water

MDPI

Article

Understanding the Complexity of Water Supply System Governance: A Proposal for a Methodological Framework

Fernando Gumeta-Gómez [1,*], Andrea Sáenz-Arroyo [1,2,*], Gustavo Hinojosa-Arango [3], Claudia Monzón-Alvarado [4], Maria Azahara Mesa-Jurado [5] and Dolores Molina-Rosales [6]

1 Departamento de Conservación de la Biodiversidad, El Colegio de la Frontera Sur, Unidad San Cristóbal de las Casas, Chiapas 29290, Mexico
2 Centro de Ciencias de la Complejidad (C3 UNAM), Universidad Nacional Autónoma de México, Ciudad de México 04510, Mexico
3 Cátedra CONACYT-CIIDIR Instituto Politécnico Nacional, Unidad Oaxaca, Oaxaca 71230, Mexico; ghinojosaar@conacyt.mx
4 Cátedra CONACYT-El Colegio de la Frontera Sur, Unidad Campeche, Campeche 24500, Mexico; cmonzon@ecosur.mx
5 Departamento de Ciencias de la Sustentabilidad, El Colegio de la Frontera Sur, Unidad Tabasco, Tabasco 86280, Mexico; mmesa@ecosur.mx
6 Departamento de Ciencias de la Sustentabilidad, El Colegio de la Frontera Sur, Unidad Campeche, Campeche 24500, Mexico; dmolina@ecosur.mx
* Correspondence: fernando.gumeta@estudianteposgrado.ecosur.mx (F.G.-G.); msaenz@ecosur.mx (A.S.-A.)

check for updates

Citation: Gumeta-Gómez, F.; Sáenz-Arroyo, A.; Hinojosa-Arango, G.; Monzón-Alvarado, C.; Mesa-Jurado, M.A.; Molina-Rosales, D. Understanding the Complexity of Water Supply System Governance: A Proposal for a Methodological Framework. *Water* **2021**, *13*, 2870. https://doi.org/10.3390/w13202870

Academic Editors: Athanasios Loukas and Luis Garrote

Received: 10 September 2021
Accepted: 11 October 2021
Published: 14 October 2021

Abstract: The question of how the complexity of water governance may be understood beyond a heuristic concept remains unanswered. In this paper, we propose a Water Governance Complexity Framework to address the complexity of water governance. Through a literature review, rapid surveys, and 79 semi-structured interviews, we propose how this framework may be operationalized using different proxies and by applying it to the case of the water supply system for domestic use in Oaxaca, Mexico. In places such as the rural communities of Oaxaca, where the state plays a partially absent role in the water supply, we found legal pluralism and diverse formal and informal stakeholders in a multi-level structure. At the local level, four modes of governance were identified, resulting from seven institutional change trajectories. These trajectories result from linear (alignment) and non-linear (resistance and adaptation) interactions between local, state, and national institutions over different periods. We provide a pragmatic framework to understand complexity through the organization and historical configurations of water governance that may be applied globally, providing a necessary starting point and solid foundation for the creation of new water policies and law reforms or transitions to the polycentric governance model to ensure the human right to water and sanitation.

Keywords: institutional change; nestedness; governance mode; legal pluralism

1. Introduction

Complexity analysis is an approach that is gaining strength when evaluating environmental policies [1]. In the water sector, complexity has been associated with problems such as environmental pollution, the overexploitation of aquifers, and the insufficient supply of adequate quality water to all people. This complexity results in the difficulty of fully understanding all variables that influence how these problems may be resolved [1,2]. These variables are linked to social, cultural, political, economic, technological, and environmental factors at different scales [3]. Moreover, complexity is an attribute assumed to be inherent in water governance, which is in part due to specific water-related problems [1,3,4] and the social–ecological system in which it is immersed [5–7]. Other studies have attributed complexity as a characteristic of adaptive [8] and polycentric governance models [9,10] due to their ability to incorporate uncertainty and feedback into the decision-making and water

management process. Nonetheless, we argue that water governance can be complex not only as a characteristic of an adaptative or polycentric governance model but because of the complex problems it addresses across different jurisdictional, spatial, and temporal scales.

However, in the field of water governance, there is a lack of appropriate frameworks and pertinent variables to address complexity beyond a heuristic concept. In other research areas, such as the forest, fisheries, and aquaculture sectors, the diversity of stakeholders and institutions [11], the multilevel governance structure [12], legal pluralism [13], and the nestedness of the institution [14,15] have been proposed as approximations to understand the complexity of governance. However, these approaches largely ignore local processes, fail to identify multilevel structural elements or processes that contribute to complexity, or are unable to clearly define nestedness measures by overlooking the ambiguity between what is or what is not nested. In addition, we consider that approaching complexity via a single property is short-sighted while not being fully linked to the theory of complexity. In this theory, complexity attempts to holistically and synergistically understand the outcomes based on the interactions (e.g., exchange of information, goods, services, or energy) of system components (e.g., stakeholders and institutions), the evolution of the system, and the manner in which component interactions define the structure of the system while allowing for the emergence of qualities that cannot be either predicted or controlled [16]. In this sense, the question of how the complexity of water governance may be understood in a way that allows for analyses of empirical cases remains unanswered. Understanding the complexity of water governance is relevant due to the tendencies towards water management decentralization in many countries [17–19] and the existence of a multi-level process regarding the human right to water and sanitation that operates from global to local levels [20]. The decentralization of water management and the creation of new institutions and rights (e.g., human water rights) can create legal pluralism, resulting in new or different interactions between stakeholders and institutions. Evaluations of these new interactions will provide a solid foundation to establish new water policies, reform existing laws, or transition to more desirable polycentric or adaptative governance models [14] to ensure the human right to water and sanitation.

In this study, we propose a new conceptual–methodological framework called the Water Governance Complexity Framework, which is based on some elements of the Kooiman Interactive Governance Framework [14,21,22], to understand the complexity of water governance. To illustrate this framework, we used the water supply system for domestic use in Mexico. As in many other rural and suburban locations in Latin America, the inhabitants of Oaxaca use a variety of institutional arrangements to govern the water supply system. In this study, we argue that framing the governance of this system under the lens of complexity allows for its structure and function at state and national levels to be evaluated. For this, we aimed to answer three questions: (1) How is the current governance of the water supply system for domestic use in Oaxaca, Mexico, structured, and how does it function, considering the different jurisdictional levels? (2) Over time, how have institutional changes shaped the current governance structure of the water supply system for domestic use? (3) Can the water governance for domestic use in Mexico be considered complex?

2. Materials and Methods

2.1. Building the Water Governance Complexity Framework

To develop the Water Governance Complexity Framework, we began by establishing and linking basic concepts such as water governance and complexity. Subsequently, based on the Interactive Governance Framework (IGF) [14], we structured a new conceptual–methodological framework to understand the complexity of water governance.

We adopted a water governance definition in a broad sense to avoid controversy. Thus, we define water governance as a set of interactions used to make decisions among different stakeholders and institutions with common objectives to manage water resources [23]. These different stakeholders include governments, the private sector, and civil society [24]. Meanwhile, we distinguished institutions as formal rules, laws, and norms (e.g., consti-

tutions, laws, regulations, and policies) and informal institutions as social agreements, as defined by North [25], which guide and regulate stakeholder decision making and actions. According to complexity theory, complexity is related to uncertainty and the challenges associated with predicting non-linear interactions between constantly changing entities [16]. A looser approach relates complexity to patterns and structures that are not easily describable or predictable [26]. If it is assumed that entities can be stakeholders and institutions and that the variables are their interactions (e.g., linear and non-linear) and change (e.g., institutional change), the first link is established between complexity and water governance. The second link between complexity and water governance is offered by the IGF proposed by Kooiman [14], as it considers the diversity of the governance system. A greater diversity of stakeholders and institutions may produce more dynamic and less predictable interactions between these entities. Ostrom sees the diversity of institutions as similar to that of ecological systems. In ecological systems, greater species diversity increases the structural complexity of biotic communities [27]. In ecological and economic systems, diversity helps to promote complexity and functionality [27,28]. However, diversity alone is not enough to produce complexity given that it requires that entities establish interactions and that new structures emerge as a result of those interactions [26]. These properties are vital in understanding the functionality of the system, which in our case, is water governance.

In this sense, the IGF offers a good starting point for integrating the variables of interaction, change, diversity, and complexity as properties of the stakeholders and institutions. The IGF is a relatively broad framework that addresses the *societal system*, defined as "the whole of interrelations among a given number of entities belonging to the natural and social worlds" [28]. According to the IGF, the societal system is made up of three parts that characterize it: the governing system (GS), system-to-be-governed (SG), and governing interactions (GI), in addition to the properties (i.e., *complexity*, *diversity*, *dynamics*, and scale), elements (i.e., image, instrument, and action), and orders (first- and second-order and meta-governance). The IGF mainly focuses on interactions to solve social problems and create opportunities, emphasizing interactions as its main innovation [15]. In this study, we focus on the properties of the GS in the first and second orders of governance. A full description of the other framework components can be found in Kooiman [14] and Kooiman and Bavinck [22].

Our proposal includes the following:

- The governing system encompasses the "total set of mechanisms and processes that are available for guidance, control, and steerage of the system-to-be-governed" [22].
- Properties are common concepts and measures that are used to understand the qualities of the system-to-be-governed and the governance system, such as superposition, links, interactions, and interdependencies [21]. The IGF considers diversity, dynamics, complexity, and scale as concepts, and measures commonalities.
    - Diversity is defined in terms of variation in the attributes or characteristics [26] of stakeholders and institutions [15] in the GS, SG, or GI [21]. Bavinck and Kooiman propose legal pluralism as a proxy for GS in the fisheries and aquaculture sectors [15].
    - Dynamics "create the potential for change" [15]. Bavinck and Kooiman propose institutional change as a proxy for GS in the fisheries and aquaculture sectors [15]. The principal analysis of institutional theory focuses on how stakeholders, institutions, and arrangements change over time [29]. The analysis also focuses on institutions that do not change or resist change due to stagnation, atrophy, or robustness [29].
    - Scale "represents the level at which the combined effects of diversity and dynamics can be best observed and analyzed" [21]. Following Gibson et al. [30], we clarify that scale and level are two different but related aspects. Scale refers to any dimension (e.g., spatial, temporal, and jurisdictional), and level refers to the unit of analysis in a different place on a given scale.

- Order of governance focuses on different processes.
  - First-order governance refers to the processes that deal with day-to-day problems. In this order, the stakeholders create opportunities each day [31] to solve operational problems related to supply, prices, costs, and user satisfaction. This first order of governance refers to what other authors consider to be management [32].
  - Second-order governance "focuses on the institutional arrangements within which first-order governance takes place" [21]. In this order, the institutional design and arrangement are expressed to allow, sustain, and focus governance [22]. Kooiman and Bavinck [15] consider a high-level expression of such institutional arrangements as the state, market, and civil society.

Our approach differs from the Kooiman IGF by viewing complexity as an umbrella property encompassing diversity and dynamics. Additionally, we propose incorporating nestedness as a property (Figure 1). Nestedness is a property linked to the interactions between entities (e.g., stakeholders and institutions). The importance of this property lies in analyzing the influence of the structure of the system on the behavior of the subsystem [33]. In this sense, emphasis is placed on the nestedness of the scalar property [34], which for our purposes represents a jurisdictional scalar (i.e., local, state, or national levels). We argue that considering complexity as a supra-property can help reconcile the IGF approach with the conceptualizations derived from complexity theory. Therefore, we consider scale to be a cross-sectional condition of all properties, as it is not practical to begin an analysis without clearly defining the scales or levels under observation [35].

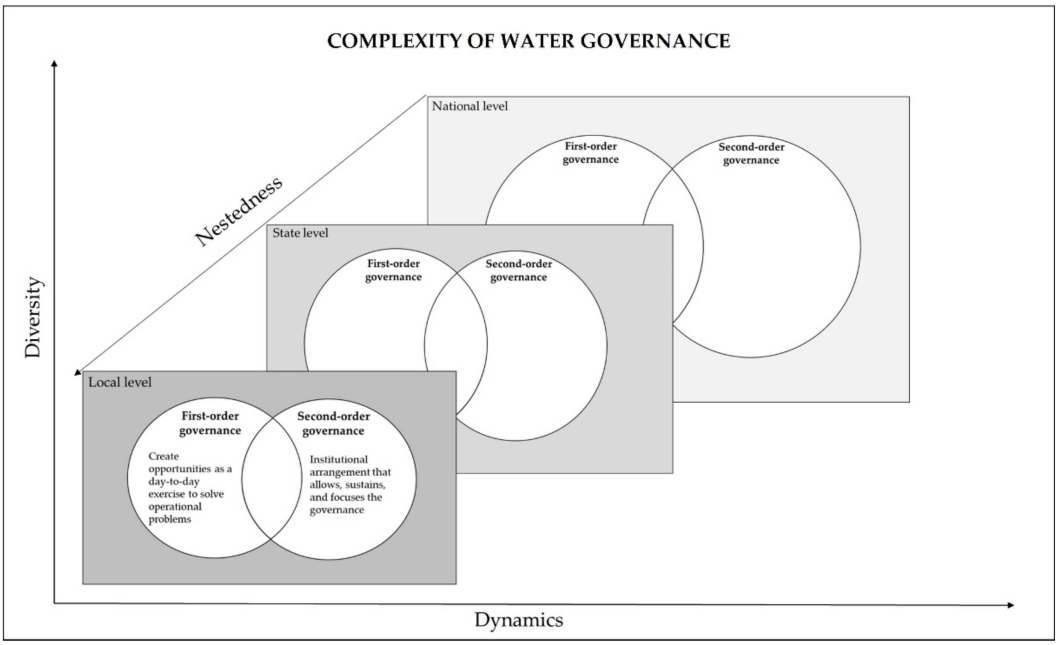

Figure 1. The Water Governance Complexity Framework proposes the analysis of diversity, nestedness, and dynamics properties in at least three levels in jurisdictional (i.e., local, state, and national) and temporal (levels are defined a posteriori according to periods of institutional change) scales in the first and second orders of governance. Source: Adapted from Kooiman and Bavinck [22].

2.2. Case Study: Water Supply System for Domestic Use in Oaxaca and Mexico

This study applies the Water Governance Complexity Framework to analyze the complexity of the governance of the water supply system for domestic use in Oaxaca and Mexico. This system refers to water obtained from freshwater resources using hydraulic infrastructure, which allows for its storage, treatment (to ensure it is suitable for human consumption), and transport (to satisfy the food, health, and hygiene needs of each house-

hold). Our analysis focuses on formal and informal stakeholders and institutions immersed or involved in managing the water supply system for domestic use to solve appropriation and provision problems [36] through jurisdictional and temporal scales.

At the national level, we reviewed the institutions, stakeholders, and institutional changes of the nineteenth, twentieth, and twenty-first centuries related to the management of the water supply system for domestic use. At the state level, we selected Oaxaca and its legislation related to water for domestic use. We chose 13 rural communities in the Mixtecan Alta region in Oaxaca (Figure 2) to explore the diversity of stakeholders and institutions, nestedness, and dynamics at the local level. In its broadest sense, we emphasize that community refers to a social unit that shares things in common, such as norms, religion, values, or identity [37]. We selected Oaxaca because the local government systems are considered unique and relatively more autonomous than those of other Mexican states [38]. The 13 rural communities selected for this study (Figure 2) are indigenous and cover different political and administrative configurations. Six communities are municipal seats (San Francisco Teopán, Santa Magdalena Jicotlan, Concepción Buenavista, Santiago Ihuitlán Plumas, San Juan de los Cues, and Santiago Tepetlapa), and seven communities are municipal agencies (El Enebro, San Miguel Aztatla, Santa Cruz Corunda, San Antonio Abad, La Mexicana, Santiago Quiotepec, and Santa Cruz Capulalpam). Municipal agencies are subdivisions of the same municipality that encompass peripheral population centers and are subordinate to the municipal seat. In the municipal seat, the municipal council is established and acts as the leading local authority in the municipality.

2.3. Operationalization, Data Collection, and Analysis

The diversity, nestedness, and dynamics of the Water Governance Complexity Framework were approached by assessing proxies for legal pluralism, formal and informal stakeholders, nestedness among jurisdictional levels, and institutional change at national and local levels, following the proposal of Kooiman [14,15,39]. We present the proxies, their operative definitions (Table 1), the methodology used to obtain data, and the implemented analyses in detail in the following subsections.

2.3.1. Diversity

This study addresses diversity through legal pluralism in managing the water supply system for domestic use. According to Tamanaha [17], a "simple" definition of legal pluralism considers the role of social actors when identifying more than one source of "law" (institutions) or normative order within a social arena. Sources of normative ordering include official legal systems (formal institutions); customary, cultural, religious, economic, functional, and community normative systems (general informal institutions according to North [25]); or even multiple legal systems, both formal and informal. According to the IGF, the result is the existence of multiple legal systems (institutions) that determine the governing system and influence the governance object [15].

To address legal pluralism and formal and informal stakeholders, we implemented a multi-level approach, which first evaluated the official legal system at national and state levels for different formal institutions that could potentially overlap or align in the management of the water supply system for domestic use. We first reviewed the Ley de Aguas Nacionales (National Water Law; LAN, acronym in Spanish). Likewise, we reviewed other laws and regulations that could influence this system. First, a search was carried out in the Political Constitution of the United Mexican States of 1917 (National Constitution) and the Political Constitution of the Free and Sovereign State of Oaxaca (State Constitution) using Nitro PDF Pro v. 12.4.0.25.9 with the Spanish keywords "agua potable", "agua para consumo humano", and "agua para uso domestico". From this search, we identified articles directly related to the management of the water supply system for domestic use. This national and state constitutional review allowed for the identification of other laws at these levels, such as:

National level

- Agrarian Law (regulates land tenure and the collective rights of the 13 selected communities);
- The General Law of Ecological Balance and Environmental Protection (LGEEPA).

State-level

- The State of Oaxaca Law for Potable Water and Sewerage;
- The State of Oaxaca Law for the Rights of Peoples and Indigenous Communities.

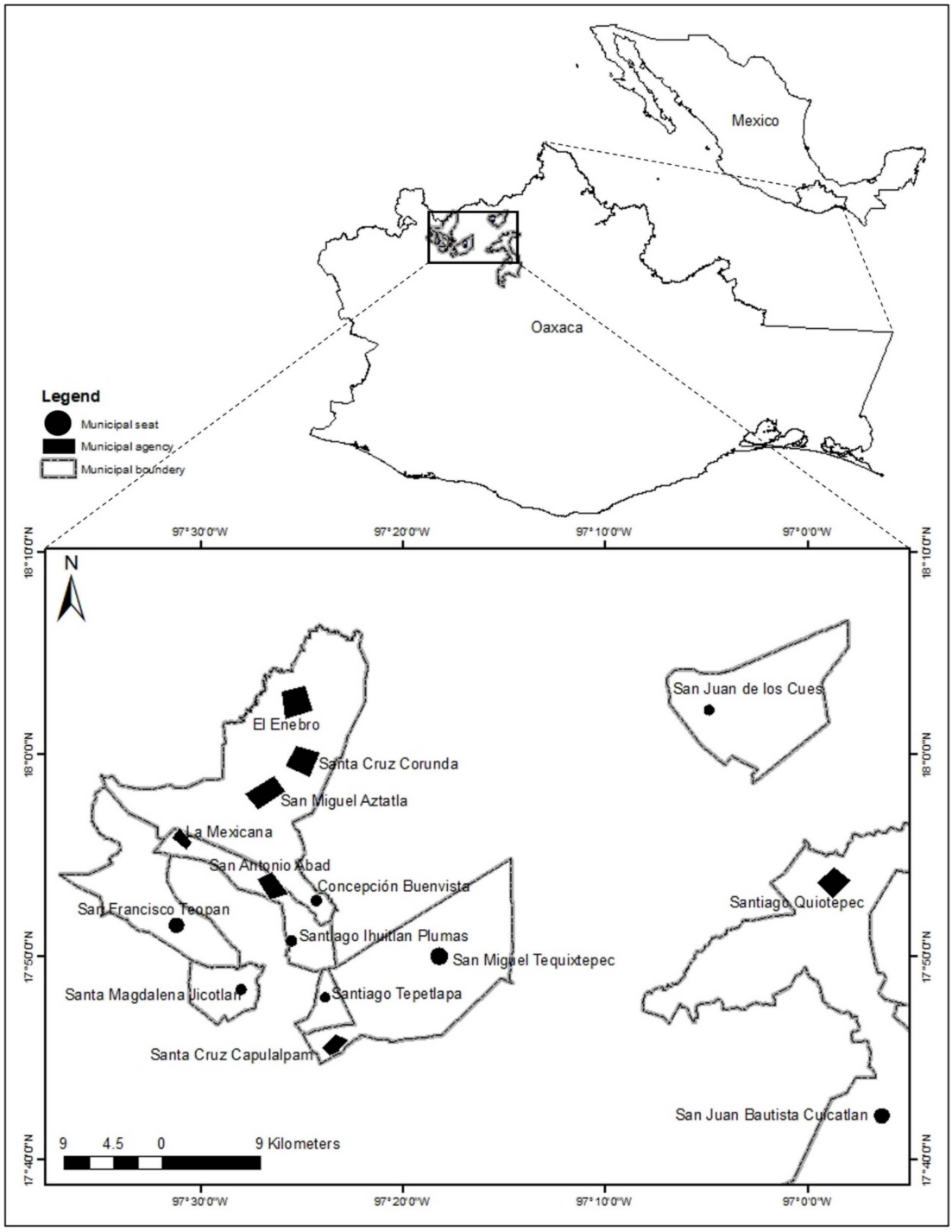

Figure 2. Macro- and micro-locations of the 13 rural communities in Oaxaca, Mexico, selected for this study. The map shows the political and administrative orders of the municipalities (dotted line), municipal seats (circles), and municipal agencies (rectangles). Municipalities are named after their municipal seats. Source: Prepared by the authors from governmental vector data.

Table 1. Operationalization of the properties that comprise the complexity of the governance of the water supply system for domestic use through the diversity, nestedness, and dynamics of the Interactive Governance Framework (IGF). Sources: Prepared by the authors based on Bavinck and Kooiman [15].

Properties	Proxies	Description
Diversity	Legal pluralism	Different formal and informal institutions (laws or regulations) that intervene in the right to administer, manage, or regulate the water supply system for domestic use
	Formal stakeholders	Stakeholders recognized by different formal institutions
	Informal stakeholders	Stakeholders not recognized by different formal institutions
Nestedness	Nestedness of formal and informal stakeholders and institutions	Interactions between different stakeholders belonging to different jurisdictional levels (municipal agency, municipality, state, and nation) in 10 different activities of the first and second orders of governance
Dynamics	Institutional change at the national level	Changes in stakeholders and institutions related to water management for domestic use at the national level during the nineteenth, twentieth, and twenty-first centuries
	Institutional change at the local level	Changes in stakeholders and institutions at the community level during the nineteenth, twentieth, and twenty-first centuries

Subsequently, we investigated the informal institutions and stakeholders involved in managing the water supply system in the 13 rural communities. A rapid survey was administered to local authorities in 2019 and consisted of four questions classified according to whether the activities corresponded to first-order (operational) or second-order governance (Table S1, Supplementary Materials).

Finally, we cross-referenced the results obtained from formal and informal institutions and stakeholders to define the structure influencing the governance of the water supply system for domestic use in Oaxaca, Mexico.

2.3.2. Nestedness

A semi-structured interview was implemented with key stakeholders within the 13 communities to obtain data on cross-level interactions among stakeholders of different jurisdictional levels. Key stakeholders included two main groups: (1) current or past hydraulic network operators and (2) officials from the municipal council or municipal agency. These stakeholder groups were identified from the rapid survey. We identified the key stakeholders following the snowball method, which identified potential interviewees and then asked them for recommendations on whom to interview later [40]. The semi-structured interview contained a matrix in which the rows represented the ten activities belonging to the first and second governance orders (Table S2, Supplementary Materials). The columns represented the stakeholders directly or indirectly responsible for the water supply system for domestic use in the studied communities. We obtained a total of 79 semi-structured interviews (La Mexicana (4), Santa Cruz Capulalpam (4), San Francisco Teopan (5), El Enebro (7), San Antonio Abad (3), Santa Cruz Corunda (3), San Miguel Aztatla (7), Santiago Quiotepec (9), Santa Magdalena Jicotlán (10), Concepción

Buenavista (12), Santiago Ihuitlan Plumas (9), San Juan de los Cues (2), and Santiago Tepetlapa (4)).

Each stakeholder was characterized according to their respective jurisdictional level (Table S3, Supplementary Materials). Subsequently, the obtained matrix was analyzed in two ways. First, we conducted a descriptive analysis of the cross-level interactions reported by the interviewees from each community. Second, we implemented a metric analysis using the Nestedness based on the Overlap and Decreasing Fill (NODF) methodology proposed by Almeida-Neto et al. [41]. Recently, NODF has been used to analyze social and commercial networks [34]. According to Almeida-Neto et al. [41], NODF is based on two simple properties, decreasing fill (DF) and paired superposition, to calculate the entire nestedness of a binary matrix.

For this reason, the first matrix obtained in the first step with binomial presence (1) and absence (0) data (Table S3, Supplementary Materials) was split into two groups: one matrix for municipal seats (Table S4, Supplementary Materials) and another for municipal agencies (Table S5, Supplementary Materials). As mentioned earlier, municipal agencies are hierarchically subordinate to the municipal seat and should hypothetically be nested. The NODF analysis was carried out with the open-source online program NeD (Nestedness for Dummies) of the Joint Research Center (http://ecosoft.alwaysdata.net/ accessed on 15 February 2021) created by Strona et al. [42]. The NeD program provides information such as the nestedness index and the probability levels after comparing the matrix under evaluation with a certain number of null matrices. According to Ulrich and Gotelli [43], the null matrices can be obtained through five different null models: EE (equiprobable row totals and equiprobable column totals), CE (proportional row totals and proportional column totals), FE (fixed row totals and equiprobable column totals), EF (equiprobable row totals and fixed column totals), and FF (fixed row and fixed column totals). The null model chosen to test nesting significance is decisive with regard to the results obtained [42].

Finally, we compared the results obtained from both approximations to generate a complete analysis of nestedness and the advantages of each approximation. A descriptive approach allowed us to obtain an overview of the results without losing detail. For its part, an approximation based on a metric NODF can help shed light on whether it is nested and to what degree it is nested, decreasing the ambiguity of the descriptive approach.

2.3.3. Dynamics

We carried out a literature review of books and scientific papers to analyze the trajectory of changes to laws, norms, and regulations or reforms such as those of the Mexican Water Law [44–50]. We also reviewed institutional changes in other laws such as those of the Agrarian Law [51]. For the analysis of institutional change at the local level, we applied three open questions in a semi-structured interview to collect retrospective information on the trajectories of the stakeholders and institutions responsible for managing the water supply system for domestic use in the 13 communities included in this study (Table S6, Supplementary Materials). For this section, we interviewed older people and recognized experts in each community who either held important positions or had experience managing water for domestic use. In the end, we compared the information obtained from the institutional changes at the national level with the institutional changes that were documented at the local level in the 13 communities studied.

The method we are proposing is summarized in Figure 3.

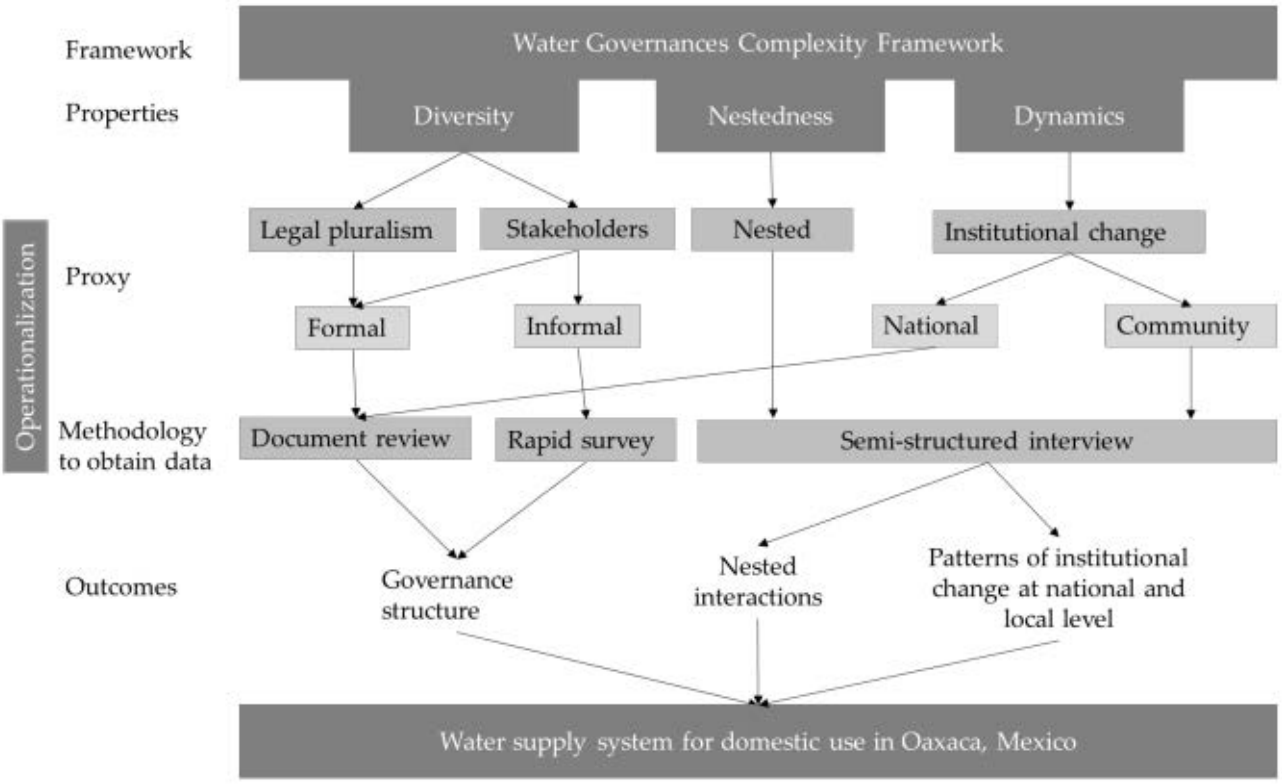

Figure 3. Scheme of the operationalization of the Water Governance Complexity Framework, the proxies used to address them, the methodology implemented to obtain data, and expected outcomes, using the case of the water supply system for domestic use in Oaxaca, Mexico.

3. Results

We present the results obtained from the proxies of the diversity, nestedness, and dynamics properties in different sections. In the last paragraph of each section, we present a cross-analysis of the different focuses and analytical approaches with which diversity, nestedness, and dynamics were evaluated. We conclude the results section with a cross-analysis of the results obtained from the different proxies of each property, integrating them through the Water Governance Complexity Framework.

3.1. Diversity

We identified multiple operating institutions or legal systems that overlapped or aligned at the local level. Plural institutions are part of the national-state legal system, as they are derived from the "supreme law" of the National Constitution, which agree with those of the Oaxaca State Constitution.

Article 27 establishes that water ownership pertains to the nation and that the nation has the right to transmit its property to individuals [52]. By declaring itself as the legitimate owner, the federal executive branch possesses all the regulating property rights of the water supply system for domestic use. However, it also establishes that:

- Landowners can extract subsoil waters and take advantage of natural outcrops within one plot. They are granted the right to access and use the water and the property right to exclude other individuals from accessing that water. However, they cannot provide water services to other individuals or populations, and landowners must first give concessions.
- Population centers that communally operate can use the water that belongs to or has been returned to the community. These centers have the right to access, use, and manage water to meet the needs of their populations and retain the right to exclude other communities from accessing their water.

The preceding statements are reaffirmed and specified in three laws derived from Article 27: The LAN of 1992 [53], the Agrarian Law of 1992 [54], and Ley General del Equilibrio Ecologico y Proteccion al Ambiente (General Law of Ecological Balance and Protection of the Environment; LGEEPA; acronym in Spanish) of 1998 [55]. The LAN is the sole law that establishes a multi-level structure for water governance. At the national level, the National Water Commission (CONAGUA; acronym in Spanish) is the autonomous and decentralized body of the Ministry of Natural Resources and the Environment (SEMARNAT; acronym in Spanish). CONAGUA is responsible for the administration, regulation, and consultation of water management in Mexico [53,56]. The LAN establishes the Watershed Council to manage Hydrological–Administrative Regions (RHAs; acronym in Spanish) at the state level.

The RHAs include groups of basins and municipal territories to facilitate the administration and integration of socioeconomic data [57]. The Watershed Council is meant to provide support and advice among CONAGUA; municipal, state, and national governments; user representatives; and civil society organizations [53]. At the local level, CONAGUA recognizes and grants access, use, and management rights to the state, municipality, non-governmental organizations (NGOs), and the private sector. Nonetheless, as the state and municipalities are considered subdivisions of the Nation-State, they do not have the right to exclude any individuals due to the recent reform to constitutional Article 4, which establishes the human right to water. In cases involving private companies and NGOs, the right of exclusion is upheld. In addition, the Agrarian Law and the LGEEPA reaffirm the rights of agrarian communities (e.g., ejidos and Bienes Comunales; article 52 of the Agrarian Law) to own water for common use for both agricultural and domestic purposes [54]. The LGEEPA also recognizes indigenous communities, which are not necessarily considered within agrarian communities. Article 15 (section XIII) of the LGEEPA establishes that the Nation-State must guarantee the rights of indigenous peoples regarding the sustainable use and exploitation of natural resources, which implicitly includes water for domestic use [55]. Although these laws are linked to Article 27, they seem to address other non-municipal social contexts, unlike the LAN. However, in the case of municipalities that are also indigenous or that have agrarian communities, these laws overlap.

Article 115 explicitly designates municipalities as responsible for the management of the water supply system for domestic use at the local level, establishing how this responsibility should be carried out in coordination with CONAGUA and the Watershed Council with regard to the planning, execution, administration, and management of national water resources [58]. This article matches those established with the LAN.

On the other hand, Article 40 of the National Constitution establishes that every Mexican state can create its constitution [52], including establishing other laws designed to regulate and manage water for domestic use. In Oaxaca, the State Law of Potable Water and Sewerage [59] establishes new stakeholders at local levels. The State Water Commission is responsible for developing the water supply system for domestic use at the state level. Article 17 recognizes municipalities and citizen water committees as stakeholders at the local level if no municipal operations agency is present. The water committee can promote the construction, conservation, maintenance, rehabilitation, and operation of its water, piped water, and sewer systems [59]. In this case, state water law in municipalities aligns with Article 115 and the LAN. However, with water committees, both national laws overlap with state law.

Article 2 of the National Constitution stipulates that each state is responsible for formulating and promoting its laws regarding the rights of indigenous peoples and communities. In the case of Oaxaca, the law of the Rights of Indigenous Peoples and Communities [59] recognizes their social, cultural, religious, political, and self-determination rights. In this sense, the self-determination rights of indigenous community stakeholders that manage water for domestic use are recognized. This state law matches with the LGEEPA and Agrarian Law but overlaps with the LAN and Article 115 of the National Constitution in indigenous municipalities. It should be mentioned that because indigenous communities

have the right to self-determination, in addition to the property rights to access, use, and manage water, the right to exclusion may also be included (e.g., if indigenous institutions consider suspending the water service as a sanction for any fault).

In addition, we identified two informal stakeholders not established by the existing national and state institutions through the surveys conducted in the 13 communities selected for this study (Table 2): the municipal agent (in 53% of the studied communities) and the assembly of water users (in 76.9% of the studied communities).

Table 2. Stakeholders identified by the survey administered in the 13 rural communities. The questions correspond to the first (operability) and second (institutional arrangement) orders of the Interactive Governance Framework (IGF) [14]. NP = no payment for water services, MA = municipal agent, WC = water committee, MC = municipal council, WUA = water users assembly.

Communities	Responsible for Managing the Water Supply System for Domestic Use	Decision Makers for Domestic Water Issues	Recipients of Payments for the Domestic Water Service	Decision Makers for the Money Collected from Payments to the Water Supply Service
La Mexicana	MA	WUA	NP	NP
Santa Cruz Capulalpam	MA	WUA	NP	NP
San Francisco Teopán	WC	WUA	NP	NP
El Enebro	MA	WUA	NP	WUA
San Antonio Abad	WC	WUA	WC	WUA
Santa Cruz Corunda	MA	WUA	WC	MA
San Miguel Aztatla	WC	WUA	WC	WC
Santiago Quiotepec	WC	WUA	WC	WC
Santa Magdalena Jicotlán	MC	WUA	MC	MC
Concepción Buenavista	MC	WUA	MC	MC
Santiago Ihuitlan Plumas	MC	MC	MC	MC
San Juan de los Cues	MC	MC	MC	MC
Santiago Tepetlapa	MC	MC	MC	MC

The information obtained from these formal national and state institutions with local impacts was complemented with information obtained in the field regarding informal stakeholders. This information was used to identify the multi-level structure of the institutions and stakeholders immersed in water governance in Oaxaca and Mexico (Figure 4).

3.2. Nestedness

Four municipal seats reported cross-level interactions with stakeholders from the two highest jurisdictional levels of the state (except Santiago Tepetlapa) and nation. Conversely, among eight municipal agencies in which the municipal agent or water committee was responsible for the water supply system for domestic use, San Antonio Abad, Santa Cruz Corunda, and El Enebro did not report interactions with any stakeholder at higher jurisdictional levels (i.e., the state level), nor did San Antonio Abad with stakeholders at the national level (Figure 5b). Reports of interactions between San Antonio Abad, San Miguel Aztatla, and Santiago Quiotepec with their municipalities (e.g., Santiago Ihuitlan Plumas, Concepción Buenavista, and San Juan Bautista Cuicatlan, respectively) were low (21–40%). A similar situation was present in the interactions reported between La Mexicana and Santa Cruz Corunda with stakeholders at the national jurisdictional level (21–40%), such as CONAGUA. The four municipal seats mainly presented interactions with the national jurisdictional level, which was recognized through interviews (81–100%, Figure 5a). In the ten activities analyzed, it should be noted that the 13 communities in this study reported

interactions with the assembly of water users with regard to decision making. Likewise, the commissariat of communal and ejidal assets (agrarian council) as well as migrant users, either individually or in an organized manner (directive), were reported as stakeholders involved in the first order of governance of the water supply system for domestic use in all communities (Table 3).

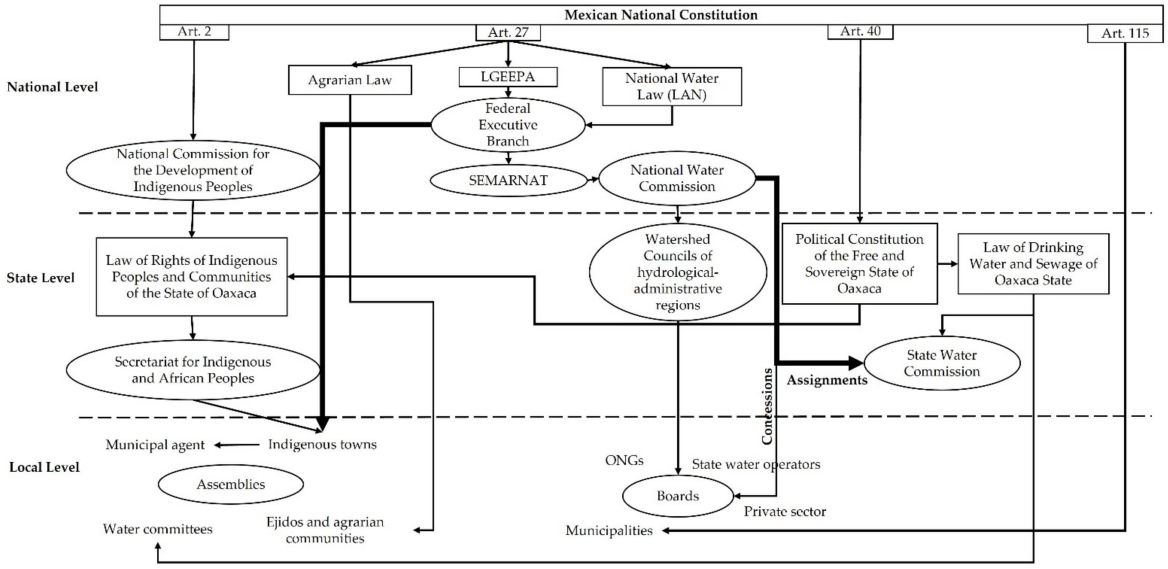

Figure 4. The multi-level structure of the governance of the water supply system for domestic use in Mexico. The squares and circles refer to the laws (institutions) and stakeholders (circles), respectively. Arrow thickness only serves to differentiate among arrows when they intersect. LGEEPA: Ley General del Equilibrio Ecologico y la Protección al Ambiente. SEMARNAT: Secretaria del Medio Ambiente y Recursos Naturales. Adapted from: Gumeta-Gómez et al. [60].

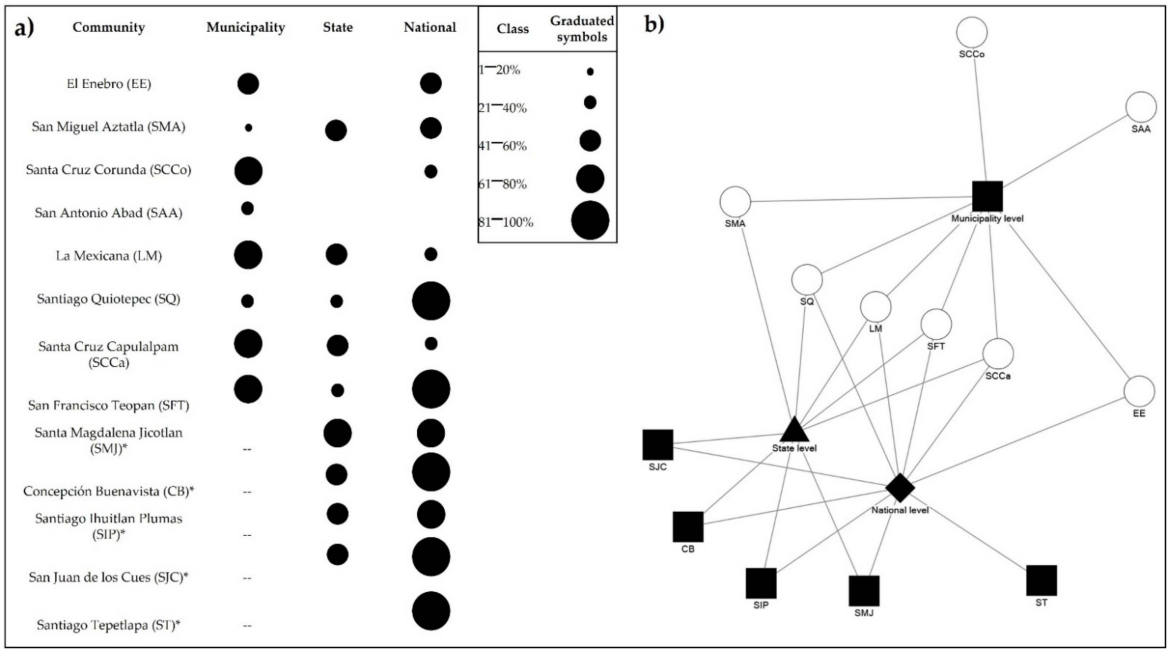

Figure 5. (**a**) Percentage of interviewees from each community who mentioned some interaction with the different stakeholders belonging to higher jurisdictional levels. Communities marked with an asterisk (*) are municipal seats that cannot be nested within themselves, so interactions at the municipal level were not considered. (**b**) Interaction scheme of the 13 communities studied with other actors at higher jurisdictional levels: municipal (square), state (triangle), and national (diamond). The communities where a municipal agent or a water committee administers the water supply system for domestic use are shown in a circle and the municipalities in squares. Abbreviation definitions can be found in (**a**).

Table 3. Interactions between actors at the local level within the 13 studied communities. The commissariat of communal or ejidal assets corresponds to those responsible for the ejido agrarian territory or agrarian community with collective land tenure. * Stakeholder responsible for the operation of the water supply system for domestic use in the community.

Community Level	Municipality	Municipal Agent	Water Committee	Commissariat of Communal Assets	Commissariat of Ejidal Assets	Assembly of Water Users	Migrant Water Users	Migrant Water Users Directive	Neighboring Municipality	Tourism Committee
La Mexicana	x	*		x		x		x		
Santa Cruz Capulalpam	x	*		x		x	x			
San Francisco Teopan	x		*	x		x	x			
El Enebro	x	*		x	x	x		x		
San Antonio Abad	x	x	*	x		x	x			
Santa Cruz Corunda	x	*		x	x	x	x			
San Miguel Aztatla	x	x	*	x	x	x		x	x	
Santiago Quiotepec	x	x	*	x	x	x	x			x
Santa Magdalena Jicotlan	*			x		x	x			
Concepción Buenavista	*			x		x		x		
Santiago Ihuitlan Plumas	*			x		x	x			
San Juan de los Cues	*	x		x		x				
Santiago Tepetlapa	*			x	x	x		x		

We did not observe significant nestedness in the results of the NeD analysis (Z = 0.538, $p > 0.05$) in any of the null models for the communities in which water committees were present or in which the municipal agent was responsible for the water supply system for domestic use (Table 4). However, in communities that are municipal seats, we obtained a significant nestedness value of 66.66 ($p > 0.001$) with the state and national levels. This result was consistent in all the null models (EE, CE, FE, FF, and EF). In all analyses of both community matrices, we used 50 random null matrices when calculating the Z value.

All municipal seats present cross-level interactions at the national level and to a lesser extent at the state level, which could explain the significant nestedness found with the NODF metric. In the case of the municipal agencies, half of them did not report cross-level interactions or only reported cross-level interactions with a single level (e.g., state or national), which could explain the non-nestedness of the group. However, we may consider that Santiago Quiotepec, La Mexicana, San Francisco Teopan, and Santa Cruz Capulalpam are nested or at least show a degree of nestedness, as they present cross-level interactions with the state and national jurisdictional levels.

Table 4. Nestedness results obtained with the Nestedness based on Overlap and Decreasing Fill (NODF) algorithm in the Nestedness for Dummies (NeD) online software for two groups: (1) communities in which water committees and municipal agents are responsible for supplying the water for domestic use and (2) municipal seats in which the municipality is responsible.

	Metrics	NODF_Total	NODF_Fill	NODF_Col
Water committee/municipal agent [1]	Index	64.516	60.714	83.33
	Z-Score	0.906	0.927	0.538
	RN	0.095	0.066	0.203
	Nested?	No [3]	No [3]	No [3]
Municipalities [2]	Index	46.154	40	66.66
	Z-Score	10825960642	NA (std = 0)	11728124031
	RN	0	0	0
	Nested?	Yes	NA (std = 0)	Yes [4]

[1] Communities with a water committee or municipal agent: Enebro, San Miguel Aztatla, Santa Cruz Corunda, San Antonio Abad, Santa Cruz Capulalpam, Santiago Quiotepec, La Mexicana, and San Francisco Teopan. [2] Municipalities: Santa Magdalena Jicotlan, Concepción Buena Vista, Santiago Ihiutlan Plumas, San Juan de Los Cues, and Santiago Tepetlapa. [3] $p > 0.05$. [4] $p > 0.001$. NODF_FILL: Nestedness of the fill. NODF COL: Nestedness of the column. NA: Not applicable.

3.3. Dynamics

We identified institutional changes in the Mexican water sector that determined the prevalence of one stakeholder over another in different periods, the creation or emergence of new institutional arrangements, or the formalization of existing stakeholders (recognition in written laws) in post-revolutionary Mexico (nineteenth, twentieth, and twenty-first centuries). These institutional changes in water governance in Mexico were framed in three periods: (1) pre-centralization, (2) centralization, and (3) decentralization [45–47] (Figure 5).

During the pre-centralization period at the beginning of the nineteenth century, colonial heritage prevailed, and water governance was considered a local matter to be handled between municipal governments, state governments, and individuals. The Mercedes (i.e., sanctioned use over a stream or spring), ordinances (i.e., the distribution of water to citizens by judges), and repartimiento (i.e., legal framework of the Repartimiento de Aguas established by the Spanish Crown in 1560) were recognized in the first Constitution of 1857. Article 27 of the National Constitution of 1857 guaranteed that the Mexican nation had to preserve property rights, including those over the water in rivers and springs [61].

The first law that gave the Federal Executive Branch control over rivers, canals, and navigable water bodies was the Ley de Vias Generales de Comunicación of 1888 [46]. However, its role regarding the ownership of national waters remained ambiguous [61]. For Rolland and Vega [48], the centralization process began with the first Ley de Aprovechamiento de Aguas de Jurisdicción Federal in 1910. This law established the Federal Executive Branch as the sole owner of all national waters. Centralization could be associated with the economic, social, and political power of controlling the water [60] and with the new technologies related to water use, health and hygiene, and distribution [62]. According to Escobar [50], municipal councils and states began to lose control over their waters with this law, as power was concentrated within a single national stakeholder. With the National Constitution of 1917, changes in water governance were introduced in article 27. These changes gave the federal government the power to issue laws regulating national waters and collect a tax for their concessions [61]. The creation of the Secretariat of Hydraulic Resources (SHR) in 1948 and the issuance of the Regulation of the Federal Drinking Water Boards in 1949 executed the transfer of municipal or state control of the water supply system for domestic use to the federal government through the Federal Water Boards (FWB) in the case of large cities, or Local Water Boards (LWB) in municipalities [62]. An LWB was made up of a municipal council member, town users, and a state government rep-

resentative who reported to the federal government [63]. During federalization, most hydraulic infrastructure investments were made to bring water from sources (e.g., springs, wells, rivers, and lakes) to homes and were implemented by the now extinct Secretary of Hydraulic Resources [64]. The decentralization process began in 1980, when the federal government handed all drinking water and sewage systems that it managed and operated through the FWB and LWB over to state or municipal governments [63]. The federal government intended to partly correct the regional development imbalances caused during the centralization period [47], retaining the role of establishing regulations and the right of alienation by controlling water concessions [48]. The states created different operating bodies of the water supply system for domestic use within municipalities [62]. In many cases, control was strictly passed on to the municipality, and in others, the state maintained a water board model, creating State Water Boards (SWB) with broad collaboration from the municipal councils [63]. With the reform of article 115 in 1983, the responsibility of the water supply system was transferred solely to the municipalities [47]. Later, the Water Law reform of 1992 that established the decentralization process was reaffirmed by The North American Free Trade Agreement (NAFTA) in 1994. This change allowed municipal authorities to grant licenses to private companies to supply water for domestic use. These licenses were granted in Mexico City, Cancun, Navojoa, Aguascalientes, and Puebla [45,65].

Parallel to the institutional changes regarding water at the national level, other national laws or reforms were also created by the end of the twentieth century, including LGEEPA in 1986 and constitutional reforms to Article 2 that recognized the inalienable rights of indigenous peoples in 1992, such as rights to natural resources (e.g., water) within their lands.

At the local level, 70 interviewees did not remember or mention institutional changes regarding the management of the water supply system for domestic use in their communities. Notably, in the communities of La Mexicana, Santa Cruz Capulalpam, San Francisco Teopan, El Enebro, San Antonio Abad, Santa Cruz Corunda, San Miguel Aztatla, and Santiago Quiotepec, the interviewees mentioned that "it has always been like this," indicating that the stakeholder currently managing the water had done so for as long as they could remember. For example, a 55-year-old municipal agent of San Miguel Aztatla said that "the water committee has been working for more than 100 years in our community [. . .], according to their uses and customs" (i.e., indigenous institution).

Only nine interviewees provided relevant information that could be used to trace the trajectories of institutional changes within their communities, neighboring communities, and the Mixtecan Alta region. The nine interviewees were between the ages of 37 and 85 years old (Table 5). Based on their responses, we can identify the presence of the Papaloapan Commission (PC) between 1954 and 1979 in the Mixteca Alta region. Another stakeholder is the State Water Board (SWB) that controls the provisioning system in Concepción Buenavista, Santiago Ihuitlan Plumas, and other municipalities such as Santa Magdalena Jicotlan. In the case of Concepción Buenavista, a transition occurred from a water committee in 1983 to an SWB in 1985. The last recent change was from the SWB to fully municipal management in 1999. In the case of Santiago Tepetlapa and San Juan de los Cues, a change from a water committee to municipal management was reported in the last decade, which seems to have been motivated by endogenous issues in the communities, such as high rates of migration and the ability of the municipality to request funds for hydraulic works.

Table 5. Local knowledge of institutional changes in the management of the water system for domestic use with implications in five communities of the Mixteca Alta region in Oaxaca, Mexico.

Interviewee Age and Residence	Quote
A 79-year-old interviewee from Concepción Buenavista	"Before there was a water committee . . . it is no longer done like that . . . now it is the municipality, and they only report to the federal and state governments."
A 64-year-old interviewee from Concepción Buenavista	"The water committee that existed, if I remember correctly, as in '83 (1983). Later it became the Potable Water Board from '85 or so . . . managed by the Coordinator of Water Works Systems of Oaxaca. However, they wanted to put water meters on us, which did not suit us, and the people thought that if the municipality could take charge of it . . . that was like in '99. The coordinator took charge of several municipalities in the region like Santiago Ihuitlan Plumas, Tepelmem Villa de Morelos, Santa Magdalena Jicotlan, and many others."
An 85-year-old interviewee from Concepción Buenavista	"Years ago, the committee disappeared because there are not many people . . . the Commission of Papaloapan trained us, and we managed hydraulic works for the community. He helped us get the concession of the well, too. Before, the school also used to count on the committee (for water issues) . . . they were supported by pure money from the town. In '85, the first network was made; the committee checked the proper use of water, there was a committee regulation . . . then it passed to the municipality".
A 37-year-old interviewee from Concepción Buenavista	"The Commission of the Papaloapan helped us build the hydraulic water network . . . helped us train us to use it. First, the Papaloapan commission was in charge . . . I think it was on the part of the state; then they left it to the municipality."
A 48-year-old interviewee from Concepción Buenavista	"Now, the Councilor of finance (part of the municipal council) is in charge of the drinking water system (water for domestic use) . . . , before 25–30 years . . . there was a water committee; it was left due to the failures of people (the managers assigned as part of the committee of water)."
An 85-year-old interviewee from Santiago Ihuitlan Plumas	"The people worked so that (water) would not be lacking . . . the water service began in 1973. In 1954, the Papaloapan (the commission) helped . . . making "pretiles" (stone borders) to retain the water and soil . . . the hills were going . . . , the land, until the Papaloapan. The Papaloapan with authority (municipal council) managed the water (hydraulic system) . . . then the Papaloapan (the commission) left, and only the municipality remained (administering the water system for domestic use)".
An 84-year-old interviewee from Santiago Ihuitlan Plumas	"The commission of the Papaloapan helped us with the hydraulic work . . . , gave us the money and taught us how to do it. The stone borders ("petriles") helped us with the commission of the Papaloapan. In 1974, the Papaloapan Commission was withdrawn. There was a water committee . . . the '70s and '80s . . . they did not feel like it".
A 55-year-old interviewee from Santiago Tepetlapa	"We had (water committee) . . . 10–12 years ago, the water committee work. The water committee disappears because of a lack of people to provide service (a position occupied as a service to the community and free of charge for a specified period). There are almost no people in the town . . . the older people are left alone. We are very few men (young adults)."
A 38-year-old interviewee from San Juan de los Cues	"Before, about ten years ago, there was a water committee . . . , but the town decided that we would administer the drinking water (it refers to the municipal council to which it belongs). I believe that the people left it to us (the water supply system for domestic use) . . . because we could get works (hydraulic works). It is necessary to rehabilitate the dam and wells and build new wells to solve the drought problems that the town suffers."

By comparing the information on institutional change at the national and local levels, we identified that periods of institutional change at the national level (pre-centralized, centralized, and decentralized) did not permeate in all communities at the local level, especially in communities where the municipal agent or a water committee was responsible for the water supply system. In the case of municipalities, institutional changes at the national level permeated differently. For example, in Santiago Ihuitlan Plumas and possibly Santa Magdalena Jicotlan, institutional change coincided with change at the national level, where power was centralized through the LWB (with the Papaloapan Commission as

the federal representative) only to be later decentralized to the municipality. In the case of Concepción Buenavista, decentralization occurred in two phases. In the first phase, decentralization resulted in the responsibility of the water supply systems for domestic use to be passed to the state through the SWB. In the second phase, control passed entirely to the municipalities. Recent institutional changes regarding the rights of indigenous peoples and the environment at the national level have not had notable impacts to date on any institutional change related to water management in the communities. Instead, these institutional changes at the national level have been made to formalize indigenous institutions (municipal agent and water user assembly).

3.4. Intertwining Properties to Address the Complexity

Using the Water Governance Complexity Framework, we cross-analyzed the results obtained from the different proxies of the properties of diversity, nestedness, and dynamics in the three jurisdictional levels (national, state, and local) and the four post-revolutionary periods of institutional change (Figure 6).

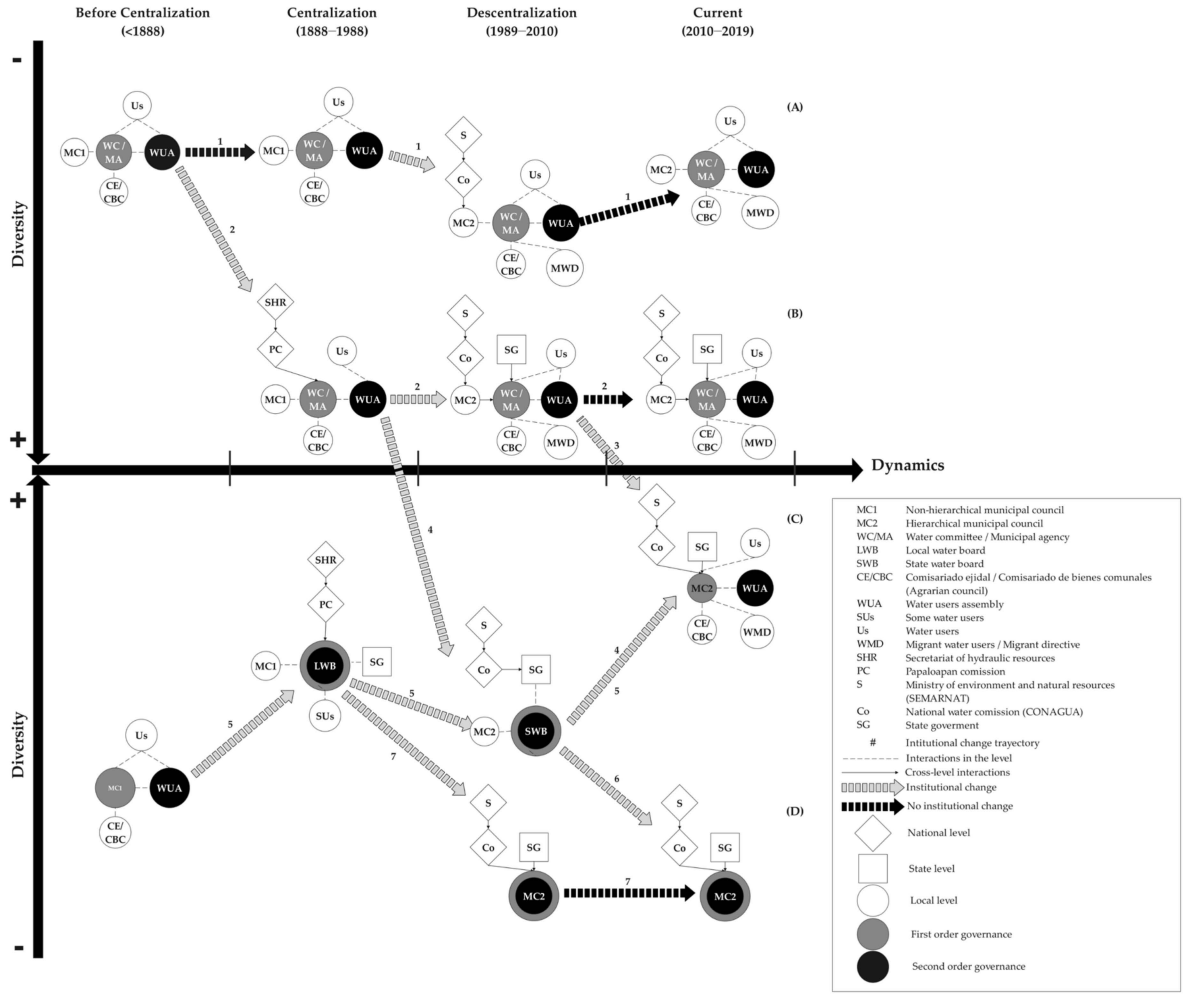

Figure 6. Intertwining the diversity, nestedness, and dynamics of stakeholders and institutions to understand the complexity of the governance of the domestic water supply system in Oaxaca, Mexico, under the Water Governance Complexity Framework. The current governance modes that resulted from the seven trajectories of institutional change are: (**A**) Non-nested community-based mode, (**B**) Nested community-based mode, (**C**) Nested hybrid mode, and (**D**) Nested municipal or hierarchical–bureaucratic mode. Source: prepared by the authors.

We found a diversity of stakeholders and evaluated how stakeholders and institutions conduct operations and decision making for the water supply system for domestic use at

the local level. This diversity has allowed different arrangements of stakeholders in the first and second orders of governance. Likewise, these arrangements are differentiated by being nested or non-nested, given the types of cross-level interactions (which implies a hierarchical relationship between the jurisdictional levels) or interactions within the same level (in the community) between stakeholders. In this sense, we established four governance arrangements or modes that are presented in the water system for domestic use in Oaxaca, Mexico, at the local level (Figure 6):

- Non-nested community-based mode (Figure 6A). This mode is characterized by little or no cross-level interaction. Operations and decision making are conducted only between community stakeholders based on water committees and indigenous institutions (municipal agent and water user assembly). This mode was found in the communities of Santa Cruz Corunda, San Miguel Aztatla, El Enebro, and San Antonio Abad.
- Nested community-based mode (Figure 6B). This mode is similar to the non-nested community-based mode but with cross-level interactions mainly in the first order of governance with regard to financing hydraulic works with municipal, national, and state governments. This mode of governance was presented by Santiago Quiotepec, San Francisco Teopan, La Mexicana, and Santa Cruz Capulalpam.
- Nested hybrid mode (Figure 6C). This mode combines decision making between the stakeholders and institutions of the communities with municipal management based on national and state institutions (LAN). The nestedness occurs due to cross-level interactions of the municipality in the first order of governance regarding the financing, repair, and maintenance of the hydraulic infrastructure. This mode of governance was presented by all the municipal seats included in this study (Concepción Buenavista, Santiago Ihuitlan Plumas, Santa Magdalena Jicotlan, Santiago Tepetlapa, and San Juan de los Cues)
- Nested municipal or hierarchical–bureaucratic mode (Figure 6D). The governance of the water supply system for domestic use is conducted following the guidelines established by the LAN and Article 115. There is no participation in decision making on behalf of community stakeholders or water users through the assemblies. All management and decision making is conducted by the municipal operating body or the municipal council. This last mode of governance was not found in the communities in this study but is established according to the national institutions. This governance mode is the one that could become dominant in most municipalities, both in Oaxaca and in the rest of Mexico.

According to the number of stakeholders that make up these governance modes, the least diverse is the nested municipal mode, followed by the non-nested community-based mode. The two most diverse modes are the nested community-based and hybrid modes because they can incorporate all stakeholders of different jurisdictional levels into operations (Table 6, Figure 6). The substantial difference between the nested hybrid mode and the nested community-based mode can be seen in the second order of governance. In the nested hybrid mode, the municipality is involved in the first and second orders of governance. In the nested community-based mode, the municipality is only involved in the operations as a financier for hydraulic works that the community has decided it needs (Table 6). Secondly, according to national and state institutions, the hybrid nested mode emerges from the mix between indigenous institutions (e.g., water user assembly) and municipality management. National or state institutions do not consider this organizational operation of the water supply system.

Table 6. Diversity of stakeholders and institutions involved in the first and second orders of governance of the four modes of governance identified at the local level in Oaxaca and possibly in much of Mexico. Bold text indicates the entities responsible for operating and making decisions related to the water supply system for domestic use at the local level. Italic text indicates the stakeholders and institutions belonging to the local jurisdictional level, while Roman text indicates entities belonging to state and national jurisdictional levels. MC = municipal council, WC/MA = water committee/municipal agent, WUA = water users assembly, US = water users, CE/CBC = agrarian council, MWD = Migrant Water Users Directive, SG = State government, CO = National Water Commission, and S = Ministry of Environment and Natural Resources.

Modes of Governance	Orders of Governance		Total of Different Stakeholders and Institutions Involved in Water Governance
	First Order (Operativity)	Second Order (Institutional Arrangement)	
Nested municipal mode	**MC**		4
	SG, S, and CO		
Non-nested community-based mode	**WC/MA**	**WC/MA and WUA**	6
	CE/CBC, *MWD*, and *MC*		
	US		
Nested community-based mode	**WC/MA**	**WC/MA and WUA**	9
	SG, CO, S, *CE/CBC*, *MWD*, and *MC*		
	US		
Nested hybrid mode	**MC**	**MC and WUA**	9
	SG, CO, S, *CE/CBC*, *MWD*, and *MC*		
	US		

The current diversity of stakeholders belonging to different jurisdictional levels (national, state, and local) and governance modes results from the trajectories of institutional changes related to water and the prevalence of indigenous institutions at the local level. The different trajectories of institutional change at the local level allow us to explain how the different modes of governance found were formed at this level. We identified seven trajectories of institutional change framed in four post-revolutionary periods, of which five were found in the 13 communities (numbers 1 to 7 represent specific trajectories of institutional change in Figure 6). All the trajectories of institutional change began in the period before centralization, starting with stakeholder and institutional arrangements based on the community through a water committee, municipal agent, water user assembly, or municipal council:

1. The water committee/municipal agent remained unchanged until the centralization period and subsequently became temporarily nested during the decentralization period. In the decentralization period, national, state, and municipal institutions constructed hydraulic infrastructure to bring water to homes. Additionally, migrant organization played an essential role in the financing, maintenance, and repair of hydraulic infrastructure. In the current period, a return to a governance structure like that present in the period before centralization is observed.
2. The water committee/municipal agent transitioned to a nested mode in the centralization period, where cross-level interactions with national government institutions were established. In the period of decentralization, nestedness was maintained although the national governmental institutions changed their names, structures, and functions, and state institutions were incorporated. Additionally, migrant organizations played an essential role in financing, maintaining, and repairing hydraulic infrastructure. In the current period, this has not changed.
3. The third trajectory of institutional change is similar to trajectory two. However, in the period from decentralization to the present, a change in stakeholders from the water committee/municipal agent to the municipal council in the first and second orders of governance was observed.

4. In this trajectory of institutional change, a change in stakeholders during the decentralization period occurred. The water committee/municipal agent disappeared, and the State Water Board (SWB) appeared in the arena of water governance at the local level. Subsequently, in the current period, the SWB disintegrated, and the municipal council takes its place in the first order of governance while water user assemblies retake the second order of governance (institutional arrangement).
5. This trajectory of institutional change is similar to trajectory 4. However, its beginnings prior to centralization are not due to a water committee/municipal agent but to a non-hierarchical municipal council. Another difference is that the governance structure changed to a Local Water Board (LWB) during the centralization period, and the municipal council lost power. In the decentralization period, the LWB was transformed into a SWB and national institutions went from being the main entities responsible to being advisors or financiers that provided technical support.
6. This trajectory of institutional change is similar to trajectory five up to the decentralization period. The difference with regard to trajectory five can be found in the current period. Instead of transitioning to a hybrid governance mode, a hierarchical–bureaucratic governance mode through the municipal council was adopted. The nested municipal council is the only one involved at the local level in the first and second orders of governance of the water supply system for domestic use.
7. This trajectory of institutional change is similar to trajectory six. However, during the period of decentralization, a swift change to the hierarchical–bureaucratic governance mode through the municipal council was observed instead of a transition to an SWB. The hierarchical–bureaucratic governance mode remains unchanged in the current period.

The last two trajectories (6 and 7) were built under the assumption that institutional changes at the national level thoroughly permeate the local level. The multiple trajectories of institutional change resulted from nestedness and the interplay of stakeholders belonging to the different jurisdictional levels. Nestedness plays an essential role in permeating institutional changes at higher jurisdictional levels or institutions to the local level. We can observe the contrasting effect in the non-nested communities of Santa Cruz Corunda, San Miguel Aztatla, El Enebro, and San Antonio Abad that have kept their local water institutions unchanged to date.

However, the interplay of stakeholders at the local level with governmental stakeholders belonging to higher jurisdictional levels in the different periods of change reflects non-linear interactions due to the resistance or adaptation of stakeholders or institutions at the local level. The interplay of stakeholders belonging to different jurisdictional levels helps to explain why institutional change at the national level did not permeate in the same way in all communities, despite communities being nested. For example, during centralization, the water supply systems for domestic use governed by water committees, indigenous institutions, or municipal councils would have disappeared, and only the LWBs would have prevailed. However, only two of the thirteen communities studied reported this change, reflecting the inability of the national government to take power away from stakeholders and local institutions over water matters. On the other hand, the resistance that local water institutions presented to change was imposed from the top down.

In the period of decentralization, there appears to be a return of water management power to the local water institutions present in the communities prior to centralization. Nevertheless, the return of power to local water institutions was accompanied by the establishment of a hierarchy and a homogenization of the operation of the water supply system for domestic use at the local level for the municipalities, concentrating operations, and decision making in a single stakeholder. For this reason, in the case of municipalities, we differentiate between municipal council 1 as non-hierarchical and municipal council 2 as hierarchical in Figure 6. Secondly, for the non-municipal water institutions (water committee, municipal agent, or water user assembly), a multilevel linkage with the municipality and state and national institutions was established. Finally, the national government

maintains the right to alienation, while the right of exclusion is limited to the local water institutions, although mainly in the case of municipalities. During decentralization, differences among the trajectories of institutional change were due to the recovery of traditional institutions that existed before centralization in communities and the adaptation of traditional institutions to a new nested structuring of state and national organizations.

In the current period, recent institutional change, as seen with the Santiago Tepetlapa and San Juan de los Cues communities, responds to the endogenous drivers. Additionally, this institutional change may reflect the capacity of stakeholders to choose between the different institutional arrangements based on the community or municipality, or to generate new institutions that mix mechanisms coming from the municipality and indigenous institutions, such as in hybrid modes.

4. Discussion

Our results show that (1) legal pluralism is present due to the evolution and convergence of multiple formal (e.g., water, agrarian, and municipal laws, indigenous peoples rights, and environmental law) and informal (e.g., indigenous institutions such as those related to community use and customs, such as a municipal agent or water user assembly) institutions that co-exist at the local level. Even in the same legal system that regulates property rights over those of water, overlaps between national and state institutions at the local level are present along with concerns regarding the recognition of municipalities as responsible for the water supply system. (2) Legal pluralism has generated a great diversity of formal and informal stakeholders that are structured across multiple levels and are involved in various ways in the first (operative) and second orders of governance (institutional arrangements) of the water supply system for domestic use. (3) Diversity is associated with the four different modes of governance that exist and operate at the local level. The governance modes are determined by interactions (cross-level or within the jurisdictional level) between stakeholders in the first and second governance orders. They include the non-nested community-based mode, nested community-based mode, nested hybrid mode, and hierarchical–bureaucratic mode (municipality). (4) The municipality is nested by institutional design, unlike all indigenous communities and their respective modes (e.g., non-nested community-based mode) that manage the water system for domestic use through a municipal agent or water committee, and water user assembly. (5) The diversity and creation of governance modes in the water supply system for domestic use in Oaxaca and possibly in the rest of Mexico result from the seven different trajectories of institutional change. (6) The seven trajectories of institutional change result from nestedness and the interplay between local water institutions (e.g., municipalities and indigenous communities) and national and state government institutions during the centralization, decentralization, and current periods. Most of the diversity of stakeholders and institutions at the local level, modes of water governance, and trajectories of institutional change do not correspond to a single centralized plan but to the interplay of different stakeholders and institutions over time to secure water for households in the Mixtecan Alta region in Oaxaca, Mexico, and probably in the rest of the country.

These findings are consistent with empirical research, and in the case of nestedness and institutional change, they contribute new elements to our understanding of governance and institutional evolution [11]. The legal pluralism in water management in this study is consistent with what has been reported in previous studies regarding the growing legal pluralism in many countries due to the decentralization of water management [17–19], the existence of a multi-level process regarding the human right to water and sanitation that operates from the global to the local levels [20], the link between land and water rights in rural communities [18], and the recent recognition of indigenous rights and their traditional institutions [66]. Although it has not been viewed from a legal plural perspective, the diversity of stakeholders and governance modes agrees with what has been reported regarding the increasing number of stakeholders and novel institutional arrangements in the arena of water governance [67–69]. A novel institutional arrangement in the form of

a hybrid mode has been suggested as being more likely to be present than other modes, such as the hierarchical–bureaucratic, market, or network modes [70]. The other modes of governance identified as non-nested community-based and nested community-based modes can be encased in the network mode [71]. However, we highlighted the critical role of the community and nestedness that reflects how the mode is affected by the system in which it is immersed [33]. Identifying nested and non-nested modes of governance allows us to identify new elements that shed light on how multi-level governance works. For example, the multi-level governance structure does not always imply a nesting of smaller organizations within larger organizations [72]. In the same structure, two subsystems can exist that function differently: one nested and another non-nested. From a functionalistic perspective, nestedness helps identify fragmented or coordinated governance in the water supply system [73]. We can observe that the existence of a non-nested mode of governance in the water supply system for domestic use in Oaxaca, Mexico, reflects the inability of national and state governmental institutions to reach specific communities, which implies a lack of multilevel coordination and a fragmented structure. It also gives us insight into the ability of a community to self-organize to meet the water demands of its inhabitants and to maintain both institutions and the household water supply over time. For its part, the trajectories of institutional change and the lack of change identified in this study contribute to filling the information gap regarding the longitudinal processes by which institutions are created and evolve [11], which were essential for explaining the structures of the modes of governance, particularly the emergence of hybrid modes.

From an overall perspective of the properties, legal pluralism, the diverse stakeholders and institutions, and nested or non-nested subsystems working in multilevel and dynamic properties due to institutional change establish the complexity of the governance of the water supply system for domestic use in Oaxaca. This complexity of the governance of the water supply system is confirmed if we consider the non-linear interactions (which are indirectly observed in the seven trajectories of institutional change) and emergence properties (new institutional arrangements such as those of hybrid modes) that were revealed due to the interrelatedness and complementarity between the diversity, nestedness, and dynamics properties. We empirically demonstrate that water governance becomes complex in structure and operation due to institutional evolution, with certain institutions aggregating, changing, adapting, and persisting over time while acting and interacting with stakeholders to supply water to people in different jurisdictional levels.

This study provides a replicable method to use the Water Governance Complexity Framework to understand the complexity of water systems. The framework considers diversity, nestedness, and dynamics at different scales (jurisdictional and temporal) and levels (national, state, and local) as well as periods of institutional change to address the complexity of water governance and the governance of the water supply system for domestic use in particular. This framework differs from the Kooiman IGF [14,39] by addressing complexity not only through a proxy (either legal pluralism [13] or nestedness [15], but as a property that encompasses diversity, nestedness, and dynamics. By themselves, each property provides an incomplete picture of water governance; however, taken together, they provide a more holistic understanding of the current structure and function of water governance, which can be complex. In the case of the governance of the domestic water supply system in Oaxaca, Mexico, we showed how this framework addresses the limitations of using a single variable or a set of separately viewed properties to understand water governance. Additionally, in contrast to the Kooiman framework that uses a more descriptive approach, we propose a variable-oriented approach that provides systematicity and replicability to describe the complexity of water governance in other regions. The Water Governance Complexity Framework joins recent efforts to advance our understanding of the past, present, and future of the institutions, and their interactions, and those of different frameworks, such as Power Polycentric Governance (PPG) [74] or a combination of PPG with other frameworks such as Institutional Analysis and Development (IAD) and the Socio-Ecological System (SES) Framework [11].

5. Conclusions

The purpose of this study was to approach the understanding of the complexity of water governance through three properties, namely diversity, nestedness, and dynamics, in jurisdictional and temporal scales and at different levels. For this, we built the Water Governance Complexity Framework based on some elements of the Kooiman Interactive Governance Framework [14,28]. We used the domestic water supply system in Oaxaca to show the operability of the proposed framework in addressing the complexity of water governance. We discovered that the properties of diversity, nestedness, and dynamics and their respective proxies when intertwined can provide good approximations of the non-linear interactions, emergence, and constant change that classify water governance as complex. The importance of this study and the Water Governance Complexity Framework is that it offers a way to understand the complexity of water governance due to historical processes without automatically assuming that water governance is complex, which limits and biases any conclusions or future improvement efforts.

The Water Governance Complexity Framework proposed in this study is not fixed. We recommend that the framework be used as a methodological guide by which new proxies can be incorporated to address the diversity, nestedness, and dynamics properties (e.g., the flow of knowledge and power dynamics) and new properties. New proxies may emerge from testing the framework in other regions or contexts and from advances in complexity theory. Additionally, a more refined level of analysis can be included in the framework, such as that at the individual level, which allows for a more profound understanding of complexity regarding how the stakeholders make decisions, how they implement specific actions, and how they interact with other stakeholders. Exploring the individual level will allow us to determine if the stakeholders of different jurisdictional levels participate in cross-level interactions from a legitimate non-hierarchical condition (different from how we assume nestedness) and the importance of leadership in inducing, resisting, or adapting to institutional change [75]. Despite the criticism of the theory of complexity when applied to social systems [76], we believe in its usefulness to diagnose the complexity of the water governance of any system, be it the water supply systems for domestic, agricultural, or industrial use. This practicality of the framework can help decision makers and practitioners generate a deeper understanding of water governance that allows for legal reforms, new laws, and new public policies to be created, along with changes to desirable models (e.g., polycentrism) based on the knowledge of current stakeholders and institutions and the historical context. This research reinforces the idea that water governance is complex, while inviting us to question this complexity and the elements and properties responsible for it.

Supplementary Materials: The following are available online at https://www.mdpi.com/article/10.3390/w13202870/s1. Table S1. Structure of the survey used in this study. We employed four questions and their possible answers. In the answers, the "others" option was left not to limit the eventual appearance of different stakeholders at the local level. Table S2. Matrix used to note the answers obtained from interviewing stakeholders regarding cross-level and internal interactions in the communities to carry out ten activities of the first and second governance orders. Table S3. Matrix of binomial presence (1)/absence (0) data resulting from the collapse of the results obtained from all the interviewees and the ten activities of each community. Table S4. Results of the binomial presence/absence matrix of the communities that are municipal seats responsible for the water supply system for domestic use. This matrix was used to carry out the nesting analysis with the NODF (Nestedness based on the Overlap and Decreasing Fill) metric in NeD software. Table S5. Results of the binomial presence/absence matrix of the communities that are municipal agencies or that have a water committee responsible for the water supply system for domestic use. This matrix was used to carry out the nesting analysis with the NODF (Nestedness based on the Overlap and Decreasing Fill) metric in NeD software. Table S6. Open-ended questions of the semi-structured interviews were applied to elders and experts to identify possible institutional changes related to water for domestic use in rural communities.

Author Contributions: Conceptualization, F.G.-G.; methodology, F.G.-G., A.S.-A., G.H.-A., C.M.-A., M.A.M.-J. and D.M.-R.; formal analysis, F.G.-G.; investigation, F.G.-G. and G.H.-A.; resources, F.G.-G. and G.H.-A.; data curation, F.G.-G.; writing—original draft preparation, F.G.-G.; writing—review and editing, A.S.-A., G.H.-A., C.M.-A., M.A.M.-J. and D.M.-R.; supervision, A.S.-A.; project administration, F.G.-G.; funding acquisition, F.G.-G., A.S.-A., G.H.-A., C.M.-A., M.A.M.-J. and D.M.-R. All authors have read and agreed to the published version of the manuscript.

Funding: This research was funded by National Geographic Society (grant number EC-62227R-19) and The National Council of Science and Technology of Mexico (CONACYT) through Doctorate Grants awarded to the first author.

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Informed consent was obtained from all subjects involved in the study.

Data Availability Statement: The data presented in this study are available on request from the corresponding author.

Acknowledgments: We thank the communities of Oaxaca who participated in this study for their support and openness. We also thank the team of the Marine and Coastal Ecosystems Governance and Management Laboratory of the CIIDIR- Oaxaca unit of the Instituto Politécnico Nacional (IPN) for helping with the community surveys and for facilitating transportation. We are also deeply grateful for the suggestions made by three anonymous reviewers that helped us improve the scope of this work.

Conflicts of Interest: The authors declare no conflict of interest. The funders had no role in the design of the study; in the collection, analyses, or interpretation of data; in the writing of the manuscript; or in the decision to publish the results.

References

1. Kirschke, S.; Borchardt, D.; Newig, J. Mapping complexity in environmental governance: A comparative analysis of 37 priori-ty issues in German water management. *Environ. Policy Gov.* **2017**, *27*, 534–559. [CrossRef]
2. Kirschke, S.; Newig, J. Addressing complexity in environmental management and governance. *Sustainability* **2017**, *9*, 983. [CrossRef]
3. Pahl-Wostl, C. The implications of complexity for integrated resources management. *Environ. Model. Softw.* **2007**, *22*, 561–569. [CrossRef]
4. Pahl-Wostl, C.; Kranz, N. Water governance in times of change. *Environ. Sci. Policy* **2010**, *13*, 567–570. [CrossRef]
5. Cox, M. Applying a Social-Ecological System Framework to the Study of the Taos Valley Irrigation System. *Hum. Ecol.* **2014**, *42*, 311–324. [CrossRef]
6. McGinnis, M.D.; Ostrom, E. Social-ecological system framework: Initial changes and continuing challenges. *Ecol. Soc.* **2014**, *19*. [CrossRef]
7. Ostrom, E. A general framework for analyzing sustainability of social-ecological systems. *Science* **2009**, *325*, 419–422. [CrossRef]
8. Chaffin, B.C.; Gunderson, L.H. Emergence, institutionalization and renewal: Rhythms of adaptive governance in complex social-ecological systems. *J. Environ. Manag.* **2016**, *165*, 81–87. [CrossRef]
9. Schröder, N.J.S. The lens of polycentricity: Identifying polycentric governance systems illustrated through examples from the field of water governance. *Environ. Policy Gov.* **2018**, *28*, 236–251. [CrossRef]
10. Carlisle, K.M.; Gruby, R.L. Why the path to polycentricity matters: Evidence from fisheries governance in Palau. *Environ. Policy Gov.* **2018**, *28*, 223–235. [CrossRef]
11. Epstein, G.; Morrison, T.H.; Lien, A.; Gurney, G.G.; Cole, D.H.; Delaroche, M.; Villamayor-Tomas, S.; Ban, N.; Cox, M. Advances in understanding the evolution of institutions in complex social-ecological systems. *Curr. Opin. Environ. Sustain.* **2020**, *44*, 58–66. [CrossRef]
12. Pahl-Wostl, C.; Holtz, G.; Kastens, B.; Knieper, C. Analyzing complex water governance regimes: The Management and Transition Framework. *Environ. Sci. Policy* **2010**, *13*, 571–581. [CrossRef]
13. Jentoft, S. Limits of governability: Institutional implications for fisheries and coastal governance. *Mar. Policy* **2007**, *31*, 360–370. [CrossRef]
14. Kooiman, J. *Governing as Governance*; SAGE: London, UK, 2003.
15. Bavinck, M.; Kooiman, J. Applying the Governability Concept in Fisheries - Explorations from South Asia. In *Governability of Fisheries and Aquaculture: Theory and Applications*; Bavinck, M., Chuenpagdee, R., Jentoft, S., Kooiman, J., Eds.; Springer: Dordrecht, The Netherlands, 2013; Volume 7, pp. 131–153.
16. Manson, S.M. Simplifying complexity: A review of complexity theory. *Geoforum* **2001**, *32*, 405–414. [CrossRef]
17. Tamanaha, B.Z. Understanding Legal Pluralism: Past to Present, Local to global. *Syd. Law Rev.* **2007**, *30*, 375–411. [CrossRef]

18. Meinzen-Dick, R.; Nkonya, L. Understanding legal pluralism in water rights: Lessons from Africa and Asia. In *Community-Based Water Law and Water Resource Management Reform in Developing Countries*; van Koppen, B., Giordano, M., Butterworth, J., Eds.; CAB International: Wallingford, UK, 2007.
19. McCord, P.; Dell'Angelo, J.; Baldwin, E.; Evans, T. Polycentric transformation in Kenyan water governance: A dynamic analysis of institutional and social-ecological change. *Policy Stud. J.* **2017**, *45*, 633–658. [CrossRef]
20. Obani, P.; Gupta, J. Legal pluralism in the area of human rights: Water and sanitation. *Curr. Opin. Environ. Sustain.* **2014**, *11*, 63–70. [CrossRef]
21. Kooiman, J. Exploring the Concept of Governability. *J. Comp. Policy Anal. Res. Pract.* **2008**, *10*, 171–190. [CrossRef]
22. Kooiman, J.; Bavinck, M. Theorizing Governability—The Interactive Governance Perspective. In *Governability of Fisheries and Aquaculture: Theory and Applications*; Bavinck, M., Chuenpagdee, R., Jentoft, S., Kooiman, J., Eds.; Springer: Dordrecht, The Netherlands, 2013; Volume 7, pp. 9–31.
23. Tortajada, C. Water governance: Some critical issues. *Int. J. Water Resour. Dev.* **2010**, *26*, 297–307. [CrossRef]
24. Lewis, K. *Water Governance for Poverty Reduction: Key Issues and the UNDP Response to Millennium Development Goals*; United Nations Development Programme: New York, NY, USA, 2004.
25. North, D.C. Institutions. *J. Econ. Perspect.* **1991**, *5*, 97–112. [CrossRef]
26. Page, S. On diversity and complexity. In *Diversity and Complexity*; Page, S., Ed.; Princeton University Press: Princeton, NJ, USA, 2011; pp. 16–53.
27. Ostrom, E. Understanding the diversity of structured human interactions. In *Understanding Institutional Diversity*; Ostrom, E., Ed.; Princeton University Press: Princeton, NJ, USA; Oxford, UK, 2005; pp. 3–29.
28. Kooiman, J.; Bavinck, M.; Chuenpagdee, R.; Mahon, R.; Pullin, R. Interactive governance and governability—An introduction. *J. Transdiscipl. Environ. Stud.* **2008**, *7*, 1–11.
29. Kingston, C.; Caballero, G. Comparing theories of institutional change. *J. Inst. Econ.* **2009**, *5*, 151. [CrossRef]
30. Gibson, C.C.; Ostrom, E.; Ahn, T.K. The concept of scale and the human dimensions of global change: A survey. *Ecol. Econ.* **2000**, *32*, 217–239. [CrossRef]
31. Bavinck, M.; Chuenpagdee, R.; Jentoft, S.; Kooiman, J. Social Justice in the Context of Fisheries—A Governability Challenge. In *Governability of Fisheries and Aquaculture: Theory and Applications*; Chuenpagdee, R., Jentoft, S., Kooiman, J., Eds.; Springer: Dordrecht, The Netherlands, 2013; Volume 7, pp. 45–66.
32. Lautze, J.; De Silva, S.; Giordano, M.; Sanford, L.; De Silva, S. Putting the cart before the horse: Water governance and IWRM. *Nat. Resour. Forum.* **2011**, *35*, 1–8. [CrossRef]
33. Blavoukos, S.; Bourantonis, D. Nested Institutions. In *Palgrave Handbook of Inter-Organizational Relations in World Politics*; Koops, J.A., Biermann, R., Eds.; Palgrave Macmillan: London, UK, 2017; pp. 303–317.
34. Mariani, M.S.; Ren, Z.M.; Bascompte, J.; Tessone, C.J. Nestedness in complex networks: Observation, emergence, and implications. *Phys. Rep.* **2019**, *813*, 1–90. [CrossRef]
35. Levin, S.A. The problem of pattern and scale in ecology. *Ecology* **1992**, *73*, 1943–1967. [CrossRef]
36. Ostrom, E. *Governing the Commons: The Evolution of Institutions for Collective Action (Political Economy of Institutions and Decisions)*; Cambridge University Press: Cambridge, UK, 1990.
37. Theodori, G.L. Community and community development in resource-based areas: Operational definitions rooted in an interactional perspective. *Soc. Nat. Resour.* **2005**, *18*, 661–669. [CrossRef]
38. Fox, J.A.; Aranda, J. *Decentralization and Rural Development in Mexico Community Participation in Oaxaca's Municipal Funds Programs*; Center for U.S.-Mexican Studies, University of California: San Diego, CA, USA, 1996.
39. Kooiman, J.; Chuenpagdee, R. Governance and Governability. In *Fish for Life: Interactive Governance for Fisheries*; Kooiman, J., Bavinck, M., Jentoft, S., Pullin, R., Eds.; Amsterdam University Press: Amsterdam, The Netherlands, 2005; pp. 325–350.
40. Naderifar, M.; Goli, H.G.; Fereshteh, G. Snowball Sampling: A Purposeful Method of Sampling in Qualitative Research. *Strides Dev. Med. Educ.* **2017**, *14*, e67670. [CrossRef]
41. Almeida-Neto, M.P.; Guimarães, R.J.; Loyota, R.D.; Ulrich, W. A consistent metric for nestedness analysis in ecological systems: Reconciling concept and measurement. *Oikos* **2008**, *117*, 1227–1239. [CrossRef]
42. Strona, G.; Galli, P.; Seveso, D.; Montano, S.; Fattorini, S. Nestedness for Dummies (NeD): A User-Friendly Web Interface for Exploratory Nestedness Analysis. *J. Stat. Softw.* **2014**, *59*, 1017–1025. [CrossRef]
43. Ulrich, W.; Gotelli, N.J. Null model analysis of species nestedness patterns. *Ecology* **2007**, *88*, 1824–1831. [CrossRef]
44. Galindo-Escamilla, E.; Palerm-Viqueira, J. Pequeños sistemas de agua potable: Entre la autogestión y el manejo municipal en el estado de Hidalgo, México. *Agric. Soc. Y Desarro.* **2007**, *4*, 127–145.
45. Pineda, P.N. La política urbana de agua potable en México: Del centralismo y los subsidios a la municipalización, la autosuficiencia y la privatización. *Reg. Soc.* **2002**, *14*, 41–70. [CrossRef]
46. Sandré, O.I.; Sánchez, M. *El eslabón Perdido. Acuerdos, Convenios, Reglamentos y Leyes Locales de Agua en México (1593–1935)*; Centro de Investigaciones y Estudios Superirores en Antropologia Social, Publicaciones de la Casa Chata: D. F., México, Mexico, 2011; pp. 11–54.
47. Aboites, A.L. *El agua de la Nación. Una Historia Política de México (1888–1946)*; Centro de Investigaciones y Estudios Superiores en Antropología Social: D. F., México, Mexico, 1998.
48. Rolland, L.; Vega, Y. La gestión del agua en México. *Polis* **2010**, *6*, 155–188.

49. Collado, M.J. Entorno de la Provisión de los Servicios Públicos de agua Potable en México. In *El Agua Potable en México. Historia Reciente, Actores, Procesos y Propuestas*; Olivares, R., Sandoval, R., Eds.; Asociación Nacional de Empresas de Agua y Saneamiento, A.C: D. F., México, Mexico, 2008; pp. 3–28.
50. Escobar, O.A. Manejo del Agua en México. Bosquejo de la evolución institucional federal 1926–2008. In *Semblanza Historica del Agua en México*; Comisión Nacional del Agua, Ed.; Secretaria de Medio Ambiente y Recursos Naturales: D. F., México, Mexico, 2009; pp. 61–73.
51. Mathews, A.S. Building the town in the country: Official understandings of fire, logging and biodiversity in Oaxaca, Mexico, 1926–2004. *Soc. Anthropol.* **2006**, *14*, 335–359. [CrossRef]
52. DOF. *Constitución Política de los Estados Unidos Mexicanos*; Diario Oficial de la Federación: D. F., México, Mexico, 1917; Volume 4, pp. 1–418.
53. DOF. *Ley de Aguas Nacionales*; Diario Oficial de la Federación: D. F., México, Mexico, 1992; pp. 1–112.
54. DOF. *Ley Agraria*; Diario Oficial de la Federación: D. F., México, Mexico, 1992; pp. 1–55.
55. DOF. *Ley General del Equilibrio Ecologico y Proteccion al Medio Ambiente*; Diario Oficial de la Federación: D. F., México, Mexico, 1988; pp. 1–268.
56. DOF. *Decreto por el que se Crea la Comisión Nacional del Agua Como Órgano Admisnistrativo Deseconcentrado de la Secretaría de Agricultura y Recursos Hidráulicos*; Diario Oficial de la Federación: D. F., México, Mexico, 1989; Volume 11, p. 2.
57. DOF. *Acuerdo Por el que se Determina la Circunscripción Territorial de los Organismos de Cuenca de la Comisión Nacional del Agua*; Diario Oficial de la Federación: D. F., México, Mexico, 2010. Available online: http://dof.gob.mx/nota_detalle.php?codigo=5137623&fecha=01/04/2010 (accessed on 10 February 2021).
58. DOF. *Decreto por el que se Declara Reformado y Adicionado el Artículo 115 de la Constitución Política de los Estados Unidos Mexicanos*; Diario Oficial de la Federación: D. F., México, Mexico, 1999. Available online: http://www.dof.gob.mx/nota_detalle.php?codigo=4958409&fecha=23/12/1999 (accessed on 4 March 2021).
59. POEO. *Ley de Agua Potable y Alcantarillado Para el Estado de Oaxaca*; Periodico Oficial del Estado de Oaxaca: Oaxaca, Mexico, 1993; Volume 22, pp. 373–388.
60. Gumeta-Gómez, F.; Durán, E.; Hinojosa-Arango, G. Gobernanza del agua para uso doméstico. *H_2O Gestión del Agua* **2019**, *26*, 22–26.
61. Birrichaga, D. Legislación entorno al agua, siglos XIX y XX. In *Semblanza Historica del Agua en México*; Comisión Nacional del Agua, Ed.; Secretaria de Medio Ambiente y Recursos Naturales: D. F., México, Mexico, 2009; pp. 43–59.
62. Zetina, R.M.D.C.; García, P.R.; Rangel, G.E. Administración del agua y los recursos de la nación: La Junta Federal de Mejoras Materiales, Ciudad Juárez, Chihuahua, 1931–1936. *Región Y Soc.* **2017**, *29*, 1931–1936. [CrossRef]
63. CONAGUA. *Manual de Agua Potable, Alcantarillado y Saneamiento. Integración de un Organismo Operador*; Secretaria del Medio ambiente y Recursos Naturales: D. F., México, Mexico, 2007; pp. 1–3.
64. Jimenez, B.; Marín, L. *El Agua en Mexico, Vista Desde la Academia*; Academia Mexicana de Ciencias: D. F., México, Mexico, 2004.
65. Wilder, M.; Romero, L.P. Paradoxes of decentralization: Water reform and social implications in Mexico. *World Dev.* **2006**, *34*, 1977–1995. [CrossRef]
66. Anaya, J. Indigenous law and its contribution to global pluralism. *Indig. LJ* **2007**, *6*, 3.
67. Gupta, J.; Pahl-Wostl, C.; Zondervan, R. 'Glocal' water governance: A multi-level challenge in the anthropocene. *Curr. Opin. Environ. Sustain.* **2013**, *5*, 573–580. [CrossRef]
68. Gawel, E.; Bernsen, K. Globalization of water: The case for global water governance. *Nat. Cult.* **2011**, *6*, 205–217. [CrossRef]
69. Pahl-Wostl, C. *Water Governance in the Face of Global Change. From Understanding to Transformation*; Springer: Osnabrük, Germany, 2015.
70. Pahl-Wostl, C. The role of governance modes and meta-governance in the transformation towards sustainable water governance. *Environ. Sci. Policy* **2019**, *91*, 6–16. [CrossRef]
71. Meuleman, L. *Public Management and the Metagobernance of Hierarchies, Networks and Markets*; Springer: Berlin/Heidelberg, Germany, 2008.
72. Sjah, T.; Baldwin, C. Options for future effective water management in lombok: A multi-level nested framework. *J. Hydrol.* **2014**, *519*, 2448–2455. [CrossRef]
73. Pahl-Wostl, C.; Knieper, C. The capacity of water governance to deal with the climate change adaptation challenge: Using fuzzy set Qualitative Comparative Analysis to distinguish between polycentric, fragmented and centralized regimes. *Glob. Environ. Chang.* **2014**, *29*, 139–154. [CrossRef]
74. Morrison, T.H. Evolving polycentric governance of the Great Barrier Reef. *Proc. Natl. Acad. Sci. USA* **2017**, *114*, E3013–E3021. [CrossRef]
75. Folke, C.; Hahn, T.; Olsson, P.; Norberg, J. Adaptive governance of social-ecological systems. *Annu. Rev. Environ. Resour.* **2005**, *30*, 441–473. [CrossRef]
76. Stewart, P. Complexity theories, social theory, and the question of social complexity. *Philos. Soc. Sci.* **2001**, *31*, 323–360. [CrossRef]