TITLE: Collective action in urban social ecological systems

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Abstract

Over the years multiple scholars have qualitatively and quantitatively studied such urban collective action scenarios in order to understand the dynamics of such self-organizing behavior. Ostrom (2007; 2009) proposes a framework of variables which "are posited to affect the likelihood of users engaging in collective action to self-organize" in a social-ecological system. Ostrom (2007) observes that "interactions and outcomes depend on the specific combination of several variables". Young et al (2006) note that scholars studying human-environment interaction in such complex social-ecological systems "often encounter analytic and methodological problems that are difficult to solve using familiar scientific procedures" as the "dangers of ending up with spurious relationships are especially serious in research on human-environment interactions". In their search for "rigorous modes of analysis usable even in small-N situations" in view of the fact that "(s)tatistical inference never establishes causal connections in any definitive sense", they find promise in the use of Qualitative Comparative Analysis (QCA) methods to study human environment interactions. In this paper I seek to identify the causal combination of variables which affect outcomes in urban collective action situations around ecological or environmental resources. I do this by applying the QCA methodology. Specifically, the research question I seek to answer is – "what causal combination of variables affects outcomes, in urban collective action scenarios around ecological and environmental social-ecological systems?" The source of data is published case studies on collective action in urban social-ecological systems. I seek to identify a framework of variables which can be used to test properties in such systems. I analyze how QCA tools can be used for testing such properties and then describe in detail the methodology used for analyzing data in this study. I also define the independent and outcome variables as used in this study. I then discuss findings and conclude this paper by highlighting the relevance of this project.

KEYWORDS: social impacts and human dimensions of natural resource management; Governance ; Urban Collective Action; Social-ecological system; QCA

Introduction

Kohler and Wissen (2003) observe that urban centers "represent to a large extent the global and local focal points of social movements". Over the years multiple scholars have qualitatively and quantitatively studied such urban collective action scenarios in order to understand the dynamics of such self-organizing behavior. Ostrom (2007; 2009) proposes a framework of variables which "are posited to affect the likelihood of users engaging in collective action to self-organize" in a social-ecological system. In this paper we seek to identify the causal combination of variables (as identified by case-writers) which affect outcomes in urban collective action situations around ecological or environmental resources by applying the QCA methodology. The methodology used to answer the research question is as follows – we identify thirteen studies on urban collective action around ecological and environmental social-ecological systems based on a literature review of academic journals. We develop a coding framework based on the variables specified in the SES framework. We then use this coding framework to code these thirteen studies by identifying instances from these studies where variables laid out in the SES framework (which have been cited by the authors of these studies) are believed to have affected outcomes. All variables are dichotomized – thus the presence of a variable in the SES is coded as 1 in the database and 0, otherwise. We then use the QCA approach to answer our research question. Additionally, we also seek to identify a set of variables which were found to affect outcomes in the studies but which we couldn't satisfactorily code based on our understanding of the SES framework.

Introduction to the SES framework

Ostrom (2007) proposed the SES framework as a conceptual map for studying social-ecological systems. The framework (Figure 1) consists of a set of nested variables which can interact with each other both vertically and horizontally as well as across time to produce outcomes at the social-ecological level. At the broadest level, the framework consists of four variables – the attributes of a resource system, the attributes of the resource units generated by that system, the attributes of the actors in that system, and the attributes of the governance system associated with the resource system. These four variables are affected by, and in turn influence the larger socioeconomic, political, and ecological settings (context) within which the system is embedded. Each of these variables can be unpacked into a set of second tier variables as listed in figure 2 (Ostrom 2007; 2009). McGinnis & Ostrom (2014) have presented an updated version of this framework.

Out of the numerous variables which constitute the second-level variables in this framework, scholars have argued that the behavior of 10 variables most likely explain whether actors in a social-ecological system are likely to self-organize in order to collectively tackle their resource governance problems. Three of these variables - size of resource system (RS3), productivity of system (RS5) and predictability of system dynamics (RS7) are attributes of the resource system. The fourth variable - resource unit mobility (RU1) is an attribute of the resource units generated by that system. Five additional variables - number of relevant actors (A1), leadership/entrepreneurship (A5), norms (trust-reciprocity)/social capital (A6), knowledge of SES/mental models (A7) and importance of resource (dependence) to users (A8) are attributes of the actors in that system. The tenth variable - Collective-choice rules (GS6) is an attribute of the governance system associated with the resource system (Ostrom 2009; McGinnis & Ostrom 2014).

Social-ecological systems & QCA

Marx et al. (2013) identify a variety of uses of a research method named Qualitative Comparative Analysis (QCA). This method can be used to "check the analytical coherence of a given set of cases with respect to relevant causal conditions". It can be used for theory testing and also for identifying propositions can correctly formulated in existing theory. In QCA, cases are "represented as configurations of variables" with the goal of identifying "configurations of causally relevant conditions" which are linked to similar kinds of outcomes across a range of cases. Thus, when one applies the QCA method to study a wide range of cases, it is important to keep in mind that the same combination of variables could produce different outcomes, depending on the context.

Ostrom (2007) observed that while traditional research methods have generally tried to eschew complexity in favor of simple intuitive solutions, researchers seeking to understand social-ecological systems should embrace complexity; and therefore, in order to understand the complex nature of reality, one needs to look out for research methods which allows researchers to "identify combinations of variables" that affect "interactions and outcomes" in SESs. Specifically she observed that one of the three interesting questions that the SES framework will enable researchers to ask is "What *patterns* of interactions and outcomes, such as overuse, conflict, collapse, stability, and increasing returns, are likely to result from using a particular set of rules for the governance, ownership, and use of a resource system and specific resource units in a specific technological, socioeconomic, and political *environment*?"

Young et al (2006) have conducted a comparative study of various analytical methods which can be used to study "complex human-environment interactions". They feel that the QCA research methodology with its desire to analyze "configurations of factors" in order "to reduce complexity" could prove to be a fairly attractive method for studying SESs. According to them a particular advantage of this method is that similar cases can be grouped together in-order to conduct "in-depth exploration" of each such case in order to better understand the characteristics which produce similar outcomes. They conclude that QCA can be used to analyze "causal patterns in situations with small numbers of cases, limited sets of drivers, and relatively clear-cut outcomes."

A parallel reading of Marx et al. (2013) and Ostrom (2007) led me to test the applicability of the research method of QCA for my current project on urban social ecological systems.

Research Question

The research question for this paper is – "Given a set of case-studies on collective action around urban social ecological systems, what is the likely configuration of causally relevant variables that have affected collective action outcomes across the cases considered for the study?"

Case Selection

I used a number of limiting criteria in order to narrow down the cases that I wanted to use for this study. The first criterion I used was that I would include only those case-studies which have been published in academic journals. I therefore excluded all conference papers, working papers, dissertations, grey literature. I next looked at all articles published in Ecology & Society/ Conservation Ecology between 1997 and 2013, and articles in the Digital Library of the Commons, LTER database, SES Library (ASU).

Next, I use the following search terms on google scholar - “movement OR collective OR activism OR "civil society" OR citizen OR community OR self-organization OR self-governance OR commons OR co-management OR "social ecological" OR resilience. The case-studies so collected were then further narrowed down by considering only those studies which focused on urban areas.

My final sample of case-studies included 13 case-studies published between the period 2004 and 2013 - 8 from Ecology & Society, 5 from other journals - Environment & Planning. A; Journal of Cleaner Production; Applied Geography; Global Environmental Change; Journal of Environmental Planning & Management. With regard to the kind of SESs covered - Urban Greens – 3; Urban Water – 8; Urban Waste – 1; Urban Bio-D – 1. The cases represented 13 different urban centers from across the world.

Coding Framework

I developed a detailed coding framework based on the variables listed in the SES framework (figure 2). For each independent variable in the coding framework, I asked the question – – According to the case-writer, is the variable important for explaining the events of the case? Only those cases were selected for coding, which detailed a collective choice outcome. I used the following question to complete the case selection process - Do events described in the case result in the achievement of a social goal, ecological goal or other goals (which could be have legal or governance implications) as a result of collective action by actors described in the case?

Preliminary findings and observations

While traditionally the general belief among researchers has been that QCA is suited for the analysis of intermediate-N sized database, and most researchers have based their analysis based on these assumptions, in recent years, QCA theorists have developed a more nuanced view (Rihoux and Ragin 2009).

Marx (2010) and Marx & Dusa (2011) observe that not only is the number of cases important, but also the number of conditions (explanatory variables). I quote – “csQCA applications with more than 7 conditions (including the outcome) and applications where the proportion of conditions on cases is higher than.33 are not able to distinguish real from random data due to the problem of uniqueness.” Ragin too agrees with this perspective (Rihoux and Ragin 2009).

According to Marx (2010), the optimal number of explanatory conditions for which QCA analysis is suited is in the range of 3 to 6. For 3 conditions, the number of cases required to meet QCA robustness conditions is 9 to 11. For 4 conditions, the number of cases required to meet QCA robustness conditions is 10 to 14. For 5 conditions, the number of cases required to meet QCA robustness conditions is 13 to 25. For 6 conditions, the number of cases required to meet QCA robustness conditions is 16 to 29.

At this stage it is important to note that the ratio of cases to combinations can be used as a measure of robustness. Measures of coverage and consistency can be used a measures of fit.

Therefore, keeping these conditions in mind, for the preliminary (QCA) analysis, I decided to focus on the ten variables identified by Ostrom (2009) that are likely to explain outcomes in collective action scenarios.

All variables are dichotomized – thus the presence of a variable in a case is coded as 1 in the database and 0, otherwise. All explanatory variables answer the question – "According to the author, is the variable important for explaining the events of the case?" The outcome variable tries to answer the question – " Do events described in the case result in the achievement of a social goal, ecological goal or other goals (which could be have legal or governance implications) as a result of collective action by actors described in the case?"

C-Id	RS3-Size	RS5-Prod	RS7-Pred	A1-Num	A5-Lead	A6-SoCa	A7-MeMo	A8-ImpR	GS6-Rules	O-Outcome
1	0	0	0	1	1	1	1	0	1	1
2	1	0	0	0	0	0	0	0	1	1
3	1	1	1	1	0	0	0	1	1	1
4	0	0	0	1	1	1	1	1	1	1
5	1	1	0	1	1	1	0	1	0	1
6	1	0	1	1	1	0	1	0	1	1
7	1	1	0	1	1	1	0	0	1	1
8	0	1	1	1	0	1	1	1	1	1
9	0	0	0	1	1	1	1	1	1	1
10	1	1	0	1	0	1	0	0	1	1
11	1	0	0	1	1	1	1	1	1	1
12	0	1	0	1	0	1	1	1	1	1
13	1	0	0	1	0	0	0	1	1	1
14	0	0	0	1	1	0	0	0	1	1
15	1	1	0	1	1	0	1	1	1	1

Table 1

As you can see, the outcome variable is 1 for all cases. This is a function of the rule used for selecting the cases. Only those cases were selected for coding, which detailed a collective choice outcome.

The variables A1-Num and GS6-Rules too is present in almost all cases (14 out of 15). All case writers thus believe that Rules are important for explaining outcomes. The variable A1-Num on the other hand, is generally present in all cases, as a lot of background of information about actors is anyway provided by most case-writers, and thus information about actors will generally always be provided in any case, irrespective of the nature of the case. Similarly, the variable <RS3 Size of resource system> too generally contains information that most case writers consider as background information. On the other hand, very few case writers, provided details on <RS7- Predictability of system dynamics>. Similarly, the coding of information for <RU1 Resource unit mobility> is I believe irrelevant. Because, very few case writers explicitly code this variable.

Therefore, for the preliminary (QCA) analysis, I consider only 5 explanatory variables - this also helps me meet the criteria set my Marx (2010) – for 5 explanatory conditions, Marx (2010) would have liked me to code atleast 13 to 25 cases. I have coded 15.

The 5 conditions I consider are –

Resource systems (RS): 1. RS5 Productivity of system

Actors (A): 2. A5 Leadership/entrepreneurship; 3. A6 Norms/social capital; 4. A7 Knowledge of SES/mental models; 5. A8 Importance of resource

As you can see from Table 1, there is ample variation in these 5 variables, and therefore meets another condition set by Rihoux & Ragin (2009) who observe that one of the best practices of QCA analysis is to ensure “do not include a condition that does not vary across the cases. In other words, a variable must vary”

The truth table for the same is attached below –

rs5prod	a5lead	a6soca	a7memo	a8impr	number	ooutcome	raw consist.	PRI consist.	SYM consist
0	1	1	1	1	3	1	1.000000	1.000000	1.000000
1	0	1	1	1	2	1	1.000000	1.000000	1.000000
0	0	0	0	0	1	1	1.000000	1.000000	1.000000
0	0	0	0	1	1	1	1.000000	1.000000	1.000000
0	1	0	0	0	1	1	1.000000	1.000000	1.000000
0	1	0	1	0	1	1	1.000000	1.000000	1.000000
0	1	1	1	0	1	1	1.000000	1.000000	1.000000
1	0	0	0	1	1	1	1.000000	1.000000	1.000000
1	0	1	0	0	1	1	1.000000	1.000000	1.000000
1	1	0	1	1	1	1	1.000000	1.000000	1.000000
1	1	1	0	0	1	1	1.000000	1.000000	1.000000
1	1	1	0	1	1	1	1.000000	1.000000	1.000000
0	0	0	0	0	0	0			

Table 2

As you can see from table 2, I have assumed that outcome is 0 when all explanatory variables have a value of 0. I had to make this assumption, as the fsQCA software will not proceed, unless atleast one of the rows as a 0 for the outcome variable. Also note that the frequency and consistency threshold conditions (during case selection for analysis in the fsQCA software) are met. However, note that 13 out of 15 coded cases represent unique paths. Ideally, if the number of cases coded is higher, then the number of unique paths is smaller, with greater frequency for each path. fsQCA generates three kinds of output the Parsimonious output, the intermediate output and the complex output. The intermediate and complex outputs use software generated counter-factuals for analysis. I feel that the use of software generated counterfactuals is not appropriate for this study.

The output generated by the software is as follows –

```
--- COMPLEX SOLUTION ---

                                             raw       unique
                                           coverage   coverage    consistency
                                          ----------  ----------  ----------
~rs5prod*a5lead*~a6soca*~a8impr            0.133333    0.133333    1.000000
~a5lead*~a6soca*~a7memo*a8impr             0.133333    0.133333    1.000000
rs5prod*a6soca*~a7memo*~a8impr             0.133333    0.066667    1.000000
rs5prod*a5lead*a6soca*~a7memo              0.133333    0.066667    1.000000
~rs5prod*a5lead*a6soca*a7memo              0.266667    0.266667    1.000000
rs5prod*a5lead*~a6soca*a7memo*a8impr       0.066667    0.066667    1.000000
rs5prod*~a5lead*a6soca*a7memo*a8impr       0.133333    0.133333    1.000000
solution coverage: 0.933333
solution consistency: 1.000000
```

The consistency scores are high. The solution coverage score is high.

The output contains 7 possible paths (causal combination of variables) for explaining outcomes. The raw coverage scores for 6 of these paths are quite good (the raw coverage of one of the paths is 0.067 which is significantly lower than the remaining 6).

The causal equation therefore is – ~rs5*a5*~a6*~a8 + ~a5*~a6*~a7*a8 + rs5*a6*~a7*~a8 + rs5*a5*a6*~a7 + ~rs5*a5*a6*a7 + rs5*a5*~a6*a7*a8 + rs5*~a5*a6*a7*a8

If we rearrange the terms a bit - a5 * [~a6* (~rs5*~a8 + rs5*a7*a8) + a6 * (rs5*~a7 + ~rs5*a7)] + ~a5 * a8 * (~a6*~a7 + rs5*a6*a7) + rs5*a6*~a7*~a8

Thus, one possible way of interpreting these results is as follows -

- for a few paths the presence of a5 is important – a5 * [~a6* (~rs5*~a8 + rs5*a7*a8) + a6 * (rs5*~a7 + ~rs5*a7)]
- For a few paths the absence of a5 is important – ~a5 * a8 * (~a6*~a7 + rs5*a6*a7)
- And, for a path, the presence of a5 is irrelevant - rs5*a6*~a7*~a8

However, the causal equation is too complex and needs to be simplified further. A more elegant equation needs to be generated.

Ragin observes that QCA is a iterative process in which the selection of cases is iterative. Cases need to be selected in such a way that the simplest causal combination of variables is obtained with the aim of obtaining "modest generalization" which explains outcomes by making explicit the contextual conditions.

Thus, the selection of the "right" or "appropriate" cases is key to the process of QCA. Similarly, the selection of the appropriate causal conditions is another important criteria. While this analysis was based on only 10 (rather 5) explanatory conditions, I had coded for all the variables in the SES framework. Please find below the distribution of these variables –

Resource systems (RS)

C-Id	RS1-Sector	RS2-Clar	RS3-Size	RS4-HuCo	RS5-Prod	RS6-Eqb	RS7-Pred	RS8-Stor	RS9-Loc
1	Biodiversity, La	1	0	1	0	1	0	0	0
2	Woodlands	1	1	0	0	0	0	0	1
3	Lake, Watersh	1	1	1	1	0	1	0	1
4	Urban Park	1	0	1	0	0	0	0	1
5	Community gar	1	1	1	1	0	0	0	0
6	waste manage	1	1	1	0	0	1	0	0
7	Water	1	1	1	1	1	0	0	1
8	Water	1	0	1	1	1	1	1	1
9	Urban river cor	0	0	0	0	1	0	0	1
10	Lake	0	1	1	1	1	0	1	1
11	Wetland	1	1	1	0	0	0	1	1
12	Wetland	1	0	1	1	1	0	1	1
13	Greenbelt	1	1	1	0	1	0	0	0
14	River catchmer	0	0	1	0	1	0	0	0
15	River Watershe	0	1	1	1	1	0	1	1
Number of 1s		11	9	13	7	9	3	5	10

Actors (A)

C-Id	A1-Num	A2-SoEc	A3-Hist	A4-Loc	A5-Lead	A6-SoCa	A7-MeMo	A8-ImpR	A9-Tech
1	1	1	1	1	1	1	1	0	0
2	0	0	1	0	0	0	0	0	0
3	1	1	1	1	0	0	0	1	0
4	1	1	0	0	1	1	1	1	0
5	1	1	1	0	1	1	0	1	1
6	1	0	1	1	1	0	1	0	0
7	1	0	0	1	1	1	0	0	0
8	1	0	1	1	0	1	1	1	0
9	1	0	0	1	1	1	1	1	0
10	1	0	1	1	0	1	0	0	0
11	1	0	1	1	1	1	1	1	0
12	1	0	1	1	0	1	1	1	0
13	1	0	1	0	0	0	0	1	0
14	1	0	0	0	1	0	0	0	1
15	1	0	1	0	1	0	1	1	1
Number of 1s	14	4	11	9	9	9	8	9	3

Governance systems (GS)

C-Id	GS1-PolA	GS2-GeSc	GS3-Pop	GS4-Regm	GS5-Orgs	GS6-Rules	GS7-Prop	GS8-Norm	GS9-NetS
1		1	1	1	1	1	1	0	0
2	Urban Develo	1	0	1	1	1	1	1	0
3	Water	1	1	1	1	1	1	0	1
4		1	0	1	1	1	0	0	1
5		0	0	1	1	0	0	0	1
6	waste manag	1	1	1	1	1	1	1	0
7	Water	1	0	1	1	1	0	1	1
8	Water/flood c	0	0	1	1	1	0	1	0
9	Sustainable ur	0	0	1	1	1	0	1	1
10	Lake manage	1	1	1	1	1	1	1	0
11	Wetland lands	1	1	1	1	1	0	1	1
12	Wetland	1	1	1	1	1	0	1	1
13	Greenbelt	0	1	1	1	1	1	0	0
14	Urban Water	1	0	1	1	1	0	1	1
15	Waste manag	1	1	1	1	1	0	0	1
Number of 1s	0	11	8	15	15	14	6	9	9

Resource units (RU)

C-Id	RU1-Mob	RU2-Grow	RU3-Intr	RU4-EcoV	RU5-Num	RU6-DiMa	RU7-Spat	RU7-Temp
1	1	0	0	0	1	0	1	1
2	1	0	0	0	0	0	0	1
3	1	0	0	0	0	0	0	1
4	1	0	0	1	0	0	1	0
5	1	1	0	1	1	1	1	1
6	1	1	0	0	1	0	0	0
7	1	0	0	0	0	0	0	1
8	0	0	0	0	0	0	0	0
9	0	0	0	1	0	0	0	0
10	1	1	1	1	1	1	1	1
11	0	0	0	0	0	0	0	0
12	0	0	0	0	0	1	1	0
13	1	0	0	1	0	0	1	0
14	0	0	0	0	0	0	1	0
15	0	0	0	0	0	0	0	0
Number of 1s	9	3	1	5	4	3	7	6

Other variables

C-Id	ECO1-Clim	ECO2-Polu	ECO3-Flow	S1-EcoD	S2-Demo	S3-Pols	S4-Poly	S5-Mark	S6-Meda
1	0	0	0	1	0	0	0	0	0
2	0	0	0	0	0	0	0	0	0
3	1	0	0	0	1	1	1	0	0
4	0	0	1	1	0	0	0	1	1
5	0	0	1	1	1	0	0	1	0
6	0	0	1	0	0	0	1	0	0
7	0	0	0	0	0	0	1	0	0
8	0	0	1	0	0	0	0	0	1
9	0	0	0	1	0	0	0	0	0
10	1	1	1	0	1	0	0	0	0
11	0	0	0	0	0	0	1	0	0
12	0	0	0	1	0	0	0	0	0
13	0	0	0	1	1	0	1	0	0
14	0	0	0	0	0	0	0	0	0
15	0	0	0	0	0	0	1	0	0
Number of 1s	2	1	5	6	4	1	6	2	2

The last row in each table gives the total number of 1s. The columns in pink have a disproportionately large number of 0s. The columns in yellow have a disproportionately large number of 0s. The columns in red are those variables for which coding is ambiguous. The columns in white have a fairly well-distributed number of 0s and 1s. Keeping in mind one of the best practices laid out by Ragin, that variables to be used for analysis should be well –distributed, the columns in white represent those variables which are suitable for QCA. The variables in yellow are present in almost all cases and therefore represent those variables which almost all case writers consider to be important, and therefore there is no need to include them in QCA analysis. Similarly, the variables in pink are present in very few cases and therefore represent those variables which almost all case writers consider to be un-important, and therefore there is no need to include them in QCA analysis. However, I am limited by Marx (2010)'s criteria that only 6 explanatory variables should be used.

The path ahead

1. Selection of explanatory conditions
   a. The challenge before me therefore is to come up with an appropriate rule for identifying these 6 important explanatory variables.
2. Selection of cases
   a. The selection of cases need to be iterative so that the causal equation finally obtained is more elegant and leads to modest generalizations
   b. For using 6 explanatory variables I need to code at-least 16 to 29 cases.
   c. I propose to review and update the list of cases I have coded.
3. As Emmenegger et al. (2012) observes, "qca needs to be complemented by a qualitative discussion - encourages the need for case by case discussion to explain findings"
   a. Therefore, I shall need to qualitatively explain each causal combination of variables by qualitatively analyzing those cases which make up that causal path.
4. However, I realized that I shall not be able to carry out statistical analysis on this dataset, as my outcome variable has no variation – my outcome variable will always take the value 1, because that is one of the rules based on which case selection will be carried out for this exercise.

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Figures

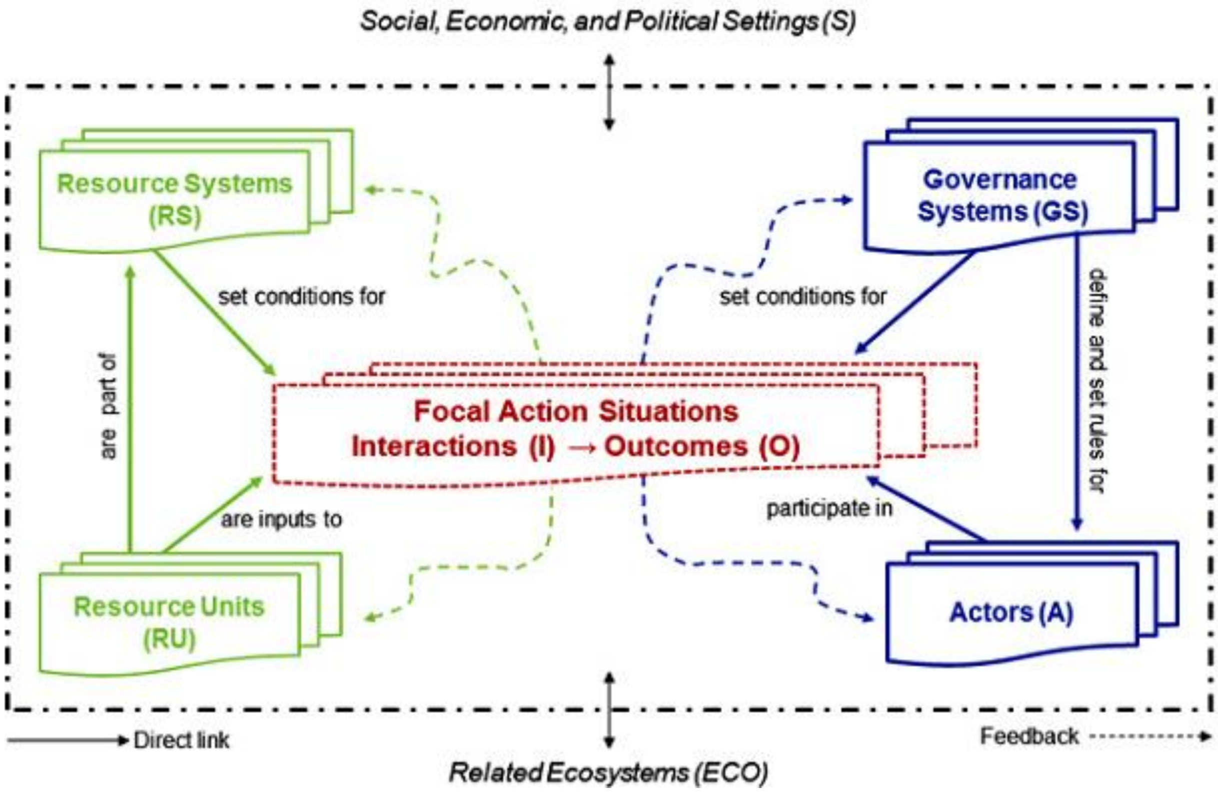

Figure 1 (adapted from McGinnis & Ostrom 2014)

First-tier variable	Second-tier variables
Social, economic, and political settings (S)	S1 – Economic development S2 – Demographic trends S3 – Political stability S4 – Other governance systems S5 – Markets S6 – Media organizations S7 – Technology
Resource systems (RS)	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
Governance systems (GS)	GS1 – Government organizations GS2 – Nongovernment organizations GS3 – Network structure GS4 – Property-rights systems GS5 – Operational-choice rules GS6 – Collective-choice rules GS7 – Constitutional-choice rules GS8 – Monitoring and sanctioning rules
Resource units (RU)	RU1 – Resource unit mobility RU2 – Growth or replacement rate RU3 – Interaction among resource units RU4 – Economic value RU5 – Number of units RU6 – Distinctive characteristics RU7 – Spatial and temporal distribution
Actors (A)	A1 – Number of relevant actors A2 – Socioeconomic attributes A3 – History or past experiences A4 – Location A5 – Leadership/entrepreneurship A6 – Norms (trust-reciprocity)/social capital A7 – Knowledge of SES/mental models A8 – Importance of resource (dependence) A9 – Technologies available
Action situations: Interactions (I) → Outcomes (O)	I1 – Harvesting I2 – Information sharing I3 – Deliberation processes I4 – Conflicts I5 – Investment activities I6 – Lobbying activities I7 – Self-organizing activities I8 – Networking activities I9 – Monitoring activities I10 – Evaluative activities O1 – Social performance measures (e.g., efficiency, equity, accountability, sustainability) O2 – Ecological performance measures (e.g., overharvested, resilience, biodiversity, sustainability) O3 – Externalities to other SESs
Related ecosystems (ECO)	ECO1 – Climate patterns ECO2 – Pollution patterns ECO3 – Flows into and out of focal SES

Figure 2 (adapted from McGinnis & Ostrom 2014)