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Application of Fuzzy Set/ Qualitative Comparative Analysis to Public Participation Projects in Support of the EU Water Framework Directive

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ABSTRACT: This study analyzes the level of satisfaction of stakeholders in the public participation process (PPP) of water resources management, which is mandatory according to the EU Water Framework Directive (WFD). The methodology uses a fuzzy set/qualitative comparative analysis (fsQCA), which allows the identification of a combination of factors that lead to the outcome that is stakeholders' satisfaction. It allows dealing with uncertain environments due to the heterogeneous nature of stakeholders and factors. The considered causes range from environmental objectives pursued, actual capacity of efficiently carrying out those objectives, socioeconomic development of the region, level of involvement and means of participation of the stakeholders engaged in the PPP, and alternative policies and measures that should be performed. Results support the argument that different causal paths explain the stakeholders' satisfaction. The methodology may help in the implementation of the WFD and conflict resolution since it leads to greater fairness, social equity, and consensus among stakeholders. *Water Environ. Res.*, **89** (2017).

KEYWORDS: fuzzy sets, qualitative comparative analysis, public participation project, conflict resolution, decision-making.

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Introduction

Environmental sustainability has gained increasing attention in recent years (e.g., Houba et al., 2015; Latinopoulos and Sartzetakis, 2015; Llopis-Albert and Pulido-Velazquez, 2015). The EU Water Framework Directive (WFD) establishes a framework for the protection of all water bodies. It promotes sustainable water use based on long-term protection of water resources, and aims to achieve good qualitative and quantitative status of all water bodies by 2015.

Public participation and stakeholder engagement has gained increasing significance over the last decades with the aim of enhancing water resources management. In this sense, the EU WFD also specifies that member states shall encourage the active involvement of stakeholders in the implementation of the directive and development of watershed management plans (EC, 2000). Member states shall also ensure that, for each watershed, they publish and make available for comments to the public, including users, a timetable and work program for the production of the plan, the significant water management issues identified in the watershed, and a draft of the watershed management plan.

In addition to the environmental regulatory compliance, stakeholder involvement has positive effects on watershed management, such as more acceptable choices from the environmental, economic, and technical points of view; better use of information and management; increased legitimacy of the decision-making process; reinforcement of democratic practices; and increased confidence in institutional actors (e.g., Edelenbos et al., 2010).

Public participation can broadly be defined as allowing people to influence the outcome of plans and working processes. Nevertheless, there are three levels of stakeholder participation, with different degrees of influence, during the decision-making process. They are information supply (i.e., stakeholders are only informed), consultation (i.e., actors express opinions in organized meetings and their voice is taken as input in the decision-making process), and active involvement (i.e., stakeholders are engaged in the search for solutions and have the authority to co-decide) (EC, 2003).

Stakeholders involved in the decision-making process of watershed management have different values, levels of knowledge, resources, interests, and perceptions of problem(s) and solution(s) and strategies. This leads to a conflict of interests among them. The fact of dealing with heterogeneous stakeholders hinders the PPP and makes the problem more complex to achieve satisfactory outcomes. Note that collective decisions have to be attained by coordinating the actions of these actors who make their own strategic choices. Moreover, PPP require patience and mutual trust for all stakeholders involved (Criado et al., 2015). In addition, other researchers carrying out studies in other countries and realities can change this list to properly tackle their own problems, but they can still follow the presented methodology using fsQCA and make use of its advantages.

This work is intended to provide insight into stakeholder conflict resolution by using a configurational comparative method. Specifically, the objective of this study is achieved by means of a fuzzy set/qualitative comparative analysis (fsQCA) (Ragin, 2008), which overcomes some of the limitations of strictly qualitative or quantitative studies. This technique has been widely used in the literature to deal with qualitative comparative analysis in complex real-world problems and different scientific fields (e.g., Berbegal-Mirabent and Llopis-Albert, 2015; Hasselström and Hakansson, 2014; Knieper and Pahl-Wostl, 2016; Zhou et al., 2015).

It differs from traditional regression analyses in that it is based on set theory and logic, not statistics, thus allowing the evaluation of social systems characterized by causal complexity. In fsQCA, causal relations are expressed in terms of necessity and sufficiency. A condition is necessary if high stakeholder satisfaction cannot be produced without it, while a condition is sufficient if it can produce the outcome by itself without the help of other conditions (Ragin, 2008). These conditions, and the outcome condition, are perceived sets, and cases can have degrees of membership in a certain set. Set theory deals with relationships among sets which are expressed in terms of logical operators (Smithson and Verkuilen, 2006). This technique has three important implications which make it especially useful for explaining complex phenomena:

- Firstly, it assumes there can be many pathways to the same outcome, a phenomenon known as equifinality.
- Secondly, it assumes each pathway can contain different combinations of explanatory characteristics. Therefore, it seeks the effect of combinations (also named configurations) of necessary and sufficient explanatory characteristics, rather than for the effect of each individual characteristic with the same importance.
- The third difference is that it requires to carefully convert data into measures of set membership by means of theoretical or substantive knowledge external to the empirical data. This process is known as calibration. The calibration of outcomes and antecedent conditions into fuzzy sets categorizes meaningful groupings of cases (Ragin, 2008).

In this work, the outcome is the level of stakeholder satisfaction during the PPP, in which they have to deal with different factors or causal conditions, such as the environmental objectives pursued, the possibility of efficiently performing the objectives, the socioeconomic development of the region, the levels and mechanisms of stakeholder involvement in the decision-making process, and the alternative policies and measures in watershed management that should be carried out. Note that stakeholders, outcomes, and factors involved in a PPP for integrated water resources management may be different among countries with distinct levels of socioeconomic development. However, the present methodology can still be applied by adjusting all the required issues to those realities. The findings of the present paper suggest which factors are necessary conditions for the outcome. The results imply that stakeholders with an active involvement may have different ways that lead to their satisfaction through the PPP, but the actors who are only informed can also obtain some causal paths.

Methodology

Public Participation Process in Water Resources Management. During the decision-making process of public participation, in coming up with the best management practices for a given watershed, stakeholder satisfaction depends on diverse factors or causal conditions such as their heterogeneous interests, educational backgrounds, employment, knowledges, resources, experiences, places of provenance, level of participation, and so forth (Llopis-Albert et al., 2015). An in-depth description and discussion of stakeholders and their associated factors is considered in the following.

The criteria used to select stakeholders are established on the basis of considering all groups who in some way will be affected by the implementation of measures. This may include those who have interests, claims, or rights (ethical or legal) to the benefits of the measures undertaken, and those who are likely to bear its costs or adverse impacts whatever its overall worth. Therefore, this study does not only include groups whose interests, resources, and position of power or authority imply that they are likely to affect substantially the way in which the measures will be implemented.

Table 1 presents the stakeholders involved in the water decision-making of a PPP. They range from governments (national, regional, and local), water agency authorities, environmental organizations (e.g., non-governmental organizations, NGOs), irrigation user communities (e.g., farmers), private firms (e.g., water or hydroelectric companies, tourism organizations, financial institutions, businesses dependent on water for their supply chain or production etc.), universities and research agencies (e.g., national institutes for water resources), political parties, labor unions, experts, advisors, mass media, citizens to international organizations (e.g., the Organization for

Table 1—Categories of stakeholders used in fsQCA to determine levels of stakeholder satisfaction in the decision-making process of a public participation project for integrated water resources management.

	Stakeholders		
Categories	Number	Percentage (%)	Subcategories
GOVERNMENTS	44	20.5	NATIONAL GOVERNMENTS REGIONAL GOVERNMENTS LOCAL GOVERNMENTS
SERVICE PROVIDERS	27	12.5	PUBLIC UTILITIES PRIVATE OPERATORS PUBLIC-PRIVATE PARTNERSHIP NETWORK OF SERVICE PROVIDERS
WATERSHED INSTITUTIONS	18	8.4	RIVER BASIN ORGANISATIONS NETWORK OF WATERSHED INSTITUTIONS RIVER WATER AUTHORITIES
REGULATORS	6	2.8	ECONOMICS REGULATORS ENVIRONMENTAL REGULATORS
BUSINESS	12	5.6	NETWORK OF BUSINESS BUSINESSES DEPENDENT ON WATER FOR THEIR SUPPLY CHAIN BUSINESSES DEPENDENT ON WATER FOR PRODUCTION
CIVIL SOCIETY	29	13.5	COMMUNITY BASED ORGANIZATIONS MEMBER BASED ORGANIZATIONS NGOs SOCIAL MOVEMENTS
FINANCIAL ACTORS	10	4.7	DONORS FINANCIAL INSTITUTIONS
INTERNATIONAL ORGANISATIONS	16	7.4	UNITED NATIONS (UN), ORGANISATION FOR ECONOMIC CO-OPERATION AND DEVELOPMENT (OECD)
ADVISORS	13	6	EXPERTS ENGINEERING/CONSULTING FIRMS
SCIENCE & ACADEMIA	35	16.3	RESEARCH CENTERS UNIVERSITIES FOUNDATION RESERCH CENTERS
OTHERS	5	2.3	MASS MEDIA TRADE UNIONS NETWORK OF AGRICULTURAL ACTORS PARLIAMENTARIANS

Economic Cooperation and Development (OECD, 2014, 2015) or the United Nations). A complete list of all factors or conditions that leads to stakeholder satisfaction in the decision-making process of public participation in watershed management is presented in Table 2. The factors or causal conditions considered are the environmental objectives pursued, the actual capacity of efficiently carrying out those objectives, the socioeconomic development of the region, the level and mechanisms of stakeholder participation in the PPP, and the alternative policies and measures that should be implemented in the hydrological plans.

The factors considered range from the evolution of natural and available water resources and their quality, the degree of compliance with environmental objectives and ecological flows, the status of surface and groundwater bodies and their evolution in achieving the proposed environmental objectives, effects on water bodies, to the implementation of programs of measures. The factors also cover economic analysis and cost recovery, protected areas, the designation of artificial and heavily modified water bodies, the river basin operating system, the current and future water demand, and the consequences of the new EU Common Agricultural Policy 2014–2020 (CAP). Furthermore, we also consider the evolution of the electricity and energy sectors; land use/land cover changes; forecasts on climate change; phenomena such as erosion, desertification, and floods; and how the public participation process should be carried out (i.e., meetings, surveys, conferences, etc.). With regard to the possible policies and measures to be undertaken to achieve the environmental objectives, the actors can choose from a wide variety of alternative actions. They encompass both control measures and technical measures. On the one hand, the control measures cover reduction of water demand by economic instruments (e.g., reduction of irrigated areas by acquisition of water rights), increase of water control and sanctions by water agencies (e.g., illegal water abstractions, illegal dumping, overfertilization practices etc.), set up of user communities as a control mechanism as established by the WFD, more inter-

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Table 2—Factors or conditions considered in the fsQCA.

Environmental interests – Objectives pursued (1)		Good quantitative status of water bodies, both surface and groundwater (e.g., ecological flows, avoid decrease in water levels and overexploitation etc.)
		Good chemical status of water bodies (surface and groundwater) (e.g., saltwater intrusion, higher concentration of pollutants etc.)
		Good status of water dependent ecosystems (e.g., recuperation of springs and wetlands etc.)
		Low environmental impacts of future land use/land cover changes and climate changes (e.g., droughts, erosion, desertification, availability of future water resources)
Socioeconomic interests – Objectives pursued (2) – (3)	Operational efficiency (2)	Short realization time
		Low implementation costs (including monetary, social and reputational costs, human resources)
		Low maintenance, management and infrastructure construction costs
	Socioeconomic development of the region (agriculture, industry and tourism) (3)	Maximize water for agricultural (high crop profitability) and industrial use
		Maximize water for tourism and urban use
		Create employment, social equity
		Increase future water demands (e.g., for tourism purposes)
Level of stakeholder engagement in the water decision-making process (4)	Perceived obstacles to the integration of stakeholder engagement in water policies and practices (4.1)	Lack of political will and the shift of power
		Lack of knowledge (e.g., technical, legal, economical etc.)
		Weak legal frameworks
		Scant participation level (information, consultation, or active)
	Perceived obstacles hindering the effective implementation of engagement processes (4.2)	Lack of clarity on the use of engagement processes
		Lack of funding
		Lack of quality, and access to, information
		Intensity and number of conflicts
		Too many or too few actors
Preferred mechanisms used for stakeholder engagement (5)		Meetings
		Workshops/conferences
		Expert panels
		Web-based communication technologies
		Water associations
		Consultations in regulatory processes
		Surveys/polls
		River basin organizations
		Others
Preferred measures and policies for sustainable water resources management (6) – (7)	Control mechanisms (6)	Control or reduction of water demand by economic instruments (e.g., reduction of irrigated areas by acquisition of water rights)
		Control or reduction of pollutants by economic instruments (e.g., implementation of fertilizer standards, water and fertilizer taxes, and water trading etc.)
		Set up of user communities as a control mechanism
		Control of water resources by application of satellite remote sensing
		More intervention by the EU Common Agricultural Policy (CAP)
		Increase of water control and sanctions by water agencies (e.g., illegal water abstractions, illegal dumping, overfertilization practices etc.)
	Alternative technical actions (7)	Efficient conjunctive use of surface water and groundwater (e.g., water banking etc.)
		Use of external water resources by means of transfers
		Use of desalination plants
		Construction of new infrastructure (e.g., drinking water and water resource recovery facilities, dams, networks of water monitoring stations etc.)
		Establishment of protected areas
		Greater funding for water resources research
		Others
Outcome	Stakeholder satisfaction	Outcome: stakeholders' satisfaction

vention of the EU CAP, and control or reduction of pollutants by economic instruments (e.g., implementation of fertilizer standards, water and fertilizer taxes; and water trading which is the process of buying and selling water access entitlements). It is worth mentioning that the control measures usually create strong opposition among water users, which may lead to negative political repercussions for governments.

The technical measures encompass the implementation of several actions: (1) the use of external water resources by means of transfers between river basins, which can lead to an important rejection between the different regions; (2) the use of desalination plants, which can lead to higher costs in both their building and operating as compared to other water resources, together with environmental impacts due to the disposal of salt removed from the water; (3) an efficient conjunctive use of surface water and groundwater, such as water banking (this being the practice of forgoing water deliveries during certain periods, and banking either the right to use the forgone water in the future, or saving it for someone else to use in exchange for a fee or delivery in-kind); (4) the construction of new infrastructure such as drinking water plants, water resource recovery facility, dams, and water monitoring station networks and so forth, which can be unaffordable in periods of economic crisis; (5) increasing the available funding for water resources research; (6) the establishment of new protected areas. As a result, there is a conflict of interest among stakeholders since they have different degrees of acceptance or preference regarding those factors. These degrees of acceptance or preference, regarding the different factors, are assessed using a continuous fuzzy set, which is ranked from 0 (low degree of acceptance or agreement) to 1 (high degree of acceptance or agreement). This eases the calibration process into fuzzy scores.

Water agency authorities must set up an official calendar with the main phases of PPP and a period for observations and allegations. In most European PPP, with regard to initial documents prepared by water agencies, a large number of contributions are made by stakeholders. These contributions must be taken into account and formally responded to by water agencies and, eventually, some of them are incorporated into the final documents and proposals. According to the literature, the modifications and additions to the initial documents are mainly focused on the factors considered in this study. This is clear proof that the factors considered here are appropriate and have a direct effect on stakeholder satisfaction.

Proposed Methodology. *Data*. One of the main objectives of this work is to show the worth of the fsQCA as an effective tool for analyzing PPP for water resources management and its applicability to real-complex problems throughout the world. In order to assess stakeholder preference or degrees of acceptance regarding the diverse factors or conditions that lead to their satisfaction, we use the actors belonging to different watersheds and countries. Hence, this work does not represent any specific case study. Instead this work deals with different watershed realities and national legislation, and thus presents a general overview of European stakeholder satisfaction in the decision-making process of PPP for water resources management. Furthermore, this diversity of watersheds. in terms of the management strategies they apply and their stakeholder engagement, makes them suitable for studying how combinations of conditions in the decision-making process can result in stakeholder satisfaction. This will identify what combination(s) (i.e., conjunctions or configurations) of the considered conditions are necessary or sufficient to achieve stakeholder satisfaction in PPP.

Due to the lack of available data regarding these issues, this study is based on different reports (e.g., EC, 2003; OECD, 2014, 2015), research papers (e.g., Srinivasan et al., 2012, Verweij et al., 2013), public domain information (such as online data from web pages of European water agency authorities), meetings, personal interviews, surveys, mass media information, and expert judgments. Note that as a transparency and confidence building measure in a PPP, all information and reports are posted in the web pages of water agency authorities, as required by the WFD. In addition, with the aim of fostering greater contributions from stakeholders, the PPP includes public information campaigns; dissemination activities; the establishment of a stakeholder organization registry; meetings; sector and territorial round tables; debate forums; workshops; surveys and so forth. Furthermore, data have been collected during several years, so that a longitudinal view on the course of stakeholder preferences has been obtained.

Method. The interest of this research is not so much which factors are necessary but which combinations of factors are sufficient to explain the outcome. Therefore, this study uses qualitative comparative analysis (QCA) to overcome some of the limitations of strictly qualitative or quantitative methods, and to more systematically analyze conjunctural causal patterns. QCA is particularly suitable for cases with small data samples and allows the generalization of conclusions and implications for larger populations. Furthermore, contrary to standard statistical procedures this technique assumes complex causality and focuses on asymmetric relationships that detect configurations which are sufficient to produce a specific outcome. A configuration is a combination of factors (named as conditions in QCA terminology) that is minimally necessary and/or sufficient for obtaining a specific outcome (Meyer et al., 1993). These configurations consist of causal conditions or factors that can be positive, negative, or absent. Very often, any conditions are sufficient or necessary for all cases analyzed. Instead, conditions are sufficient and necessary only in combination with other conditions (i.e., conjunctural causation) or which are only one alternative among others that only apply to some cases but not to others (i.e., equifinal causation).

The QCA can analyze only binary variables. Fuzzy-set qualitative comparative analysis (fsQCA) overcomes this limitation by incorporating the possibility of examining varying levels of membership of cases to a particular set. The theoretical aspects of the fsQCA has been presented in-depth by Mendel and Korjani (2012, 2013). The steps required by the fsQCA are as follows (the interested reader is referred to Mendel and Korjani for details regarding the underlying concepts and mathematical basis of the methodology):

(1) Choose a desired outcome and associated cases.
(2) Propose k causal conditions. The aim of the methodology is to determine if a certain combination of those conditions leads to the outcome and to find out what groups of cases share a given combination of conditions. Complex causality means that causal factors combine with each other to lead to the occurrence of the outcome; different combinations of causal factors can lead to the occurrence of the outcome; and causal factors may have opposing effects depending on the combinations with other factors in which they are situated.
(3) Obtain the desired outcome and causal conditions as fuzzy sets, and determine their membership functions (*MFs*). This step requires a calibration process of outcomes and antecedent conditions into fuzzy sets, and thus it categorizes meaningful groupings of cases (Ragin, 2008). On the one hand, fuzzy values range from full membership (1) to full non-membership (0). On the other hand, the crossover point (0.5) represents neither in, nor out, of the set.
(4) Determine the *MFs* for all cases.
(5) Create 2^k candidate rules, in other words, causal combinations (the 2 is due to the consideration of both the causal condition and its complement). In this step, the truth table is constructed, which is a matrix space with 2^k rows, where k is the number of antecedent conditions. This matrix presents all the logically possible combinations of causal conditions (i.e., configurations) and sorts the cases according to these logically possible combinations. Each column represents a condition (Fiss, 2011) and each empirical case corresponds to a configuration, depending on which antecedent conditions the case meets.
(6) Compute the *MF* of each of these candidate causal combinations for all cases, and maintain only the surviving causal combinations (*RS*) whose *MF* values are >0.5, what happens for NF_i cases (N is finite space of all appropriate cases and F_i are the firing level fuzzy sets), where $NF_i > f$ (f is an integer frequency threshold that must be set by the user).
(7) Compute the subsethoods (consistencies) of these *RS* surviving causal combinations. The consistency quantifies the degree to which instances sharing similar conditions display the same outcome (Ragin, 2008). In other words, it measures the degree to which membership in the solution (the set of solution terms) is a subset of membership in the outcome.
(8) Then keep only those actual causal combinations (*RA*) whose subsethoods are ≥ 0.80 (this parameter can be modified by the expert judgment of the user).
(9) This step reduces the number of rows in the truth table. The fsQCA technique uses a version of the Quine–McCluskey (*QM*) algorithm (i.e., the method of prime implicants), which is a method used for minimization of Boolean functions (Quine, 1952). However, there are other algorithms that can also minimize a truth table. The algorithm returns a set of combinations of causal conditions by using Boolean algebra, where each combination is minimally sufficient to produce the outcome. Then, this step allows obtaining the R_C complex solutions (prime implicants) and the R_P parsimonious solutions (minimal prime implicants).
(10) Perform a Counterfactual Analysis (*CA*) on the complex solutions (R_C), constrained by the parsimonious solutions (R_P), which allow obtaining the intermediate solutions (R_I). This step requires expert knowledge of the problem in hand by the user.
(11) Carry out *QM* on the R_I to obtain the R_{SI} simplified intermediate solutions.
(12) Keep only those R_{SI} whose subsethoods are approximately ≥ 0.80, the R_{BSI} believable simplified intermediate solutions.
(13) Connect each of the R_{BSI} with its best instances.
(14) Compute the coverage of each solution. The coverage indicates the empirical relevance of a solution, in other words, it measures the proportion of memberships in the outcome that is explained by the complete solution. There are other terms used in the fsQCA. The raw coverage indicates which share of the outcome is explained by a certain alternative path or configuration (i.e., solution), while the unique coverage indicates which share of the outcome is exclusively explained by a certain alternative path.

Results and Discussion

In this study the outcome is the stakeholder satisfaction in the water resources decision-making process of a PPP, which can be used as a decision support system for stakeholder conflict resolution. This is an important problem since it impedes the realization and success of any hydrological plan. Table 1 presents the stakeholders involved in such a process, while Table 2 shows all the factors or conditions that leads to stakeholder satisfaction.

Once the conditions that are important for the stakeholder satisfaction have been raised, the goal is to determine which particular combination of those conditions leads to it. As stated, the fsQCA is particularly useful in attaining that aim since it allows the examination of which combinations of these conditions are necessary or sufficient to achieve high stakeholder satisfaction. Truth tables are analyzed by fsQCA software (Ragin, 2008).

The degree of acceptance or preference of the stakeholders regarding the different factors is assessed using a continuous fuzzy set, which is ranged from 0 (low degree of acceptance or agreement) to 1 (high degree of acceptance or agreement). Seven factors or antecedent conditions are considered, which comprises several subfactors (Table 2). A calibration process is needed in order to transform the diversity of factors used in this study into fuzzy variables, so that they match or conform to external standards.

Fuzzy scores are calibrated based on all available information, which constitutes the raw data. This study encompasses a huge amount of raw data, which covers different reports, research papers, public domain information (such as online data from web pages of European water agency authorities), meetings, personal interviews, surveys, mass media information, and expert judgments. The available information and stakeholder categories are highly heterogeneous, even more so by taking into account that they belong to countries with different levels of development.

The preferences of each stakeholder category, with regard to each factor, based on the raw data, are organized using Likert scale or interval scale variables. Likert scales are psychometric scales widely used in scaling responses in survey research. Interval scales are representations of numerical values, such as the budget each stakeholder is willing to devote to a certain measure in the water plan, or the national income of the different countries considered. The methodology assumes that the underlying concept can be structured and labelled in set-theoretic terms, for instance, "degree of membership in the set of developed countries", which can be based on its national income. The verbal labels of the scales must be transformed into metrics without any loss of information. An appropriate way to do this is the use of calibrated fuzzy sets, which allows the scaling of the degree of membership.

Fuzzy sets are able to capture all the relevant information, in other words, both differences-in-degree (more or less satisfaction) as well as differences-in-kind (satisfaction or no satisfaction). In addition, fuzzy sets can tackle both quantitative and qualitative measurements, thus overcoming many of the limitations of both. Moreover, fuzzy sets allow the proper combination of multiple data sources, as the problem in hand. The transformation between verbal labels and fuzzy scores is performed using three qualitative anchors that structure fuzzy sets: 1.0 (the threshold for full membership); 0.0 (the threshold for full non-membership); and 0.5 (the crossover point separating "more in" versus "more out" regarding a specific factor, i.e., it denotes the stakeholders with the maximum ambiguity about their membership in the set). In other words, the degree of agreement of the stakeholder with a certain statement in a five-level scale ranges from strong disagreement, disagreement, neither agreement nor disagreement, agreement, and strong agreement. Nevertheless, as stated, the usefulness of a fuzzy set analysis is to develop well constructed fuzzy sets, which leads to the issue of calibration of set membership scores based upon qualitative anchors, that is, a calibration process is performed in order to transform these scales into fuzzy variables.

Furthermore, a quantitative and qualitative calibration is simultaneously carried out, then, fuzzy scores are calibrated using theoretical and substantive criteria external to the data, due to the complexity of the problem in hand. These external criteria can be, for instance, the definition of the requirements to be fulfilled for a country to be considered as developed or the qualitative setting of the thresholds. This study uses the national income for the purpose of considering a country as developed.

The calibration of interval scales is carried out using the direct method (Ragin, 2008), which entails several steps. Firstly, the degree of set membership is defined, which is linked to each verbal label ranging from full non-membership to full membership. Secondly, the associated odds of this degree of set membership are computed using the formula "odds of membership = (degree of membership) / (1 - (degree of membership))". Thirdly, the log odds of full membership is obtained from the transformation of the associated odds, using the formula "degree of membership = exp(log odds)/(1 + exp(log odds))". Fourthly, the deviations from the designated crossover point are used to rescale the variables to obtain the fuzzy scores. Then, using the external criteria and the expert knowledge, the verbal labels can be coded into fuzzy scores, thus defining the degree of membership to a certain set.

The fuzzy scores are subsequently recoded according to the relative importance among stakeholder groups and the level of development in each country. This is because of the large existing heterogeneity among stakeholder groups, even more so when considering different countries with diverse levels of development. The present work qualitatively assigns higher fuzzy scores to stakeholders with greater influence on the measures to be undertaken, which is based on the three levels of their participation in the PPP (information supply only, consultation, or active involvement). In this sense, it is clear that a stakeholder from the government has more importance than one from the civil society, since they can further influence the final politics to be undertaken. Higher fuzzy set membership scores are also assigned to stakeholders belonging to developed countries, which is computed according to their national income. Therefore, we consider that stakeholders with higher influence who belong to developed countries are more difficult to satisfy. With this way of proceeding, the calibration is able to reflect these qualitative differences. As a result, the calibration leads to qualitative decisions in order to define the consistency, membership thresholds, and the selection of conditions that may influence the results.

The aggregate final score of each factor is determined through the arithmetic average of the fuzzy scores for each subfactor. This way of proceeding is performed for each of the stakeholders considered. The aggregate scores covering the seven factors and the outcome used in the PPP are combined into a raw data matrix (i.e., the truth table), which was obtained after several rounds of analyses. Since there are seven factors, the matrix dimensions are (2^7) rows (i.e., 128 possible configurations) and 7 columns. This matrix was first tested for necessary conditions for the outcome and also for the negation of the factors, indicated by the tilde ($\sim$) sign in Table 3.

We have considered that a condition is necessary when its consistency score exceeds the threshold value of 0.9 (Schneider et al., 2010). Table 3 displays the consistency and coverage values for all antecedent conditions. Results show that two out of seven variables present a consistency above the threshold, thus are necessary conditions to produce the outcome. These variables are the environmental objectives and the socioeconomic development of the region, which need to be present in order to

Table 3—Analysis of necessary conditions.

Conditions tested*	Consistency	Coverage
Environmental objectives	0.981875	0.786680
~ Environmental objectives	0.455000	0.906600
Operational efficiency of the objectives	0.831250	0.905995
~ Operational efficiency of the objectives	0.725000	0.870871
Socioeconomic development	0.916250	0.774432
~ Socioeconomic development	0.526250	0.928335
Level of stakeholder engagement	0.784375	0.748807
~ Level of stakeholder engagement	0.701250	0.998221
Mechanisms for stakeholder engagement	0.726875	0.939418
~ Mechanisms for stakeholder engagement	0.818750	0.838668
Policies and measures (control mechanisms)	0.863125	0.886393
~ Policies and measures (control mechanisms)	0.650625	0.838164
Policies and measures (technical actions)	0.848125	0.850784
~ Policies and measures (technical actions)	0.714375	0.948548

* Nomenclature: the symbol (~) represents the negation of the characteristic.

achieve stakeholder satisfaction. After the minimization process using Boolean algebra, the algorithm returns a set of combinations of causal conditions. Each combination is minimally sufficient to produce the outcome. The minimization is based on the coverage and consistency values reported by the algorithm.

Table 4 shows that eight solutions are found. Following Ragin's (2009) recommendation, this study reports the intermediate solution. We follow the notation of the solution table as presented in Ragin and Fiss (2008). Black circles (•) indicate the presence of a condition, white circles (○) denote its absence, and blank cells represent ambiguous conditions. This variety of configurations or paths suggest that no unifying causal path explains the outcome. All configurations of antecedent conditions present acceptable consistency indices (<0.80). In addition, high raw coverage values are obtained. The results imply that, apart from the necessary conditions, the presence of policies - both control measures and technical measures - appears in most of the configurations. This clearly shows that stakeholder satisfaction strongly depends on the types of policies undertaken. However, due to the high diversity and complexity of actors and their conflicting interests, these factors are not necessary but appear in most configurations. As a result, one of the conclusions to be drawn in the present work is that the fsQCA should be used during a PPP in conjunction with simulation-optimization models, and these results could be shown to the different stakeholders.

Despite some of the actors lack of adequate knowledge about technical issues supporting the policies, and measures to be undertaken, they may be presented and explained to them using the different mechanisms of stakeholder involvement as presented in Table 2. These models would range from groundwater flow and mass transport models, rainfall runoff models, agronomic models, hydro-economic models, system design and operation models, to climate change models. They take into account the key underlying biophysical processes of each particular setting (e.g., Llopis-Albert et al., 2014, 2016). The stakeholders will achieve a correct understanding of environmental problems by considering important hydrological processes such as surface-groundwater interaction, climatic variables, crop yields, nutrient balances, or land-use/land-cover changes.

In order to deal with uncertainty about the reliability and validity of the results, the fsQCA allows for robustness tests to enhance the level of confidence in the results; such as consistency, raw coverage, and unique coverage. Table 3 and 4 show the results of these tests, which have led to suitable levels of confidence in the proposed relationships, in accordance with the literature (Ragin, 2008). Eventually, with a greater understanding, better management practices and consensus will be achieved among the different actors.

As for the other factors (i.e., operative efficiency of the objectives, level of stakeholder engagement, and mechanisms for stakeholder engagement), results are imprecise. Although the presence of such factors appears in several configurations, their absence is relevant in other recipes. Note that the presence or absence of the factors in a certain configuration is due to stakeholder heterogeneity.

Table 4—Sufficient configurations of antecedent conditions for stakeholder satisfaction.

	Antecedent conditions (factors)							Coverage		
Configurations (C)	1	2	3	4	5	6	7	Raw	Unique	Consistency
C1	•	•	•			○	•	0.743125	0.030625	0.948166
C2	•	○	•	•	○	○	•	0.596875	0.001030	0.893358
C3	•	•	•		○	•		0.680000	0.005625	0.943625
C4	•	○	•	○	•	•	•	0.623750	0.006875	1.000000
C5	•	○	•	•	○	•	○	0.631250	0.003500	0.963740
C6	•		•	○	•	•	○	0.513750	0.011250	0.959160
C7	•		•	•	○	○	•	0.627500	0.001530	0.896429
C8	•	•	•	•	○		•	0.711250	0.002530	0.914791
Solution coverage: 0.818125										
Solution consistency: 0.891082										

Black circles (•) indicate the presence of a condition, white circles (○) denote its absence, and blank cells represent ambiguous conditions. Frequency threshold = 1; consistency threshold = 0.908924.

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These results are reinforced if actors are involved at an early stage, since they are less likely to obstruct decisions and more likely to support them. Furthermore, satisfied stakeholders are less likely to delay the decision-making process through their opposition, for instance by litigation (Berry et al., 1993), at a time when involving stakeholders will generate more knowledge (Mandell, 2001). The achievement of good outcomes in a PPP is also closely related to clear goals, strong control of time, organization, and information.

Conclusion

This study has provided insight into stakeholder conflict resolution by using a configurational comparative method. This is achieved by using an fsQCA for determining which combinations of factors are necessary and/or sufficient for stakeholder satisfaction throughout the decision-making process of public participation in water resources management. A wide range of factors have been analyzed, ranging from environmental objectives pursued, operational efficiency of the objectives, socioeconomic development of the region, level and mechanisms of stakeholder engagement, to alternative watershed management policies and measures. The presented fsQCA facilitates dialogue between theoretical ideas and empirical evidence, and allows the selection and construction of cases and conditions.

Stakeholder satisfaction has been operationalized as the degree to which actors are satisfied with the realized substantive outcomes. From the eight configurations or paths found, results show that environmental objectives and socioeconomic development of the region are necessary conditions, while, for other factors, results are imprecise due to stakeholder heterogeneity and conflicts of interest among them. This study shows that satisfactory outcomes in a PPP and stakeholder engagement do not depend upon single conditions, but result from combinations.

The results of the methodology can help the decision-making process of a PPP to come up with the best policies and regulations for integrated water resources management. This is because the results of the methodology can be easily understood by nontechnical and nonexpert stakeholders and can encourage a participative approach to water and land use management. In addition, different rounds of participation can be carried out in order to ease and improve the process, thus leading to greater fairness, social equity, and consensus among stakeholders. The methodology has proven to be useful in uncertain environments due to the heterogeneous nature of stakeholders and their conflict of interests regarding the measures and polices to be undertaken. Furthermore, the uncertainty also covers possible discrepancies between public statements of stakeholders and what they really think and seek; which may affect their actions, conflicts in the level of stakeholder engagement in the decision-making process, and the types of mechanisms used for their engagement, which may prevent appropriate stakeholder involvement.

Consequently, the results of the fsQCA can be used as a decision support system to support decision-making processes under uncertainty. The results obtained allow the factors, theoretical model, and/or case selection to be re-conceptualized or adjusted, thus leading to different findings. This allows to a more profound case-based knowledge. The analysis provides a transparent and multidisciplinary framework for informing and optimizing water policy decisions and has some contribution to the implementation of the WFD.

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