Center for Behavior, Institutions and the Environment CBIE Working Paper Series Making Sense of a Babbling Equilibrium across Common-pool Resources Frameworks

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Making Sense of a Babbling Equilibrium across Common-pool Resources Frameworks

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Abstract:
Conceptual frameworks provide a language with which to describe the states and dynamics of common-pool resource (CPR) management systems. Coding manuals define the vocabulary of coding questions and relationships that comprise CPR frameworks. As empirical study contributes to conceptual advance, it is tempting to offer novel framework languages without also translating coding vocabularies around which existing frameworks are built. However, if the scholarly community is to generate robust knowledge for the study of CPR dilemmas, we must also provision for the underlying work of translation across frameworks. In this paper, we report on one way the community might provision such translation. We present the process, results, and challenges of using a group consensus process to link the more than 450 coding questions derived from original Institutional Analysis and Development (IAD) Framework to the recently proposed Coupled Infrastructure Systems (CIS) Framework. Despite much overlap, discrepancies in the conceptual languages of the IAD and CIS Frameworks suggest a need to modify or create several new coding questions related to concepts of system boundaries, externalities, cross-scale interactions, multiple functionalities, and technological change. We offer the idea of provisioning a Wiki-site to serve as a piece of shared infrastructure for commons scholars to help navigate the continued challenges of tailoring framework languages and coding vocabularies to evolving common-pool resource management dilemmas.

Keywords:
Methods; Coding; Infrastructure; Common-pool Resources; Institutional Analysis and Development Framework; Frameworks; Research Design; Meta-Analysis

Making sense of a babbling equilibrium across common-pool resources frameworks

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Abstract

Conceptual frameworks provide a language with which to describe the states and dynamics of common-pool resource (CPR) management systems. Coding manuals define the vocabulary of coding questions and relationships that comprise CPR frameworks. As empirical study contributes to conceptual advance, it is tempting to offer novel framework languages without also translating coding vocabularies around which existing frameworks are built. However, if the scholarly community is to generate robust knowledge for the study of CPR dilemmas, we must also provision for the underlying work of translation across frameworks. In this paper, we report on one way the community might provision such translation. We present the process, results, and challenges of using a group consensus process to link the more than 450 coding questions derived from original Institutional Analysis and Development (IAD) Framework to the recently proposed Coupled Infrastructure Systems (CIS) Framework. Despite much overlap, discrepancies in the conceptual languages of the IAD and CIS Frameworks suggest a need to modify or create several new coding questions related to concepts of system boundaries, externalities, cross-scale interactions, multiple functionalities, and technological change. We offer the idea of provisioning a Wiki-site to serve as a piece of shared infrastructure for commons scholars to help navigate the continued challenges of tailoring framework languages and coding vocabularies to evolving common-pool resource management dilemmas.

Keywords: methods; coding; infrastructure; common-pool resources; institutional analysis and development framework; frameworks; research design; meta-analysis

INTRODUCTION

The Institutional Analysis and Development (IAD) Framework (Kiser and Ostrom 1982) was conceived to explain collective action in complex public economies of U.S. metropolitan areas. After this initial application, the framework was adapted to facilitate the systematic analysis of case studies in which a diverse range of communities address social dilemmas within a wide variety of common pool resource contexts (Ostrom 2005, Poteete, Janssen and Ostrom 2010). The IAD Framework provided a language for comparative analysis by defining a vocabulary of coding questions associated with specific framework elements (e.g., operational rules, location issues, etc.) (Table 1). This vocabulary was collected by Elinor Ostrom and colleagues through a comprehensive effort to identify and evaluate coding questions of interest from more than one thousand unpublished case studies (Poteete, Janssen and Ostrom, 2010) before being set down in the *Common-Pool Resource (CPR) Coding Manual* (1989) (referred to henceforth as "the manual[1]"). From the large number of cases that went into the creation of the manual, a smaller number were selected for detailed analysis--the results of which formed the body of *Governing the Commons* (Ostrom 1990), which earned Elinor Ostrom the Nobel Prize in Economics in 2009.

Over time, scholarship building on the IAD Framework has generated deeper collective understanding of human influences on biophysical processes, and how social dilemmas related to these interactions are or are not successful[2] (Ostrom 2009a). This deeper understanding has, in turn, fueled the creation of additional frameworks with which to study open-access resource dilemmas from different perspectives. For example, the Social-Ecological Systems (SES) Framework arose as an effort to improve on the IAD Framework by giving more equal attention to biophysical and ecological dimensions of systems, and to facilitate interdisciplinary research in this vein (Ostrom 2007, 2009). Most recently, Anderies, Janssen and Schlager (2016) proposed the Coupled Infrastructure Systems (CIS) Framework to better understand the external variables that structure action situations of the IAD Framework (Kiser and Ostrom 1982) by re-framing "external variables" as different classes of "infrastructures"[3], and then proposing a means of studying the interactions and dynamic feedbacks of interactions among infrastructures (as well as how infrastructures cope with disturbances and uncertainty).

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[1] The coding manual included a set of forms, instructions and coding questions

[2] Ostrom defines successful case studies as those governed by institutions (i.e., rules, norms, and shared strategies) "...that enable individuals to achieve productive outcomes in situations where temptations to free-ride and shirk are ever present" (1990, p. 15). In her analysis, she uses the notion of "long-enduring systems" as well, meaning "resource systems, as well as the institutions, [that] have survived for long periods of time" (1999, p58).

[3] Anderies, Janssen and Schlager (2016) define "infrastructure" as any type of structure or organization that requires investment and can be combined (with other infrastructures) to potentially produce a variety of mass, energy and information flows that people value (7-8).

Despite the sophistication of evolving research frameworks, attention to rigorously linking new frameworks to the original empirical questions of the *CPR manual* has not kept pace. If the vocabularies underlying the growing babel of framework languages are not deliberately translated, the community of CPR scholars risks becoming fragmented, making cross-case communication, comparison, and learning increasingly inefficient and costly. In a time of accelerating global change, it is more important than ever for the community of commons scholars to understand each other in order to learn from our collective knowledge and experiences and better inform the use of alternative approaches to open-access resource management.

In the remainder of this paper, we present the efforts to demonstrate a means of provisioning translation across common-pool resource frameworks. We share results of our translation of the original *CPR Coding Manual* questions (Ostrom et al. 1989), associated with the IAD Framework, to a pared-down version of the CIS Framework (note, to facilitate testing of this novel approach to translation, we omitted fine-grained distinction between of private and social infrastructures (Figure 2)). Our work entailed a group consensus process for "translating" the more than 450 coding questions to the ten links and four nodes of the CIS Framework. Our results demonstrates how the process sheds light on the conceptual foci of CPR frameworks, and can help identify areas for further research and conceptual renewal in the field. We discuss ambiguities we encountered in the translation process, as well as implications from this study for provisioning future work to translate across other CPR frameworks. We close with a commentary on the potential of a Wiki-site to facilitate continued engagement with the coding manuals that underlie CPR frameworks. Our hope is that this paper helps the open-access resource scholars who collaboratively manage the 'knowledge commons' on commons governance.

METHODS

The CIS Framework was selected for mapping as it represents a) the most recent iteration of a CPR framework available and b) was developed at the Center for Behavior, Institutions, and the Environment (CBIE)[4], an Arizona State University center originally founded by Elinor Ostrom in 2006 and the organizing center of the authors. As a framework, the CIS re-conceptualizes governance of resource-resource user interactions as an emergent feature of a system (Anderies 2015). As Anderies continues:

> The notion that "governance" is not something we do but, rather, something that emerges as a system feature may seem strange at first glance. Upon closer inspection, however, it becomes evident that most outputs of human activities are "emergent" in the sense that

[4] Originally named the Center for the Study of Institutional Diversity (CSID) in 2006 and renamed as the Center for Behavior, Institutions and the Environment (CBIE) in 2016.

> they involve inputs that are taken for granted, not a design consideration, or may even be unrecognized in the production process *(p. 270).*

Similar to the creation of the IAD Framework, the CIS Framework was developed through the collection, comparison, revision, and refinement of a multitude of common-pool resource cases (Poteete, Janssen and Ostrom 2010).

Data source: original CPR coding manual

The original *CPR coding manual* project sought to clarify terms used in the study of collective action (Ostrom et al. 1989).[5] This 358-page manual was to serve as a standardized list with definitions of coding questions associated with the IAD Framework to be used to dissect future CPR cases. The document contains an introduction to the CPR project and the Institutional Analysis and Development (IAD) Framework, as well as eleven specific coding forms (Supplementary Table 1). These eleven coding forms contain descriptions of the overarching themes of the section; instructions for use; general notes relevant to questions within the form; a list of coding questions; and set of response options for the analyst. Each variable contains questions about the theme of the respective coding form, and is delineated by a set of capitalized text. For example, the "Operational Rules Coding Form" states:

> This form is designed to provide information about the operational-level rules, particular to a single subgroup who appropriates from this resource. This form is subgroup specific. The questions on this form, what is being asked is 'what are the rules,' not 'what is the behaviour.' Rules are human-made prescriptions and proscriptions, but they may not be followed or observed exactly as they are written or understood. The form has a list of coding questions sorted alphabetically (Ostrom et al. 1989, 235).

Within this coding form, an example question, as seen in the manual, is offered in figure 1:

[5] References to the historical development of the coding manual are drawn from preface and introductory material in the coding manual itself. This document is available here: https://seslibrary.asu.edu/resources

BOUNDARY RULES

Questions B3 to B6 below are follow-up questions for rows x and y of the above matrix. If multiple sources are involved, code the lowest relevant level only.

If multiple sets of rules are involved, code the most restrictive set (i.e. "1") only.

B3. If an entry fee or license is required or permitted, is there an upper limit on the number of licenses that can be issued (if multiple sources, code lowest relevant level)? <LICLIMIT>

(1) ______ No
(2) ______ Yes, but the upper limit is large compared to the number of persons likely to apply for a license
(3) ______ Yes, and the upper limit is likely to lead to the exclusion of some potential appropriators
(4) ______ Yes, and the upper limit severely restricts the number of potential appropriators who could appropriate from this resource
(-1) ______ MIC
(-2) ______ NA

Figure 1: Example section of Operational Rules Coding Form variable, question, and answer options for analyst.

Distributed across forms in the manual are 454 coding questions--the data source for our mapping project. Each individual coding question made up one unit of observation, analyzed based on its corresponding coding form and in relation to a give theme (section) of the CIS Framework. Detailed descriptions of the CIS Framework components such as resource users, public infrastructure providers, and associated links can be found in Anderies et al. 2004 and Anderies 2015 (Fig. 2 is a representation of the CIS Framework, with elements expanding on the 2004 Robustness framework covered in grey[6]).

Sorting process

We employed a consensus method to sort coding questions among CIS Framework themes. Each member of the group was assigned to lead the sorting process for one coding form. This was done in order to minimize the bias of any one individual group member steering a sorting conversation. Each team member was tasked with printing out and cutting their coding form so that each code existed on an individual strip of paper, marking the back of the paper with its original location in the coding manual. This allowed us to trace individual coding questions from the coding manual to CIS Framework, enabled shared learning, and created an analog, dialogic approach in the spirit of the original Ostrom Workshop.

[6] As noted in the introduction for the purposes of this initial translation effort, we opted to maintain a coarser-grained perspective. As a result, we did not distinguish between private and social infrastructure.

Our group met to conduct the sorting exercises at monthly 4-hour working sessions over the course of three semesters, beginning in Fall 2015. During the initial sorting, each team member led discussion of the coding questions in their coding form until all questions had been discussed. At this point, either: a) all coding questions from the original CPR coding manual were sorted to the CIS Framework themes or b) placed aside as “unresolved,” and saved for further discussion in a second round of sorting with input from additional researchers. Given the nature of the consensus process, if even one person withheld consent, the code was placed aside for future discussion.

After the initial round of sorting, the group continued to meet to revisit “unresolved” coding questions. In these sessions the group engaged Anderies and Janssen--former Ostrom collaborators of and co-developers of the Robustness framework--with specific questions on issues of sorting unresolved coding questions to framework themes. Responses, conversations, and implications explored in these sessions are presented through the results and discussion sections of this paper.

Data management

Data were captured in multiple formats. A representation of the CIS Framework was drawn on large panel paper to coding question, cut-out as strips of paper, were taped. Mapping results were photographed. In addition, during meetings, two group members were assigned with digitally recording the placement of the coding questions in the CIS Framework: one set of coding questions were placed in a spreadsheet; another set was entered into a newly created Wiki-site. Entering data into the spreadsheet enabled rapid quantitative analyses of the distribution of coding questions among CIS Framework themes. These quantitative distributions enhanced the group’s ability to communicate results, and informed discussion and qualitative analysis of the effort to “translate” from the original CPR coding manual to the CIS Framework. The Wiki-site served as a broader dissemination tool and will be further developed to allow for ongoing and future efforts to “translate” the coding manual to other frameworks, and compare across these translations.

Conversations around “unresolved” coding questions were recorded and transcribed, as well as annotated in real time. As issues related to these coding questions were resolved, decisions of resolution were summarized and the placement of coding questions was digitally recorded. Because the process of sorting stretched over two-years, detailed meeting notes were critical to the group’s “institutional memory.”

RESULTS

The *CPR Coding Manual* (Ostrom et al. 1989) was founded in the IAD Framework. Table 1 presents the results of mapping the coding questions from the 11 sections of the coding manual into the 12 components of the CIS Framework (Anderies et al. 2004, Anderies 2015). In the first half of this section, we report on coding questions from the coding manual that were fit to the framework by consensus; in the second half we report on issues and proposed ways to resolve ambiguities where coding questions could not be matched to the framework.

Coding questions were mainly distributed to the components of Public Infrastructure (PI) (n=136) and Resource Users (n=100) (Figure 2, Table 1). The next largest distributions of coding questions went to Public Infrastructure Providers (PIPs) (n=47), Resource, (n=38) and Link 1 (n=38). The last hundred coding questions were distributed among the remaining seven components of the CIS Framework. In addition to the original components, we suggest two sets initial considerations (called "General "meta" category" and "Meta-PIPs" in Figure 2). These two additional considerations are not amendments to the framework, but recommendations when using coding methodologies with the CIS Framework. Only ten coding questions ended up in Link 2 which assesses the interaction between resource users and public infrastructure providers. Only seven coding questions ended up in Link 4, which examines the interaction between the public infrastructure (hard and soft) and the resource. Only five coding questions were placed in the "exogenous" portion of the CIS Framework, four of them in Link 8 (three related to shocks to public infrastructure providers and one to resource users), with only one variable assigned to Link 7 (affecting the resource, none affecting the public infrastructure).

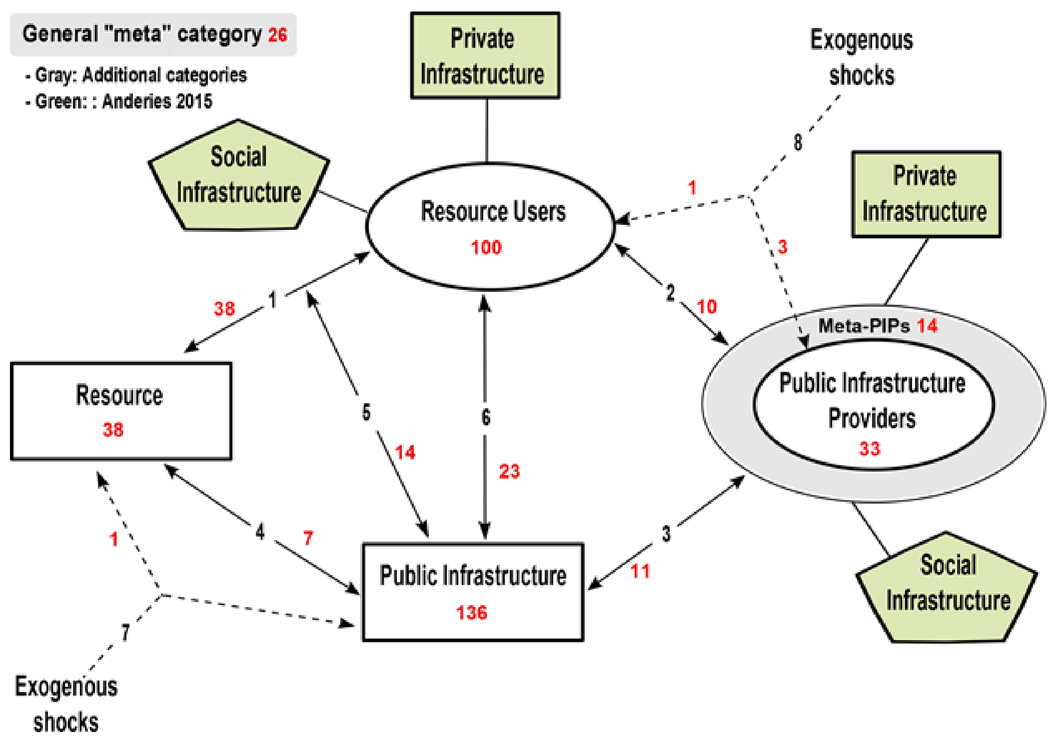

Figure 2. The Coupled Infrastructure Systems Framework (adapted with permission from Anderies 2015) with the distribution of coding questions.

Table 1. Distribution of coding questions among the CIS Framework components and the CPR Coding Manual.

		CIS Framework Component														
Type of Information	CPR Coding Form	Resource	Resource Users	PI	PIPs	Meta-PIPs	Link 1	Link 2	Link 3	Link 4	Link 5	Link 6	Link 7	Link 8	Meta	Total
	1.Screener	1	1													2
Physical and material conditions of CPRs	2.Location	16	5	3	1			1			1	2			4	33
	3.Appropriation resource	19		1	7		5			4	1				2	39
Attributes of the community Action situations Patterns of interactions Outcomes	4.4.Operational level	1	41	21	4		24		3		5	13	1	1	13	127
	5.Subgroup	1	49	1			9	4	5		6	5			1	81
Operational rules-in-use	6.Operational rules			101								2			6	109
Collective and constitutional-choice levels of analysis	7.Country/Region/Time			4	4				1			1		2		12
	8.Collective choice		4		4											8
	9.Organizational structure			5	8	14		3	2	1				1		34
	10.Interorganizational level				5			2			1					8
	11.Nepal irrigation									2						2
	Total	38	100	136	33	14	38	10	11	7	14	23	1	4	26	455

"*Coding questions that fit the framework*"

Physical and material conditions of a CPR

This information group contained the Location and Appropriation Resource coding forms of the *CPR Coding Manual*. There were a total of 72 original coding questions in these forms. Almost half of these coding questions were sorted into the "Resource" section of the CIS (n=35). The remaining coding questions were distributed across most other sections of the CIS, especially in "Public Infrastructure Providers" (n=8) ", "Resource Users" (n=5), "Link 1" (n=5). The large number of coding questions in the resource section of the CIS is not surprising given that the two coding forms related to the physical and material conditions of a resource. In addition, the distribution of coding questions in links and sections related to the resource section of the CIS suggest that the Location and Appropriation Resource coding forms describe not only the state of the resource, but also some interactions between the resource users and the natural infrastructure, i.e., the Resource.

Attributes of the community, action situations, patterns of interactions, outcomes

This information group contained the Operational Level and Subgroup coding forms of the *CPR Coding Manual*. There were a total of 208 original coding questions in these forms. Just under half of these coding questions were sorted into the Resource Users component of the CIS (n=90). In addition, 33 coding questions were sorted into Link 1, with noticeable concentrations in Link 6 (n=18), Public Infrastructure (n=22), Link 5 (n=11), and Link 3 (n=8). The large number of coding questions in the resource users section of the CIS is not surprising given that the two coding forms related to the attributes of community and action situations. In addition, the distribution of coding questions in links and sections related to public infrastructure suggest that the coding forms in this section detail interactions of the Public Infrastructure (hard and soft) with resource users through Link 6.

Operational rules-in-use

This information group contained the Operational Rules coding form of the coding manual. There were a total of 109 coding questions in this section--twice the number of coding questions in any other coding form. Nearly all of these coding questions were sorted into the "Public Infrastructure" component of the CIS Framework, an unsurprising result given the source for the manual and CIS-connectedness in human institutions.

Collective and constitutional-choice levels of analysis

This information group contained the Country/Region/Time, Collective choice, Organizational structure, and Interorganizational level coding forms of the the manual. There were a total of 62 coding questions in this section. More than half of these coding questions were sorted into the Public Infrastructure Provider (n=35) component of the CIS Framework. The remaining coding questions were distributed mainly into Public Infrastructure (n=9), Link 2 (n=5), Resource Users (n=4), and Link 3 (n=3). Given that public infrastructure providers are generally tasked with creating constitutional, collective choice, and operational level rules, this dominant distribution of coding questions into Public Infrastructure Provider, and surrounding links and nodes, makes sense.

"What could not be matched"

Figure 2 shows that the vast majority of coding questions had straightforward interpretations between frameworks. However, several coding questions were more difficult to translate, leading to much discussion. This included several areas which can broadly be described in several categories: 1) Issues related to the homogeneity of and distinction between physical and institutional boundaries of a social dilemma; 2) The need for an expanded set of coding questions to understand externalities between goods and collective action situations; 3) The dilemma of multiple functionality in which an entity may act as a rule creator, interpreter, and enforcer, and how to bound the scales and scope to the relevant feedbacks; and 4) The need to develop additional coding questions to investigate differences in ownership, use and expertise over existing and developing technology systems.

Natural vs human made (location/boundaries issues)

The original coding manual addressed issues related to physical and institutional characteristics of the area where the resource system was located, its boundaries, and the biophysical conditions of the resource within two coding forms: the Location Coding Form and the Appropriation Resource Coding Form (Supplementary Table 1). However, these coding questions are more tailored to contained, small-scale resource systems, which pose two related problems.

First, using these coding questions as they are originally defined complicates the distinction between natural boundaries separating biophysical resource flows from human-constructed institutional boundaries, and the relationships between them. For example, the coding question RAINDIST asks "What is the distribution of rainfall in this location?" , with the potential answers referring to rainfall spreading evenly throughout the year or concentrated over rainy seasons. Multiple coding questions ask the researcher about similar, various biophysical components (e.g. temperature, dominant soil type, rainfall distribution, elevation, and size) of the defined location, which depending on scale can range from a small village to a larger region (Supplementary Table 2). However, the use of the word "location" in these questions does not ask the researcher to distinguish between a natural location or an institutional one. The concepts of "locations" and "boundaries" entail interacting natural and social components, thus requiring more precise definitions.

The CIS Framework offers clear distinctions between *Natural Infrastructure* (i.e., a particular resource such as a forest or fishery) and *Public Infrastructure* (hard and soft human-made infrastructure such as a public road and a fishing regulation) (Anderies 2015, Anderies, Janssen and Schlager 2016). These concepts allow for a clearer distinction between how boundaries are created and manipulated within the study system. To allow for a clearer characterization of more complex and interconnected CPR systems, we recommend modifying the coding questions in Supplementary Table 2 to specify whether the question refers to infrastructure that is natural (i.e. replacing "location" with "natural infrastructure") or institutional (i.e. replacing "boundary" with "institutional infrastructure").

The second problem is that the original coding questions also limit the ability to explore complex systems where it becomes difficult to identify single "locations" and their exact "boundaries", which can lead to issues when defining and bounding the scale of the study system and, potentially, the research question (i.e. at which spatial scale is the research question operating at, and how do we define it). For example, variable "BOUNDAR2" asks the researcher to identify whether the boundary of the resource is a result of natural/constructed and/or institutional arrangements, whereas the variable "LOCBOUND" asks the researcher to describe how the boundaries of the location were determined.. With their focus on small-scale resource, less complex governance systems, the original coding questions did not specifically address issues of scale interaction. The CIS Framework also opens the possibility of exploring issues related to multiple scales of institutional infrastructures. To address address issues of scale mismatch and overlap, we propose three modified questions to replace LOCBOUND and BOUNDAR2 to help the researcher identify specifics about the research location and its boundaries in a way that clearly bounds the scale of the research question(s) (see Supplementary Table 3 for full description):

- 2_BOUNDNIB: Are the boundaries natural, hard human-made, or institutional (i.e. soft human-made)?
- 2_BOUNDDET: By what process have the institutional boundaries been determined?

- 2_BOUNDAFA: How do boundaries affect access?
  Natural resource externalities

Although the study of externalities is the subject of entire journals and professions, the subject of externalities between resources was only captured with a single question: RESCONF (see Supplementary Table 3 for full description). This question, originally located in the location coding form asks the researcher to characterize the majority of the effects between the appropriation of multiple resources as adverse, conflicting, complementary, or nested. The fact that there is only a single variable to cover what today is an entire area of study is a logical extension of the type of cases which Ostrom et al. (1989) selected for analysis, i.e., small-scale and largely focused on a single primary resource, and thereby having minimal impacts on other resources.

In a more complex coupled infrastructure system this is a significantly more challenging area for analysis. Consider, for example, the driving question of whether wolves should be reintroduced to a national park. It is possible that the introduction of wolves will have effects on cattle, sheep, bears, tourists, deer, etc., each of which can be valued as a resource. Considering this question in the context of the CIS Framework gives rise to several immediate issues: 1) What are the boundaries of the analysis? 2) How does this question need to be expanded to take into account the multitude of potential inter-resource effects and 3) How can the issues of scale that result from the diversity of resource infrastructures be included.

To solve the first two issues of boundaries and many resources we recommend including RESCONF in the Meta section of the coding manual which can be accomplished by adding a new variable code called 2_RESCONF_M. Other coding questions (NUMBERES, 2_RESNAMES, GRESNAME) allow the researcher to clarify what resources will be included in the system itself. A new variable code, 2_RESNAMES, proposes a reformulation of the original follow-on coding questions of RESNAME1, RESNAME2, RESNAME3, RESNAME4, to delineate specifically which resources are being considered as part of the relevant coupled infrastructure system, and then M_RESCONF should be considered for any of the resources in the system that generate negative externalities or spillovers.

Table 2. Proposed coding questions on the topic of resource externalities and spillovers allow for characterization of externality specific infrastructure

Proposed coding questions	Description
2_RESNAMES	Delineation of all resources to be considered in the analysis
2_RESCONF_M	Characterization of all between resource interactions (spillovers and externalities) to be considered in the analysis
2_RESCONF_PI	Is there public infrastructure created specifically to mitigate/promote externalities/spillovers?
2_RESCONF_L5	How does 2_RESCONF_PI alter resource?

Although a classic economic solution to solving externalities in Western industrialized countries is to create market systems, in reality a large number of other infrastructure tools can be used to mitigate externalities, (e.g. emission standards, gear restrictions, location/temporal constraints) (Arrow, 2000). We therefore propose two additional coding questions, 2_RESCONF_PI and 2_RESCONF_L5, shown above in Table 2. 2_RESCONF_PI is created to address whether there is public infrastructure created to address such an externalities identified. 2_RESCONF_L5 captures the dynamics by which such Public Infrastructure may impact resource use by users. Both of these are created to determine what human-made infrastructures (both soft and hard) are created to mitigate, manage, or promote externalities, and how these infrastructures alter the dynamics of resource appropriation/production. In addition to these two new coding questions we suggest that additional coding questions may be needed to capture aspects of public infrastructure such as: Through what means do resource users have a seat at the table in designing 2_RESCONF_PI (constitutional/collective choice levels)? At what scale is 2_RESCONF_PI created? How does the physical scope of resource 1 relate to resource 2? How is 2_RESCONF_PI enforced? What conflict resolution mechanisms are available to mitigate resource conflicts? Creation of more nuanced cross-scale coding questions should be the result of a comprehensive literature review and case study analysis similar to that which developed the original coding manual.

Issues of multiple function (cross-function application)

The issue of multiple function arose from a perceived need for increased resolution in describing systems of coupled human/natural infrastructures. By identifying the issue of multiple function, we attempted to resolve ambiguities about organizations, or individuals within an organization, that serve as public infrastructure public infrastructure providers in different circumstances; and/or when sets of infrastructures are difficult to meaningfully bound and differentiate in the course of analysis. We observed three general types of challenges in sorting CPR coding questions from the original manual to the CIS Framework. One challenge related to specifying which Public Infrastructure and Public Infrastructure Provider organizations should be considered in analysis. Another type of challenge came from separating operational-level and collective-choice level infrastructures that interact with each other and with appropriators. The final type of challenge pertained to bounding and specifying the set of infrastructures implicated in appropriation and/or provisioning. Ultimately, each challenge relates to the core observation that infrastructure has embedded within it legacies of operational and collective choice level decisions. In the following subsections, we address the original coding sections from the manual implicated by each type of issue with multiple function, associated coding questions, and our proposed resolutions in light of our coding process.

1) Complexity in specifying organizations

Complexities of specifying organizations in analysis traced predominantly to the “Organizational Structure and Process Form” in the original *CPR Coding Manual*, with one instance of a variable coming from the “Location” form. A complete list of coding questions for which this issue arose can be found in Supplementary Table 3**.** The variable MEMBAPPR exemplifies this type of challenge of multiple functions. This variable question asks, “What is the relationship of the size of this organization (or group) to the number of appropriators” (Ostrom et al. 1989, 133). In the context of the CIS Framework the question seems to be about a description of an organization, which, by nature, will be underlain by social infrastructure, and thus potentially classifiable as a public infrastructure provider. And yet, the question is also asking for description of the resource user community. Further, the word “relationship” seems to imply that a link is involved...and yet because the comparison seems to ask about number only, the description may be more generally about an organization.

To resolve the issue of complexity in specifying organizations, we recommend creating a meta Public Infrastructure Provider category. This “meta-PIPs” category, in the spirit of describing the “attributes of community” in original application of the IAD Framework, creates a space for analysts investigating coupled infrastructure systems to describe the Public Infrastructure Providers involved in an overarching manner and get into greater detail for specific Public Infrastructure Provider organizations. A question then arose: what type of organization ought to be described? And here we turned to the CPR coding manual itself, in which the authors describe in the organizational structure and process coding form, the specification of focusing on “organizations that are related to the appropriation process of the resource” (Ostrom et al. 1989, 128). We recommend that organizations of focus be specified based on the nature of the social dilemma being investigated (note, we suggested creating a general “Meta” category with a proposal for the variable 2_SOCDIL, asking about the nature of the social dilemma). Our consensus was that the analyst ought to tailor his or her analysis to the organizations implicated by or involved in managing the social dilemma.

Modifications to this resolution were needed for several coding questions in this collection of coding questions. ORGPARAG, which requests a thick, qualitative summary description in the original question, was simply placed in meta-PIPs. For MEMBSUB, the challenge here was less about describing the organization, than about describing the resource users and their subgroups. Therefore, just as we suggested the creation of a meta-PIPs section, we recognized a need for a meta-RU section related to resource user subgroup characterization. Once establishing a meta-RU, describing the membership of the organization relative to subgroups becomes more straightforward where Public Infrastructure Providers are concerned. Finally, for RULECLAS we recognized that a question of "for what audience" went begging in this variable. Analytically, differences in rule perception may translate into differences in compliance and other realizations of rules in use. So understanding the potential value in learning, for each resource user group, how rules are understood differently, meant that once the meta-PIPs section is completed, this RULECLAS variable could be asked for each user group involved in the case.

2) Operational and collective choice level ambiguities.

The issue of operational and collective choice levels of decision-making ambiguities arose in cases where a variable plausibly referenced either the execution of a rule by an individual or organization, or inquired after the individual or organization charged with said execution. For example, consider the case of a water appropriator who is a member of a water appropriation association and serves formally as a water monitor. If a coding question tests for the association charged with provisioning monitoring rules, then it is serving to set operational level rules, and can be said to operate at the collective choice level as a Public Infrastructure Provider. In this example, however, any given individual member of the association serving as a monitor could also be said to carry out enforcement at the operational level, and thus be considered Public Infrastructure. Four coding questions encapsulated the issue of operational and collective choice level ambiguity. A complete elaboration of these coding questions can be found in Table 5.

The cases of original coding questions, FUNDS and FISOURCE, offer an illustration of the way we proposed to resolve the ambiguity of operational and collective choice levels in our analysis. Each of these coding questions refer to the source of funds for an organization. FUNDS, as written in the coding manual, appears to be about an attribute of the general purpose local government, and thus Public Infrastructure Providers. However, the answer choices for FUNDS imply underlying rules about the taxation (e.g., "More than 80% from local taxes and related sources" p. 68), and thus a relationship between Public Infrastructure Providers and Public Infrastructure (Llink 3). FISOURCE appears to be an attribute of an appropriation management organization, and thus also related to Public Infrastructure Providers, however, answer choices here also imply underlying rules about the ways that funds are permitted to be sourced, thus implicating Public Infrastructure (e.g., "Membership fee", p. 140). To remain true to the original CPR manual, we determined that coding questions FUNDS and FISOURCE each belong to Public Infrastructure Providers. Yet, we agreed there is good reason to have a question that explicitly digs into rules regarding the source of funding/finance of general purpose local governments and appropriation management organizations. Therefore, we propose that in the future the larger community studying the commons create new coding questions related to rules governing organizational financial sources for general purpose local governments and appropriation management organizations (e.g., 2_ORGFISRULG (enumerating the actual rule that enables FUNDS); 2_ORGFISRULA (enumerating the actual rule that enables FISOURCE)).

We also observed a difficulty sorting four coding questions that referenced appropriation, production, and provisioning resources (see table 5)**.** In the original coding manual glossary (Ostrom et al. 1989), definitions of the above are offered as follows:

- "Appropriation Resource: One of four stages of the delivery of a resource: production, distribution, appropriation, and use" (p. 354).
- "Production Resource: The production of water for irrigation involves making water available at locations and times when it does not naturally occur in the form of precipitation and immediate runoff" (p. 357).
- "Provision: Provision has a distinct and separate meaning from production. The following quotation provides a definition for provision: The organization of provision relates primarily to consuming, financing, arranging for production, and monitoring the production of a set of goods and services" (p. 357)

As such, any of the coding questions related to appropriation, production, and provisioning by design entail a diverse array of different infrastructures. Such an observation aligns with with the underlying rationale for evolving the Robustness and CIS Frameworks: shared infrastructures are necessarily leveraged with natural infrastructures in the process of managing open-access resources. The challenge for managing variable assignment in this case became how to word a sufficiently generalizable variable with respect to changes in the state of shared infrastructures. Our determination was that an alternative wording of a single question, with references to a beginning and end state, be developed and placed in a meta category for public infrastructure (PI_META). Although we hope the community will come together to develop actual wording and response options at a later date, we offer a potential re-characterization of coding questions (2_SHRDINF; 2_BEGCONDI and 2 ENDCONDI) under the question "What are the hard physical structures maintained by the community that are used to access, withdraw, and distribute the resource". Our intent in offering the question is to sufficiently capture the diversity of shared infrastructures accounted for in the original coding manual glossary, in the process of analysis of a coupled infrastructure system.

Technology

A final general class of issues we encountered as emergent difficulties in mapping the original *CPR Coding Manual* and the CIS Framework pertains to coding questions related to technology and technology systems. By and large, reference to technology in the coding manual pertains to whether "technology or technologies employed were the same throughout the period" of inquiry

(Ostrom et al. 1989, p. 143) (See Table 6). We observed two challenges related to these references. First, we note a relative under-attention to technology in the coding manual is noticeable given reliance on technologies in resource management. As CPR research frameworks attempt to grapple with what are increasingly recognized as complex interdependent social-technical-ecological systems (Miller et al. 2014), greater inclusion of advances in scholarship related to the ways in which values and cultures shape and are shaped by technology (c.f., Callon 1987; Pinch and Bijker 1987; Law 1987, etc.) may be of increasing importance as empirical and theoretical work continue.

The second challenge associated with technology and technology systems related to the question of externalities, specifically the difficulty of attributing public-ness and private-ness to interconnected infrastructures. Public technologies can be captured for private use and benefit. Similarly, private technologies can impinge on or be used or exploited for public benefit. Consider, for example, an unsecured home wifi-network (owner's private infrastructure, available for external public use). As a counter example, consider the public technology of a road: if a private company builds a remote facility, then public infrastructure must be built to the facility, despite the "public road" *de facto* use for private purpose (similar case of water infrastructure). This complexity with demarcating externalities associated with technologies raised to our attention the need for elaboration on or amendment of elements of the CPR manual for use in the analysis of more complex coupled infrastructure systems.

In the original coding manual, specific questions related to rules governing the use of technology (USETECH, RULTECHX, BEGTECHX, ENDTECHX) while limited in number, were unambiguous in linking to the CIS Framework. Coding questions TECHEXTR, BEGNTFER, and ENDNTFER pertained to the overall case under analysis, and were thus placed in the "META" category in the process of mapping.

In the case of NEWTECH, the question "Is there new technology introduced?" (Ostrom et al. 1989, 167) underspecified details of central importance for the CIS Framework, i.e.,the answer would carry different analytical weight depending on the publicness or privateness of the technology. For use in the CIS Framework, it is the *de facto* result of how a technology is employed, rather than the *de jure* ownership that defines a technology as public or private to the ontology of the CIS Framework. As such, we recommend splitting NEWTECH into two separate questions, one each about public and private infrastructures, respectively, allowing then for more straightforward linking of these new coding questions to locations in the framework.

DISCUSSION

The CIS Framework seeks to provide an alternative way to study CPR governance of increasingly complex resource systems with more elaborate, interdependent collections of social and physical infrastructures. Central to the CIS Framework is an emphasis on dynamic interactions and interdependencies among community attributes, biophysical conditions, and rules-in-use that structure action situations. However, the framework currently lacks a specific, structured set of coding questions that allow for more rigorous case development and cross-case comparison, and greater accessibility of the framework to those unfamiliar with the methodology. In this paper we explored how coding questions from the original *CPR Coding Manual*--founded in the IAD Framework--aligned with and benefited from adaptation for the study of commons governance from a coupled infrastructure perspective. Our analysis sought to facilitate the way in which the CPR coding manual can be utilized to support future comparative case study analyses of complex resource systems.

The process of sorting each original coding question into the CIS Framework highlighted some of the major gaps in the existing coding questions to address complex resource systems, thus leaving room for modification of existing and addition of new coding questions to the CPR codebook. Our analysis highlights three sets of results. The first set is composed of the majority of original coding questions that "map neatly" onto the CIS Framework, with a large majority being aligned with the categories of public infrastructure and resource users. A second type of results is identification of the areas within the CIS Framework that do not currently have many coding questions mapped to them. This includes the external shocks (link 7 and link 8) as well as links 2,3 & 4. This is due to the focus of the CIS Framework on the underlying dynamics of a system. The final set of results includes those coding questions that produced dispute and which were grouped as belonging to four categories of issues. While the majority of coding questions transferred easily without disagreement, the discrepancies of coding questions that did not fit well highlighted areas of interest to researchers of more complex commons. We found this type of exercise helpful and necessary for maintaining the relevance of the original coding manual and its suitability to address new and more complex resource systems.

In many ways, the four issues we identified as not mapping neatly from the *CPR Coding Manual* to the CIS Framework are a direct reflection of the challenges of bringing coupled infrastructure systems to bear to govern resource systems in a more complex world (or, at least a world that we are more aware of the complexities of, as well as our role in compounding these complexities). Each of these areas of "mis-fit" point to areas in vital need of further development of the methodological tools available to support empirical study of CPR systems using the CIS Framework.

First, as our understanding of what functions as infrastructure expands with the CIS perspective, the traditional IAD Framework metatheoretical distinction of location from boundary becomes more difficult. As such, there is a need to update the *CPR Coding Manual* to reflect the coupled infrastructure perspective on boundaries -- a perspective that enables a differentiation of types of separation, some of which are human mediated (e.g., demarcation of nation states), and others not (e.g., the presence of the ocean). Second, relatively little attention is paid to externalities in the *CPR Coding Manual*. This may have been acceptable for a metatheoretical perspective that holds as exogenous variables relate to externalities, as in the IAD Framework. However, the CIS Framework internalizes and focuses on the dynamics among the very infrastructures and resources that were once considered external. Any coding manual for the CIS Framework would need to attend to ways in which "externalities" actually need to be reframed as part of coupled infrastructures and/or resources affecting the system.

To emphasize these issues of location, boundaries, and externalities in a practical context, consider the case of researchers and practitioners working on issues such as, for example, marine conservation of bluefin tuna, a species which migrates thousands of miles every year. This makes the idea of identifying a single location of concern problematic. First of all, this causes complexity when identifying salient user groups. Not only do different user groups need to be identified, but the multitude of different potentially relevant rules, strategies, and norms is also complicated. Such identification may also change both with the group of users at any particular time, as well as the rules that they follow based on their citizenship or business they are pursuing, in addition to the rules and conditions of the actual location the fish may be at frequenting at any point.

The ability to detect, manage and engage with complex externalities may also change depending on the scale of observation and the boundaries of what is considered a relevant location. With the case of fisheries, a common example of this is pollution in or damming of waterways that are used for spawning. Fishermen that face the overfishing dilemma often have no knowledge about or leverage over the "upstream" decision points. This may greatly affect their ability to predict future conditions and to engage in successful collective action.

While one solution to this problem is to enlarge the boundaries of the problem to an ever larger set of coding questions and parameters, this is not always useful to 1) inform analysis of what may induce actors with limited scopes or 2) to ask answerable questions. The concept of a location is often an emergent feature of a system that includes a specific set of rules, physical features, and actor sets. Gaining clarity as to what are the scales of interest important to answer a particular problem is paramount and requires a more rigorous understanding of issues of locations and boundaries.

Returning to issues of 'mis-fit' a third area in need of attention was how, in larger-scale, interconnected, dynamic CPR governance arrangements, organizations may have multiple functions, making them difficult to disentangle as resource users or public infrastructure providers. From a CIS perspective, this creates two potential ambiguities that require attention with regard to a coding manual update. First, there is the need to clarify the ambiguity that comes with having groups of people with responsibilities both at the operational and the collective choice level. Second, there is the need to capture the effects created when rule development at a collective choice level may be far removed from operational level action, a phenomenon of increasing concern as the more immediate connections between governance action and resource users of original IAD Framework cases become the exception, rather than the rule.

The need to delineate between when an agent is acting at either an operational or collective choice level capacity is prominent in situations in which the agents of an organization are responsible for decision making about the funding and worth of their own organization, which can quickly lead to corruption. Examples of this exist when the structure of licenses or permits can be altered by those in charge of dispensing the permits, such as has happened in fisheries and civil forfeitures. Fishery licensors have the potential to gain benefits and large rents by preferencing willingness to pay over other attributes such as knowledge of the resource or responsible fishery practices, this includes potential bribes (Hanich and Tsamenyi, 2009) Civil forfeiture by police faces similar multiple function challenges in which police may have the opportunity to enrich their departments at the collective choice level through actions at the operational level, i.e., the seizing of individual items of worth from individuals who are arrested (Piety, 1990).

Finally, our study revealed the need to expand attention to issues with technology in CPR systems. Questions of *de jure* vs *de facto* use of technology bring to the fore a potential opportunity for future scholarship by the community of commons scholars. Knowledge of and rights to exclusive rents of technologies confer political power to organizations, enabling them to reshape collective choice arrangements to their advantage. Technologies privilege communities of certain abilities, and disadvantage others. Social groups involved in technology development have specific attributes that reinscribe themselves on physical artifacts, and thus impose additional norms to a new user community--especially if that community was excluded (intentionally or unintentionally) from the development process. And of course, excluded social groups find ways to “hack” technologies designed for one context to realize benefits in a completely different one. Each of the above scenarios implicates resource use, rules on the rights of parties involved in technology development, cultures of business, research, policy, user, and public communities, and rules governing the use and flow of information about such technologies. Whereas the original *CPR Coding Manual* was not developed with such questions in mind due to its focus on small-scale CPR systems, the CIS Framework is well suited to investigate these questions, and more, marking an opportunity to augment the set of coding questions used by commons researchers generally, and for a better understanding of the shared infrastructure systems in contemporary, “advanced technology-dependent societies,” in particular. A coding manual updated for the CIS would need to attend to these dimensions.

These issues of technology in CPR systems can be easily noted in the area of industrial agriculture where large research and development companies are direct partners with agriculture. This not only induces new types of uncertainty into the resource environment, that has little experiential or long term understanding of the ecological or social implications, but also selects for different larger scale resource managers that have the sophistication to engage with large research organizations. These larger scale resource managers change the types of instabilities that a resource systems can be vulnerable to as they require optimization of a small set of outcome coding questions to decrease variation and meet the scales of returns necessary to invest in technological research and development. Coupling issues of sociotechnical developments reveals the need for an entire new class of coding questions to understand the types, interactions, and changes that are part of linked CIS systems, and have a profound effect on the 'things we care about when we study these systems.'

CONCLUSION

By connecting the original CPR Coding Manual with the latest iterations of the CIS Framework, we have bridged the idiosyncrasies that inhibit our abilities to build on the foundations established by early scholars in this field of research while also pushing into new territory. Using an established coding system allows the commons research community to continue the development of an already valuable resource of existing case studies and utilize them to generate new insights through synthesis and comparative analyses, but the resource requires updating to remain relevant and useful as the field develops. The results of this work suggest that to enable interdisciplinary research on more complex large scale and diverse resources that additional and altered coding questions that can break apart the multiple scales and complexity of resource systems may be useful. These coding questions focus on the complexity that occurs due to multiple nested physical scales, human organizational scales, issues of multifunctional entities, and externalities among resource systems.

Just as additional infrastructure is created to manage each of these additional scales of complexity in inter-connected systems, so too do the tools of the researcher need commensurate expansion and re-specification if they are to be applied to evolving methods, theories and frameworks. Such research community infrastructure would be vital to supporting processes for creating new coding questions and new processes to establish the text and definitions of the coding questions. Most immediately, it could be useful to continue to elaborate considerations of private, public, soft-human, human-made, and social infrastructures on the decision-making processes of Resource Users and Public Infrastructure Providers (greyed out areas of Figure 1). The example of the wiki represents another infrastructure that might be used and beneficial for capturing the development of commons research. More generally, the community might benefit from a formal set of arrangements for updating existing and developing new coding variable text for the CPR coding manual.

Going back to the language of the CPR coding manual helped us better understand areas of overlap, divergence, and general gaps between CPR Frameworks. Understanding the relationships among frameworks can support more robust synthesis of empirical work and, in turn, continue to drive theory-building on governance of open-access resource systems. Our effort, however, demonstrates that such an initiative of translation requires the investment of a range of resources (person hours, web infrastructures, print materials, meeting space, patient mentoring, etc.)--requires provisioning. As such we hope that demonstrating this case of translation between the IAD and CIS Frameworks serves to inspire future group efforts to connect other frameworks, such as the SES Frameworks, and to spark a larger conversation about how we, as a community of CPR scholars, can take action to ensure the foundational language of governing the commons remains relevant far into the future.

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Supplementary Material

Supplementary Table 1: Organization of the original *Common-Pool Resource (CPR) Coding Manual* (Ostrom et al. 1989).

Coding questions were generally organized by three levels of institutional rules related to actions and outcomes in CPR systems: the operational, collective-choice, and constitutional (Ostrom 2005). The operational level covers institutions governing day-to-day activities and outcomes; the collective choice level determining how operational level rules are changed, by whom, and in what circumstances; the constitutional choice level determining how decisions about changes to collective choice level factors of by whom and when may be made or modified (Ostrom 2005).

Type of information	Coding form	Description
	Screener	To determine the usefulness of articles for the research project and whether they contain citations to other potentially useful articles.
Physical and material conditions of a CPR	Location	Questions testing for the general physical and institutional characteristics of the area in which the resource(s) of interest is located, including the appropriation resource(s) and other crucial features of the resource environment.
	Appropriation resource	Questions testing for major physical characteristics of the appropriation resource, delineation the boundary of the appropriation resource, and description of how the appropriation resource is related to the relevant resources for producing, distributing, and using the resource units.
• Attributes of the community • Action situations • Patterns of interaction • Outcomes	Operational governance level	Characterization of the operational level of decision-making where individuals take actions or adopt strategies that directly affect their day-to-day operations, depending on expected contingencies.
	Subgroup	Characterization of the subgroups that act at the operational governance level.
Operational rules-in-use	Operational rules	Information about the operational-level rules, particular to a single subgroup who appropriate from the defined resource (subgroup specific).
Collective and constitutional-choice levels of analysis	Country / Region / Time	Questions testing for the general constitutional-choice of decison-making processes related to the area where a CPR is located.
	Collective choice	Contains the organizational inventory matrix, which enables coding information about all of the organizations that affect the production, distribution,

		appropriation, and use activities in a particular CPR.
	Organizational structure	Information about the organizations that affect the operational rules of a particular CPR.
	Inter-organizational level	Information about higher-level organizations that are related to the organizations directly affecting operational rules.
	Nepal irrigation cases	Specific to small-scale irrigation CPR systems in Nepal.

Supplementary Table 2. Original coding questions about biophysical components.

Variable and Point of Origin in *Coding Manual*	**Short Description**	**General Resolution**
LOWELEV - Location Coding Form	What is the lowest elevation of this location?	To specify that "location" refers to natural infrastructure.
RAINDIST - Location Coding Form	What is the distribution of the rainfall of this location?	
TEMPERTR - Location Coding Form	What is the average annual temperature of this location?	
LOWTEMP - Location Coding Form	What is the average low temperature of this location?	
HIGHTEMP - Location Coding Form	What is the average high temperature of this location?	
SOILTYPE - Location Coding Form	What is/are the dominant soil type(s) of this location?	
VARSOIL - Location Coding Form	What is the level of variation in the soil type?	
LOCSIZE - Location Coding Form	What is the size of this location in square meters?	
LATITUDE/LONGITUDE Location Coding Form	What is the latitude/longitude of this location?	
LOCNAME Location Coding Form	What is the name of the state, province, or region in this location?	

Supplementary Table 3. Sample coding questions proposed for modification.

Proposed Variable Code	Coding question (short description)	Answer choices
2_BOUNDNIB	Are the boundaries natural, hard human-made, or institutional (i.e. soft human-made)?	• Natural • Hard human-made (physical) • Institutional (soft human-made)
2_BOUNDDET	By what process have the institutional boundaries been determined (i.e. how is link 3 determined)?	Consensus, majority rule, external agent, internal norm of the community, de facto, de jure, other
2_BOUNDAFA	How do boundaries affect access (i.e. how does link 5 operate)?	• Natural boundary which limits entry • Natural boundary which does not limit entry • Institutional boundaries which limit entry • Institutional boundaries which do not limit entry • Natural and institutional boundaries which limit entry • Natural and institutional boundaries which do not limit entry • Hard human-made infrastructure which limits entry • Hard human-made infrastructure which does not limit entry

Supplementary table 3

Existing Variable Name	Coding question (short description)	Answer Choices

RESCONF	Characterize the relationship among appropriation processes for multiple resources	• Little adverse effects • Complimentary effects • Conflictual effects • Sometimes adverse, sometimes complimentary • Sometimes complimentary, sometimes conflictual • Sometimes complementary, sometimes conflictual, sometimes adverse
RESNAME1, RESNAME2, RESNAME3, RESNAME4	What is the name of the first/second/third/fourth resource described?	Open answer

Supplementary Table 3

General resolutions consisted of two types Type 1 entailed ...; Type 2 entailed designating a version of the variable relating to PI or PIP, depending on original...Type N. Note, recommendations for new coding questions does not mean that new coding questions were constructed / proposed.

	Variable Code and Point of Origin CPR Handbook	**Short Description**	**General Resolution**
Multiple Function: Complexity of specifying organization	MEMBAPPR, Organizational Structure and Process Form	Relationship of the size of organization (or group) to number of appropriators	Type 1
	EXECOTHR, “”	Positions of chief executive in other governmental bodies	Type 1
	EXECOWN, “”	Ownership by chief executive of assets dependent on units from the resource	Type 1
	EXECPAID, “”	Pay of the chief	Type 1

		executive	
	EXECPER, “”	Time period of chief executive service	Type 1
	EXPOTHER, “”	Activities of group to express needs to officials of other organizations	Type 1
	EXPOWN, “”	Activities of group to express needs to officials of this organizations	Type 1
	EXTREMOV, “”	Higher level authority than the chief executive(s)	Type 1
	EXTREP, “”	Higher level authority than the chief executive(s)	Type 1
	OFFNEAR, “”	Proximity of officials responsible for appropriation resource to the resource	Type 1
	ORGPARAG, “”	Day-to-day operating structure for organization	Type 1
	RULECLAS, “”	Ease of understanding rules of organization	Type 1
	SERVICES, “”	Major services provided by organization to appropriators	Type 1
	TERJUR1, “”	Relationship of territorial jurisdiction to physical boundaries of resource	Type 1

	TERJUR2, “”	Relationship of territorial jurisdiction to smallest relevant general purpose government	Type 1
Issues of operational and collective choice level ambiguity	ENRULE, Organizational Structure and Process Form	Primary rule enforcement / rule enforcement organization	Type 2
	EXTREP, “”	Reporting of chief executive to higher level authority	PI, noting EXTREMOV refers to PIP
	FISOURCE, “”	Major financial sources of organization	Type 2
	FUNDS, Location form	Source of public funds used by general purpose government	Type 2
Complexity bounding and defining the sets of infrastructures implicated in appropriation and/or provisioning	BEGCONDA, Operational level coding form	Level of maintenance of appropriation resource at beginning of case	
	ENDCONDA, “”	Level of maintenance of appropriation resource at end of case	
	BEGCONDP, “”	Level of maintenance of production resource at beginning of case	
	ENDCONDP, “”	Level of maintenance of production resource at end of case	

Supplementary Table 4

Variable Code and Point of Origin CPR Handbook	**Short Description**	**General Resolution**
NEWTECH, Operational level form	Introduction of new technology	Resolve as two public and private questions: 2_PUUNEWTECH; 2_PRUNEWTECH
TECHTIME, Subgroup level form	Most recent technological change experienced by subgroup	Relates to attribute of resource users
TECHUSED, “”	Duration of use of unchanged technologies	Relates to attribute of resource users
TECHEXTR, “”	Effect of appropriative power of a technology by a subgroup on resource	Meta
BEGNTFER, Operational level form	Extent of interference of appropriation technology with appropriation process at beginning of case	Meta
ENDNTFER, “”	“” at end of case	Meta