Appendix 1: Project descriptions

1. The common-pool resources (CPR) database project

1.1. Origins, actors and purpose

The seed for the CPR database project emerged from a National Research Council Panel on the Study of Common Property Resource Management formed in 1983. Based on discussion at this meeting Oakerson (1986) developed a framework that captured key concepts and variables drawn from multiple disciplines to allow scholars to consistently analyze and compare how resource users interact with respect to their use and governance of different types of commons. Oakerson's framework provided the foundation for developing coding forms to capture key features of common pool resources and resource users. In the mid-1980s, Elinor Ostrom and colleagues completed these forms as part of a larger commons project. In addition to the development of the CPR database, the larger project included fieldwork, game theory, and laboratory experiments (Ostrom et al. 1994).

1.2. Description and process

The CPR database was innovative for its time because it was relational, which reflected the importance given in the IAD framework to the joint impact of biophysical, social and institutional conditions on resource use decisions. Thus, each coding form has a relation to other coding forms. For instance, a single location coding form would be linked to multiple appropriation resource forms. The appropriation resource form represents the "Biophysical conditions" in the IAD framework. It consists of a series of questions about the location, size, stock, and flows as well as questions about physical infrastructure related to an appropriation resource. Adequately identifying key biophysical features applicable across many resources was a key challenge for the project.

The operational level coding form capture how resource users interacted with one another and with the resource. In other words, it captured the focal action situations. When it became clear that resource users differed from one another in ways important to the IAD framework, a subgroup form was introduced. Related to the subgroup form was the operational rules form, which was organized around the IAD framework's rule typology (Kiser and Ostrom 2000). The rules form is arguably the most complex of the forms, in order to capture rules that would be applicable across different types of resources, and at the same time capture key dimensions of the rules. In sum, the CPR coding forms attempted to develop a set of questions, based on the IAD framework, which could be applied to any common pool resource, and to store that information in a way that would be efficient and accessible.

1.3. Innovations, outcomes and lessons learned

The CPR coding forms were the first comprehensive effort to operationalize the IAD framework in relation to a type of good –common pool resources—and to operationalize variables from an emerging theory of common pool resources not explicitly represented in the framework. The CPR database has been used to test hypotheses concerning the relationship between user group characteristics, collective action and resource conditions (Ruttan 2006; Frey and Rusch 2014). Throughout the initial process, the framework and theory evolved together. For instance, measures of some, but not all, of Ostrom's (1990) design principles are captured in the coding forms. And some parts, but not all, of the syntax of the grammar of institutions (Crawford and Ostrom 1995) are captured in the rules coding form.

However, even though frameworks and theory work hand-in-hand, it is important to recognize the distinction between them. The coding forms consist of several hundred variables. Not surprisingly, there is a lot of missing data, which points to the limitations of exclusive reliance on secondary data. In addition, the abundance of missing data also suggests the need for further prioritization of included variables through a process of theory development and testing. Ultimately the CPR database should be viewed as a part of a larger research project: the CPR database provided the foundation for the NIIS and IFRI projects.

2. The Nepalese irrigation institutions and systems (NIIS) project

2.1. Origins, actors and purpose

Development of the Nepal Irrigation Institutions Study (NIIS) began in 1988 when Ostrom and other colleagues at the workshop engaged with USAID about a study of decentralization in Nepal's irrigation sector. This built on previous research on decentralization at the Workshop (Ostrom et al. 1993). In Nepal, decentralization translated into a process of increased involvement of communities in the irrigation sector, following a period of partially donor-driven centralization. Some scholarly works from the Ostrom workshop are based on these data and describe them in more detail (Lam 1998; Tang 1992; Ostrom 1992).

2.2. Description and process

Throughout its implementation, the NIIS database was based on the framing and infrastructure of the CPR database. Its focus was still very much on the social dilemmas that local resource users faced, and the scale of analysis was still highly local. To develop the project, Ostrom visited Nepal and began to engage with colleagues there, obtaining written reports of local irrigation systems produced from rapid rural appraisal, student theses, field notes, and standard publications. The Workshop team and colleagues began to develop a set of coding forms based directly on the CPR coding forms, but increasingly adapted to the irrigation sector. Over time it was determined that these secondary materials left too many gaps in the data for the studies they reported on. Thus, a protocol was developed to quickly collect primary data on existing sites to fill these data gaps.

Core to the Workshop frameworks is the distinction between resource systems/infrastructure and resource units, and the understanding that management requires separate attention to each (Hinkel et al. 2013). In terms of identifying these components, the irrigation system has served as a paradigmatic "simplest case." The irrigation system itself is seen as the resource system associated with public good provision problems, while the water obtained via this public good is seen as a resource unit (see Ostrom et al. 1994). Moreover, because of their connection to a physical subcomponent of the irrigation system, identifying groups within this project proved to be easier than it has for the CPR or IFRI programs.

2.3. Innovations, outcomes and lessons learned

The NIIS represents a step forward by incorporating secondary and primary data collection, and multiple visits over time, whereas the CPR only consisted of one-shot secondary data. This introduced the new challenge of obtaining such data consistently, which was partially addressed by the use of the existing coding forms originally developed for the CPR database. A second innovation in the NIIS database was the theoretical focus on decentralization as a process, and an explicit comparison between relatively centralized and decentralized systems in Nepal. This focus helped constrain the research and provide a theoretical basis for the ensuing work, thereby addressing a key challenge faced by the CPR project, which was the sheer number of variables involved compared to the number of cases described in the database. 21 cases (8%) described in the database are managed by the Nepalese government (AMIS, agency-managed irrigation systems), 208 cases (79%) are managed by users (FMIS, farmer-managed irrigation systems), and 28 cases (11%) are jointly managed. A third innovation was the explicit analysis within resource user groups of heterogeneities in resource dependence and associated vulnerabilities (Ostrom 1992). Finally, the NIIS added sector-specific biophysical indicators of the irrigation systems to enable analyses tying institutional arrangements to these outcomes. A key finding that resulted from this work is that farmer-managed systems often outperformed agency managed systems, even with the superior technology of the latter, in part because this technology did not conform well with the traditional institutions of the farmers in those systems (Lam 1998). More recently, the database has been used to the variety of factors that make farmer and agency managed systems more sustainable (Lam and Ostrom 2010), and the different ways that local communities and government divide labor in co-managed irrigation systems (Frey et al. 2016).

3. International Forestry Resources and Institutions (IFRI) project

3.1. Origins, actors and purpose

The IFRI project started in 1992 with funding from the United Nations Food and Agriculture Organization (UNFAO). The IFRI database is relational, separately identifying community forests, forest user groups, nearby communities, and on-the-ground biophysical measures of forest conditions such as species, tree density, and biomass. While building on the CPR and NIIS databases and containing some overlapping variables, it is also larger and more complex than either previous database. Later projects have used IFRI protocols as a baseline and collected additional data such as remote sensing information and household surveys. Furthermore, a major vision for IFRI was to make a longitudinal database where sites could be visited at regular intervals in order to assess social, institutional, and ecological variation both cross-sectionally and over time. From the beginning, the project was an interdisciplinary collaboration meant to link institutional variation with ecological outcomes.

3.2. Description and process

The Workshop required a training seminar on IFRI data collection methods for every primary investigator for an IFRI case. Research sites around Bloomington, Indiana served as pedagogical laboratories for quantitative and qualitative training. Around 2003 the IFRI project moved to the University of Michigan under the direction of Arun Agrawal. The IFRI program has moved once again under the direction of Ashwini Chhatre at the Indian School of Business in Hyderabad, India.

Research teams for an IFRI team are composed of at least one person to head social science data gathering (social and institutional data) and one person to lead efforts at biophysical data (forest measurement). Research teams have a binder of information with each variable (question) that they answer and then upload into site-specific spreadsheets. The research subjects (users of community forests) are not surveyed to answer a specific set of questions; rather, IFRI researchers talk with key informants, gathering information that they then later enter as data. To complement these, there are standard protocols to collect biophysical data through well-established forest mensuration techniques.

3.3. Innovations, outcomes and lessons learned

In Ostrom's inaugural publication when elected to the National Academy of Science (Ostrom and Nagendra, 2006), she relied on IFRI data to provide some of the first quantitative comparative analysis for her main thesis in Governing the Commons (Ostrom 1990) -that formal designations such as private, community, or government management of forests were not significant predictors of good biophysical outcomes. Instead, she found that rule enforcement was a significant and meaningful predictor. Coleman (2009) also used comparative IFRI data to show that this result holds when looking at trends in forest change (thus controlling for place-specific differences between forests). In a series of papers, Chhatre and Agarwal (2009) and Persha, Agrawal, and Chhatre (2011) found that local rulemaking autonomy is important both for carbon storage (as proxied by above-ground biomass), biodiversity preservation, as well as forest livelihood benefits. IFRI data have also been used to examine the ability of local actors to evaluate forest condition. Salk et al. (2014) showed that foresters' qualitative assessments of forest condition are broadly correlated with extensive and highly time-consuming quantitative measurements using hundreds of plots. Salk et al. (2020) later examined the feasibility of using IFRI data to capture biodiversity outcomes in forests, concluding that the plot-based tree-centric IFRI protocol should be complemented by additional methods at little additional cost.

A challenge for the IFRI program has been the collection of data for hundreds of variables at each research site. The tradeoff of a program seeking to collect such fine-grained, comparable data across sites is that some variables in some sites were less relevant than others. It also proved to be quite burdensome for someone wanting to be involved in collecting the entire inventory of data if resources were limited in doing so. Recently, alternative, short-form IFRI protocols were adopted to lessen the burden of researchers unable to collect data on variables within the full protocol. Furthermore, it has proven difficult to convince funding agencies to continue funding the main project and recurring visits to the same field sites over time. Instead, the program has come to rely more and more on individual researchers finding funding to collect data at a particular site. Thus, some sites in IFRI have been studied multiple times across semi-regular intervals over time, while for many sites data collection has only occurred once.

4. The SES library

4.1. Origins, actors and purpose

The SES Library (seslibrary.asu.edu) project emerged from two NSF-funded projects focused on characterizing robust institutions. Both projects involved collaborations with Elinor Ostrom to use data from the CPR database and other case studies to extend Ostrom's focus on institutions and collective action in an attempt to understand the capacity of institutional arrangements to cope with change and persist over time, i.e. their robustness. The study of the dynamics of institutions and institutional change required the development of formal mathematical models connected to data. The SES Library is an effort to develop and curate qualitative case study data, coded data (CPR, NIIS) and mathematical models.

Understanding robustness either requires a mathematical model or a number of time series data sets (one related to exogenous drivers and another to system change related to the external drivers of sufficient duration). Such time series are exceedingly rare for SES. Thus, emerges the importance of dynamic models for studying robustness. Understanding the robustness of institutional forms was the impetus to develop the Robustness of SES Framework. This is the reason why the SES Library uses the Robustness of SES Framework to organize conceptual models and emphasizes the curation of mathematical models.

4.2. Description and process

Unlike the other databases described here, the SES Library is not organized around the coding of institutional arrangements, social, and biophysical contexts. Rather, it is organized around the underlying structure of SESs. That is, the SES Library is designed to develop conceptual models of classes of related SESs. For this, the SES Library uses the Robustness Framework which characterizes SES as composed of 4 key elements: Resource Users, Resource System (the natural resource system from which resource users withdraw resource units, Public Infrastructure (institutions + monitoring and sanctioning capacity to operationalize institutions as rules-in-use), and Public Infrastructure Providers (collective choice). The nature of these elements and how they are linked up provides a way to classify the structure of feedbacks in SES.

The SES Library is organized around 'cases'. A 'case' is a 'unit of scholarship' around an SES or collection of SESs. Thus, a case can be place based – i.e. a study of a particular SES. It can also be theme-based – i.e. a comparative analysis of a specific type of SESs, e.g. of coastal systems. A key element of the SES Library is that it is an "ecosystem" of cases where place-based cases can be linked to theme-based cases and models. This is facilitated by the structure of a 'case' data type which includes 1) spatial information,

2) summary of resource type and social dilemma, 3) brief “institutional analysis” that follows a fixed template that employs the IAD, rule types, etc. and is linked to coded institutional data if available, 4) a system representation, 5) sources – i.e. case contributors and source documents, and 6) related studies and models. The last element allows users to follow links to studies in nearby areas (e.g. with similar problems and issues), to models either of the case itself, or to models that address similar issues and problems.

4.3. Innovations, outcomes and lessons learned

The main technical innovation is the inclusion of a real-time dynamic model visualization tool. This tool allows users to explore how key parameters affect model behavior without downloading any software, etc. Also, the SES Library should not be seen as a “database”. It is both a database and a meta database. It has its own data and connects to other databases - as part of cases. That is, if a place-based case has multiple related models in different databases, those databases are linked. Further, the SES Library works on a “wikipedia” model. Anyone can request access, add cases or edit cases. The SES Library is focused on developing a community of practice rather than providing data. Given the costs involved, the fact that the SES Library is used as part of the developer’s research program helps considerably in maintaining, improving, and expanding the database. Perhaps the key take home lesson is such databases should be tightly integrated with teaching practice, and/or funding and collaborative agreements.

5. The Social-ecological systems meta-analysis database (SESMAD) project

5.1. Origins, actors and purpose

The SESMAD project was initially conceived to enable comparative analysis across a range of cases of environmental governance, particularly complex, large-scale cases (see Cox 2014). While it is not limited to large-scale cases, the database was developed with the idea that multiple interactions among social and ecological components in large systems would be represented for each case. The project was conceived at a meeting of Resilience Alliance Young Scholars (RAYS), prior to a meeting of the Resilience Alliance in 2011. Scholars associated with this group were joined by several others associated with the Workshop in Political Theory and Policy Analysis at Indiana University, USA.

5.2. Description and process

Physically, at the core of the SESMAD approach is a relational database and a website-based front-end (sesmad.dartmouth.edu). The set of interconnected tables in the database store information on social-ecological systems, as well as the variables used to measure relevant aspects of these systems and the theories that subsequent analyses could test. This database and a series of data-entry forms enables a user to consistently enter data and describe their system(s).

Over a series of in-person meetings, SESMAD group members developed a common understanding of the variables required to describe the subsequent cases. Computing support staff were heavily involved in the design of the final version of the database and providing much of its functionality. As such the SESMAD project has benefited from a type of transdisciplinarity between scientists and software engineers. Once the database was near completion, an initial set of five large-scale cases was coded (Fleischman et at. 2014a). Following this, a set of marine cases were analyzed and a theories table was added to leverage the existing variables table.

5.3. Innovations, outcomes and lessons learned

The two primary innovations associated with the SESMAD database are based on the structure of the database itself. First, the SESMAD database represents the first repository of variables and theories relevant to natural resource management and governance. These aspects have enabled a major synthesis of the variables and theories that have been developed to study natural resource governance (Cox et al. 2016). Second, the SESMAD database directly implements the “action situation” concept, initially associated with the IAD framework and implicitly included in the SES framework via the concept of “interactions”. When cases are coded in the SESMAD database, users code the interactions of multiple system components, following the framing that the database inherited from the initial frameworks (see Epstein et al. 2014, Evans et al. 2014, Fleischman et al. 2014b, and Villamayor-Tomas et al. 2014 for examples). With this fidelity the SESMAD database answers an important question: how might we store data that reflects the complexity described by the most common representations of these frameworks? The subsequent analyses of these complex cases have led to several publications documenting the complex trade-offs among social and ecological outcomes that large-scale MPA governance experiences (Davies et al. 2018), and the extent to which design principles for successful community-based resource management can explain patterns in these outcomes (Ban et al. 2017).

As early-career researchers, the SESMAD team faced the traditional incentives and constraints (publish or perish) that could have discouraged them from contributing to a longer-term project that would not yield immediately legible results. To counteract this, much of the success of the SESMAD project depended on the social capital that has existed among a relatively small group of around 14 members. This social capital benefited from and enabled the multiple in-person meetings that were held during the early years of the project.

When designing the database that would be used to represent cases, the SESMAD project has had to contend with the trade-off between complexity and generalizability. Due to its fidelity to the SES framework and the concept of an action situation involving multiple actors and biophysical components inherited from the IAD framework, cases in SESMAD are costly to code and difficult to directly compare with each other. If we envision a comparison as occurring between units at the same scale, it is not obvious, for example, how we can compare large complex cases with multiple interacting components. The framework and database also do not provide guidance on what the boundaries of the system should be set at. Finally, the project has suffered from the “many variables, few cases” problem, due to the large number of variables the database contains and the costliness of coding the cases. The literature that describes complex frameworks generally does not address these critical issues.

6. Small-scale Fisheries Institutions and Governance (ssfIG)

6.1. Origins, actors and purpose

The small-scale Fisheries Institutions and Governance (ssfIG) framework originated as an intent of a group of academics and practitioners to systematize existing knowledge on the social-ecological dimensions of marine systems in northwest Mexico and to coordinate future work in the region through the development of a common framework. The initiation of the National Diagnostics of Fisheries Organizations project, funded by the Walton Family Foundation and the Resilience and Adaptive Capacity of Small-Scale Fishing Communities and Coastal Marine Ecosystems to Environmental and Economic Variability, funded by the NSF (CNH-L: 1632648), served as a catalyst for the development of the framework.

6.2. Description and process

Conceptually, the ssfIG system framing is rooted in the structure of the IFRI database. Each fishing community studied has one or more user groups that interacts with one or more resources. Each system component is characterized via a set of systematically measured variables. Theoretically, the ssFIG framing draws on the common pool resources literature (e.g. Agrawal 2003). The primary goal behind this initiative is to evaluate institutional performance by examining variation of a range of ecological and/or social outcomes.

The ssfIG framework consists of 147 variables that are arranged around the SES framework. Each variable is operationalized through one or more questions, and is linked to a particular data collection instrument. Such instruments range from surveys and interviews to focus groups and participant observations. Social science data are stored in a proprietary data repository, ssfIG database (http://ssfdatabase.vm.duke.edu). Ecological data is currently not unified, although there is an ongoing effort to consolidate it within a data storage and visualization platform, dataMares (http://datamares.ucsd.edu/).

The variable identification process started with a review of the common pool resource, resilience, and organizational literatures. It was further refined through workshops and focus groups that included practitioners, managers, and resource users from Mexico. Knowledge and expertise of the participants in these venues was a critical step towards generating a list of variables that were fully relevant to the small-scale fisheries context. Variable operationalization followed a similar path where the initial set of questions developed for each of the variables was discussed and modified with input from all participants.

The ssfIG framework and its methodological approach have been implemented in Mexico and are currently ongoing in Trinidad and Tobago and Suriname in collaboration with Food and Agriculture Organization of the United Nations. There is an ongoing effort to expand it to other regions of the world.

6.3. Innovations, outcomes and lessons learned

The ssfIG framework has been implemented to systematically collect data on small-scale fishery governance at multiple points in time and across different spatial contexts. The goal of the project has been the co-production and co-ownership of knowledge by all partners (Shackeroff and Campbell 2007). This requires active engagement of all the research partners in all phases of research.

During the initial phase partners evaluated the framework and ensured that the identified variables and their operationalization were adapted to local social-ecological realities. The continuous and sustained interaction among the partners created a space that allows for honest and respectful discussions and debates to emerge, which, over time, led to strengthening of social capital among the participants. The result was a generation of more reliable data and more robust interpretations of the results based on diverse expertises and experiences. Introduction of the ssfIG framework as a boundary object at the inception allowed participants to clarify and agree on a common set of terms and their meanings. Within the transdisciplinary setting, this substantially reduces transaction costs associated with the development of research questions and interpretation of results that can emerge from having multiple, and sometimes conflicting, interpretations of the same concepts.

Active participation of a diverse set of actors is a fundamental requirement for the successful implementation of the ssfIG framework as their respective expertises and experiences are necessary for a firm grounding of the framework within the particular social-ecological context. However, initiating and maintaining active participation within the interdisciplinary setting is largely constrained due to differences in political, ethnic, cultural, or religious values that may exist among the participants, limited financial and/or personnel resources, and changes in the broader political and environmental setting (e.g. government elections, civil unrests, droughts, and cyclones). This inevitably results in longer timeframes when compared to conventional research and needs to be explicitly considered in planning activities.

7. The Marine and Coastal Monitoring (MACMON) project

7.1. Origins, actors and purpose

The Marine and Coastal Monitoring (MACMON) framework (Gurney and Darling 2017, Gurney et al. 2019) was developed through a two-year transdisciplinary process with the aim of supporting the Wildlife Conservation Society (WCS), an international non-profit, in identifying the social and ecological outcomes of their coral reef management programs. Since 2016, it has been implemented in six countries (Indonesia, Fiji, Kenya, Madagascar, Solomon Islands, Papua New Guinea), yielding data on over 125 communities and 5000 households, and is intended to form the basis of WCS's long-term coral reef monitoring.

7.2. Description and process

The MACMON framework comprises ~90 variables that are organized under Ostrom's SES framework. Data are elicited using underwater ecological surveys, household and key-informant surveys, and publicly available secondary data. Importantly, the social surveys are designed to be supplemented with project- and context-specific variables. Data are housed in open-source data platforms, with social data managed in Kobo Toolbox (www.kobotoolbox.org) and ecological data in the built-for-purpose MERMAID tool (www.datamermaid.org).

Selection of MACMON variables reflected an Essential Variables Approach (Pereira et al. 2013), whereby a transdisciplinary team aimed to develop a monitoring framework that distilled coral reef SES down to the minimum set of relevant variables to understand the social and ecological outcomes of management and their institutional and contextual drivers (Gurney et al. 2019). Variables were identified through an iterative process, involving reviewing the relevant literature and drawing on academics' and practitioners' understanding of coral reef SES, including through creating theories of change (Pressey et al. 2017).

7.3. Innovations, outcomes and lessons learned

The transdisciplinary MACMON project seeks to contribute to advancing the science and practice of SES and commons governance, thereby contributing to bridging the research-implementation gap. Indeed, MACMON data are currently informing decision-making at multiple levels, from individual project assessment to global program-level prioritization, and are being used for multi-country comparative analyses addressing some critical gaps in the literature related to multiple outcomes. A key innovation of the MACMON framework is the transdisciplinary development of Ostrom's SES framework for application to real-world management across multiple countries. The MACMON approach of standardized SES variables supplemented with context-specific indicators helps ensure the framework is relevant to a range of projects and contexts, providing a means to address the tension between case-based relevancy and data comparability (Partelow 2016).

An important lesson relates to the transdisciplinary development of the framework, specifically the utility of Ostrom's SES framework as a 'boundary object' to facilitate integration of diverse perspectives. Other crucial lessons relate to developing a standardized multi-country framework include: (1) privileging breadth over depth of inquiry; (2) inability to capture all the SES attributes critical to each site; and (3) employing largely closed-ended survey questions to ensure reliability, favoring those elements of the SES that are easily quantified (Gurney et al. 2019). Together, these constraints contribute to the well-recognized trade-off between generalizability and case-based relevancy.

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