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Using Ostrom's DPs as Fuzzy Sets to Analyse How Water Policies Challenge Community-Based Water Governance in Colombia

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Abstract: Ostrom's design principles have been broadly used to analyse the governance of common pool resources. However, they are normally assessed as present or absent. We challenge this assumption by considering them as fuzzy sets where membership scores range from 0 to 1, because, in real situations, the design principles can be present at a certain level. We define categories to assess the level of membership and apply it to a single case study analysing how changes in water policy can affect the community-based management of the Water User Association of Mondomo (Colombia). In rural areas of Colombia, most water and sanitation services are provided by water user associations, wherein civil society has developed governance systems based on active citizen involvement and community-based management. Some of these associations have been operating for decades and are essential pillars of the local social fabric. However, recent changes in the country's policy and legal framework threaten these long-lasting governance systems. The results show that most of the design principles would suffer important changes that undermine the governance system. Essential principles for sustainable community-based governance, such as the congruence of the rules with local conditions, the local monitoring and sanctioning capacities, the internal conflict-resolution mechanisms and the recognition of the rights to organize, are dramatically reduced after the policy implementation.

Keywords: democratic water governance; Latin America; Ostrom design principles; water user associations

1. Introduction

Water is at the core of sustainable development, as recognised by Sustainable Development Goal 6 [1]. Water resources, and the range of services they provide, underpin poverty reduction, economic growth and environmental sustainability. However, in 2015, an estimated 663 million people were still using unimproved water sources or surface water, and eight out of 10 people who lack improved drinking water sources live in rural areas [2]. Although water policies regulate the provision, rights of access and use, and distribution and disposal of water resources, developing country governments often lack the means to effectively provide water and sanitation, especially in rural areas. This situation has forced citizens to develop alternative governance systems to secure their access to water [3].

Governance has been defined as a way of collectively managing social relations to define or allocate possible resources [4,5] between public or private actors to obtain mutual gains while also

managing possible conflicts [6]. The governance of natural resources can be understood as the broader system of formal and informal institutions in which management actions are embedded and that provide the essential direction, resources, and structures needed to meet overarching resource management goals [7,8]. It can also be explained as the interactions—among structures, processes and traditions—that determine how power and responsibilities are exercised, how decisions are taken and how citizens and other stakeholders have their say in the management of natural resources [9]. Management is often considered to be the operationalization of governance processes that support decision making and develop direct actions on the ground [10]. Governance processes usually involve a large number of key players with different skills, values, and preferences; these players represent different interests in the management of natural resources [11,12]. Constraints on local communities, such as poverty, low educational levels and inefficient political participation, hinder their effective involvement in the governance and co-management of natural resources [13]. These asymmetries of power mean that the poor and marginalized often lose when confronted by more influential actors [14,15]. The well-known Ostrom's design principles (DPs) [16] were proposed to analyse the governance of common pool resources (CPR) as described below. CPR are natural or human-made resources where one person's use subtracts from another's use and where it is often necessary, but difficult and costly, to exclude other users outside the group from using the resource [17].

In many Latin America countries, both civil society and the private sector have organised to facilitate water accessibility and sanitation in rural areas where governments do not provide these services. Approximately 80,000 water user associations (WUAs) supply water to more than 40 million people and have the residual capacity to service another 18 million [18]. WUAs have been defined as social structures created by groups of neighbours in suburban and rural areas which are generally out of the range of the public, private or mixed capital companies that service major cities. Using self-government statutes, teamwork and a simple, open and democratic leadership election process, they focus their efforts on establishing a system for water capture, purification, distribution and payment. Their management staff generally work pro-bono out of a sense of social commitment [18].

Although Colombia ranks as one of the world's leading countries in water resources supply, more than 60% of Colombia's rural population currently depends on WUAs to guarantee their access to water for human consumption and small-scale production [19]. Actually, more than 12,000 WUAs, known as acueductos comunitarios (community water pipelines), exist and supply water to more than 8.5 million people, or 20% of the country's population [20]. Andean rural communities have high water supply levels, but almost 80% of them depend on WUAs to obtain access to water. A good number of WUAs have been operating for over 30 years, indicating that they are not merely temporary agents. Rather, they provide quality water to rural communities at affordable prices and in equitable quantities [21].

WUAs operational method has been defined as "democratic water governance" and is grounded in the principles of community-based management, fairness, responsible and active citizen involvement, and agreements to safeguard sustainable and equitable access to water and sanitation services [18,22]. In fact, the role of these WUAs often transcends water service provision. They have come to foster rural empowerment, the deepening of democracy, and active local participation in water policy-making, despite the fact that they are very often neither recognized nor adequately coordinated by other water policy-making entities [23,24]. Therefore, they are unevenly able to shape local affairs and defend their interests.

This paper has a double objective: to introduce a methodological innovation by considering Ostrom's DPs as fuzzy sets where membership scores range from 0 to 1 [25]. Most analyses to date have considered the DPs as crisp sets (e.g., 1 if the DP is present and 0 if is absent), without considering that DPs can be present at a certain level. We based this assumption on the fact that DPs are imprecise categories and, quite often, scoring them exclusively as present or absent implies homogenizing very different real situations and excludes the possibility of introducing a degree of variation (membership)

in how the DPs are expressed in each governance system. The second objective is to assess how the external disturbances created by the new policy and regulations could challenge the governance of Colombia's traditional and long-standing water provision systems, using this methodological innovation and applying to a reference case, the Mondomo's WUA.

This WUA has more than 60 years of history and is considered a successful case of democratic water governance in Colombia. It is also considered an example of robust collective action following Ostrom's approach [16]. To describe Mondomo's WUA, we used the general variables included in the Institutional Analysis and Development framework (IAD) proposed by Ostrom [26]. To analyse how the new regulation may affect the robustness of the governance system of Mondomo's WUA, we assessed how the membership scores of the DPs change.

This study further contributes to the literature by: (1) considering the DPs as fuzzy sets and not as dichotomous categories, as well as proposing a transparent and reliable protocol to establish categories to assign membership scores that can be of high interest in the analysis of other common pool resources (CPR) governance systems; (2) analysing the influence of the new Colombian legal framework on the governance systems of traditional WUAs; and (3) using the DPs to analyse water provision and distribution systems (there is an extensive literature using them to analyse irrigation systems but not these water systems). By provision and distribution systems, we refer to the facilities used to supply water from its source to the point of usage. Given the relevance of WUAs in Colombia, this paper supports the advancement of knowledge.

1.1. The Institutional Analysis and Development Framework (IAD)

Institutions are broadly defined as the prescriptions and procedures that humans use to organize all forms of interactions [27]. The IAD framework was created and refined by Ostrom and her colleagues [28,29] as a systematic and consistent method of analysing the deeper structures that constitute specific action situations where human behaviour is central to understanding contextual changes [26]. The framework is a conceptual map; it integrates different parts or sections that need to be approached to understand how institutions change based on potential and real changes in context (biophysical, economic, social, legal, etc.) (Figure 1).

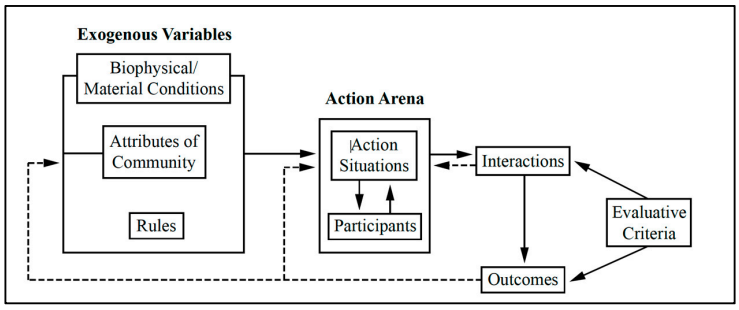

Figure 1. A framework for institutional analysis [26].

The focal unit of analysis is the "action arena", which is the social space where participants interact. It is composed of an action situation and the participants in that situation. Action arena can be considered a set of dependent variables affected by three clusters of exogenous variables: (1) the attributes of the biophysical or material conditions that are acted upon in these arenas; (2) the structure and defining conditions of the community within which the action arena is placed; and (3) the rules used by participants to regulate their relationships [29]. The IAD framework intends to explore the different conditions that play a role in institutional change as well as the possible changes that different institutional configurations might produce in the action arena and in the exogenous variables. Finally, actors' interactions with other actors and with the exogenous attributes produce different outcomes that can be analysed by different evaluation criteria, thus producing outcomes that reinforce complex

and changing behaviours [29]. Therefore, there is no single way to approach institutional change; such change can be defined based on research objectives or based on the disciplines according to which one is attempting to understand the conceptualization of actions [26].

1.2. Ostrom's Design Principles as Fuzzy Sets

After extensive study of long-lasting CPR systems, Ostrom enumerated eight design principles that characterized their governance systems. These principles enabled resource users to engage in collective actions that led to sustainable management [16]. These DPs were present in long-lasting systems but were absent in those that collapsed; thus, she proposed using the DPs to characterize successful self-governance strategies. The DPs were defined as follows:

(1) Clearly defined boundaries: the boundaries of the resource system (e.g., irrigation system or fishery) and the individuals or households with rights to harvest resource units are clearly defined;
(2) Proportional equivalence between benefits and costs: the rules specifying the amount of resources that a user is allocated are related to local conditions and to rules requiring labour, materials, and/or monetary inputs;
(3) Collective-choice arrangements: many of the individuals affected by harvesting and protection rules are included in the group that can modify these rules;
(4) Monitoring: monitors, who actively audit biophysical conditions and user behaviour, are at least partially accountable to the users and/or are the users themselves;
(5) Graduated sanctions: users who violate rules-in-use are likely to receive graduated sanctions, depending on the seriousness and context of the offense, from other users, from officials accountable to these users, or from both;
(6) Conflict-resolution mechanisms: users and their officials have rapid access to low-cost, local action arenas to resolve conflicts among users or between users and officials;
(7) Minimal recognition of rights to organize: the rights of users to devise their own institutions are not challenged by external governmental authorities, and users have long-term tenure rights to the resource;
(8) Nested enterprises: appropriation, provision, monitoring, enforcement, conflict resolution, and governance activities are organized in multiple layers of nested enterprises. This last DP applies to resources that are parts of larger systems.

Cox et al. [30] with the analysis of approximately 100 case studies, provided evidence that the design principles hold up when challenged with data and suggested a revision of the DPs, splitting DP1, DP2 and DP4 into two principles each, which led to 11 DPs (Table 1). We analysed this 11 DPs.

Table 1. Design principles.

DPs as Enunciated by Ostrom		DPs as Enunciated by Cox et al.	
1	Clearly defined boundaries	1A 1B	User boundaries Resource boundaries
2	Equivalence between benefits and costs	2A 2B	Congruence with local conditions Appropriation and provision
3	Collective-choice arrangements	3	Collective-choice arrangements
4	Monitoring	4A 4B	Monitoring users Monitoring the resource
5	Graduated sanctions	5	Graduated sanctions
6	Conflict-resolution mechanisms	6	Conflict-resolution mechanisms
7	Minimal recognition of rights to organize	7	Minimal recognition of rights to organize
8	Nested enterprises	8	Nested enterprises

In this research, we consider the DPs as fuzzy sets, since we assume that they are not just present or absent, but can have a gradation of presence. Fuzzy sets can help social scientists conceptualize social and political phenomena as sets with imprecise boundaries between membership and non-membership. Crisp sets perceive cases only as members or non-members of a set. The problem is that many core concepts in social research are best understood as graded sets [31]. Fuzzy sets are not ordinal scales or mere rankings of categories, but each degree represents a different empirical situation [25]. The basic idea behind fuzzy sets is to permit the scaling of membership scores and thus allow partial or fuzzy membership. A membership score of 1 indicates full membership in a set, scores close to 1 (e.g., 0.8 or 0.9) indicate strong but not quite full membership in a set, scores less than 0.5 but greater than 0 (e.g., 0.2 and 0.3) indicate that objects are more "out" than "in" but still weak members of a set, and a score of 0 indicates full non-membership in a set. Thus, fuzzy sets combine qualitative and quantitative assessment: 1 and 0 are qualitative assignments ("fully in" and "fully out", respectively); values between 0 and 1 indicate partial membership. The 0.5 score is also qualitatively anchored, for it indicates the point of maximum ambiguity (fuzziness) in the assessment of whether a case is more "in" or "out" of a set [32]. Fuzzy sets require that researchers establish a very close correspondence between fuzzy membership scores and the concepts they represent, as well as a careful calibration of the fuzzy scores that reflect the degree of membership [25].

1.3. The New Water Regulatory Framework in Colombia

Colombia's WUAs actually feel threatened by a regulation in process of implementation, proposed in 2014 by the National Council of Economic and Social Policy [19] and partially ratified by national law number 1898 [33]. This framework has as its core objective, the promotion of access to drinking water and basic sanitation in Colombia's rural areas by improving the general conditions of access to good quality water for all rural inhabitants. Its objectives are: (1) strengthening the institutional capacity of the state to intervene in rural areas; (2) promoting the structuring of sustainable schemes for drinking water provision and sanitation in rural areas; (3) investing in infrastructures; and (4) promoting effective practices of sanitary and environmental management. The regulation will be implemented in two phases during 10 years, starting in 2014 with its presentation and discussion with WUA´s national representatives.

At the local level, the regulation is perceived as a water privatization process [24] that will affect the autonomy and governance of WUAs. The emphasis of the new regulation in the implementation of activities through national government agencies limit the role of local communities and organized WUA's in implementing it [34]. Several outcomes of the policy are considered as threats by WUAs: (1) it opens options to increase the number and type of users with access to the WUAs' water facilities; (2) it introduces new priorities in water access displacing household needs in favor of other economic sectors; (3) it transfers the control and supervision of water quality to national agencies, undermining the management capacities of WUAs and probably increasing water prices; (4) it challenges community-based governance systems based on solidarity, reciprocity and direct democracy; (5) it reduces the legitimacy of social participation in water management systems; and (6) it only affects WUA's and aqueducts that serve rural villages and towns, but does not guarantee services to isolated areas. The Colombian Network of Community Pipelines has recently contested this regulation by proposing to the Government a draft regulation that preserve the right to the community-based management of water and maintain the WUA's autonomy, preventing what they called as the "privatization" of water supply to rural communities [35].

2. Case Study Selection

Mondomo village locates in the Santander de Quilichao municipality (Cauca Department, Colombia). The village is located at 1350 m a.s.l. and is mainly composed of Afro-Colombian, indigenous and mestizo inhabitants. Mestizos and Afro-Colombians mainly locate in Mondomo's town, while indigenous communities locate in the upper areas of the Mondomo's river watershead.

Mondomo village has approximately 3500 inhabitants and is currently considered an agro-industrial centre because of its high provision of water and productive lands, as well as its proximity to roads and ports. Livelihoods are linked to agriculture and the transformation of cassava to extract starch (*rallería*). Starch extraction is the area's principal economic activity, resulting in high water demand and pollution. This processing creates a complex trade-off between using water for human consumption and for agroindustry activities [34].

Water provision in the region comes mainly from independent WUAs [36]. The Mondomo's WUA initiated approximately 60 years ago, when a small group of water users defined their particular needs, built an aqueduct and developed a payment scheme and participation processes. They prioritized household needs, followed by water use for agricultural production. The first aqueduct was mainly dedicated to water distribution but lacked an effective sanitation system. This aqueduct was managed by a water administration committee plagued by management problems and economic deficit.

In 1994, a seismic shift damaged the water distribution system, acting as a trigger factor to configure a private–public alliance around the construction of a new aqueduct. Different public and private institutions [37] worked with the community in the design of the new aqueduct and in the definition of the management rules, where the beneficiaries were the system's administrators and could define the local water governance scheme [38]. Design and execution activities for the new aqueduct lasted from 1994 to 1998 and approximately 718,000 USD were invested by national and international donors (World Bank, European Union and Inter-American Foundation). Initially, the community was sceptical due to the long tradition of corruption and uncompleted projects. People were also frustrated with the lack of transparency and control in the management of the first aqueduct. However, a local University fostered a legitimate participatory process that attracted the interest of most of the inhabitants, overcoming their traditional resistance and mistrust to work with publics agencies and authorities [39].

The principal achievements of this alliance were as follows: the design, construction and start-up of a complete clean drinking water supply, with almost 100% coverage; the creation of the Mondomo's WUA, as a public utility company with a community base; the land acquisition of plots on both sides of the principal watershed to guarantee water access; the creation of a new culture around participation processes, rationalization of water consumption and payment for the aqueduct services; the effectiveness and transparency in the management of economic resources and investments; the community's credibility in managing a public service; and a strong feeling of ownership among the users [40].

The Mondomo's WUA has been selected as case study due to several reasons: (1) it is considered as an example in the Colombian context of efficient combination of water national policies with local needs [39]; (2) it uses technologies and maintenance methods that reduce electricity and chemical products use [37]; (3) it currently fully covers increasing demand of water maintaining quality and preserving the autonomous water governance designed schemes [21]; and (4) it belongs to the founder group of one of the biggest second level WUA's platform called AQUACOL [41,42]. Additionally, in 1998, it was distinguished by the World Bank as an example of an integral local initiative focused on poverty alleviation in Colombia [43].

3. Methods

To consider the DPs as fuzzy sets, the first step was to define the categories that support varying degrees of membership in the set [44] and represent real situations. We found inspiration in the coding system proposed by Ratajczyk et al. [45], based on the codes established by Ostrom et al. [46] in the Common Pool Resources Coding Manual, but we proposed our own definition of the categories that represent potential situations in the governance systems of common pool resources.

The scores ranged from 0 ("fully out") to 1 ("fully in"). We used 0.5 as the crossover point (neither in nor out) [25] and established 4 additional degrees of membership for each DP. The degrees of membership 0.2 and 0.4 are "more out than in", and those of 0.6 and 0.8 are "more in than out", and

there are differences between them defining if they are "more or less in/out", and "mostly in/out" (see Table 2). The proposed degree of membership aimed to support the systematically coding of DPs and increase the replicability of this working method by other researchers.

The second step was to describe the actual situation of the water governance in Mondomo's WUA using the IAD framework [26]. This descriptive single case study [47] is based on qualitative and quantitative information collected between 2012 and 2015. We initially collected secondary information from different technical, economic and legal sources to construct a narrative that describes the different spheres (environmental, social, economic, etc.) interacting in the water management. After, we analysed how the new legal framework could affect its governance system.

Finally, we scored membership for each of the DPs, both in the actual and in the most plausible situation after the change of policy. MacQueen et al. [48] recommend the use of two or more coders for qualitative analysis. We used four coders (two researchers and two members of NGOs working on water management issues), all of them with working experience in the area, in WUAs and in community-based management and governance. Both the number of coders and the clear definition of the conditions that defined each score were intended to increase the transparency, reliability and replicability of the research and to avoid the traditional bias of subjectivity in the social sciences. To assess intercoder reliability we calculated Krippendorff alpha [49] using the irr-package in R. The coders used the existing literature, most grey literature (Text S1), to characterize Mondomo's WUA, together with their knowledge of the situation. They independently scored each DP in both situations; after, the scores were compared. Often, the scores were similar; where differences existed, the coders assessed discrepancies and discussed the reasons behind their scores. The exercise of interpreting the scores was very useful for identifying possible biases and for reaching a final consensus about the score closest to reality. Finally, the differences between the actual and the new situations were analysed to obtain answers to the second research objective.

4. Results

4.1. Categories of Membership Scores for Each DP

Table 2 present the results for the first research objective, depicting the six categories of membership score established for each DP.

Table 2. Categories of membership score for each DP.

	1A User Boundaries
0.0	No boundaries defined
0.2	The boundaries between users and nonusers are blurry
0.4	The boundaries between users and nonusers are clearly defined, but users cannot exclude nonusers
0.6	The boundaries between users and nonusers are clearly defined, but nonusers only can be excluded by external enforcement
0.8	The boundaries between users and nonusers are clearly defined, and users have internal means to exclude nonusers
1.0	The boundaries between users and nonusers are clearly defined, and nonusers can be excluded by both, internal mechanisms and external enforcement
	1B Resource Boundaries
0.0	No boundaries defined
0.2	Boundaries result of institutional arrangements which do not limit entry
0.4	Boundaries result of natural/constructed attributes which do not limit entry
0.6	Boundaries result of institutional arrangements which limit entry
0.8	Boundaries result of natural/constructed attributes which limit entry
1.0	Boundaries result of natural/constructed and institutional arrangements which limit entry

Table 2. *Cont.*

2A Congruence with Local Conditions	
0.0	Rules do not match local social and environmental conditions
0.2	Externally imposed rules that partially match local social and environmental conditions
0.4	Internal rules partially congruent with local social and environmental conditions and no capacity to modify external rules that not consider these conditions
0.6	Internal rules congruent with local social and environmental conditions and some capacity to modify external rules that not consider these conditions
0.8	Internal rules congruent with local social and environmental conditions and externally recognized internal mechanisms to push the adaptation of external rules
1.0	Internal and external rules congruent and fully adapted to the local social and environmental conditions
2B Appropriation and Provision	
0.0	Inputs (associated costs) and benefits are not proportional
0.2	Inputs (associated costs) exceed benefits and are externally decided
0.4	Inputs (associated costs) exceed benefits and are internally decided
0.6	Inputs (associated costs) equal benefits but are externally decided
0.8	Inputs (associated costs) equal benefits and are internally decided
1.0	Benefits highly exceed inputs
3 Collective-Choice Arrangements	
0.0	Operational rules cannot be modified
0.2	Most individuals cannot participate in modifying the operational rules
0.4	Most individuals can participate in modifying the operational rules, but need external approval
0.6	Most individuals can participate in modifying the operational rules without external approval, but external rules highly influence operational rules
0.8	Functional collective-choice arrangements exist, can be modified by users, but are not respected by non-users
1.0	Functional collective-choice arrangements exist, can be modified by users and are respected by users and non-users
4A Monitoring Users	
0.0	Appropriation and provision levels are not monitored
0.2	Appropriation and provision levels are poorly monitored by monitors who are not accountable to users
0.4	Appropriation and provision levels are systematically monitored by monitors who are not accountable to users
0.6	Appropriation and provision levels are occasionally monitored by monitors who are accountable to users; the information collected is non-necessarily used to inform group decisions
0.8	Appropriation and provision levels are often monitored by monitors who are accountable to users; the information collected is used to inform group decisions
1.0	Appropriation and provision levels are systematically monitored and recorded by monitors who are accountable to users; the information collected is used to inform group decisions
4B Monitoring the Resource	
0.0	The condition of the resource is not monitored
0.2	The condition of the resource is poorly monitored by monitors who are not accountable to users
0.4	The condition of the resource is systematically monitored by monitors who are not accountable to users
0.6	The condition of the resource is occasionally monitored by monitors who are accountable to users; the information collected is non-necessarily used to inform group decisions
0.8	The condition of the resource is often monitored by monitors who are accountable to users; the information collected is used to inform group decisions
1.0	The condition of the resource is systematically monitored and recorded by monitors who are accountable to users; the information collected is used to inform group decisions
5 Graduated Sanctions	
0.0	No sanctioning capacity
0.2	Rule violation derives in non-graduated sanctions
0.4	Rule violation derives in graduated sanctions by officials not accountable to the users (law enforcement)
0.6	Rule violation derives in graduated sanctions by other users (social sanctions)
0.8	Rule violation derives in graduated sanctions by officials accountable to the users (punishments, penalties . . .)
1.0	Rule violation derives in graduated sanctions by both, other users and officials accountable to users
6 Conflict-Resolution Mechanisms	
0.0	Users have no access to conflict-resolution arenas
0.2	Conflicts are solved in external arenas (courts, environmental authorities . . .)
0.4	Low-cost arenas exist, but are not easily accessible
0.6	Low-cost arenas exist, are easily accessible, but decisions are not always accepted (lack of trust, lack of responsibility . . .)
0.8	Low-cost arenas exist, are easily accessible and decisions are respected based on values such as legitimacy and reciprocity
1.0	Low-cost arenas exist, are easily accessible and have enforcement capacity

Table 2. *Cont.*

	7 Minimal Recognition of Rights to Organize
0.0	Users have no right to devise their own institutions
0.2	Users have de facto right to devise their own institutions, but their decisions are not considered by external governmental authorities
0.4	Users have de facto right to devise their own institutions, and their decisions are partially considered by external governmental authorities
0.6	Users have de facto right to devise their own institutions, and their decisions are considered by external governmental authorities
0.8	Users have de jure right to devise their own institutions, and their decisions are considered by external governmental authorities
1.0	Users have de facto and de jure rights to devise their own institutions, and their decisions are considered and respected by external governmental authorities
	8 Nested Enterprises
0.0	CPR management activities are not organized in multiple layers of nested enterprises
0.2	CPR management activities lack horizontal (intercommunity connections) and vertical linkages (connections between multiple jurisdictional levels)
0.4	CPR management activities have horizontal linkages but not vertical
0.6	CPR management activities are organized in multiple layers of nested enterprises that create horizontal links
0.8	CPR management activities are organized in multiple layers of nested enterprises that create vertical links
1.0	CPR management activities are organized in multiple layers of nested enterprises that create horizontal and vertical links

4.2. Description of Mondomo´s WUA through the IAD Framework

4.2.1. Exogenous Variables

- Biophysical/Material Conditions

The basin of the Mondomo River covers approximately 11,200 hectares, of which approximately 60% located at the upper side of the watershed are covered by forests and natural vegetation and inhabited by indigenous communities. The main sources of water are the Mondomo river, the Montañitas stream and the Tiembla and San Pablo creeks. San Pablo creek is the most important source of supply of the town and provides water to another three WUA's (Cascajal, Pedregal, and Concepción) with no aqueducts or treatment plants. The medium part of the basin (representing 20% of the area) has a high degree of intervention by agricultural, mining and livestock activities. The lower part (the remaining 20% of the surface) is where Mondomo village located and is characterized by high levels of water consumption by the more than 60 cassava starch extraction industries (Figure 2).

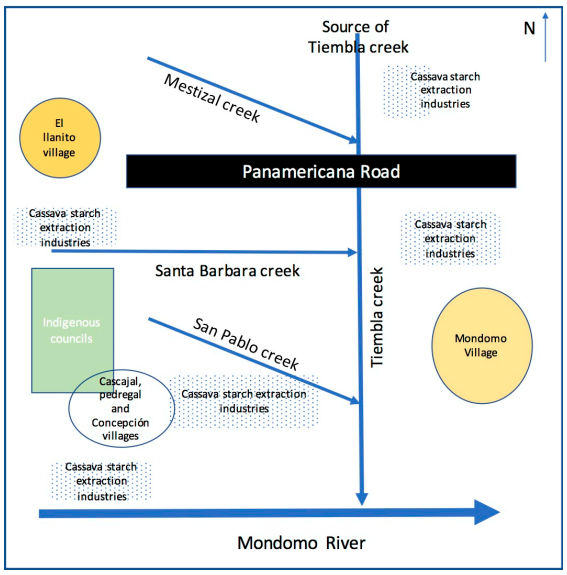

Figure 2. Watershed scheme.

Mondomo´s aqueduct is catalogued as the most advanced drinking water supply system in Colombia's rural areas. The technology used for water purification is multi-stage filtration with low consumption of chemicals and the distribution networks operate by gravity, minimizing the use of energy for distribution [39]. Wastewater is collected by a system of sewage and discharged without treatment to the Zanjón Tiembla, a tributary of Mondomo River. The sewage service is provided by the Municipality, and the cleaning service by a public service company that has an agreement with the WUA to include this charge in billing. As a management strategy, the WUA develops several reforestation programs with the participation of environmental agencies and the local community in their upper lands [40].

- Attributes of Community

Most of the users of the aqueduct are mestizo, but at the upper lands locate the indigenous councils of La Concepción and Las Delicias. Approximately 780 Mondomo's houses are currently connected to, the aqueduct [39]. In the town centre, there are seven neighbourhoods, each with a Community Action Board. The Association of Community Action Boards has become the most representative community body. Another instance of strong representation is the guild of the rallanderos (processors of cassava starch), as this industry is one of the main employers in the area. Community members are in charge of the operation and maintenance of the water system. A police unit addresses minor conflicts and represents the municipal administration in the area. Nowadays, illegal mining at the upper part of the watershed is jeopardizing the water governance structure defined by the WUA, due to the difficulties to solve conflict with armed actors [20].

- Rules

The aqueduct has a water concession issued by the local environmental agency (Corporación Autónoma Regional del Cauca (CRC)), which, according to the Ministry of Environment and Sustainable Development, is responsible for administering and granting authorizations for the use of water (Law 99 of 1993). The maximum authority of the WUA is the Assembly of Users that defines the general management of the WUA, hosts annual meeting to analyse the performance and the users behaviour and implement changes in the general statutes, if needed. The Managing Board oversees the implementation of the Assembly's decisions [50].

The rules for the use of water are set forth in the statutes of the WUA, which establishes the rights and duties of the associates and the functions of both administrative bodies. The statutes and the procedures for the water provision service were structured per the guidelines of Law 142 of 1994 [34]. The initial rule design focused on the autonomy of local water governance, and was a participatory process accompanied by research centres and universities. From the beginning, the community develop a monitoring system, more oriented to capacity building than to punishment or exclusion [41].

The WUA has defined constitutional rules, internal operation rules and users' regulation terms that clearly count it as a community enterprise. The two first sets define the rules for elections of the representative board, the duties and responsibilities of members and the aqueduct working method, based on participatory and democratic constitution and functioning. The second set defines the tariffs (entrance fee and water prices according to socioeconomic conditions), the mechanisms of conflict resolution, and the duties of users (reforestation activities, payment, collective work, participation in the WUA Board, etc.). The current WUA administrative board consider that the new water regulation will particularly affect their autonomy to define fees, entrance regulations and reduce the investment in conservation activities [34]. Therefore, they have actively participated in the design of the mentioned draft submitted to the national government by the Colombian Network of Community Pipelines [35].

In terms of conflict management, the protocol to manage conflict internally is based on traditional values such as cooperation, reciprocity and the identity created around the aqueduct beneficiaries that help to maintain a low-cost conflict solving arena [50]. However, most of the actual conflicts are with other communities that allow illegal mining in their territory. The attempts to establish

agreements with members of the indigenous council La Concepción that permit productive (and polluting) activities in conservation areas have not worked [34]. Campaigns have also been launched by the CRC to prohibit bauxite mining in the tributary streams of the community aqueduct.

4.2.2. Action Arena

- Action Situations

The WUA has a granted water concession and pays the CRC an annual fee for water use. It executes conservation actions with community members. Water purification treatment is performed according to the regulations of the Ministry of Health. The payment system and tariffs are defined in accordance with the guidelines of the water and basic sanitation regulation commission at the CRC and the water use fees follow the rules established by the superintendents of public services [21].

- Participants

The identified actors or participants that are—directly or indirectly—part of Mondomo´s WUA are as follows: water users, peasants and ranchers, "rallanderos", WUA Managing Board members, major municipalities, bauxite miners, the inspector of police, sanitation technicians, the CRC and the Universidad del Valle [37]. The members of the WUA are organized in sub-commissions for health, education and water quality that work together with the representatives to improve the governance system through improving the social conditions of the members [34].

4.2.3. Interactions

The process of "formalization" of the WUA has entailed compliance with the sectoral regulations of the administration and with the operation of water and sanitation systems, but has rendered some agreements established by the community (i.e., free delivery of water to very poor families, the performance of some works by users) as illegal, undermining the WUA's operational capacity [50]. A relationship of compliance between the association and the sectoral authorities is then established through the adoption of the normative package [21]. Between users and the Managing Board, a collaborative relationship exists, evidenced by the presence of users in the assemblies and the active users' participation in conservation and maintenance activities. Contrarily, with the rallanderos and the WUA of Cascajal there is a competitive relationship to secure access to water resources.

Three factors related to social interactions are highlighted by users, representatives and international NGOs as drivers of WUA's success: (1) the strong and active participation of the local community, from the beginning; (2) the proven local capacity to solve local internal conflicts; and (3) the managing capacity of the WUA board, not only in solving the economic problems of the first water association but also in increasing the economic revenues to be invested in maintaining the aqueducts, using social water prices.

4.2.4. Evaluative Criteria

Mondomo's WUA indicators clearly differentiated it from other WUAs in Colombia: service coverage is 100%; water losses are less than 7%; micro-measurement coverage is 100%; and users' payment delays is 15% [40]. The implementation of other criteria is pending, such as criteria to evaluate the co-responsibility for the pollution of the Mondomo River, as well as those to measure the vulnerability of the sub-basin, and the effectiveness of the adopted measures of protection.

The highly active participation of the WUA management board has also been recognized by different regional and national WUA second level platforms such as AQUACOL and the Colombian Network of Community Pipelines, strengthening the influence of this WUA´s in the recognition of alternative governance water models in Colombia [34].

4.3. Changes in the Desing Principles Due to the New Policy Regulations

Table 3 presents the score of each DP in the actual and future situations, and the descriptions that justify these scores.

Table 3. DP scores according to the fuzzy membership categories.

Design Principles
1A User Boundaries
Currently: Access to water is regulated. New users must request admission and fulfil requirements (entrance fee, water fees and community work to maintain the aqueduct facilities), but Mondomo's WUA has no enforcement capacity (e.g., illegal users).
After policy changes: Water access can be determined by the capacity and willingness to pay and not necessarily by the collective action mechanisms that currently define access. Mondomo's WUA might lose capacity to exclude current nonusers.
1B Resource Boundaries
Currently: Access to water in Colombia is a right, and where water sources such as rivers or gullies exist, different actors can claim access. Thus, the limits cannot be easily defined, especially in rural areas. However, the constructed limits of the aqueducts are perfectly defined. Only users legally connected to the system can have access to water.
After policy changes: No major changes are expected because the conflicts do not depend on the resource boundaries but rather on the access to the water sources.
2A Congruence with Local Conditions
Currently: Appropriation and provision rules are congruent with local social and environmental conditions. A clearly established and collectively decided payment system based on the consumption level, the use of water and the economic status of households exists. Local rules not only cover provision and payment but also other activities such as the rationalization of use, improvement of water provision and fostering a water-saving culture. However, Mondomo's WUA has little capacity to modify external rules that do not consider its local conditions.
After policy changes: External rules might be imposed over the traditional schemes and local social structures, giving access to users according to their financial means. WUAs might function as private or mixed service provider companies, losing their local-social approach and their matching of local conditions.
2B Appropriation and Provision
Currently: The benefits obtained by users thanks to the building of the aqueduct and the actual performance of Mondomo's WUA greatly exceed the inputs. Most of the time, users have access to quality water in the quantities they need, and at a cheap price modulated as a function of the use and status of the users.
After policy changes: Costs might increase because WUAs will lose part of their decision-making and bargaining powers and water price will be decided by regional and national regulation systems. The potential expansion of users might surpass the resource provision levels, and benefits could be clearly reduced (e.g., many families could not afford the water price).
3 Collective-Choice Arrangements
Currently: Mondomo's WUA collective-choice arrangements are clearly defined. The managing board is appointed by the users and its work is based on transparency and accountability schemes. All individuals affected by the operational rules have the opportunity to participate in modifying them. The main decisions are taken in public assemblies open to all the users but are not always respected by non-users.
After policy changes: The local/traditional decision-making process might be jeopardized, and new and more bureaucratic processes can be imposed, complicating users' options to modify rules.
4A Monitoring Users
Currently: Appropriation and provision levels are monitored, recorded and delineate the payment system. Monitors are selected among the users and accountable to them (e.g., they can be asked to disclose their decisions regarding a user's violations of regulation codes). The information is used to make decisions.
After policy changes: The system monitoring can be taken over by external authorities. Mondomo's WUAs might face a decline in their capacity to monitor users' appropriation and provision levels because their options to decide who monitors users' actions might be reduced.

Table 3. *Cont.*

Design Principles
4B Monitoring the Resource
Currently: Monitors selected from the community continuously monitor water conditions to have information in real time about the conditions of the resource. The information collected is used to make group decisions.
After policy changes: The resource monitoring can be taken over by external authorities. The capability to keep systematic data to evaluate the state of the resource and the real capacity of users to access updated information might decrease.
5 Graduated Sanctions
Currently: Mondomo's WUA regulations define an internal gradual sanction scheme (known by all the users) that starts with a private caution, followed by a public caution; then, a penalty or fine is applied and, if none of these options works, the service is suspended. This sanction scheme is not only based on secure payment but includes social activities and collective work related to the maintenance of the aqueduct. There are also social sanctions.
After policy changes: Sanctions might be established by external officials not accountable to users and principally based on secure payment.
6 Conflict-Resolution Mechanisms
Currently: Mondomo's WUA has local well-established conciliation and bargaining protocols based on social values (e.g., high reciprocity) and accessible to all users, which helps to low-cost conflict solving. Quite rarely, conflicts among users are managed by national authorities (Superintendent of Public Services).
After policy changes: Conflicts might be negotiated and arbitrated by national-level institutions that are costly and difficult to access for users.
7 Minimal Recognition of Rights to Organize
Currently: Mondomo's WUA have de facto (users and non-users accept the existence and rules of WUA) and de jure (nationally recognised as public service provider association) rights to devise their own institutions and its organizational structure and functioning are clearly recognized by national and regional environmental authorities.
After policy changes: Traditional de jure water rights recognized as belonging to Mondomo's WUA might be transferred to new users and agencies. Internal decisions might not be recognised by the authorities.
8 Nested Enterprises
Currently: Mondomo's WUA is organized in multiple layers of nested enterprises with horizontal (its role exceeds water management and external authorities rely on it to implement different health, education and investment programs at local level) and vertical links (it belongs to AQUACOL, a second-tier organization, and to an aggrupation of regional WUAs).
After policy changes: They will continue participating in different vertical activities and organizations, but users fear they could lose independence and autonomy for horizontal links when other actors enter the scene.

The coding values and the Krippendorff alpha test for intercoder reliability, can be consulted in Supplementary Materials Tables S1 and S2. Results showed that the agreement between coders is higher for the situation after policy change (Krippendorff alfa = 0.490 and 0.829, respectively), but, in both cases, the percentage of agreement (0.88 and 0.96, respectively) is higher than the percentage of agreement by chance (0.77 and 0.79, respectively) at p-value < 0.05.

Figure 3 depicts how the scores change between the actual and the potential future situations. In the actual situation, all DPs except 2A score 0.8 or 1 on membership. However, the situation might dramatically change with the new legal and policy frameworks, leading to a general decrease in the membership scores of most DPs.

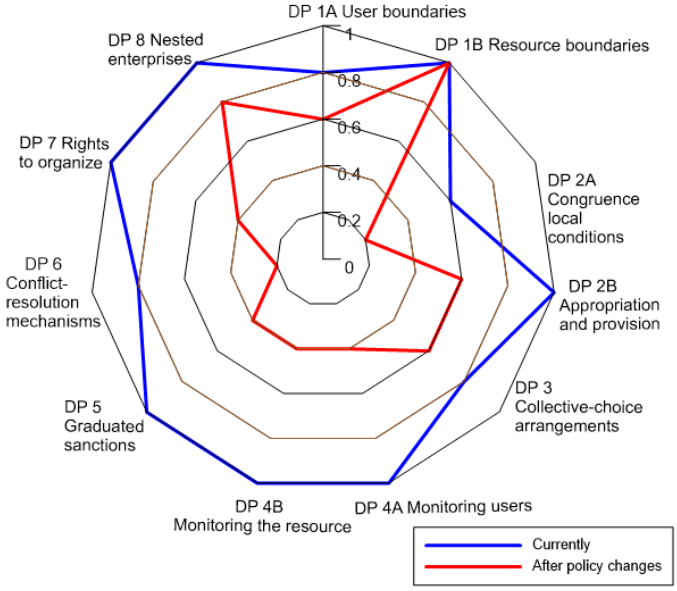

Figure 3. DPs scores in the actual situation and after policy changes.

5. Discussion

5.1. Considering DPs as Fuzzy Sets Methodological Contributions

DPs are configurations of rules that support the emergence of effective governance [51] and one of the primary methodologies within the literature to analyse CPR governance. However, the method has received several critiques: (1) the problems to measure outcomes meaningfully and reliably [52,53]; (2) the measurement validity, especially with small samples [54]; (3) the difficulties to unpack causal complexity in qualitative work [55]; and (4) the lack of comparability between case studies [52,56].

Considering DPs as fuzzy sets can contribute to theory building by addressing some of them. The experience documented illustrates that approaching them as fuzzy sets allows a fine-grained definition [25] of these rules and avoids the simplification of considering the DP as simply present or absent. These rules can be present at a certain level or can be better developed in some systems than in others. The proposed categories establish a protocol to identify features that should be present in each of the DPs, support methodological transparency, help to systematically code the DPs in categories according to the extent to which these rules are present, and as such, impose consistency and reliability on the data collection, and facilitate comparisons and replicability of the findings [45].

Further, the categories proposed can help researchers to explore which combinations of rules are present for each membership score and create opportunities to identify the necessary steps toward sustainable governance models.

Finally, the visualization using a spider web diagram gives a quick insight of the situation (in our case of the initial and final ones). This graphical representation immediately communicates the DPs in need of attention. In the analysed case study, the tool and results can support Colombia WUAs in their discussions with policymakers of the draft regulation to preserve the rights to the Community-Based Management of Water [19,35]. The results provide evidences on how the policy regulations and actions might (unintendedly) hamper highly empowered local governance systems (as represented by many WUAs in Colombia), and negatively affect long-lasting, effective collective-choice rules, and monitoring and sanctioning processes [57]. Its use might assist communities, decision makers and politicians in creating awareness and setting priorities for action, and CPR users to identify the shortcomings of their governance system.

5.2. A Long-Lasting Governance System in Danger

DPs cannot be conceived as a protocol for successful management or as a panacea; rather, they are a first diagnostic tool to determine the "health" of the governance of a CPR [16]; further, not all DPs need to be present in successful governance systems, and the non-existence of some of them should not be considered a governance failure. From Figure 3 we deduce that the actual governance system of Mondomo's WUA can be considered healthy and robust [16], based on ecologically sustainable management of water [58] and lacking important conflicts [59], as most DPs scored close to 1. Mondomo's governance system, based on collective management and values such as trust, reciprocity and social cohesion, provides water for households and livelihoods at a social price that, in turn, covers the costs of the service and generates surplus. Further, it protects the sources of water and conforms to a social patrimony [20].

However, the new policy challenges this effective governance system. Some DPs (1A, 1B, 3, and 8) only change slightly, but others undergo moderate (2A and 2B) or intense changes (4A, 4B, 5, 6, and 7). Furthermore, the changes in the scores of six DPs (2A, 4A, 4B, 5, 6 and 7) place them below the crossover point for membership, which might introduce important pressures into the actual governance system.

Both DP2s decrease but DP-2A (congruence with local conditions) shifts to "more out than in" scores. Hence, the local rules based on solidarity (different water prices according to the household's socioeconomic status), self-organization to solve water problems and local cultural understanding of the value of water [60] lose relevance. External standardized rules not recognizing the social value of water nor its role in the community living standards can be imposed. Further, access and entitlements to water security are mediated by institutions and infrastructure [61]. The potential shifts in institutions and new infrastructures for water-demanding sectors will decrease the water available to many families.

The actual situation of DP-2B (appropriation and provision) indicates the following: (1) users' involvement in management and collective work is considered fair and not excessively demanding; (2) the low tariffs derived from the technology used and the reduced distribution costs guarantee the sustainability of the system; and (3) the internal rules recognize the inputs (labour and involvement in decision making) of those users who worked on the construction of the aqueduct by establishing an entrance fee for those who did not participate. These values of genuine involvement, respect and appreciation for the governance system [62] will lose relevance if market principles regulate the appropriation and provision of the resource.

The modifications in monitoring (DP-4A and DP-4B) and sanctioning (DP5) challenge democratic water governance. The new policy reduces the WUAs power to monitor and sanction in favor of national regulation agencies, opening options to governance mismatches. These agencies are often considered inefficient, and users fear that this transfer of the monitoring process [63] might hamper water management, giving outsiders or powerful economic sectors access to water and decreasing the water allocation of current users. Further, the technology used and the community involvement provide high quality water at a low cost, with minimal use of chemicals and electricity, but the new situation will increase the costs of operation and consequently the price of water. Moreover, proximity and local relations allow the actual sanctioning system to consider the local conditions and the users' necessities before taking decisions, but the external agencies will not include these social considerations in their operational system. The power inequalities between current users and external agencies will decrease the capacity of the former to access the resource [15]. Some rights, such as the rights to make transparent, equitable and evidence-based choices, can be lost by the local community as found by Pahl-Wostl et al. [64].

Conflicts (DP6) are actually managed by the WUA's board members. The democratic methods used for settling differences [60] solve conflicts effectively. Boards are composed of neighbors who are generally aware of each other's realities and problems, as well as those of the community. Although this does not preclude the existence of disagreement, it does enhance the Mondomo's WUA's ability

to manage conflicts. The transfer of these powers to external agencies will dramatically erode this capacity, challenging the traditional values that characterized the relations among users and increasing the costs (time, money, accessibility) of solving them [65].

The dramatic change in the DP7 (recognition of rights to organize) score shows how the new policy regulations might challenge the current governance institutions. They are based on the periodic renewal of authority, the non-partisan nature of the WUA, and the awareness of community history. Community leaders have a strong sense of commitment and dedicate significant efforts, free of charge, to ensuring the WUA's functioning [60]. The new regulation introduces the option to create new institutions based on market criteria and payment capacity, without considering the existing local social principles. Users fear that corruption practices could transfer power from the WUA to other actors and that operational management results will be more inefficient and expensive [63].

However, DPs do not just occur together, they interact to produce outcomes [59]. Not only the number of DPs present, but the configurations of DPs determine the success of the collective action [59]. These configurations differ according to the mobility of the resource and the intensity of the human-made infrastructure necessary for its management. In systems with high intensity of hard human-made infrastructure and high mobility, such as water provision and distribution systems, the combination of principles leading to successful governance are 1A (clearly defined social boundaries), 2A and 2B (congruence of rules and benefits), 5 (graduated sanctions) and 4A and 4B (monitoring of users and resources) [59].

All these principles suffer important reductions in membership in the new scenario; moreover, four of them (2A, 4A, 4B, and 5) shift to a "more out than in" score. The new regulation's failure to recognize the customary rights of Mondomo's users might lead to governance mismatches [66] and affect not only water security but also the social fabric articulated around Mondomo's WUA. This WUA faces the possibility that the actual local privatization of water by the aqueduct users might shift to what Araral [54] describes as an externally imposed privatization of local commons. Users might be frustrated by the difficulty of making decisions in mixed arenas subject to cognitive mismatch and power plays [67] and by the little recognition at national and regional scales of WUA's important contribution to water access and other basic services for the population [23].

6. Conclusions

Considering DPs as fuzzy sets open new avenues for CPR governance research. It addresses some of the problems of homogenizing different real situations and work with imprecise categories, and introduce more possibilities to compare situations. We are cautious to affirm that the proposed categories have to be the final ones and we cannot conclude on external validity [68], since we only tested the method in one case study. We propose a starting point to the scholarly community; the future testing of the method in a bigger number of case studies will permit to refine them and to be more categorical about their validity.

The new water regulation intends to increase the quality and access to water in rural areas, but, policymakers should not implement one-size-fits-all approaches that might led to the fading of long-lasting place-based governance approaches like those represented by many Colombia WUAs. The shift in the DPs highlights common dilemmas in CPR management and how the multi-level context and power asymmetries affect community-based management. As repeatedly noted by Ostrom, institutional arrangements are costly [16,29,69]. Mondomo's users have made long-term investments in creating their institutional arrangements. As a result, they have a locally managed water governance system that is sustainable, efficient, democratic, adapted to local needs and provides water at a low cost. Further, the system is part of a social patrimony that strengthens the social fabric, local empowerment and the sustainable management not only of water but also of most local needs. The new policy should adapt to ensure the safeguarding of these democratic governance systems.

As has been discussed throughout this manuscript, the above-mentioned threats might or might not materialize. It will depend on how the policy is implemented in each place. We hopefully expect

that the results of this analysis will be considered by the Colombian authorities to guarantee that the new legal framework does not destroy something that works. We also hope that these results will be of interest for other WUAs and support them in getting approved a specific water regulation that recognise their role and preserve these democratic water governance systems.

Supplementary Materials: The following are available online at www.mdpi.com/2073-4441/9/7/535/s1, Text S1: List of documents used for coding the DPs, Table S1: Coding values, Table S2: Interrater reliability with Krippendorff.

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References

1. Nations, U. *Transforming Our World: The 2030 Agenda for Sustainable Development*; United Nations, Department of Economic and Social Affairs: New York, NY, USA, 2015.
2. WWAP. *Water and Jobs*; United Nations World Water Assessment Programme: Paris, France, 2016.
3. WWAP. *The United Nations World Water Devemlopment Report 4: Managing Water Under Uncertainty and Risk*; United Nations World Water Assessment Programme: Paris, France, 2014.
4. Patsy, H. *Collaborative Planning: Shaping Places in Fragmented Societies*; Palgrave: New York, NY, USA, 1997.
5. Kooiman, J. *Governing as Governance*; Sage Publishing: London, UK, 2003.
6. Türke, R.-E. *Governance: Systemic Foundation and Framework*; Springer: Berlin, Germany, 2008.
7. Agrawal, A. Common property institutions and sustainable governance of resources. *World Dev.* **2001**, *29*, 24. [CrossRef]
8. Agrawal, A.; Chhatre, A.; Hardin, R. Changing governance of the world's forests. *Science* **2008**, *320*, 3. [CrossRef] [PubMed]
9. Moore, P.; Zhang, X.; Triraganon, R. *Natural Resource Governance. Trainers´ Manual*; IUCN, RECOFTC, SNV: Bangkok, Thailand, 2011.
10. Reichert, P.; Langhans, S.D.; Lienert, J.; Schuwirth, N. The conceptual foundation of environmental decision support. *J. Environ. Manag.* **2015**, *154*, 316–332. [CrossRef] [PubMed]
11. Bandura, A. *Social Learning Theory*; General Learning Press: New York, NY, USA, 1977.
12. Portes, A. Social capital: Its origins and applications in modern sociology. *Annu. Rev. Sociol.* **1998**, *24*, 1–24. [CrossRef]
13. Franks, T.; Cleaver, F. Water governance and poverty: A framework for analysis. *Prog. Dev. Stud.* **2007**, *7*. [CrossRef]
14. Acreman, M.; Harding, R.; Lloyd, C.; McNamara, N.; Mountford, J.; Mould, D.; Purse, B.; Heard, M.; Stratford, C.; Dury, S. Trade-off in ecosystem services of the Somerset Levels and Moors wetlands. *Hydrol. Sci. J.* **2011**, *56*, 1543–1565. [CrossRef]
15. Komakech, H.C.; Van Der Zaag, P.; Van Koppen, B. The last will be first: Water transfers from agriculture to cities in the Pangani river basin, Tanzania. *Water Altern.* **2012**, *5*, 700.
16. Ostrom, E. *Governing the Commons: The Evolution of Institutions for Collective Action*; Cambridge University Press: New York, NY, USA, 1990.
17. Ostrom, E. Common-pool resources and institutions: Toward a revised theory. In *Handbook Of Agricultural Economics*; Gardner, B., Rausser, G., Eds.; Elsevier Science: Amsterdam, The Netherlands, 2002; pp. 1315–1339.
18. Avina, F. Modelos de Gobernabilidad Democrática para el Acceso al Agua en América Latina. Available online: http://www.avina.net/ (accessed on 14 July 2017).

19. CONPES. *Política Para el Suministro de Agua Potable y Saneamiento Básico en la Zona Rural*; Social, C.N.d.P.E.y., Ed.; Departamento Nacional de Planeación: Bogotá, Colombia, 2014; Volume 3810, p. 46. (In Spanish)
20. Cadavid, N. Acueductos comunitarios: Patrimonio social y ambiental del Valle de Aburrá. *Av. Recur. Hidrául.* **2009**, *20*, 57–64.
21. Superservicios. Informe Sectorial. Acueducto y Alcantarillado. Available online: http://www.superservicios.gov.co/content/download/8257/70149 (accessed on 14 July 2017). (In Spanish)
22. Castro, J.E. Water governance in the twentieth-first century. *Ambient. Soc.* **2007**, *10*, 97–118. [CrossRef]
23. Dupuits, É.; Bernal, A. Scaling-up water community organizations: The role of inter-communities networks in multi-level water governance. *Flux* **2015**, *1*, 19–31.
24. Llano-Arias, V. Community knowledge sharing and co-production of water services: Two cases of community aqueduct associations in Colombia. *Water Altern.* **2015**, *8*, 77–98.
25. Ragin, C.C. *Fuzzy-Set Social Science*; The University of Chicago Press: Chicago, IL, USA, 2000.
26. Ostrom, E.; Levin, S.A. Governance and Institutions. In *The Princeton Guide to Ecology*; Princeton University Press: Princeton, NJ, USA, 2009.
27. Anderies, J.M.; Janssen, M.A. *Sustaining the Commons*; Center for the Study of Institutional Diversity: Arizona, AZ, USA, 2013.
28. Ostrom, E.; Gardner, R.; Walker, J. *Rules, Games and Common-Poll Resources*; University of Michigan Press: Ann Arbor, MI, USA, 1994.
29. Ostrom, E. *Understanding Institutional Diversity*; Princeton University Press: Princeton, NJ, USA, 2005.
30. Cox, M.; Arnold, G.; Tomás, S.V. A review of design principles for community-based natural resource management. *Ecol. Soc.* **2010**, *15*, 17. [CrossRef]
31. Klir, G.; Yuan, B. *Fuzzy Sets and Fuzzy Logic*; Prentice hall New Jersey: Upper Saddle River, NJ, USA, 1995.
32. Ragin, C.C.; Pennings, P. Fuzzy sets and social research. *Sociol. Methods Res.* **2005**, *33*, 423–430. [CrossRef]
33. Ministerio de Vivienda, C.y.T. *Esquemas Diferenciales Para la Prestación de los Servicios de Acueducto, Alcantarillado y Aseo en Zonas Rurales*; Ministerio de Vivienda, Ciudad y Territorio: Bogotá, Colombia, 2016; Volume 1898. (In Spanish)
34. Lasso, E. *Los Retos y Perspectivas de la Gestión Comunitaria del Agua: El Caso del Acueducto Comunitario del Corregimiento de Mondomo*; Municipio de Santander de Quilichao: Cauca, Colombia; Pontificia Universidad Javeriana: Bogotá, Colombia, 2017. (In Spanish)
35. Colombia., R.N.d.A.C. *Proyecto de Ley "Por Medio del Cual se Consagra el Derecho a la Autogestión Comunitaria del Agua, su Uso Individual, Colectivo y se Dictan Otras Disposiciones"*; Red Nacional de Acueductos Comunitarios: Bogotá, Colombia, 2017; p. 21. (In Spanish)
36. Carrasco, W. Estado del arte del agua y saneamiento rural en Colombia. *Rev. Ing.* **2016**, *44*, 8. (In Spanish)
37. García, M.; Peña, M.; Toro, A.F.; Vargas, J.; Cerón, V.A.; Tamayo, S.; Mena, E.; Orjuela, V.; Morales, D.; Bolaños, S.; et al. Community-based water associations in Colombia´s rural areas. *WATERLAT-GOBACIT Work. Pap.* **2015**, *2*, 111.
38. Castro, J.E. *Socio-Technical Solutions for the Provision of Safe WSS in Vulnerable Communities: A Synthesis*; DESAFIO´s project: Newcastle upon Tyne, UK, 2015.
39. Valle, U.D. Mondomo: Una Comunidad, un acueducto. In *Democratisation of Water and Sanitation Governance by Means of Socio-Technical Innovation*; Gobacit, W., Ed.; DESAFIO´s project: Cali, Colombia, 2015.
40. Valle, U.D. *Informe de Estudio de Caso. Gestión Comunitaria del Agua Rural en Colombia y Asociatividad Comunitaria*; DESAFIO´s project: Cali, Colombia, 2014. (In Spanish)
41. Cardenas, F. Community Knowledge in Action a Path towards a Sustainable Water Access: The Case Study of AQUACOL, Colombia. Master's Thesis, Lund University, Lund, Scania, Sweden, 2012.
42. Vargas Garcia, M. Strengthening grassroots capacita with AQUACOL. *Waterlines* **2007**, *26*, 22–23. [CrossRef]
43. Smiths, S.; Tamayo, P.; Ibarra, V.; Rojas, J.; Benavides, A.; Bey, V. *Gobernanza y Sostenibilidad de los Sistemas de Agua Potable y Saneamiento Rurales en Colombia*; Banco Interamericano de Desarrollo: Bogotá, Colombia, 2012.
44. Zadeh, L.A. Fuzzy sets. *Inf. Control* **1965**, *8*, 338–353. (In Spanish) [CrossRef]
45. Ratajczyk, E.; Brady, U.; Baggio, J.A.; Barnett, A.J.; Perez-Ibarra, I.; Rollins, N.; Rubiños, C.; Shin, H.C.; Yu, D.J.; Aggarwal, R.; et al. Challenges and opportunities in coding the commons: Problems, procedures, and potential solutions in large-N comparative case studies. *Int. J. Commons* **2016**, *10*. [CrossRef]

46. Ostrom, E.; Agrawal, A.; Blomquist, W.; Schlager, E.; Tang, S.Y. CPR Coding Manual. Blomington. Indiana University. Workhsop in Political Theory and Policy Analysis. Available online: https://seslibrary.asu.edu/sites/default/files/cprcodingmanual-fullwcovercopytoc.pdf (accessed on 14 July 2017).
47. Yin, R. *Case Study Research: Design and Methods*, 3rd ed.; SAGE Publications: New York, NY, USA, 2003.
48. MacQueen, K.M.; McLellan, E.; Kay, K.; Milstein, B. Codebook development for team-based qualitative analysis. *CAM J.* **1998**, *10*, 31–36. [CrossRef]
49. Krippendorff, K. *Content Analysis: An Introduction to Its Methodology*; Sage Publishing: London, UK, 2004.
50. Mondomo, A.d.u.d.a.d. *Estatuto de la Asociación de Usuarios del Acueducto de Mondomo E.S.P.*; AUAM, Ed.; Mondomo: Cauca, Colombia, 1997; p. 10. (In Spanish)
51. Schlager, E. Introducing the "The Importance of Context, Scale, and Interdependencies in Understanding and Applying Ostrom's Design Principles for Successful Governance of the Commons". *Int. J. Commons* **2016**, *10*. [CrossRef]
52. Young, O.; Lambin, E.; Alcock, F.; Haberl, H.; Karlsson, S.; McConnell, W.; Myint, T.; Pahl-Wostl, C.; Polsky, C.; Ramakrishnan, P. A portfolio approach to analyzing complex human-environment interactions: Institutions and land change. *Ecol. Soc.* **2006**, *11*, 31. [CrossRef]
53. Agrawal, A. Studying the commons, governing common-pool resource outcomes: Some concluding thoughts. *Environ. Sci. Policy* **2014**, *36*, 86–91. [CrossRef]
54. Araral, E. Ostrom, Hardin and the commons: A critical appreciation and a revisionist view. *Environ. Sci. Policy* **2014**, *36*, 11–23. [CrossRef]
55. Cox, M.; Villamayor-Tomas, S.; Arnold, G. Design principles in commons science: A response to "Ostrom, Hardin and the commons"(Araral). *Environ. Sci. Policy* **2016**, *61*, 238–242. [CrossRef]
56. Poteete, A.R.; Janssen, M.A.; Ostrom, E. *Working Together: Collective Action, the Commons, and Multiple Methods in Practice*; Princeton University Press: Princeton, NJ, USA, 2010.
57. Tucker, C.M. Learning on governance in forest ecosystems: Lessons from recent research. *Int. J. Commons* **2010**, *4*, 687–706. [CrossRef]
58. Barnett, A.; Baggio, J.; Shin, H.; Yu, D.; Perez-Ibarra, I.; Rubiños, C.; Brady, U.; Ratajczyk, E.; Rollins, N.; Aggarwal, R. An iterative approach to case study analysis: Insights from qualitative analysis of quantitative inconsistencies. *Int.J. Commons* **2016**, *10*, 467–494. [CrossRef]
59. Baggio, J.A.; Barnett, A.J.; Perez-Ibarra, I.; Brady, U.; Ratajczyk, E.; Rollins, N.; Rubiños, C.; Shin, H.C.; Yu, D.J.; Aggarwal, R.; et al. Explaining success and failure in the commons: The configural nature of Ostrom's institutional design principles. *Int. J. Commons* **2016**, *10*. [CrossRef]
60. Ochoa, E.; Soto, L.; Burt, P. Organizaciones Comunitarias de Servicios de Agua y Saneamiento. In *Modelos de Gobernabilidad Democrática Para el Acceso al Agua en América Latina*; Avina, F., Ed.; Available online: http://www.avina.net/ (accessed on 14 July 2017).
61. Tickner, D.; Parker, H.; Moncrieff, C.R.; Oates, N.E.M.; Ludi, E.; Acreman, M. Managing Rivers for Multiple Benefits–A Coherent Approach to Research, Policy and Planning. *Front. Environ. Sci.* **2017**, *5*. [CrossRef]
62. Bakker, K.; Morinville, C. The governance dimensions of water security: A review. *Phil. Trans. R. Soc. A* **2013**, *371*, 20130116. [CrossRef] [PubMed]
63. Correa, H.D. Acueductos Comunitarios. Patrimonio Público Y Movimientos Sociales. Notas Y Preguntas Hacia Una Caracterización Social Y Política. Available online: http://www.corpenca.org/images/stories/documentos/acueductoscomunitariospatrimoniopublicomovimientossociales.pdf (accessed on 17 July 2017). (In Spanish)
64. Pahl-Wostl, C.; Conca, K.; Kramer, A.; Maestu, J.; Schmidt, F. Missing links in global water governance: A processes-oriented analysis. *Ecol. Soc.* **2013**, *18*. [CrossRef]
65. Warner, M. *Conflict Management in Community-Based Natural Resource Projects: Experiences from Fiji and Papua New Guinea*; Overseas Development Institute: London, UK, 2000.
66. Barnett, A.J.; Anderies, J.M. Weak feedbacks, governance mismatches, and the robustness of social-ecological systems: An analysis of the Southwest Nova Scotia lobster fishery with comparison to Maine. *Ecol. Soc.* **2014**, *19*. [CrossRef]
67. Devisscher, T.; Vignola, R.; Coll Besa, M.; Cronenbold, R.; Pacheco, N.; Schillinger, R.; Canedi, V.; Sandoval, C.; Gonzalez, D.; Leclerc, G. Understanding the socio-institutional context to support adaptation for future water security in forest landscapes. *Ecol. Soc.* **2016**, *21*. [CrossRef]

68. Shadish, W.R.; Cook, T.D.; Campbell, D.T. *Experimental and Quasi-Experimental Designs for Generalized Causal Inference*; Wadsworth Cengage learning: Boston, MI, USA, 2002.
69. Brondizio, E.S.; Ostrom, E.; Young, O.R. Connectivity and the governance of multilevel social-ecological systems: The role of social capital. *Annu. Rev. Environ. Resour.* **2009**, *34*, 253–278. [CrossRef]