and March 2019. In each case, we used participatory methods similar in design to foster collective action for sustainable watershed management. Yet, these interventions influenced collective action differently in each case. We use a 'most similar systems design' approach—that is, the difference method (Anckar 2008; Collier 1993; Poteete et al. 2010)—to compare these cases and gain insight into factors that can potentially explain the difference in outcome. Following the concepts and considerations of the previous section, we focus on the linkages between the NAS constituting each participatory intervention and the relevant ASs outside the intervention as the main potential explanatory factor for the differences in outcome. As the cases are similar but naturally not identical, we also compare the context of each case and thus probe for additional potentially relevant explanatory factors.

Our deep engagement as facilitators and academic advisors in the design and implementation of both participatory interventions provided us with access to a rich vein of primary information with which to describe and compare the cases. As primary data sources, we drew on our observations and field

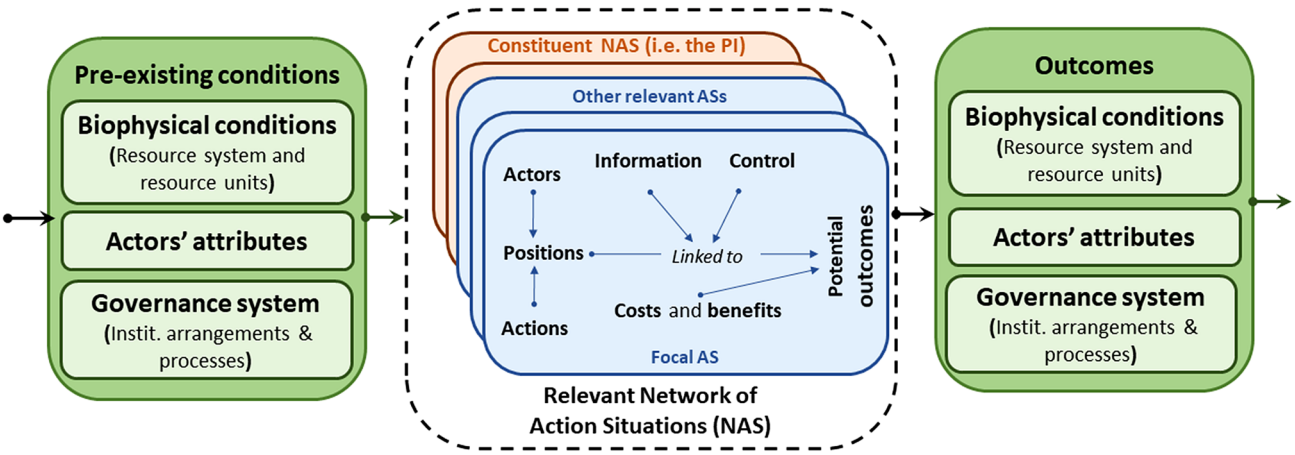

Fig. 1 IAD, NAS and SES frameworks combined for the analysis of participatory interventions (PI). Source: Based on Ostrom (2005), Poteete et al. (2010), McGinnis and Ostrom (2014), Pahl-Wostl et al. (2010), Klok and Denters (2018) and, particularly, Cole et al. (2019)

[6] We thank an anonymous reviewer for drawing our attention to and highlighting the importance of this point.

notes, the notes from 25 individual and 5 group interviews and the minutes of 17 multi-actor workshops. We also considered secondary sources, including media coverage and the available reports and studies on the resource management challenges of these watersheds (Fonseca Martel and Mayer 1978; CDMB 2006, 2011; Quintero et al. 2013a, b; Francesconi et al. 2016; Tristán-Febres et al. 2018; Sarmiento and Ungar 2014; Stern and Echavarría 2013; Blundo-Canto et al. 2016). These sources complemented the actor analysis, enriched our understanding of both contexts, allowed us to triangulate the interviewees', participants' and our own perspectives and helped us to validate our initial assessments to avoid potential judgement biases. Furthermore, we enriched the analysis with insights from previous project reports and articles in which we had already processed and analysed parts of the information from each case independently (Cárdenas et al. 2015; Cárdenas and Ortiz-Riomalo 2018; Ortiz-Riomalo and Miranda-Montagut 2019; Ortiz-Riomalo et al. 2020).[7]

The IAD, NAS and SES frameworks, used in combination, provided us with a systematic guide for organising the data and structuring the case comparison. The structured approach also helped to minimise biases that may have occurred due to our own perspectives and direct involvement in the processes. By following the framework, we were prompted to describe, compare and analyse the interventions across all relevant factors and categories and constantly re-assess our findings. First, we described the main ecological, governance and social attributes of each watershed, thus defining the pre-existing contextual conditions of each participatory intervention. Then, we identified the focal AS and relevant NAS, demarcated the boundaries of the participatory intervention (i.e. the boundaries of the constituent NAS) and established the connections between the NAS constituting the participatory intervention and the other relevant ASs—that is, those ASs outside the boundaries of the intervention that could also influence the outcomes of interest.[8] To trace the boundaries of each AS, the relevant NAS and the constituent NAS, we grouped similar activities according to their function and linked them by their outcomes and participants.

In the online supplementary information, we present the data, underlying guiding questions and resulting case characteristics in detail.[9] Specifically, section S1 expands on the details, scope and limitations of our data. Section S2 includes the specific guiding questions we followed to apply the frameworks and organise the data. Sections S3A and S3B, in turn, summarise the data for each case using the template we derived by combining the methodological guidelines that the IAD, NAS and SES frameworks offer. The analytic description and comparison of the cases that we present in the next section is based on these data. Figures 2 and 3 in "Contextual factors" offer a graphic summary of the main features of each case.

Comparative analysis: results

The NAS constituting each participatory intervention

The main aim of the two participatory interventions was to facilitate collective agreements between upstream and downstream resource users on the desired institutional arrangements for securing water provision in their respective watersheds. That is, in both watersheds, the interventions targeted the institutional level—specifically, the collective-choice level—and not the focal AS—where operational decisions and actions on water provision and appropriation take place. Three types of adjacent ASs constituted the participatory processes: *knowledge generation*, *coordination* and *collective-choice* ASs.

The informal *collective-choice* ASs, created through multi-actor workshops, were the central ASs of the participatory process. The workshops were intended for the relevant state and non-state actors from all sections, sectors and levels of the watershed to meet and to exchange and reflect upon their common challenges, desirable ecological, governance and socioeconomic outcomes and potential joint strategies. For this purpose, we actively encouraged participants to extricate themselves from the roles they occupy in their day-to-day activities and instead take a broader, watershed-wide perspective. Furthermore, we organised participants into subgroups involving representatives of different sections and sectors of the watershed. In the end, the workshops aimed at facilitating shared understandings and agreements on the nature of the collective action challenge and its desirable solutions.

To stimulate reflection and facilitate deliberation, we employed three types of participatory methods, namely economic games, social cartography methods and group-moderation techniques such as the Metaplan. The

[7] Ideally, we would have had an independent third party evaluate the outcomes and potential explanatory factors of the two participatory interventions to verify our findings. Unfortunately, to our knowledge, no independent evaluation has been conducted so far. Readers interested in potential shortcomings of the approach we followed—specifically the multi-actor workshops within the participatory process—should refer to Duarte-Abadía and Boelens (2016). Although they focus on the first multi-actor workshop in the Colombian case, one can derive more general implications from their criticism.

[8] As hinted at in the previous section, operational activities around water provision and appropriation constitute the focal AS (Ostrom and Gardner 1993; Lubell et al. 2002; Cardenas et al. 2011).

[9] Check the Supplementary file 1. Also available here: https://osf.io/tzcwm.

economic games reflected collective action situations concerning the provision of public goods and the management of common-pool resources. The games raised awareness of the interdependencies among the actors, the tensions that can emerge between individual interests and societal ends, the common goals all participants share and deem desirable, and the appropriate courses of actions that may contribute to socially desirable outcomes (Cárdenas and Ramos 2006; Cardenas and Carpenter 2008; Cárdenas et al., 2013; Janssen et al. 2010; Meinzen-Dick et al. 2016).[10,11] The games recreated collective action challenges similar to the ones participants face in their day-to-day resource use and management activities. Hence, they facilitated general, rather abstract reflections on collective action problems and their potential solutions, which participants linked to their experiences outside the games.

Subsequently, a social cartography exercise (e.g. Liebman and Paulston 1994) helped participants focus their discussions on the concrete collective action challenges they have been facing in the sustainable management of their watersheds. On maps of their watersheds, participants jointly identified the main current resource uses, discussed their consequences, reflected upon the social–ecological and governance outcomes they would like to realise (e.g. sustainability, biodiversity conservation, sustainable development and participatory decision-making) and outlined specific joint courses of action (e.g. transitions towards cleaner technologies in mining and agriculture).

All these discussions laid the groundwork for the final sub-group and plenary discussions on the general goals and specific objectives and strategies participants deemed desirable and wanted to prioritise for their respective watersheds. Employing group-moderation techniques such as the Metaplan (Schnelle 1978), we strove for each participant to be able to voice their concerns, preferences and general opinions throughout the workshop, providing the tools and the time needed to expound on their ideas.

In adjacent *coordination* ASs with relevant actors from development and environmental agencies, local authorities, universities and community leaders, we discussed and decided how to best design and implement the collective-choice multi-actor workshops in each case's specific context. We aimed to involve these diverse relevant actors in the *coordination* ASs so they would likely follow-up on the process outcomes and eventually realise them through the relevant institutional and operational ASs outside of the boundaries of the participatory intervention.

Finally, research activities comprising desk research, individual and group interviews, and multi-actor workshops made up the *knowledge generation* ASs (see also Section S1 in the ESM). These were linked to the *coordination* and *collective-choice* ASs to support the participants' interactions therein. Through these research activities, we gathered critical information to diagnose the social–ecological context and governance system. This allowed us to identify the relevant actors and ASs that the participatory process should consider, involve and link. We employed the IAD and SES frameworks to guide the search for and consolidation of the relevant information concerning the different elements of the corresponding biophysical conditions, governance systems and actors' attributes.[12]

The outcomes of the constituent NAS

From the *knowledge generation* ASs emerged the knowledge base for the *coordination* and *collective-choice* ASs. From the *coordination* ASs emerged the specific rules, that is, the design features and participatory methods shaping the informal *collective-choice* ASs of each participatory intervention. From these, a consensus on desirable watershed management strategies gradually emerged. The content and degree of implementation nevertheless varied in each case.

In the Suratá River Watershed, participants contributed to an agenda of watershed governance and sustainable development through eleven multi-actor workshops, one at the *páramo*[13] level, two at the watershed level and eight at the local level, in the municipalities of the upper and lower watersheds. The agenda comprised six policy areas: environment, governance, agriculture, mining, tourism and social policy. Each contained a desirable goal and a series of policy actions. Nonetheless, the resulting agreement did not address all the relevant concerns driving the existing social–ecological conflicts in the watershed. Namely, it did not address the absolute opposition of downstream users to mining activities in the upper watershed. Nor did it address the disagreements among (upstream and downstream) resource users and the relevant state actors on the delineation and regulation of the protected area for the *páramo* in the upper watershed. As of

[10] We used the watershed game, the public goods game and the trust game, primarily based on the designs by Cárdenas and Ramos (2006) and Cárdenas et al. (2013). Cárdenas and Ortiz-Riomalo (2018) and Ortiz-Riomalo et al. (2020) describe each participatory process and method in more detail. For the (potential) impacts of serious games in natural resource management, see Medema et al. (2016), Meinzen-Dick et al. (2018), Falk et al. (2021) and Meyer et al. (2021).

[11] In each game, participants' decisions had financial implications. Depending on their decisions during the games, participants received a pay-off at the end of the workshop.

[12] These knowledge generation activities and the incorporation of different perspectives and sources of knowledge throughout the participatory process represent the main transdisciplinary features of both participatory interventions (cf. Lang et al. 2012).

[13] High-mountain Andean moorland. Here, it refers to the Santurbán *páramo*, located in the upper section of the Suratá, Zulia and Pamplonita river basins.

June 2021, the relevant actors had not agreed upon the actors and actions that formal institutional arrangements should permit in the upper watershed. In other words, they had not agreed on the *boundary* and *scope* rules (see Ostrom 2005) that should govern resource use in the upper watershed. Whereas downstream users were demanding strict conservation measures in the upper watershed, resource users in the upper watershed were reclaiming their right to derive their livelihoods from the economic activities they have traditionally performed, so far without causing major negative impacts on the surrounding ecosystems. This ongoing disagreement has delayed the development and implementation of any major agreement on watershed management involving all relevant resource users.

In the Cañete River Watershed, participants in the only collective-choice multi-actor workshop of the participatory intervention agreed on a general goal for the watershed, two specific objectives for each section of the watershed (lower, lower middle, middle, upper middle and upper) and two management strategies for each specific objective. This agreement is to feed into the watershed management plan of the water resources council, which was in the formation stage at the time of the participatory intervention. In contrast to the Suratá case, none of the participants in Cañete indicated that any major issue had been left out of the agreed-upon watershed management recommendations. Moreover, during the multi-actor workshop, representatives of the local hydropower company (the main non-consumptive user of water in the watershed), the Ministry of Environment, the manager of the landscape reserve in the upper watershed, the water utility in the lower watershed and representatives of the downstream farmers (the main users of surface water in the watershed) voluntarily committed to carry out the relevant actions in the corresponding ASs to which they had access. In personal communications with the participants, each reported trusting the others' willingness to take up collective action. They also expressed an understanding that the sustainable management of the watershed is a desirable outcome that hinges on everyone's actions. In fact, some of the agreed-upon measures have already been implemented. For example, in 2019, downstream farmers visited the upper watershed to learn more about the ongoing and potential conservation measures to which they could potentially contribute funding. In addition, representatives of the Ministry of Environment have continued to support the negotiation of conservation and to reward agreements[14] for sustainable water provision in the watershed. However, the agreement participants reached left out specific provisions for the mining, fishing and tourism industries, of some importance in this watershed. Furthermore, the implementation of the agreed-upon measures on waste management and water pollution, as well as the watershed management plan, was still pending as of July 2021.

What factors may have driven these outcomes? The proposition we put forth in "Participatory interventions" leads us to first focus the analysis on the (types of) linkages, or lack thereof, between the constituent NAS and the relevant ASs (and actors) located outside the boundaries of the participatory intervention that could also influence the outcomes of interest.

Other relevant ASs outside the boundaries of the participatory intervention

As noted earlier, in the Colombian case, the participatory intervention did not directly target the focal AS, that is, the operational AS for water provision and appropriation. Instead, it focussed on choice and action at the institutional level. However, we noted relevant formal institutional ASs with no clear connection with the participatory intervention. These formal institutional ASs concern the licensing of mining operations and the delineation of the protected area for the *páramo* ecosystem. These ASs influence the design and application of *boundary* and *scope* rules (Ostrom 2005) regarding the actors and actions allowed in the upper watershed—some of, if not the same critical institutional arrangements for resource use that the participatory process sought to influence. Downstream users pushed for strict command-and-control conservation measures upstream in these ASs, and they did not participate in the watershed level multi-actor workshops. In contrast, upstream users sought in both types of institutional ASs (formal and informal) to advance measures that would allow and promote sustainable practices and cleaner production technologies in mining and farming upstream. In sum, downstream and upstream users sought to move their preferences forward in separate, unconnected ASs. This has protracted the disagreement on the rules for resource use in the watershed, limiting the scope and impact of the participatory intervention on collective action.

In contrast, our observations and interviews suggest that in the Cañete case, it was possible to establish proper actor, knowledge and (informal) institutional linkages between the NAS constituting the participatory process and other relevant ASs. In this case, the *coordination* and *collective-choice* ASs managed to convene most of the relevant actors involved in water resources management in this watershed. They included representatives of the environmental authorities, the landscape reserve management committee (in the upper watershed), the hydropower company, the water utility company from the lower watershed and the main downstream agricultural water user committees and boards. Moreover, participants agreed to follow-up on and further develop and implement the outcomes of the informal *collective-choice*

[14] These are similar to payment for environmental services (PES) schemes (Engel et al. 2008; Wunder 2015).

ASs in other formal institutional ASs (i.e. the existing multi-actor governance platforms for land and water use in this watershed) and their day-to-day operations in other sections of the watershed. Nonetheless, as of July 2021, no clear link had been made to operational ASs involving the monitoring of water quality, the management of waste and the use of mining and fishing resources. Participants noted the lack of this linkage and the need to connect with the relevant actors to realise concrete action in these areas in the near future (i.e. with the local mayors, mining companies, local water utilities, local water authorities, fishers' organisations and tourism organisations). They also stressed the importance of moving forward the formation and consolidation of the water resources council. This would allow the integration of different perspectives and existing multi-actor governance platforms to design and adopt a comprehensive watershed management framework, which would draw on the outcomes of the participatory intervention.

The above analysis suggests that the (absence of) proper linkages between the NAS constituting the participatory intervention and other relevant ASs shaped the scope and implementation of the agreements that participants reached during the participatory process. However, our analysis also suggests that some pre-existing contextual conditions concerning the attributes of the relevant actors and governance system may also help explain the observed differences in the outcomes of each case. We review these in the following.

Contextual factors

In the Suratá River Watershed, upstream and downstream users have generally held conflicting preferences on the *boundary* and *scope* rules for resource use in the upper watershed. Downstream users, most of them urban dwellers and the main users of surface water for household consumption in the watershed, have deemed it critical to adopt strict conservation measures upstream to secure water provision downstream. Upstream users, traditionally reliant on mining and farming to secure their livelihoods, have instead favoured institutional arrangements that allow for these activities in the upper watershed, provided they use cleaner technologies and sustainable land use practices.

Our observations and interviews indicate that tensions between upstream and downstream water users around the actors and actions that should be allowed in the upper watershed influenced their willingness to participate in the informal collective-choice AS that the participatory intervention facilitated. Downstream users have staunchly opposed the ('express', that is, rushed) licensing of any new (large-scale) mining operations upstream. They have also objected to any delineation of the protected area of the *páramo* that may allow (large-scale) mining and (unsustainable) farming within the protected area. They have coalesced with other non-state national and international actors to put pressure on the corresponding environmental authorities. They have also litigated before the courts against the *páramo* delineation

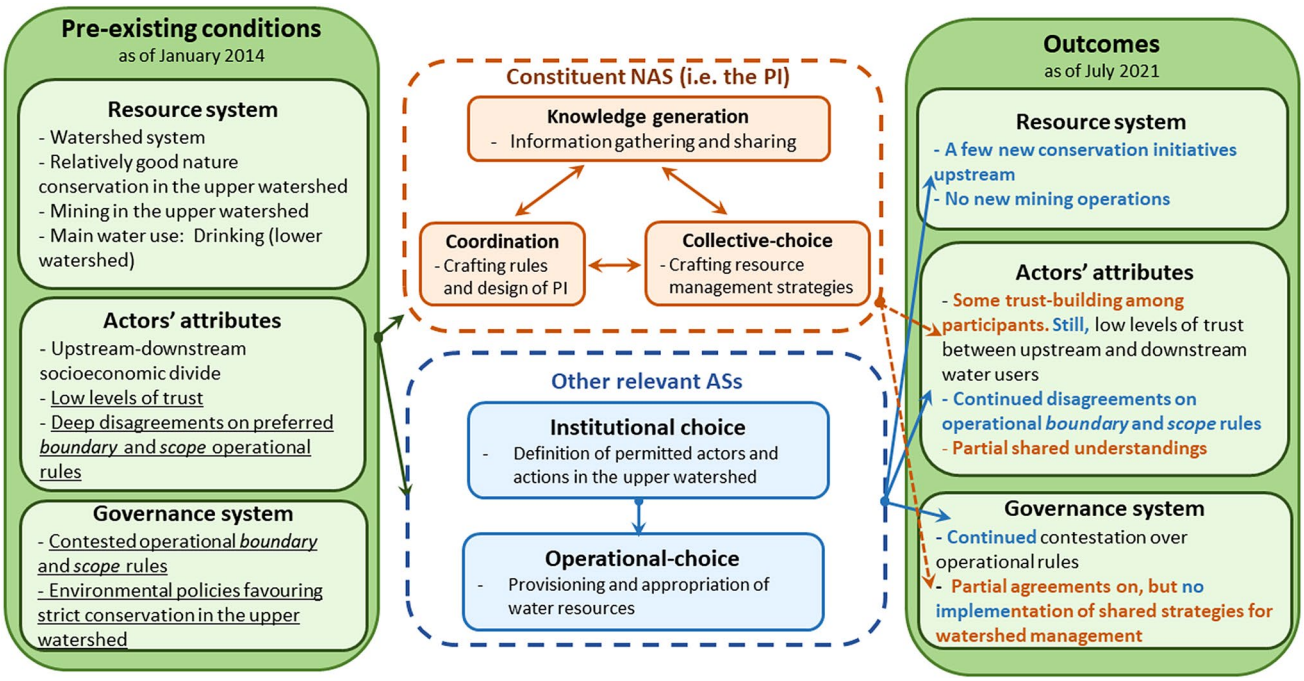

Fig. 2 Representation of the PI in Suratá using the IAD, NAS and SES frameworks. Source: Own elaboration. Graphic representation leaning on Cole et al. (2019). Case-specific pre-existing conditions are underlined

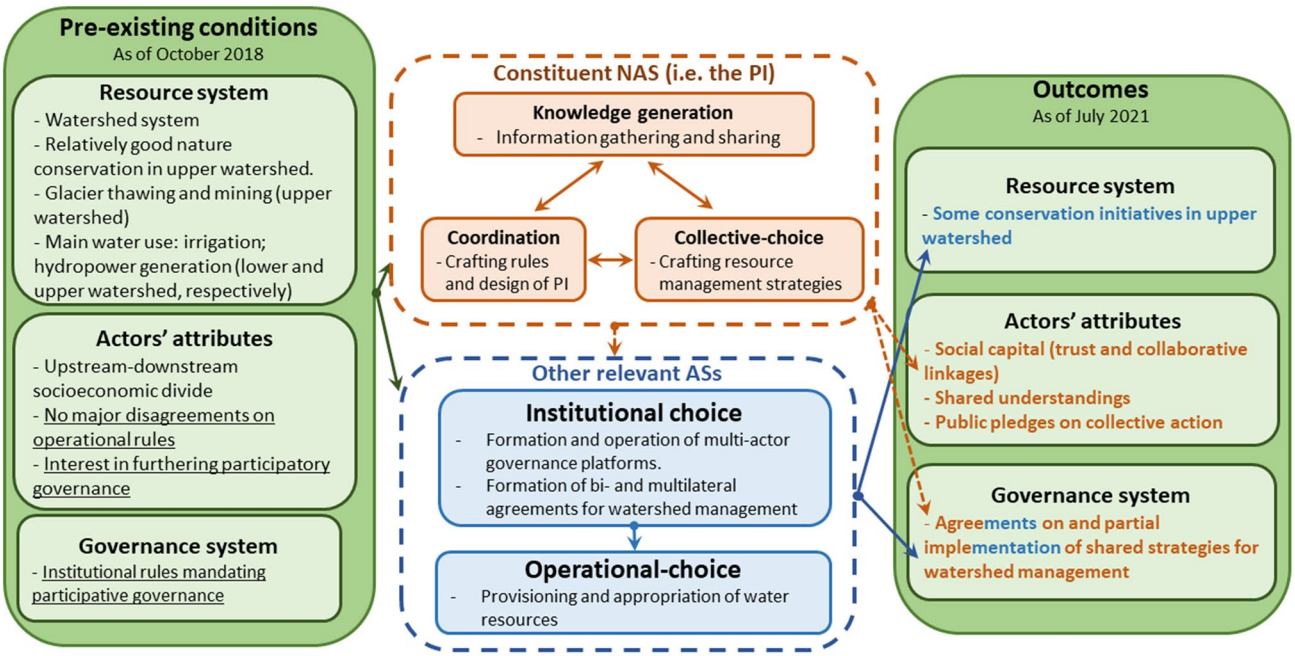

Fig. 3 Representation of the PI in Cañete using the IAD, NAS and SES frameworks. Source: Own elaboration. Graphic representation leaning on Cole et al. (2019). Case-specific pre-existing conditions are underlined

initially proposed by the Ministry of Environment in 2014, which allowed some forms of mining and agriculture in the upper watershed. A combination of downstream users' strong preference for strict conservation upstream, popular support for these preferences, and access to relevant institutional ASs external to the participatory intervention may help to explain the reluctance of downstream users to seek a compromise with upstream users on less strict conservation measures through the participatory process. Consequently, tensions and disagreements on the institutional arrangements that should govern resource use in the upper watershed have remained difficult to address and resolve.

In the Cañete River Watershed, we did not find any major open disagreements between upstream and downstream users on the rules for governing resource use by the time the participatory process had begun. Furthermore, to the best of our knowledge, no relevant actor has opposed the idea of finding a consensus on the appropriate watershed management measures involving all relevant actors from the different sections of the watershed. Despite previous specific conflicts between some upstream and downstream water users, they all showed an interest in finding ways to bring the relevant actors together to build collective agreements for sustainable watershed management.

Our observations, interviews and data suggest that, in both cases, features of the broader, pre-existing institutional arrangements that set the stage for each participatory intervention likely influenced the aforementioned patterns of conflict and co-operation. They also seem to have influenced the attractiveness of crafting collective agreements to move institutional preferences forward through participatory processes. The delineation of protected areas for *páramo* ecosystems and strict conservation measures forbidding mining and restricting agriculture within *páramos* have become prominent features of Colombia's environmental policies regulating land and resource use in the country's Andean high mountains (Sarmiento et al. 2013; Ungar 2021). In contrast, these types of strict command-and-control conservation measures seem not to have been central to the environmental and natural resource management policies for Peru's upper watersheds. Largely motivated by the recently approved law on rewards for ecosystem services, the main interest of the environmental authorities has been to facilitate upstream–downstream agreements around ecosystem services provision.[15] By the time the participatory intervention had begun in Cañete, the Peruvian Ministry of Environment, the landscape reserve management and the farmers' community organisations had already been working together on the implementation of conservation and sustainable agriculture measures in the upper watershed. Furthermore, the National Water Authority, part of the Ministry of Agriculture, had not moved forward in the delineation of strictly protected areas for water sources in the upper watersheds, even though the Peruvian water resources legislation would

[15] The Reward for Ecosystem Services Law in Peru (i.e. Law 30215).

allow such a policy measure.[16] Instead, it had put forward the creation of a water resources council to promote integrated and participatory water resources management in the Cañete River Watershed—as in other Peruvian watersheds. In sum, in Cañete, there were neither actors requesting nor laws enforcing restrictive command-and-control conservation measures upstream by the time the participatory process started. In fact, we have observed that the current legislative framework has been rather insistent on the need to find ways to bring the relevant resource users and state and non-state actors together to find common ground, build shared understandings and craft collective agreements on watershed management.[17]

The analysis of these pre-existing contextual conditions complements our initial assessment. It suggests that a configuration of factors, rather than a single factor, may explain the observed differences in the outcomes of each participatory intervention. In addition to the linkages—or the lack thereof—between the constituent NAS and other relevant ASs outside the boundaries of the participatory intervention, two other factors seem relevant. The first involves the initial attributes of the relevant actors,[18] including their preferences, perceived levels of conflict and co-operation, and available resources (e.g. to form coalitions and access relevant ASs). The second factor entails the features of the broader governance system, namely the institutional arrangements regulating resource use and biodiversity conservation in the Andean high mountains.[19]

Based on these findings, our analysis also hints at the design features participatory interventions should consider. Although the type of participatory intervention in our two cases seems to work to foster collective action among the involved actors, engaging other relevant actors and ASs when high initial levels of conflict are present warrants further effort and the use of complementary methods (see also NRC 2008). In particular, an overarching, all-encompassing participative strategy, embedded in the institutional context and supported by the relevant state actors (e.g. backed up by the broader judicial system), may contribute to involving and bringing together all the relevant actors to craft comprehensive collective agreements. This may be particularly important in cases in which actors seem unwilling to compromise by considering less-preferred options and have access to other relevant ASs to move their preferences forward. Complementary strategies, such as iterative bilateral *negotiation* ASs, may help address hard pre-defined institutional preferences and facilitate shared understandings and collective agreements (see also Ostrom 1990; Beierle and Cayford 2002; NRC 2008; Edelenbos et al. 2009; Bodin 2017).[20]

Conclusion

Insights from research on collective action and research on participatory governance indicate that participatory processes should carefully address the complexity of the relevant (social–ecological and governance) context to effectively foster collective action and sustainable natural resource management. In our study, we show how combining the IAD, NAS and SES frameworks with key concepts on participatory governance helps to synthesise and apply insights which were hitherto largely disconnected. In particular, this combined approach helps us to define, characterise and reflect upon participatory interventions as a series of distinct but interconnected constituent NAS in interaction with other relevant ASs that can also influence the outcomes of interest. Based on the specific features of each case, these ASs can be adjacent or distant and linked or unlinked to the ASs that constitute the participatory intervention. The potential of participatory interventions for collective action thus depends on the structure of the constituent NAS, the other relevant ASs, the linkages—or lack thereof—between all of these, and the attributes of the relevant actors and the broader context. Sound design, implementation, assessment and analysis of participatory processes should thus consider and address the complex interactions and linkages between these factors.

Our comparative analysis of two similar participatory interventions, one in Colombia and another in Peru, illustrates this proposition. In the Colombian case, (the lack of connection

[16] See section 75 of the Water Resources Law in Peru (i.e. Law 29338).

[17] Both the aforementioned Water Resources Law and Reward for Ecosystem Services Law provide for stakeholder participation in natural resource management, for instance.

[18] Beierle and Cayford (2002), NRC (2008), Newig and Fritsch (2009), Fritsch and Newig (2012), Bodin (2017) and Newig et al. (2018) provide additional insights on the relevance of context and actors' attributes to participatory processes.

[19] On the interplay between the overarching governance system context and participatory processes, see Beierle and Cayford (2002), Kallis et al. (2006), Reed (2008), NRC (2008), Gerlak et al. (2013), Bodin (2017), and Lubell and Balazs (2018).

[20] After years without progress on defining the relevant institutional arrangements, the Colombian Ministry of Environment has now been directly leading the consultation and consensus-building process to delineate, zone and plan the management of the *páramo* in the Suratá river upper watershed after the Constitutional Court declared the initial 2014 delineation unconstitutional in 2016. The direct leadership of the ministry following the court's mandate and guidelines hints at a participatory process which now seems to be more embedded in the broader governance system. This resonates with the (rather successful) collective action processes and negotiations on watershed management among heterogenous actors in the shadow of the Californian state courts that Ostrom described in 1990 (see Ch. 4 in particular).

with) other relevant operational and institutional ASs limited the potential of the participatory intervention for collective action. Outside the participatory process, before the courts and the environmental authorities as well as in the streets, a coalition of downstream users and non-state actors continuously pushed for stricter conservation measures in the upper Suratá watershed, hindering any form of collective agreement for water management involving both upstream and downstream users. In contrast, in the Peruvian case, the participatory intervention seems to have managed to address, include, and link the relevant actors, context and operational and institutional ASs, facilitating upstream–downstream agreements and concrete actions for sustainable watershed management. The presence of institutional arrangements and relevant actors already favouring upstream–downstream agreements and co-operation may have also contributed to this outcome. Nonetheless, a lack of progress in defining measures for wastewater management and watershed management plans shows how the (lack of) action by relevant actors in other relevant ASs (e.g. local mayors interacting in local councils and the water resources council) can nonetheless stall actual co-operation on the ground. In all, these findings further highlight the importance of thoroughly and appropriately considering, including and linking the broader constellation of relevant actors, (linked and unlinked) ASs and (ecological, governance and social) context. Although the NAS approach tends to focus on ASs that are linked to one another, our study indicates the importance of considering all relevant ASs influencing the outcomes of interest.[21]

More generally, this comparative analysis illustrates how researchers and practitioners could apply the IAD, NAS and SES frameworks to the design and analysis of participatory interventions such as mini-publics, facilitated multi-actor forums and transdisciplinary action-oriented research projects (e.g. Fals-Borda 1987; Cárdenas et al. 2003; Fung 2003, 2006; Kallis et al. 2006; Lang et al. 2012; Tribaldos et al. 2020). They invite researchers and practitioners to thoroughly reflect upon the structure and connections of the relevant ASs (both those constituting and those outside the boundaries of the participatory intervention), the interactions they can facilitate and the ways in which the (available information about the) context can shape their structure, connections, interactions and outcomes. More empirical research should, however, help identify further possible nuances, examine the relative importance of specific explanatory factors and assess the generalisability of our findings. Even though general insights from the frameworks guided both interventions and our own analysis and learning process, we did not use them ex-ante to systematically design, implement and plan the assessment of both interventions. We used them ex-post to organise our data, identify all potentially relevant explanatory factors and structure the case comparison. Moreover, the participatory interventions we analysed, albeit similar, were not identical. We cannot rule out that there were design and contextual features, as well as interactions between them, that we did not capture but that influenced the observed outcomes. For instance, despite our systematic efforts to identify all relevant ASs, we may have disregarded the indirect influence of asymmetric interactions involving relevant distant actors and ASs. Furthermore, factors that seem not to have influenced the outcomes in our cases—such as the geographical distance between the upper and lower watersheds—may be relevant in other cases. To neatly disentangle the impact of such factors is extremely difficult, if not impossible, in very small-n case comparisons such as the one we performed in this paper. Researchers and practitioners could, therefore, strive from the outset to implement large-scale evaluations (e.g. Newig et al. 2019; Jager et al. 2020) or causal case study methods, such as process tracing methods (Beach and Pedersen 2016), to neatly identify the underlying causalities.

Future (transdisciplinary) research efforts can draw on the approach we have outlined and applied in this study to carefully design, implement, compare, analyse and assess, in a controlled fashion, a larger number of participatory processes. Through our illustrative application, we hope we can motivate further research. Our study suggests a methodological template—amenable to further refinements and improvements—that can contribute to guiding such efforts. Future implementations and evaluations of participatory interventions may then expand the set of relevant explanatory factors and evaluative criteria for the outcomes of participatory processes, in terms of sustainability and multiple dimensions of equity, justice and empowerment, see for example Lukes (2005), Boillat et al. (2018), Morrison et al. (2019) and Epstein et al. (2020). Further, (the implications of) alternative definitions of and approaches to tracing the boundaries of relevant NASs and participatory interventions could be tested by drawing, for instance, on complementary landscape or telecoupling approaches (Oberlack et al. 2018; Boillat et al. 2018; Reed et al. 2020; Kimmich et al. 2022). Such analyses may shed further light on ways to best address actors' heterogeneous attributes in terms of their influence and access to the relevant (networks of) ASs, as well as their pre-existing patterns of conflict and co-operation. Overall, these efforts would and should contribute to gaining and accumulating new knowledge about the participatory methods, process design, relevant contextual conditions and linkages between actors and ASs that enable participatory interventions to fulfil their potential for collective action and sustainability in natural resource management.

[21] We thank to the guest editors for drawing our attention towards and noting the importance of this point.

Supplementary Information The online version contains supplementary material available at https://doi.org/10.1007/s11625-022-01215-x.

Acknowledgements We thank Christian Kimmich, Cristoph Oberlack and two anonymous reviewers for their constructive feedback as well as Amy Samuelson and Angélica López for their editorial assistance. We would also like to thank all state and non-state actors from the Suratá River Watershed (i.e. the Soto Norte province and Bucaramanga), Bogotá, the Cañete River Watershed (i.e. the Cañete and Yauyos provinces) and Lima that participated in the activities comprising the participatory processes we describe in this paper. We also gratefully acknowledge the support and contribution of several individuals and organisations at various points during these processes. Carlos Kong, Estefany Siccha and Alejandra Zúñiga, in Peru, and Daniel Rivera and Jorge Rincón, in Colombia, industriously provided research and logistical assistance in the field. The Alexander von Humboldt Biological Resources Research Institute, the Ministry of the Environment and the sub-national environmental authorities (CDMB and CORPONOR) contributed with useful information and valuable logistical support in several instances during the activities conducted in Colombia. PROMAC (GIZ's environmental program in Colombia) and USAID's ABC-LA program contributed funding, and Foro Nacional por Colombia provided valuable input in coordinating the realisation of several of the planned activities in the field. In Peru, GIZ's ProAmbiente II, the MERESE-FIDA project, the Institute for Nature, Earth and Energy at the Pontifical Catholic University of Peru (INTE-PUCP), the *Nor Yauyos Cochas* landscape reserve (RPNYC), L+1 and CELEPSA actively participated by providing their views, ideas, logistical support and funding in the design and implementation of the participatory process. All the aforementioned individuals and organisations are disclaimed of any responsibility regarding the views and arguments expressed in this paper, but we do want to thank all of them for readily contributing with their time, input and help when it was requested.

Author contributions Initial basic concepts on aims, scope, structure and study design for this paper were developed by JFO-R and A-KK and, subsequently, enriched by YM-M and JCC. JFO-R and YM-M extracted and organised the data from the cases for the comparative analysis. JFO-R took the lead in writing and revising initial outlines as well as full drafts of the paper including preliminary analysis of the data, figures and supplementary material. A-KK and YM-M further contributed writing, feedback and revisions of outlines and previous drafts of the manuscript, figures and supplementary material. JCC provided additional feedback on previous drafts of the manuscript. Based on his previous experience in the field, JCC suggested employing economic games as participatory tools for collective action in watershed management, thereby laying out the basic design features of the participatory interventions carried out in Colombia and Peru. JFO-R joined him in developing the design of the intervention in the Suratá River Watershed and implemented it in the field. YM-M supported the implementation of the initial activities of this intervention. A-KK and JFO-R—together with Stefanie Engel (Osnabrück University)—adapted the intervention design to the Peruvian case. JFO-R and YM-M were in charge of coordinating and implementing it in the field, together with the partner organisations, in the Cañete River Watershed. JCC provided additional feedback and academic advice throughout the design and implementation of the participatory interventions and the process of writing and revising the current manuscript.

Funding Open Access funding enabled and organized by Projekt DEAL. Part of the time Ortiz-Riomalo and Koessler spent on this paper was supported by the Alexander von Humboldt-Foundation within the framework of the Alexander von Humboldt-Professorship endowed by the Federal Ministry of Education and Research and granted to Stefanie Engel in form of the professorship of environmental economics at Osnabrück University. Ortiz-Riomalo received complementary funding from the Ministry for Science and Culture of Lower Saxony (Germany).

Data availability The data employed for the comparative analysis reported in this paper are available in the Supplementary file 1.

Declarations

Conflict of interest The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper. Neither the funding bodies nor the partner organisations involved in the implementation of the participatory interventions had direct influence on the concepts, arguments, analysis, discussion or conclusions of the paper.

Statement of exclusive submission This paper has not been submitted elsewhere in identical or similar form.

References

Anckar C (2008) On the applicability of the most similar systems design and the most different systems design in comparative research. Int J Soc Res Methodol 11:389–401. https://doi.org/10.1080/13645570701401552

Baland J-M, Platteau J-P (1996) Halting degradation of natural resources. Is there a role for rural communities? Food and Agriculture Organization of the United Nations, Rome

Bates RH (1988) Contra contractarianism: some reflections on the new institutionalism. Polit Soc 16:387–401. https://doi.org/10.1177/003232928801600207

Beach D, Pedersen RB (2016) Causal case study methods. Foundations and guidelines for comparing, matching and tracing. University of Michigan Press, Ann Arbor

Beierle TC, Cayford J (2002) Democracy in practice: public participation in environmental decisions. Resources for the Future, Washington, DC

Blundo-Canto G, Cruz García G, Tristán-Febres M, Pareja Cabrejos P, Quintero M (2016) Prioridades de conservación y desarrollo en las comunidades de Nor Yauyos Informe para el MRSEH de la cuenca del río Cañete. Centro Internacional de Agricultura Tropical (CIAT), Cali

Bodin Ö (2017) Collaborative environmental governance: achieving collective action in social-ecological systems. Science 357(6352):eean1114. https://doi.org/10.1126/science.aan1114

Boillat S, Gerber J-D, Oberlack C, Zaheringer JG, Speranza CI, Rist S (2018) Distant interactions, power and environmental justice in protected area governance. Sustainability 10:3954. https://doi.org/10.3390/su1011395

Bowles S (2016) The moral economy. Why good incentives are no substitutes for good citizens. Yale University Press, Connecticut

Cárdenas JC (2018) (Real) behavior meets (real) institutions: towards a research agenda on the study of the commons. In: Ménard C,

Shirley MM (eds) A research agenda for new institutional economics. Elgar, Northampton, pp 119–126. https://doi.org/10.4337/9781788112512.00022
Cardenas JC, Carpenter J (2008) Behavioural development economics: lessons from field labs in the developing world. J Dev Stud 44:311–338. https://doi.org/10.1080/00220380701848327
Cárdenas JC, Ortiz-Riomalo JF (2018) Acción colectiva para abordar conflicto socio-ambientales. El caso de Santurbán. In: Hernández Quiñones A (ed) Modos de gobernanza del agua y sostenibilidad. Aportes conceptuales y análisis de experiencias en Colombia: Centro Interdisciplinario de Estudios sobre Desarrollo (CIDER), Ediciones Uniandes. Universidad de los Andes, Bogotá, DC
Cárdenas J, Ramos P (2006) Manual de juegos economicos para el analisis del uso colectivo de los recursos naturales. CIP, Condesan, Redcapa, Ministerio Federal de Cooperación Económica y Desarrollo de Alemania, GTZ, Bogotá, DC
Cardenas J-C, Stranlund J, Willis C (2000) Local environmental control and institutional crowding-out. World Dev 28:1719–1733. https://doi.org/10.1016/S0305-750X(00)00055-3
Cárdenas JC, Maya DL, López MC (2003) Métodos experimentales y participativos para el análisis de la acción colectiva y la cooperación en el uso de recursos naturales por parte de comunidades rurales. Cuad de Desarro Rural 50:63–96. Retrieved from https://revistas.javeriana.edu.co/index.php/desarrolloRural/article/view/1279
Cardenas JC, Rodriguez LA, Johnson N (2011) Collective action for watershed management: field experiments in Colombia and Kenya. Environ Dev Econ 16:275–303. https://doi.org/10.1017/S1355770X10000392
Cárdenas JC, Janssen M, Bousquet F (2013) Dynamics of rules and resources: three new field experiments on water, forests and fisheries. In: List J, Price M (eds) Handbook on experimental economics and the environment. Elgar, Northampton, pp 319–345
Cárdenas JC, Ortiz-Riomalo JF, Rivera DE, Sánchez CA (2015) Acción colectiva para la transformación de conflictos socio-ambientales derivados de la minería en los complejos de páramo. Piloto en la sub-cuenca del río Suratá (Santander, Colombia). Reporte final de actividades y resultados. Universidad de los Andes, USAID ABC-LA
Carter DP, Weible CM, Siddiki SN, Basurto X (2016) Integrating core concepts from the institutional analysis and development framework for the systematic analysis of policy designs: an illustration from the US National Organic Program regulation. J Theor Politics 28:159–185. https://doi.org/10.1177/0951629815603494
CDMB (2006) Plan de Ordenamiento y Manejo Ambiental Subcuenca (POMCA) del río Suratá. Bucaramanga, Colombia
CDMB (2011) Estudio Técnico Soporte para la Implementación de un Pago por Servicio Ambiental del Recurso Hídrico en la subcuenca del río Suratá. Bucaramanga
Clement F (2010) Analysing decentralised natural resource governance: proposition for a "politicised" institutional analysis and development framework. Policy Sci 43:129–156. https://doi.org/10.1007/s11077-009-9100-8
Cole DH (2017) Laws, norms and the Institutional Analysis and Development framework. J Inst Econ 13(4):829–847. https://doi.org/10.1017/S1744137417000030
Cole DH, Epstein G, McGinnis M (2019) Combining the IAD and SES frameworks. Int J Commons 13:244–275. https://doi.org/10.18352/ijc.864
Collier D (1993) The comparative method. In: Finifter A (ed) Political science: the state of the discipline. American Political Science Association, Washington, DC, pp 319–345
Cox M, Arnold G, Villamayor Tomás S (2010) A review of design principles for community-based natural resource management. Ecol Soc 15:38. http://www.ecologyandsociety.org/vol15/iss4/art38/
Dannenberg A, Gallier C (2020) The choice of institutions to solve cooperation problems: a survey of experimental research. Exp Econ 23:716–749. https://doi.org/10.1007/s10683-019-09629-8
Dasgupta P (2021) The economics of biodiversity: the Dasgupta review. HM Treasury, London
DeCaro D, Janssen M, Lee A (2015) Synergistic effects of voting and enforcement on internalized motivation to cooperate in a resource dilemma. Judgm Decis Mak 10:511–537. Retrieved from http://journal.sjdm.org/15/15529/jdm15529.html
Dietz T, Ostrom E, Stern P (2003) The struggle to govern the commons. Science 302:1907–1912
Duarte-Abadía B, Boelens R (2016) Disputes over territorial boundaries and diverging valuation languages: the Santurban hydrosocial highlands territory in Colombia. Water Int 41:15–36. https://doi.org/10.1080/02508060.2016.1117271
Economic Commission for Latin America and the Caribbean, ECLAC (2018) Regional agreement on access to information, public participation and justice in environmental matters in Latin America and the Caribbean. ECLAC, Escazú. Retrieved from https://repositorio.cepal.org/bitstream/handle/11362/43583/1/S1800428_en.pdf
Edelenbos J, Klok P-J, van Tatenhove J (2009) The institutional embedding of interactive policy making: insights from a comparative research based on eight interactive projects in the Netherlands. Am Rev Public Adm 39:125–148. https://doi.org/10.1177/0275074008317157
Edwards VM, Steins NA (1998) Developing an analytical framework for multiple-use commons. J Theor Politics 10:347–383. https://doi.org/10.1177/0951692898010003008
Engel S, Pagiola S, Wunder S (2008) Designing payments for environmental services in theory and practice: an overview of the issues. Ecol Econ 65:663–674. https://doi.org/10.1016/j.ecolecon.2008.03.011
Epstein G, Morrison TH, Lien A, Gurney GG, Cole DH, Delaroche M et al (2020) Advances in understanding the evolution of institutions in complex social-ecological systems. Curr Opin Environ Sustain 44:58–66. https://doi.org/10.1016/j.cosust.2020.06.002
Ezzine-de-Blas D, Corbera E, Lapeyre R (2019) Payments for environmental services and motivation crowding: towards a conceptual framework. Ecol Econ 156:434–443. https://doi.org/10.1016/j.ecolecon.2018.07.026
Falk T, Wei Z, Meinzen-Dick RS, Bartels L (2021) Games for triggering collective change in natural resource management: a conceptual framework and insights from four cases from India. Discussion Paper 1995. International Food Policy Research Institute (IFPRI), Washington DC. https://doi.org/10.2499/p15738coll2.134238
Fals-Borda O (1987) The application of participatory action-research in Latin America. Int Sociol 2:329–347. https://doi.org/10.1177/026858098700200401
Fonseca Martel C, Mayer E (1978) Sistemas agrarios y ecología en la cuenca del río Cañete. Debates Sociol 2:25–51. Retrieved from https://revistas.pucp.edu.pe/index.php/debatesensociologia/article/view/6783
Francesconi W, Srinivasan R, Pérez-Miñana E, Willcock SP, Quintero M (2016) Using the soil and water assessment tool (SWAT) to model ecosystem services: a systematic review. J Hydrol 535:625–636. https://doi.org/10.1016/j.jhydrol.2016.01.034
Frey BS, Benz M, Stutzer A (2004) Introducing procedural utility: not only what, but also how matters. J Inst Theor Econ 160:377–401. Retrieved from https://www.jstor.org/stable/40752468
Fritsch O, Newig J (2012) Participatory governance and sustainability: findings of a meta-analysis of stakeholder involvement in

environmental decision making. In: Brousseau E, Dedeurwaerdere T, Siebenhüner B (eds) Reflexive governance for global public goods. MIT Press, Cambridge, pp 181–203
Fung A (2003) Survey article: recipes for public spheres: eight institutional design choices and their consequences. J Polit Philos 11:338–367. https://doi.org/10.1111/1467-9760.00181
Fung A (2006) Varieties of participation in complex governance. Public Adm Rev 66:66–75. Retrieved from https://www.jstor.org/stable/4096571
Gerlak AK, Heikkila T, Lubell M (2013) The promise and performance of collaborative governance. In: Kraft ME, Kamieniecki S (eds) The Oxford handbook of U.S. environmental policy, online edn. Oxford Academic. https://doi.org/10.1093/oxfordhb/9780199744671.013.0019
Heikkila T, Andersson K (2018) Policy design and the added-value of the institutional analysis and development framework. Policy Polit 46:309–324. https://doi.org/10.1332/030557318X15230060131727
Heinz N, Koessler A-K (2021) Other-regarding preferences and pro-environmental behaviour: an interdisciplinary review of experimental studies. Ecol Econ. https://doi.org/10.1016/j.ecolecon.2021.106987
Jager NW, Newig J, Challies E, Kochskämper E (2020) Pathways to implementation: evidence on how participation in environmental governance impacts on environmental outcomes. J Public Adm Res Theory 30:383–399. https://doi.org/10.1093/jopart/muz034
Janssen MA, Holahan R, Lee A, Ostrom E (2010) Lab experiments for the study of social-ecological systems. Science 328:613–617. https://doi.org/10.1126/science.118353
Kallis G, Videira N, Antunes P, Guimaraes Pereira A, Spash C, Coccossis H et al (2006) Participatory methods for water resources planning. Environ Plan C Gov Policy 24:215–234. https://doi.org/10.1068/c04102s
Kimmich C (2013) Linking action situations: coordination, conflicts, and evolution in electricity provision for irrigation in Andhra Pradesh, India. Ecol Econ 90:150–158. https://doi.org/10.1016/j.ecolecon.2013.03.017
Kimmich C, Villamayor-Tomas S (2019) Assessing action situation networks: a configurational perspective on water and energy governance in irrigation systems. Water Econ Policy 5:1850005. https://doi.org/10.1142/S2382624X18500054
Kimmich C, Baldwin E, Kellner E, Oberlack C, Villamayor-Tomas S (2022) Networks of action situations: a systematic review of empirical research. Sustain Sci. https://doi.org/10.1007/s11625-022-01121-2
Kiser LL, Ostrom E (1982) The three worlds of action: a metatheoretical synthesis of institutional approaches. In: Ostrom E (ed) Strategies of Political Inquiry. SAGE, Beverly Hills, pp 179–222
Kiser LL, Ostrom E (1987) Reflections on the elements of institutional analysis. Workshop in Political Theory and Policy Analysis, Indiana University. Paper prepared for the conference on "Advances in comparative institutional analysis" at the Inter-University Center of Post-Graduate Studies, Dubrovnik, Yugloslavia, October 19–23
Klok P-J, Denters B (2018) Structuring participatory governance through particular 'rules in use': lessons from the empirical application of Elinor Ostrom's IAD framework. In: Heinelt H (ed) Handbook on participatory governance. Edward Elgar Publishing, Cheltenham, pp 120–142. https://doi.org/10.4337/9781785364358.00012
Lang DJ, Wiek A, Bergmann M, Stauffacher M, Martens P, Moll P et al (2012) Transdisciplinary research in sustainability science: practice, principles, and challenges. Sustain Sci 7:25–43. https://doi.org/10.1007/s11625-011-0149-x
Liebman M, Paulston R (1994) Social cartography: a new methodology for comparative studies. Compare 24:233–245. https://doi.org/10.1080/0305792940240304
Lubell M, Balazs C (2018) Integrated water resources management. In: Conca K, Weinthal E (eds) The Oxford handbook of water politics and policy. Oxford Handbooks Online, Oxford
Lubell M, Schneider M, Scholz JT, Mete M (2002) Watershed partnerships and the emergence of collective action institutions. Am J Pol Sci 46:148–163. https://doi.org/10.2307/3088419
Lukes S (2005) Power: a radical view. Palgrave Macmillan, London
McGinnis M (2011a) An introduction to IAD and the language of the Ostrom workshop: a simple guide to a complex framework. Policy Stud J 39:169–183. https://doi.org/10.1111/j.1541-0072.2010.00401.x
McGinnis MD (2011b) Networks of adjacent action situations in polycentric governance. Policy Stud J 39:51–78. https://doi.org/10.1111/j.1541-0072.2010.00396.x
McGinnis MD (2018) The IAD framework in action: understanding the source of the design principles in Elinor Ostrom's governing the commons. In: Cole D, McGinnis MD (eds) Elinor Ostrom and the Bloomington School of political economy: a framework for policy analysis, vol 3. Lexington Books, Lexington, pp 97–108
McGinnis M, Ostrom E (2014) Social-ecological system framework: initial changes and continuing challenges. Ecol Soc 19:30. https://doi.org/10.5751/ES-06387-190230
Medema W, Furber A, Adamowski J, Zhou Q, Mayer I (2016) Exploring the potential impact of serious games on social learning and stakeholder collaborations for transboundary watershed management of the St. Lawrence River basin. Water 8:175. https://doi.org/10.3390/w8050175
Meinzen-Dick R, Chaturvedi R, Domènech L, Ghate R, Janssen MA, Rollins ND, Sandeep K (2016) Games for groundwater governance: field experiments in Andhra Pradesh, India. Ecol Soc 21:38. https://doi.org/10.5751/ES-08416-210338
Meinzen-Dick R, Janssen MA, Kandikuppa S, Chaturvedi R, Rao K, Theis S (2018) Playing games to save water: collective action games for groundwater management in Andhra Pradesh, India. World Dev 107:40–53. https://doi.org/10.1016/j.worlddev.2018.02.006
Meyer S, Santos P, Yang F (2021) Economic games can be used to promote cooperation in the field. PNAS 118:e2026046118. https://doi.org/10.1073/pnas.2026046118
Morrison T, Adger W, Lemos M, Huitema D, Phelps J, Evans L et al (2019) The black box of power in polycentric environmental governance. Glob Environ Change 57:101934. https://doi.org/10.1016/j.gloenvcha.2019.101934
Muradian R, Cardenas J (2015) From market failures to collective action dilemmas: reframing environmental governance challenges in Latin America and beyond (editorial to special section). Ecol Econ 120:358–365
National Research Council, NRC (2008) Public participation in environmental assessment and decision making. The National Academies Press, Washington, DC. https://doi.org/10.17226/12434
Newig J, Fritsch O (2009) Environmental governance: participatory, multi-level—and effective? Environ Policy Gov 19:197–214. https://doi.org/10.1002/eet.509
Newig J, Challies E, Jager NW, Kochskaemper E, Adzersen A (2018) The environmental performance of participatory and collaborative governance: a framework of causal mechanisms. Policy Stud J 46:269–297. https://doi.org/10.1111/psj.12209
Newig J, Jager NW, Kochskämper E, Challies E (2019) Learning in participatory environmental governance—its antecedents and effects. Findings from a case survey meta-analysis. J Environ Policy Plan 21:213–227. https://doi.org/10.1080/1523908X.2019.1623663

North D (1994) Economic performance through time. Am Econ Rev 84:359–368. Retrieved from https://www.jstor.org/stable/2118057

Oberlack C, Boillat S, Brönnimann S, Gerber J-D, Heinimann A, Speranza CI et al (2018) Polycentric governance in telecoupled resource systems. Ecol Soc 23:16. https://doi.org/10.5751/ES-09902-230116

Ortiz-Riomalo JF, Miranda-Montagut Y (2019) Comportamiento prosocial y acción colectiva para el manejo del agua en el Perú: una estrategia participativa basada en juegos y experimentos económicos en la cuenca del río Cañete. Informe final sobre actividades y resultados de los talleres realizados. Lima, Perú; Osnabrück, Alemania: Instituto de Investigaciones sobre Sistemas Ambientales (IUSF) de la Universidad de Osnabrück (Alemania), ProAmbiente II (GIZ, Perú), Proyecto MERESE-FIDA, Instituto de Ciencias de la Naturaleza, Territorio y Energías Renovables de la PUCP (INTE-PUCP)

Ortiz-Riomalo JF, Miranda-Montagut Y, Castro S, Koessler A-K, Rojas M (2020) Estrategia participativa para la gestión colectiva de cuencas basada en juegos económicos. Lima: Ministerio del Ambiente. Lima, Peru: Ministerio del Ambiente, INTE-PUCP. https://cdn.www.gob.pe/uploads/document/file/1706679/Gu%C3%ADa%20de%20acci%C3%B3n%20colectiva.pdf

Ortiz-Riomalo JF, Koessler AK, Engel S (2022) Fostering cooperation for sustinable resource management through participation. A literature review. Osnabrück University. Working paper. Retrieved from https://papers.ssrn.com/sol3/papers.cfm?abstract_id=4093075

Ostrom E (1990) Governing the commons: the evolution of institutions for collective action. Cambridge University Press, Cambridge

Ostrom E (1998) A behavioral approach to the rational choice theory of collective action: presidential address, American Political Science Association, 1997. Am Polit Sci Rev 92:1–22. https://doi.org/10.2307/2585925

Ostrom E (1999) Social capital: a fad or a fundamental concept? In: Dasgupta P, Serageldin I (eds) Social capital: a multifaceted perspective. World Bank, Washington, DC, pp 172–214

Ostrom E (2000) Crowding out citizenship. Scan Polit Stud 23:3–16. https://doi.org/10.1111/1467-9477.00028

Ostrom E (2005) Understanding institutional diversity. Princeton University Press, Princeton

Ostrom E (2006) The value-added of laboratory experiments for the study of institutions and common-pool resources. J Econ Behav Organ 61:149–163. https://doi.org/10.1016/j.jebo.2005.02.008

Ostrom E (2007a) Challenges and growth: the development of the interdisciplinary field of institutional analysis. J Inst Econ 3:239–264. https://doi.org/10.1017/S1744137407000719

Ostrom E (2007b) A diagnostic approach for going beyond panaceas. PNAS 104:15181–15187. https://doi.org/10.1073/pnas.0701886104

Ostrom E (2009) A general framework for analyzing sustainability of social-ecological systems. Science 325:419–422

Ostrom E (2010a) Polycentric systems for coping with collective action and global environmental change. Glob Environ Change 20:550–557. https://doi.org/10.1016/j.gloenvcha.2010.07.004

Ostrom E (2010b) Beyond markets and states: polycentric governance of complex economic systems. Am Econ Rev 100:641–672. Retrieved from https://www.jstor.org/stable/27871226

Ostrom E (2011) Background on the institutional analysis and development framework. Policy Stud J 39:7–27. https://doi.org/10.1111/j.1541-0072.2010.00394.x

Ostrom E, Gardner R (1993) Coping with asymmetries in the commons: self-governing irrigation systems can work. J Econ Perspect 7:93–112. https://doi.org/10.1257/jep.7.4.93

Ostrom E, Nagendra H (2006) Insights on linking forests, trees, and people from the air, on the ground, and in the laboratory. PNAS 103:19224–19231. https://doi.org/10.1073/pnas.0607962103

Ostrom E, Gardner R, Walker J (1994) Rules, games and common-pool resources. The University of Michigan Press, Ann Arbor

Pahl-Wostl C (2015) Water governance in the face of global change: from understanding to transformation. Springer International Publishing, Berlin

Pahl-Wostl C, Holtz G, Kastens B, Knieper C (2010) Analyzing complex water governance regimes: the management and transition framework. Environ Sci Policy 13:571–581. https://doi.org/10.1016/j.envsci.2010.08.006

Polski MM, Ostrom E (1999) An institutional framework for policy analysis and design. Workshop in Political Theory and Policy Analysis, Indiana University, Bloomington

Poteete A, Janseen M, Ostrom E (2010) Working together: collective action, the commons, and multiple methods in practice. Princeton University Press, Princeton

Quintero M, Loyola R, Puemape Y (2013a) Case studies on remuneration of positive externalities (RPE)/payments for environmental services (PES): prepared for the multi-stakeholder dialogue. FAO, Rome

Quintero M, Tapasco J, Pareja P (2013b) Diseño e implementación de un esquema de retribución por servicios ecosistémicos hidrológicos en la cuenca del Río Cañete. Ministerio del Ambiente (MINAM), Centro Internacional de Agricultura Tropical (CIAT), Lima

Quist J, Thissen W, Vergragt PJ (2011) The impact and spin-off of participatory backcasting: from vision to niche. Technol Forecast Soc Change 78:883–897. https://doi.org/10.1016/j.techfore.2011.01.011

Ravnborg HM, Guerrero M (1999) Collective action in watershed management—experiences from the Andean hillsides. Agric Human Values 16:257–266. https://doi.org/10.1023/A:1007522912099

Reed M (2008) Stakeholder participation for environmental management: a literature review. Biol Conserv 141:2417–2431. https://doi.org/10.1016/j.biocon.2008.07.014

Reed MS, Vella S, Challies E, de Vente J, Frewer L, Hohenwallner-Ries D et al (2018) A theory of participation: what makes stakeholder and public engagement in environmental management work? Restor Ecol 26:S7–S17. https://doi.org/10.1111/rec.12541

Reed J, Ickowitz A, Chervier C, Djoudi H, Moombe K, Ros-Tonen M et al (2020) Integrated landscape approaches in the tropics: a brief stock-take. Land Use Policy 99:104822. https://doi.org/10.1016/j.landusepol.2020.104822

Rowe G, Frewer L (2005) A typology of public engagement mechanisms. Sci Technol Hum Values 30:251–290. https://doi.org/10.1177/0162243904271724

Sarmiento C, Ungar P (2014) Aportes a la delimitación del páramo mediante la identificación de los límites inferiores del ecosistema a escala 1:25.000 y análisis del sistema social asociado al territorio: Complejo de Páramos Jurisdicciones – Santurbán – Berlín Departamentos de Santa. Instituto de Investigación de Recursos Biológicos Alexander von Humboldt (IAvH), Bogotá, DC. http://repository.humboldt.org.co/handle/20.500.11761/32539

Sarmiento C, Cadena C, Sarmiento MV, Zapata JA (2013) Aportes a la conservación estratégica de los páramos de Colombia: actualización de la cartografía de los complejos de páramo a escala 1:100.000. Instituto de Investigación de Recursos Biológicos Alexander von Humboldt (IAvH), Bogotá DC. http://repository.humboldt.org.co/handle/20.500.11761/31406

Schill C, Wijermans N, Schlüter M, Lindahl T (2016) Cooperation is not enough—exploring social-ecological micro-foundations for sustainable common-pool resource use. PLoS ONE 11:e0157796. https://doi.org/10.1371/journal.pone.0157796

Schlager E, Cox M (2018) The IAD framework and the SES framework: an introduction and assessment of the ostrom wokshop frameworks. In: Weible CM, Sabatier P (eds) Theories of the policy process, 4th edn. Westview Press, Nashville, pp 215–252

Schnelle E (1978) Neue Wege der Kommunikation: Spielregeln, Arbeitstechniken und Anwendungsfälle der Metaplan-Methode. Veröffentlichungen der Stiftung Gesellschaft und Unternehmen, 10

Steins NA, Edwards VM (1999) Platforms for collective action in multiple-use common-pool resources. Agr Hum Values 16:241–255. https://doi.org/10.1023/A:1007591401621

Stern M, Echavarría M (2013) Mecanismos de retribución por servicios hídricos para la cuenca del Cañete, Departamento de Lima, Perú. Forest Trends, EcoDecisión, Washington DC

The United Nations, UN (2015) Paris agreement

The United Nations Conference on Environment and Development, UNCED (1992) The Rio Declaration on Environment and Development. United Nations, Rio de Janeiro. Retrieved from https://www.un.org/en/development/desa/population/migration/generalassembly/docs/globalcompact/A_CONF.151_26_Vol.I_Declaration.pdf

The United Nations Economic Commission for Europe, UNECE (1998) Convention on access to information, public participation in decision-making and access to justice in environmental matters. UNECE, Aarhus. Retrieved from https://unece.org/environment-policy/public-participation/aarhus-convention/text

Tribaldos T, Oberlack C, Schneider F (2020) Impact through participatory research approaches: an archetype analysis. Ecol Soc 25(3):15. https://doi.org/10.5751/ES-11517-250315

Tristán-Febres MC, Blundo-Canto G, Cruz-Garcia GS, Quintero M, Pareja Cabrejos P (2018) Competing uses and access to hydrological resources in upstream peasant communities of the Cañete River Watershed, Perú. In: Rivera DA, Godoy-Faundez A, Lillo-Saavedra M (eds) Andean hydrology. Taylor & Francis, Routledge, pp 1–19

Ungar P (2021) Assembling an ecosystem: the making of state páramos in Colombia. Conserv Soc 19:119–129. https://doi.org/10.4103/cs.cs_19_103

Velez MA, Moros L (2021) Have behavioral sciences delivered on their promise to influence environmental policy and conservation practice? Curr Opin Behav Sci 42:132–138. https://doi.org/10.1016/j.cobeha.2021.06.008

Villamayor-Thomas S, Grundmann P, Epstein G, Evans T, Kimmich C (2019) The water-energy-food security nexus through the lenses of the value chain and the institutional analysis and development frameworks. Water Altern 8:735–755. Retrieved from https://www.water-alternatives.org/index.php/all-abs/274-a8-1-7/file

Voinov A, Bousquet F (2010) Modelling with stakeholders. Environ Model Softw 25:1268–1281. https://doi.org/10.1016/j.envsoft.2010.03.007

von Korff Y, d'Aquino P, Daniell K, Bijlsma R (2010) Designing participation processes for water management and beyond. Ecol Soc 15:1, Retrieved from https://www.jstor.org/stable/26268180

Whaley L, Weatherhead EK (2014) An integrated approach to analyzing (adaptive) comanagement using the "politicised" IAD framework. Ecol Soc 19:10. https://doi.org/10.5751/ES-06177-190110

Wunder S (2015) Revisiting the concept of payments for environmental services. Ecol Econ 117:234–243. https://doi.org/10.1016/j.ecolecon.2014.08.016