The E. Ostrom's SES framework in the course of understanding the problem of complexity of the CPRs. A meta-analysis of case studies of Mexican community forests.

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Abstract: The problem of misuse or loss of natural resources like the forests are due to a limited understanding of the processes that lead to improvements in or deterioration of natural resources (E. Ostrom, 2009). This is because the Social-Ecological systems (SESs) are inherently complex, hence the problems related to their use are rarely due to a single cause which complicate the institutional design and change to solve it. It is in this context that the E. Ostrom's SES framework was developed as a tool of diagnostic analysis to understand the complexity embedded into the governance of the SESs (E. Ostrom, 2007). However, the use of the SES framework to identify how institutional change can be stimulated is still at lower level of development (E. Ostrom, 2009).

The objective of this paper is to present how institutional change can be studied using SES framework in a concrete SES case study, and how the micro-/macro-relations can be modelled to understand the functionality of the commons in the context of variable patterns of interactions. This paper bases its methodology on the E. Ostrom SES framework theory and its application (E. Ostrom, 2011), and the meta-analysis of 32 case studies of Mexican community forests in the context of the Social-Ecological System Meta-Analysis Database (SESMAD, 2014). As the results, it was identified that: (i) the performance of each case study is based on a complex set of interactions whose patterns of interactions result into desired or undesired outcomes, hence the institutional change should be based on, to set out the configurations of variables of each case which may lead or not to desired outcomes, (ii) based on a case study as a unit of analysis, the micro-/macro-relations can be modeled through the institutional design founded on and fostered by considering the community forests SES as a complex system of variable interactions, whose patterns lead to successful of unsuccessful situations of the resource use. These results share a conception of that each case should not be considered as unique. The successful cases share some attributes whereas the failed cases present a lack of some of those attributes. Thus, a comparative study is necessary.

Keywords: Social-Ecological Systems (SESs), Social-Ecological System (SES) framework, variable patterns of interactions, micro-/macro-relations of the commons, case-based meta-analysis.

1. Introduction

The problem of the CPRs management is a complex one. This most of the CPRs are inherently complex and the problems related to their use are rarely due to a single cause (Ostrom E. , 2010). Hence the awareness of the impact of the CPRs management is stimulated by sustainability and destruction situation which is in relation with limited knowledge about the processes that lead to improvement or deterioration of these resources (Ostrom E. , 2009). The complexity problem of the CPRs is attributable to the nature of the resources and the action situation in which incentives and actions towards the resource use are realized. This is for example the community forests where the attributes of resources, ecological systems, and socioeconomic and political systems that affect the ability of resource users to recognize how their actions affect the condition of the resource (Ostrom, Janseen, & Poteete, 2012). To get simple solutions to the complex problem, the problem must be well understood and this requires a structured approach (Adamsen, 2000). It is in this context that, to solve the complex problem of the SES, E. Ostrom and her collaborators developed a SES framework (E. Ostrom, 2007). However, even if the use of this framework marked important development in diagnosis analysis of the problem related to the SES sustainability management, based on the nature of the SESs and SES framework development tendency of meta-approach, the use of the SES framework in the comparative study of concrete SES case studies is still at lower level of development (Ostrom E. , 2009).

The objective of this paper is to present how institutional change can be studied using SES framework in concrete SES cases, and that the micro-/macro-relations can be modelled to understand the functioning of the commons in the context of variable patterns of interactions. Thus, the questions of: how SES framework development is in the purpose of solving the complexity problem of the SESs? and how can SES framework be used to foster the institutional change which grantees the sustainable management of the SESs? are focused on. To achieve the objective and to respond the questions of this research, a methodology which consists of scientific progress of the E. Ostrom SES framework and its application (E. Ostrom, 2011), and the meta-analysis of 32 case studies of Mexican community forests in the context of the Social-Ecological System Meta-Analysis Database (SESMAD, 2014) is used. To avoid the methodological complexity, a meta-level approach of the SES framework of decomposable system as well as the case based meta-analysis were used (Bergh, Button, Nijkamp, & Pepping, 1997). As the results, it was identified that the SES framework was developed hand in hand with coping with the complexity problem of the CPRs. This is justified with the meta-analysis results by which the performance of each case study is based on a complex set of interactions whose patterns of interactions result into desired or undesired outcomes, hence the institutional change has to be based on the configurations of variables of each case. However, this does not mean that each case is unique. The successful cases share some attributes whereas the failed cases present a lack of some of those attributes. The article is organized as follows: the conceptual explanation of the Social-Ecological Systems, SES framework development, case-based meta-analysis, and institutional change, methodology, the results and conclusions.

2. The SESs and their complexity problem

SES can be defined as "social systems in which some of the interdependent relationships among humans are mediated through interactions with biophysical and non-human biological units" (Ostrom & Cox, 2010). This definition puts more emphasis on the possibility of change in human behavior towards the ecological system depending on its state condition. Social systems are thought of as interdependent systems of organisms. Thus, both social and ecological systems contain units that interact interdependently and each may contain interactive subsystems as well. The term-SES is used to refer to "the subset of social systems in which some of the interdependent relationships among humans are mediated through interactions with biophysical and non-human biological units" (Anderies, Janssen, & Ostrom, 2004).

The SESs are complex systems (Ostrom, Janseen, & Poteete, 2012). This is due to the interactions of the social and ecological systems. This can be viewed into two perspectives. The first perspective is that the ecological system is composed of ecological units or ecological resources. These are CPRs characterized by the difficult but not impossible to exclude potential users and the substractability of resource units. Hence, as far as the SESs are complex, unless there are no robust institutions to govern the incentives and actions of the SESs' users, there should be a problem of free-ride which read to resource system destruction (Anderies, Janssen, & Ostrom, 2003). The second perspective is that social systems are complex in terms of that they involve many interrelated action arenas of users and providers of the public infrastructures. Hence, if there are no robust institutions to regulate the interactions in the action arenas, the outcomes from the SES may be undesired. Thus, the complexity embedded into the SESs becomes a problem when it prevents the actors in SES management to scrutiny those processes that lead to resources destruction or improvement (Ostrom E. , 2009). This affects the possibility of designing accurate institutions and institutional change. To be able to solve the complexity problem related to the SESs management, it necessary to have a structured and easily understandable approach (Adamsen, 2000), and it is in this context, E. Ostrom and her collaborators established a SES framework to deal with complex problems of the SES management like community forests (Ostrom E. , 2009). The problem of the forests become more complex because there is no fixed spatial level to be sustainably managed as SESs (Brondizio, Ostrom, & Young, 2009), all depends on the level at which the problem is presented and the possibility of institutional design which appropriate to this multilevel nature. To achieve this, the SES framework should be used in a concept of meta-approach (Bergh, Button, Nijkamp, & Pepping, 1997), to help to model the micro-/macro relationships of the SES management problem.

3. E. Ostrom's Social-Ecological System Framework

The SES framework is a meta-theoretical framework and it attempts to identify the universal elements that characterize any theory relevant to the phenomena of the study of the SESs, it is considered as a conceptual map, and it also identifies basic working parts and critical relationships among those elements. In this view, SES framework is considered as a decomposable system built on three aspects of decomposable complex system which are: the conceptual partitioning of variables into classes and subclasses, the existence of relatively separable subsystems that are independent of each other in the accomplishment of many functions and development but

eventually affect each other's performance, and complex systems are greater than the sum of their parts. Based on these aspects, SES framework is composed of four ''first-level core subsystems,'' namely: (i) a resource system, (ii) resource units, (iii) a governance system, and (iv) users, and they affect each other as well as linked social, economic, and political settings and related ecosystems. These subsystems contain a set of variables known as a set of ''second-level'' variables of the SES and they constitute a basis in the SESs analysis efforts (Ostrom E. , 2007). The parts and the interactions of the SES framework reflects the level of the complexity of the SESs. The more the subject matter of the study is complex, the more is sophisticated the framework to study it (Adamsen, 2000). The SES framework has been increasingly converted into a complex framework that can be identified through a view of the two faces of opposite directions by which, each part of the framework is autonomous agent of the whole system and though interactions with other variables or individual parts, dynamically evolves to form changing configurations of the system (Rivero & Hakizimana, 2016). The decomposition of SES framework focused on is given in annexed Figure 1.

This figure focuses on how a Resource System, Resource Units, Governance System, and Actors embedded in larger or smaller Social, Economic, and Political Settings and Related Ecosystems might affect interactions and outcomes within action situation (Ostrom E, 2011; 2007). These subsystems of the first level of the whole system, are further decomposed into second level or second-tier independent variables, and they help diagnosing the causal patterns that affect outcomes. A list of these variables is found in the annexed Table 5. In this view, SES framework describes a case study as a unit of analysis and a group of cases studies in the perspective of the meta-approach (Bergh, Button, Nijkamp, & Pepping, 1997, p. 4), whereas, its subsystems and their sets of variables are its parts on the first order and second order respectively. As far as diagnosis of complex problem of the SES is concerned, the view in the face turned towards the lower levels where SES parts on the first order and second order are considered as autonomous whole is expressed (Rivero & Hakizimana, 2016). This view applies a methodological approach of considering a case study as a unit of analysis in which natural phenomena, human behavior, policy instruments are in structural form and autonomous.

Apart of the view in the face turned towards the lower levels, the SES is viewed in the face turned upward-that of a dependent part (Ibidem). In this view, a variable is taken as a unit part of the SES, and it is considered as autonomous whole where its variability depends on its inner characteristics and its variable interactions. As parts of a system, these variables interact and form patterns of interactions to determine overall outcomes of the system, and any change in formed patterns of interactions may affect positively or negatively outcomes of the system (Ostrom E. , 2007). When this analysis is done across the case studies within a meta-approach context, it helps to identify that each case study must not be considered as a unique, neither as common-there are variables whose performances are constant and others are heterogeneous. The later are the one whose interactions may lead to resource use improvement or destructions (Ostrom E. , 2009). These variables have been structed by E. Ostrom indicated in the annexed Table 5. According to this table, the SES framework contains 42 variables which have been increased to 172 variables due to further analysis and concerns with the complex problem of the SES management (SESMAD, 2014). Based on identification and understanding of the impact of interactions of these variables

in terms of configurations, the complex functionality of the SESs is understood (Niazi & Hussain, 2013). To understand how the same processes across the cases can lead to different results, a meta-analysis of the case studies is used.

4. Meta-Analysis of the case studies

The meta-analysis and the SES framework are both methodologically meta-approaches. Being meta-approaches, are suitably applied to solve those environmental problems at meso-level (Bergh, Button, Nijkamp, & Pepping, 1997, p. 4). They can solve these complex problems because of their capabilities of dealing with the intrinsic methodological complexity inherent to meta-approach tendency. Taking a case study as a unit of analysis, a meta-analysis of case studies as a technique is used to make a synthesis of research analysis across the case studies, and it offers a transversal comparison and summary analysis of various studies to various addressed issues. The transversal method and the meta-approach of the meta-analysis of the case studies helps to solve the complex problem of the SESs form a single case study to meso-level (Bergh, Button, Nijkamp, & Pepping, 1997). It does this by helping to identify those variables whose interactions and formed patterns of interactions lead to improvement or destruction of the SES resources across the case studies. This helps to conduct institutional design and change for achieving the desired results in case undesired outcomes are realized. This transversal method provides a congruent methodology to model the micro-/macro-relations which helps understanding the functionality of the commons in the context of variable interactions and formation of patterns of interactions. This process determines the successful and unsuccessful conditions of a case study as unit of analysis (micro-level relationships) and across the case studies (macro-level relationships).

5. Institutional change

The institutions[1] play an important role in the successful management. They are used to determine the proprietorship and the rights hold over the resources (Ostrom E. , 2005). In order to realize the said impact, they must be rules-in-use applied to specific resources in the particular areas where any decision about the resource use is bound by a set of institutions (Ostrom, Gibson, & A., 2000). In this context, the rules behave into an evolutionary process to determine the desired outcomes (Ostrom E. , 2007).

The purpose of having institutional arrangements is to realized desired optimal outcomes from the CPRs use, i.e the institutional arrangements are founded on rational choice theory (Rivero, 2015), which means that the SES users are supposed to know how the institutions and their set of arrangements lead to better outcomes. When these outcomes are not achieved, the institutional change is needed, and it is possible when the CPR users are collectively willing and capable to carry out it (Ostrom, Gardyner, & James, 1994, pp. 15-17). Institutional change affects the resource or/and the incentives at the same time by changing the behavior of participants in the situation action. If community participants do not understand how particular combinations of rules affect actions and outcomes in a particular ecological and cultural environment, rule changes may

[1] According to E. Ostrom, the institutions are the prescriptions that humans use to organize all forms of repetitive and structured interactions of daily life (Ostrom E. , 2005, pág. 3).

produce unexpected and disastrous outcomes. Thus, the community members must understand well in a broad way, the applied institutions to their CPRs and the benefits got from use of these institutions. Therefore, this is not an easy task (Ostrom E. , 2005). There must be a structured and easily understandable framework to help understanding the processes. This is for example the case of the Institutional Analysis framework which was later converted into SES framework (Ostrom E. , 2011). Thus, the use of the SES framework and the meta-analysis helps to determine the variables whose interactions and patterns of interactions lead to the successful or unsuccessful conditions, and the institutional design and change must be based on these variables to create a social environment that favors the achievement of the successful situations (Rivero & Hakizimana, 2016).

6. Methodology

The methodology of this research consists of both theoretical and empirical analyses. The theoretical analysis consists of description of the complexity problem of the SESs in the context of the SES framework development as a meta-approach. The empirical analysis applies the SES Meta-Analysis method (SESMAD) to study how variable interactions and formation of patterns of interactions affect the outcomes within a concrete case study of community forests of Mexico.

The meta-analysis of the case studies is composed of 32 case studies of the community forests in Mexico for a period of 2000 to 2015. This goes hand in hand with what F. V. Laerhoven says that generally, the study of community forest governance relies heavily on case-study materials (Laerhoven, 2010) . By using the Analytical Hierarchy Process (AHP) technique, a sample of case studies of 60 out of 172 variables which characterize the SES of the common-pool resources was systematically chosen from SESMAD. The idea of selecting 60 variables is based on the criteria of how much the selected variables are implicated in the characterization of community forests governance performance.

Based on the SESMAD method, the variables used in this paper, are classified depending on their type, their component type, attached component, and the theme that they talk about:

i) Variable type which comprises; 8 variables are binary, 14 variables are categorical variables, 2 variables are interval variable, 34 variables are ordinal variables, and 2 variables are texts. The content of these variables is annexed.
ii) Variable Component Type: The variables are classified into the components such as natural resource system with 17% total of all variables, actors with 63% total of all variables, and governance system with 20% of all variables. To know how they influence the outcomes of the community forests, it is needed to identify how far are represented in the interactions and outcomes process, this is given by viewing how variables are distributed in the attached component.
iii) Variable attached component. The variables are attached to either case component or component-interaction. Thus, in this paper, 70% of variables are of component interaction and 30% are of case component which means the high viability and reliability on the

information got for analysis and the existence of diversity in the outcomes resulting from various possible patterns of interactions.

iv) Theme: the variables used in this paper present the themes of: spatial, outcomes, institutions, context, enforcement, incentives, heterogeneity, basic, external, leadership, social capital, biophysical. In this research the concern is the outcomes which is presented by 17% of the variables.

After classifying the variables generally characterizing the community forests in the SESMAD format, the meta-analysis statistical techniques are used to identify the performance effect size across the case studies. These techniques among others are: firstly, means and standard deviations of the variable performances across the case studies. These techniques help to identify if the degree to which the case studies are identical or diverse. In other words, they help to identify homogeneity and heterogeneity across the case studies. Secondly, since there is diversity among the variable performances within the case studies, it is possible to identify the successful and unsuccessful case studies. This is done by referring to the mean of the outcome performances. Thirdly and finally, since the successful and unsuccessful case studies are determined, the mean effect size technique is used to identify those variables whose interactions and patterns of interactions leads to successful or unsuccessful situations. These variables are the ones to which institutional change should be based on to generate particular and general effect across the case studies. This methodology helps to model the micro-macro relationships because it helps to understand how variable interactions and patterns of interactions cause improvement or destruction of the SES resources at micro level (at a case study as a unit of analysis) as well as at macro level (across the case studies).

7. Results

The meta-analysis of the studies on the Mexican community forest case studies brought to the following results:

i) Constant and heterogeneous variables across the case studies

The analysis of 60 variable performance effects across 32 case studies shows that the variables behave in two types: there are 10 variables whose effect sizes are consistent across the case studies and 50 variables with varied effect sizes. The former variable classification generates consistent performance effects across the case studies, and they are not significant to explain the process that lead to successful or unsuccessful conditions. In other words, they explain little about the complexity problem of the community forests in Mexico. These variables are: commons actions[2], commons aggregation, governance knowledge use, governance scale, governance system description, governance system spatial extent, markets, rights type, the actor group size, commons spatial extent. The other 50 variables are the variables which explain the diversity across the case studies. These variables are the one which complicate understanding of the processes which lead

[2] The common actions identified in all cases studies are extraction, monitoring, conflict resolution, rule-making, sanctioning, trading, consumption. These actions are currently extended and acted under management plan by large group size, with rights of access, use, exclusion, management, and alienation. The proportionality of these rights is not identified, and per SESMAD project, if there is not rights proportionality, there may be a lack of motivation to contribute to the successful governance of the common resources, thus for example in this research there is no habit of self-sanctions. Even if there are no self-sanctions, community forests are governed to the extent to which conflicts are solved.

to success or failure situation from one case to another, they are the one which explicit the problem of the complexity through their complex interactions and formation of patterns of interactions.

ii) Successful and unsuccessful behavior conditions

The successful or unsuccessful conditions across 32 case studies are explained by 50 out of 60 variables whose performance effects change from one case study to another. The division of the case studies into successful and unsuccessful case studies is based on the overall average of the outcomes[3] of the all case studies which is equal to 2.18. Based on this criterion a case study whose average of the outcomes is greater than the overall average, is successful and the ones with averages of the outcomes which are below than the overall average is unsuccessful. Thus, the successful cases are seventeen and the unsuccessful cases are fifteen. As far as the successful case studies are diverse from the unsuccessful ones by the realized outcomes, it was also identified that this difference is observed in each variable performance into these groups. This difference is shown in the below table.

Table 1: Variable performance into successful and unsuccessful case studies

Variables	Total observed perfor mance	Average observed perfor mance	Successful cases		Unsuccessful cases	
			Total	Average	Total	Average
Actor adaptive capacity	65	2.03	41	2.41	24	1.60
Actor group boundary clarity	83	2.59	49	2.88	34	2.27
Actor group boundary fuzziness	18	0.58	14	0.875	4	0.27
Actor group coordination	90	2.81	53	3.12	37	2.47
Actor group trust	68	2.13	46	2.71	22	1.47
Biodiversity trend	64	2.00	45	2.65	19	1.27
Collective action	66	2.06	47	2.76	19	1.27
Commons boundaries	88	2.75	50	2.94	38	2.53
Commons boundary negotiability	69	2.16	30	1.76	39	2.60
Commons condition trend	65	2.03	46	2.71	19	1.27
Commons feedback speed fix	60	1.88	38	2.24	22	1.47
Commons feedback speed use	45	1.41	29	1.71	16	1.07
Commons feedback visibility fix	59	1.84	37	2.18	22	1.47
Commons feedback visibility use	45	1.41	29	1.71	16	1.07
Commons political power	63	1.97	43	2.53	20	1.33
Community Participation	68	2.13	47	2.76	21	1.40
Conflict resolution	23	0.72	17	1.00	6	0.40
Costs of exit	27	0.84	17	1.00	10	0.67
Cultural dependence	60	2.07	34	2.43	26	1.73
Cultural services condition	56	2.33	34	2.83	22	1.83
Ecosystem service management	36	1.16	28	1.65	8	0.57
Ecosystem services markets	29	0.91	15	0.88	14	0.93

[3] This is important because helps comparing the outcomes achieved and what are expected to be achieved.

Effect confidence	102	3.19	60	3.53	42	2.80
Environmental monitoring	51	1.59	33	1.94	18	1.20
External monitoring	20	0.63	10	0.59	10	0.67
External recognition	28	0.88	15	0.88	13	0.87
External support	40	1.25	20	1.18	20	1.33
Governance strictness trend	57	1.78	38	2.24	19	1.27
Governance system effect	65	2.03	45	2.65	20	1.33
Incentive type	13	0.87	7	1.00	6	0.75
Institutional diversity	54	1.69	31	1.82	23	1.53
Interest heterogeneity	64	2.00	23	1.35	41	2.73
Inter-group trust	62	1.94	45	2.65	17	1.13
Leadership	68	2.83	36	3.00	32	2.67
Leadership accountability	44	1.69	30	2.00	14	1.17
Leadership authority	55	1.83	39	2.29	16	1.14
Multiple levels	25	0.83	14	0.82	11	0.85
Participation in environmental monitoring	58	1.81	41	2.41	17	1.13
Participation in rule making	61	1.91	45	2.65	16	1.07
Participation in social monitoring	59	1.84	43	2.53	16	1.07
Past collaboration	67	2.09	45	2.65	22	1.47
Personal communication	101	4.59	64	4.92	37	4.11
Perverse incentives	19	0.59	10	0.59	9	0.60
Proportionality (of costs and benefits)	27	0.90	16	1.00	11	0.79
Provision services condition	63	1.97	45	2.65	18	1.20
Regulating services condition	68	2.13	45	2.65	23	1.53
Self-monitoring	60	1.88	41	2.41	19	1.27
Self-Sanctions	17	0.53	15	0.94	2	0.13
Transaction costs	66	2.28	30	1.88	36	2.77
User group well-being change	64	2.13	43	2.53	21	1.50

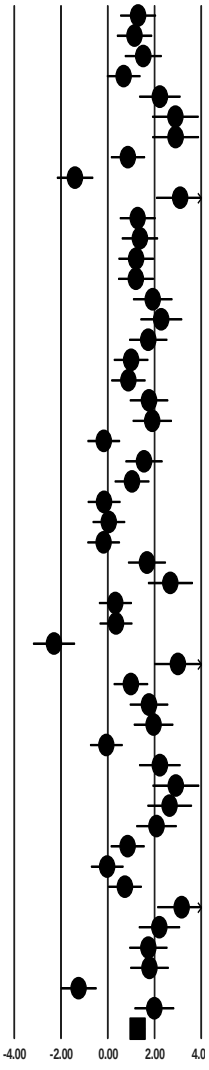
Source: Proper design based on the concept of E. Ostrom, 2007, 2012 & SESMAD, 2014

According to the above table, the variables in unsuccessful case studies have lower performances than the variables in successful case studies. This is indicated by their average performances which are red colored in the unsuccessful case studies for the variables whose increase in performance, positively affect the outcomes. whereas to the variables whose increase in performance affect negatively the outcomes, their performances in unsuccessful case studies are greater than the performances in successful case studies. This difference is shown by variables with green color of variable average performances in successful case studies. This differentiation of variable performances between the successful and unsuccessful case studies has the purpose of responding the question of that why and how the processes of interactions and patterns of interactions in some cases lead to successful conditions whereas in other cases lead to the unsuccessful conditions. To respond to this question, it is necessary to identify the more relevant variables to explain the processes of interactions and patterns of interactions which lead to successful or unsuccessful conditions.

These variables one whose mean effect sizes vary from one case study to another and they have the Z-values greater than critical Z-value of |1.96| and the significant P-values. They are significantly determinants of the successful and unsuccessful conditions because they have the good performance in the successful case studies and the poor performance in the unsuccessful ones. These variables, as well as their corresponding statistical parameters are given in the below table.

Table 2: Meta-Analysis of 32 case studies of community forests in Mexico

Model	Study name	Statistics for each study						Std diff in means and 95% CI
		Std diff in means	Standard error	Lower limit	Upper limit	Z-Value	p-Value	
	Actor adaptive capacity	1.299	0.390	0.535	2.063	3.333	0.001	
	Actor group boundary clarity	1.143	0.382	0.395	1.892	2.993	0.003	
	Actor group boundary fuzziness	1.521	0.402	0.733	2.309	3.783	0.000	
	Actor group coordination	0.680	0.364	-0.034	1.394	1.866	0.062	
	Actor group trust	2.230	0.451	1.347	3.114	4.947	0.000	
	Biodiversity trend	2.896	0.506	1.903	3.889	5.718	0.000	
	Collective action	2.902	0.507	1.909	3.896	5.724	0.000	
	Commons boundaries	0.865	0.370	0.139	1.591	2.335	0.020	
	Commons boundary negotiability	-1.401	0.395	-2.176	-0.627	-3.546	0.000	
	Commons condition trend	3.101	0.525	2.072	4.130	5.905	0.000	
	Commons feedback speed fix	1.282	0.389	0.520	2.044	3.296	0.001	
	Commons feedback speed use	1.377	0.394	0.605	2.149	3.497	0.000	
	Commons feedback visibility fix	1.217	0.386	0.461	1.973	3.157	0.002	
	Commons feedback visibility use	1.204	0.385	0.449	1.958	3.127	0.002	
	Commons political power	1.926	0.428	1.087	2.766	4.497	0.000	
	Community Participation	2.290	0.455	1.397	3.182	5.027	0.000	
	Conflict resolution	1.732	0.415	0.918	2.546	4.172	0.000	
	Costs of exit	1.000	0.376	0.264	1.736	2.662	0.008	
	Cultural dependence	0.884	0.371	0.157	1.612	2.383	0.017	
	Cultural services condition	1.764	0.417	0.947	2.582	4.228	0.000	
	Ecosystem service management	1.904	0.427	1.068	2.740	4.461	0.000	
	Ecosystem services markets	-0.170	0.355	-0.866	0.526	-0.479	0.632	
	Effect confidence	1.551	0.404	0.759	2.342	3.841	0.000	
	Environmental monitoring	1.036	0.377	0.297	1.776	2.748	0.006	
	External monitoring	-0.157	0.355	-0.853	0.538	-0.444	0.657	
	External recognition	0.046	0.354	-0.648	0.740	0.130	0.897	
	External support	-0.176	0.355	-0.872	0.520	-0.496	0.620	
	Governance strictness trend	1.678	0.412	0.871	2.485	4.077	0.000	
	Governance system effect	2.679	0.487	1.723	3.634	5.495	0.000	
	Incentive type	0.326	0.357	-0.373	1.025	0.914	0.361	
	Institutional diversity	0.354	0.357	-0.346	1.053	0.991	0.322	
	Interest heterogeneity	-2.299	0.456	-3.193	-1.405	-5.040	0.000	
	Inter-group trust	3.004	0.516	1.993	4.016	5.819	0.000	
	Leadership	0.991	0.375	0.255	1.727	2.641	0.008	
	Leadership accountability	1.764	0.417	0.946	2.582	4.228	0.000	
	Leadership authority	1.962	0.431	1.117	2.806	4.553	0.000	
	Multiple levels	-0.059	0.354	-0.753	0.636	-0.166	0.868	
	Participation in environmental monitoring	2.231	0.451	1.347	3.115	4.948	0.000	
	Participation in rule making	2.915	0.508	1.919	3.912	5.736	0.000	
	Participation in social monitoring (enforcement)	2.646	0.485	1.696	3.596	5.460	0.000	
	Past collaboration	2.085	0.440	1.223	2.947	4.741	0.000	
	Personal communication	0.851	0.370	0.126	1.576	2.302	0.021	
	Perverse incentives	-0.023	0.354	-0.718	0.671	-0.065	0.948	
	Proportionality (of costs and benefits)	0.737	0.366	0.019	1.454	2.013	0.044	
	Provision services condition	3.162	0.531	2.122	4.202	5.958	0.000	
	Regulating services condition	2.210	0.449	1.330	3.091	4.920	0.000	
	Self monitoring	1.736	0.415	0.922	2.550	4.179	0.000	
	Self Sanctions	1.787	0.419	0.966	2.608	4.267	0.000	
	Transaction costs	-1.247	0.387	-2.006	-0.489	-3.222	0.001	
	User group well-being change	1.993	0.433	1.144	2.842	4.602	0.000	
Random		1.280	0.160	0.966	1.594	7.998	0.000	



However, not all variables equally contribute to the success and unsuccessful situations across the case studies. Thus, based on the criteria of significance of the standard difference in means with Z-values greater than 3.00 points[4] and significant P-values, 33 variables are considered as more

[4] This was deliberately chosen to be able to identify the variables which bitterly explain the process that lead to successful or unsuccessful situations.

significant explicative of the successful and failure situations within the case studies. These variables are listed in the below table.

Table 3:Variable that explain more the successful and unsuccessful situations

Variable of the study	Standard difference in Means	Standard error	Z-value	P-value
Actor adaptive capacity	1.299	0.390	3.333	0.001
Actor group boundary fuzziness	1.315	0.391	3.783	0.000
Actor group trust	2.230	0.451	4.947	0.000
Biodiversity trend	2.896	0.506	5.718	0.000
Collective action	2.902	0.507	5.724	0.000
Commons boundary negotiability	-1.401	0.395	-3.546	0.000
Commons condition trend	3.101	0.525	5.905	0.000
Commons feedback speed fix	1.282	0.389	3.296	0.001
Commons feedback speed use	1.377	0.394	3.497	0.000
Commons feedback visibility fix	1.217	0.386	3.157	0.002
Commons feedback visibility use	1.204	0.385	3.127	0.002
Commons political power	1.926	0.428	4.497	0.000
Community Participation	2.290	0.455	5.027	0.000
Conflict resolution	1.732	0.415	4.172	0.000
Cultural services condition	1.764	0.417	4.228	0.000
Ecosystem service management	1.904	0.427	4.461	0.000
Effect confidence	1.551	0.404	3.841	0.000
Governance strictness trend	1.678	0.412	4.077	0.000
Governance system effect	2.679	0.487	5.495	0.000
Interest heterogeneity	-2.299	0.456	-5.040	0.000
Inter-group trust	3.004	0.516	5.819	0.000
Leadership accountability	1.764	0.417	4.228	0.000
Leadership authority	1.962	0.431	4.553	0.000
Participation in environmental monitoring	2.231	0.451	4.948	0.000
Participation in rule making	2.915	0.508	5.736	0.000
Participation in social monitoring-enforcement	2.646	0.485	5.460	0.000
Past collaboration	2.085	0.440	4.741	0.000
Provision services condition	3.162	0.531	5.958	0.000
Regulating services condition	2.210	0.449	4.920	0.000
Self-monitoring	1.736	0.415	4.179	0.000
Self-Sanctions	1.787	0.419	4.267	0.000
Transaction costs	-1.247	0.387	-3.222	0.001
User group well-being change	1.993	0.433	4.602	0.000

Source: Proper design based on meta-analysis of case studies and the concept of E. Ostrom, 2007& SESMAD, 2014.

The variables contained in the above table 3, are classified into two groups. The variables with positive standard difference in means, which shows that the increase in variable performance contributes to the success situation and vice versa, and the variables with negative standard difference in means show that decrease in performance positively contribute to the success situation and vice versa. It is supposed that the successful and unsuccessful conditions result from the complex processes of interactions and patterns of interactions of the variables like those listed above. The question then is how to identify and explain the complexity embedded into the process of interactions and the formation of the patterns of interactions in order to be able to design policies that can help to achieve successful governance.

iii) Variable interactions and configurations of patterns of interactions

According to the SES framework, the variable interactions and configurations of patterns of interactions which affect the realized outcomes across case studies are done through a set of the second level variables of SES framework. At this level, each case study has its own configuration of the variables which result in success or unsuccessful conditions. This can be shown in the below table where three successful and three unsuccessful case studies are compared.

Table 4: Variable performance in three higher successful case studies and in three lower unsuccessful case studies

Social, Economic, and Political Settings (S)

RESOURCE SYSTEM (RS)	Successful cases			Unsuccessful cases			GOVERNANCE SYSTEM (GS)	Successful cases			Unsuccessful cases		
	C1	C3	C11	C4	C10	C15		C1	C3	C11	C4	C10	C15
Biodiversity trend	3	3	3	1	1	1	Governance strictness trend	3	3	3	1	1	1
Commons condition trend	3	3	3	1	1	1	Governance system effect	3	3	3	1	1	1
Cultural services condition	3	3	3	1	(-)	1	Inter-group trust	3	3	3	1	1	1
Provision services condition	3	3	3	1	1	1	Transaction costs	2	(-)	2	3	(-)	3
Regulating services condition	3	3	3	1	1	1	**USERS(U)**						
							Actor adaptive capacity	3	3	3	2	1	1
							Actor group boundary fuzziness	1	1	1	1	0	0
							Actor group trust	3	3	3	2	1	1
							Collective action	3	3	3	1	1	1
							Commons boundary negotiability	2	1	1	3	2	3
							Commons feedback speed fix	2	2	2	1	1	1
							Commons feedback speed use	2	2	2	1	1	1
							Commons feedback visibility fix	2	2	2	1	1	1
							Commons feedback visibility use	2	2	2	1	1	1
							Commons political power	3	3	3	1	1	1
							Community Participation	3	3	3	1	1	1
							Conflict resolution	1	1	1	0	0	1
							Ecosystem service management	2	2	2	0	0	1
							Effect confidence	4	4	4	3	2	3
							Interest heterogeneity	1	1	1	3	3	3
							Leadership accountability	3	(-)	2	1	1	1
							Leadership authority	3	3	2	1	1	1
							Participation in environmental monitoring	3	3	3	1	1	1
							Participation in rule making	3	3	3	1	1	1
							Participation in social monitoring	3	3	3	1	1	1
							Past collaboration	3	3	3	1	2	1
							Self-monitoring	1	2	3	1	2	3

							Self-Sanctions	1	1	1	0	0	0
							User group well-being change	3	3	3	1	1	1
INTERACTIONS (I)-OUTCOMES (O)														
Actor adaptive capacity (A)	3	3	3	2	1	1	Actor adaptive capacity	3	3	3	2	1	1
Actor group boundary fuzziness (A)	1	1	1	1	0	0	Biodiversity trend	3	3	3	1	1	1
Biodiversity trend (RS)	3	3	3	1	1	1	Collective action	3	3	3	1	1	1
Collective action (A)	3	3	3	1	1	1	Commons condition trend	3	3	3	1	1	1
Commons boundary negotiability (A)	2	1	1	3	2	3	Cultural services condition	3	3	3	1	(-)	1
Commons condition trend (RS)	3	3	3	1	1	1	Effect confidence	4	4	4	3	2	3
Commons feedback speed fix (A)	2	2	2	1	1	1	Governance system effect	3	3	3	1	1	1
Commons feedback speed use (A)	2	2	2	1	1	1	Provision services condition	3	3	3	1	1	1
Commons feedback visibility fix (A)	2	2	2	1	1	1	Regulating services condition	3	3	3	1	1	1
Commons feedback visibility use (A)	2	2	2	1	1	1	User group well-being change	3	3	3	1	1	1
Commons political power (A)	3	3	3	1	1	1							
Cultural services condition (RS)	3	3	3	1	(-)	1							
Ecosystem service management (A)	2	2	2	0	0	1							
Effect confidence (A)	4	4	4	3	2	3							
Governance strictness trend (GS)	3	3	3	1	1	1							
Governance system effect (GS)	3	3	3	1	1	1							
Inter-group trust (GS)	3	3	3	1	1	1							
Participation in environmental monitoring (A)	3	3	3	1	1	1							
Participation in rule making (A)	3	3	3	1	1	1							
Participation in social monitoring (A)	3	3	3	1	1	1							
Provision services condition (RS)	3	3	3	1	1	1							
Regulating services condition (RS)	3	3	3	1	1	1							
Self-monitoring (A)	1	2	3	1	2	3							
Self-Sanctions (A)	1	1	1	0	0	0							
Transaction costs (GS)	2	(-)	2	3	(-)	3							
User group well-being change (A)	3	3	3	1	1	1							

Related Ecosystems (ECO)

Source: proper design based on the concept of E. Ostrom, 2007 & SESMAD, 2014

Where C= Case, (-) stands for unidentified data, the variable performances in red color are the one which are below the average of performances in the case studies. The high performance of the variables, positively affect the outcomes. The variable scores which are greater than their respective average show that their high score performances imply the negative influence to the outcomes.

Comparing three highest successful case studies and three lowest unsuccessful case studies, the successful situations of the case studies are due to the patterns of interactions of best variable performances which result to desired outcomes, whereas the unsuccessful situations are due to patterns of interactions of poor performances of the variables.

However, not all successful case studies specifically have same characteristics, neither are the failed case studies. Each case has its unique configuration of variable interactions and formed patterns of interactions. In the next part the detailed interactions and patterns of the interactions for one of three successful case studies and one of three unsuccessful case studies are given.

The example of successful situation is the case study number one (1) which is successful case study with total outcomes of 31 points. It has a resource system characterized by improved biodiversity trend, improved commons condition trend, improved cultural services condition, improved provision services condition, and improved regulating services condition. The improvement in the state of the resource system is in relation with the interactions on one hand with the governance system characterized by: more strict governance, a governance system which

meets goals, high inter-group trust and medium transaction costs, and on the other hand with a system of actors characterized by: a high trust in actor group, high collective actions, a moderate commons boundary negotiability, medium commons feedback fix and use and medium commons feedback visibility fix and visibility use, a high common political power, a high community participation, existence of the conflict resolution, a high effect confidence, a high participation in environmental monitoring, a high participation in rule making, a high participation in social monitoring, a low self-monitoring, an existence of self-sanctions, and an improved user group well-being change. The interactions of the resource system, and governance system with action arena of actors result in high adaptive capacity of actors, improved biodiversity trend, high collective action, improved commons condition trend, improved cultural services condition, high effect confidence, high governance system effect, improved provision services condition, improved regulating service condition, and improved user group well-being.

Whereas the successful case studies present better performance of variables interactions ad ending results, the failed case studies present poor variable performances as well as poor performance in outcomes. This situation is explained in the following example of unsuccessful case study:

The example of failed case studies is case number four (4) with total outcomes of 13 points. Its resource system is characterized by: worsen biodiversity trend, worsen commons condition trend, worsen cultural services condition, worsen provision services condition, and worsen regulating services condition. The state of these resources is in relationship with the interactions with the governance system and system of actors. A governance system characterized by: less strict governance, a governance system which fails to meet goals, low inter-group trust, and high transaction costs. A system of actors characterized by: a medium actor group trust, low collective actions, a high commons boundary negotiability, low commons feedback fix and use and low commons feedback visibility fix and visibility use, a low common political power, a low community participation, lack of conflict resolution, lack of ecosystem service management, a low effect confidence, a high interest heterogeneity, a low leadership accountability and authority, a low participation in rule making, a low participation in social monitoring, a low past collaboration, a low self-monitoring, a lack of self-sanctions, and a worsen user group well-being change.

When the realized outcomes are not desired, this is the case of unsuccessful case studies and that there is a possibility of that institutional change to raise the variable performances for generating desired outcomes, then the institutional change is done with a focus on the variable performances and their interactions. Depends on the spatial extent of SESs impact, this process helps to model the micro-/macro-relations.

8. Conclusion

To conclude, by its intrinsic methodological complexity related to its meta-approach for studying the Social-Ecological Systems, the SES framework is a useful framework to help to understand the complex problem of the SES resources use. In this context, the SES as an easily understandable framework provides a structured analysis of the SES complex problem through systems of the variable interactions and formation of patterns of interactions which lead to either improvement or destruction in SES resources. These effects can be studied at micro level by particularly studying each case study or at macro level by conducting a meta-analysis of the case studies in the context of the SES framework method. The importance of this is that the micro-/macro relationships can be modelled by identifying and understanding those variable interactions and patterns of

interactions which leads to successful or unsuccessful situations at the micro level (at the level of a case study as a unit of analysis), as well as at macro level (across the case studies which can be at regional level or national level). This helps to carry out a feasible institutional design and change within unsuccessful case studies at multilevel of the CPRs governance.

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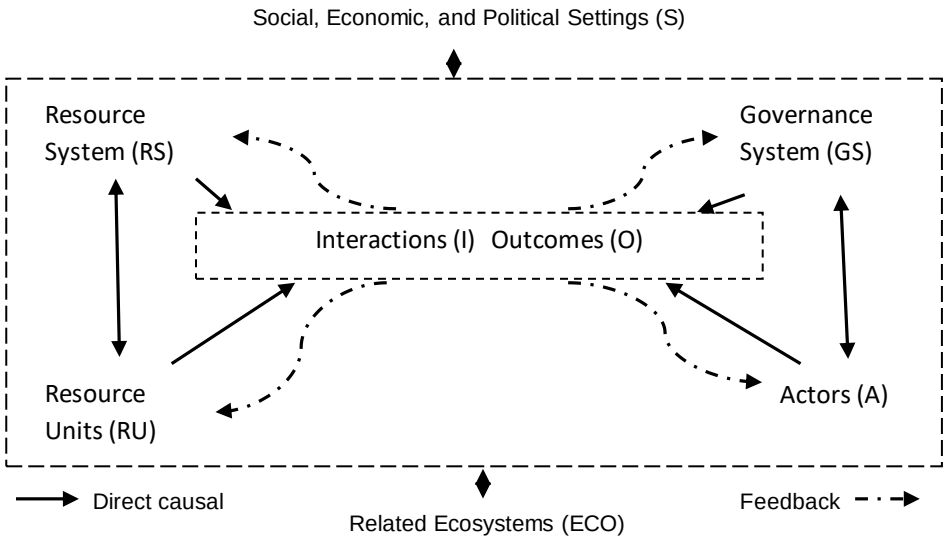
Annexes

Figure 1: Multitier Framework for Analyzing a Social-Ecological System



Source: E. Ostrom, 2007

Table 5: Second-Tier Variables of SES Framework

Social, Economic, and Political Settings (S) S1-Economic development. S2-Demographic trends. S3-Political stability. S4-Government settlement policies. S5-Market availability.	
Resource System (RS)	**Governance System (GS)**
RS1-Sector (e.g., water, forests, pasture, fish) RS2- Clarity of system boundaries RS3- Size of resource system RS4- Human-constructed facilities RS5- Productivity of system RS6- Equilibrium properties RS7- Predictability of system dynamics RS8- Storage characteristics RS9- Location	GS1- Government organizations GS2- Non-government organizations GS3- Network structure GS4- Property-rights systems GS5- Operational rules GS6- Collective-choice rules GS7- Constitutional rules GS8-Monitoring & sanctioning process
Resource Units (RU)	**Users (U)**
RU1- Resource unit mobility RU2- Growth or replacement rate RU3- Interaction among resource units RU4- Economic value RU5- Size RU6- Distinctive markings	U1- Number of users U2- Socioeconomic attributes of users RU3- History of use U4- Location U5- Leadership/entrepreneurship U6- Norms/social capital

RU7- Spatial & temporal distribution	U7- Knowledge of SES/mental models U8- Dependence on resource U9-Technology used
Interactions (I)? Outcomes (O)	
I1- Harvesting levels of diverse users I2- Information sharing among users I3- Deliberation processes I4- Conflicts among users I5- Investment activities I6- Lobbying activities	O1- Social performance measures (e.g., efficiency, equity, accountability) O2- Ecological performance measures (e.g., overharvested, resilience, diversity) O3- Externalities to other SESs
Related Ecosystems (ECO) ECO1-Climate patterns. ECO2-Pollution patterns. ECO3-Flows into and out of focal SES.	

Source: E. Ostrom, 2007